Chromalox®

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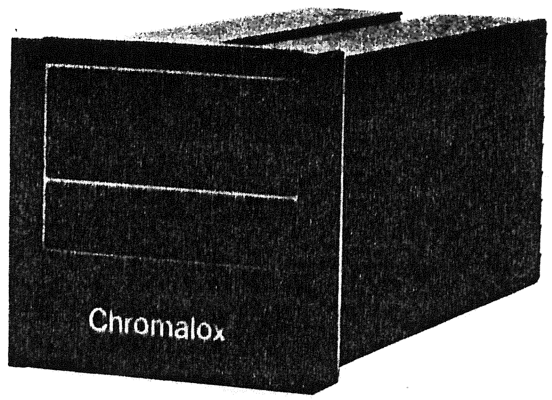
DATE 1 July 1987		

Installation Instructions

START-UP and SERVICE MANUAL

2001 MICROPROCESSOR-BASED TEMPERATURE CONTROLLER



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SUBJECT

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APPENDIX

1.0 MODEL IDENTIFICATION

MODEL	MICROPROCESSOR-BASED 1/4 DIN TEMPERATURE CONTROLLER
2001	P, PI, PD, PID and On-Off Control Modes—Dual Display (Process and Set Point)—Programmable Scale °F or °C—Reverse or Direct Acting—Two Alarm Relays with Programmable Mode Selection

CODE	CONTROL OUTPUT
1	Relay—1 N.O. Form A Contact, 5 A at 120 Vac, 2.5 A at 230 Vac
2	Triac, 1 amp at 120 or 230 Vac
4	4-20mA into 0-800 ohm load
7	Solid State Relay Drive 20 Vdc at 40 mAdc

CODE	NOT USED
0	Add to Complete Model Number

CODE	ALARM OUTPUT
2	2 Relay Outputs—1 N.O. Form A Contact Per Relay, 5 A at 120 Vac,2.5 A at 230 Vac

CODE	AUXILIARY INPUT/OUTPUT OPTION
0	None
1	Analog Remote Set Point, 4-20mA or 1-5 Vdc
2	Analog Remote Set Point and Analog Process Readout Signal for J Thermocouple input (1-5 Vdc)
3	Analog Remote Set Point and Analog Process Readout Signal for K Thermocouple input (1-5 Vdc)
4	Analog Remote Set Point and Analog Process Readout Signal for 100 ohm RTD input (1-5 Vdc)

CODE	SENSOR TYPE	RANGE
1	Thermocouple (field selectable):	
	Type J	−100 to 1400°F (−73 to 760°C)
	Type K	−100 to 2300°F (−73 to 1260°C)
4	RTD 100 ohm Pt	−200 to 1000°F (−129 to 538°C)

2001	—	2	0	2	1	1	Typical Model Number

FIGURE 1-1. MODEL IDENTIFICATION

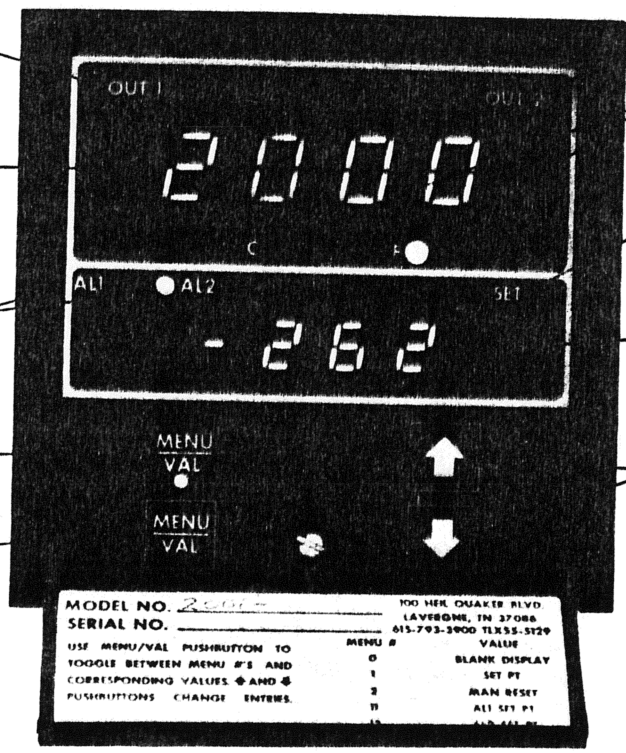


FIGURE 1-2. FRONT PANEL IDENTIFICATION

2.0 GENERAL DESCRIPTION

The Chromalox model 2001 Controller provides unmatched features and flexibility in the realm of single-loop 1/4 DIN control. Its microprocessor-based design and **menu listed programming features** allow quick, easy field configuration of all control parameters and make it appropriate for a broad range of temperature and process control applications. As user needs change, the 2001 will accommodate those changes through simple front-panel commands. Reconfiguring internal jumper positions and replacing plug-in modules allows even greater flexibility.

The dual digital displays provide continuous readout of process input in the primary display, while set points, menu numbers and menu selections can be viewed in the secondary display. Front panel LED's identify Set Points, Menu Numbers or Values as they appear in the secondary display, as well as indicating control output "ON," alarm conditions, and temperature scale selected. Additionally, the 2001 gives negative range indication of both process input and set points.

The 2001 operates in either ON/OFF or Proportional (P, PI, PD, or PID) control modes. Control mode is selectable and field changeable via the menu, as is dead band, proportional band, reverse-acting (heating) or direct-acting (cooling) control action and temperature scale selection (°C or °F). Other menu selectable control parameters include automatic and manual reset, rate, cycle time and output limit. The control action continues even while programming is taking place.

Control output type selections are Relay, Triac, 4-20mA Current and Solid State Relay (SSR) Drive. The 2001 is supplied with the output type specified by its part number, however, this output type may be changed by easy field replacement of the control output module. Thermocouple or RTD input type is also specified by part number. Thermocouple models are designed to accept both type "J" and type "K" thermocouple.

In addition to the control output, the 2001 has **two Alarm Relay Outputs.** Each of these two, normally open Form A alarm relays may be assigned any one of the following alarm modes: high alarm, low alarm, + deviation, − deviation or ± deviation. This variety of alarm mode selection allows the user to change alarm modes as the application demands.

The "Process Signal Out" and Remote Set Point features further enhance the 2001's capabilities. The "Process Out" feature allows transmission of the process variable to an external computer or recorder via a 1-5 Vdc analog signal. With the analog Remote Set Point feature, the control set point is adjusted by a remote device (1-5 Vdc or 4-20mA). No special connections or hardware changes are necessary to implement these features.

Four security levels, selectable via the menu, prevent unauthorized access to programming. All programmed information is stored in nonvolatile memory (EEPROM), eliminating the need for battery backup. The reliability of the 2001 is further complemented by hardware test circuitry that monitors microprocessor operation ("watch dog timers"). Digital filtering techniques ensure the controller's integrity in applications where electrical noise would typically be a problem.

Calibration is performed from the front panel, and the circuitry and software design is such that the unit is continually self-calibrating to compensate for temperature changes and component aging.

The 2001 controller is 1/4 DIN size and housed in a durable, noise resistant aluminum case. The instrument chassis does not have to be removed from the case for installation, but "plugs" into the case for easy removal if necessary.

3.0 SPECIFICATIONS

CONTROL MODE (Field Selectable)

- ON/OFF
- Proportional (P)
- Proportional with automatic reset/integral (PI)
- Proportional with automatic reset/integral and rate/derivative (PID)

CONTROL ADJUSTMENTS (Field Selectable)

Control Set Point	0 to 100% of span (°F or °C)
Deadband	1 to 100°F
Proportional Band (Gain)	0.1 to 999.9% of span
Manual Reset	Adjustable to any output level requirement
Automatic Reset	0.00 to 99.99 repeats per minute
Rate	0 to 500 seconds
Output Cycle Time	0.1 to 60.0 seconds
Output Limit	0 to 100%

CONTROL OUTPUTS (Field Changeable)

Relay	Normally open (N.O.) contact rated 5.0 amps at 120 Vac, 2.5 amps at 230 Vac (resistive load).
Triac	Rated at 1 amp, 10 amp in-rush current, 120 Vac or 230 Vac.
Current	4 to 20 mAdc into a 0 to 800 ohm load.
SSR Drive	Transistor output of +20 Vdc at 40mAdc.

ALARM OUTPUTS

Relay	Two (2) normally open (N.O.) contact rated 5.0 amps at 120 Vac, 2.5 amps at 230 Vac (resistive load).
Alarm Modes (Field Selectable for each Relay)	High, range 100% of span, non-latching Low, range 100% of span, non-latching + Deviation, 0-250°F above control set point, non-latching − Deviation, 0-250°F below control set point, non-latching ± Deviation, 0-250°F above/below control set point, non-latching
Reset Differential	10°F (5°C) for high and low alarms 2°F (1°C) for deviation alarms

INPUT SPECIFICATIONS

Type J Thermocouple (Iron/Constantan)	– 100 to 1400°F (– 73 to 760°C)
Type K Thermocouple (Chromel/Alumel)	– 100 to 2300°F (– 73 to 1260°C)
100 ohm Platinum RTD	– 200 to 1000°F (– 128 to 537°C)

INPUT SAMPLE RATE

Greater than 3 samples per second.

READOUT ACCURACY

Type J Thermocouple	±0.3% of span over 100% of span at 77°F ±0.2% of span over upper 65% of span at 77°F
Type K Thermocouple	±0.3% of span over 100% of span at 77°F ±0.2% of span over middle 75% of span at 77°F
Thermocouple Readout Stability	Typically better than ±1°F for ±10°F change in ambient temperature (including both cold junction compensation and front-end stability).
100 ohm Platinum RTD	±0.2% of span over 100% of span at 77°F

OPEN SENSOR INDICATION

Control output is disabled (OFF). High alarms are actuated. Display for process variable indicates "HHHH."

OUT OF RANGE INDICATION

Control output is disabled. Over-range of full scale by 11°F is indicated by display of "HHHH." Under range by 1°F is indicated by "LLLL."

EFFECT OF INPUT LEADWIRE RESISTANCE

Thermocouples	≤0.5% of span for less than 150 ohms resistance, operates to 1000 ohm with reduced accuracy.
RTD (100 ohm Pt. 3-wire)	≤0.25% of span for 20 ohm balanced leadwire resistance.

ANALOG REMOTE SET POINT (Option)

Input Range	4-20mA standard, conversion to voltage (1 to 5 Vdc) by internal jumper change. Both referenced to instrument common.
Input Resistance	4-20mA source, 250 ohms 1-5 Vdc source, 110K ohm

ANALOG PROCESS OUTPUT (Option)

Output Signal	1 to 5 Vdc referenced to instrument common.
Minimum load resistance	≥100K ohms for <1% error
Linearity	
Type J thermocouple	±1% span (0 to 1200 °F)
Type K thermocouple	±1% span (−100 to 2000 °F)
100 ohm Pt RTD	±0.20% span (−200 to 1000 °F)

INSTRUMENT POWER REQUIREMENTS

120 or 230 Vac +10%-15% 50 to 60 Hz.
Nominal power consumption is 7 VA.

OPERATING ENVIRONMENT

30 to 130 °F (0 to 55 °C) ambient with relative humidity less than 95% non-condensing.

DIMENSIONS

Requires 3.62″ × 3.62″ (92mm × 92mm) panel cutout (per DIN 43700). Depth behind panel: 7.88″ (200mm). Projection at front of panel: 0.97″ (25mm).

INFLUENCE OF LINE VOLTAGE VARIATION

Maximum change in readout of ±1 °F for ±10% nominal line voltage.

NOISE REJECTION

Common Mode	Less than ±2 °F (1 °C) with 230 Vac, 60 Hz applied from sensor input to instrument case (with digital filter enabled).
Series Mode	Less than ±2 °F (1 °C) with 300 mV peak to peak, 60 Hz series mode noise (with digital filter enabled).
Radio-Frequency Interference (RFI)	Typically less than 0.5% of set point span at a distance of 1m (3.1 ft.) from a transmitter (4W at 464MHz).

4.0 INSTALLATION

4.1 INSPECTION

Upon receipt of the 2001 Controller, immediately make note of any overt damage to the shipment packaging and note on the shipping documents. Unpack the controller and carefully inspect the unit for obvious damage due to shipment. If any shipping damage has occurred, YOU as the receiver must file a claim with the transporter. Chromalox Instruments and Controls, as the shipper, cannot file the damage claim.

If the controller is not to be immediately installed and placed into operation, it should be stored in a cool, dry environment until time for installation and operation. Temperature extremes and moisture can damage the instrument.

Read this instruction manual carefully in its entirety before attempting installation or operation of the unit.

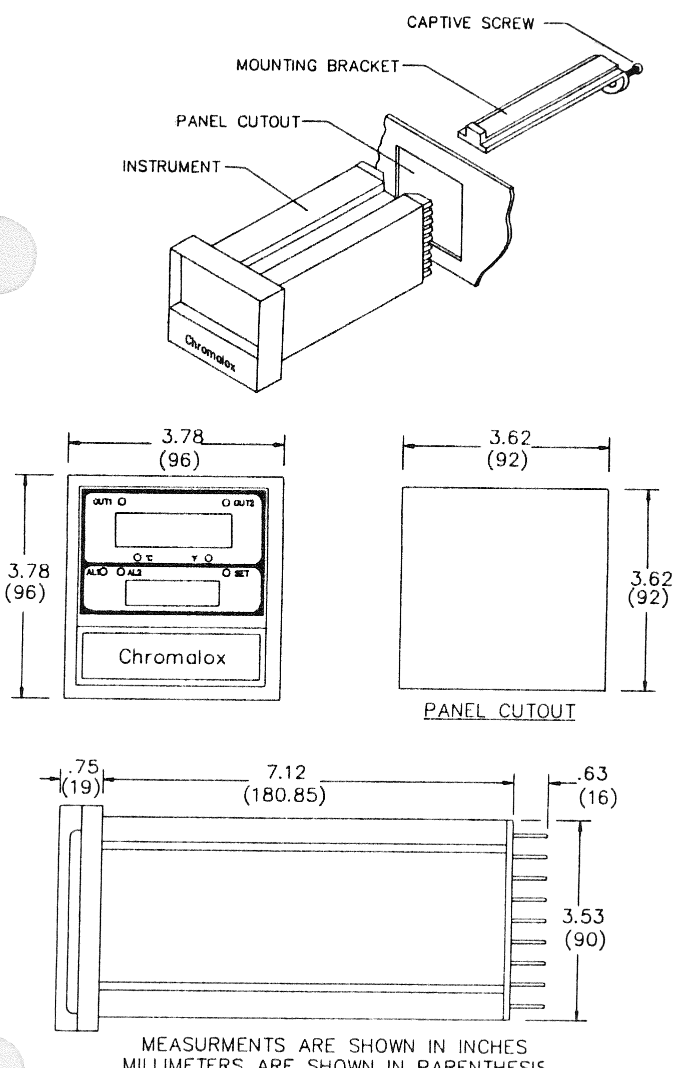


FIGURE 4-1. MOUNTING & DIMENSIONS

4.2 MOUNTING

Figure 4-1 is the mounting and outline dimensional drawing for the unit.

Mount the instrument in a location free from excessive dust, oil accumulations and moisture. The controller may be mounted in any position at ambient temperatures of 30°F to 130°F (0°C to 55°C). Cut out the square mounting hole and install the unit in accordance with Figure 4-1. If the panel thickness is greater than 0.25″ (6.35mm), it will be necessary to remove the captive screw from the mounting bracket and replace it with a longer screw.

4.3 EXTERNAL WIRING

All wiring must comply with local codes, regulations, and ordinances. This instrument is intended for panel mounting and the terminals must be enclosed within the panel. Use NEC Class I wiring for all terminals except the sensor terminals. Maintain separation between wiring of the sensor terminals and other wiring.

Check the serial tag on the unit to verify the model number. The wiring decal on the side of the unit shows wiring terminations. All wires will be connected to the terminals on the back of the case (refer to Figure 4-2). Use the proper size wire for rated circuits.

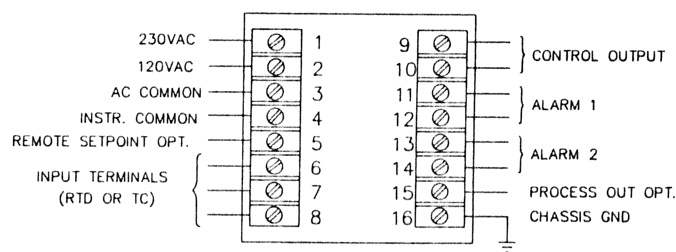


FIGURE 4-2.
TERMINAL IDENTIFICATION FOR FIELD WIRING

4.3.1 Case Ground

The case ground is located at terminal 16 of the instrument and serves as a safety ground. During installation, the ground must be connected to this point.

4.3.2 Sensor Wiring

The Model 2001 is supplied with either a thermocouple input (Type J or K) or an RTD input. Check the specific model number to verify input type. (Thermocouple units *cannot* be converted to RTD units, and vice versa.)

Thermocouple: Always observe polarity whenever connecting thermocouple leadwires. The negative (−) leadwire typically has red insulation. For isolated (ungrounded) thermocouples, the shield lead should be connected to the case ground (terminal 16).

The following Figure 4-3 shows typical color coding for the thermocouples used with this instrument.

T/C TYPE	MATERIAL	(+)	(−)
J	Iron-Constantan	White	Red
K	Chromel-Alumel	Yellow	Red

FIGURE 4-3. THERMOCOUPLE COLOR CODING

Notes:

1. If thermocouple extension wire is required, it must be the same type as the thermocouple (i.e., if a Type J thermocouple is used, then Type J extension must be used).
2. If shielded thermocouple wire is used, the shield must be grounded at one end only, preferably at terminal 16 on the controller. See Figure 4-4.

The 2001 must be programmed to accept the thermocouple type being used ("J" or "K"). Refer to Figure 5-1, Menu No. 17 for selection of thermocouple type.

RTD's: With 3-wire RTD input, make the resistance of all three leadwires equal (i.e., use the same gauge of wire) for optimum leadwire compensation. 3-wire RTD's are recommended for greatest accuracy. (See Figure 4-5 for field wiring.) If using a 2-wire RTD input, use heavier gauge leadwires to reduce leadwire resistance since any leadwire resistance adds directly to sensor resistance and thus adds error to the measurement. It is also necessary to jumper the RTD common and one lead of the RTD together (Terminals 7 & 8) on the instrument to complete a 2-wire hookup. (See Figure 4-6.)

Note: It is recommended that signal/sensor leads are not run together in the same conduit with power lines. Twisted pair shielded wire is recommended.

4.4 ALARM OUTPUTS

Each Model 2001 has two alarm output contacts. Each can be individually set to be a high, low or deviation alarm. See Figure 4-7 for wiring.

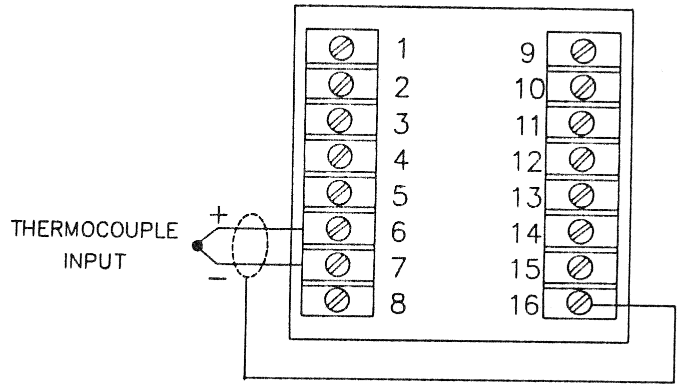


FIGURE 4-4. THERMOCOUPLE CONNECTIONS

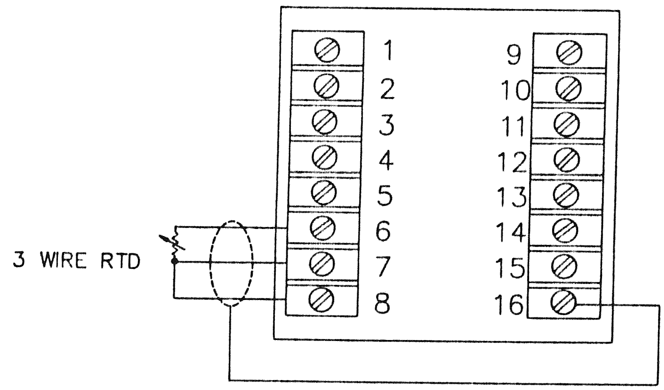


FIGURE 4-5. THREE WIRE RTD CONNECTIONS

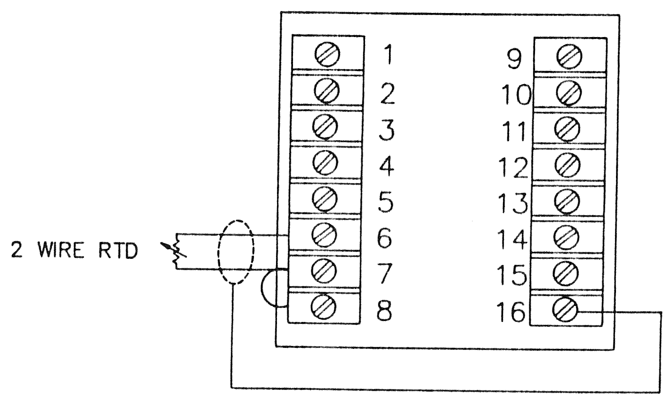


FIGURE 4-6. TWO WIRE RTD CONNECTIONS

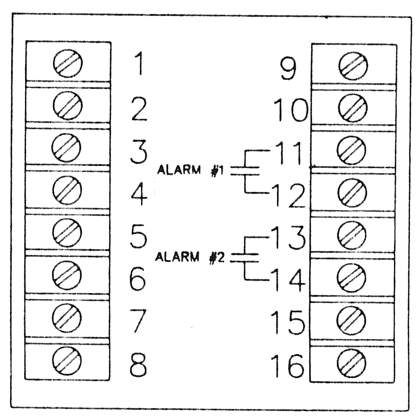


FIGURE 4-7. ALARM OUTPUTS

4.5 CONTROL OUTPUT LOAD CONNECTIONS

The Model 2001 is shipped with one control output mod- To verify which output module was ordered, compare model number of the unit with Figure 1-1, Model Identification. The output circuits are shown for reference only.

4.5.1 Relay Output Module: Model Number 2001-1XXXX

A relay output is generally used to drive small resistive loads (<5 A at 120 volts or <2.5 Amps at 230 volts) or a contactor. When driving a contactor load, connect appropriately rated A.C. snubber circuits across the contactor coil. See Figure 4-8 for wiring.

4.5.2 Triac Output Module: Model Number 2001-2XXXX

A triac output generally drives a small load (less than 1 amp) or the coil of a contactor. Since triacs are solid state devices (no contacts), they will perform much longer than a mechanical relay. When driving a small load directly, triacs can cycle faster than a conventional relay to maintain tighter control. See Figure 4-9 for wiring.

4.5.3 4-20mA Output Module: Model Number 2001-4XXXX

The 4-20mA signal is an industrial standard method of transmitting and receiving information. To use this output, it must be connected to a device that accepts a 4-20mA signal and has an input impedance of less than 800 ohms. Figure 4-10 for wiring.

By moving a jumper on the 4-20mA output module card, the user can convert the output from a 4-20mA analog signal to a 1-5 volt dc analog signal (1-5 Vdc output can drive high resistance loads). See Figure 4-13 for jumper positioning.

4.5.4 Solid State Relay Drive Output Module: Model Number 2001-7XXXX

The Solid State Relay (SSR) Drive Output is a 20 Vdc signal that will drive SS Relays (such as the Chromalox 4115 or 4117 Power Modules) which accept 3 to 32 Vdc input signals. See Figures 4-11 and 4-12 for typical wiring arrangements.

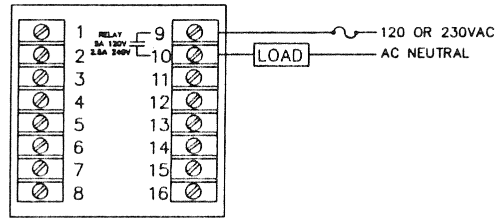


FIGURE 4-8. RELAY OUTPUT 2001-1XXXX

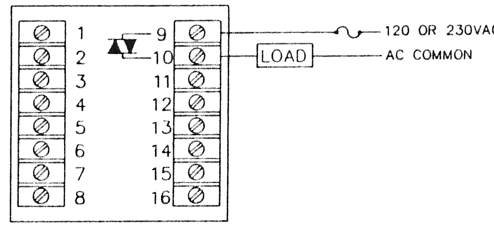


FIGURE 4-9. TRIAC OUTPUT 2001-2XXXX

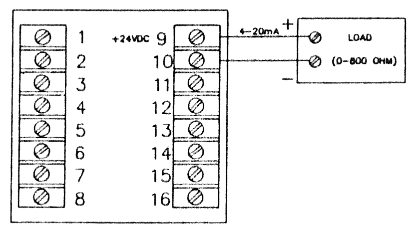


FIGURE 4-10. 4-20mAmp 2001-4XXXX

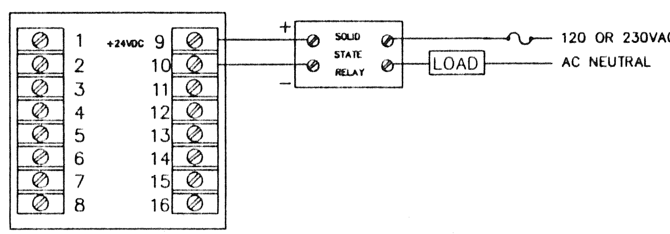


FIGURE 4-11.
SOLID STATE RELAY DRIVE 2001-7XXXX
SINGLE SOLID STATE RELAY

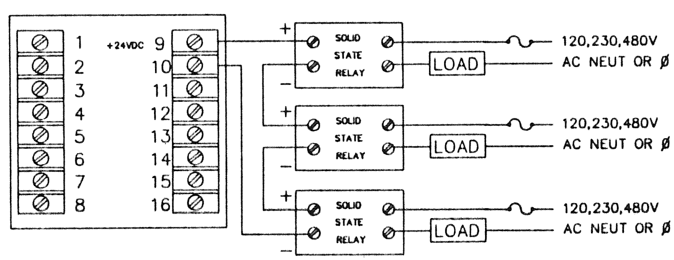
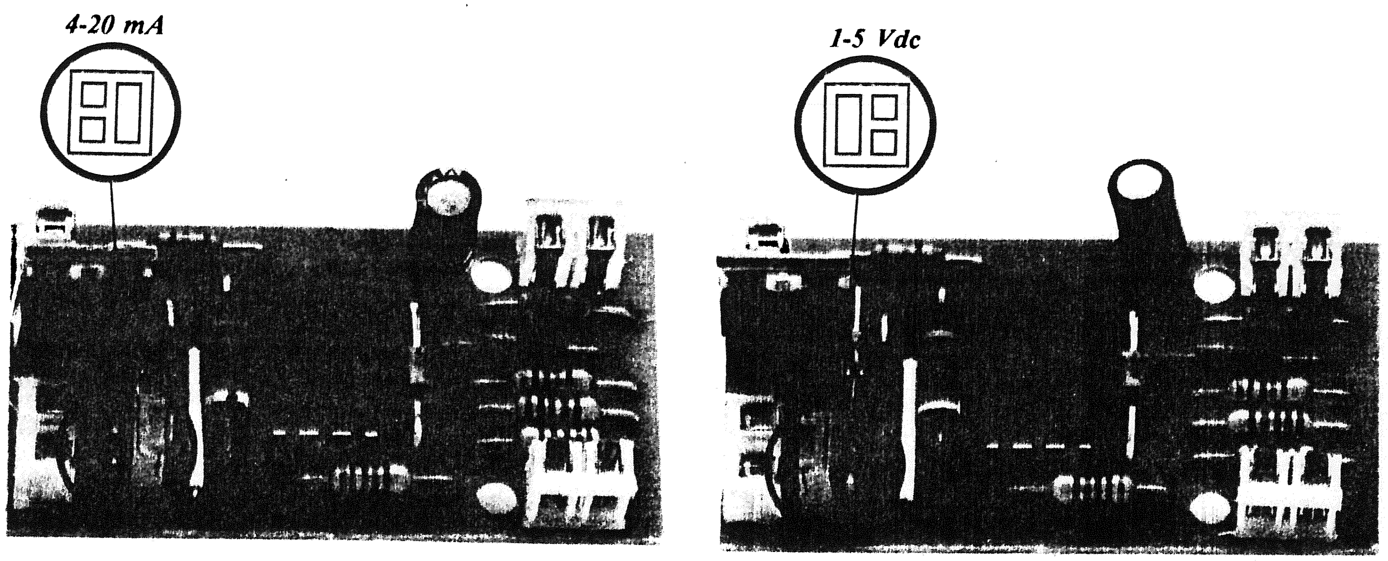
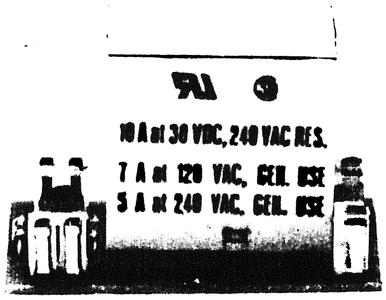


FIGURE 4-12.
SOLID STATE RELAY DRIVE 2001-7XXXX
MULTIPLE SOLID STATE RELAYS DRIVING SINGLE PHASE LOADS
3-PHASE LOADS CAN ALSO BE DRIVEN

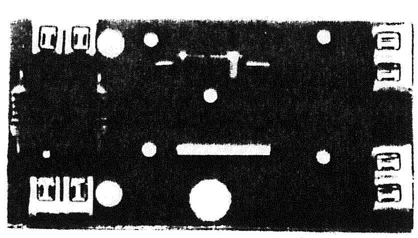


PART NO. 0149-27009

FIGURE 4-13.
CONTROL OUTPUT MODULE
(enlarged view)
4-20 mA to 1-5 Vdc



RELAY
PART NO. 0149-27008



SOLID STATE RELAY DRIVE
PART NO. 0149-27007

TRIAC
PART NO. 0149-27006

FIGURE 4-14. CONTROL OUTPUT MODULES

4.6 CHANGING CONTROL OUTPUT MODULES

As stated previously, the 2001 is designed to facilitate changes in control output type by changing the control output module. Figure 4-14 illustrates the four output module types. To change an output module, remove the instrument chassis from the instrument case by loosening the screw under the front door flap and pulling the control chassis out (see Figure 4-15) to expose the control module. Unplug the output module from the 4 connector posts and replace it with another output module (Figure 4-16). Make appropriate changes in load wiring and cycle time before operating the controller.

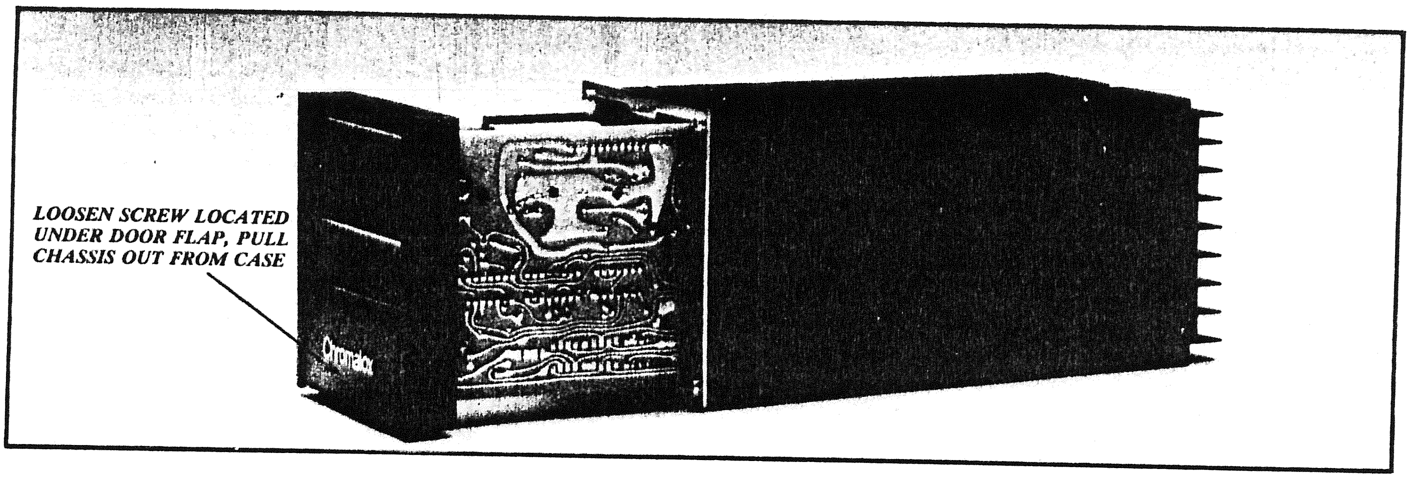


FIGURE 4-15. REMOVING INSTRUMENT FROM CASE

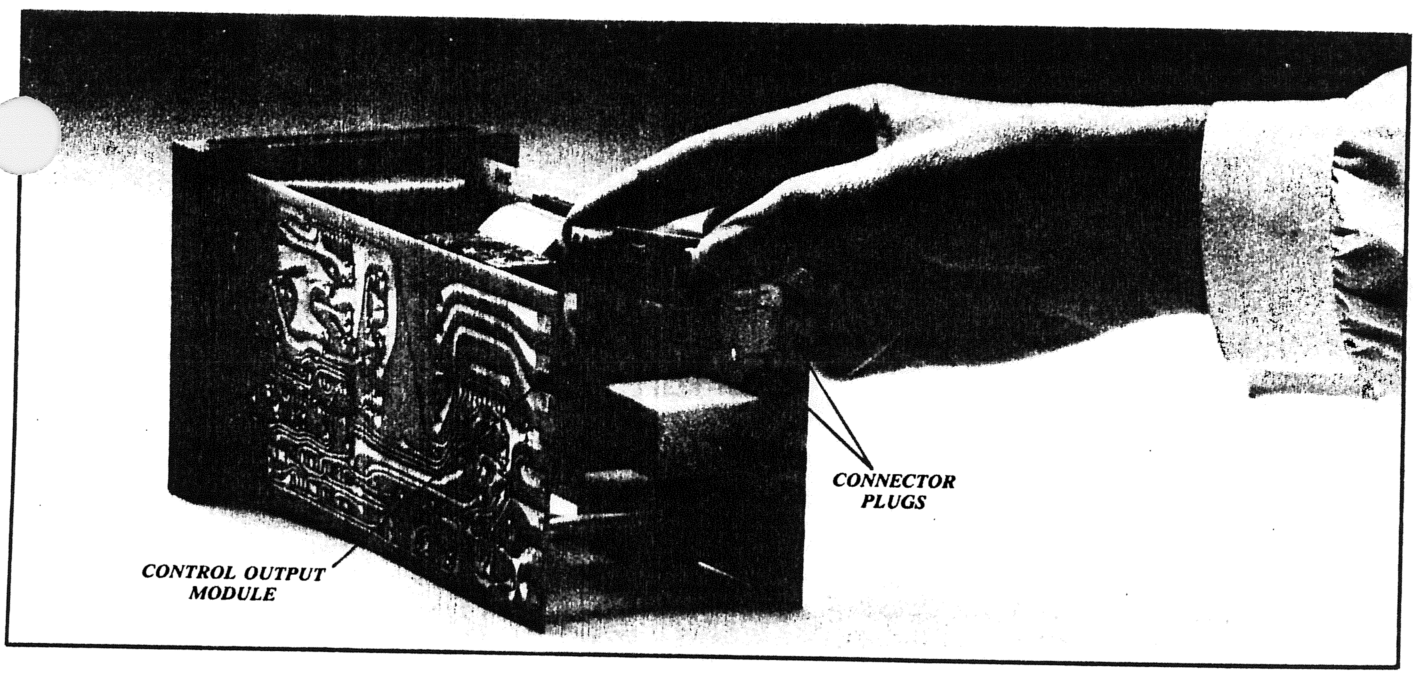


FIGURE 4-16. CHANGING CONTROL OUTPUT MODULES

5.0 OPERATION

All control parameters, settings and calibration operations for the 2001 controller are accomplished through menu listed programming. There are a total of 27 Menu Numbers, each of which corresponds to a specific parameter, setting or calibration function. This menu listing allows the operator to go directly to the parameter/setting to be adjusted without stepping through long loops of unnecessary entries. Figure 5-1, Menu Settings Table, describes each of these functions, the available settings and the factory settings. Also, in Appendix I, a more detailed description may be found on particular settings or control parameters. Note that in Figure 5-1 the Menu Numbers are divided into three groups: **General** Control Parameters and Settings, **ON/OFF** Control Parameters and **Proportional/PID** Control Parameters. Those Menu Numbers coded as "General" should be addressed for any control type selection. Those Menu Numbers coded as "ON/OFF" need to be addressed only if ON/OFF control is selected (Menu #7), and the same applies to those Menu Numbers coded as "Proportional/PID."

5.1 ADJUSTING CONTROL PARAMETERS AND SETTINGS

Adjustments are performed with the three pushbuttons located behind the door flap on the front of the controller (see Figure 1-2 for location of pushbuttons):

▲	Pushbutton used to **increase* Set Points, Menu Nos.**, and **Values** (all displayed in lower digital display)
▼	Pushbutton used to **decrease* Set Points, Menu Nos.**, and **Values** (all displayed in lower digital display)
"MENU/VAL"	Pushbutton used to **select Menu No.** or **Value** to be **displayed** in lower digital display. (Appropriate LED will illuminate to show which selected. If the Value displayed is a Set Point, the Set Point LED indicator will also illuminate.)

*The ▲ and ▼ pushbuttons will increase and decrease the display value faster as the pushbutton is held pressed.

The upper display provides continuous readout of the process temperature while adjustments are being made. The 2001 may be adjusted "on line," meaning that control parameters and settings may be changed without interrupting the controller operation and that the operator may continue to monitor the process temperature. New menu values/settings are automatically entered into nonvolatile memory when the ▲ or ▼ pushbutton is released, and the controller begins to use these new values immediately.

To change a setting,

1. From the "Function" column of Figure 5-1, select the parameter to be adjusted. Determine the Menu No. and new setting from the "Available Setting" column of the table.
2. Press "MENU/VAL" so that "MENU" is selected.
3. ▲ or ▼ until correct Menu No. is displayed in lower digital display.
4. Press "MENU/VAL" so that "VALUE" is selected. Current setting will appear in lower digital display.
5. ▲ or ▼ until new setting appears in lower digital display.
6. New setting is automatically entered into memory. Adjustment is complete.
7. Repeat steps 2-6 for other adjustments to be made.

5.2 SECURITY LEVELS

The design of the 2001 allows selective protection of Menu Numbers to prevent unauthorized changes to control parameters and settings. This protection is accomplished by 4 coded levels of security, represented in Figure 5-2. Each Level allows adjustments and viewing of selected Menu Numbers.

Security Codes are entered at Menu #20. Upon receipt, the controller has Security Code "458" entered at Menu #20, meaning that Level 2 security is in effect (Menu Nos. 1 through 20 may be adjusted and viewed, access to Menu Nos. 21 through 27 is blocked), and all control parameters may be adjusted but calibration may not be accessed. This level of security will remain in effect until the entry in Menu No. 20 is changed. Also note that security codes are retained in the controller memory even if power to the instrument is removed.

SECURITY LEVELS	CODE	ADJUST MENU NOS.	VIEW MENU NOS.
1	736	1-20 All Control Parameters 21-27 Calibration	1-27
2	458	1-20 All Control Parameters	1-20
3	123	1,2,20 Set Point Manual Reset Security Lock	1-20
4	Any Number except above (3) Codes	20 Security Lock	1-20

FIGURE 5-2. SECURITY LEVELS

MENU #	FUNCTION	INPUT TYPE	AVAILABLE SETTINGS	FACTORY SETTING
1	Process Set Point	"J" T/C "K" T/C RTD	– 100 to 1400°F (– 73 to 760°C) – 100 to 2300°F (– 73 to 1260°C) – 200 to 1000°F (– 129 to 538°C)	0°F 0°F 0°F
2	Manual Reset		– 99.9 to 99.9	0.0
3	Proportional Band		0.1 to 999.9% of span	5.0%
4	Automatic Reset		0.00 to 99.99 Repeats/minute	0.00
5	Rate		0 to 500 sec.	0
6	Control Action		1 = Direct Acting (Cooling) 2 = Reverse Acting (Heating)	2
7	Control Mode		1 = Proportional/PID 2 = ON/OFF	1
8	Output Limit		0 to 100%	100%
9	Cycle Time		0.1 to 60 sec.	30 sec—Relay Output 1.0 sec—Triac Relay Output 0.3 sec—4-20mA Relay Output 1.0 sec—SSR Driv
10	Dead Band		1 to 100°F	5°F
11	Alarm #1 Set Point	"J" T/C "K" T/C RTD	– 100 to 1400°F (– 73 to 760°C) – 100 to 2300°F (– 73 to 1260°C) – 200 to 1000°F (– 129 to 538°C)	1400°F (760°C) 2300°F (1260°C) 1000°F (538°C)
12	Alarm #2 Set Point	"J" T/C "K" T/C RTD	– 100 to 1400°F (– 73 to 760°C – 100 to 2300°F (– 73 to 1260°C) – 200 to 1000°F (– 129 to 538°C)	– 100°F (– 73°C) – 100°F (– 73°C) – 200°F (– 129°C)
13	Alarm #1 Mode		1 = High Alarm 2 = Low Alarm 3 = + Deviation 4 = – Deviation 5 = ± Deviation	1 = High
14	Alarm #2 Mode			2 = Low
15	Not Used			
16	Not Used			
17	Sensor Type/ Temperature Scale	"J" T/C 2001-XXXX1	1 = °F 2 = °C	1
		"K" T/C 2001-XXXX1	3 = °F 4 = °C	
		RTD 2001-XXXX4	5 = °F 6 = °C	5
18	Digital Filter		0 = Disable 1 = Enable	1 = Enable
19	Remote Set Point		0 = Disable Remote Enable Local 1 = Enable Remote Disable Local	0 = Disable Remote
20	Security Code		see Section 5.2	458 (Level 2)
21-27	Calibration		see Section 7.0	

[ ] = General Control Parameters

[ ] = ON/OFF Control Parameters

[shaded] = Proportional/PID Control Parameters

FIGURE 5-1. MENU SETTINGS

5.3 INITIAL POWER-UP

After the 2001 Controller has been properly installed and power is turned on for the first time, it will begin to operate using the parameters and setting programmed at the factory (refer to Figure 5-1). The upper digital display will contain four dashes "----," and the lower display will contain the controller model number "2001." After a short delay, during which the controller performs self tests, the upper display will indicate the process temperature and the lower display will indicate the control set point. Other LED's will display the current operating status, including alarm conditions, output condition and temperature scale selected.

5.4 EXAMPLE CONTROL SETUP

In the following steps, the 2001 will be configured for an example heating application. The controller will be set up for a PID control loop, with high alarm and low alarm outputs. Assume the PID parameters have been defined. (See Section 6.0, PID Tuning.) Also assume that this unit is in "factory" shipped condition and no adjustments have been made to factory settings. The model number purchased is a 2001-70201, (Solid State Relay Drive output, two alarm outputs and thermocouple input).

Parameters:
Process set point: 250 °C
Relay output #1: High alarm
Set point: 275 °C
Relay output #2: Low alarm
Set point: 200 °C
Proportional Band: 25 °C
Auto Reset: 1.5 repeats/minute
Rate: 1 second
Cycle time: 1 second
Input sensor: "J" thermocouple

Security Code, Menu No. 20. The 2001 is shipped with the Security Lock set to "458" for Level 2 access. This allows the operator to change all the control parameters which are in Menus Nos. 1-20. No adjustment is necessary.

Sensor Type/Temperature Units, Menu No. 17. The 2001-XXXX1 is factory configured to be a "J" thermocouple unit with °F indication. Since the process and alarm set points in the example are in degrees Celsius, the 2001 needs to be configured as a °C unit. All set points may be entered in °F, and then the temperature scale selection (Menu No. 17) is changed from °F to °C, or the temperature scale may be selected first (Menu No. 17) and then set points entered in °C. For this example, the second method is used. Press MENU/VAL so that the "MENU" indicator lights. Increase or decrease, ▲ or ▼, the menu number in the lower display until "17" appears. Press MENU/VAL so that the "VAL" indicator lights up. The value will be displayed in the lower display. (For "J" thermocouple with degrees Celsius indication, the value is "2.") Press ▲ or ▼ until "2" is displayed in the lower display. (The °C LED should light when "2" is selected.)

Process Set Point, Menu No. 1. Press MENU/VAL until the "MENU" indicator lights. Decrease, ▼, the MENU number until a "1" appears in the lower display. Press MENU/VAL again for that the "VAL" indicator lights. Increase or decrease, ▲ or ▼, until "250" °C appears in the lower display.

Proportional Band, Menu No. 3. Since the Proportional Band VAL is in percent of span units, a 25 °C proportional band needs to be calculated for % of span of a "J" thermocouple. The "J" span is −73 to 760 °C (833 °C span). 25 °C is "3%" of the entire "J" span.

Press MENU/VAL until the "MENU" indicator lights. Increase or decrease, ▲ or ▼, until "3" is displayed in the lower display. Press MENU/VAL until the "VAL" indicator lights. Increase or decrease, ▲ or ▼, until a "3.0" is displayed in the lower display. (This sets 3% of span or 25 °C.)

Auto Reset, Menu No. 4. Press MENU/VAL so that the "MENU" indicator lights. Increase or decrease, ▲ or ▼, until "4" is displayed in the lower display. Press MENU/VAL so that the "VAL" indicator lights. Increase or decrease, ▲ or ▼, until "1.50" is displayed in the lower display.

Rate, Menu No. 5. Press MENU/VAL until the "MENU" indicator lights. Increase or decrease, ▲ or ▼, until "5" appears in the lower display. Press MENU/VAL until the "VAL" indicator lights. Increase or decrease, ▲ or ▼, until "1" appears in the lower display.

Control Action, Menu No. 6. Factory Setting for control action is "2" REVERSE ACTING (Heat). No adjustment is necessary.

Control Mode, Menu. No. 7. Factory setting for Control Mode is "1," Proportional/PID. No adjustment is necessary.

Cycle Time, Menu No. 9. Factory Setting for a unit with a Solid State Relay Drive (2001-7XXXX) is "1" second. No adjustment is necessary.

Alarm No. 1 Set Point, Menu No. 11 and Alarm No. 1 Mode, Menu No. 13. This example uses Alarm No. 1 as a high alarm, set at 275 °C. Menu No. 13 is factory configured to be a "high" alarm (VAL = 1) so only the set point needs to be changed. Press MENU/VAL until the "MENU" indicator lights. Increase or decrease, ▲ or ▼, until "11" appears in the lower display. Press MENU/VAL until the "VAL" indicator lights. Increase or decrease, ▲ or ▼, until "275" °C appears in the lower display.

Alarm No. 2 Set Point, Menu No. 12, and Alarm No. 2 Mode, Menu. No. 14. This example uses Alarm No. 2 as a low alarm set at 200 °C. Menu No. 14 is factory configured as a "low" alarm (VAL = 2), so only the set points need to be changed. Press MENU/VAL until the "MENU" indicator lights. Increase or decrease, ▲ or ▼, until "12" is displayed in the lower display. Press MENU/VAL until

the "VAL" indicator lights. Increase or decrease, ⬆ or ⬇, until "200" °C is displayed in the lower display.

Security Lock, Menu No. 20. After programming the 2001, the operator can decide to change the security level of the unit and limit access of changing the control parameters. See Section 5.2, Security Levels, for further information.

Final Set-Up. The 2001 will always be operating no matter which MENU No. it is accessing. However, the operator will probably prefer to have Menu No. 1, Process Set Point displayed with the Process Temperature. Press MENU/VAL until the "MENU" indicator lights. Decrease, ⬇, until "1" is displayed in the lower display. Press MENU/VAL until the "VAL" indicator lights. Notice the "SET" LED lights indicating that the Process Set Point is being displayed in the lower display. Close the "door" of the 2001.

Configuration for this example is now complete.

6.0 PID TUNING

This section presents a general description of and basic instructions for PID tuning. In applications where the 2001 is being used as a Proportional (P), Proportional with Integral (PI) or Proportional with Integral and Derivative (PID) controller, the following tuning procedures will determine the parameter setting(s) that will provide optimum process stability. Tuning requires three parameter adjustments, accessible via Menu Nos. 3, 4 and 5:

- Proportional Band—Menu No. 3
- Automatic Reset (Integral)—Menu No. 4
- Rate (Derivative)—Menu No. 5

6.1 DEFINITIONS

PROPORTIONAL BAND—The first PID control parameter adjustment is the proportional band. The objective of this adjustment is to achieve the **smallest** possible proportional band setting (greatest gain) while maintaining process stability. In Step 1, the **Ultimate Proportional Band** is determined. The proportional band can be adjusted from 0 to 999.9% of span.

AUTOMATIC RESET—The automatic reset (Integral) function compensates for deviations from set point resulting from sustained, long term process load changes. Examples of long term load changes would be (1) Changes in ambient temperature (day to night) which affect the heat loss of the process, or (2) changing the load in a batch oven. The objective of the automatic reset function is to vary the control output in an amount proportional to the load change. If the automatic reset rate is too slow, the process temperature will not return to set point within an acceptable period of time. If the automatic reset is too fast, the process temperature becomes unstable and results in overshoots/undershoots undesirable to the process. Automatic Reset is calculated in Step 3 by applying the Ultimate Proportional Band (determined in Step 1) and the Ultimate Period (determined in Step 2) to an equation. The automatic reset can be adjusted from 0.00 to 99.99 repeats/minute.

RATE—The rate (derivative) function compensates for sudden, short term process load changes such as opening a furnace door or adding new material to a process. The objective of the rate function is to minimize the overshoot and undershoot that results from these short term process load changes. Rate, like Automatic Reset, is determined in Step 3 by applying the Ultimate Proportional Band and Ultimate Period to an equation. The rate can be adjusted from 0 to 500 seconds.

6.2 TUNING PROCEDURE

The tuning procedure consists of 3 steps:

Step 1: Following the diagrammed procedure in Figure 6-1, the **Ultimate Proportional Band** is determined.

Step 2: The **Ultimate Period is determined** by observing the process temperature curve generated in Step 1.

Step 3: The Ultimate Proportional Band and Ultimate Period are applied to equations, **determining the Proportional Band, Automatic Reset and Rate settings** for the appropriate control type (P, PI, PID).

Step 1. Ultimate Proportional Band

The controller is tuned while operating in the process as a Proportional *only* controller (P). It is important that Menu Nos. 4 and 5 (Automatic Reset and Rate) are at "0.00" and "0," respectively.

Following Figure 6-1, the Proportional Band setting is gradually increased/decreased until the process temperature begins **a steady, small oscillation about set point.** The Proportional Band setting where this steady, small oscillation occurs is referred to as the **Ultimate Proportional Band.**

Stable = steady process temperature, does not increase or decrease greatly with time, no oscillation (except oscillation due to output cycle time).

Unstable = process temperature has extreme, undesirable excursions.

Slightly Unstable = process temperature has steady, small, even oscillations about set point.

The **Stable** process temperature is most desirable for normal operation, while **Unstable** is the least desirable. The **Slightly Unstable** condition is the condition generated in this flowchart procedure that allows determination of Ultimate Proportional Band and Ultimate Period.

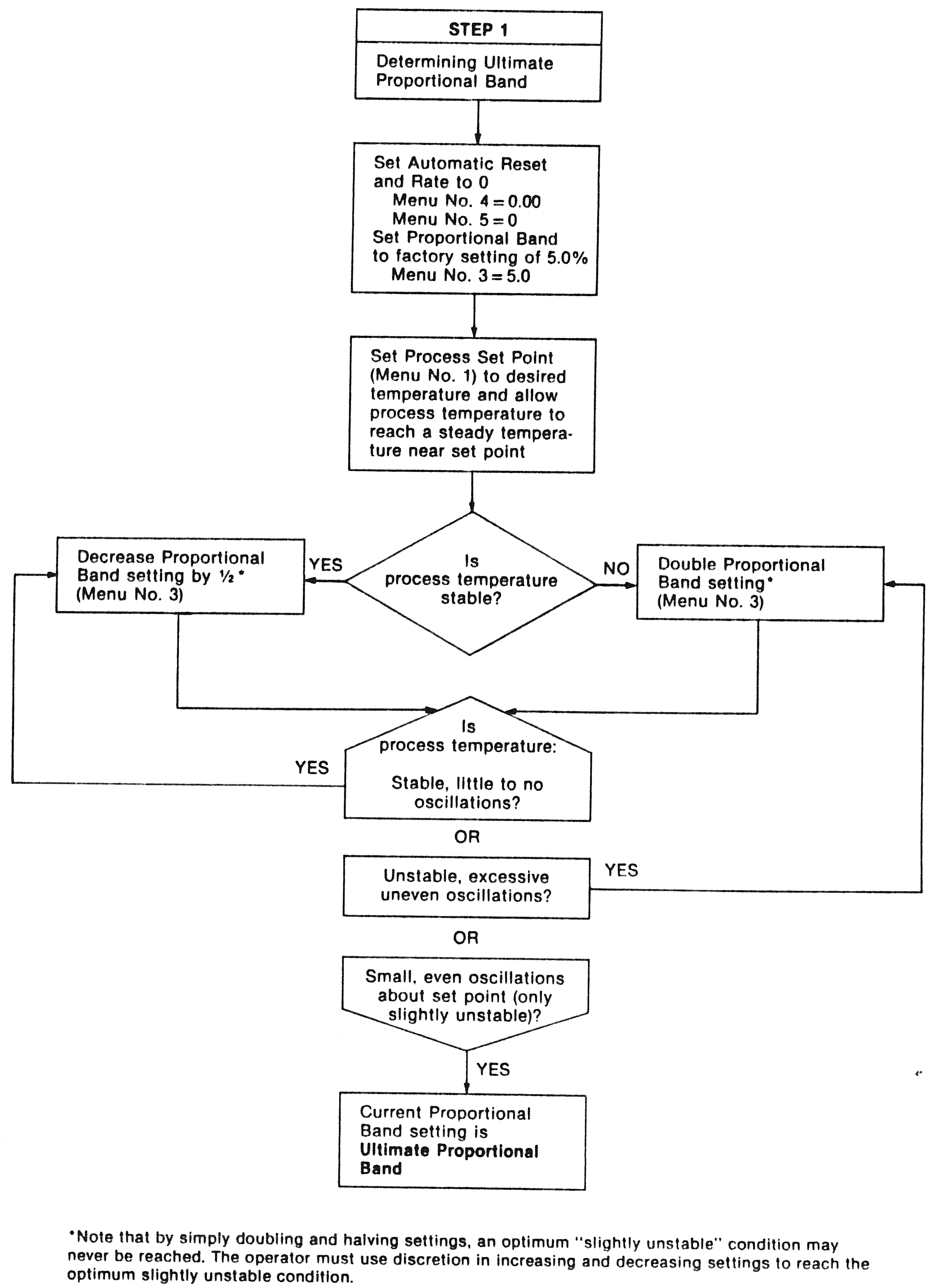


FIGURE 6-1. DETERMINING ULTIMATE PROPORTIONAL BAND

Step 2. Ultimate Period

Once the Ultimate Proportional Band setting is determined, and the process temperature is reacting in a steady, small oscillation about set point, the Ultimate Period is determined. **The Ultimate Period is the time from peak-to-peak maximum temperature in process temperature curve** (illustrated in Figure 6-2). The Ultimate Period should be expressed in minutes for calculation of Automatic Reset, and in seconds for calculation of rate.

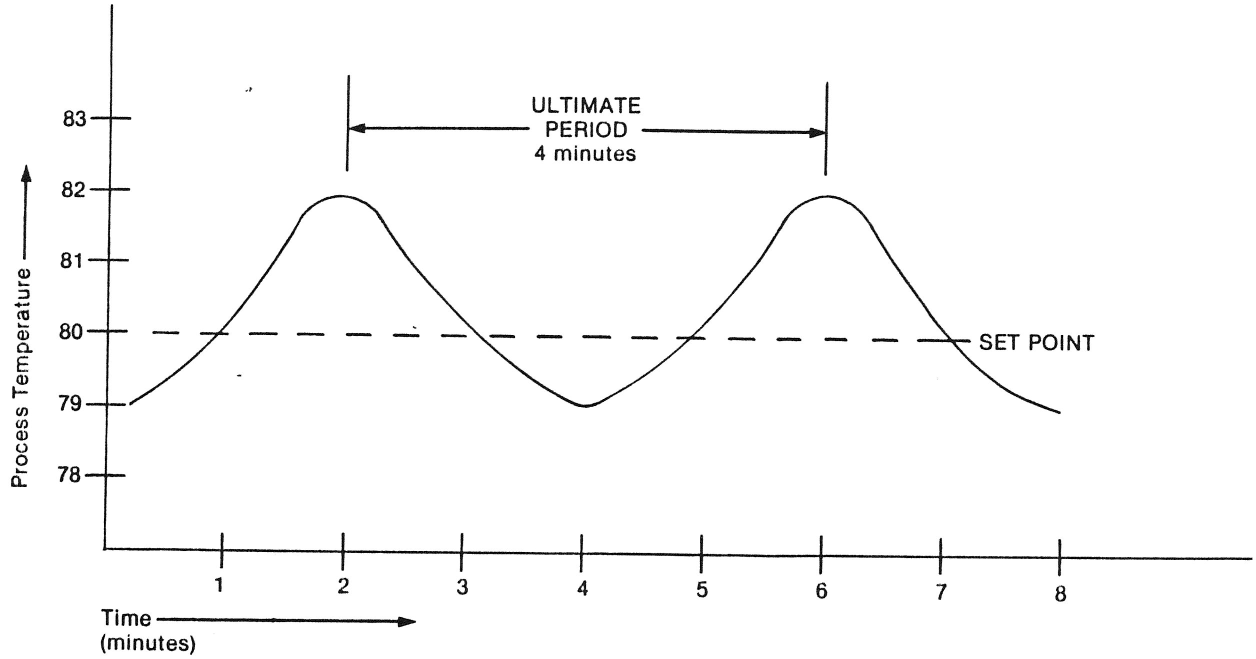


FIGURE 6-2. DETERMINING ULTIMATE PERIOD

Step 3. Calculating Parameters

The process values Ultimate Proportional Band (PB) and Ultimate Period (Period) are applied to equations to determine Proportional Band, Automatic Reset and Rate (if applicable). From Figure 6-3, select the appropriate control mode and calculate the parameter settings.

CONTROL MODE / PARAMETER	P PROPORTIONAL	PI PROPORTIONAL WITH INTEGRAL	PID PROPORTIONAL WITH INTEGRAL AND DERIVATIVE
Proportional Band Menu No. 3	2×PB	2.22×PB	1.67×PB
Automatic Reset Menu No. 4		$\frac{1.2}{\text{Period (minutes)}}$	$\frac{2.0}{\text{Period (minutes)}}$
Rate Menu No. 5			$\frac{\text{Period (seconds)}}{8}$

PB=Ultimate Proportional Band
Period=Ultimate Period

FIGURE 6-3. PID PARAMETER EQUATIONS

7.0 REMOTE SET POINT AND "PROCESS SIGNAL OUT" OPTIONS

7.1 REMOTE SET POINT OPTION

The contents of Section 7.1 apply only to the following model numbers:
2001-XXX1X
2001-XXX2X
2001-XXX3X
2001-XXX4X

The remote set point feature allows the control set point to be adjusted by a remote instrument or device such as a computer. The remote device sends either a 4-20mA or 1-5 Vdc (field changeable) analog signal to the controller to determine the set point.

7.1.1 Input Signal Selection for Remote Set Point Option

The operator can select either 4-20mA or 1-5 Vdc input signal by moving an internal jumper. The jumper is in the 4-20mA position when shipped from the factory. To change the unit to accept a 1-5 Vdc signal:

1. Remove Instrument Power from the unit (120 or 230Vac).
2. Remove the 2001 chassis from the instrument case by loosening the screw in front of the unit (see Figure 4-14).
3. **To select 1-5 Vdc** input, place the jumper in the position shown in Figure 7-1.

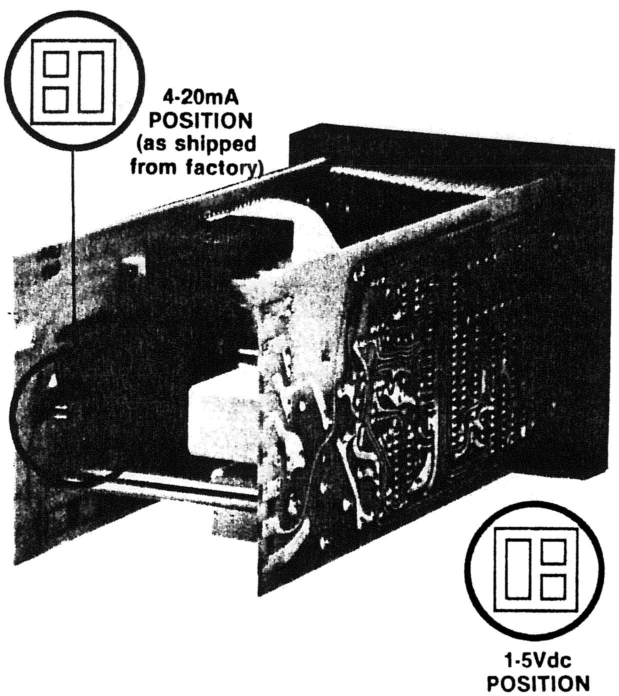


FIGURE 7-1. JUMPER POSITIONING FOR REMOTE SET POINT INPUT SIGNAL SELECTION

7.1.2 External Wiring

The 2001 provides terminals on the back of its case for easy field wiring of the Remote Set Point and "Process Signal Out" options. For recommended wiring, see Figure 7-2.

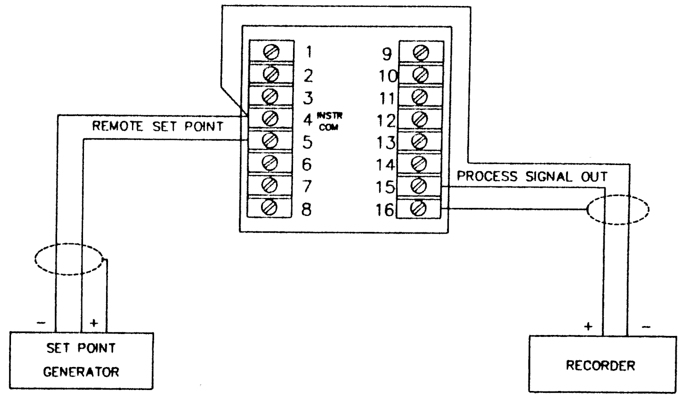


FIGURE 7-2. FIELD WIRING DIAGRAM FOR "PROCESS SIGNAL OUT" AND REMOTE SET POINT OPTIONS

7.1.3 Remote Set Point—Menu 19

The 2001 is shipped with "local" set point in operation. To set the unit so that it accepts the remote set point signal, Menu #19 should be changed from local (VAL = 0) to remote mode (VAL = 1):

1. Select "MENU" using MENU/VAL.
2. ▲ or ▼ until Menu No. 19 is displayed in the lower display.
3. Select "VAL" using MENU/VAL.
4. To program remote set point, ▲ until "1" is displayed in the lower display.

The 2001 will now accept the remote set point provided by the remote device, and will not respond to "local" set point adjustment.

7.1.4 Remote Set Point Range

The available range for remote set point selection is the same as the range available for local set point selection, with the remote set point signals generating a corresponding temperature set point. This range is determined by the sensor input type, as demonstrated in Figure 7-3.

MODEL NO.	INPUT TYPE	REMOTE SET POINT SIGNAL / TEMP. SET POINT GENERATED	
2001-XXXX1	"J" T/C	4 mA,1Vdc / −100°F	20mA,5Vdc / 1400°F
	"K" T/C	4mA,1Vdc / −100°F	20mA,5Vdc / 2300°F
2001-XXXX4	RTD	4mA,1Vdc / −200°F	20mA,5Vdc / 1000°F

FIGURE 7-3. REMOTE ANALOG SET POINT RANGES

Additionally, a specific range can be selected in the field if the application demands. Refer to Section 8.0, Calibration.

7.2 "PROCESS SIGNAL OUT" OPTION

The contents of this section apply only to the following model numbers:

2001-XXX2X
2001-XXX3X
2001-XXX4X

The "Process Signal Out" feature allows the process temperature to be transmitted to a remote recorder or computer via a 1-5 Vdc analog signal. This 1-5 Vdc analog signal follows the input sensor type curve ("J" T/C, "K" T/C or RTD), and is factory calibrated over the entire sensor range.

7.2.1 Field Wiring

Terminals are provided for simple field wiring of the "Process Signal Out" option. Refer to Figure 7-2.

7.2.2 Calibration

The "Process Signal Out" option is factory calibrated and calibration is not required on initial receipt and installation. Figure 7-4 presents factory recommended calibration points that have been determined to provide optimum linearity in the middle of each of the sensor ranges.

If calibration is necessary, a precision sensor simulator should be substituted for inputs. To calibrate,

1. Connect thermocouple source to terminals 6(+) and 7(−) (for thermocouple units), or, for RTD units, connect decade box to terminals 6 and 7 and jumper between terminals 7 and 8.
2. Connect a voltmeter to terminals 15(+) and 4(−) to measure "Process Signal Out."
3. Set the sensor simulator to the zero value (from Figure 7-4).
4. Locate the zero and span "pots" (Potentiometers) at the rear of the unit (see Figure 7-5). Adjust the zero pot until the voltmeter reads the "Vdc Process Out" value corresponding to the zero value (from Figure 7-4). (For example, if calibrating a "K" T/C unit, set the input source at 320°F. Adjust the zero pot until the voltmeter reads 1.700 Vdc.)
5. Set the sensor simulator to the span value (from Figure 7-4) and adjust the span pot until voltmeter reads the "Vdc Process Out" value corresponding to the span value (from Figure 7-4).
6. Repeat steps 4 and 5 until *both* zero and span calibration points equal their respective "Vdc Process Out" values.

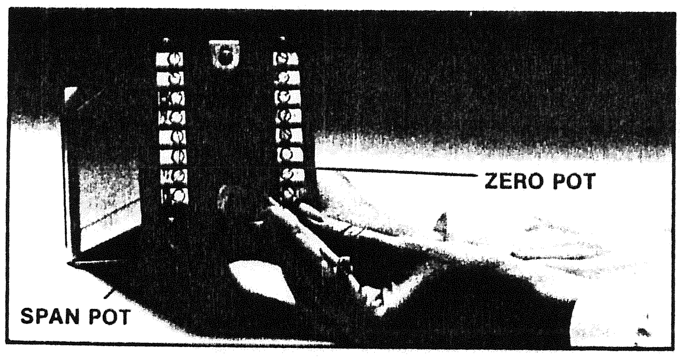


FIGURE 7-5. "PROCESS SIGNAL OUT" ZERO AND SPAN POTENTIOMETERS

MODEL NO.	INPUT TYPE	SENSOR RANGE	CALIBRATION FUNCTION	RECOMMENDED SENSOR INPUT	VDC PROCESS OUT
2001-XXX2X	"J" T/C	−100 to 1400°F	Zero Span	200°F 900°F	1.800 3.667
2001-XXX3X	"K" T/C	−100 to 2300°F	Zero Span	320°F 1600°F	1.700 3.833
2001-XXX4X	100 ohm Pt RTD	−200 to 1000°F	Zero Span	−200°F (48.520 ohms) 1000°F (293.43 ohms)	1.000 5.000

FIGURE 7-4. "PROCESS SIGNAL OUT" CALIBRATION TABLE

7.2.3 Sensor Input Selection for "Process Signal Out" Option

As stated previously, the "Process Signal Out" feature is calibrated for the sensor input type specified by the unit's model number (i.e., 2001-XXXX1 indicates **"J" or "K" T/C input**, 2001-XXXX4 indicates **RTD input**). Since "J" and "K" thermocouple models are interchangeable, the "Process Signal Out" feature is designed to accommodate this conversion from type "J" to type "K," or "K" to "J." This is accomplished by repositioning of 2 jumpers on the Process Out Card (see Figure 7-6), as illustrated in Figure 6-7. **Although it appears from Figure 7-7 that RTD units can be converted to Thermocouple units by mere repositioning of the jumpers, this is not true, and should not be attempted.**

To convert the "Process Signal Out" option from a "J" T/C input to a "K" T/C input,

1. Confirm that correct sensor input type has been selected via Menu No. 17 (refer to Figure 5-1).
2. Remove instrument power from the controller.
3. Remove the 2001 chassis from the case (as illustrated in Section 4.0).
4. The "Process Signal Out" card is located at the rear of the chassis (see Figure 7-6). Position the 2 jumpers in the "K" T/C position, as shown in Figure 7-7.
5. Place the instrument chassis back in the case.
6. Repower instrument, wait approximately 90 minutes to allow electronics to stabilize and recalibrate the 1-5 Vdc output signal as instructed in Section 7.2.2.

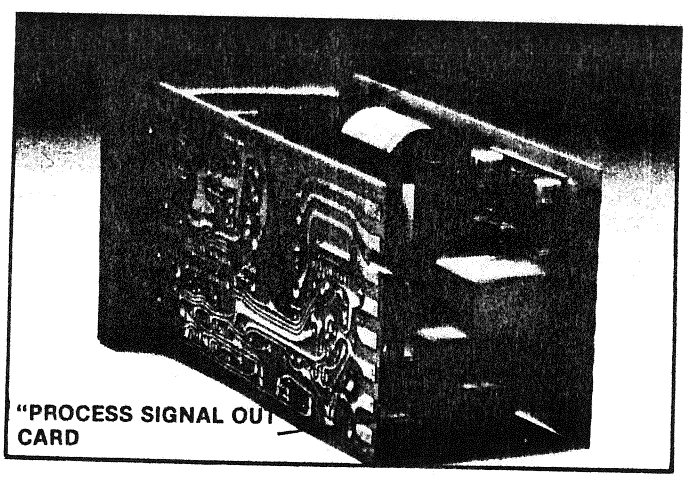
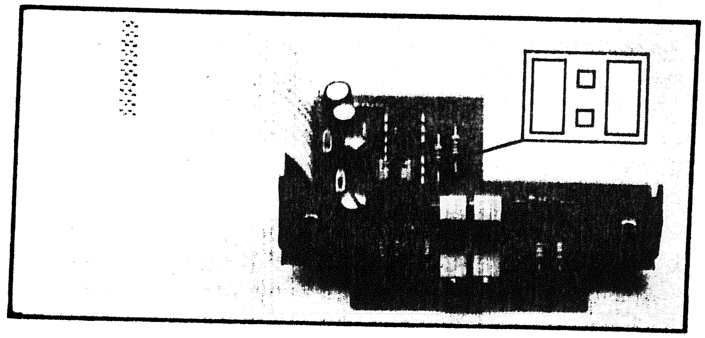
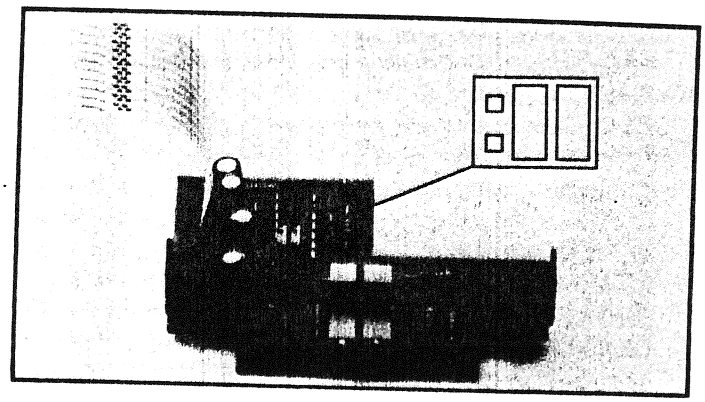


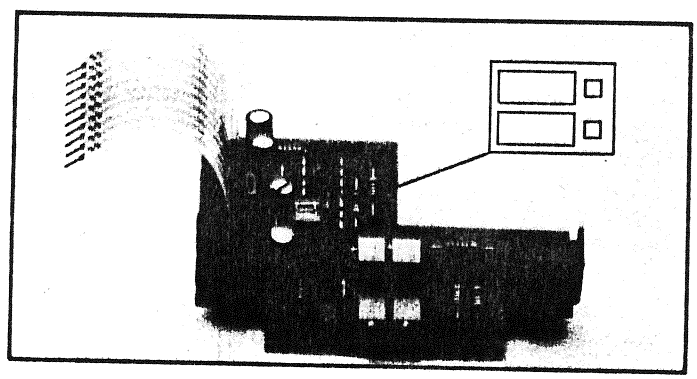
FIGURE 7-6. "PROCESS SIGNAL OUT" CARD IN CONTROLLER



"J" THERMOCOUPLE



"K" THERMOCOUPLE



RTD

FIGURE 7-7. "PROCESS SIGNAL OUT" CARDS
JUMPER POSITIONING FOR INPUT TYPE SELECTION

8.0 CALIBRATION

8.1 INTRODUCTION

For periodic calibration checks or adjustments, the microprocessor-based design of the 2001 controller allows sensor input and remote set point input calibration via Menu Numbers 21 through 27. To access the calibration section, code number "736" must be entered at Menu #20 (Security Lock). Factory calibration is performed prior to shipment, therefore, it is not necessary to calibrate the controller on receipt and installation.

Figure 8-1, Calibration Menu Table, lists the Menu Numbers, corresponding sensor calibration functions and recommended settings.

For each sensor type, there are 2 **Menu Numbers** that correspond to Zero and Span calibration points (see Figure 8-1). Recommended **Sensor Input Values** are provided for full range calibration. These recommended zero and span calibration points have been determined as providing optimum linearity calibration over the complete sensor range.

The Value Displayed refers to the upper digital display, which indicates the sensor input value (refer to Figure 8-2). Note in Figure 8-1 that the display value should, in some cases, slightly differ from the actual sensor simulator input value. Figure 8-1 also presents **Reference Values** that correspond to the sensor input values displayed. These reference values, which appear in the lower display, are *typical* values and will vary from controller to controller. It is recommended that the zero and span reference values be recorded in the **Your Ref. Value column** when calibrating the controller(s) to track any changes over time and to maintain updated calibration records.

8.2 CALIBRATION INSTRUCTIONS

Substitute a precision sensor simulator for the sensor inputs. It is recommended that Menu #18, Digital Filter, be *disabled* during calibration. It may be enabled after calibration is complete (if desired). The controller should be allowed to warm up with the sensor simulator connected for at least 90 minutes prior to calibration.

Calibration of the 2001 controller is very much like manual trimmer potentiometer "pot" adjustments of other instruments. Instead of turning a "pot," the sensor input display is adjusted with the [↑] and [↓] pushbuttons until the sensor input value and the displayed value are equal (per Figure 8-1). It is usually necessary to repeat Zero and Span adjustments several times until both display values equal their respective input values.

As stated previously, the [↑] and [↓] pushbuttons are used to increase and decrease the sensor input value displayed in the upper display. At *span* calibration points, the relationship between the pushbutton and process readout value in upper display is direct (i.e., when [↑] is pushed, the value increases). At *zero* calibration points, the relationship be-

MENU NO.	SENSOR TYPE	SENSOR RANGE	CALIBRATION FUNCTION	RECOMMENDED SENSOR INPUT	VALUE² DISPLAY	REFERENCE VALUE (±15%)	YOUR REFERENCE VALUE
21			Calibration Reference				
22	Type "J" T/C RTD	−100 to 1400°F −200 to 1000°F	Zero Zero	120°F 48.520Ω	120 −200	1250 832	
23	Type "J" T/C RTD	−100 to 1400°F −200 to 1000°F	Span Span	1260°F 293.430Ω	1259 1000	1850 1246	
24 25	Type "K" T/C Type "K" T/C	−100 to 2300°F	Zero Span	175°F 2225°F	172 2224	1670 2600	
26	Remote Set Point With (1) "J" T/C¹ (2) "K" T/C¹ (3) RTD		Zero	8.00mA³ (2.000V)	(1) 275°F (2) 500°F (3) 100°F	7095	
27	Remote Set Point With (1) "J" T/C¹ (2) "K" T/C¹ (3) RTD		Span	16.00mA³ (4.000V)	(1) 1025°F (2) 1700°F (3) 700°F	7050	

NOTES:
1. Remote Set Point in T/C instrument may be calibrated either as "J" or "K." Recalibration when switching between T/C types is not needed.
2. Remote Set Point displayed in process temperature display when at Menu Numbers 26 and 27 if in remote mode (Menu #19 = 1).
3. Instrument may be calibrated with voltage input or with current input. Jumper on input card must be in correct position to accept input signal (refer to Figure 7-1).

FIGURE 8-1. CALIBRATION MENU TABLE

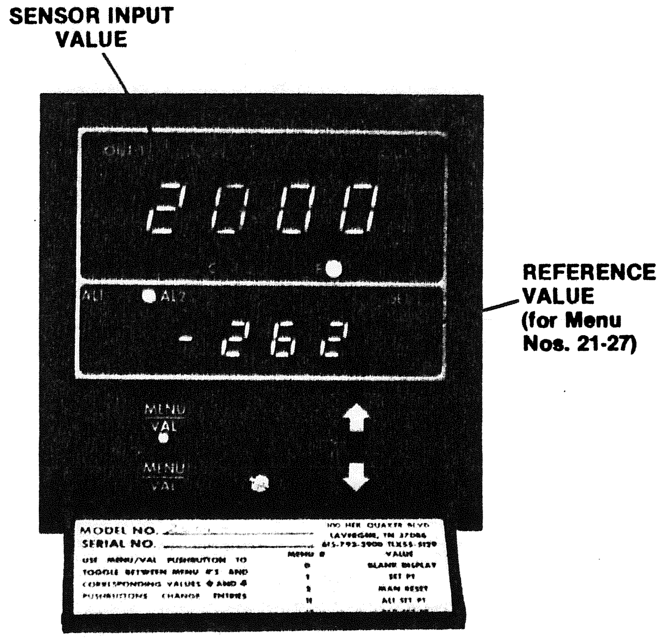


FIGURE 8-2. CALIBRATION DISPLAYS

tween the pushbutton and the process readout value in upper display is indirect (i.e., when [↑] is pushed, the value decreases). This is illustrated in Figure 8-3.

	ZERO CAL. POINTS	SPAN CAL. POINTS
[↑]	Decreases	Increases
[↓]	Increases	Decreases

[ ] = Process Readout Value In Upper Display

FIGURE 8-3.
PUSHBUTTONS IN CALIBRATION MODE

8.3 EXAMPLE CALIBRATION

In this instruction example, assume that sensor input type "K" thermocouple is used. From Figure 8-1, it is known that Menu Nos. 24 and 25 perform the Zero and Span calibration function for type "K" thermocouple controllers, and recommended sensor inputs are 175°F (zero) and 2225°F (span).

1. Access Level I security (see Section 5.2).
2. Select "MENU" using MENU/VAL.
3. [↑] until Menu No. "24" displayed in lower display.
4. Select "VAL" using MENU/VAL.
5. Set sensor simulator to 175°F.
6. Wait 30 seconds to allow electronics to stabilize.
7. [↑] or [↓] upper display until "172" is displayed.
8. Select "MENU" using MENU/VAL.
9. [↑] until Menu No. "25" displayed in lower display.
10. Select "VAL" using MENU/VAL.
11. Set sensor simulator to 2225°F.
12. Wait 30 seconds to allow electronics to stabilize.
13. [↑] or [↓] upper display until "2224" displayed.
14. Repeat steps 2 through 13 until both display values equal respective input values (per Figure 8-1).

8.4 CALIBRATION REFERENCE—MENU. NO. 21

This calibration operation updates the electronic component values in the 2001 controller memory. It is not necessary to perform Calibration Reference on receipt of the controller since it is pre-calibrated at the factory.

Calibration Reference is necessary only in situations where complete recalibration is indicated and should be performed prior to zero and span calibration.

To perform this operation,

1. Access Level I security (see Section 5.2).
2. Select "MENU" using MENU/VAL
3. [↑] until Menu No. "21" is displayed in lower display.
4. Select "VAL" using MENU/VAL.
5. "0" will be displayed in lower display.
6. Press and hold [↑] as display increase to "4" ("1,2,3,4").
7. Release [↑], display "4" will change to "0" indicating Calibration Reference functiôn is complete.

9.0 MAINTENANCE AND TROUBLESHOOTING

SYMPTOM	PROBABLE CAUSE	CORRECTION
POWER APPLIED, DISPLAY DOES NOT LIGHT AND CONTROLLER DOES NOT FUNCTION	a) No power applied b) Power loss transient	a) Check power wiring and fusing b) Power down and up
DISPLAY READS "HHHH" or "LLLL"	a) Open sensor b) Out of calibration	a) Check sensor wiring (Section 4.3) b) Check Sensor Type and selection entered in Menu No. 17 (Figure 5-1) c) Attach sensor stimulator and verify calibration
PROCESS DOES NOT HEAT UP/ COOL DOWN	a) No power being applied to load b) Incorrect control mode	a) Verify load wiring & fusing (Figure 4-11) b) Verify that load is not open—pluggable output module properly installed c) Check "Control Action" entered in Menu No. 6 (Figure 5-1) d) Check Control Mode entered in Menu No. 7 (Figure 5-1)
ERRATIC OPERATION	a) Intermittent sensor connections b) Controller failure (internal electronics)	a) Check sensor wiring or substitute sensor simulator b) Power down and up c) Contact factory
PROCESS NOT IN CONTROL	a) Incorrect "Control Action" selected b) Not tuned correctly	a) Check "Control Action" entered at Menu No. 6 (Figure 5-1)
INSTRUMENT CONTINUALLY GOES THROUGH POWER-UP RESET	a) Sensor incorrectly connected b) Internal electronic failure	a) Check sensor wiring (Section 4.2–4.6) b) Contact factory
"Err1" DISPLAYED	a) Internal RAM failed on power-up self-test	a) Power down and up to retest RAM b) Contact factory
"Err2" DISPLAYED	a) Internal ROM failed on power-up self-test	a) Power down and up to retest ROM b) Contact factory
"Err3" DISPLAYED WITH MENU NOS. "1-20" IN LOWER DISPLAY	a) EEPROM failed redundancy check	a) Power down and up to retest EEPROM b) Re-enter settings for Menu Nos. shown in lower display, power down, then re-power up to clear error (see Figure 5-1 for Menu Settings) c) Contact factory
"Err3" DISPLAYED WITH MENU NOS. "21-27" IN LOWER DISPLAY	a) EEPROM failed redundancy check	a) Power down and up to retest EEPROM b) Recalibrate sensor and remote set point input (see Sections 7.1 and 8.0) c) Contact factory
"Err3" DISPLAYED WITH MENU NOS. "28-30" IN LOWER DISPLAY	a) EEPROM failed redundancy check	a) Power down and up to retest EEPROM b) Contact factory

FIGURE 9-1. TROUBLESHOOTING GUIDE

10.0 WARRANTY AND RETURN

The warranty below complies with the Federal Law applicable to products manufactured after December 31, 1976. This warranty gives you specific legal rights. You may also have other rights which vary from state to state.

10.1 CHROMALOX WARRANTY

Chromalox Instruments and Controls' products are warranted against defects in workmanship and materials. No other express warranty, written or oral, applies with the exception of a written statement from an officer of Chromalox Instruments and Controls, Edwin L. Wiegand Division, Emerson Electric Co.

10.2 WARRANTY PERIOD

This warranty extends for twelve months from date of shipment from factory or authorized distributor.

10.3 LIMITATIONS

Products must be installed and maintained in accordance with Chromalox instructions. Users are responsible for the suitability of the products to their application. There is no warranty against damages resulting from corrosion, misapplication, improper specification or other operating conditions beyond our control. Claims against carriers for damage in transit must be filed by the buyer.

10.4 RETURNS

Items returned to Chromalox Instruments and Controls must be accompanied by a Return Authorization Number. This number may be obtained from Chromalox Instruments and Controls, Customer Service Department, Telephone Number (615) 793-3900. Defective items will be repaired or replaced at our option, at no charge.

Return the defective part or product, freight prepaid to:
Chromalox Instruments and Controls
100 Heil Quaker Blvd.
LaVergne, TN 37086-3536

SUCH REPAIR OR REPLACEMENT IS THE EXCLUSIVE REMEDY AVAILABLE FROM CHROMALOX INSTRUMENTS AND CONTROLS, EDWIN L. WIEGAND DIVISION, EMERSON ELECTRIC CO. CHROMALOX INSTRUMENTS AND CONTROLS IS NOT LIABLE FOR LABOR COSTS INCURRED IN REMOVAL, REINSTALLATION OR UNAUTHORIZED REPAIR OF THE PRODUCT OR FOR DAMAGE OF ANY TYPE WHATSOEVER, INCLUDING INCIDENTAL OR CONSEQUENTIAL DAMAGE. Some states do not allow the exclusion or limitation of incidental or consequential damages, so the preceding limitation or exclusion may not apply to you.

APPENDIX I. DETAILED DESCRIPTION OF MENU NUMBERS

MENU NO.	SELECTION	DESCRIPTION
1	Set Point (General)	The process set point is set by selecting Menu #1 and setting the displayed value to the desired temperature. Whenever the value at Menu #1 is selected, the front panel "Set" indicator will be ON. In normal operation, it is recommended that the Menu be left in this condition so that the value of the Process Set Point is displayed in the MENU/VAL Display for reference. The available range of set point values depends on the input sensor selected: For "J" T/C, −100 to 1400°F "K" T/C, −100 to 2300°F RTD, −200 to 1000°F The Remote Set Point is displayed in Menu #1 when the Remote Set Point option is installed and the Remote Set Point option is enabled via Menu #19. **Note:** The temperature units (°F or °C) of the value entered in Menu #1 (Process Set Point) corresponds to the temperature units as indicated by the front panel indicators. If the Unit-Sensor type is changed (Menu #17), the value of the Process Set Point is automatically converted to the appropriate temperature units (°F or °C).
2	Manual Reset (Proportional Control)	The manual reset adjustment is for Proportional Control only. It permits matching the process temperature to the set point after a controller offset is established. To enter a value for manual reset, select Menu #2 and enter the value of output required to return the process temperature to set point (−99.0 to +99.9). Increasing the setting increases the temperature, i.e., if the process temperature stabilizes *below* the set point, increase the Manual Reset.
3	Proportional Band (Proportional/ PID Control)	To set the proportional band, address Menu #3 and enter the value of the proportional band in % of input span (0.1 to 999.9%). Most applications require a Proportional Band between 1 and 20% of span. The factory setting is 5% of span. The factory set proportional band setting corresponds to 75°F for the thermocouple span (−100 to 1400°F), 120°F for the K thermocouple span (−100 to 2300°F) or 60°F for the 100 ohm platinum RTD span (−200 to 1000°F). With manual reset at 0.0, the output will be turned on 50% when the process temperature is equal to set point. If the control loop is initially operated with proportional only control (Menu 2, 4, 5 = 0.0), some difference in temperature between process set point and actual steady state temperature should be expected since it is unlikely that the 50% output will provide precisely the needed heat transfer to achieve operation at set point. To tune the proportional band, decrease the proportional band settings by 50% (this corresponds to greater gain settings) to cause loop instability. The process temperature will then oscillate, perhaps very slowly, without settling to a constant value. The proportional band then should be increased by 50% from the point where oscillation occurs. Wait 5-10 minutes between adjustment to allow stabilization. Also note that the proportional band should be adjusted prior to making reset and rate adjustments (Menu #4 and #5), and is adjusted while the load is being controlled.
4	Automatic Reset (Integral Action) (Proportional/ PID Control)	The Automatic Reset setting is used to determine how fast the controller responds to a difference between actual process temperature and the set point, in repeats per minute. To set the reset time, address Menu #4 and enter the value of the reset time in repeats per minute (0.00 to 99.99). A value of 0.00 disables the automatic reset function and enables the Manual reset function. Adjustment of reset should be made while the load is being controlled. Too large a setting for repeats/minute will cause severe overshoot when starting up as a PI controller. Also, too low a setting will not allow the error, the difference between the set point and process temperature, to be quickly eliminated in steady state operation. An anti-reset windup feature is included to minimize overshoot by inhibiting reset action during warm up or cooling time.

[ ] = General Control Parameters

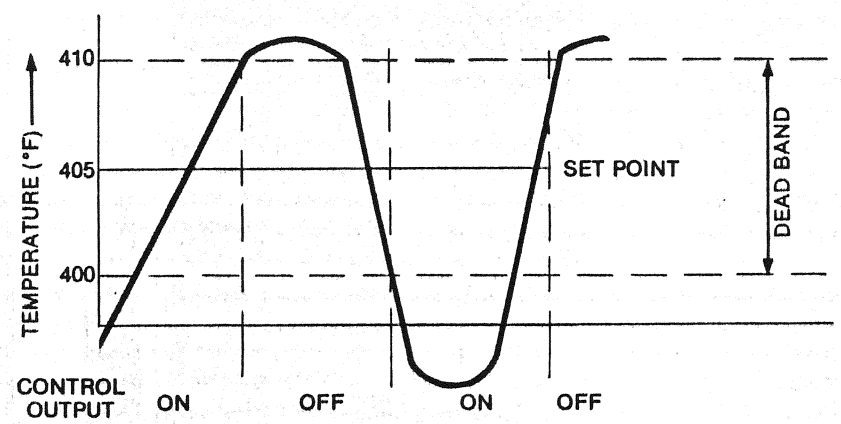
[ ] = ON/OFF Control Parameters

[shaded] = Proportional/PID Control Parameters

MENU NO.	SELECTION	DESCRIPTION
5	Rate (Derivative Rate) (Proportional/PID)	Rate allows the controller to react more quickly to sudden changes in the process temperature. The Rate feature measures the change, anticipates its severity and makes output corrections to quickly return the temperature to set point. If the proportional band, reset and rate are not properly coordinated with process characteristics, the process loop may be unstable. Section 6.0 can help determine PID settings. Rate can also be used without automatic reset for PD control with manual reset. Since rate is an anticipatory action, the rate contribution to the overall output command can override the cycle time setting. For example, if a heating process loop is operating at set point in steady state with an output cycle time of 30 seconds and output at 50%, (15 seconds on, 15 seconds off), and if the 15 second off-time has just begun when cold material is added causing the temperature to drop suddenly, a large enough rate setting will cause the 15 second off-time to immediately end and the output to again turn on. To set the rate time, address Menu #5 and enter the value of rate time in seconds (0-500). A value of 0 disables the rate function.
6	Control Action Reverse or Direct (General)	The direction of the control action determines the relation between increasing or decreasing output as the process temperature increases. With direct acting control (cooling), the value of the output increases as the process temperature increases. For reverse-acting control (heating), the value of the output decreases as the process temperature decreases. To enter the control action selection, address Menu #6 and enter the value "1" for the direct acting or "2" for reverse acting.
7	Control Mode ON/OFF or PID (General)	To enter the type of control to be used (ON-OFF or PID), address Menu #7 and enter the value "1" for combinations of PID control or "2" for ON-OFF control. If value "1" (PID) is selected, all control parameters except Menu #10 apply. If value "2" (ON-OFF) is selected, Menu #'s 1, 6 and 10-20 apply. (Further illustrated by different shading of all PID control settings and all ON/OFF control settings.) If PID control (Proportional + Integral + Derivative) is selected, the operator can choose whether he wants P, PI, PD or PID control by turning on or off the Integral (Menu #4) or the Derivative (Menu #5) actions.
8	Output Limit (Proportional/PID)	The PID output can be limited by setting the value of the output limit. This limit can be set to the nearest 1% from 0-100%. If the limit is set at 0%, a time-proportioned output will remain off and a 4-20mA output will stay below 4mA. A setting of 100% allows full output. This limit allows prevention of dangerous overheating or over-cooling. The setting of the limit value will affect PID tuning. Tuning should be performed with the output limit already set if possible. The output limit does not operate in On-Off mode. As an example of how the output is limited, if a 4-20mA output controller had its Output Limit set at 50%, the output would never have an output above 12mA. **Warning:** Setting the Output Limit to 0% should never be used as a method to disable the power to the load for servicing. Interrupt the power to the load using an approved positive disconnect method.
9	Output Cycle Time (Proportional/PID)	With time proportional control, the output cycle time may be set by addressing Menu #9 and setting the value to correspond to the cycle time in seconds (0.1 to 60.0). For most processes, a fast cycle time (less than 5 seconds) will produce better control of loads with fast response and little time lag. Caution should be used in setting the cycle time on contactor driven loads, as a faster cycle time will cause added wear on the contactor. Magnetic contactors should not be switched at cycle times less than 30 seconds. The cycle time must be set for both the time-proportioned output types (relay, triac, solid state relay driver) and the analog proportional 4-20mA output. The recommended setting for the 4-20mA output is 0.3 seconds. The factory suggested settings for cycle times are: Relay — 30.0 sec Triac — 1.0 sec (for direct loads) — increase time if triac drives contactor, B 4-20mA — 0.3 sec Solid State Relay Drive — 1.0 sec Cycle time is only functional if PID control is selected (Menu #7, Val #1).

<table>
<tr><th>MENU NO.</th><th>SELECTION</th><th>DESCRIPTION</th></tr>
<tr><td>10</td><td>Dead Band
(ON-OFF Control)</td><td>Dead Band applies to ON-OFF control only (Menu #7, VAL "2"). The On-Off control mode has an adjustable switching hysteresis (dead band) which can be set from 1°F to 100°F. This adjustment is always in °F, even if °C has been selected for display of the process temperature. Narrow dead band settings give more accurate control but result in more frequent output switching which can cause early failure of electromechanical contactors.

The switching of the output is balanced around the control set point. For example, a reverse acting (heating), ON-OFF controller with the process set point set at 405°F and the dead band set at 10°F, the output would be energized as the process increased up to 410°F where the output would then de-energize and remain de-energized until the process temperature was less than 400°F.


</td></tr>
<tr><td>11</td><td>Alarm Set Point #1
(General)</td><td>Menu #11 allows for the selection of the set point for Alarm Relay #1. This set point will act as a low, high or deviation alarm depending on its alarm mode setting which is selected in Menu #13.

The temperature units (°F or °C) of the alarm set point are indicated by the LEDs on the front panel and correspond to the process set point (Menu #1) units.

The range of available settings for the high and low alarm set points depend on the input sensor selected.
For "J" T/C, −100 to 1400°F
"K" T/C, −100 to 2300°F
RTD, −200 to 1000°F
The range of settings for the deviation alarm set point is ±250°F.</td></tr>
<tr><td>12</td><td>Alarm Set Point #2
(General)</td><td>Menu #12 allows for the selection of the set point for Alarm Relay #2. This set point will act as a low, high or deviation alarm depending on its alarm setting which is selected in Menu #14.

The temperature units (°F or °C) of the alarm set point are indicated by the LEDs on the front panel and correspond to the process set point (Menu #1) units.

The range of available settings for the high and low alarm set point depends on the input sensor selected.
For "J" T/C, −100 to 1400°F
"K" T/C, −100 to 2300°F
RTD, −200 to 1000°F
The range of settings for the deviation alarm set point is ±250°F.</td></tr>
</table>

MENU NO.	SELECTION	DESCRIPTION
13	Alarm Mode for Alarm #1 (General)	The Alarm Relay #1 can be set to be a high, low or deviation alarm by selecting the appropriate value (1-5) in Menu #13. When Alarm #1 is energized, the front panel indicator "AL1" will light. The following values will select the alarm type desired: Value — Alarm Type 1 — High Alarm 2 — Low Alarm 3 — + Deviation Alarm 4 — − Deviation Alarm 5 — ± Deviation Alarm The high and low alarms have a 10°F reset differential, and the deviation alarms have a 2°F reset differential. The examples which follow detail the alarm modes. Examples: **High Alarm:** This alarm is a high absolute alarm that actuates whenever the process temperature is equal to or greater than the Alarm Set Point. The reset differential is 10°F (6°C). Example: High alarm set at 500°F Therefore, Alarm will energize at 500°F Alarm will de-energize at 490°F **Low Alarm:** This alarm is a low absolute alarm that actuates whenever the process temperature is equal to or less than the Alarm Set Point. The reset differential is 10°F (6°C). Example: Low alarm set at 200°F Therefore, Alarm will energize at 200°F Alarm will de-energize at 210°F **+ Deviation Alarm:** This alarm will actuate whenever the process temperature is equal to or greater than the Process Set Point by the predetermined (Alarm Set Point) amount. When the Process Set Point (Remote or Local) is moved, the deviation alarm moves with it maintaining the same deviation from set point. The reset differential is 2°F (1°C). Example: Process Set Point is set to 300°F and Alarm Set Point is set to 10°F. Therefore, Alarm will energize at 310°F Alarm will de-energize at 308°F **− Deviation Alarm:** This alarm will actuate whenever the process temperature is equal to or less than the Process Set Point by the predetermined (Alarm Set Point) amount. When the Process Set Point (Remote or Local) is moved, the deviation alarm moves with it maintaining the same deviation from set point. The reset differential is 2°F (1°C). Example: Process Set Point is set to 400°F and Alarm Set Point is set to 20°F. Therefore, Alarm will energize at 380°F Alarm will de-energize at 382°F **± Deviation Alarm:** The deviation band alarm will actuate whenever the process temperature deviates from the Process Set Point more than the predetermined (Alarm Set Point) amount in either a positive or negative direction. The reset differential is 2°F (1°C). Example: Process Set Point is set to 700°F and Alarm Set Point is set to 50°F. Therefore, Alarm will energize whenever the process temperature is greater than 750°F or is less than 650°F Alarm will de-energize whenever the process temperature is less than 748°F or greater than 652°F Non-symmetrical ± deviation can be programmed using Alarm #1 as (+) deviation and Alarm #2 as (−) deviation. The alarm relay contacts must then be wired in parallel for this application.

MENU NO.	SELECTION	DESCRIPTION
14	Alarm Mode for Alarm #2 (General)	The Alarm Relay #2 can be set to be a high, low or deviation alarm by selecting the appropriate value (1–5) in Menu #14. When Alarm #2 is energized, the front panel indicator "AL2" will light. The following values will select the alarm type desired. Value — Alarm Type 1 — High Alarm 2 — Low Alarm 3 — + Deviation Alarm 4 — − Deviation Alarm 5 — ± Deviation Alarm The high and low alarms have a 10°F reset differential, and the deviation alarms have a 2°F reset differential. See the examples in the Menu #13 section to clarify the alarm modes.
15	Not Used	
16	Not Used	
17	Input Sensor °C or °F units (General)	Refer to the model number of the 2001 Series Controller to determine the type of sensor (thermocouple or RTD) that the controller will accept. If the unit requires a thermocouple input (2001-XXXX1), the type of thermocouple and the units (°F or °C) must be selected by addressing Menu #17 and setting the value (1 through 4) to correspond to the Unit-Sensor type as indicated in the following table. For RTD input (2001-XXXX4), selection of the units (°F or °C) are entered in Menu #17 by setting the value (5 or 6) as indicated in the table. Menu #17 Value — Sensor — Units — Model # 1 — Type J TC — °F — 2001-XXXX1 2 — Type K TC — °C — 2001-XXXX1 3 — Type J TC — °F — 2001-XXXX1 4 — Type K TC — °C — 2001-XXXX1 5 — 100 ohm Pt RTD — °F — 2001-XXXX4 6 — 100 ohm Pt RTD — °C — 2001-XXXX4
18	Digital Filter (General)	The 2001 Series Controller is provided with a program selectable Digital Filter to reduce response to series or common mode noise and switching transients. To select the Digital Filter, address Menu #18 and enter the value 1 (enable) or 0 (disable). It is recommended that for all normal operations that the Digital Filter be enabled, and disabled during calibration.
19	Remote Process Set Point (General)	Refer to Model # of the 2001 to determine if the Remote Set Point option is included. Model Nos. 2001-XXX1X, -XXX2X, -XXX3X and -XXX4X all include the remote set point option. If the Remote Process Set Point is to be used, the unit must first be enabled for remote set point by addressing Menu #19 and setting the value to 1 (enable). The unit may be returned to local set point operation at any time by setting the value of Menu #19 to 0 (disable). The factory setting of the unit is for local set point (Remote Process Set Point disable). If Remote Process Set Point is enabled, the value displayed in Menu #1 will correspond to the Remote Set Point signal according to the span of the input type selected. For more detail on Remote Set Point, see Section 7.1. If the Remote Set Point option is not installed (i.e., not specified by the model number), the controller will operate with the *local* set point, even if Menu #19 is enabled ("1" value).
20	Security Codes (General)	The security lock feature allows for selection of one of four levels of security. This feature prevents unauthorized or inadvertent changes to the controller settings. Security Codes are entered at Menu #20. Upon receipt, the controller has Security Code "458" entered at Menu #20, meaning that Level 2 security is in effect (Menu Nos. 1 through 20 may be adjusted and viewed, access to Menu Nos. 21 through 27 is blocked). This level of security will remain in effect until the entry in Menu No. 20 is changed. Also note that security codes are retained in the controller memory even if power to the instrument is removed. Refer to page 13 for listing of Security Codes.

E41000
RSS-8559-1-1-7

SPACE TRANSPORTATION SYSTEM
TECHNICAL MANUAL

INSPECTION CRITERIA SPACE SHUTTLE MAIN ENGINE

PART NUMBER RS007001

ROCKWELL INTERNATIONAL CORPORATION
ROCKETDYNE DIVISION
02602

REPLACEMENT NOTICE

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10 MARCH 1993

LIST OF EFFECTIVE PAGES	INSERT LATEST CHANGED PAGES. DESTROY SUPERSEDED PAGES.

NOTE: The portion of the text affected by the changes is indicated by a vertical line in the outer margins of the page.

Dates of issue for original and changed pages are:

Original 0 10 March 1993

TOTAL NUMBER OF PAGES IN THIS PUBLICATION IS 188 CONSISTING OF THE FOLLOWING:

Page No.	*Change No.	Page No.	*Change No.	Page No.	*Change No.
Title	0				
A	0				
i thru viii	0				
1-1 thru 1-48	0				
2-1 thru 2-68	0				
3-1 thru 3-11/3-12	0				
4-1 thru 4-31/4-32	0				
5-1 thru 5-18	0				

*Zero in this column indicates an original page.

CHANGE RECORD

REV	DATE	CHANGE SUMMARY
PRELIM	3/6/85	PRELIMINARY ISSUE FOR OMRSD REVIEW/APPROVAL CYCLE (REF RCN MV6596)
BASIC	3/6/85	BASIC MANUAL RELEASED PER RCN MV6596 APPROVAL 9/26/85
REV	8/10/87	UPDATED MANUAL TO THE LATEST REQUIREMENTS
REV	7/27/88	UPDATED MANUAL TO THE LATEST REQUIREMENTS
CHG 1	7/5/89	UPDATED MANUAL TO THE LATEST REQUIREMENTS
CHG 2	8/18/89	UPDATED MANUAL TO THE LATEST REQUIREMENTS
REV	11/1/89	UPDATED MANUAL TO THE LATEST REQUIREMENTS
CHG 1	2/12/90	UPDATED MANUAL TO THE LATEST REQUIREMENTS
CHG 2	4/11/90	UPDATED MANUAL TO THE LATEST REQUIREMENTS
CHG 3	5/2/90	UPDATED MANUAL TO THE LATEST REQUIREMENTS
CHG 4	10/24/90	UPDATED MANUAL TO THE LATEST REQUIREMENTS
REV	10/25/90	UPDATED MANUAL TO THE LATEST REQUIREMENTS
REV	2/10/92	UPDATED MANUAL TO THE LATEST REQUIREMENTS
CHG 1	3/27/92	UPDATED MANUAL TO THE LATEST REQUIREMENTS
REV	5/29/92	UPDATED MANUAL TO THE LATEST REQUIREMENTS
REV	7/31/92	UPDATED MANUAL TO THE LATEST REQUIREMENTS
REV	11/5/92	UPDATED MANUAL TO THE LATEST REQUIREMENTS
REV	2/16/93	UPDATED MANUAL TO THE LATEST REQUIREMENTS
REV	3/10/93	UPDATED MANUAL TO THE LATEST REQUIREMENTS

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LIST OF TABLES

INTRODUCTION

This manual contains the formal, approved, accept/reject criteria for inspections conducted on the SSME at launch sites and landing sites. The data herein supports the SSME inspection requirements contained in the Level II OMRSD and Rockwell Specifications RF0001-053, RL00050-04, RL00056-06, and RL00056-07.

CHANGE CONTROL

A Publication Change Suggestion (PCS) Form 609 K-11 will be prepared, in accordance with the FE&L Operating Manual, when a change to this manual is required. The PCS will be mailed to the FE&L Data Services Coordinator D/579-420.

Technical changes to this document are controlled by Specification RF0001-053, which is processed through the Rocketdyne Change Control Board (CCB) chaired by the Rocketdyne SSME Program Manager. Changes approved by the Rocketdyne CCB are forwarded to the SSME MSFC Project Office for approval and subsequent submittal in accordance with Level II OMRSD, File I RCN processing requirements. (See figure 1 for approval process.)

DEFINITIONS

Dent - An indentation in which no material has been removed or scraped.

Leak - Fluid passing through a defect in a tube or vessel. Nozzle tube leakage is defined as follows:

- Class I - Steady formation of very small, long-persisting bubbles, frequently too small to see as individual bubbles, thereby creating a characteristic milky appearance that may build up to a shaving-cream-lather like appearance, fuzz (0.001 to 1.3 scim).
- Class II - Mixture of random size bubbles of moderate persistence (1.3 to 4.0 scim).
- Class III - Large, fast-forming bubbles of short persistence, most of which break as the next one forms (4.0 to 50.0 scim).
- Blowing - Bubble formation does not form because of large gas flow.

Scratch, Nick, or Gouge - A damaged area in which material has been removed, or moved, with a resultant decrease in wall thickness.

Spalling - Flaking, scaling, or delamination of material.

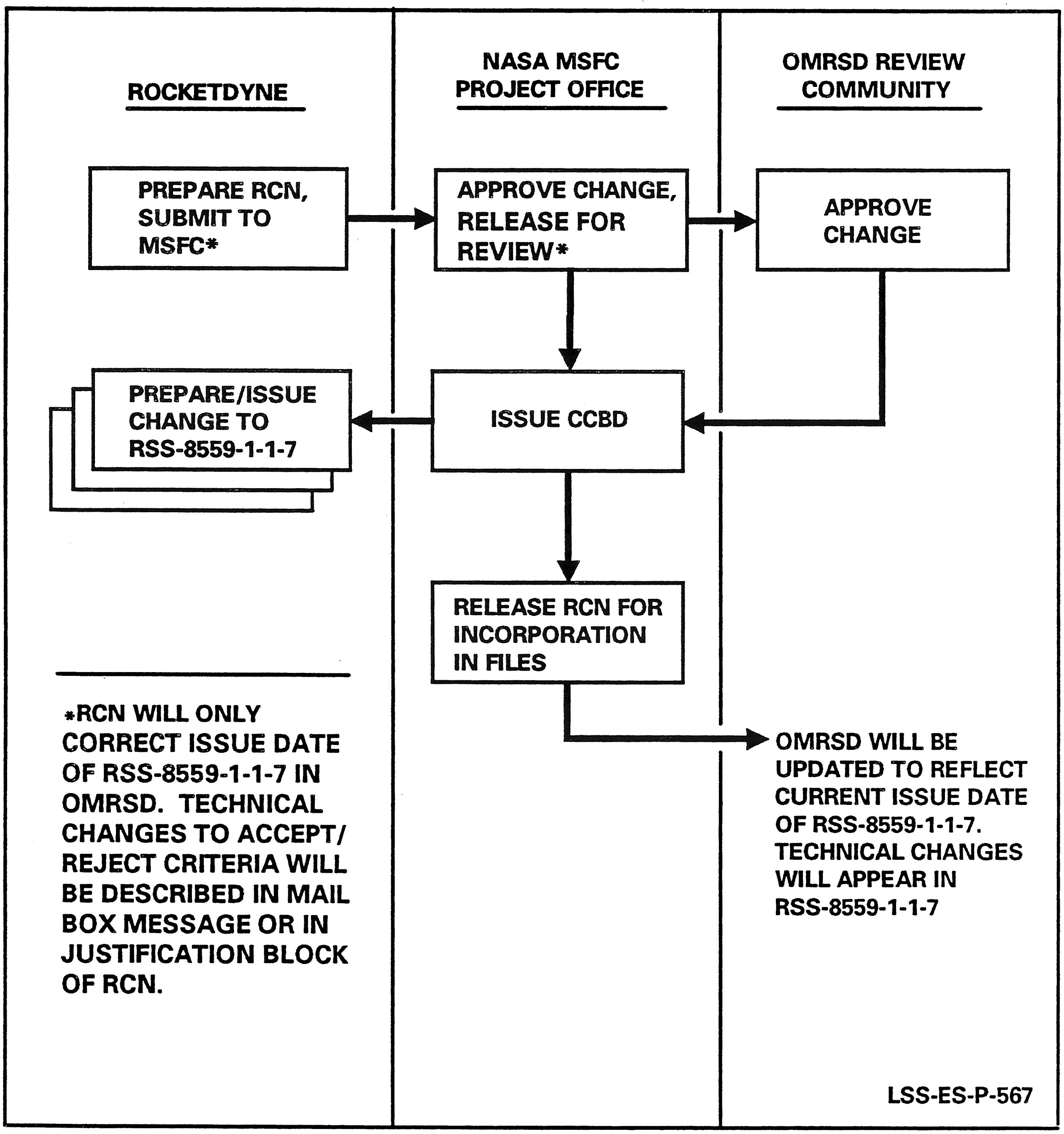


Figure 1. SSME Inspection Criteria Approval Process

SECTION I

INSPECTION CRITERIA
FOR
COMBUSTION DEVICES

SECTION I

CHANGE RECORD

REV/ CHG	DATE	CHANGE SUMMARY	PAGE EFFECT	RCN/CCBD
PRELIM	3/6/85	PRELIMINARY FOR OMRSD REVIEW/ APPROVAL CYCLE	ALL	RCN MV6596 (RELEASED FOR REVIEW 8/26/85)
BASIC	3/6/85	BASIC SECTION RELEASED	ALL	RCN MV6596 (APPROVED 9/26/85)
REV	8/10/87	UPDATED SECTION TO THE LATEST REQUIREMENTS	ALL	RCN MV8301 (APPROVED 7/28/88)
CHG 1	7/5/89	UPDATED SECTION TO THE LATEST REQUIREMENTS	1-3, 1-4, 1-8, 1-11, 1-14, 1-14A/ 1-14B, 1-27, 1-35/ 1-36	CCBD NO. ME3-00-7675 (APPROVED 6/29/89)
CHG 2	8/18/89	ADDED FLOW RECIRCULATION INHIBITOR (FRI) INSPECTION CRITERIA		CCBD NO. ME3-00-7672A (APPROVED 7/28/89)
REV	11/1/89	UPDATED SECTION TO THE LATEST REQUIREMENTS	1-4, 1-14	CCBD NO. ME3-00-7909 (APPROVED 9/29/89)
CHG 1	12/22/89	UPDATED SECTION TO THE LATEST REQUIREMENTS	ALL	CCBD NO. ME3-00-7909 (APPROVED 9/29/89)
CHG 2	4/11/90	UPDATED SECTION TO THE LATEST REQUIREMENTS OF ECP 1103	1-14 THRU 1-20, 1-30 THRU 1-42	CCBD NO. ME3-00-8576 (APPROVED 4/5/90)
REV	10/25/90	UPDATED SECTION TO THE LATEST REQUIREMENTS	NONE	CCBD NO. ME3-AA-5445 (APPROVED 6/20/89)

SECTION I

CHANGE RECORD (continued)

REV/ CHG	DATE	CHANGE SUMMARY	PAGE EFFECT	RCN/CCBD
REV	2/10/92	UPDATED SECTION TO THE LATEST REQUIREMENTS	1-5, 1-6, 1-9, 1-13, 1-15, 1-16, 1-19, 1-22, 1-25, 1-30, 1-32, 1-46 THRU 1-48	SPECIFICATION RF0001-053 REVISION E-1 (APPROVED 10/30/91)
REV	5/29/92	UPDATED SECTION TO THE LATEST REQUIREMENTS	1-6, 1-16, 1-17, 1-19, 1-25	SPECIFICATION RF0001-053 REVISION F-4 (APPROVED 5/19/92)
REV	7/31/92	UPDATED SECTION TO THE LATEST REQUIREMENTS OF RF0001-053	1-6	SPECIFICATION RF0001-053 REVISION G (APPROVED 8/13/92)
REV	11/5/92	UPDATED SECTION TO THE LATEST REQUIREMENTS OF RF0001-053	1-6, 1-9, 1-17	SPECIFICATION RF0001-053 REVISION G-1 (APPROVED 11/17/92)
REV	2/16/93	UPDATED SECTION TO THE LATEST REQUIREMENTS OF RF0001-053	1-6, 1-21	SPECIFICATION RF0001-053 REVISION G-2 (APPROVED 2/11/93)
REV	3/10/93	UPDATED SECTION TO THE LATEST REQUIREMENTS OF RF0001-053	1-6	SPECIFICATION RF0001-053 REVISION G-3 (APPROVED 3/16/93)

SECTION I

INSPECTION CRITERIA FOR COMBUSTION DEVICES

1.1 SCOPE

This section contains inspection criteria for the main SSME injector, hot gas manifold, FPB injector, OPB injector, augmented spark ignition chamber, main combustion chamber, nozzle, and nozzle TPS. (Refer to table 1-1.)

1.2 OMRSD

The hardware condition limitation of the inspection criteria supports the OMRSD requirements listed below. Hardware conditions that are within these limitations require no further action or rework. Hardware conditions resulting from operational degradation that do not meet these limitations shall be processed through the PR/MR system.

V41BU0.030 PERFORM SSME COMPONENTS EXTERNAL INSPECTION

V41BU0.031 SSME MCC BONDLINE ULTRASONIC INSPECTION

V41BU0.040 INTERNAL INSPECTIONS OF SSME COMPONENTS

V41BU0.081 SSME FPB INSPECTIONS WITH HPFTP REMOVED

V41BU0.082 SSME OPB INSPECTIONS WITH HPOTP REMOVED

V41BU0.093 SSME HGM FUEL SIDE INSPECTION

V41BU0.096 SSME HGM OXIDIZER SIDE INSPECTION

V41BU0.105 SSME FPB INJECTOR OXIDIZER POSTS INSPECTION

V41BU0.351 SSME POST-FLIGHT MCC LINER POLISHING

V41BU0.353 SSME POST-LANDING NOZZLE INSPECTION

1.3 COMPONENT DESCRIPTIONS

Figures 1-1 through 1-25 identify the components and the areas to be inspected.

1.4 APPLICABLE DOCUMENTS

The following documents are listed for source reference only.

SPECIFICATIONS

Rockwell International

	REV	
RF0001-053	G-3	Space Shuttle Main Engine Inspection Criteria
RF0004-057	A	Components, Combustion Devices, Hardware Condition Limits of
RL00050-04	AG-4	Space Shuttle Main Engine Acceptance Test, Calibration and Adjustment Procedure
RL00059	E-1	SSME Overhaul/Recycle/Repair Requirements
RL00324	C	SSME Powerhead, Overhaul/Recycle/Repair Requirements
RL00529	C-1	SSME Main Injector, Overhaul/Recycle/Repair Requirements
RL00563	D-1	SSME Main Combustion Chamber, Overhaul/Recycle/ Repair Requirements
RL00571	B-3	SSME Nozzle Assembly, Overhaul/Recycle/Repair Requirements
RL00573	C-1	SSME Fuel and Oxidizer Preburners and Igniter System, Overhaul/Recycle/Repair Requirements
RL00649	B-1	Preburner LOX Post, Eddy Current Inspection of

TABLE 1-1. SSME COMBUSTION DEVICES COMPONENTS INSPECTION CRITERIA
(Sheet 1 of 20)

Condition	Hardware Condition Limit
A. Main Injector (See figure 1-1.)	
1. Faceplate, facenuts, and LOX posts:	
Discoloration	Discoloration to any degree is acceptable in areas normally exposed to hot gases.
Erosion	Erosion is not acceptable.
Looseness	Looseness of facenuts is not acceptable.
Cracks	Facenut thread cracks are not acceptable.
2. Baffles: (See figure 1-2.)	
Discoloration	Discoloration to any degree is acceptable in areas normally exposed to hot gases.
Surface defects	Surface defects on copper jacket that are less than 0.010 inch in depth are acceptable.
Erosion	Erosion of baffle tip and spalling of ceramic coating is acceptable if erosion is not through tip. Erosion of baffle upstream of tip area is not acceptable.
3. Injection elements (figure 1-3) and film coolant holes:	
Blockage	Blockage with contamination that cannot be dislodged is not acceptable.

TABLE 1-1. SSME COMBUSTION DEVICES COMPONENTS INSPECTION CRITERIA
(Sheet 2 of 20)

Condition	Hardware Condition Limit
A. Main Injector (continued)	
4. Flow shields, heat shield, heat shield retainers, and secondary faceplate retainers:	
Impact damage	Impact damage is acceptable if items are not displaced and provide coverage of underlying components.
Unseated retainer	Unseating of secondary faceplate retainers from secondary faceplate is not acceptable.
Exposure	Exposure of interpropellant plate through heat shield is not acceptable.
Loose shields	Looseness of flow shields and bolts is not acceptable.
Cracked or dented shields	Cracks or dents in flow shields are not acceptable.
5. Deactivated LOX posts:	
Pin position	LOX post deactivation pins not verifiable by inspection through oxidizer manifold port C02d (08.3) are not acceptable. Also, contamination in the LOX dome is not acceptable.
Cracks	Cracked LOX post tip welds are not acceptable.
6. Augmented spark ignition (ASI) chamber: (See figures 1-4 and 1-5.)	
Discoloration	Discoloration to any degree is acceptable in areas normally exposed to hot gases.
Orifice blockage	Blockage of fuel or oxidizer injection orifices with contamination is not acceptable.

TABLE 1-1. SSME COMBUSTION DEVICES COMPONENTS INSPECTION CRITERIA
(Sheet 3 of 20)

Condition	Hardware Condition Limit
A. Main Injector (continued)	
Cracks	Cracks in ASI combustion dome area and LOX injection orifices are not acceptable.
Erosion	Erosion is not acceptable.
Clearance	A clearance of less than 0.040 inch between fuel ASI line and thrust cone or evidence of line rubbing thrust cone is not acceptable.
B. Fuel Preburner (See figure 1-27.)	
1. Thermal shield:	
Cracks	Cracks or interlaminar chipping are acceptable.
Debonding	Adhesive debonding of shields is not acceptable.
2. Liner:	
Spalling	Spalling of ceramic coating is acceptable.
Discoloration	Discoloration to any degree is acceptable in areas normally exposed to hot gases.
Erosion	Erosion is not acceptable.
Tabs (adjacent to inspection ports) (See figure 1-26.)	Tabs must be in the proper upright position.
3. Liner extension:	
Roundness	Roundness condition is acceptable if extension does not interfere with HPFTP liner check fixture or HPFTP installation.

TABLE 1-1. SSME COMBUSTION DEVICES COMPONENTS INSPECTION CRITERIA
(Sheet 4 of 20)

Condition	Hardware Condition Limit
B. Fuel Preburner (continued)	
Discoloration	Discoloration to any degree is acceptable in areas normally exposed to hot gases.
Erosion	Erosion is not acceptable.
4. Injection element:	
Erosion	Erosion to 0.050 inch maximum depth without slag or burs protruding from LOX post tip is acceptable.
Support pin condition	Damaged, shifted, or missing LOX post support pins are not acceptable. (See figure 1-6.)
Cracks	Cracked deactivated LOX post tip welds are not acceptable.
Blockage	Blockage with contamination is not acceptable.
5. Faceplate:	
Discoloration	Discoloration to any degree is acceptable in areas normally exposed to hot gases.
Erosion	Erosion is not acceptable.
Cracks	Surface cracks between elements and/or coolant holes that do not exceed 0.003 inch in width and 0.5 inch in length are acceptable. Cracks that emanate from surface damage (ie dents, dings, gouges, tooling marks, weld mistrack, and so on) are not acceptable.
Blockage	Blockage of faceplate injection holes with contamination is not acceptable.

TABLE 1-1. SSME COMBUSTION DEVICES COMPONENTS INSPECTION CRITERIA
(Sheet 5 of 20)

Condition	Hardware Condition Limit
B. Fuel Preburner (continued)	
6. Inspection hole elliptical plug (FG1d):	
Surface roughness	Surface roughening is acceptable if surface finish is uniform.
Erosion/pitting/cracks	Erosion, pitting, or cracks are not acceptable.
Discoloration	Discoloration to any degree is acceptable in areas normally exposed to hot gases.
7. Baffles:	
Discoloration	Discoloration to any degree is acceptable in areas normally exposed to hot gases.
Erosion	Erosion or melting of baffle trailing edge adjacent to ASI (inboard row A or B) not exceeding 0.100 inch in depth is acceptable.
Cracks	Cracks or pitting in braze material of baffle inspection hole closeout plugs (rows A and B) are acceptable unless cracks are continuous and exceed 180 degrees around plug.
Blockage	Blockage of coolant holes with contamination is not acceptable.
8. Augmented spark ignition (ASI) system: (See figure 1-5.)	
Cracks	Radial, tangential (race track) cracks in ASI combustion dome area and a single orifice crack are acceptable. (See figure 1-7.)

TABLE 1-1. SSME COMBUSTION DEVICES COMPONENTS INSPECTION CRITERIA
(Sheet 6 of 20)

Condition	Hardware Condition Limit
B. Fuel Preburner (continued)	
Discoloration	Discoloration to any degree is acceptable in areas normally exposed to hot gases.
Blockage	Blockage of fuel or oxidizer injection orifices with contamination is not acceptable.
Erosion	Erosion is not acceptable.
ASI metering orifice deformation	Deformation or erosion of removable ASI metering orifices is not acceptable.
Delamination	Delamination or unraveling of oxidizer line graphite reinforcement wrap is not acceptable.
9. Instrumentation bosses:	
Cracks	Cracks are not acceptable.
Erosion	Erosion is not acceptable.
C. Oxidizer Preburner (See figure 1-8.)	
1. Liner:	
Spalling	Spalling of ceramic coating is acceptable.
Discoloration	Discoloration to any degree is acceptable in areas normally exposed to hot gases.
Erosion	Erosion is not acceptable.
2. Liner extension:	
Discoloration	Discoloration to any degree is acceptable in areas normally exposed to hot gases.

TABLE 1-1. SSME COMBUSTION DEVICES COMPONENTS INSPECTION CRITERIA
(Sheet 7 of 20)

Condition	Hardware Condition Limit
C. Oxidizer Preburner (continued)	
Erosion	Erosion is not acceptable.
Tabs (adjacent to inspection ports) (See figure 1-8.)	Verify tabs are in the proper upright position.
3. Injection element:	
Erosion	Erosion to 0.050 inch maximum depth without slag or burs protruding from LOX post tip is acceptable.
LOX post	Eddy current measurement with EM 3300 scope divisions of 5 volts or greater are not acceptable.
Support pin condition, if installed.	Damaged, shifted, or missing LOX post support pins are not acceptable, if previously installed. (See figure 1-6.)
Cracks	Cracked deactivated LOX post tip welds are not acceptable.
Blockage	Blockage with contamination is not acceptable.
4. Faceplate:	
Discoloration	Discoloration to any degree is acceptable in areas normally exposed to hot gases.
Erosion	Erosion is not acceptable.
Cracks	Surface cracks between elements and/or coolant holes that do not exceed 0.003 inch in width and 0.5 inch in length are acceptable. Cracks that emanate from surface damage (ie dents, dings, gouges, tooling marks, weld mistracks, and so on) are not acceptable.

TABLE 1-1. SSME COMBUSTION DEVICES COMPONENTS INSPECTION CRITERIA
(Sheet 8 of 20)

Condition	Hardware Condition Limit
C. Oxidizer Preburner (continued)	
Blockage	Blockage of faceplate injection holes with contamination is not acceptable.
5. Baffles:	
Discoloration	Discoloration to any degree is acceptable in areas normally exposed to hot gases.
Erosion	Erosion or melting of baffle trailing edge adjacent to ASI (inboard row A or B) not exceeding 0.100 inch in depth is acceptable.
Blockage	Blockage of coolant holes with contamination is not acceptable.
6. Instrumentation port plug (OG1a, OG1b):	
Surface roughness	Surface roughening is acceptable if surface finish is uniform.
Erosion/pitting/cracks	Erosion, pitting, or cracks are not acceptable.
Discoloration	Discoloration to any degree is acceptable in areas normally exposed to hot gases.
7. Augmented spark ignition (ASI) system: (See figure 1-5.)	
Cracks	Cracks in ASI combustion dome area and LOX injection orifices are acceptable to the extent shown in figure 1-7.
Discoloration	Discoloration to any degree is acceptable in areas normally exposed to hot gases.

TABLE 1-1. SSME COMBUSTION DEVICES COMPONENTS INSPECTION CRITERIA
(Sheet 9 of 20)

Condition	Hardware Condition Limit
C. Oxidizer Preburner (continued)	
Blockage	Blockage of fuel or oxidizer injection orifices with contamination is not acceptable.
Erosion	Erosion is not acceptable.
ASI metering orifice deformation	Deformation or erosion of removable ASI metering orifices is not acceptable.
8. Instrumentation bosses:	
Cracks	Cracks are not acceptable.
Erosion	Erosion is not acceptable.
D. Hot Gas Manifold (See figures 1-9, 1-27, and 1-28.)	
1. Liner sheet metal and transfer tube sheet metals:	
Cracks	Cracks in liners or transfer tubes are not acceptable. (ECP 1196)
Erosion	Erosion is not acceptable.
2. Liner welds 1-6, 46, 52, 54, 56-69, 76-79, and 150-155 (Refer to drawing RS007051), and RPL to FPL conversion welds 5A and 5B.	
Cracks	Flight units: Surface flaws less than or equal to 0.125 inch in length are acceptable. End-to-end flaws are acceptable if the sum of the length of each flaw and the space between them is less than or equal to 0.125 inch in length. (ECP 1196)

TABLE 1-1. SSME COMBUSTION DEVICES COMPONENTS INSPECTION CRITERIA
(Sheet 10 of 20)

Condition	Hardware Condition Limit
D. Hot Gas Manifold (continued)	
3. Button welds and doubler welds (welds 19 through 24) on the center transfer tube (Refer to drawing RS007065 and RPL to FPL conversion welds 2A/2B.	
Cracks	Cracks in these welds are not acceptable. (ECP 1196)
4. External surfaces (fuel supply to OPB/FPB and coolant duct):	
Cracks	Cracks are not acceptable.
Dents, scratches, nicks, gouges, and pits	Dents, scratches, nicks, gouges, pits, and/or similar damage less than 0.002 inch in depth are acceptable. Damage that does not exceed 5 percent of wall thickness will require rework. Damage up to allowable depths with a minimum radius of 0.060 inch is acceptable.
5. RE113-XXXX-XXXX studs:	
Stud rotation	Rotational displacement (turning) of stud less than 2 degrees in either direction is acceptable and distortion of locking key attributable up to 2 degrees of rotation is acceptable.
Axial plane angularity	Maximum side-to-side displacement at end-face plane (using hand pressure only) shall not exceed 0.053 inch.
Axial looseness	Axial looseness (using hand pressure only) that exceeds 0.004 inch, when measured in stud axis, is not acceptable.
Broken locking key	One broken key is acceptable per stud at joint G3 and/or joint G6.

TABLE 1-1. SSME COMBUSTION DEVICES COMPONENTS INSPECTION CRITERIA
(Sheet 11 of 20)

Condition	Hardware Condition Limit
D. Hot Gas Manifold (continued)	
6. Liner to preburner welds:	
Weld 94/3 - oxidizer bowl liner to OPB	
Cracks	Indications less than 2.5 inches long are acceptable.
Weld 85/5 - fuel bowl liner to FPB	
Cracks	Indications less than 2.5 inches long and up to within 0.450 inches from the ID of the G5 machined surface are acceptable.
Broken locking key	One broken key is acceptable per stud at joint G3 and/or joint G6.
E. Main Combustion Chamber (See figures 1-10 through 1-14.)	
1. Hot gas wall liner:	
Discoloration	Discoloration to any degree is acceptable in areas normally exposed to hot gases.
Flame spray	Flame spray or oxide deposits are acceptable prior to polishing; not acceptable after polishing.
Erosion	After polishing, local erosion of the acoustic cavity aperture less 0.060 inch is acceptable. Erosion of the hot gas wall liner is not acceptable.

TABLE 1-1. SSME COMBUSTION DEVICES COMPONENTS INSPECTION CRITERIA
(Sheet 12 of 20)

Condition	Hardware Condition Limit
E. Main Combustion Chamber (continued)	
Cracks	Channel cracks, pinholes, blisters, and surface cracking are acceptable. Major through cracks in excess of 3 affected channels are unacceptable. A major crack is greater than 3 inches long and displays parent material loss in the crack or is not visibly closed. (ECP 1A-2676)
Surface finish	1. From throat centerline to within 4 inches of injector face: >16 microinches not acceptable after polishing.
	2. All other areas: >32 microinches not acceptable after polishing.
	3. Local roughness: >150 microinches (before polishing) is acceptable unless main injector film coolant holes above local roughness have not been enlarged. Local roughness below enlarged film coolant holes (to maximum allowed by drawing) is not acceptable.
2. MCC Bondline (See figure 1-11.)	Debonding between the Narloy-Z/EDNi interface and 1.2 inches from the aft end of the MCC is not acceptable. (ECP 1103)
3. Weld joints 2 and 19 (See figure 1-12.)	Cracks or areas of separation contained in weld 2 and/or 19 are acceptable.
	Cracking or separation in the adjacent parent material are not acceptable.
4. Nozzle tube-to-MCC clearance at joint G15	No contact, or previous contact, allowed. (See figure 1-13.) (ECP 1103)

TABLE 1-1. SSME COMBUSTION DEVICES COMPONENTS INSPECTION CRITERIA
(Sheet 13 of 20)

Condition	Hardware Condition Limit
F. Flow Recirculation Inhibitor (FRI)	
Location	Using the unaided eye, verify the four segments are in place as shown in figure 1-14. Protrusions beyond the internal plane of the MCC hot gas wall are unacceptable. (ECP 1102)
Degradation	Using the unaided eye, no visible physical deterioration is acceptable. (ECP 1102)
G. Nozzle (See figures 1-15 through 1-25.)	
1. Coolant tubes:	
Nicks	Nicks or similar damage resulting in material removal or displacement are not acceptable if depth exceeds 0.002 inch or exhibits sharp edges.
Dents	Coolant tube dents that meet all of the following criteria for each tube are acceptable. (ECP 1211) (a) No raised or removed A286 parent material. (Scratches of the nickel plating are acceptable.) (b) Depth does not exceed 0.030 inches. (c) A maximum of two dents in the area from the forward mainfold (datum-D-) to 12 inches aft. (d) A maximum of four dents in the area from 12 inches aft of the forward mainfold (datum-D-) to the aft mainfold.
Discoloration	Discoloration and flame spray of foreign material on hot gas side is acceptable.

TABLE 1-1. SSME COMBUSTION DEVICES COMPONENTS INSPECTION CRITERIA
(Sheet 14 of 20)

Condition	Hardware Condition Limit
G. Nozzle (continued)	
Blanching/Erosion (See figure 1-17.)	Tube crown blanching/erosion with obvious material removed is not acceptable. This occurs in the region located within two inches of the coolant tube crown. (ECP 1103)
Bulges (See figure 1-17.)	Tube bulges (five or more adjacent tubes protruding 0.020 inch or more past nonprotruding adjacent tubes) within two inches of the coolant tube crown area are unacceptable. (ECP 1103)
Leakage (flight engines)	1. Hot wall tube leaks of Class I category (fuzz) or smaller are acceptable. 2. Cold wall tube leaks at aft end of nozzle jacket and aft manifold are not acceptable; pin holes and obvious tube failure are not acceptable.
2. Drain lines:	
Nicks	Nicks or similar damage resulting in material removal or displacement are not acceptable.
Dents	Dents are acceptable if depth does not exceed 10 percent of tubing OD and dents do not exhibit sharp corners or edges.
3. Fuel feed lines and ducts:	
Nicks	Nicks or similar damage resulting in material removal or displacement are not acceptable.
Dents	Dents are not acceptable.

TABLE 1-1. SSME COMBUSTION DEVICES COMPONENTS INSPECTION CRITERIA
(Sheet 15 of 20)

Condition	Hardware Condition Limit
G. Nozzle (continued)	
Arc burns	Arc burns are not acceptable.
Antiwear shims	Evidence of wear or broken spot welds are not acceptable. (See figure 1-18.) (ECP 1103)
4. Aft manifold:	
Arc burns	Arc burns are not acceptable.
SLAM zero index and lockwire holes (development and certification engines) (See figure 1-19.)	Surface cracks are not acceptable. (ECP 1103)
Drainline bolt holes (development and certification engines) (See figure 1-20.)	Cracks in the top of aft manifold lip are not allowed. Fastener need not be removed for inspection. (ECP 1103)
5. Forward end (visible with joint G15 disassembled):	
Nozzle seal lip (See figure 1-21.)	Thermal discoloration is acceptable. Material erosion is not acceptable. (ECP 1103)
Uralite (See figure 1-21.)	Discoloration of uralite ranging from amber to black is acceptable, provided there is no discoloration of the metal component of the seal.
Bellows seal (RS008861)	Minor discoloration of teflon ranging from dark green to black is acceptable, provided there is no discoloration of the metal component of the seal. Discoloration (shades of blue, indigo, brown, yellow, or green) of the metal component of the seal is not acceptable.

TABLE 1-1. SSME COMBUSTION DEVICES COMPONENTS INSPECTION CRITERIA
(Sheet 16 of 20)

Condition	Hardware Condition Limit
G. Nozzle (continued)	
6. General nozzle condition:	
Cracks/gouges/arc burns	Cracks, gouges, arc burns, or similar anomalous conditions are not acceptable.
Nozzle jacket creases	The cold wall surface of the nozzle jacket shall be visually inspected between hatbands 8 and 9 (see RS009150, sheet 10, panel -023) for surface cracking or creasing. Nozzle surface cracks are not allowed. Sharp creases of 0.060-inch radius or less and/or depths greater than or equal to 0.015 inch are unacceptable (see figure 1-22). If position-unique insulation is installed between hatbands 8 and 9, the area under the insulation panel adjacent to fuel feedlines 5 and 8 (see figure 1-23) shall be borescope-inspected using RG000109-051 or equivalent in accordance with figure 1-23. (ECP 1103)
Erosion/corrosion	Erosion or corrosion damage is not acceptable.
Looseness	Looseness of any mechanical fastener is not acceptable, except for heat shield support ring nutplate.
Heat shield support ring nutplate	Looseness between nutplate and its support ring bracket is acceptable as long as there is no damage to nutplate or attaching rivets.
Foreign material deposits	Solid rocket booster, separation motor, and other foreign material deposits not associated with parent metal erosion are acceptable.

TABLE 1-1. SSME COMBUSTION DEVICES COMPONENTS INSPECTION CRITERIA
(Sheet 17 of 20)

Condition	Hardware Condition Limit
G. Nozzle (continued)	
Spot weld orientation	Spot welds are acceptable only in those areas authorized by drawing requirements (R0020621) for installation of the thermal protection system; spot welds are not acceptable on thin wall portion of jacket or tubes.
Parent metal discoloration	In-flight heating, which causes nozzle parent metal discoloration, is anomalous. Any abnormal parent metal discoloration due to heating will require performance of a nondestructive hardness test to verify material properties are within drawing requirements. Discoloration of the nozzle is acceptable if the hardness readings are within acceptable limits. (ECP 1103)
H. Nozzle Thermal Protection System (TPS) (See figures 1-23 and 1-24.)	
1. Insulation screen, foil, and batting (nozzle hatbands, flat surfaces, feedlines, aft manifold, and drainlines):	
Wrinkles/bulges	Screen wrinkles and bulges are acceptable.
Cuts/tears	Cuts or tears in screen or foil less than 0.5-inch long are acceptable except on insulators R0014126, R0014128, R0020605, and R0020606 in which cuts or tears less than 0.2-inch long are acceptable. Above hatband No. 6, 1-inch tears in screen are acceptable unless crushing of underlying batting exceeds half insulator thickness.

TABLE 1-1. SSME COMBUSTION DEVICES COMPONENTS INSPECTION CRITERIA
(Sheet 18 of 20)

Condition	Hardware Condition Limit
H. Nozzle Thermal Protection System (TPS) (continued)	
Dents	In all areas except high heating zone (item 6, reentry heating zone), dents in insulation are acceptable, unless total continuous dented area exceeds 75 percent of insulator surface area.
Melting	Melting of the insulator screen, foil, or batting is unacceptable. (ECP 1103)
2. Insulator attachment:	
Separation	Separation of hardware detail or attachment spot welds is not acceptable; hardware and bracket attachment clamping shall show no change of security or relative position.
3. Convective shield foil on all insulators except for the R0011202 panels between hatbands 8 and 9 and reentry heating zone insulation:	
Holes/tears	Holes or tears in foil accumulating less than 0.5 square inch in area in any 6-inch span on hatband, manifold, or tubular surface, or in a 6-inch-square region (ie, 3 inch x 2 inch) on flat surfaces is acceptable except where batting is missing (void) directly behind foil damage.

TABLE 1-1. SSME COMBUSTION DEVICES COMPONENTS INSPECTION CRITERIA
(Sheet 19 of 20)

Condition	Hardware Condition Limit
H. Nozzle Thermal Protection System (TPS) (continued)	
4. R0011202 flat panels between hatbands 8 and 9: on engine No. 1, both panels; on engine No. 2, panel in the -Y to -Z sector; on engine No. 3, panel in the +Y to +Z sector: (See figure 1-25.)	
Degradation	Foil and batting degradation (ie, cracking, wrinkling, or crimping, etc) is acceptable.
5. Nozzle drainline or feedline bracket insulator:	
Deformation	Bracket cover deflections due to batting deformation from hot fire strains up to 0.5 inch are acceptable unless parent metal is visible.
6. Reentry heating zone, as defined in figure 1-25, on engines No. 2 and 3, aft of hatband 8 with the addition of 6 inches of area on each side of fairing system:	
Dents	Local visible dents exceeding 10 percent of insulator surface area and/or half thickness of primary insulator are not acceptable.
Gaps	Gaps between insulators exposing parent metal are not acceptable.
Degradation	Foil degradation, including holes or tears, accumulating 0.5 square inch in area in any 6-square-inch area is not acceptable.

TABLE 1-1. SSME COMBUSTION DEVICES COMPONENTS INSPECTION CRITERIA
(Sheet 20 of 20)

Condition	Hardware Condition Limit
H. Nozzle Thermal Protection System (TPS) (continued)	
7. TPS aft panel brackets:	
Bowing	Outward bowing of brackets is acceptable.
8. General nozzle insulator condition:	
Foreign material	Contamination by water is acceptable. Contamination by hydraulic oil or RTV that does not contact nozzle tubes is acceptable.
Discoloration	Thermal discolorations and solid rocket booster deposits are acceptable.
Erosion/corrosion	Erosion or corrosion damage is not acceptable.
Parent metal exposure	Exposure of any parent metal in normally insulated areas (including position unique and reentry zone insulation) is not acceptable.

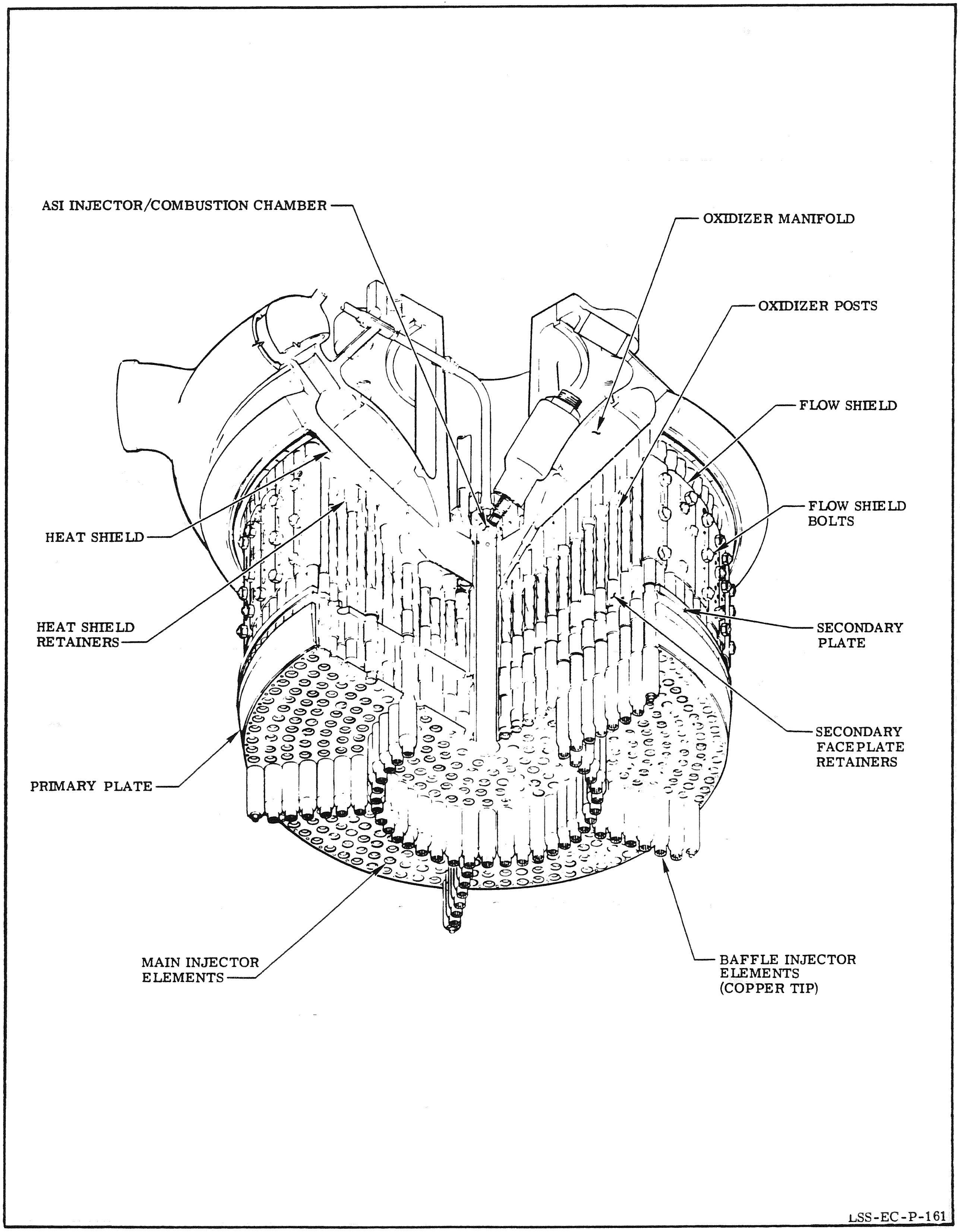


Figure 1-1. Main Injector

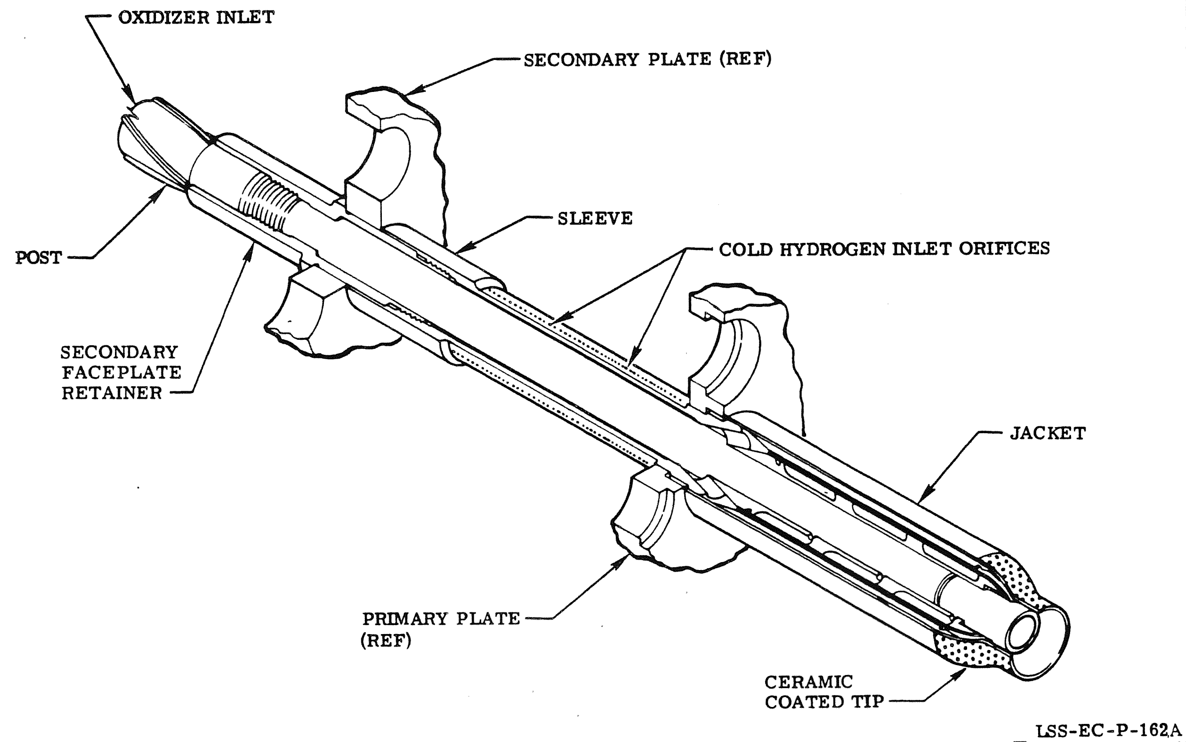


Figure 1-2. Main Injector Baffle Element

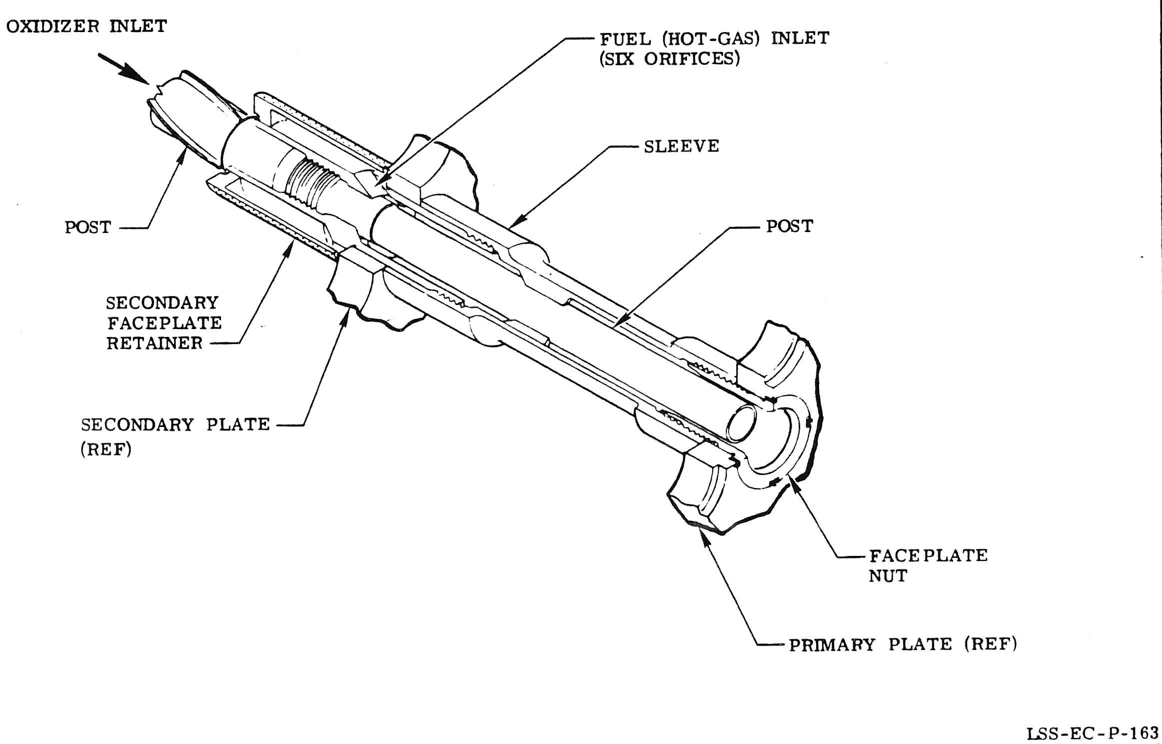


Figure 1-3. Main Injector Element

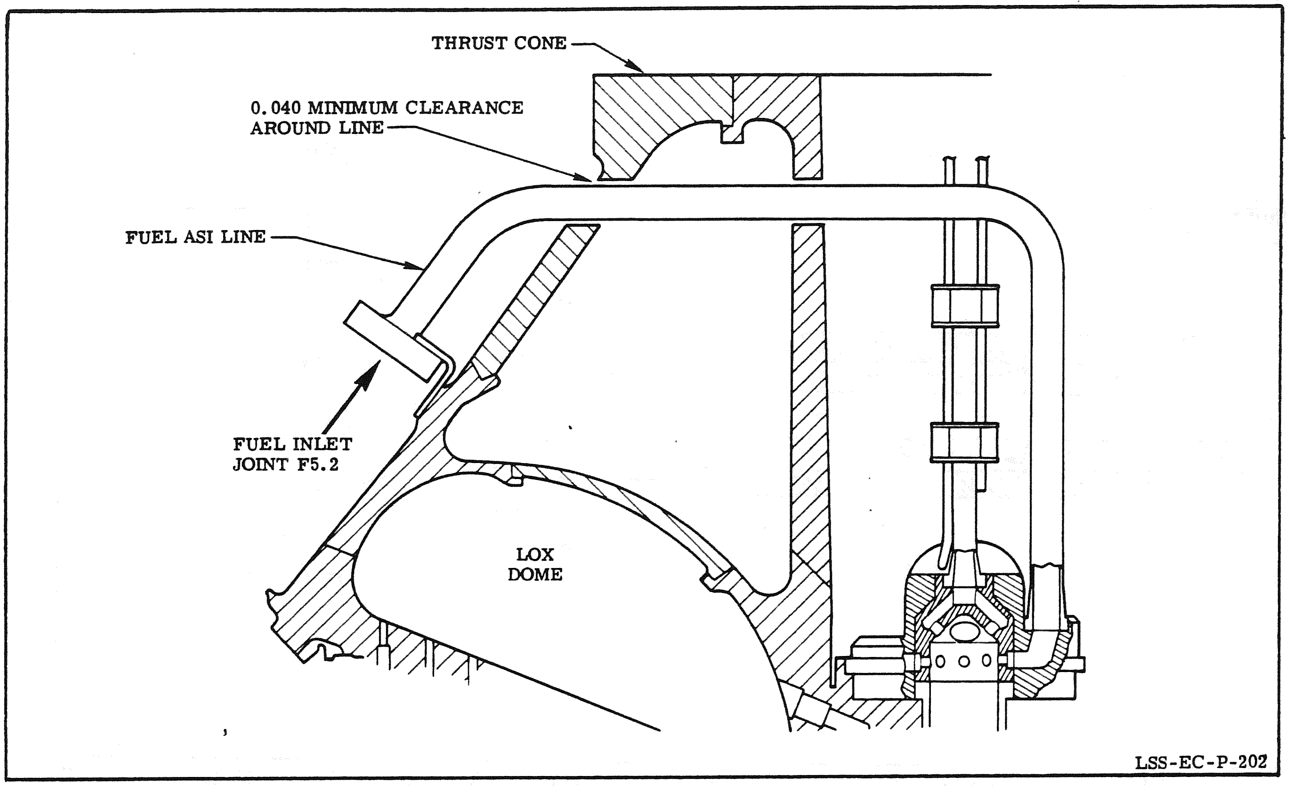


Figure 1-4. Main Injector Fuel ASI Line

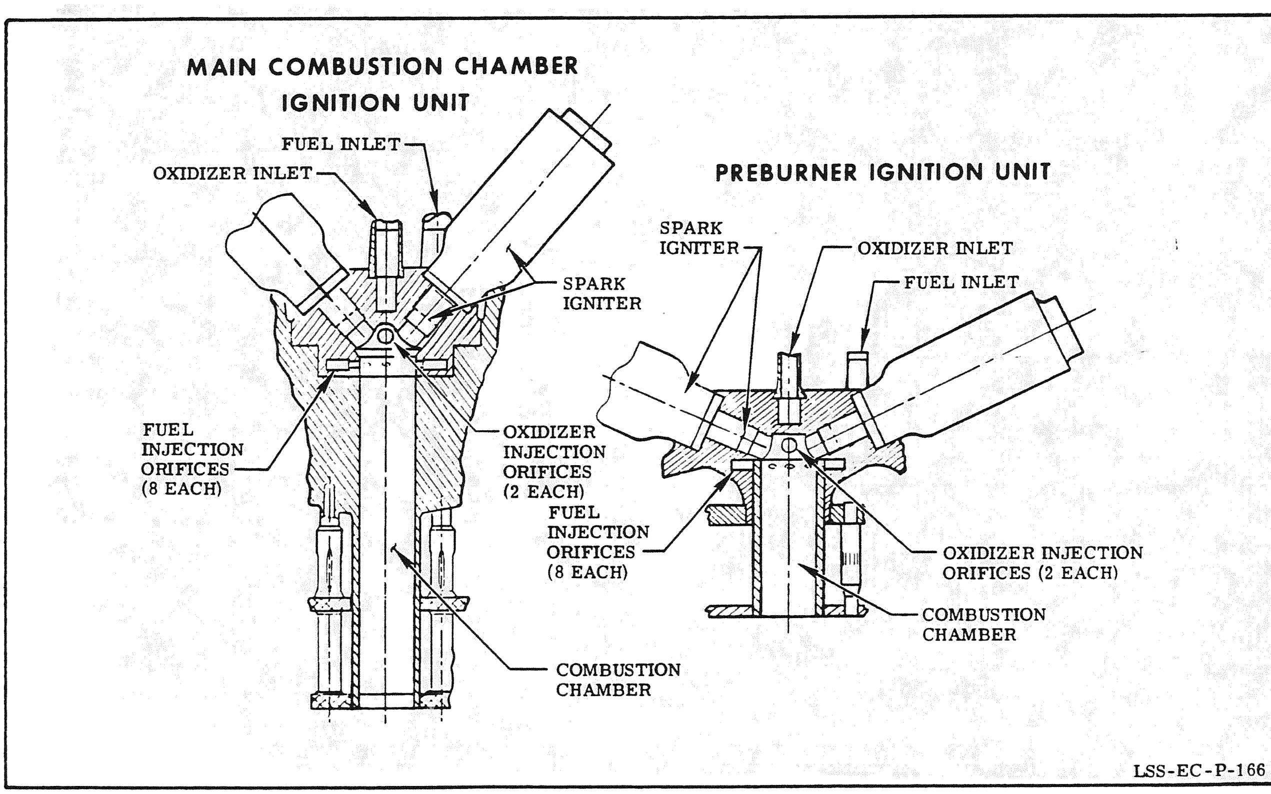


Figure 1-5. Augmented Spark Ignition System

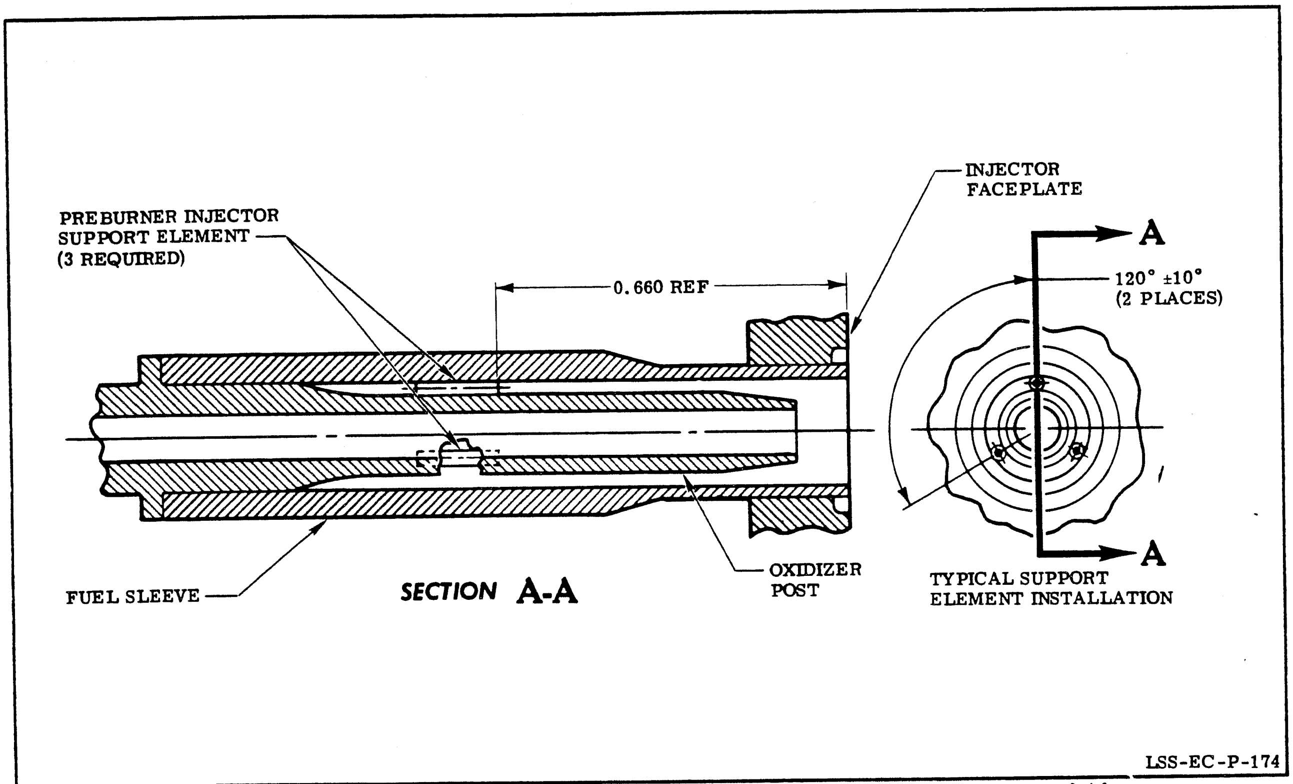


Figure 1-6. Oxidizer Post Support Elements in Fuel and Oxidizer Preburner Injector

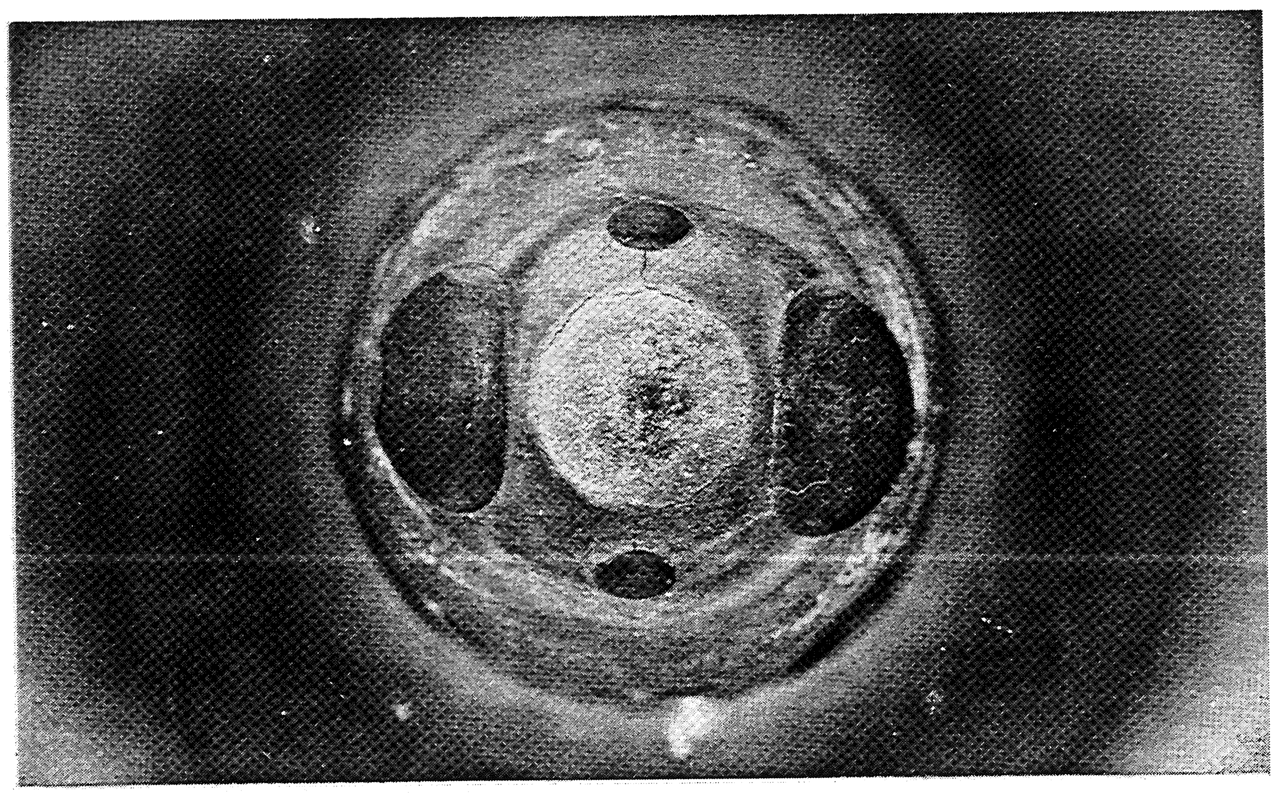


Figure 1-7. Oxidizer and Fuel Preburner ASI Combustion Dome Area

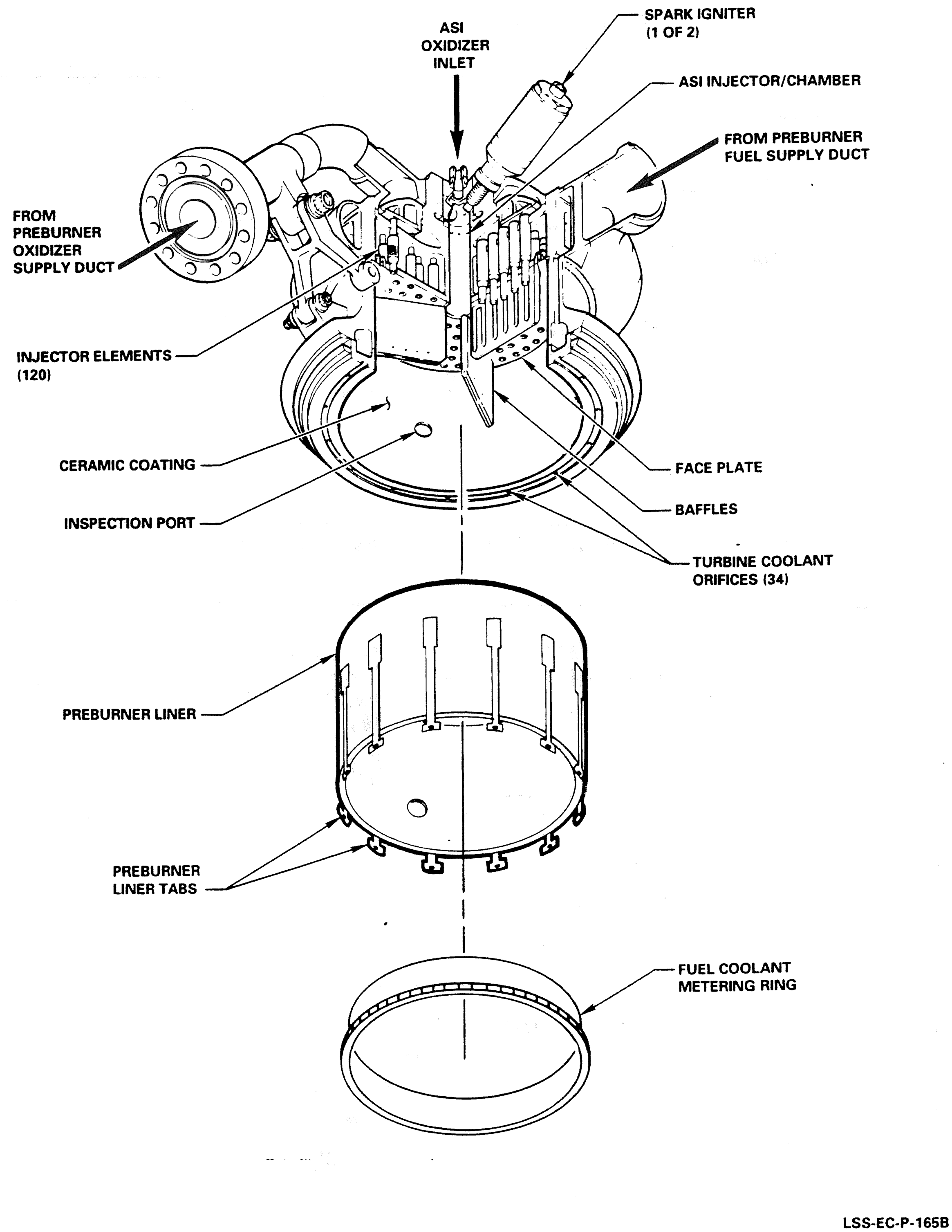


Figure 1-8. OPB Liner Tab Inspection

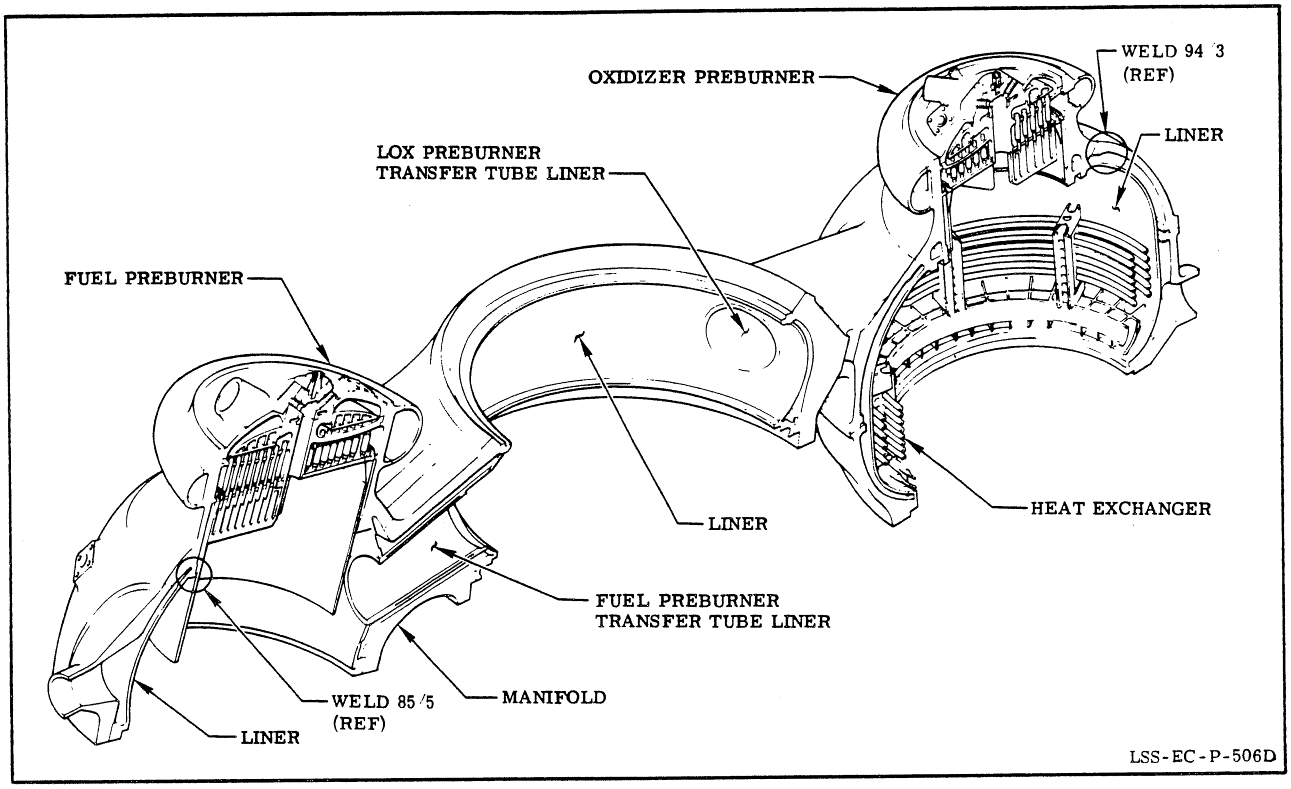


Figure 1-9. Hot Gas Manifold

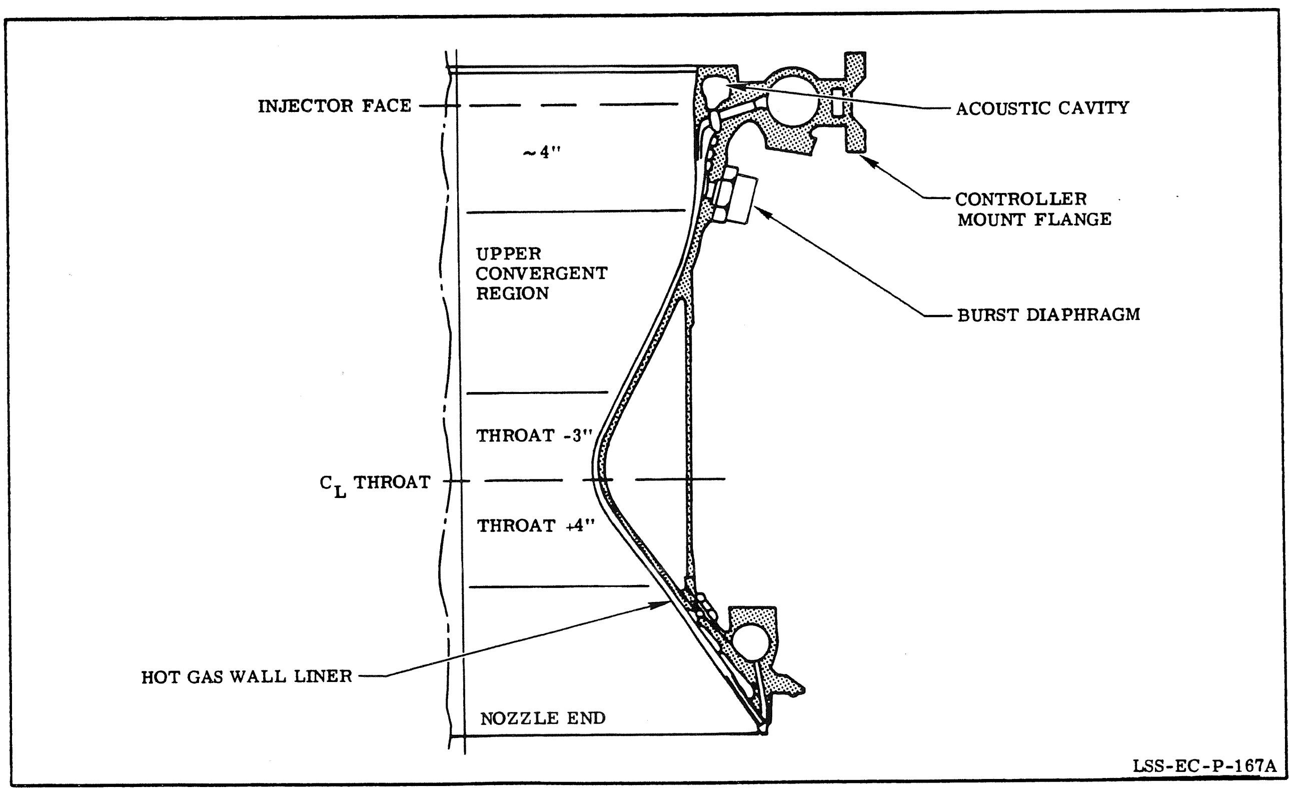


Figure 1-10. Main Combustion Chamber

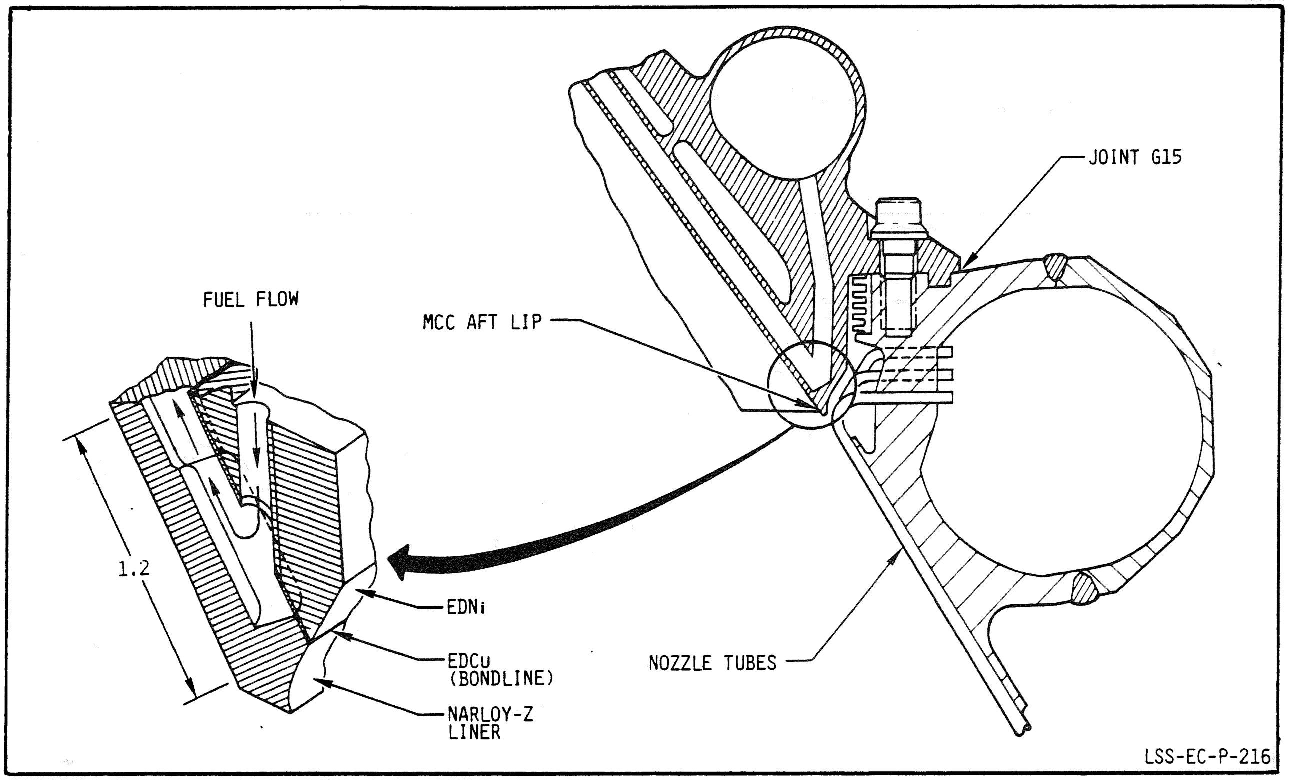


Figure 1-11. MCC Bondline Inspection

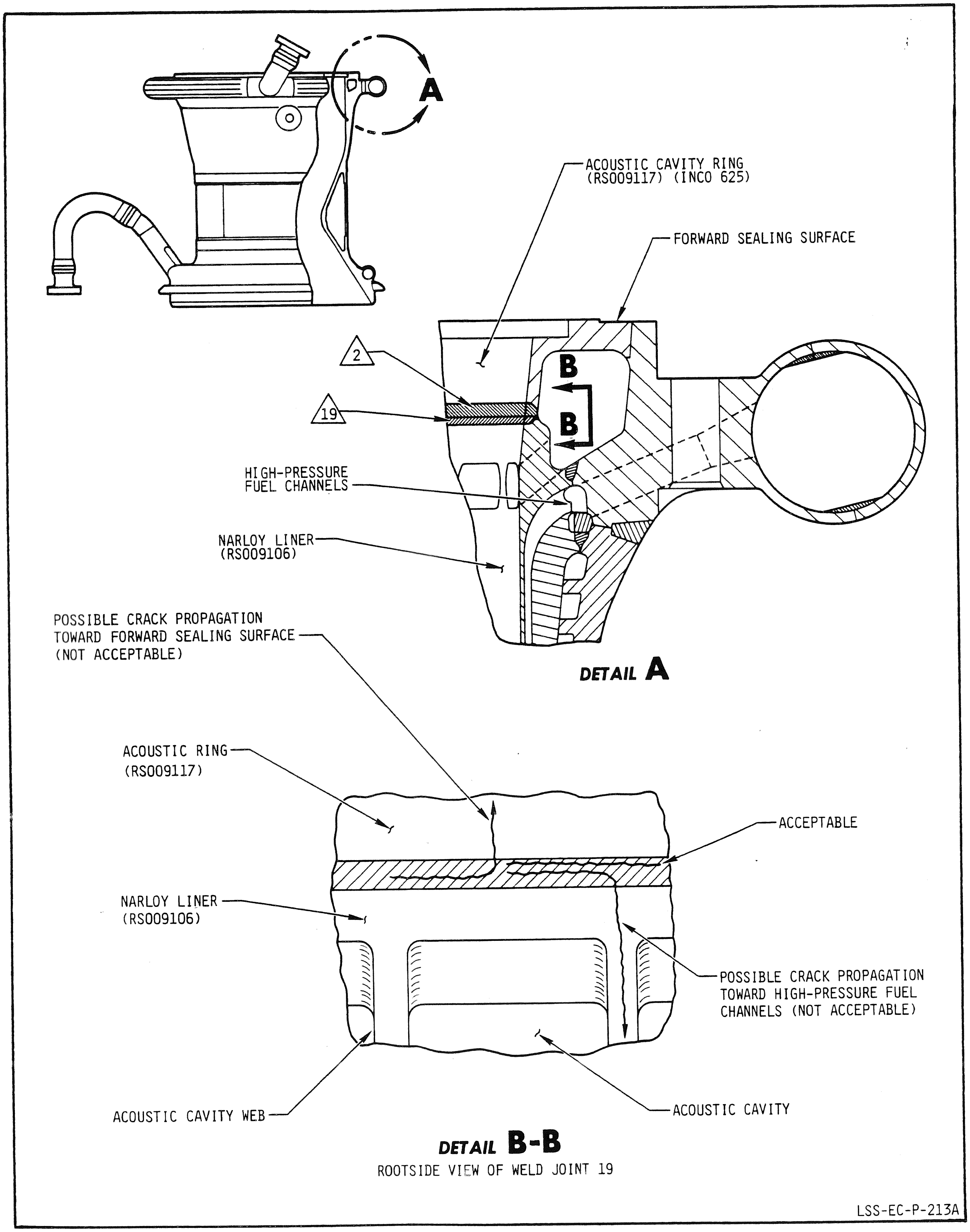


Figure 1-12. Location of Weld Joints 2 and 19

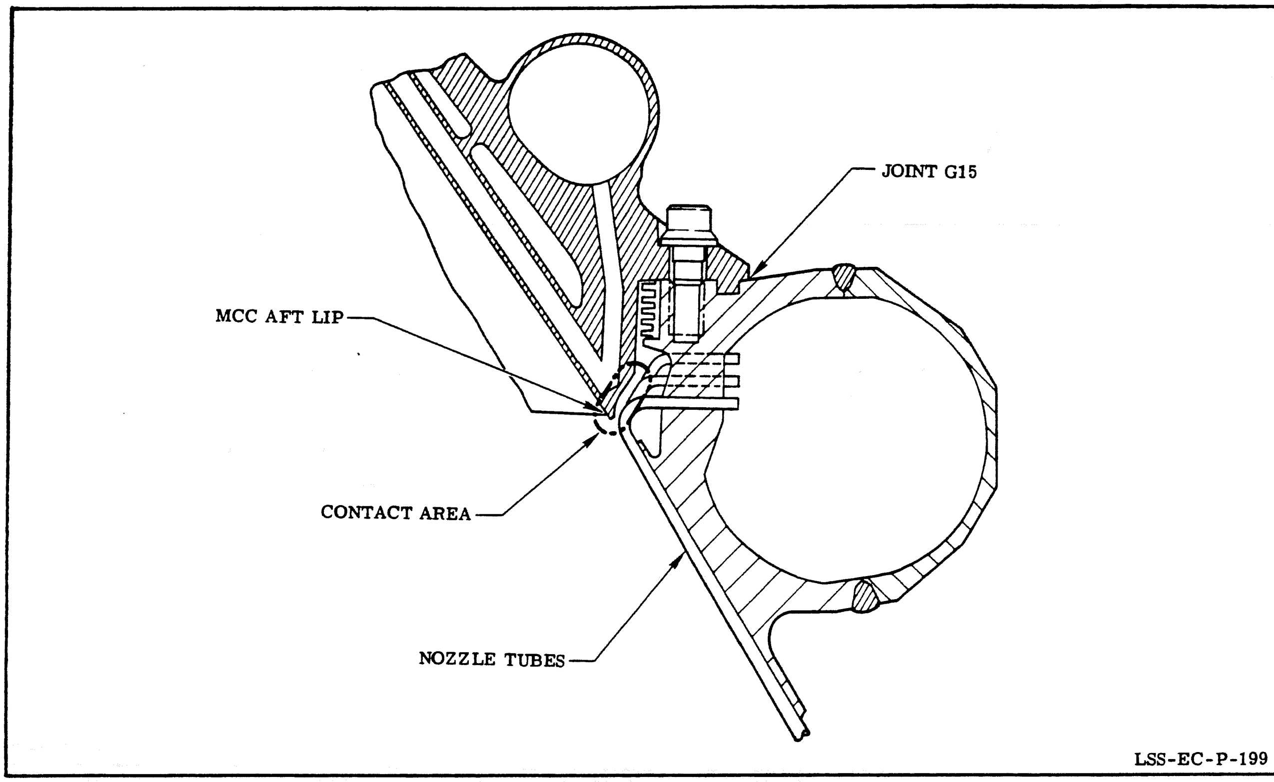


Figure 1-13. Nozzle Coolant Tube-to-MCC Clearance

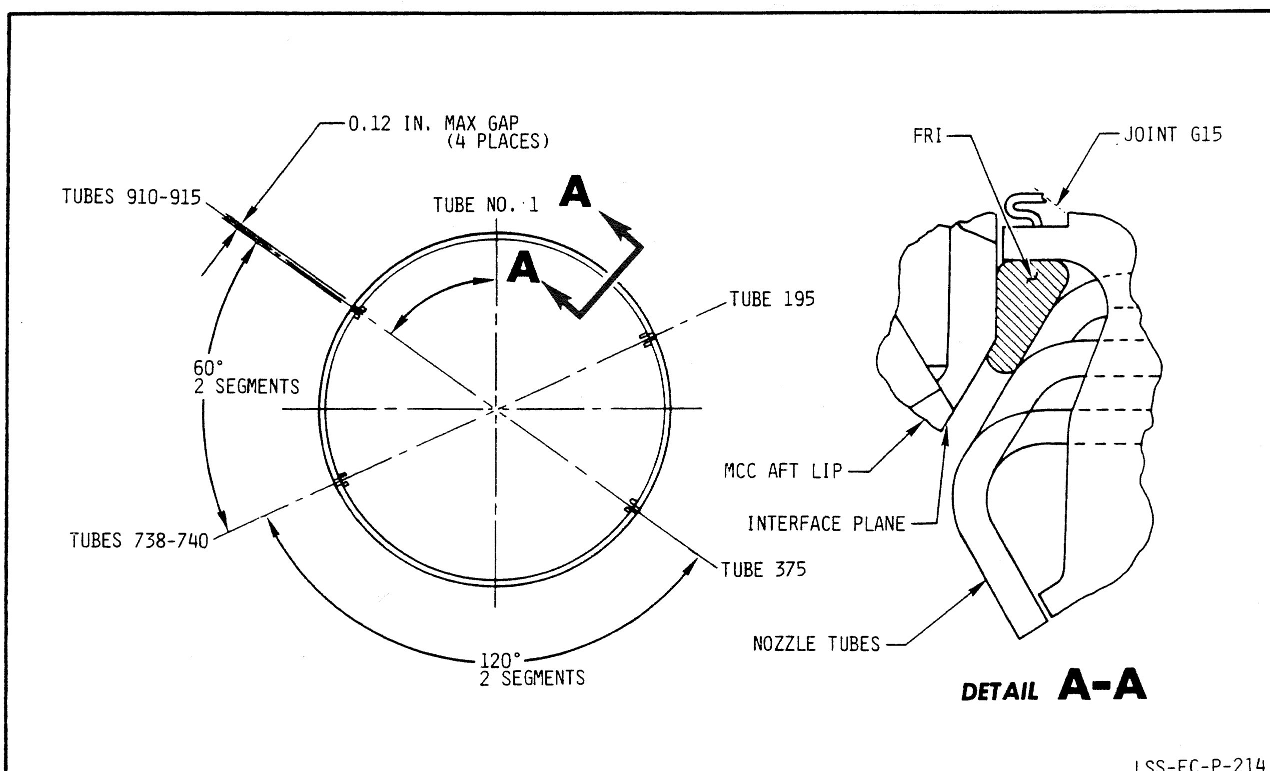


Figure 1-14. Flow Recirculation Inhibitor (FRI)

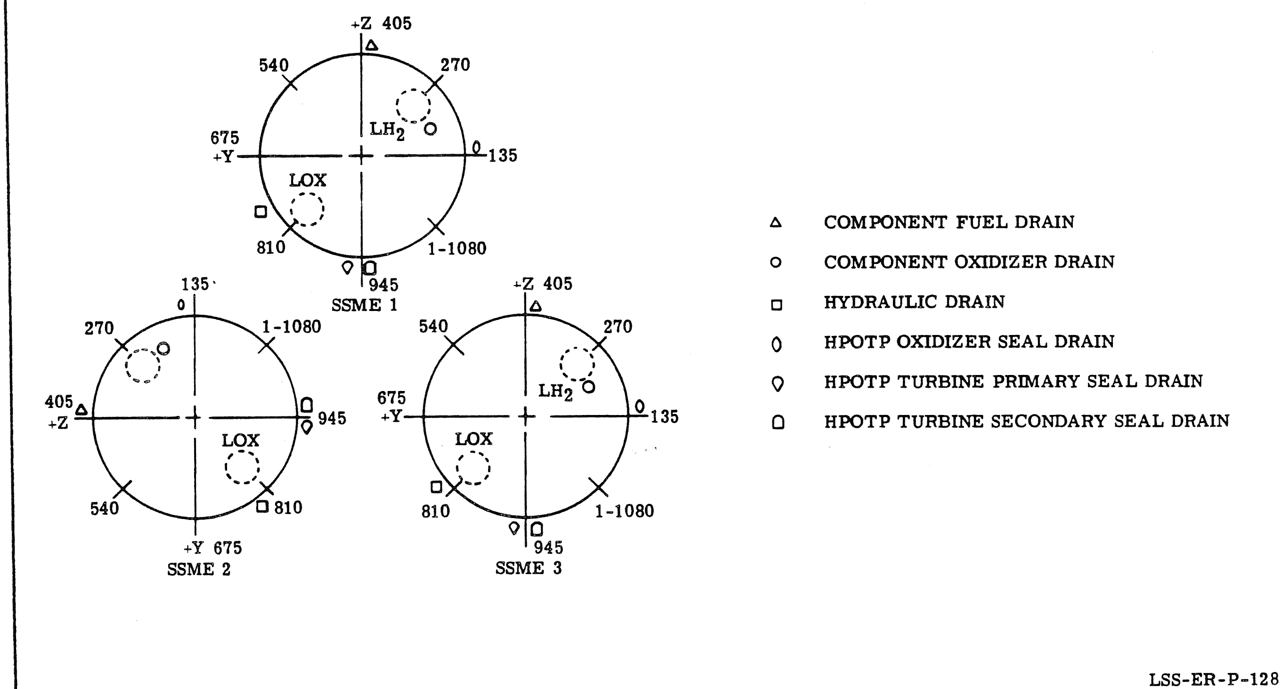


Figure 1-15. Nozzle Tube/Drainline Orientation, Aft View as Installed on Orbiter, Looking Forward

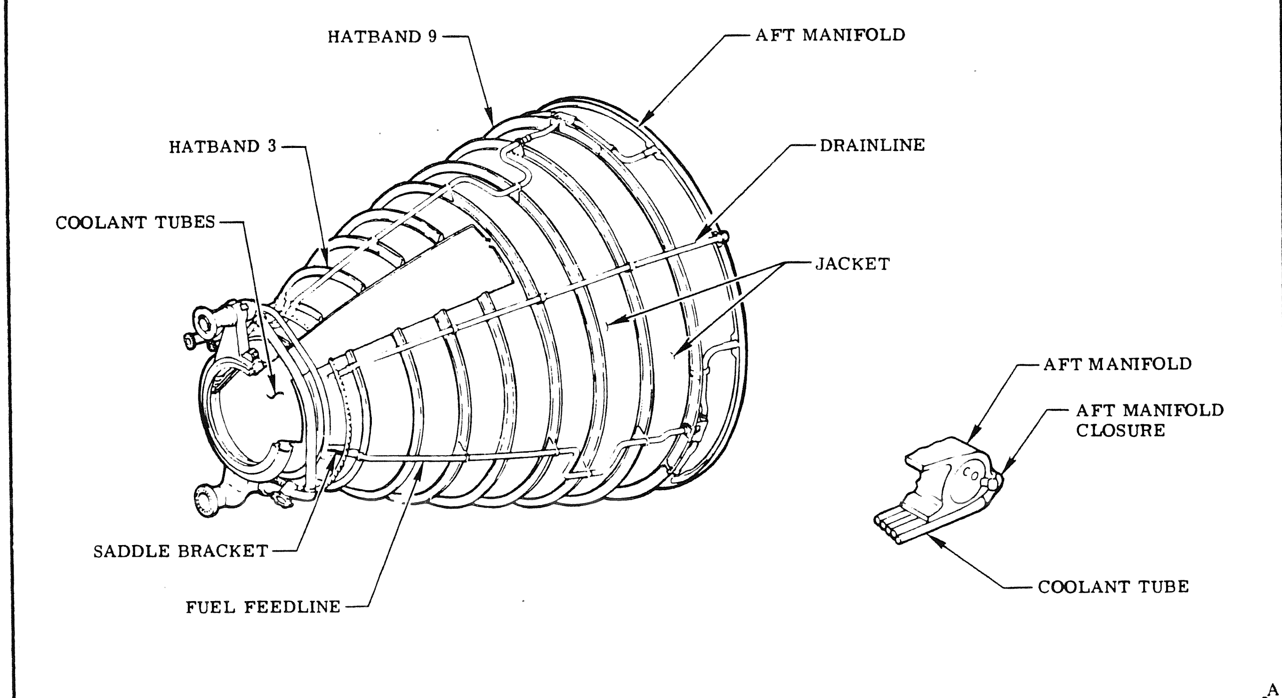


Figure 1-16. Nozzle

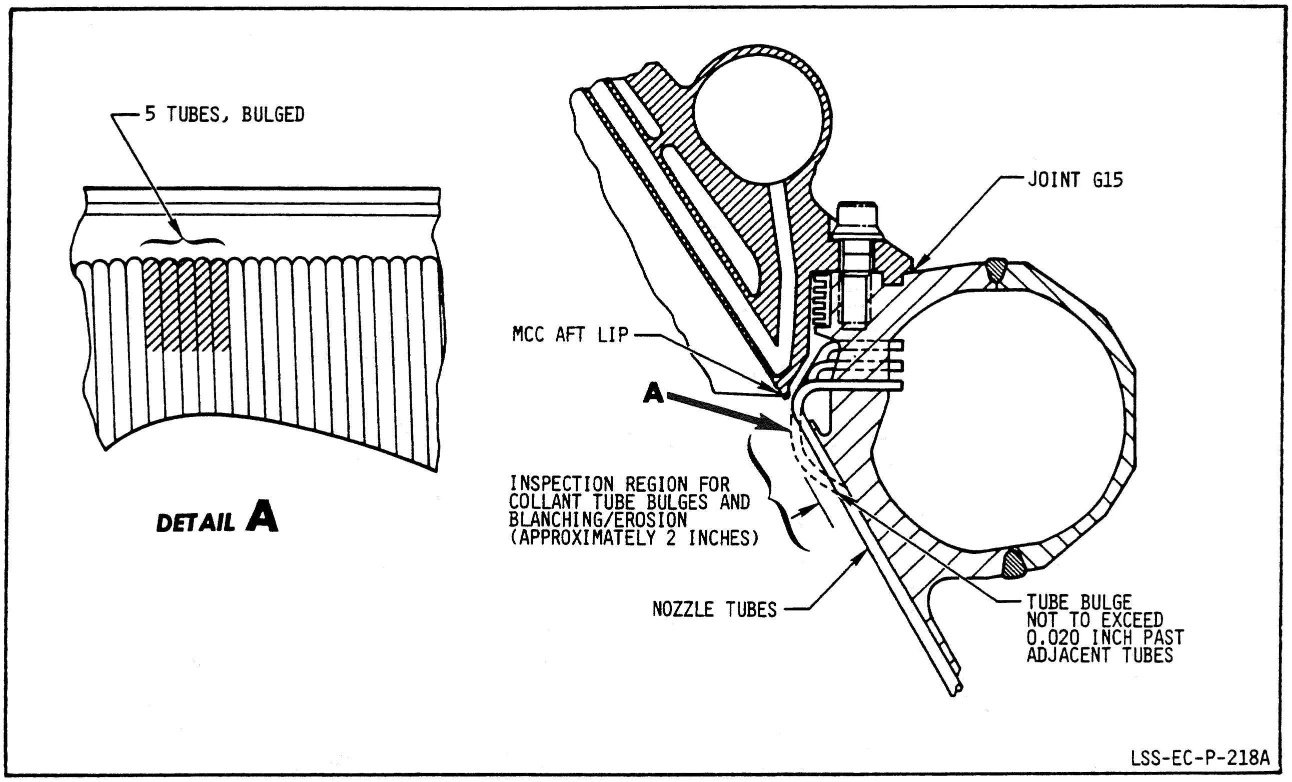


Figure 1-17. Nozzle Coolant Tube Bulge Inspection

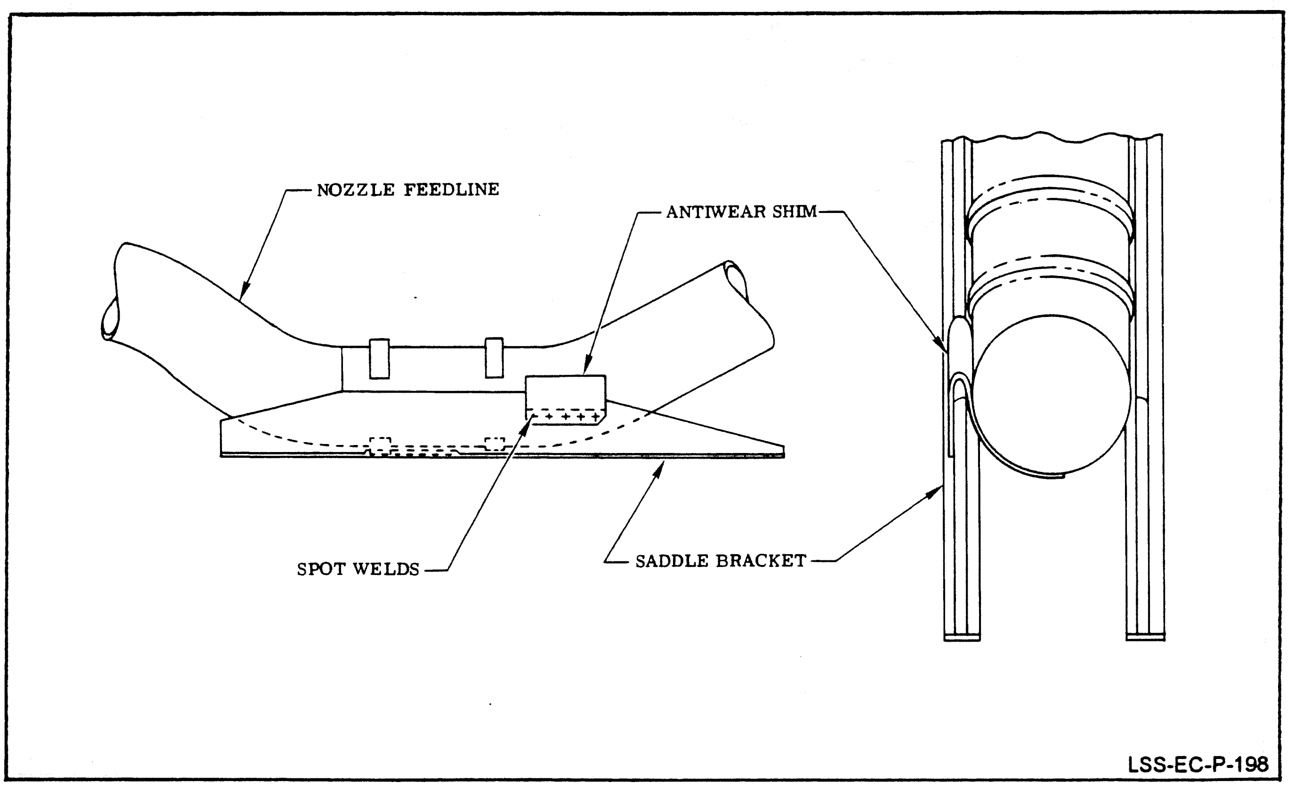


Figure 1-18. Fuel Feed Line Antiwear Shim

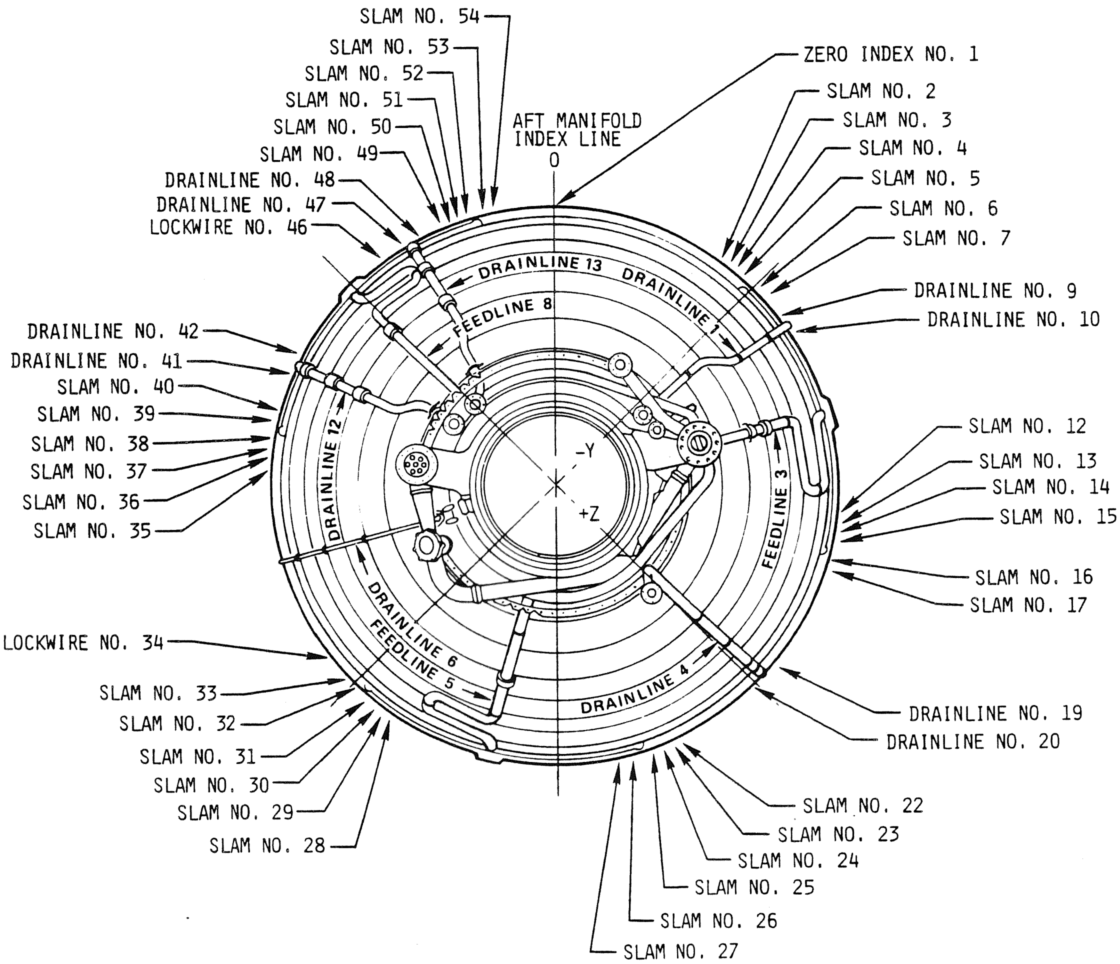


Figure 1-19. Aft Manifold Bolt Hole Indexing Chart

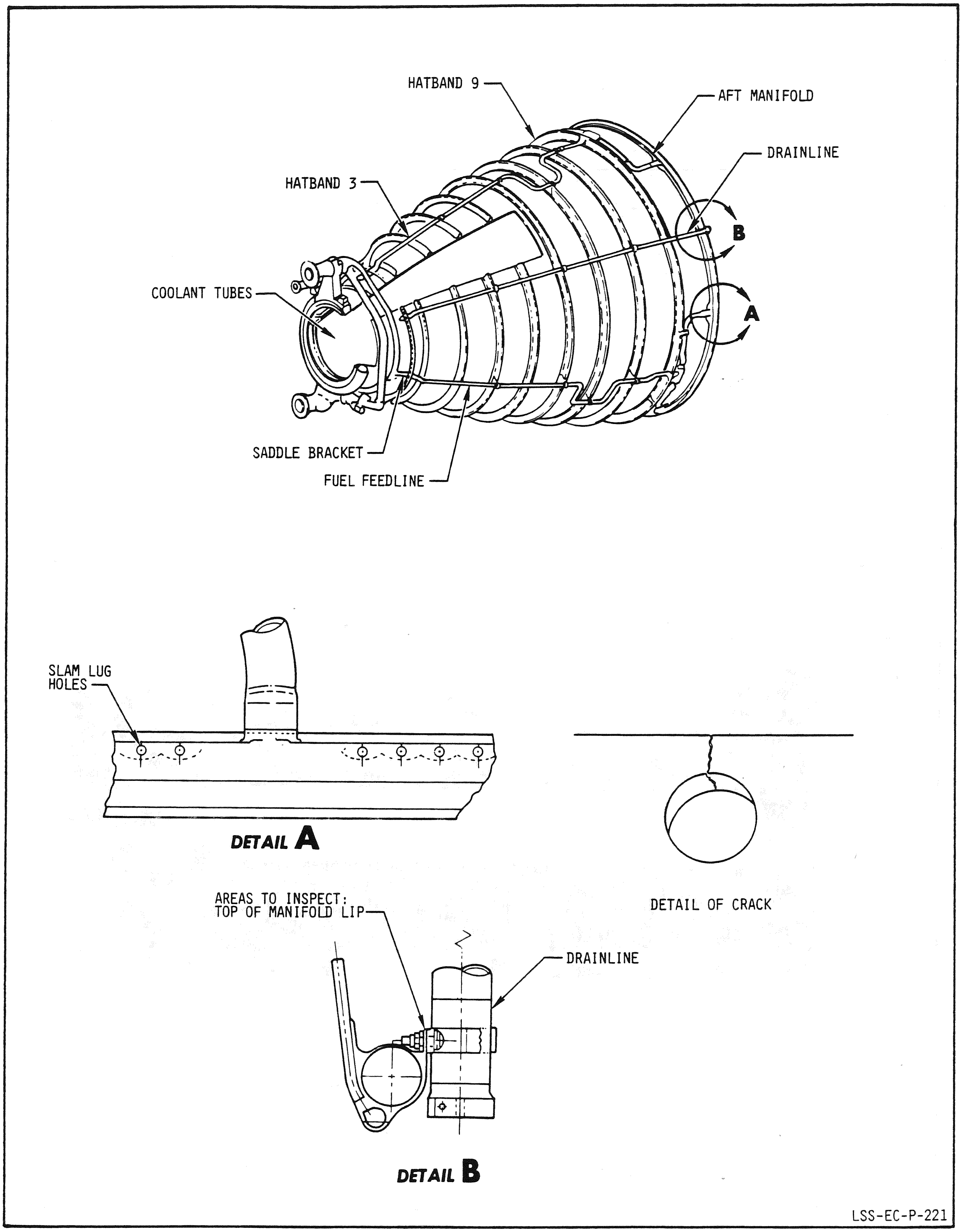


Figure 1-20. Drainline and SLAM Lug Hole Inspection

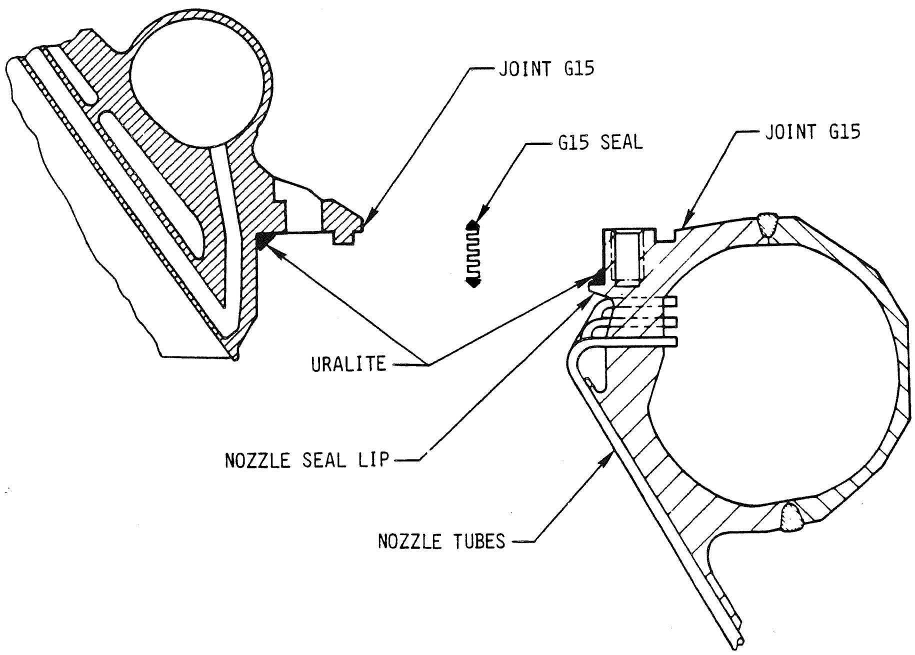


Figure 1-21. Nozzle/MCC Joint G15 Inspection

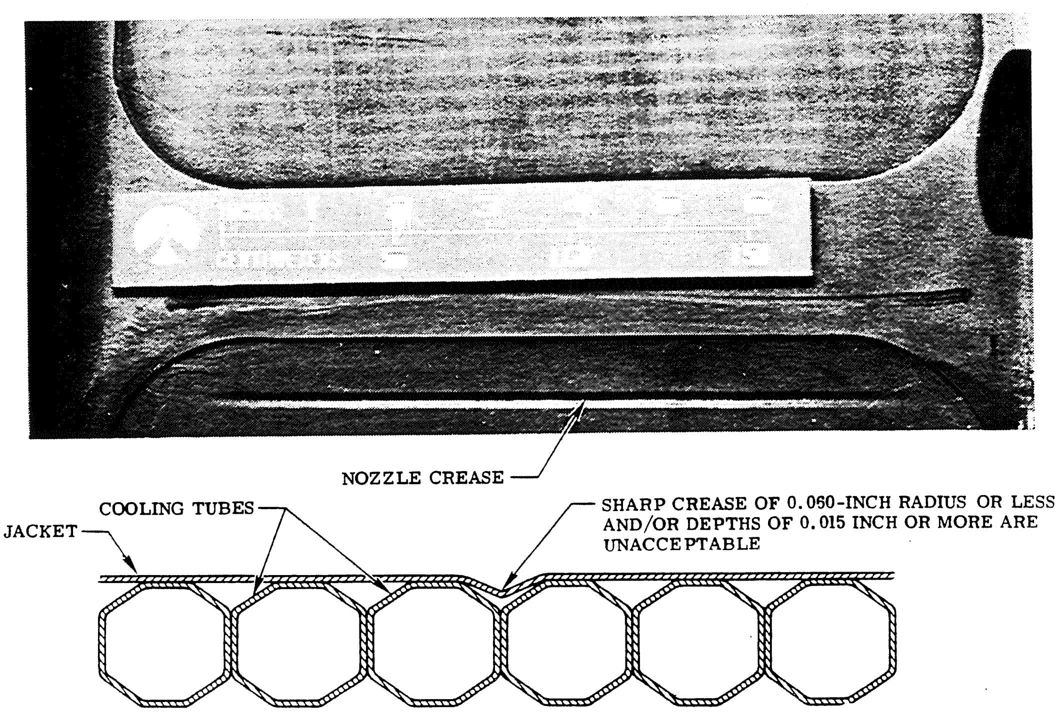
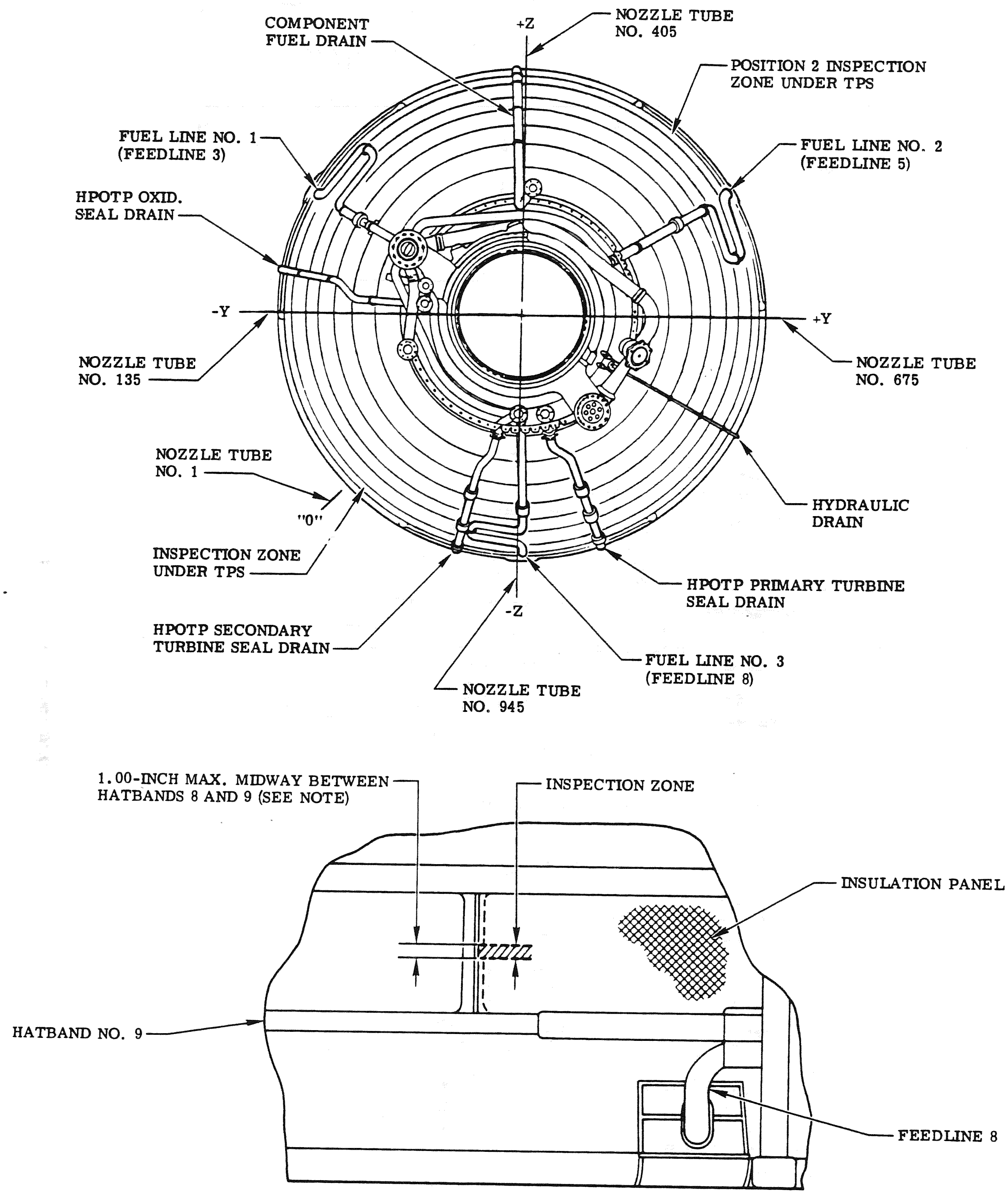


Figure 1-22. Nozzle Jacket Crease



NOTE: BREAK SPOTWELDS AS REQUIRED IN THIS AREA.
DO NOT RE-TACK BROKEN WELDS IN THIS AREA.
INSPECT UNDER ENTIRE PANEL.

LSS-EC-P-201A

Figure 1-23. Engine Nozzle Insulation Panel Inspection Zone (Sheet 1 of 2)

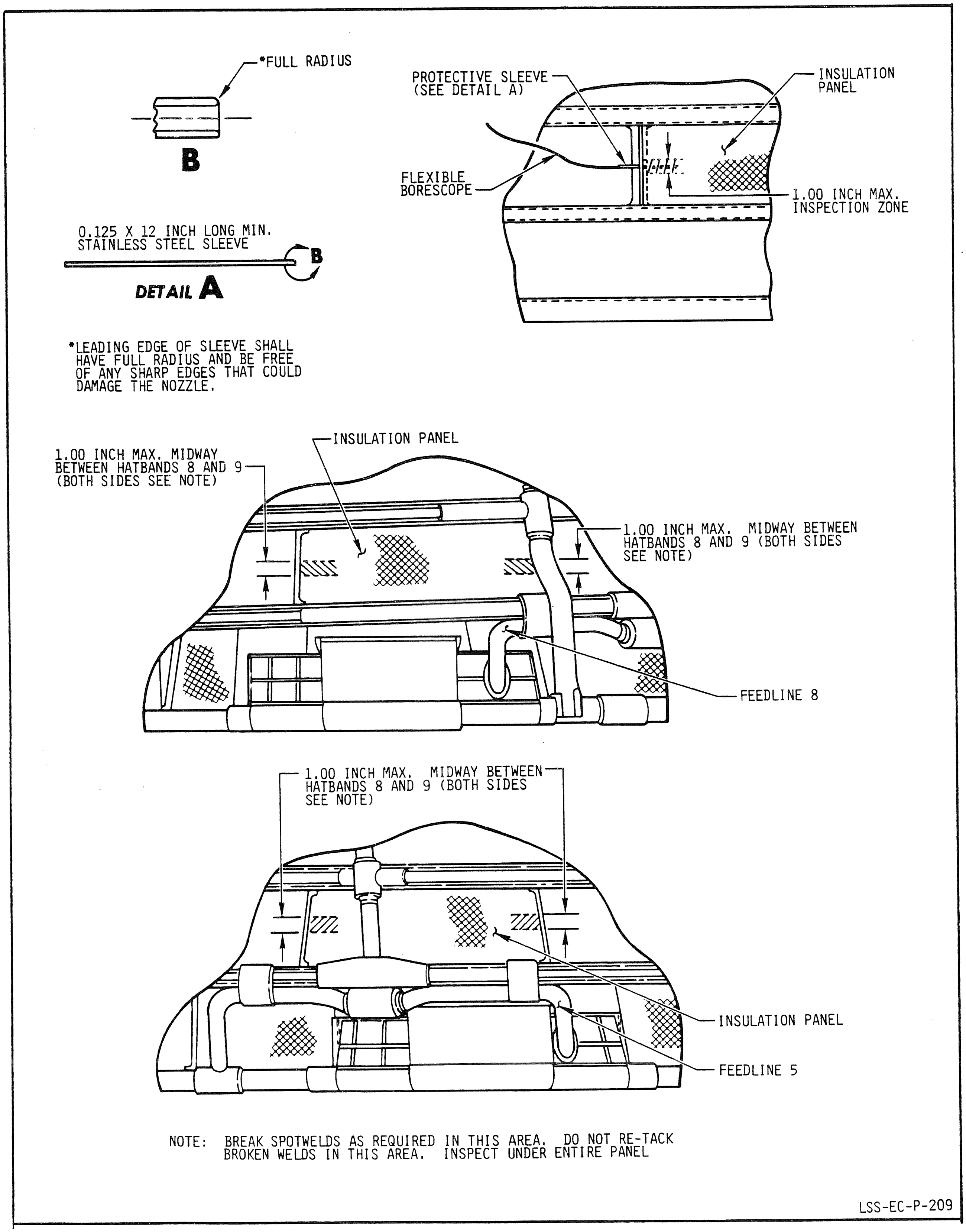


Figure 1-23. Engine Nozzle Insulation Panel Inspection Zone (Sheet 2 of 2)

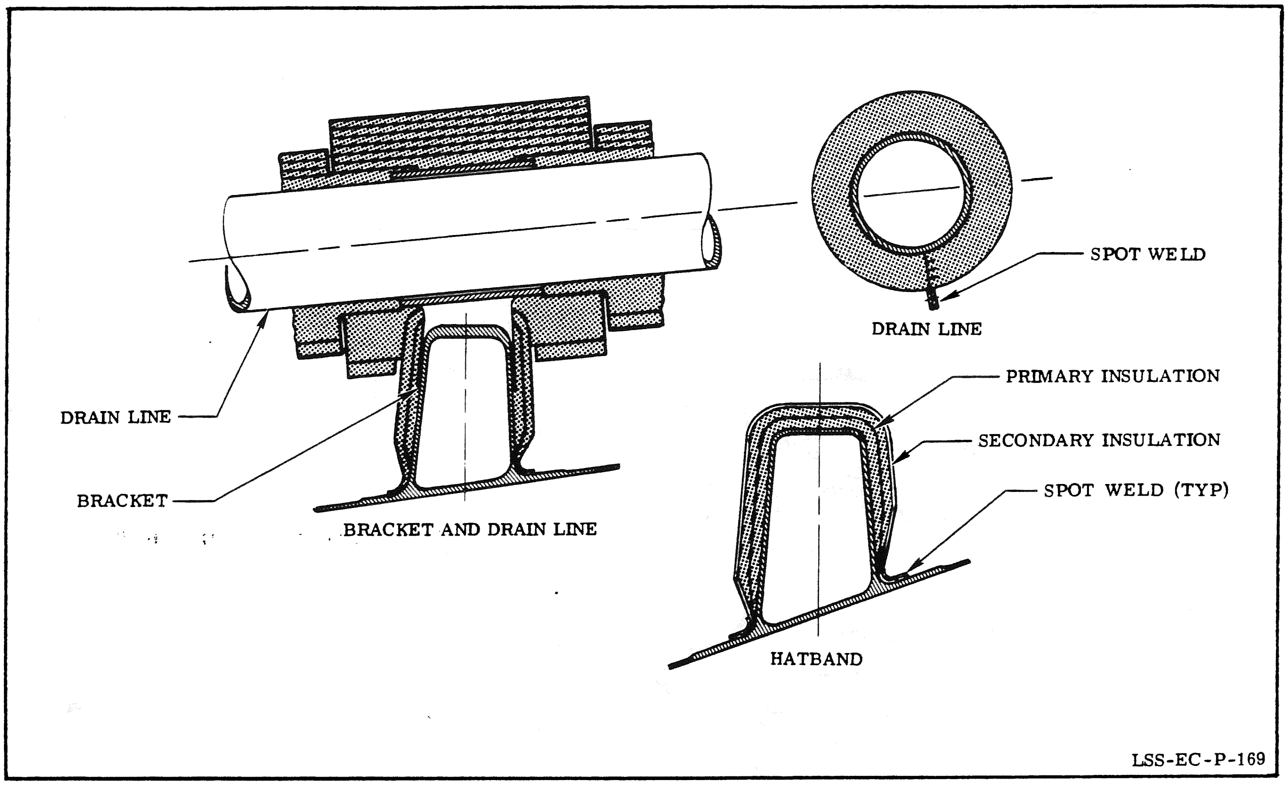


Figure 1-24. Thermal Protection System

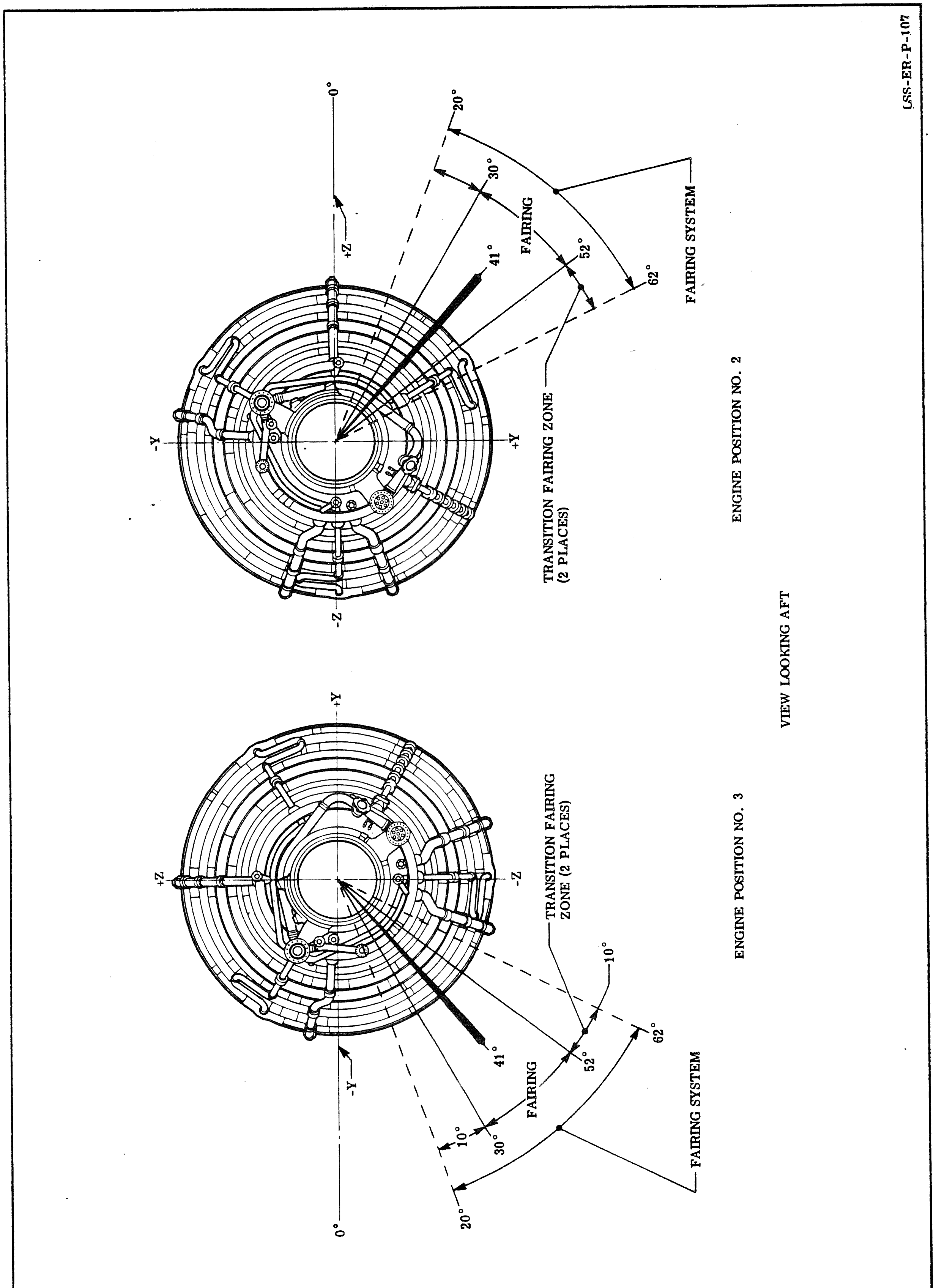


Figure 1-25. Nozzle Reentry Heating Zone Insulation Location

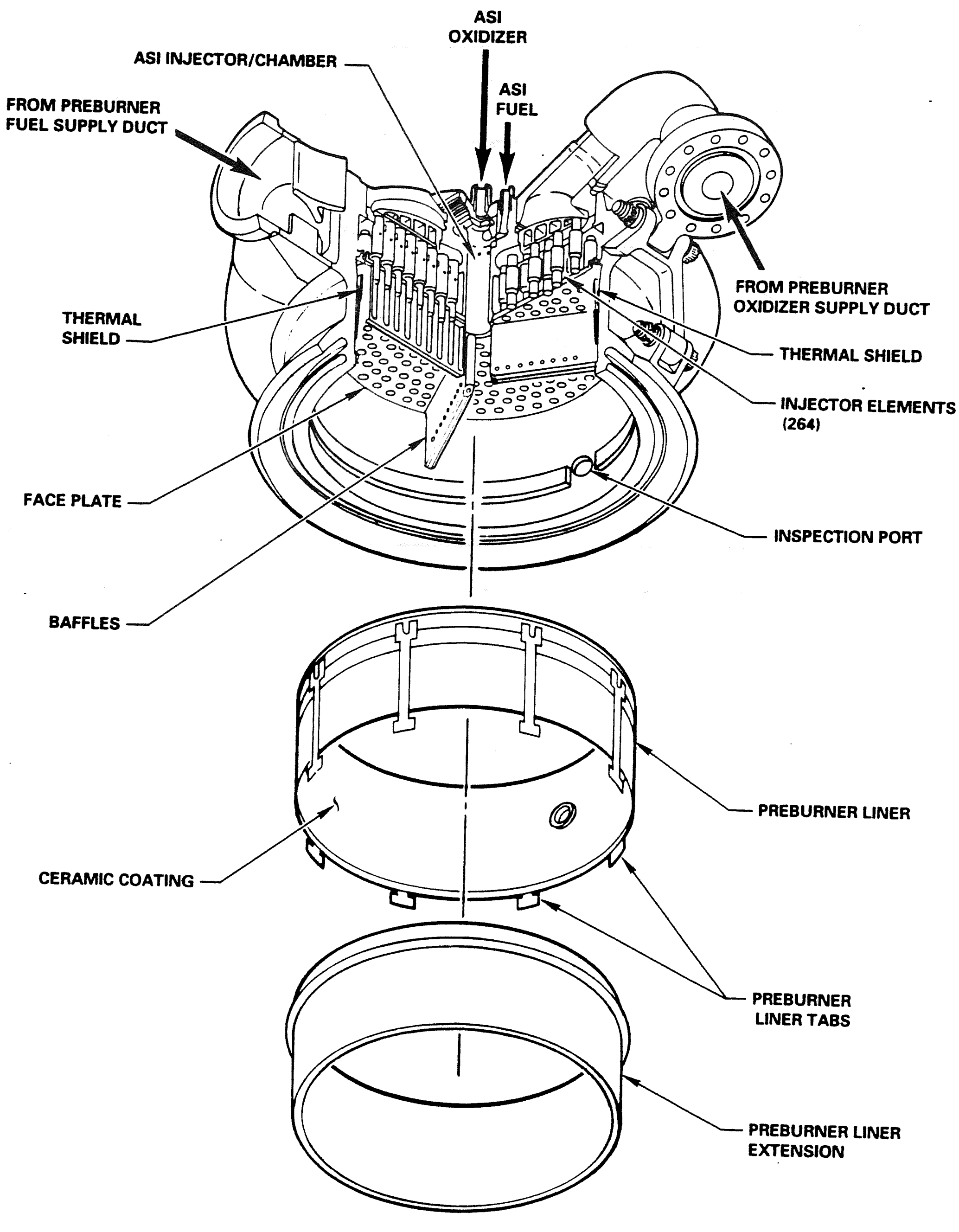


Figure 1-26. FPB Liner Tab Inspection

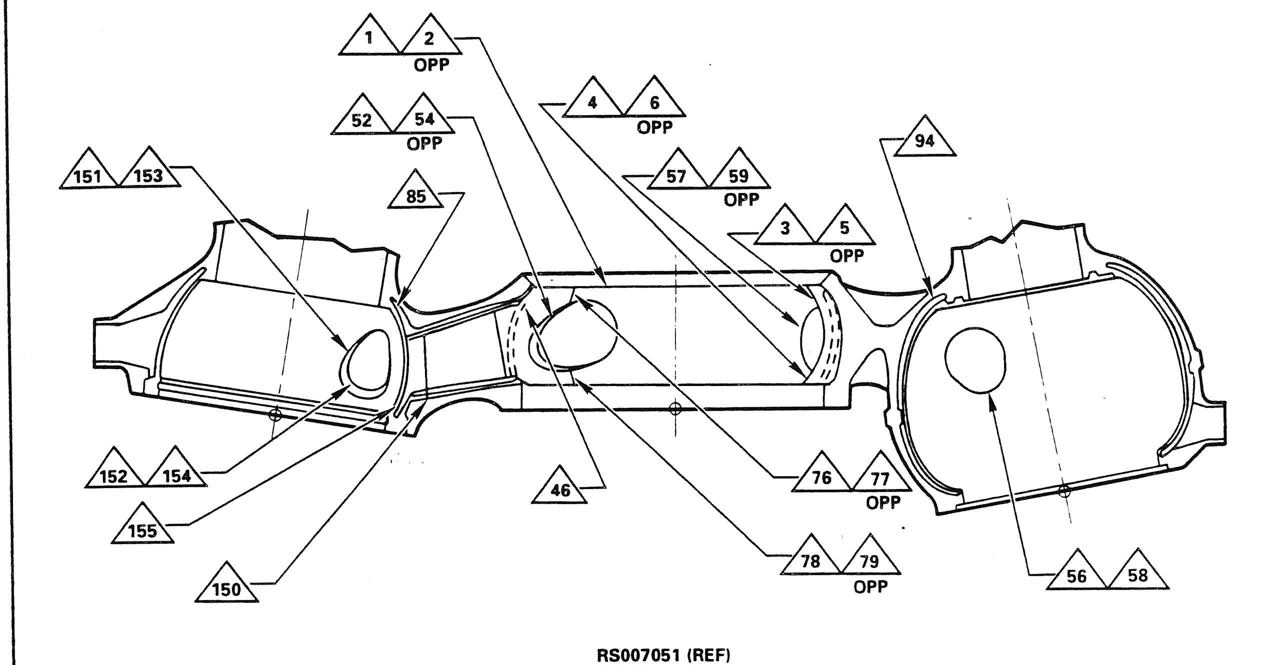


Figure 1-27. Hot Gas Manifold Liner Weld Joint Locations (RS007051)

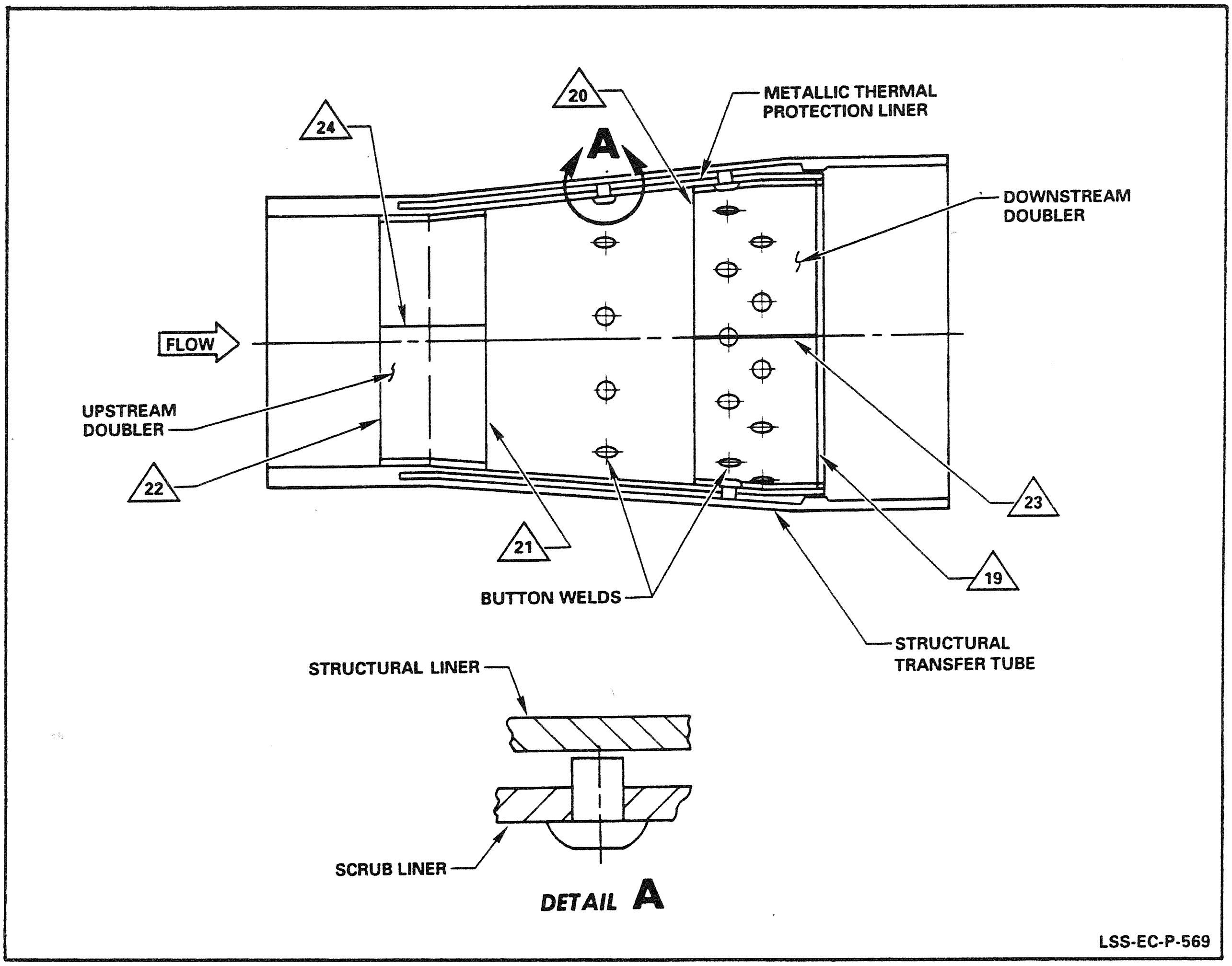


Figure 1-28. Center Transfer Tube and Liner Assembly (RS007065)

SECTION II

INSPECTION CRITERIA FOR TURBOPUMPS

SECTION II

CHANGE RECORD

REV/ CHG	DATE	CHANGE SUMMARY	PAGE EFFECT	RCN/CCBD
PRELIM	3/6/85	PRELIMINARY FOR OMRSD REVIEW/ APPROVAL CYCLE	ALL	RCN MV6596 (RELEASED FOR REVIEW 8/26/85)
BASIC	3/6/85	BASIC SECTION RELEASED	ALL	RCN MV6596 (APPROVED 9/26/85)
REV	8/10/87	UPDATED SECTION TO THE LATEST REQUIREMENTS	ALL	RCN MV8301 (APPROVED 7/28/88)
CHG 1	7/5/89	UPDATED SECTION TO THE LATEST REQUIREMENTS	2-3, 2-5, 2-11, 2-14, 2-15	CCBD NO. ME3-00-7675 (APPROVED 6/29/89)
REV	11/1/89	UPDATED SECTION TO THE LATEST REQUIREMENTS	2-4	CCBD NO. ME3-00-7909 (APPROVED 9/29/89)
CHG 1	2/12/90	UPDATED SECTION TO THE LATEST REQUIREMENTS OF ECP 1A-2959	2-16 2-38 2-39	CCBD NO. ME3-AA-5536 (APPROVED 11/30/89)
CHG 3	5/2/90	UPDATED SECTION TO THE LATEST REQUIREMENTS OF ECP 1108	2-14, 2-16	CCBD NO. ME3-00-8726 (APPROVED 5/2/90)
REV	10/25/90	UPDATED SECTION TO THE LATEST REQUIREMENTS OF ECP 1A-2999	2-4 2-22 2-49	CCBD NO. ME3-AA-5445 (APPROVED 6/20/89)

SECTION II

CHANGE RECORD (continued)

REV/ CHG	DATE	CHANGE SUMMARY	PAGE EFFECT	RCN/CCBD
REV	2/10/92	UPDATED SECTION TO THE LATEST REQUIREMENTS	2-5 THRU 2-14, 2-18 THRU 2-19, 2-23, 2-25, 2-33, 2-35, 2-63 THRU 2-67/ 2-68	SPECIFICATION RF0001-053 REVISION E-1 (APPROVED 10/30/91)
REV	5/29/92	UPDATED SECTION TO THE LATEST REQUIREMENTS	2-5 THRU 2-14, 2-23, 2-31, 2-33	SPECIFICATION RF0001-053 REVISION F-4 (APPROVED 5/19/92)
REV	7/31/92	UPDATED SECTION TO THE LATEST REQUIREMENTS OF ECP SSME-1220	2-5, 2-13, 2-33	SPECIFICATION RF0001-053 REVISION G (APPROVED 8/13/92)
REV	11/5/92	UPDATED SECTION TO THE LATEST REQUIREMENTS OF RF0001-053	2-5, 2-6, 2-12, 2-15 THRU 2-16, 2-33, 2-68	SPECIFICATION RF0001-053 REVISION G-1 (APPROVED 11/17/92)
REV	2/16/93	UPDATED SECTION TO THE LATEST REQUIREMENTS OF RF0001-053	2-5, 2-6, 2-12	SPECIFICATION RF0001-053 REVISION G-2 (APPROVED 2/11/93)

SECTION II

CHANGE RECORD (continued)

REV/ CHG	DATE	CHANGE SUMMARY	PAGE EFFECT	RCN/CCBD
REV	3/10/93	UPDATED SECTION TO THE LATEST REQUIREMENTS OF RF0001-053	2-5, 2-7 THRU 2-9, 2-16, 2-22, 2-32, 2-59 THRU 2-68	SPECIFICATION RF0001-053 REVISION G-3 (APPROVED 3/16/93)

SECTION II

INSPECTION CRITERIA FOR TURBOPUMPS

2.1 SCOPE

This section contains inspection criteria for the SSME HPOTP, HPFTP, LPFTP, LPOTP, and fuel pump nickel insulation. (Refer to table 2-1.)

2.2 OMRSD

The hardware condition limitation of the inspection criteria supports the OMRSD requirements listed below. Hardware conditions that are within these limitations require no further action or rework. Hardware conditions resulting from operational degradation that do not meet these limitations shall be processed through the PR/MR system.

V41BS0.020 SSME HPFTP Torque Test

V41BU0.033 SSME Fuel System LAI Inspection

V41BU0.040 INTERNAL INSPECTION OF SSME COMPONENTS

V41BU0.065 SSME HPOTP Internal Inspection

V41BU0.075 SSME HPFTP Internal Inspection

V41BU0.079 SSME HPFTP First-Stage Turbine Inspection

V41BU0.080 HPFTP TURBINE INSPECTION

2.3 APPLICABLE DOCUMENTS

The following documents are listed as source reference only.

SPECIFICATIONS

<u>Rockwell International</u>

	REV	
RF0001-053	G-3	Space Shuttle Main Engine Inspection Criteria
RF0001-007	D	HPFTP - Housing, Standard Repair of
RF0001-015	E	Support HPFTP Standard Repair of
RF0001-054	-	Copper Plated Surfaces, HPOTP Housing Acceptance Criteria

	REV	
RF0004-027	A	Sealing Surface Requirements
RF0004-059	C	SSME HPFTP, P/N R0019821 and RS007520, Visual Inspection and Acceptance Criteria for Used Blades
RL00470	B-3	SSME Turbopump Assembly, High Pressure Oxidizer, Servicing (Overhaul) Requirements
RL00473	C-2	SSME Turbopump Assembly, Low Pressure Oxidizer, Overhaul/Recycle/Repair Requirements
RL00528	L	SSME High-Pressure Fuel Turbopump, Overhaul/ Recycle/Repair Requirements
RL00531	F-3	SSME Low-Pressure Fuel Turbopump Overhaul/Recycle/Repair Requirements
RL00655	C-4	HPFTP Sheet Metal, Inspection of
RL00703	A	HPOTP Turbine Housing Sheet Metal, Inspection
RF0001-080	-	Cracks, HPOTP Turbine Shield, Standard Repair of

TABLE 2-1. SSME TURBOPUMP INSPECTION CRITERIA (Sheet 1 of 27)

Condition	Hardware Condition Limit
A. LPFTP	
1. External seal surfaces:	
(a) Joint F1 fuel inlet flange	
Primary sealing surface defects (See figures 2-39 and 2-40.)	Depth shall not exceed 0.004 inch. Radial length shall not exceed 0.030 inch. Any circumferential width that does not exceed radial length limit is acceptable. When the defect exhibits no sharp edges and has generally rounded surface features with a minimum root radius of 0.03 inches, this is acceptable. Raised material, sharp edges within the defect, and cracks are not acceptable.
Secondary sealing surface defects	Same as primary sealing surface, except allowable radial length is increased to 0.100 inch.
Nonsealing surface defects	Depth shall not exceed 0.004 inch. Radial length shall not exceed 0.250 inch. Any circumferential width that does not exceed radial length limit is acceptable. When the defect exhibits no sharp edges and has generally rounded surface features with a minimum root radius of 0.03 inches, this is acceptable.

TABLE 2-1. SSME TURBOPUMP INSPECTION CRITERIA (Sheet 2 of 27)

Condition	Hardware Condition Limit
A. LPFTP (continued)	Raised material, sharp edges within the defect, and cracks are not acceptable.
(b) Joint F2 fuel discharge flange defects	
Sealing surface defects	Depth shall not exceed 0.004 inch.
	Radial length shall not exceed 0.030 inch.
	Any circumferential width that does not exceed radial length limit is acceptable.
	When the defect exhibits no sharp edges and has generally rounded surface features with a minimum root radius of 0.03 inches, this is acceptable. (See figure 2-41.)
	Raised material, sharp edges within the defect, and cracks are not acceptable.
Nonsealing surface defects	Depth shall not exceed 0.004 inch.
	Radial length shall not exceed 0.250 inch.
	Any circumferential width that does not exceed radial length limit is acceptable.
	When the defect exhibits no sharp edges and has generally rounded surface features with a minimum root radius of 0.03 inches, this is acceptable.
	Raised material, sharp edges within the defect, and cracks are not acceptable.

TABLE 2-1. SSME TURBOPUMP INSPECTION CRITERIA (Sheet 3 of 27)

Condition	Hardware Condition Limit
A. LPFTP (continued)	
(c) Joint F8 turbine inlet flange defects	
Sealing surface defects (See figure 2-42.)	Defects are not acceptable.
Nonsealing surface defects	Depth shall not exceed 0.004 inch. Radial length shall not exceed 0.025 inch. Any circumferential width that does not exceed radial length limit is acceptable. When the defect exhibits no sharp edges and has generally rounded surface features with a minimum root radius of 0.03 inches, this is acceptable. Raised material, sharp edges within the defect, and cracks are not acceptable.
(d) Joint F9 turbine discharge flange defects	
Sealing surface (See figure 2-43.)	Defects are not acceptable.
Nonsealing surface defects (See figure 2-43.)	Depth shall not exceed 0.004 inch. Radial length shall not exceed 0.250 inch. Any circumferential width that does not exceed radial length limit is acceptable.

TABLE 2-1. SSME TURBOPUMP INSPECTION CRITERIA (Sheet 4 of 27)

Condition	Hardware Condition Limit
A. LPFTP (continued)	When the defect exhibits no sharp edges and has generally rounded surface features with a minimum root radius of 0.03 inches, this is acceptable.
	Raised material, sharp edges within the defect, and cracks are not acceptable.
(e) Joint D17 liftoff seal drain port defects	
Sealing surface defects	Defects are not acceptable.
Nonsealing surface defects	Depth shall not exceed 0.004 inch.
	Radial length shall not exceed 0.250 inch.
	Any circumferential width that does not exceed radial length limit is acceptable.
	When the defect exhibits no sharp edges and has generally rounded surface features with a minimum root radius of 0.03 inches, this is acceptable.
	Raised material, sharp edges within the defect, and cracks are not acceptable.
(f) Joint F1.1 transducer port	
Sealing surface defects	Defects are not acceptable.
Nonsealing surface defects	Depth shall not exceed 0.004 inch.
	Radial length shall not exceed 0.250 inch.

TABLE 2-1. SSME TURBOPUMP INSPECTION CRITERIA (Sheet 5 of 27)

Condition	Hardware Condition Limit
A. LPFTP (continued)	Any circumferential width that does not exceed radial length limit is acceptable. When the defect exhibits no sharp edges and has generally rounded surface features with a minimum root radius of 0.03 inches, this is acceptable. Raised material, sharp edges within the defect, and cracks are not acceptable.
2. Nonsealing surfaces defects	Surface defects of 0.004 inch or less are unconditionally acceptable providing there is no raised material or sharp edges and any defect exhibits generally rounded surface features with a minimum root radius of 0.03 inches.
3. Housing inlet:	
Rub marks	Rub marks are acceptable provided area has no raised material. (See figure 2-1.)
4. LPFTP nickel insulation:	
Dents and blisters	Minor dents are acceptable providing the dent does not decrease the thickness of the foam to less than 0.25 inch. Minor blisters are acceptable providing they are not cracked, punctured, or contain pin holes.
Cracks, punctures, and pinholes	Cracks, punctures, and pinholes are not acceptable.
Separation of nickel plating at closeout to housing parent metal	Separation is not acceptable.

TABLE 2-1. SSME TURBOPUMP INSPECTION CRITERIA (Sheet 6 of 27)

Condition	Hardware Condition Limit
A. LPFTP (continued)	
5. Liquid air insulators:	
Damage that penetrates surface of insulator	Any damage that penetrates surface of insulator is not acceptable.
Cracks	Cracks are not acceptable.
Debonding	Debonding is not acceptable.

B. HPFTP

NOTE

Note 1: Pinholes are allowable up to 1/16 inch maximum. There are no restrictions on location or number, but pinholes must be at least 2 diameters apart.

Note 2: Intersecting cracks are not acceptable except as stated in the Note (1) of turbine inlet cracks.

Note 3: Missing weld filler material of 1/8 inch diameter or less is acceptable. Weld material splatter is acceptable.

Note 4: The heat affected zone referred to in the following criteria is defined as one-half the existing weld width on either side of a weld.

Note 5 (applicable to all sections): Conditions recognized as acceptable by specification RF0001-053 may be submitted for material review disposition (MRD). An unsatisfactory condition report (UCR) will be generated if the conditions are considered abnormal by Engineering/Quality Assurance. (ECP 1228)

Condition	Hardware Condition Limit
1. Turbine inlet sheet metal:	
Metallic overspray (copper from preburner)	Metallic overspray deposited on turbine inlet sheet metal is acceptable.

TABLE 2-1. SSME TURBOPUMP INSPECTION CRITERIA (Sheet 7 of 27)

Condition	Hardware Condition Limit
B. HPFTP (continued)	
Cracks	Upstream End - Cracks that are located at the upstream end of the strut cover in the weld or the weld heat-affected zone, and propagate for a distance equal to or less than 3/8 inch on either side, shall be acceptable. If the cracks extend along both sides, the combined length of cracks on an end may be equal to or less than 3/4 inch. Axial cracks located anywhere along the sides of the struts, in the weld or heat affected zone, that are 3/8 inch or less are acceptable. One crack on each side of a strut, on both the inner and outer shroud is allowable. (See figure 2-2 (C).) (Ref. notes 1-4.) Downstream End - Cracks that are within 1/2 inch of the downstream end in the weld or heat-affected zone shall be no greater than 1/4 inch. If the cracks extend along both sides, the combined length of the cracks on an end may be equal to or less than 1/2 inch. (Ref. figure 2-2.) Additionally, cracks between struts in the same flow passage shall be no greater than 1/8 inch on either side. (Ref. ECP SSME-1202.) a. A crack that intersects the shroud edge and propagates along both sides of the strut cover at the upstream or downstream end, similar to that shown in figure 2-2 (A) and (D) , is considered to be separate nonintersecting cracks on each side of the strut cover. b. Adjacent cracks in the same immediate weld area are not allowed. (See figure 2-2 (B).)

TABLE 2-1. SSME TURBOPUMP INSPECTION CRITERIA (Sheet 8 of 27)

Condition	Hardware Condition Limit
B. HPFTP (continued)	
2. Turbopump housing sheet metal:	
Cracks	Combined Length - Cracks at the inner liner and outer liner of the strut covers which do not exceed 50 percent of the combined lengths of the welds at the inner and outer liner are acceptable. A crack may extend the full perimeter of the strut cover at the inner or outer liner, provided there are no cracks at the opposite diameter. (See figure 2-3 (A).) (Ref. notes 1-4.)
	Radial Welds - Cracks in the radial welds at the downstream end of the strut covers which extend the full radial length of the strut are acceptable. The combined length of multiple radial cracks shall not exceed the radial length of one weld. (See figure 2-3 (B).) (Ref. notes 1-4.)
	Vent Holes - Cracks of any length that intersect the vent holes at the downstream end of the strut covers are acceptable. (See figure 2-3 (C).) NOTE: More than one crack of this type in a strut cover shall be unacceptable.

TABLE 2-1. SSME TURBOPUMP INSPECTION CRITERIA (Sheet 9 of 27)

Condition	Hardware Condition Limit
B. HPFTP (continued)	Discharge Post Weld - Cracks that originate in the discharge post welds or heat affected zone are acceptable within the following limits. (See figure 2-3 Ⓓ.) A single crack shall not extend more than 1/4 inch along the length of the weld on either side of the post. If the crack extends from the end of the post along both sides, the total length shall not exceed 1/2 inch. NOTE: Adjacent cracks in the same immediate weld area are not allowed. (See figure 2-3 Ⓔ.) (Ref. notes 1-4.)
3. Housing, other than discharge sheet metal:	
Cracks, G6 flange	All units: Y cracks and circumferential cracks are not acceptable. Multiple cracks that do not intersect the seal groove (figure 2-4, types 1 through 4) are acceptable. (ECP 1228)
Cracks, weld 450	Cracks are not acceptable. (Ref. notes 1-4.)
Cracks, weld 56	Cracks are not acceptable. (ECP 1228)
Cracks, stiffener vanes	Cracks adjacent to the stiffener vanes are not acceptable. (Ref. notes 1-4.)
Cracks, volute liner	Cracks are not acceptable.

TABLE 2-1. SSME TURBOPUMP INSPECTION CRITERIA (Sheet 10 of 27)

Condition	Hardware Condition Limit
B. HPFTP (continued)	
Cracks, turbine inner ring bolt holes:	More than two type A cracks are not acceptable. NOTE: A type A crack is a radial crack that intersects a bolt hole and is visible across the axial face of the inner ring from the ID to the OD. During field inspection, a crack is classified as type A if it extends across surface -C- and as far as can be seen on the adjacent pilot diameter surfaces. (See figure 2-45.) (ECP 1228) NOTE: Borescope inspection is the examination of the full length of the 12 bolt holes used to attach the turbine ring and support assembly to the housing. (ECP 1228) NOTE: Visual inspection is the disassembly and complete examination of all visible surfaces of the turbine end of the housing assembly. (ECP 1228) A bolt hole with cracks that extend the full length of the bolt hole on both the inboard and outboard side of a single hole is not acceptable. NOTE: A full length crack is a crack that extends from the turbine end axial face to the drill point but not into the drill point or, during field inspections, that extends across surface -C- and as far as can be seen on the adjacent pilot diameter surfaces. (See figure 2-45.) (ECP 1228) Regardless of length, a crack that extends into the drill point is not acceptable. (ECP 1228) NOTE: Drill point is the entire conical end (bottom surface) of the bolt hole. (See figure 2-45.) (ECP 1228)

TABLE 2-1. SSME TURBOPUMP INSPECTION CRITERIA (Sheet 11 of 27)

Condition	Hardware Condition Limit
B. HPFTP (continued)	
4. Turbine bellows shield:	
Cracks	Cracks are not acceptable.
Discoloration and fretting	Discoloration and fretting are acceptable.
5. Shield (coolie-hat) retainer nut and lock key:	
Cracks	Cracks are not allowed.
Discoloration	Discoloration is acceptable.
Nut retention	Lock tab must retain nut.
6. First-stage nozzle inner and outer shrouds:	
Cracks	Trailing Edge - Cracks are not acceptable. Inner Shroud Leading Edge - Cracks that do not extend more than 0.240 inch from the leading edge shall be acceptable provided: 1. Individual passages containing multiple cracks to lug face plane are separated by at least 2 flow passages (3 vanes). 2. In a single passage containing multiple cracks, only one crack may extend 0.240 inch. All other cracks must be 0.120 inches or less.

TABLE 2-1. SSME TURBOPUMP INSPECTION CRITERIA (Sheet 12 of 27)

Condition	Hardware Condition Limit
B. HPFTP (continued)	Outer Shroud Leading Edge - Cracks that do not extend beyond a plane through upstream faces of lugs (approx equal to 0.15 inch) shall be acceptable provided: 1. ultiple cracks to lug face plane are separated by 2 passages (3 vanes). 2. No crack extends into lug.
7. First-stage nozzle vanes:	
Cracks	Leading Edge - Cracks measuring less than or equal to 0.150 inch in length are acceptable. No more than 6 cracks greater than 0.100 inch in length are acceptable per vane. Determine crack length by measuring the shorter of the two indications on either side of the high point of the vane. Trailing Edge - Cracks are not acceptable.
8. First-stage turbine blades: (See figure 2-5 for blade nomenclature.)	
a. Airfoil, leading edge (borescope and 22X inspection)	
Cracks, base metal (See figure 2-6.)	Cracks in base metal are not acceptable.
NiCrAly coating separation (See figure 2-7.)	NiCrAly coating separation is acceptable. If separation is visible during borescope inspection, 22X inspection is mandatory to determine if flaw extends into parent metal.
NiCrAly coating erosion	Erosion not greater than illustrated in figure 2-8 is acceptable.

TABLE 2-1. SSME TURBOPUMP INSPECTION CRITERIA (Sheet 13 of 27)

Condition	Hardware Condition Limit
B. HPFTP (continued)	
Parent metal melt	Parent metal melt is not acceptable.
Nicks and dings	Nicks and dings are not acceptable on downstream edge and bottom one-third of airfoil. Nicks and dings are acceptable to a width of 0.030 inch on blade providing defect depth is no deeper than one-half the defect width up to a maximum depth of 0.010 inch and no cracks propagate from nicks or dings. (See figure 2-9.)
NiCrAly coating spalling	NiCrAly coating spalling is acceptable. (See figure 2-10.)
NiCrAly coating melt	NiCrAly coating melt not greater than illustrated in figure 2-11 is acceptable.
b. Airfoil, pressure (concave) and suction (convex) side	
Cracks	Cracks are not acceptable.
Erosion	Erosion is not acceptable.
Parent metal melt	Parent metal melt is not acceptable.
Nicks and dings	Nicks and dings are not acceptable on downstream edge and bottom one-third of airfoil. Nicks and dings are acceptable to a width of 0.030 inch on blade providing defect depth is no deeper than one-half the defect width up to a maximum depth of 0.010 inch and no cracks propagate from nicks or dings. (See figure 2-9.)

TABLE 2-1. SSME TURBOPUMP INSPECTION CRITERIA (Sheet 14 of 27)

Condition	Hardware Condition Limit
B. HPFTP (continued)	
NiCrAly coating spalling	NiCrAly coating spalling is acceptable.
c. Airfoil, trailing edge	
Cracks	Cracks are not acceptable.
Erosion	Erosion is not acceptable.
Parent metal melt	Parent metal melt is not acceptable.
Nicks and dings	Nicks and dings are not acceptable.
NiCrAly coating spalling	NiCrAly coating spalling is acceptable.
d. Airfoil tip	
Rub marks from tip seals	Airfoil tip rubbing over 80 percent of the airfoil chord length is acceptable.
e. Platform upstream tip (leading edge)	
Cracks	Cracks are not acceptable.
Erosion	Erosion is acceptable to a depth of 0.100 inch. (See figure 2-12.)
Rub on airfoil side	Rub on airfoil side from outside diameter lip of fishmouth seal is acceptable to a depth of 0.010 inch. (See figure 2-13.)
Rub on tip	Rub on tip by roof of fishmouth is acceptable. (See figure 2-14.)

TABLE 2-1. SSME TURBOPUMP INSPECTION CRITERIA (Sheet 15 of 27)

Condition	Hardware Condition Limit
B. HPFTP (continued)	
f. Platform concave and convex side	
Cracks	Cracks are acceptable on concave and convex sides, as shown in figure 2-15, providing they are farther apart than local platform width, would not intersect airfoil leading edge, and do not extend into airfoil fillet radius.
Erosion	Erosion is not acceptable.
g. Platform downstream tip (trailing edge)	
Cracks	Cracks are not acceptable.
Erosion	Erosion is not acceptable.
h. Dampers (See figures 2-5 and 2-16.)	
Position	All dampers must be in proper position.
9. Second-stage turbine blades:	
a. Airfoil, trailing edge	
Cracks	Cracks are not acceptable.
Erosion	Erosion is not acceptable.
Parent metal melt	Parent metal melt is not acceptable.
Nicks and dings	Nicks and dings are not acceptable.
NiCrAly coating spalling	NiCrAly coating spalling is acceptable.

TABLE 2-1. SSME TURBOPUMP INSPECTION CRITERIA (Sheet 16 of 27)

Condition	Hardware Condition Limit
B. HPFTP (continued)	
b. Platforms	
Cracks	Cracks are acceptable on concave and convex sides, as shown in figure 2-15, providing they are farther apart than local platform width, would not intersect airfoil leading edge, and do not extend into airfoil fillet radius.
Missing material	Missing pieces are not acceptable.
c. Platform downstream tip (trailing edge)	
Cracks	Cracks are not acceptable.
Erosion	Erosion is not acceptable.
d. Dampers (See figure 2-17.)	
Position	All dampers must be in proper position.
10. External seal surfaces:	
Scratches, nicks, dents, pits, and other damage	
Sealing surface	Defects are not acceptable. (See figures 2-40 and 2-44 for joints F3 and F4.)
Nonsealing surface	Depth shall not exceed 0.004 inch.
	Radial length shall not exceed 0.250 inch.
	Any circumferential width that does not exceed radial length limit is acceptable.

TABLE 2-1. SSME TURBOPUMP INSPECTION CRITERIA (Sheet 17 of 27)

Condition	Hardware Condition Limit
B. HPFTP (continued)	When the defect exhibits no sharp edges and has generally rounded surface features with a minimum root radius of 0.03 inches, this is acceptable. Raised material, sharp edges within the defect, and cracks are not acceptable.
11. Thrust bearing thrust ball and insert:	
Cracks	Cracks on ball surface are not acceptable.
Nicks, scratches, or galling	Nicks, scratches, or galling of ball surface are not acceptable.
Dry lubricant coating	Minor dry-film-lubricant wear of thrust ball RES1163 (thin coat remaining or narrow band of base metal showing) is acceptable provided there are no cracks visible in worn area (visual inspection - unaided eye) and a thin coat of Molykote G or GN grease is applied to worn area of ball per RA0112-002, Method Z, at final installation. Application of lubricant to be conducted by certified personnel. Insert R0019215 nonconcentric wear or parent metal exhibits galling is not acceptable. Minor dry-film-lubricant wear (thin coat remaining or narrow band of parent metal showing) is acceptable provided there are no cracks visible in worn area (visual inspection - unaided eye) and a thin coat of Molykote G or GN grease is applied to worn area of insert per RA0112-002, Method Z, at final installation. Application of lubricant to be conducted by certified personnel.

TABLE 2-1. SSME TURBOPUMP INSPECTION CRITERIA (Sheet 18 of 27)

Condition	Hardware Condition Limit
B. HPFTP (continued)	
Green powder residue	Green powder residue found in the thrust bearing area and adjacent areas is acceptable provided that no cage fiber material is present. NOTE: Green powder residue is a by-product of fluorinated ethylene polymer (FEP)/15 percent molybdenum disulfide coating on bearing cages.
Thrust ball movement	Thrust ball rotation within the socket, when light finger pressure is applied, is acceptable. Axial or radial movement is unacceptable.
12. Turbine Support Ring OD (inspections with bellows shield removed):	
Cracks on ring	Visually examine the accessible area of the ring (between the turbine support and the hatband). Specifically inspect for axial cracks emanating from the turbine end, in the area of the bolt holes. Cracks of any orientation on the ring are not acceptable.
Fretting on ring	Fretting is acceptable.
Fractures	Multiple cracks and missing pieces are allowed. If accessible, remove all loose seal fragments. Reposition any portion of the seal that protrudes from the seal groove that would interfere with the installation of the bellows shield. (ECP 1108)

TABLE 2-1. SSME TURBOPUMP INSPECTION CRITERIA (Sheet 19 of 27)

Condition	Hardware Condition Limit
B. HPFTP (continued)	
13. HPFTP nickel insulation:	
Dents and blisters	Minor dents are acceptable providing the dent does not decrease the thickness of the foam to less than 0.25 inch. Minor blisters are acceptable providing they are not cracked, punctured, or contain pin holes.
Cracks, punctures, and pinholes	Cracks, punctures, and pinholes are not acceptable.
Separation of nickel plating at closeout to housing parent metal	Separation is not acceptable.
14. Liquid air insulators:	
Damage that penetrates surface of insulator	Any damage that penetrates surface of insulator is not acceptable.
Cracks	Cracks are not acceptable.
Debonding	Debonding is not acceptable.
15. First-stage tip seal housing retaining lugs	No missing lugs are allowed. (See figure 2-18.)
16. First-stage fishmouth seal: (See figure 2-19.) (ECP 1108)	
Cracks in outer lip	Maximum number of cracks acceptable in any one inch of circumferential length is seven. Total maximum number of cracks acceptable is fifteen. Maximum crack length acceptable is 0.063 inch. Minimum crack-to-crack spacing is 0.090 inch.

TABLE 2-1. SSME TURBOPUMP INSPECTION CRITERIA (Sheet 20 of 27)

Condition	Hardware Condition Limit
B. HPFTP (continued)	Maximum angle acceptable from the axial direction (ie, no circumferential cracks; axial cracks are acceptable) is 45 degrees.
	Maximum angle acceptable of either branch of a Y crack (ie, no branch may be circumferential if both branches are less than or equal to 45 degrees; Y crack is acceptable) is 45 degrees.
Rubbing on fishmouth outer lip	Rubbing on fishmouth seal lip by the first-stage blade platform is acceptable.
Rubbing on fishmouth roof	Rubbing on fishmouth seal roof by the first-stage blade platform leading edge tip is acceptable.
Missing material	Missing pieces are not acceptable.
C. LPOTP	
1. External seal surfaces:	
Joint 01	Defects in primary sealing area such as scratches, dings, porosity, and individual pits with radial dimension of 0.030 inch or less and depth of 0.005 inch or less are acceptable, except spiral-shaped defects that cross over seal area. (See figure 2-20.)
	All requirements for secondary seal area are the same as for primary seal area, except that radial dimension is increased to 0.100 inch. (See figure 2-20.)

TABLE 2-1. SSME TURBOPUMP INSPECTION CRITERIA (Sheet 21 of 27)

Condition	Hardware Condition Limit
C. LPOTP (continued)	All other defects in nonsealing areas that do not exceed 0.005 inch in depth, 0.250 inch in length or width, or do not extend into primary seal area more than 0.030 inch or do not extend into secondary seal area more than 0.100 inch are acceptable. (See figure 2-20.)
	Cracks are not acceptable. Raised material is not acceptable.
Joint 01.1	Defects in seal surface such as nicks, scratches, pits, and cracks are not acceptable. (See figure 2-21.)
	Defects in bolthole flange face that do not exceed 0.005 inch in depth, 0.250 inch in length or width are acceptable. (See figure 2-21.) Raised material is not acceptable.
Joint 01.2 and 01.3	Defects in seal surface such as nicks, scratches, pits, and cracks are not acceptable. (See figure 2-22.)
	Defects in bolthole flange face that do not exceed 0.005 inch in depth, 0.250 inch in length or width are acceptable. (See figure 2-22.) Raised material is not acceptable.
Joint 01.2 and 01.3 closeout disc	Defects in seal surface such as nicks, scratches, and pits, with radial dimension of 0.005 inch or less and depth of 0.005 inch or less are acceptable, except spiral-shaped defects that cross over seal area. (See figure 2-23.) Cracks are not acceptable.

TABLE 2-1. SSME TURBOPUMP INSPECTION CRITERIA (Sheet 22 of 27)

Condition	Hardware Condition Limit
C. LPOTP (continued)	All other defects in nonsealing area that do not exceed 0.005 inch in depth, 0.250 inch in length or width, or extend into seal area more than 0.005 inch are acceptable. (See figure 2-23.) Raised material is not acceptable.
Joint 02	Defects in seal area such as scratches, dings, porosity, and individual pits with radial dimension of 0.030 inch or less and depth of 0.005 inch or less are acceptable, except spiral-shaped defects that cross over seal area. (See figure 2-24.)
	All other defects in nonsealing areas that do not exceed 0.005 inch in depth, 0.250 inch in length or width, or do not extend into seal area more than 0.030 inch are acceptable. (See figure 2-24.)
	Cracks are not acceptable. Raised material is not acceptable.
Joint 05	Defects in seal area such as scratches, dings, porosity, and individual pits with radial dimension of 0.005 inch or less and depth of 0.005 inch or less are acceptable, except spiral-shaped defects that cross over seal area. (See figure 2-25.)
	All other defects in nonsealing area that do not exceed 0.005 inch in depth, 0.250 inch in length or width, or do not extend into seal area more than 0.005 inch are acceptable. (See figure 2-25.) Cracks are not acceptable. Raised material is not acceptable.

TABLE 2-1. SSME TURBOPUMP INSPECTION CRITERIA (Sheet 23 of 27)

Condition	Hardware Condition Limit
C. LPOTP (continued)	
2. Housing inlet liner:	
Nicks, scratches, and rubbing	Nicks, scratches, raised material, or evidence of inducer rubbing is not acceptable.
D. HPOTP	
1. Bearing balls:	
Discoloration	Discoloration is acceptable.
Surface distress	Surface distress, ie, localized or banded pitting without significant material removal is acceptable. (See figure 2-26.)
Spalling	Spalling with definite material removed from the surface of the ball is not acceptable. (See figure 2-27.)
2. Bearing cage:	
Fraying	Individual filaments unraveling from fibers on downstream ID edge are acceptable. (See figure 2-28.) Fuzzy appearance on OD and ID edges at downstream face of cage or in ball pockets is acceptable. Fraying originating at ball pocket is not acceptable. (See figure 2-29.)
Delamination	Delamination of 5 plies or less originating at downstream ID edge, going upstream, is acceptable. (See figure 2-30.) Delamination exceeding 5 plies is not acceptable. Delamination originating at ball pocket is not acceptable. (See figure 2-29.)

TABLE 2-1. SSME TURBOPUMP INSPECTION CRITERIA (Sheet 24 of 27)

Condition	Hardware Condition Limit
D. HPOTP (continued)	
3. Bearing races:	
Cracks	Cracks are not acceptable.
Dry lube indications	Residual dry lube spots are acceptable.
4. Main impeller, and inlet turning vanes:	
Nicks, dents, and scratches	Nicks, dents, and scratches in impeller inducer blade fillet areas or leading edges are not acceptable. Nicks, dents, and scratches in all other areas that do not exceed 0.002 inch in depth or width are acceptable.
Cavitation damage	Cavitation damage on inlet turning vanes that does not exceed 0.050 inch in depth is acceptable. (See figure 2-31 for areas of concern.) Frosty-appearing erosion on impeller inducer blades caused by cavitation that does not exceed 0.005 inch in depth is acceptable. (See figure 2-32.)
5. Preburner pump volute and impeller:	
Nicks, dents, or scratches	Nicks, dents, or scratches in leading edge of impeller blades are not acceptable. Nicks, dents, and scratches in other areas of impeller and volute that do not exceed 0.002 inch in depth or width are acceptable.

TABLE 2-1. -SSME TURBOPUMP INSPECTION CRITERIA (Sheet 25 of 27)

Condition	Hardware Condition Limit
D. HPOTP (continued)	
6. Turbine housing inlet sheet metal:	
Cracks in all welds and sheet metal except cone and shell	Cracks that do not exceed 0.15 inch in length are acceptable providing: a. No more than 3 cracks greater than 0.10 inch exist in a 0.50- by 0.50-inch area. b. Cracks do not intersect.
Cracks or erosion in cone or shell	Cracks or erosion are not acceptable.
Slag deposits	Light slag deposits uniformly distributed are acceptable.
Discoloration	Discoloration is acceptable.
Turbine shield cracks originating from 13/64-inch and 3/8-inch drilled holes (ECP 1A-2999)	A single crack propagating from either the 13/64- or 3/8-inch drilled hole to the adjacent drilled hole is acceptable. (See figure 2-33.) Cracks propagating from the 13/64- and/or 3/8-inch drilled hole in any manner other than to the adjacent drilled hole is unacceptable and shall be repaired per specification RF0001-080. (See figure 2-33.)
7. First-stage nozzle:	
Erosion	Leading edge erosion is not acceptable. (See figure 2-34.)
Cracks or missing material	Cracks or missing pieces are not acceptable. (See figure 2-34.)
Slag deposits	Slag deposits are acceptable if uniformly distributed. (See figure 2-35.)

TABLE 2-1. SSME TURBOPUMP INSPECTION CRITERIA (Sheet 26 of 27)

Condition	Hardware Condition Limit
D. HPOTP (continued)	
Discoloration	Discoloration is acceptable.
8. First-stage blades: (ECP 1218)	
Shroud chipping	Breaks in a single plane with a maximum size of 0.070 X 0.070 X 0.070 inch are acceptable. (See figure 2-36.)
Cracks	Cracks are not acceptable.
Gold plate splatter	Gold plate splatter is not acceptable.
Erosion	Blade erosion is not acceptable. (See figure 2-37.)
Slag deposits	Slag deposits are not acceptable. (See figure 2-38.)
Fretting	Fretting is acceptable.
Imbedded material	Imbedded material is not acceptable.
Smeared material	Honeycomb material smeared/deposited onto the blade is acceptable.
Discoloration	Discoloration is acceptable.
Nicks, dings, dents, pits, and scratches	Discontinuities with a generally rounded surface contour and visible bottom are acceptable in the areas and depths specified below:

Acceptable Discontinuity Sizes

Location	Max. Depth	Max. Height
Squealer rails	0.010	0.002
Shroud (inner and outer)	0.005	0.010
Airfoil	0.010	0.010
Airfoil leading edge	0.005	0.005
Airfoil trailing edge	0.002	0.010

TABLE 2-1. SSME TURBOPUMP INSPECTION CRITERIA (Sheet 27 of 27)

Condition	Hardware Condition Limit
D. HPOTP (continued)	
9. External seal surfaces:	
Scratches and nicks	Scratches or nicks in static sealing area are not acceptable. Scratches, nicks, dents, pits, and other damage in nonsealing surfaces less than 0.002 inch in depth or width are acceptable.
10. Drain lines: (excluding weld joints)	
Dents	Dents up to and including 0.100-inch deep with a minimum 0.060-inch fillet radius with smooth changes of contour are acceptable. (See figure 2-38.)
Scratches and nicks	Scratches, nicks, pits, and other similar damage not exceeding 0.004 inch deep by 0.020 inch wide, with unlimited lengths, are acceptable. Remove raised/displaced material. Maintain original surface contour.
11. HPOTP main housing copper plating	Acceptance of copper plating defects must be in accordance with RF0001-054. (ECP 1210)

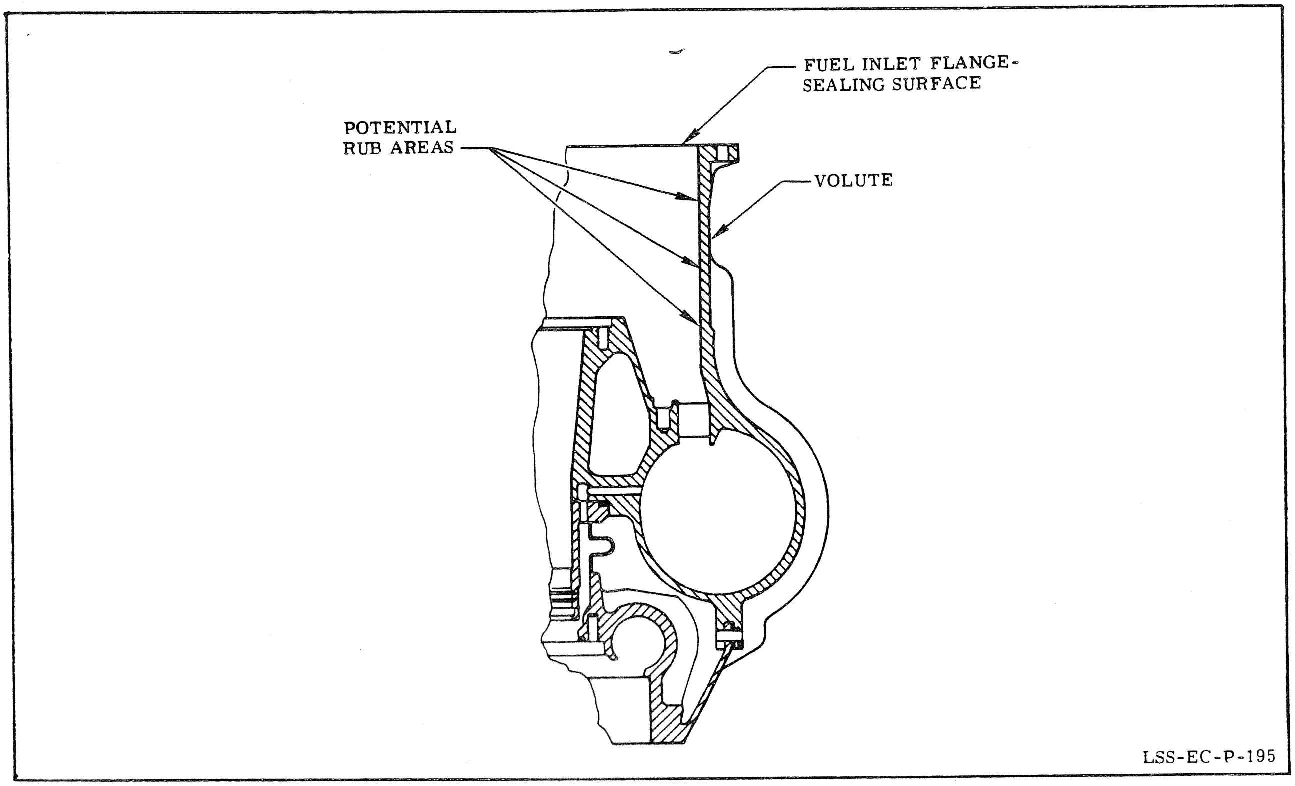


Figure 2-1. LPFTP Housing Volute Inspection Guide

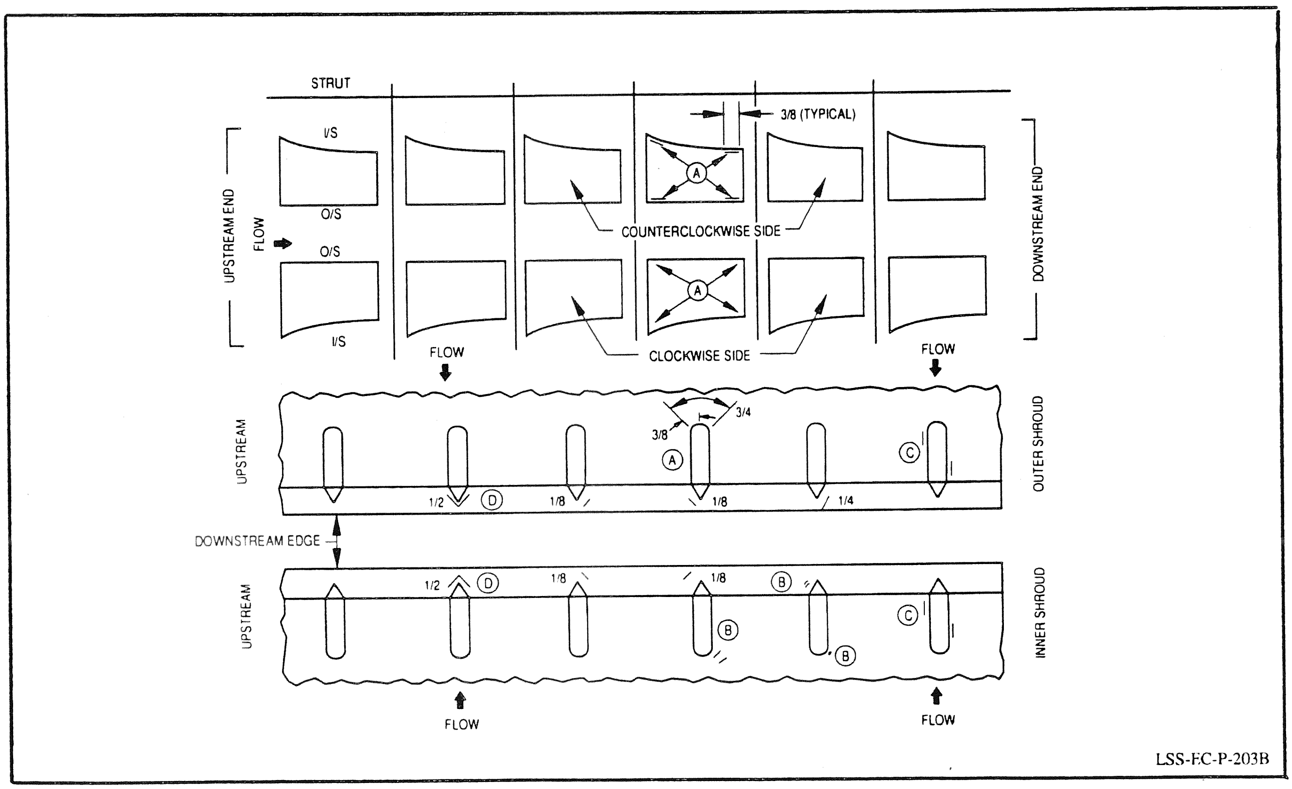


Figure 2-2. Turbine Bearing Support Mapping

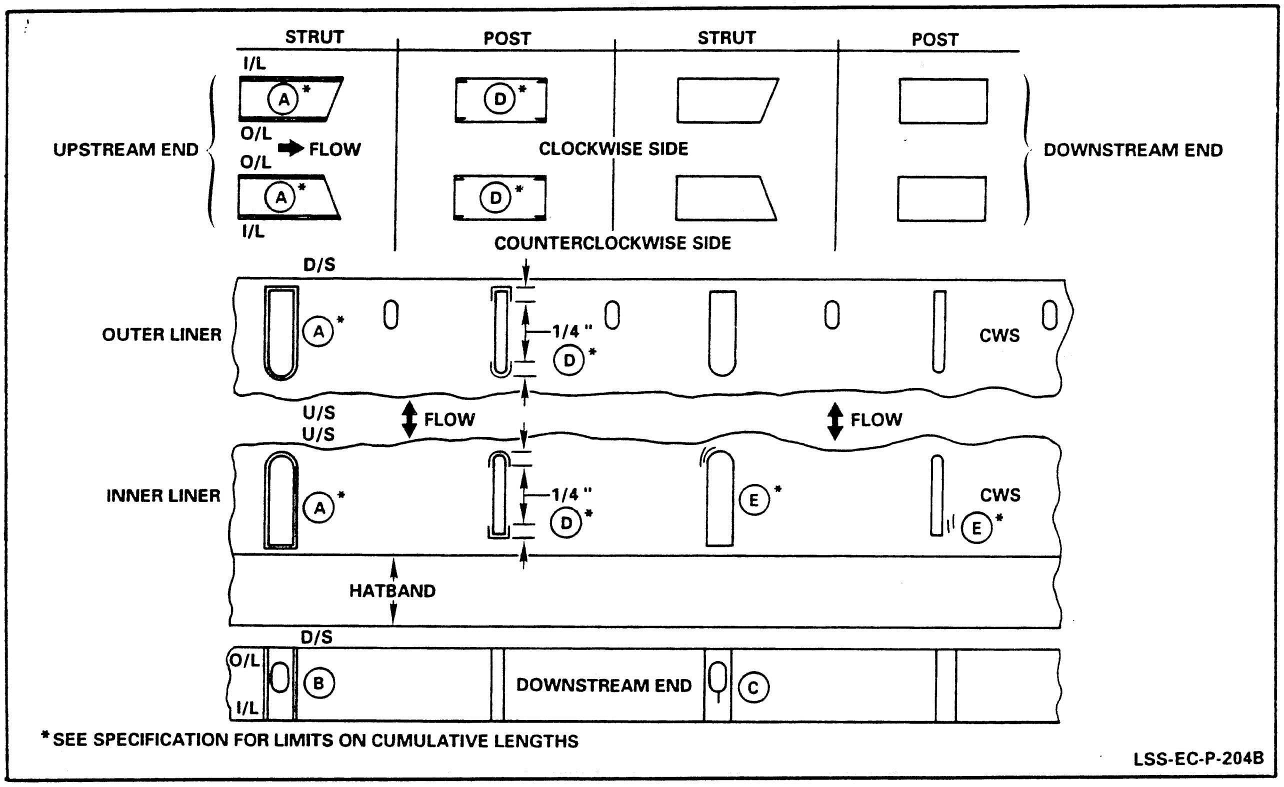


Figure 2-3. HPFTP Turbopump Housing Damage Definitions

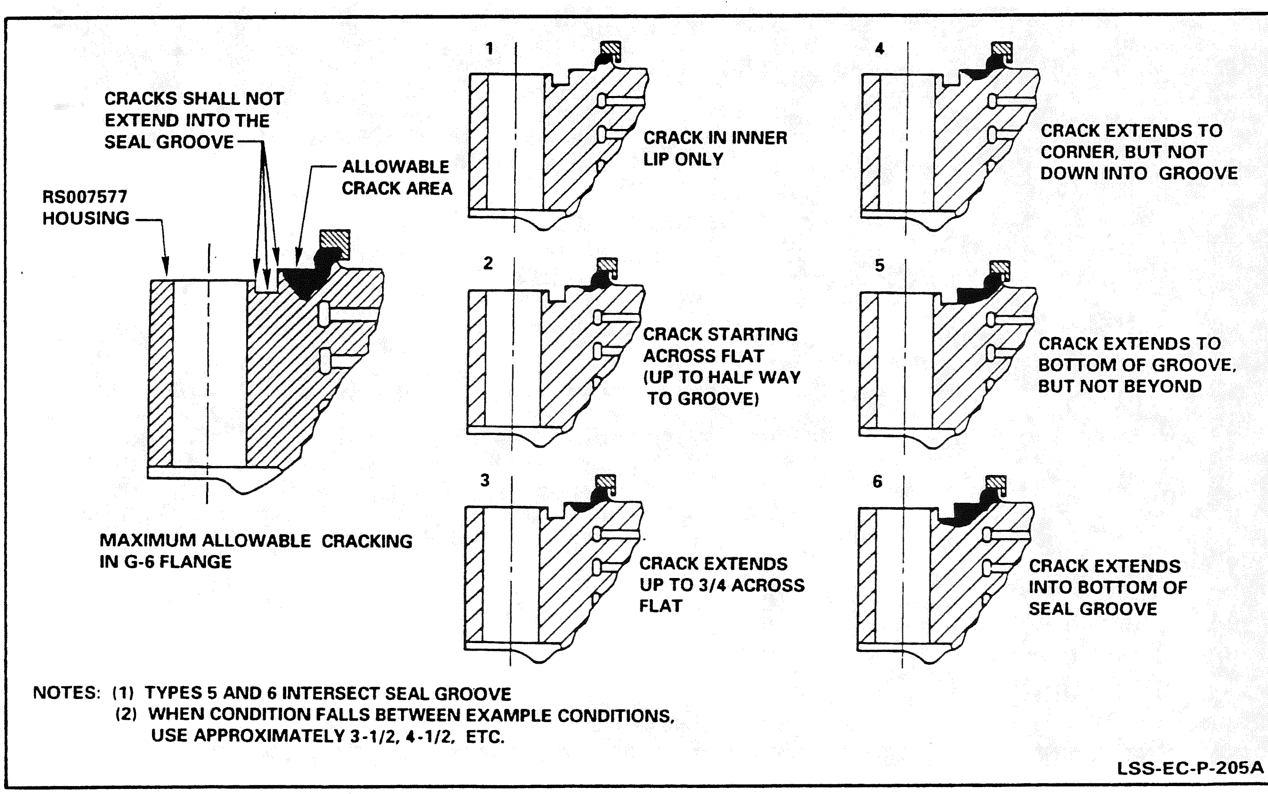


Figure 2-4. HPFTP Joint G6 Flange Crack Definitions

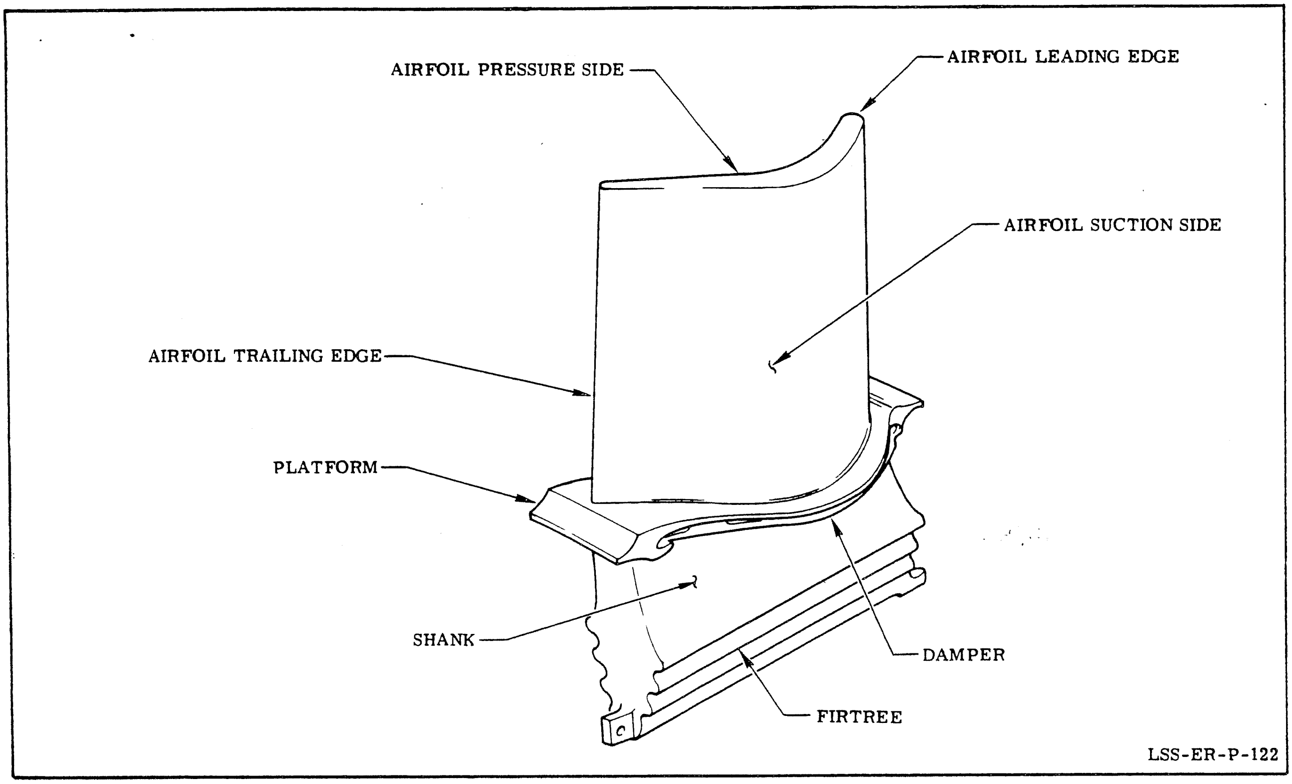


Figure 2-5. HPFTP First-Stage Turbine Blade Identification

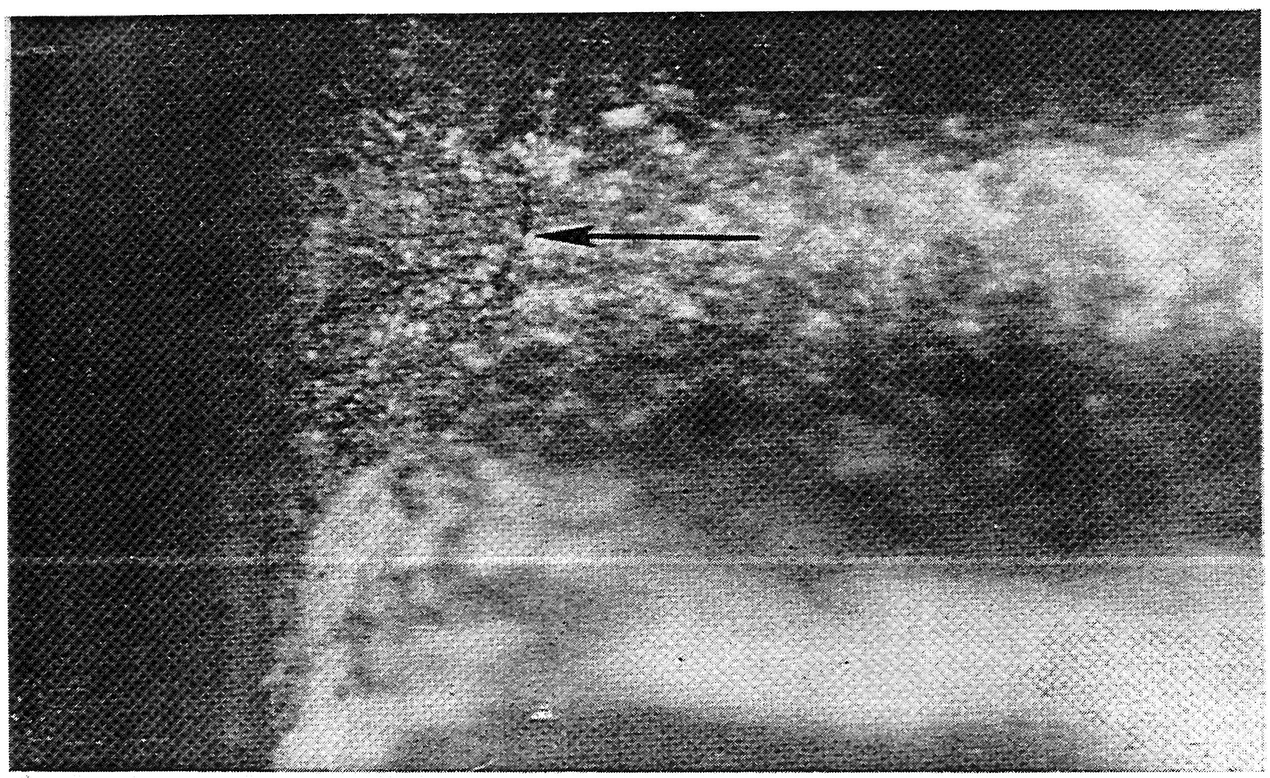


Figure 2-6. HPFTP First-Stage Turbine Blade - Leading Edge Airfoil Crack in Base Metal (22X Magnification)

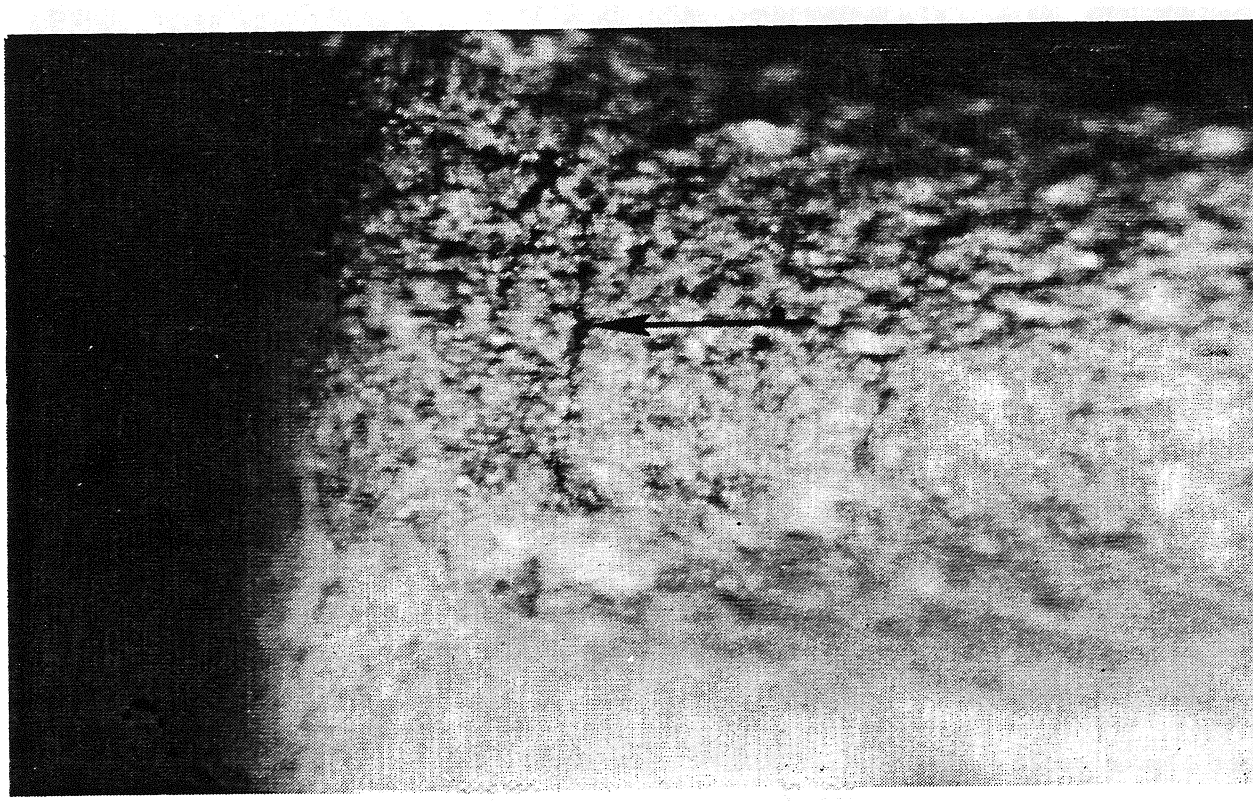
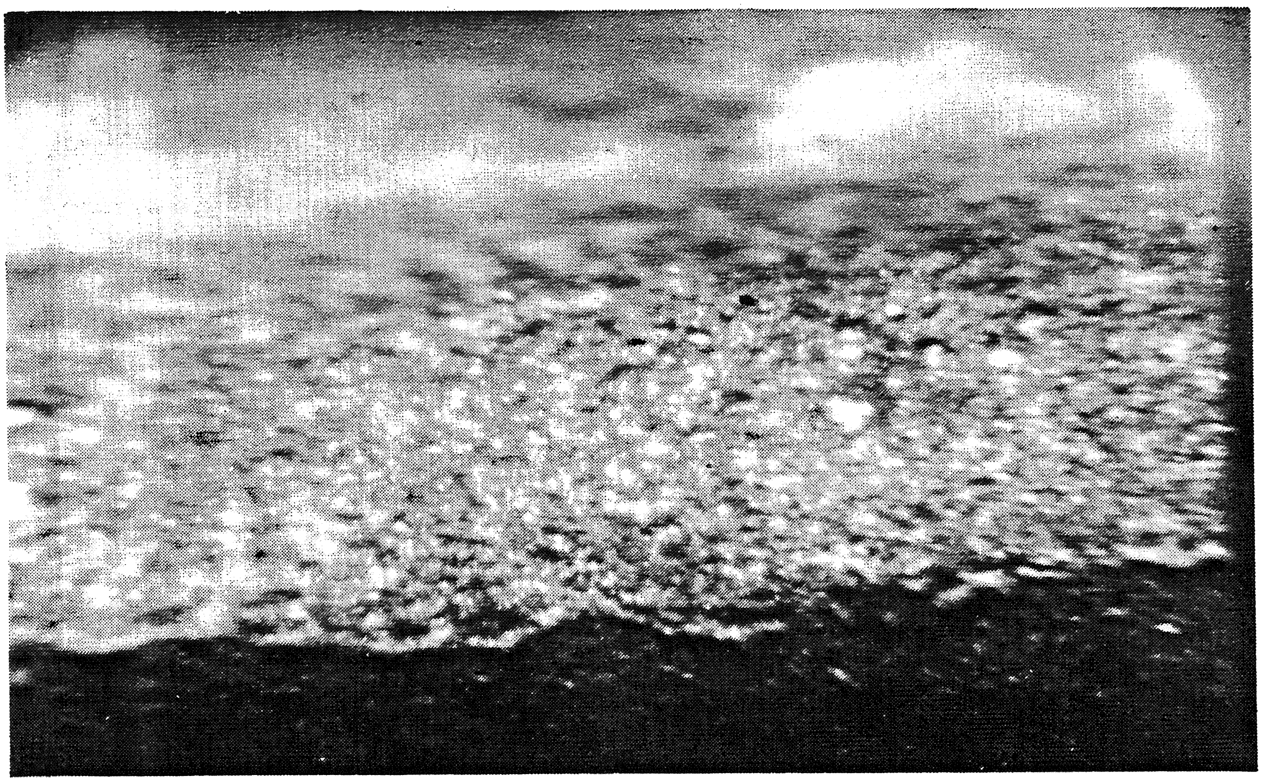


Figure 2-7. HPFTP First-Stage Turbine Blade - Airfoil Leading Edge Separation in NiCrAly (22X Magnification)



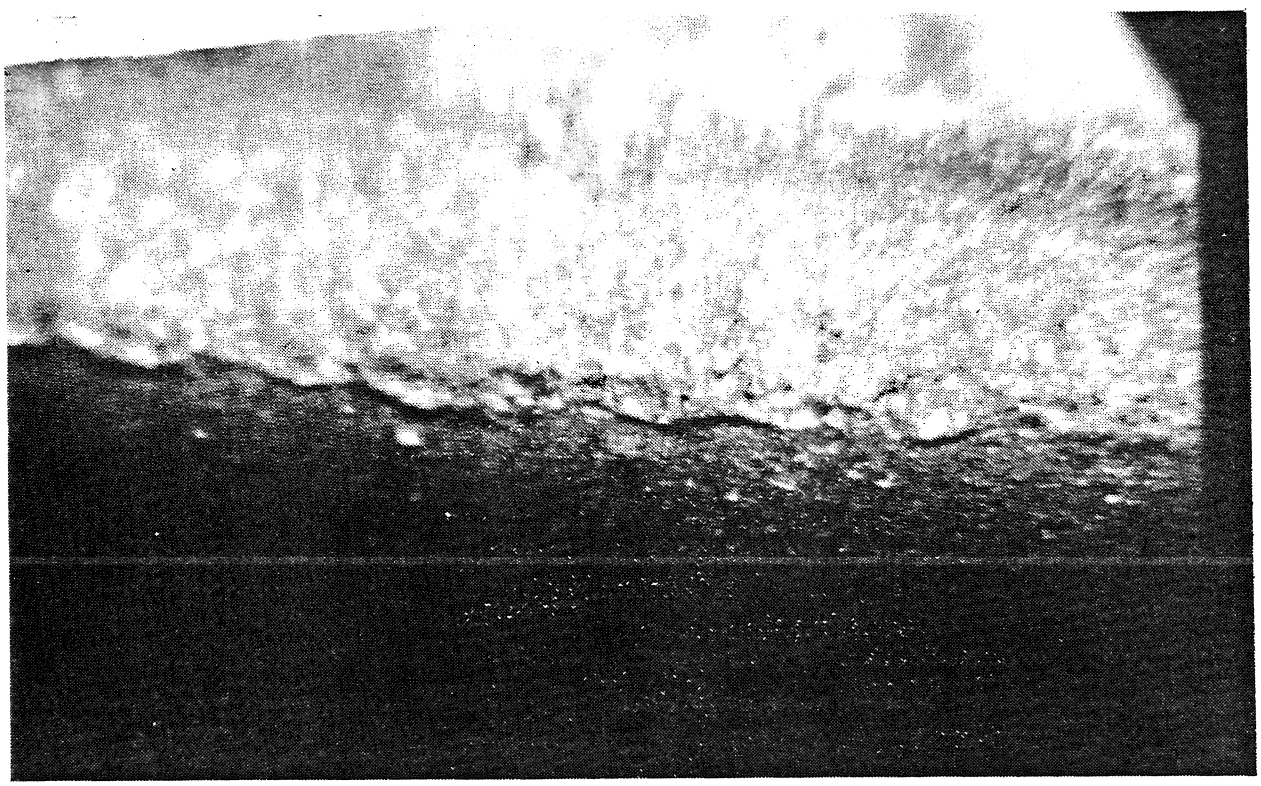


Figure 2-8. HPFTP First-Stage Turbine Blade - Airfoil Leading Edge Erosion (22X Magnification)

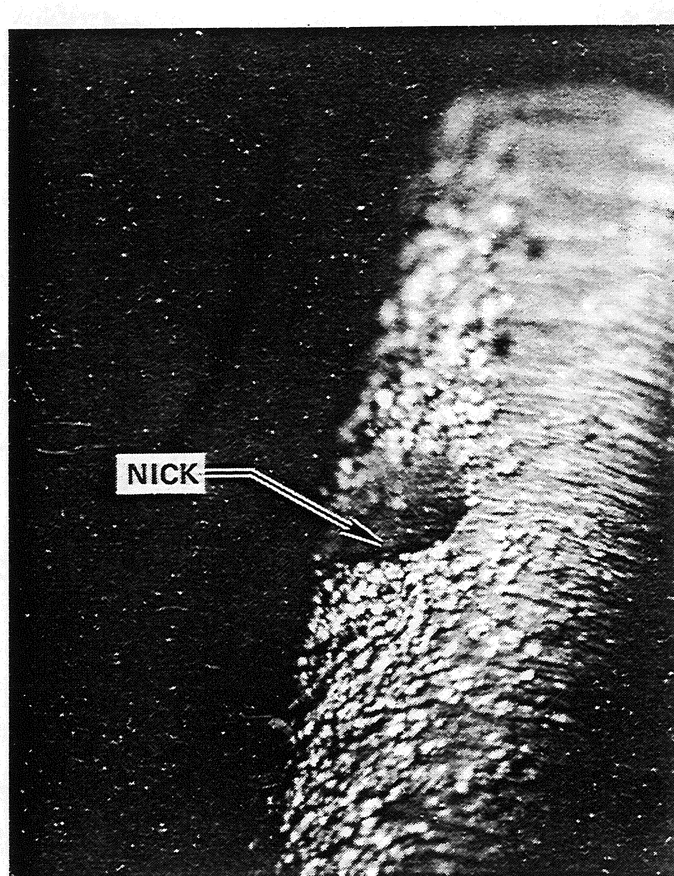


Figure 2-9. Turbine Blades

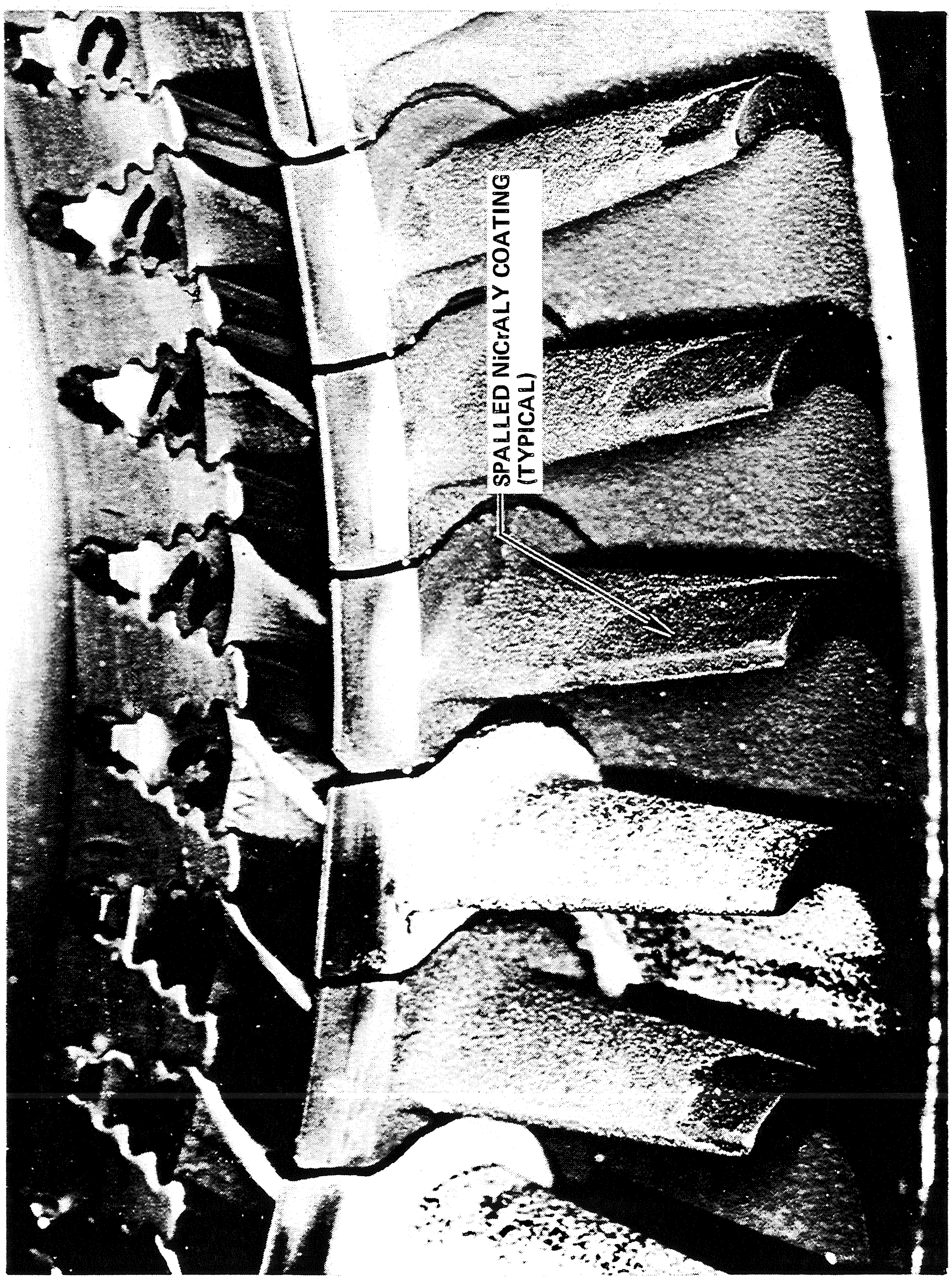


Figure 2-10. Spalled NiCrAly Coating - First-Stage Turbine Blades

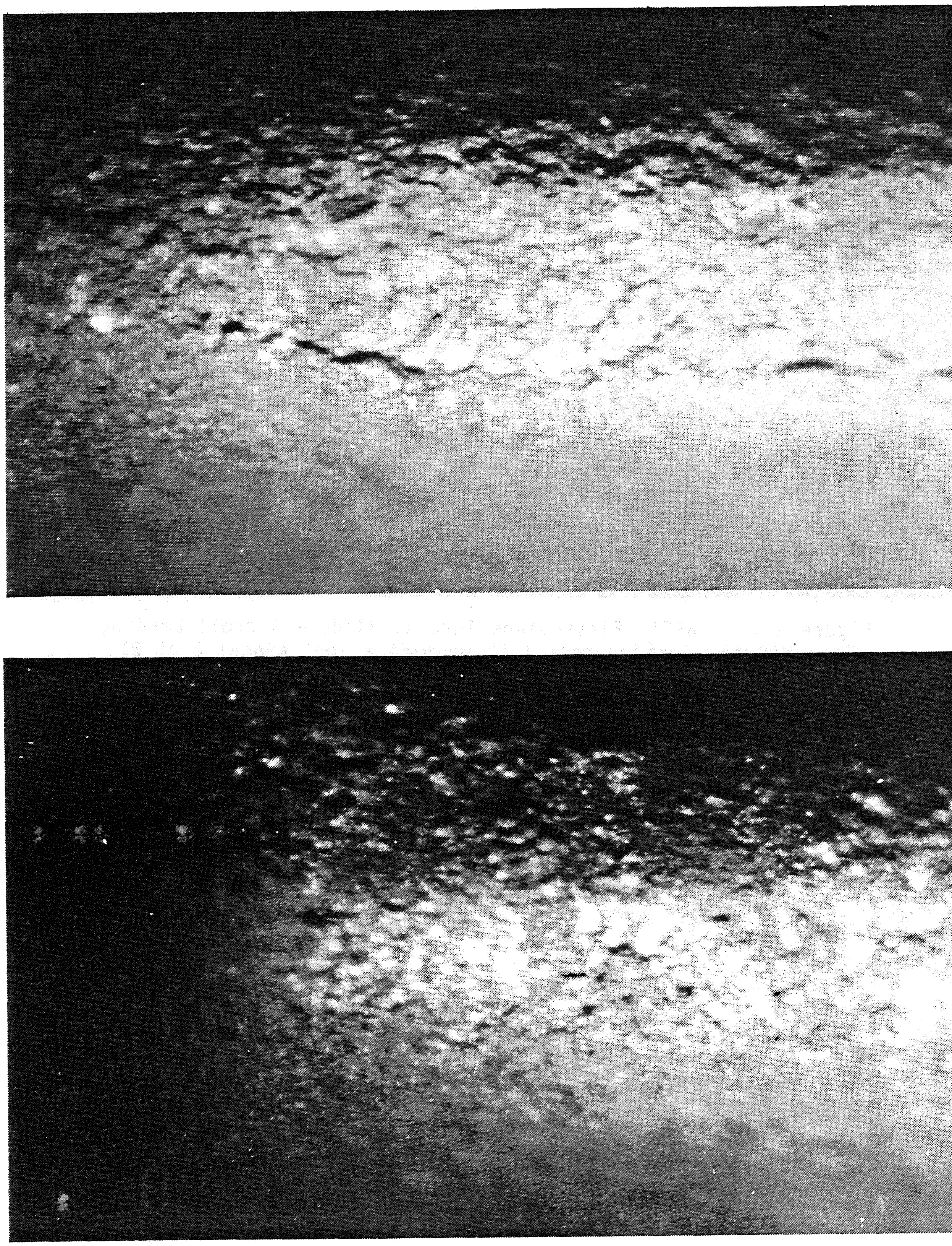


Figure 2-11. HPFTP First-Stage Turbine Blade - Airfoil Leading Edge NiCrAly Coating Melt (22X Magnification) (Sheet 1 of 2)

Figure 2-11. HPFTP First-Stage Turbine Blade - Airfoil Leading Edge NiCrAly Coating Melt (22X Magnification) (Sheet 2 of 2)

MINOR EROSION - ACCEPTABLE

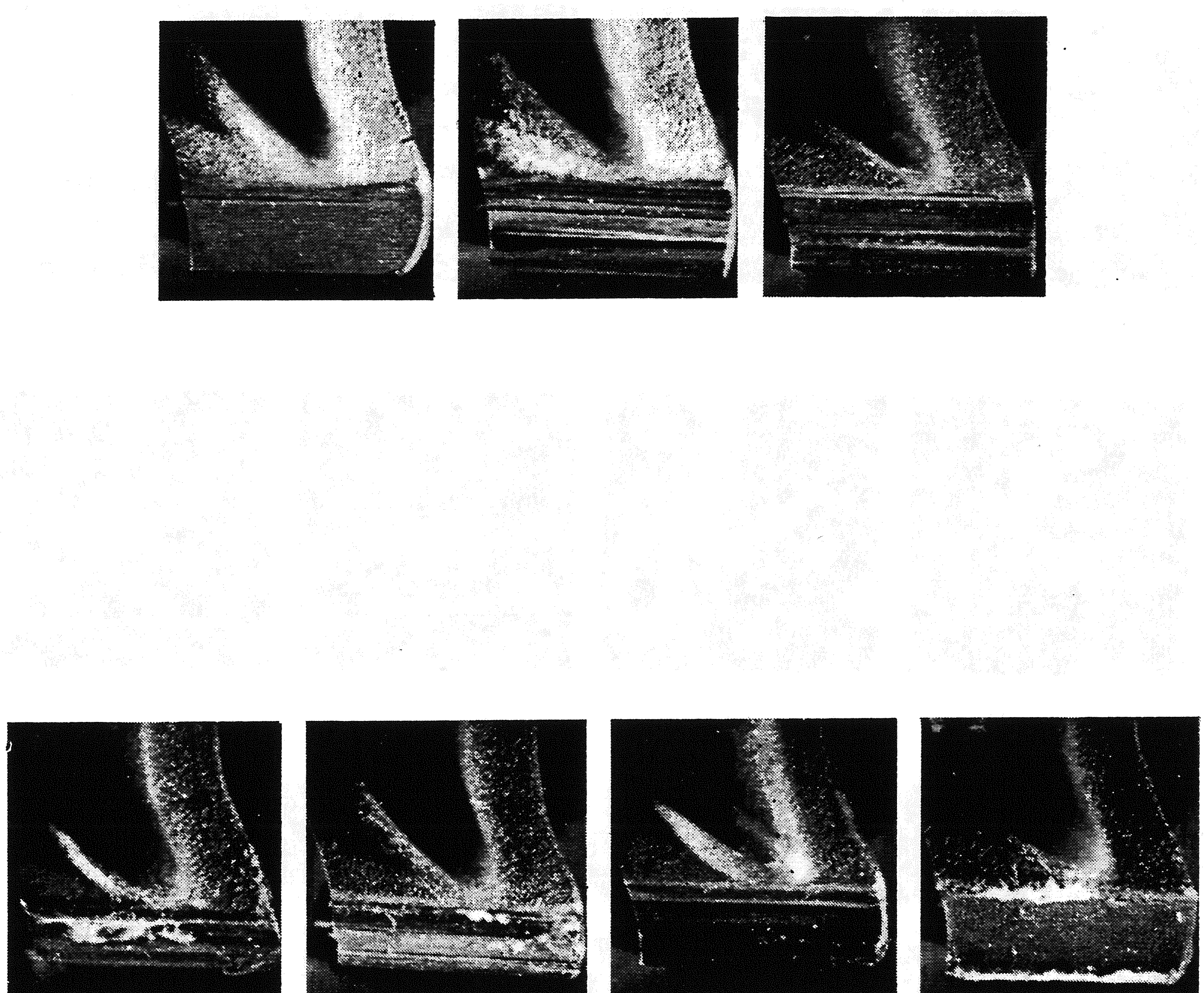


Figure 2-12. HPFTP First-Stage Turbine Blade - Platform Erosion Definition (Sheet 1 of 3)

MODERATE EROSION - ACCEPTABLE

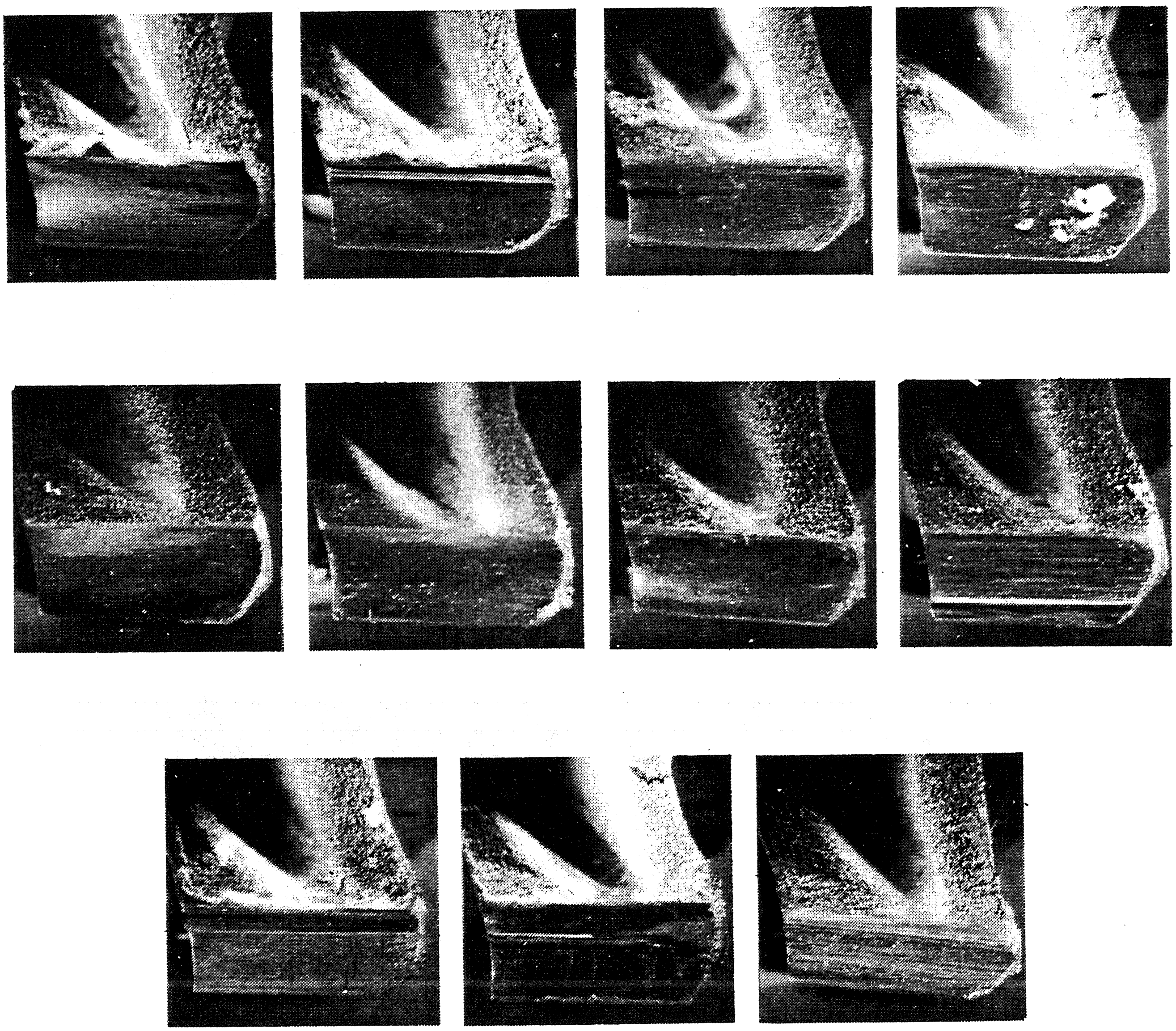


Figure 2-12. HPFTP First-Stage Turbine Blade - Platform Erosion Definition (Sheet 2 of 3)

HEAVY EROSION - NOT ACCEPTABLE

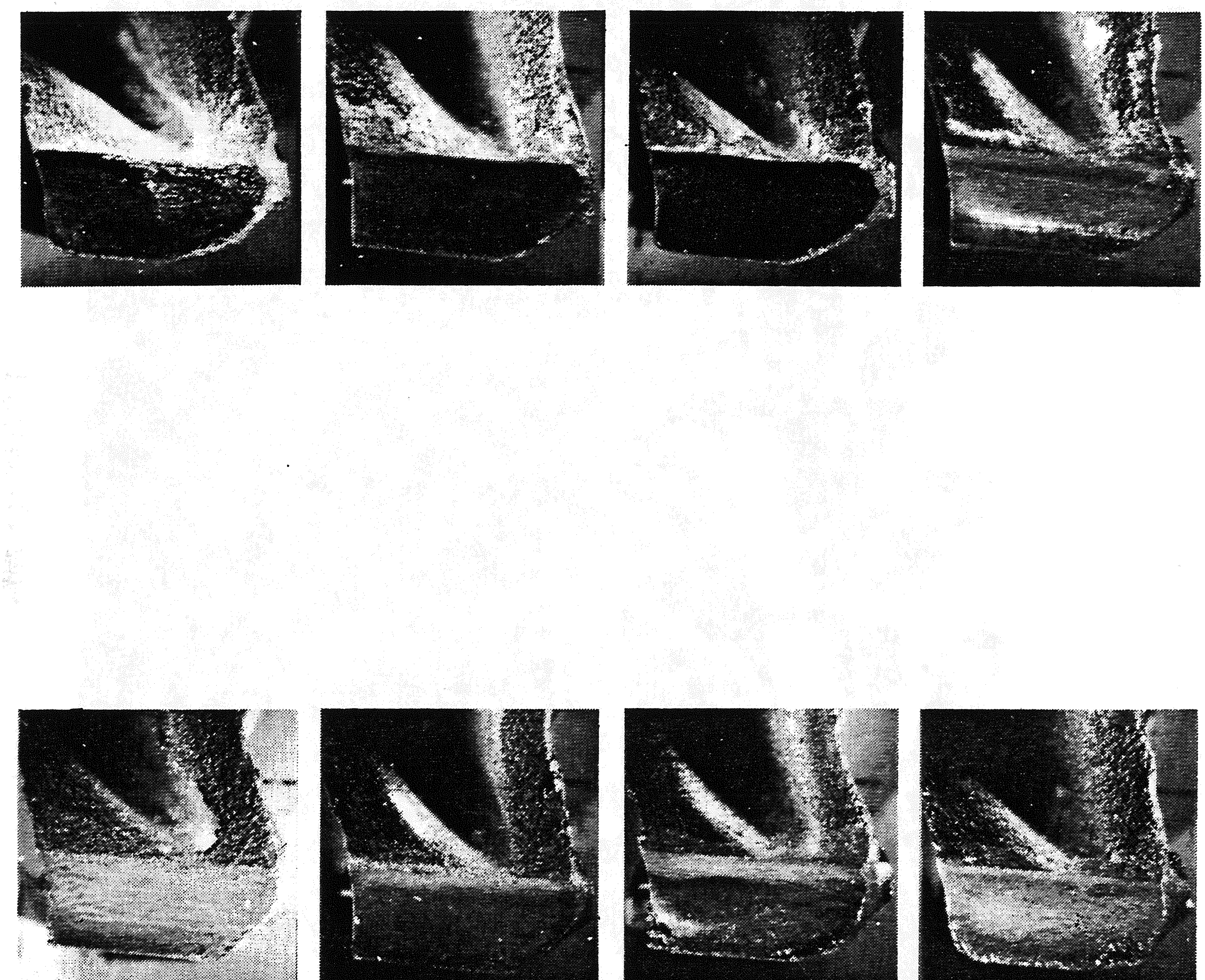


Figure 2-12. HPFTP First-Stage Turbine Blade - Platform Erosion Definition (Sheet 3 of 3)

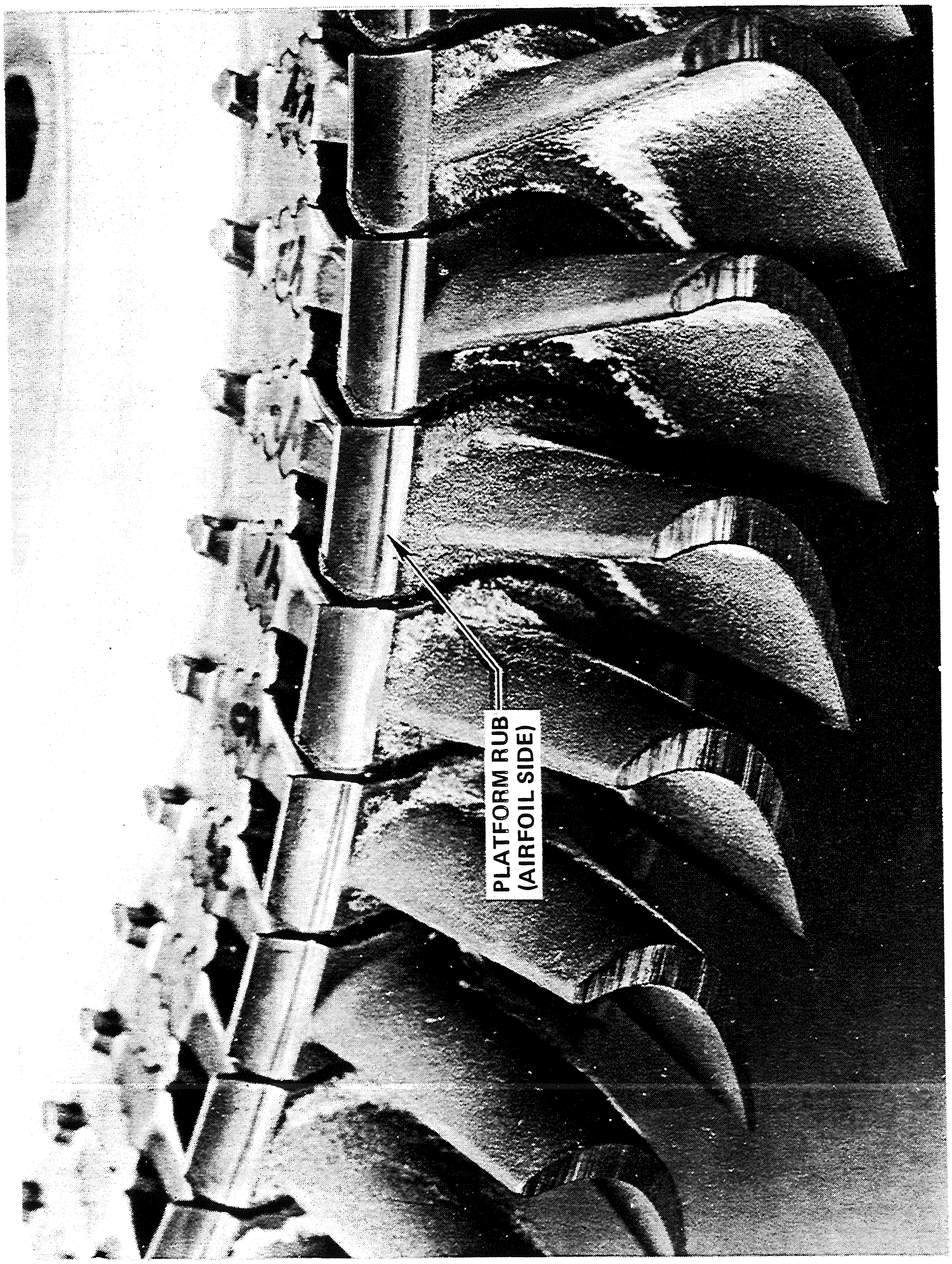


Figure 2-13. Platform Rubbing (Airfoil Side) - First-Stage Turbine Blades

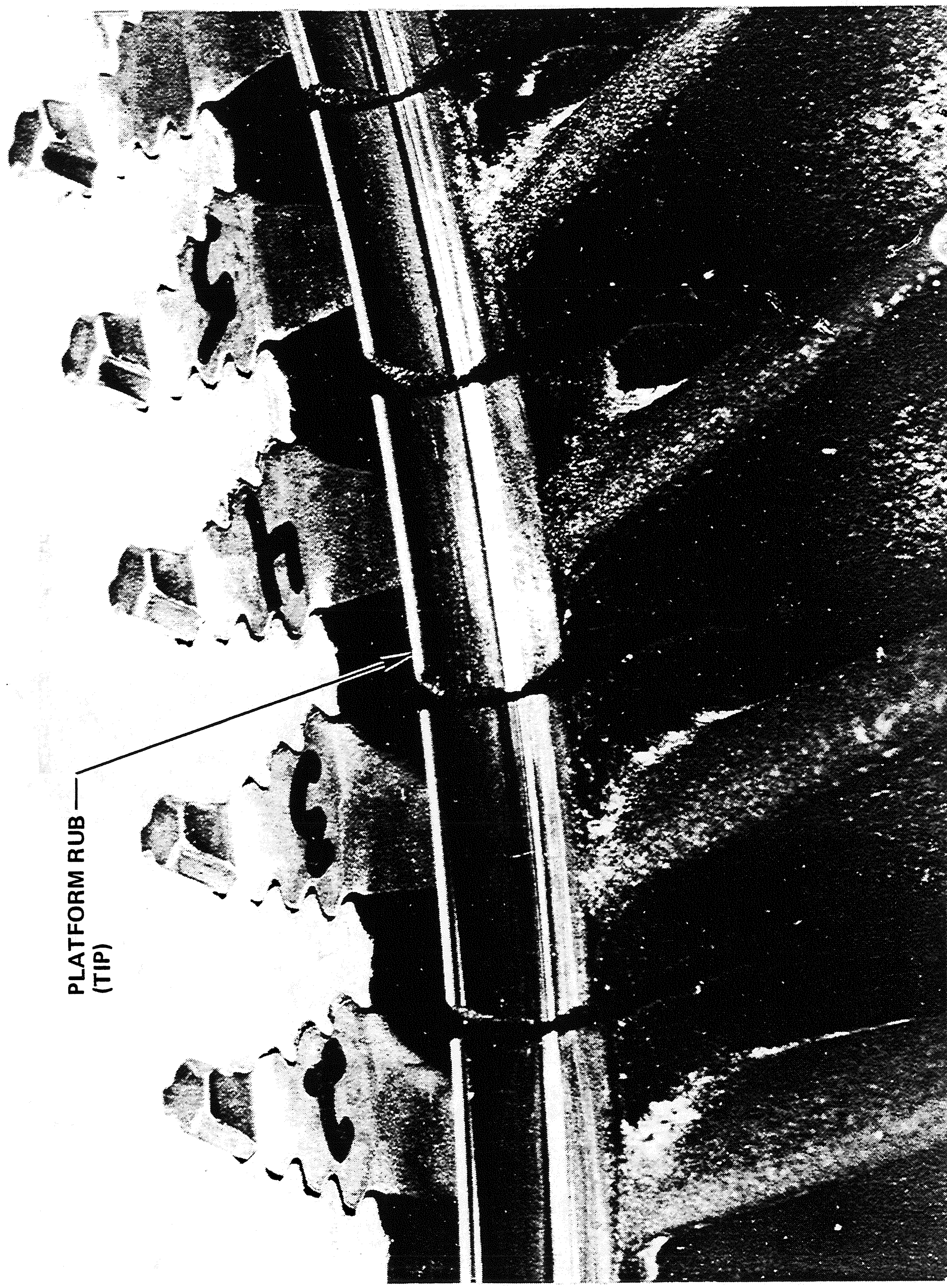
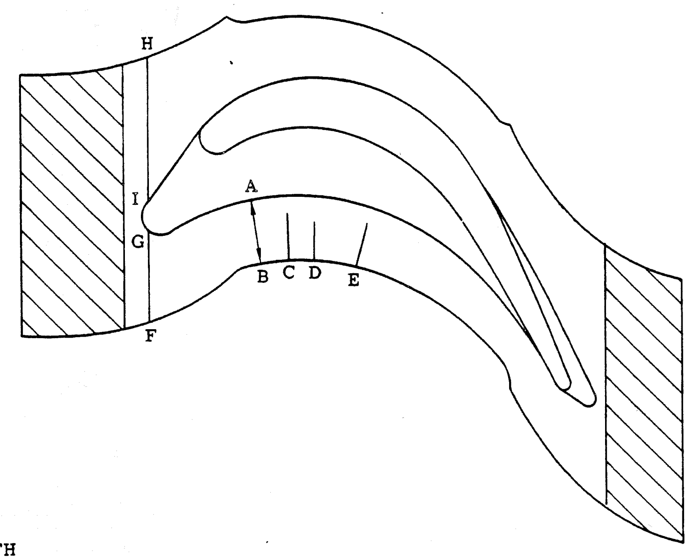


Figure 2-14. Platform Rubbing (Tip) - First-Stage Turbine Blades



A——B = PLATFORM WIDTH
SAMPLES
C——D = CRACK NOT ACCEPTABLE, DISTANCE BETWEEN THEM IS LESS THAN A TO B.
C——E = CRACK ACCEPTABLE, DISTANCE BETWEEN THEM IS GREATER THAN A TO B.
E——G = LINEAR OR HORIZONTAL CRACKS NOT ACCEPTABLE.
H——I = LINEAR OR HORIZONTAL CRACKS NOT ACCEPTABLE.

[hatched box] = NO CRACKS ALLOWED

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Figure 2-15. HPFTP First- and Second-Stage Turbine Blade - Platform Crack Definition

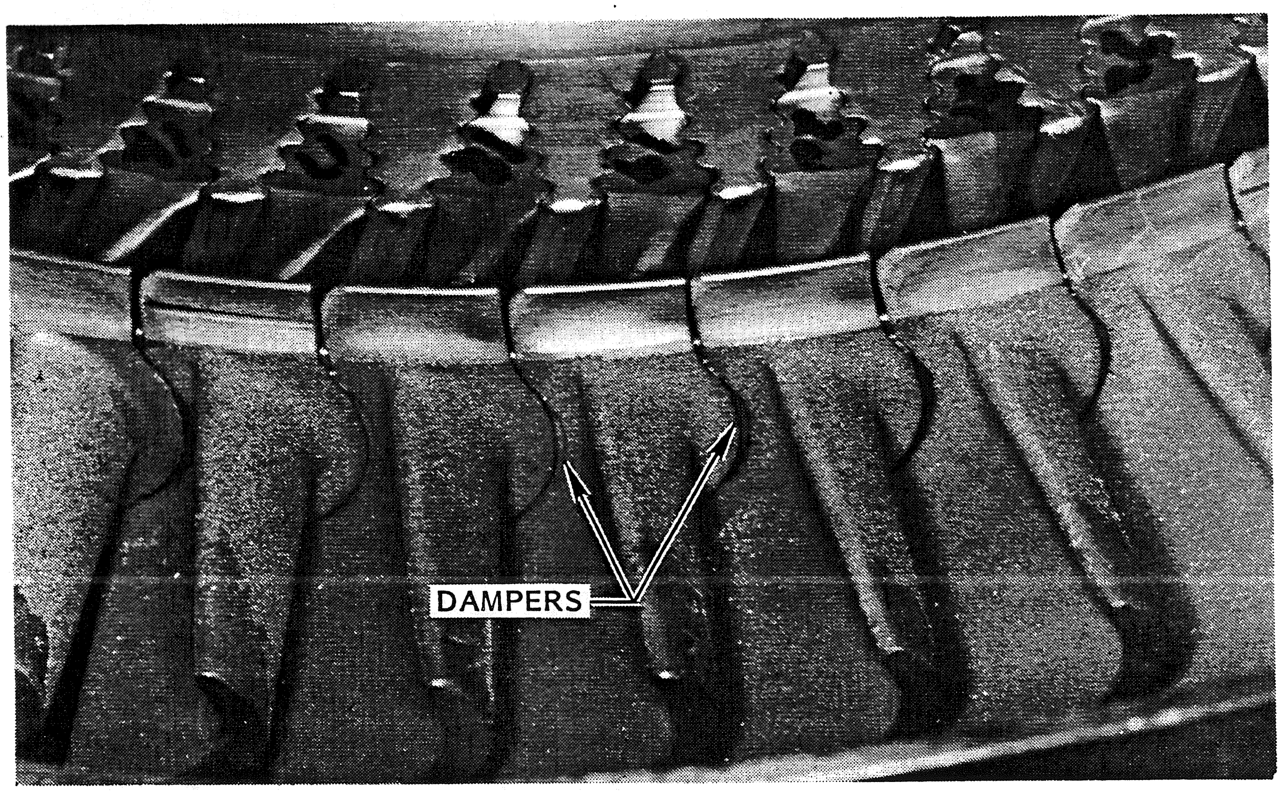


Figure 2-16. HPFTP First-Stage Turbine Blades - Damper Position

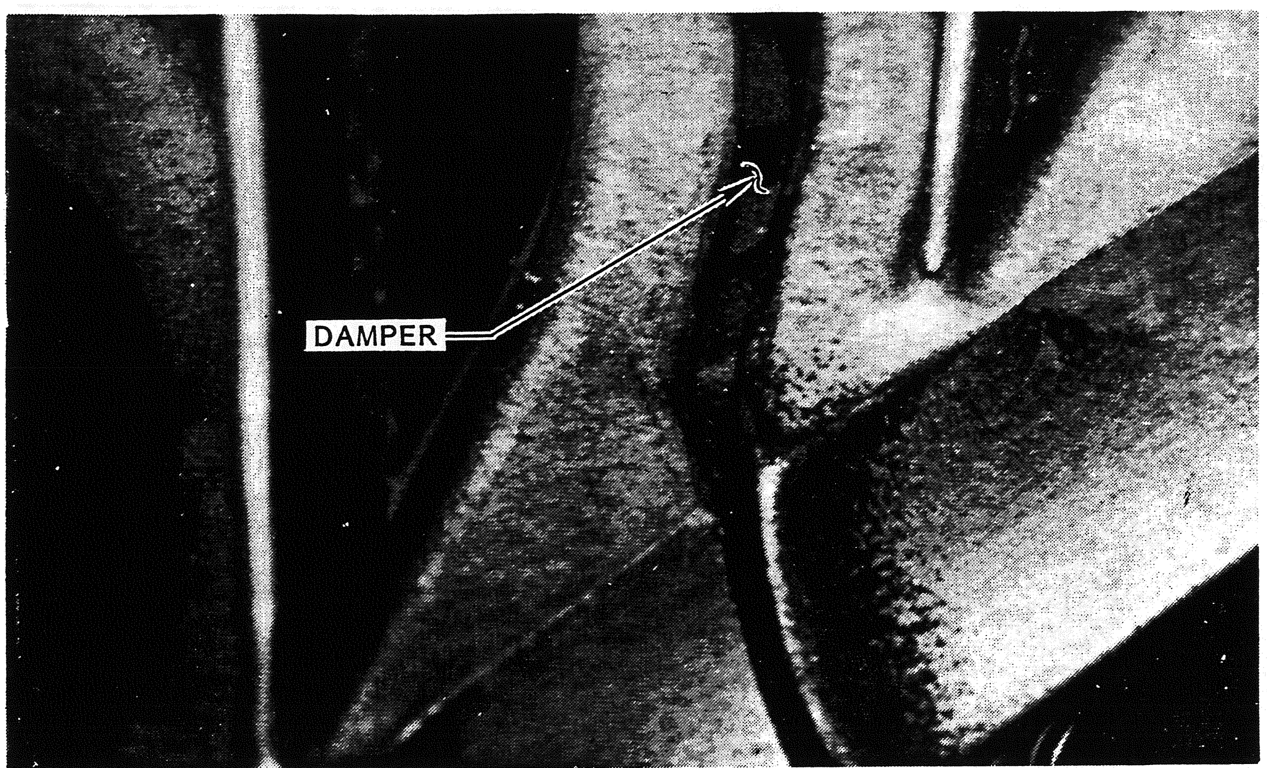


Figure 2-17. HPFTP Second-Stage Turbine Blades - Damper Position

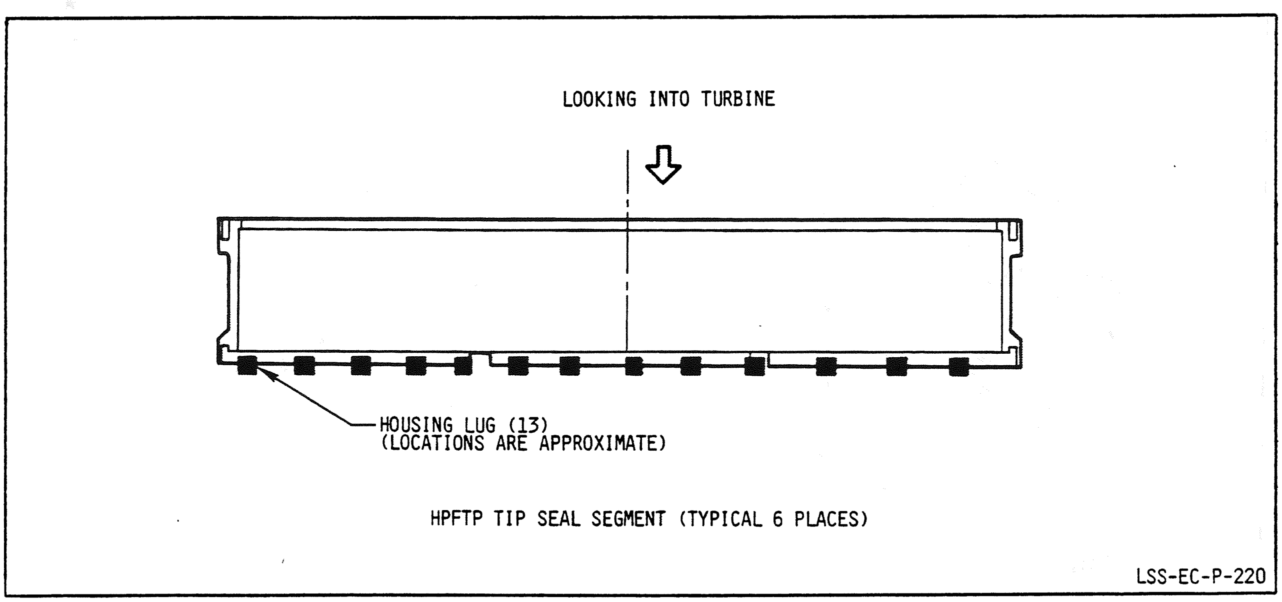


Figure 2-18. HPFTP First-Stage Tip Seal Retaining Lugs (Sheet 1 of 2)

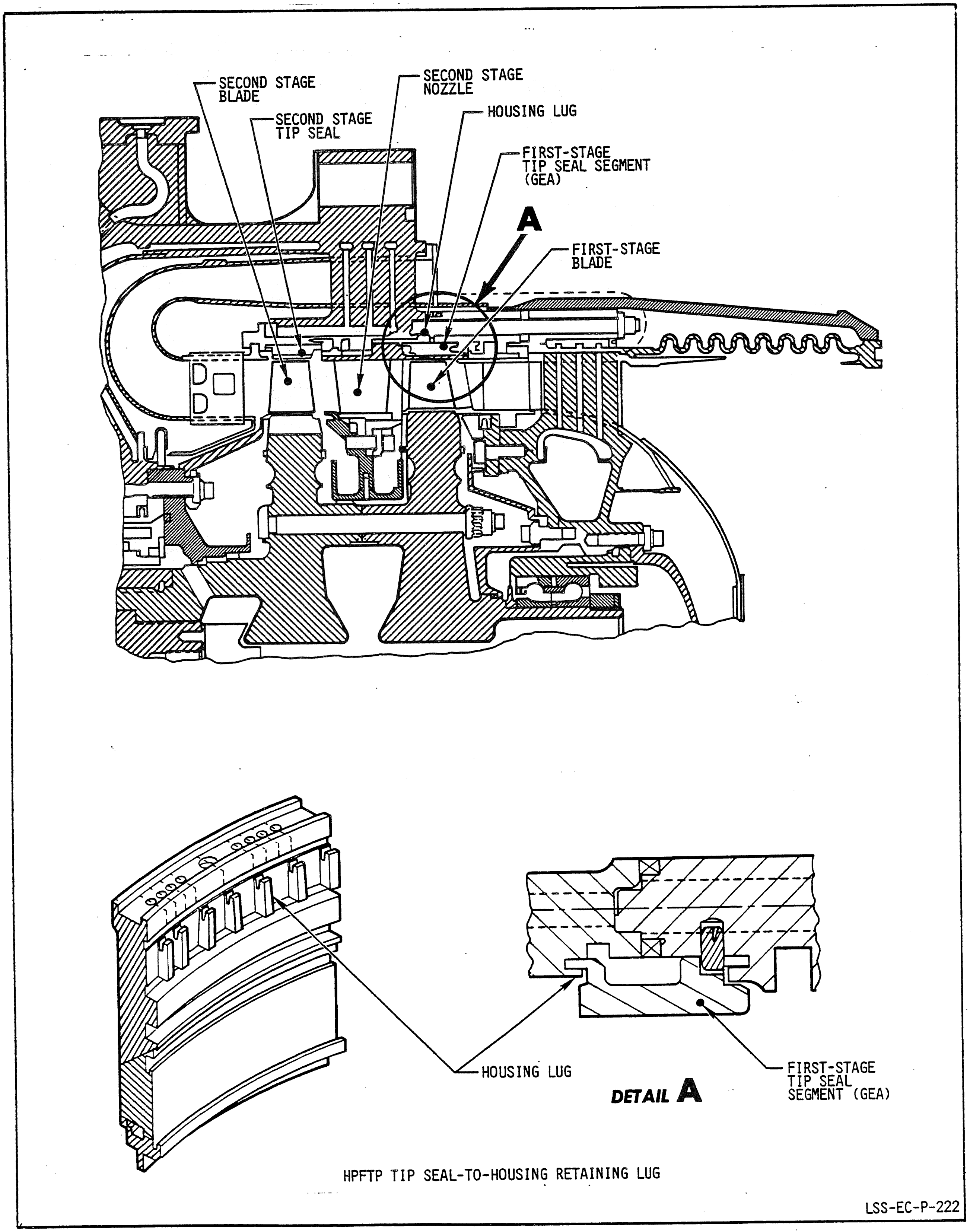


Figure 2-18. HPFTP First-Stage Tip Seal Retaining Lugs (Sheet 2 of 2)

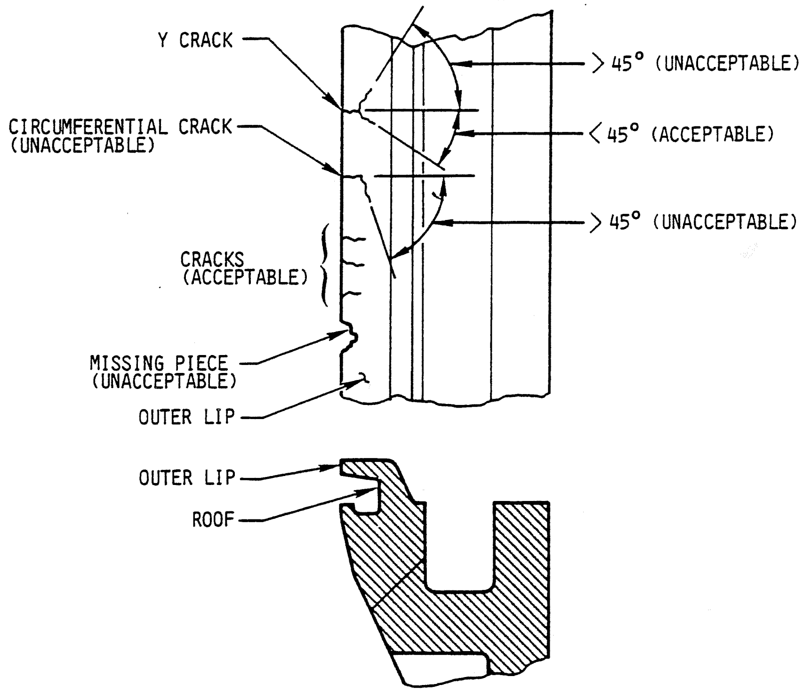
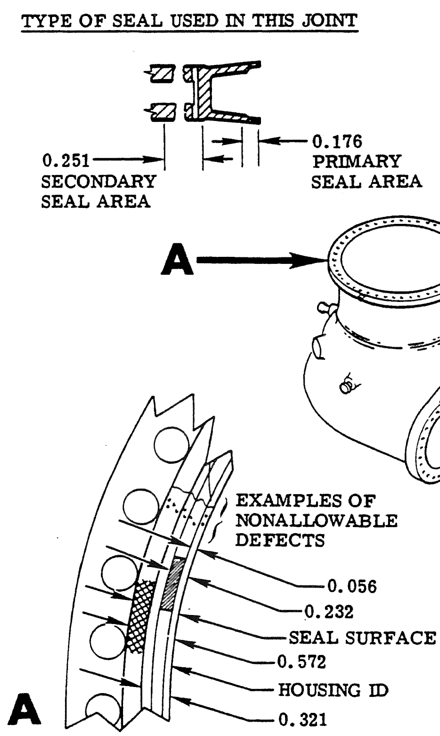


Figure 2-19. First-Stage Fishmouth Seal



PRIMARY SEAL AREA

1. DEFECTS (SUCH AS SCRATCHES, DINGS, POROSITY, AND INDIVIDUAL PITS) WITH RADIAL DIMENSION OF 0.030 INCH OR LESS AND DEPTH OF 0.005 INCH OR LESS ARE ACCEPTABLE, EXCEPT SPIRAL-SHAPED DEFECTS THAT CROSS OVER SEAL AREA SHALL BE REMOVED.
2. PART SHALL BE REJECTED IF CRACKS ARE FOUND.
3. RAISED MATERIAL SHALL BE REMOVED BY REPAIRING LOCALLY.

SECONDARY SEAL AREA

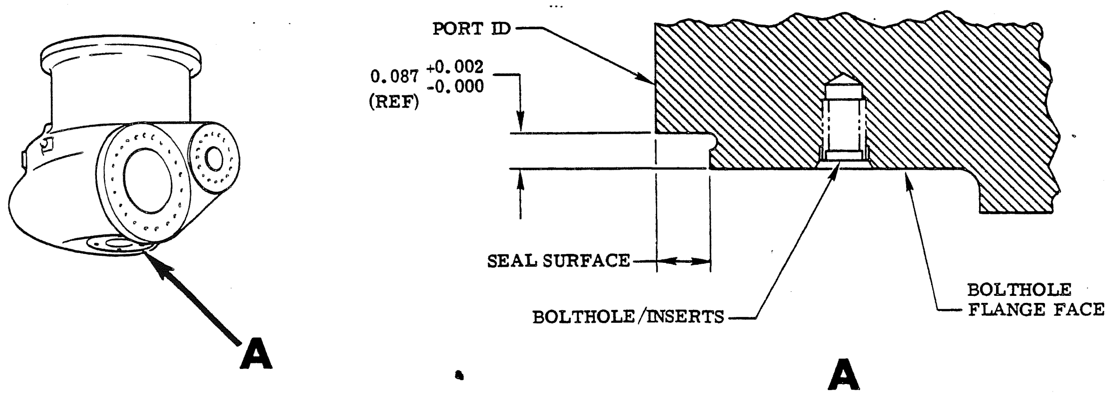
ALL REQUIREMENTS ARE THE SAME AS FOR THE PRIMARY SEAL AREA, EXCEPT THAT THE RADIAL DIMENSION IS INCREASED TO 0.100 INCH.

NONSEAL AREAS

1. RAISED MATERIAL SHALL BE REMOVED BY REPAIRING LOCALLY.
2. ALL OTHER DEFECTS SHALL NOT EXCEED 0.005 INCH IN DEPTH, 0.250 INCH IN LENGTH OR WIDTH, OR EXTEND INTO PRIMARY SEAL AREA MORE THAN 0.030 INCH OR EXTEND INTO SECONDARY SEAL AREA MORE THAN 0.100 INCH.

LSS-EC-P-196A

Figure 2-20. LPOTP Housing Inlet Flange Seal Surface Inspection Guide When Using RS0008847-021 Seal Assembly (Joint 01)

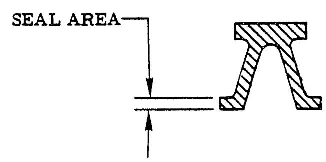


SEAL SURFACE

1. SEAL SURFACE SHALL BE FREE OF NICKS, SCRATCHES, AND PITS.
2. PART SHALL BE REJECTED IF CRACKS ARE FOUND.
3. RAISED MATERIAL SHALL BE REMOVED BY REPAIRING LOCALLY.

BOLTHOLE FLANGE FACE

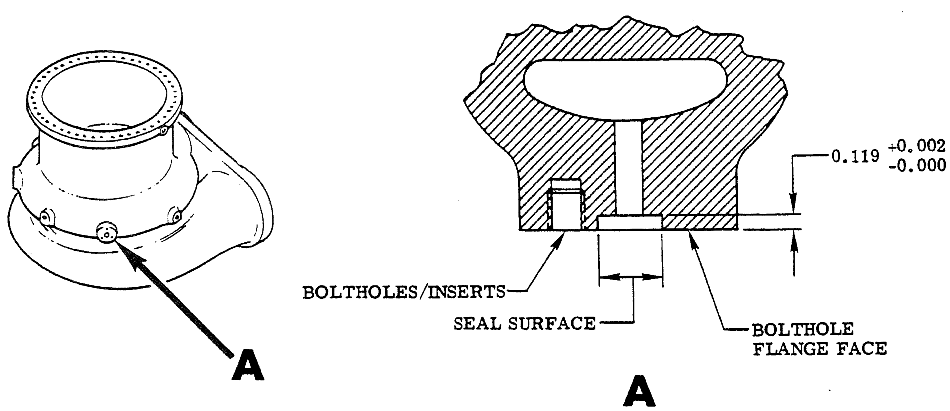
1. RAISED MATERIAL SHALL BE REMOVED BY REPAIRING LOCALLY.
2. DEFECTS SHALL NOT EXCEED 0.005 INCH IN DEPTH, 0.250 INCH IN LENGTH OR WIDTH.



TYPE OF SEAL USED IN THIS JOINT

LSS-ER-P-124

Figure 2-21. LPOTP Housing RS007802 Speed Transducer Port Seal Surface Inspection Guide (Joint 01.1)

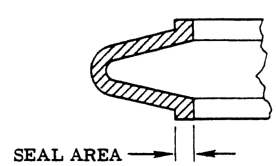


SEAL SURFACE

1. THE SEAL SURFACE SHALL BE FREE OF NICKS, SCRATCHES, AND PITS.
2. PART SHALL BE REJECTED IF CRACKS ARE FOUND.
3. RAISED MATERIAL SHALL BE REMOVED BY REPAIRING LOCALLY.

BOLTHOLE FLANGE FACE

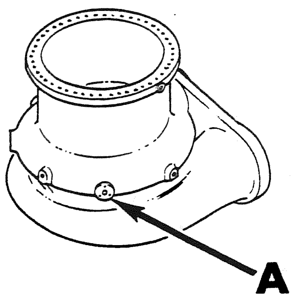
1. RAISED MATERIAL SHALL BE REMOVED BY REPAIRING LOCALLY.
2. DEFECTS SHALL NOT EXCEED 0.005 INCH IN DEPTH, 0.250 INCH IN LENGTH OR WIDTH.

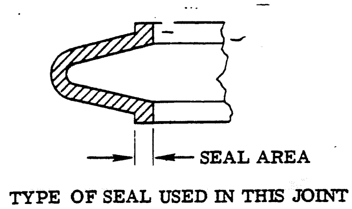


TYPE OF SEAL USED IN THIS JOINT

LSS-EC-P-197

Figure 2-22. LPOTP Housing RS007802 Turbine Drive Manifold Closeout Seal Surface Inspection Guide (Joints 01.2 and 01.3)



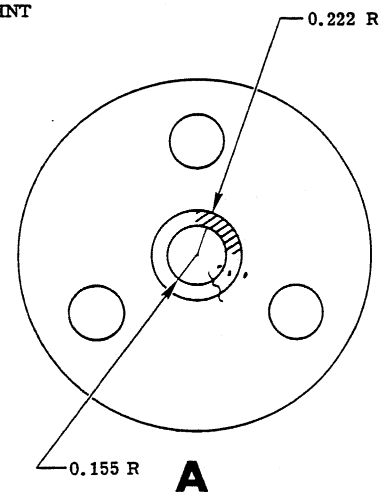


SEAL AREA

1. DEFECTS (SUCH AS NICKS, SCRATCHES, AND PITS) WITH RADIAL DIMENSION OF 0.005 INCH OR LESS AND DEPTH OF 0.005 INCH OR LESS ARE ACCEPTABLE, EXCEPT SPIRAL-SHAPED DEFECTS THAT CROSS OVER SEAL AREA SHALL BE REMOVED.
2. PART SHALL BE REJECTED IF CRACKS ARE FOUND.
3. RAISED MATERIAL AND CORROSION/FOREIGN PARTICLES SHALL BE REMOVED BY REPAIRING LOCALLY.

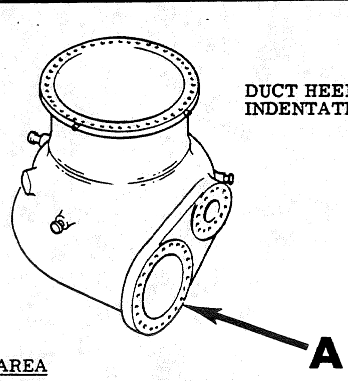
NONSEAL AREAS

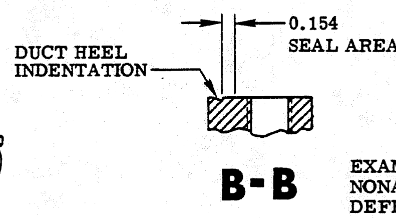
1. RAISED MATERIAL AND CORROSION/FOREIGN PARTICLES SHALL BE REMOVED BY REPAIRING LOCALLY.
2. ALL OTHER DEFECTS SHALL NOT EXCEED 0.005 INCH IN DEPTH, 0.250 INCH IN LENGTH OR WIDTH, OR EXTEND INTO SEAL AREA MORE THAN 0.005 INCH.

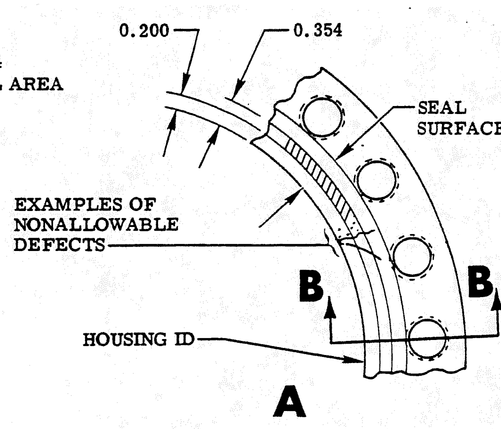


LSS-ER-P-125

Figure 2-23. LPOTP Housing RS007802 Turbine Drive Manifold Closeout Disc RS007836 Seal Surface Inspection Guide (Joints 01.2 and 01.3)





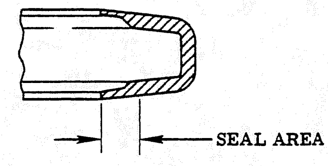


SEAL AREA

1. DEFECTS (SUCH AS SCRATCHES, DINGS, POROSITY, AND INDIVIDUAL PITS) WITH RADIAL DIMENSION OF 0.030 INCH OR LESS AND DEPTH OF 0.005 INCH OR LESS ARE ACCEPTABLE, EXCEPT SPIRAL-SHAPED DEFECTS THAT CROSS OVER SEAL AREA SHALL BE REMOVED.
2. PART SHALL BE REJECTED IF CRACKS ARE FOUND.
3. RAISED MATERIAL SHALL BE REMOVED BY REPAIRING LOCALLY.

NONSEAL AREAS

1. RAISED MATERIAL SHALL BE REMOVED BY REPAIRING LOCALLY.
2. ALL OTHER DEFECTS SHALL NOT EXCEED 0.005 INCH IN DEPTH, 0.250 INCH IN LENGTH OR WIDTH, OR EXTEND INTO SEAL AREA MORE THAN 0.030 INCH.



LSS-ER-P-126A

Figure 2-24. LPOTP Housing Discharge Flange Seal Surface Inspection Guide When Using Seal RS008862-005 (Joint 02)

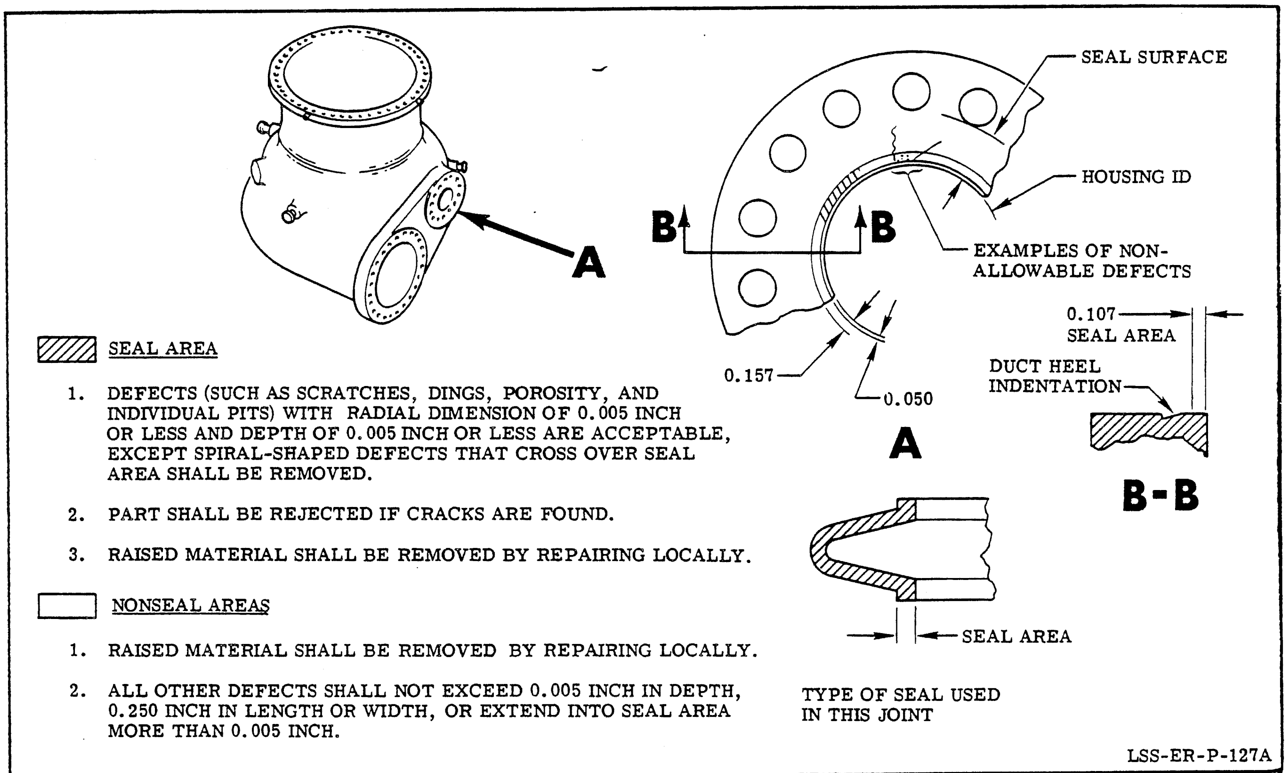


Figure 2-25. LPOTP Housing RS007802 Turbine Drive Inlet Seal Surface Inspection Guide (Joint 05)

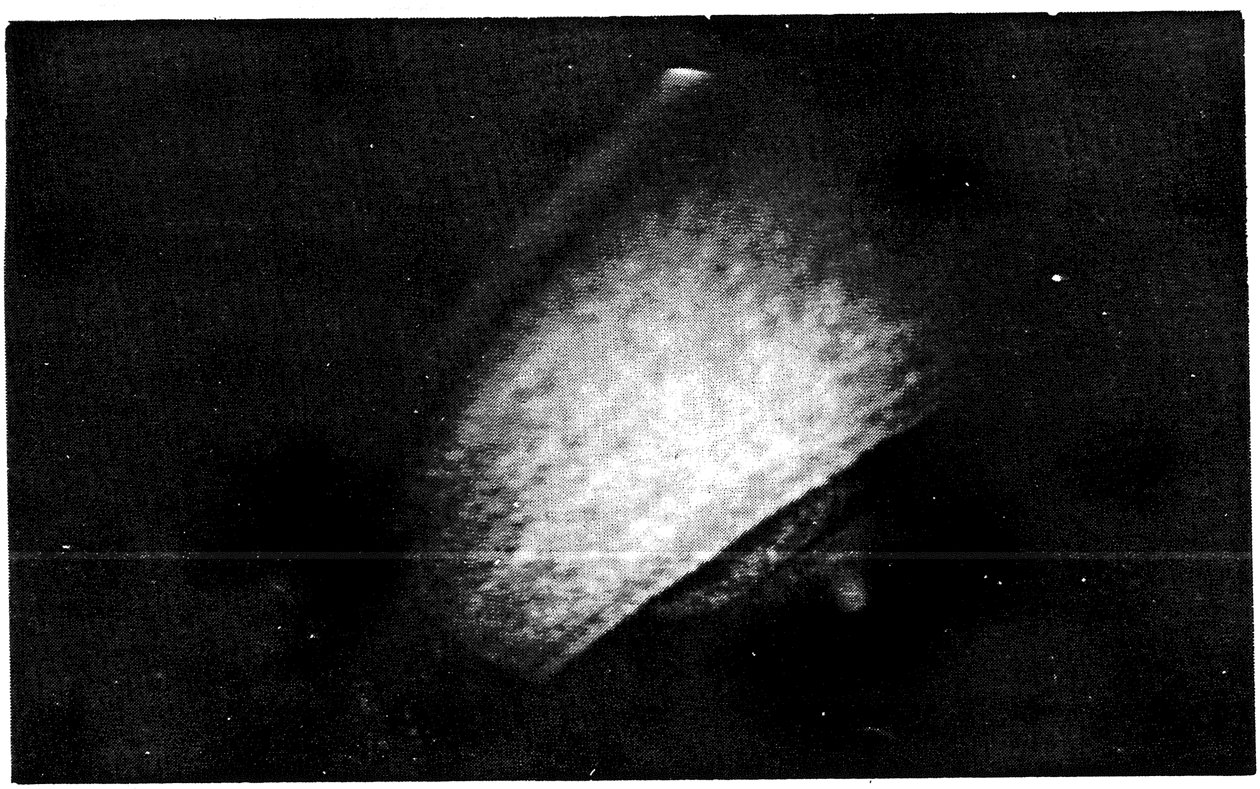


Figure 2-26. HPOTP Bearing Balls, Acceptable Surface Distress (Typical)

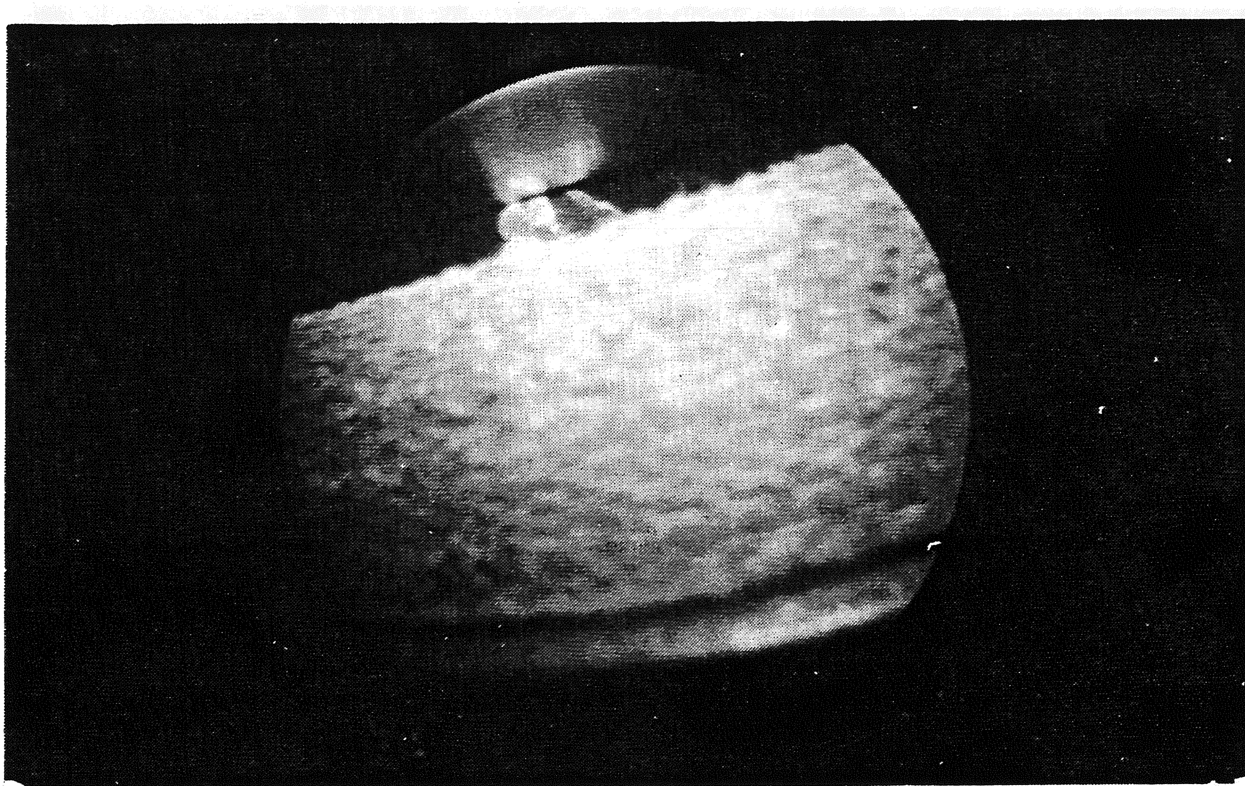


Figure 2-27. HPOTP Bearing Balls, Unacceptable Spalling (Typical)

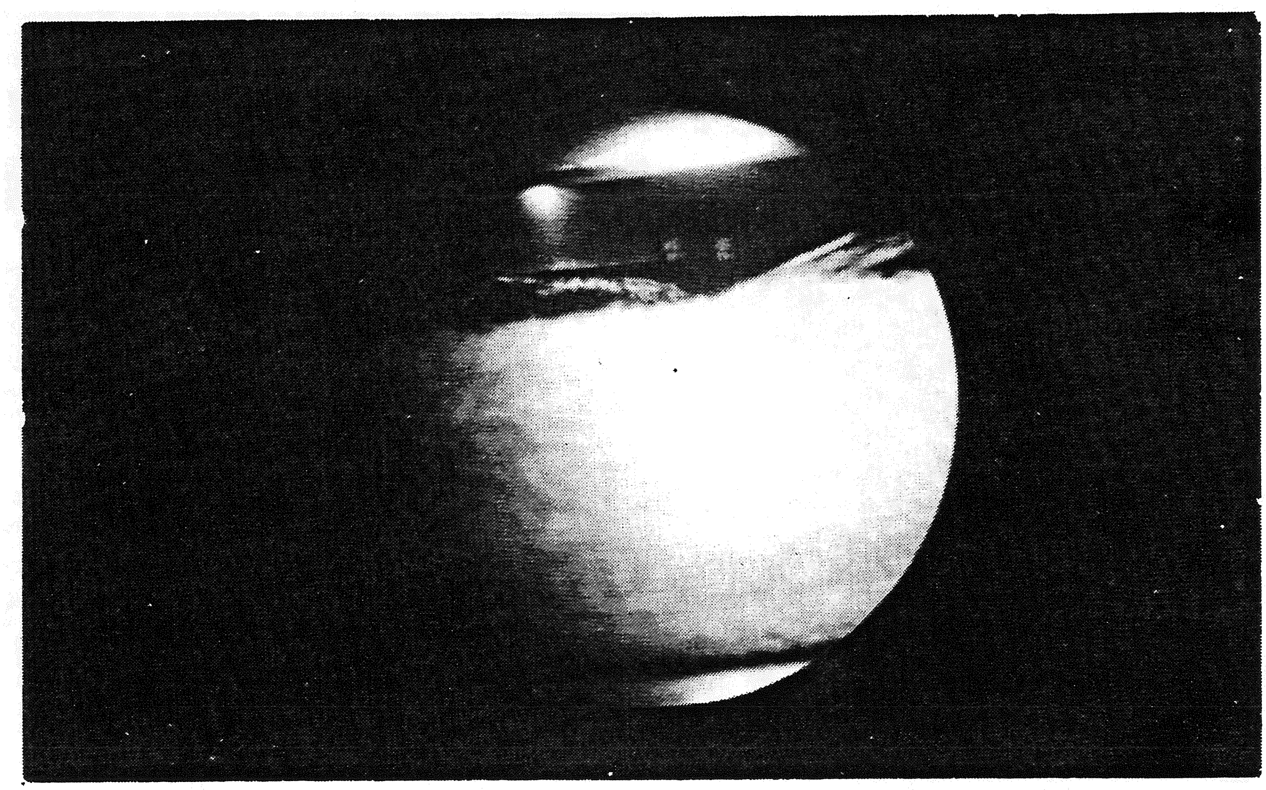


Figure 2-28. HPOTP Bearing Cage, Acceptable Fraying (Typical)

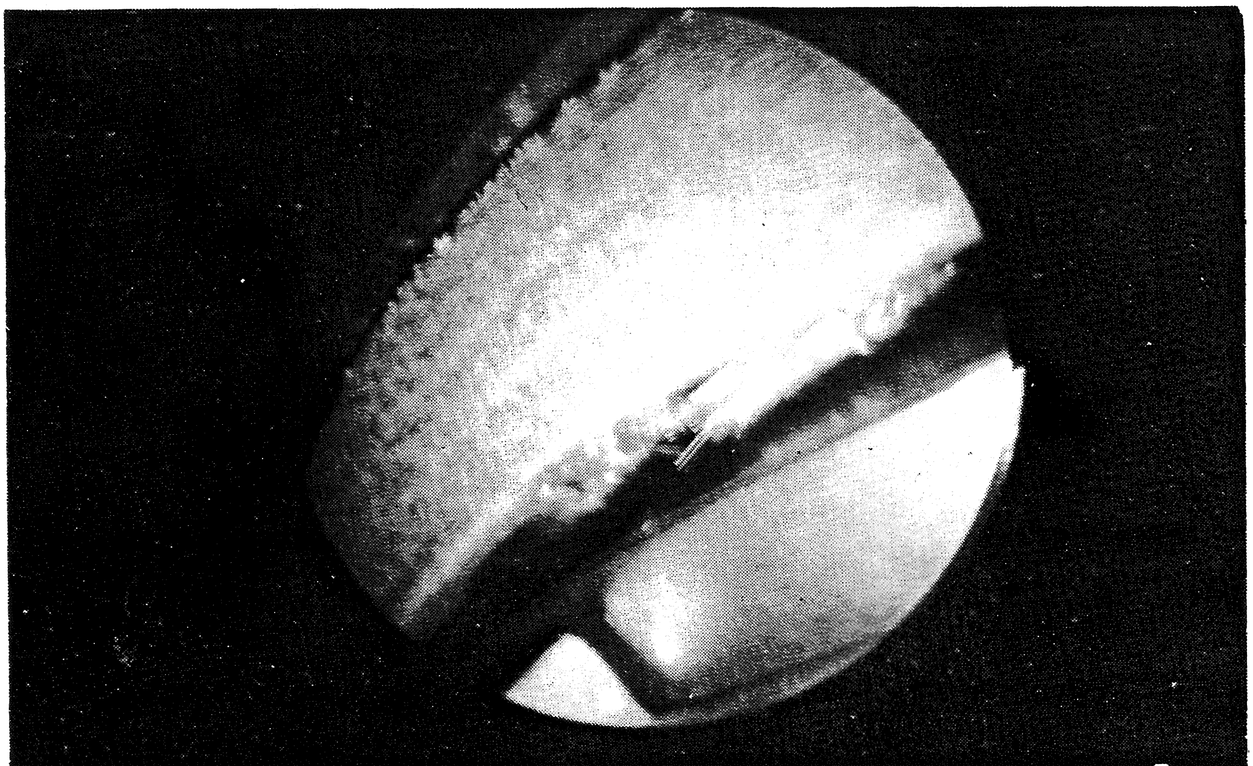


Figure 2-29. HPOTP Bearing Cage, Unacceptable Delamination/Fraying Originating at Ball Pocket (Typical)

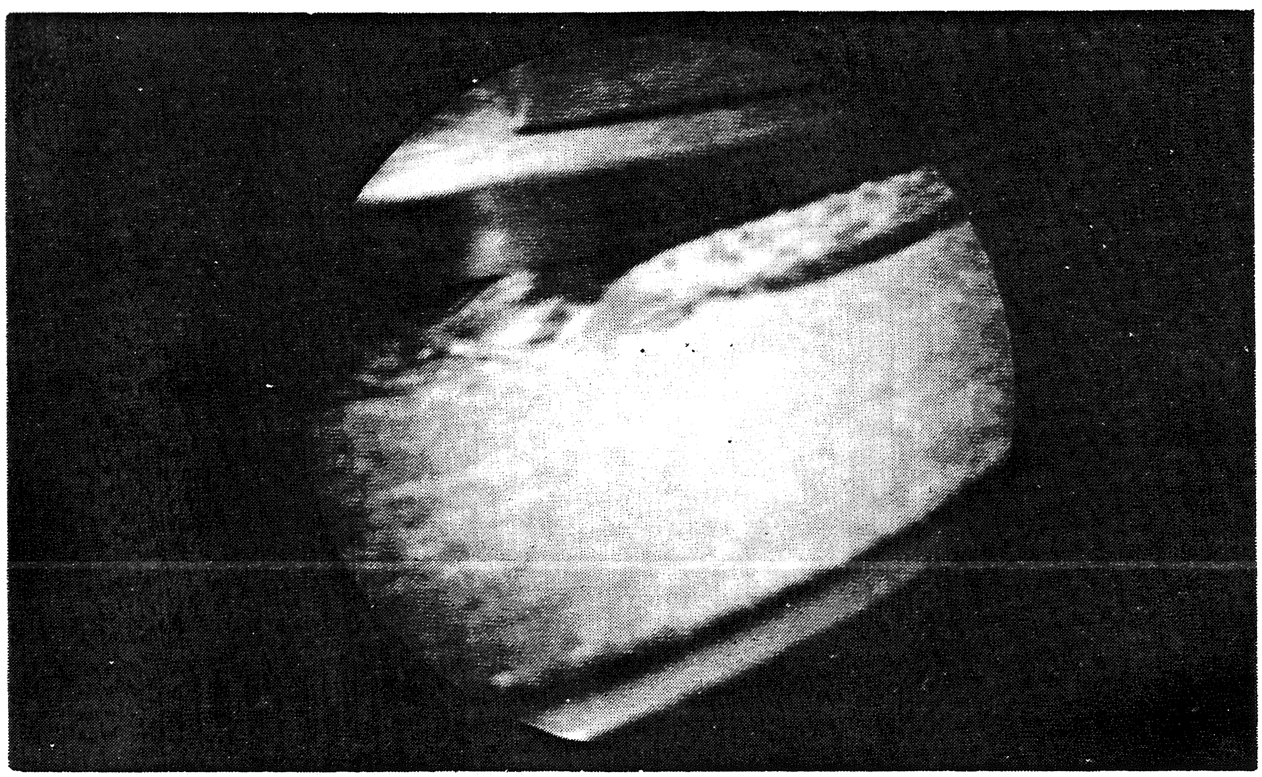


Figure 2-30. HPOTP Bearing Cage, Acceptable Delamination (Typical)

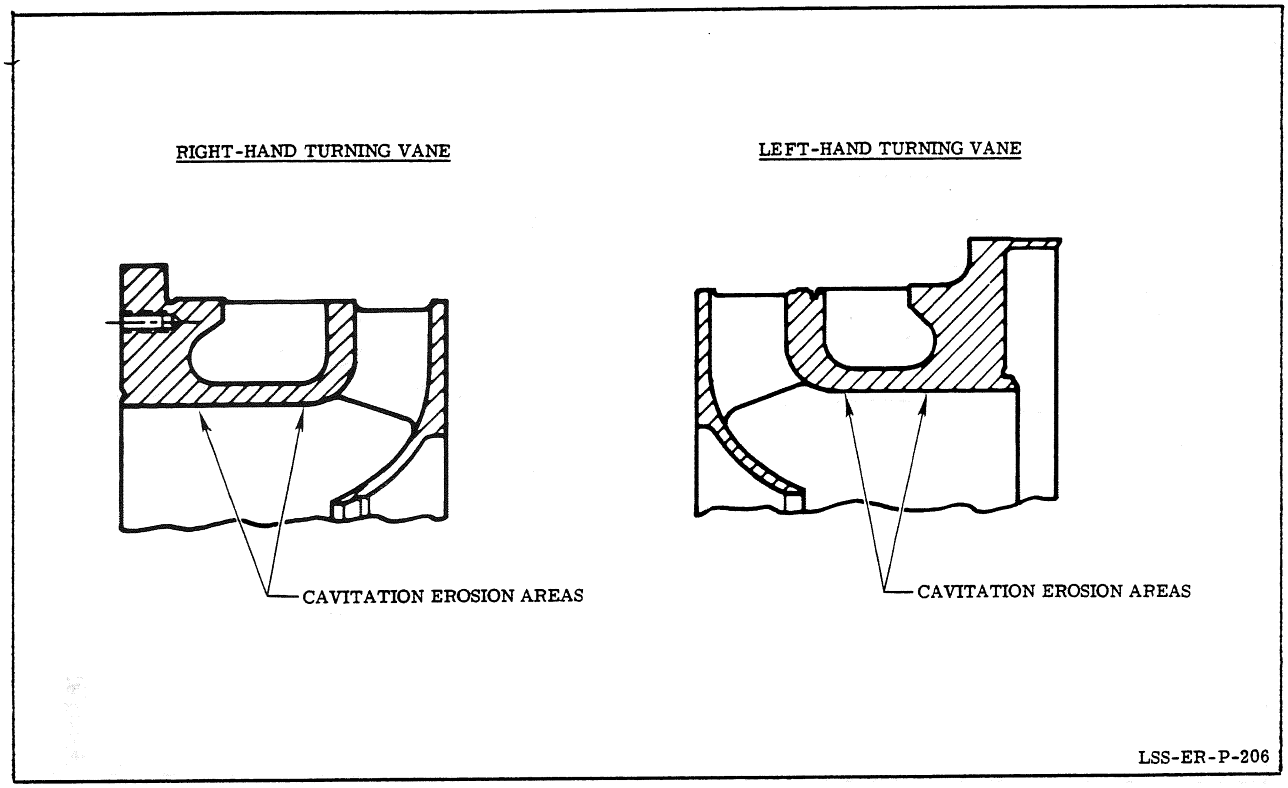


Figure 2-31. Inlet Turning Vanes Inspection

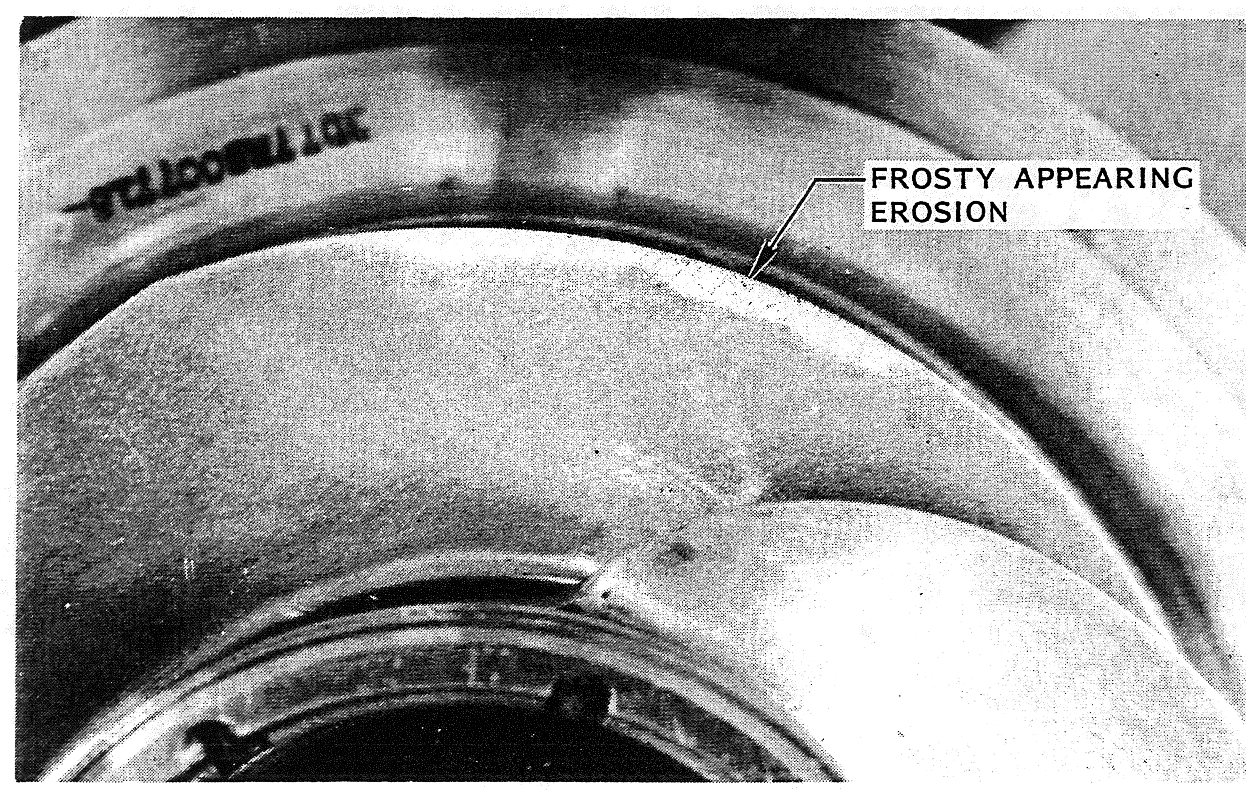


Figure 2-32. HPOTP Main Impeller, Acceptable Frosty Condition (Typical)

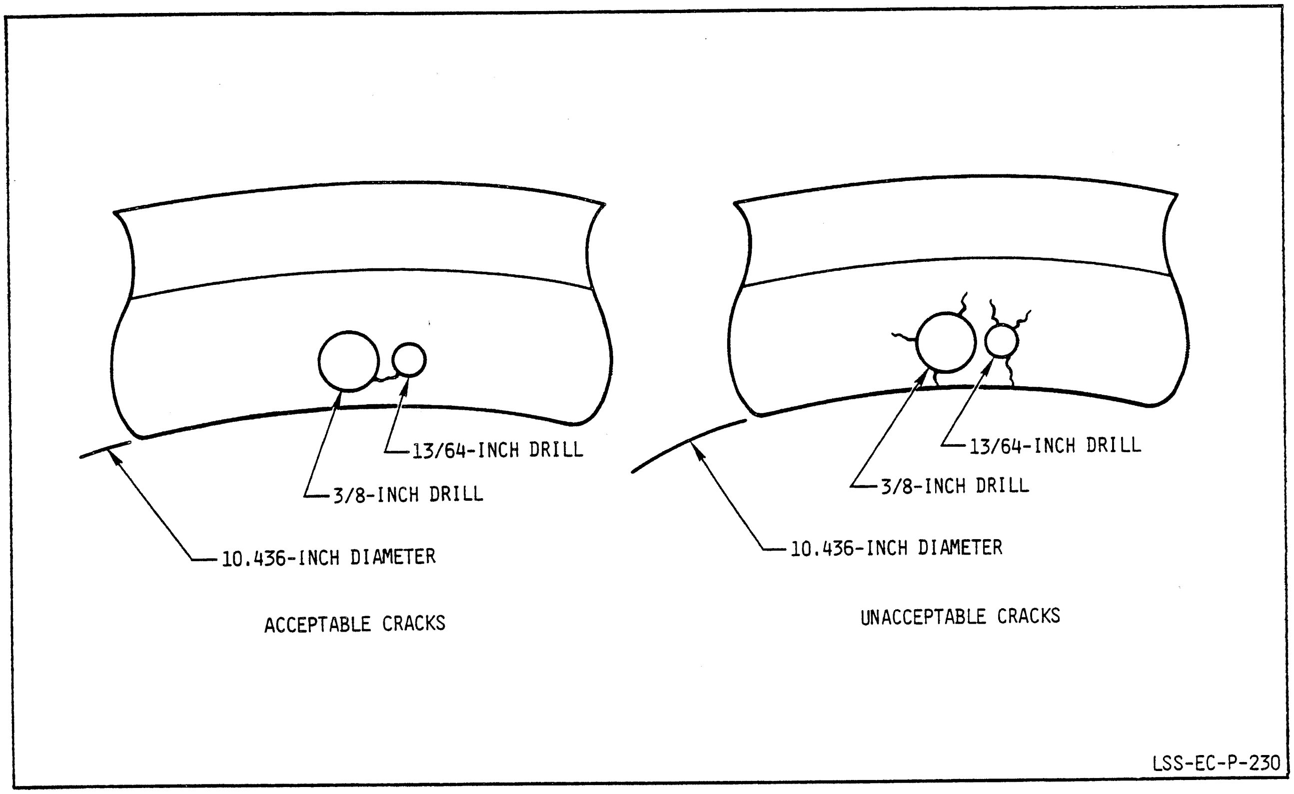


Figure 2-33. HPOTP Turbine Shield Cracks

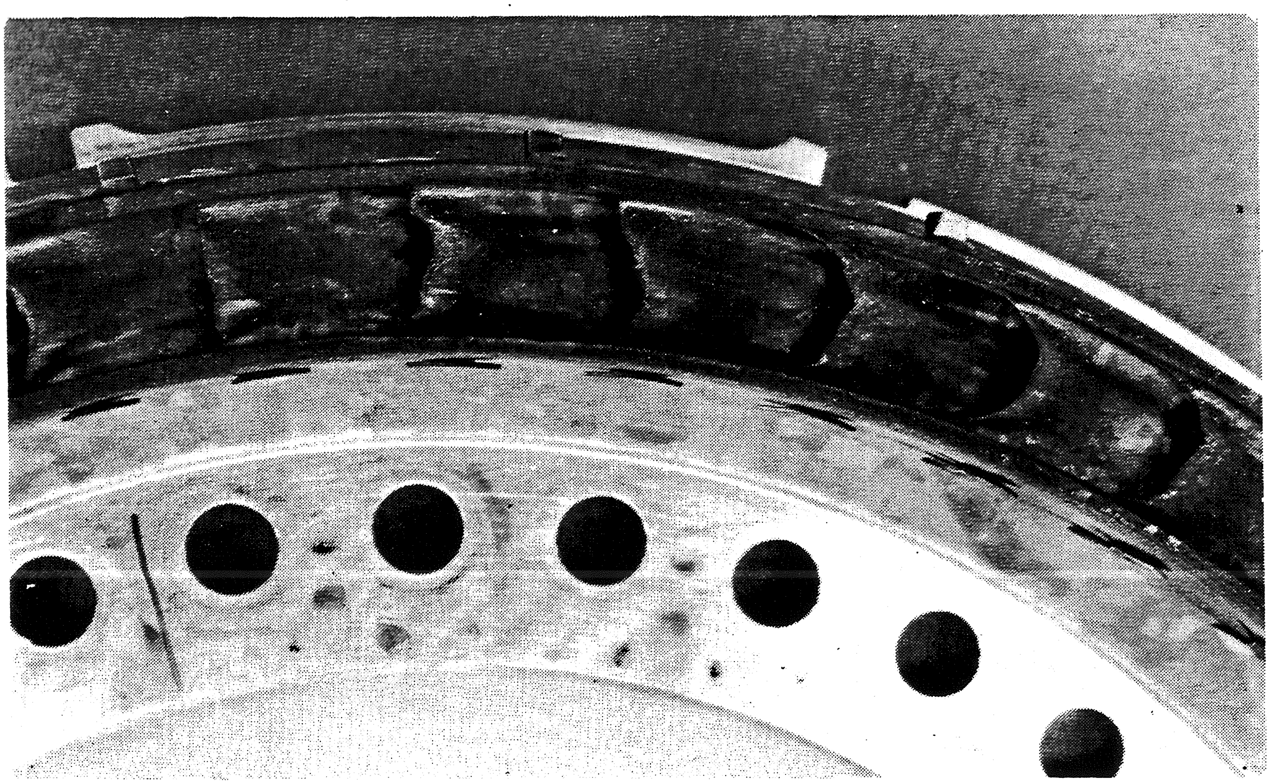


Figure 2-34. HPOTP First-Stage Nozzle, Missing Material (Example)

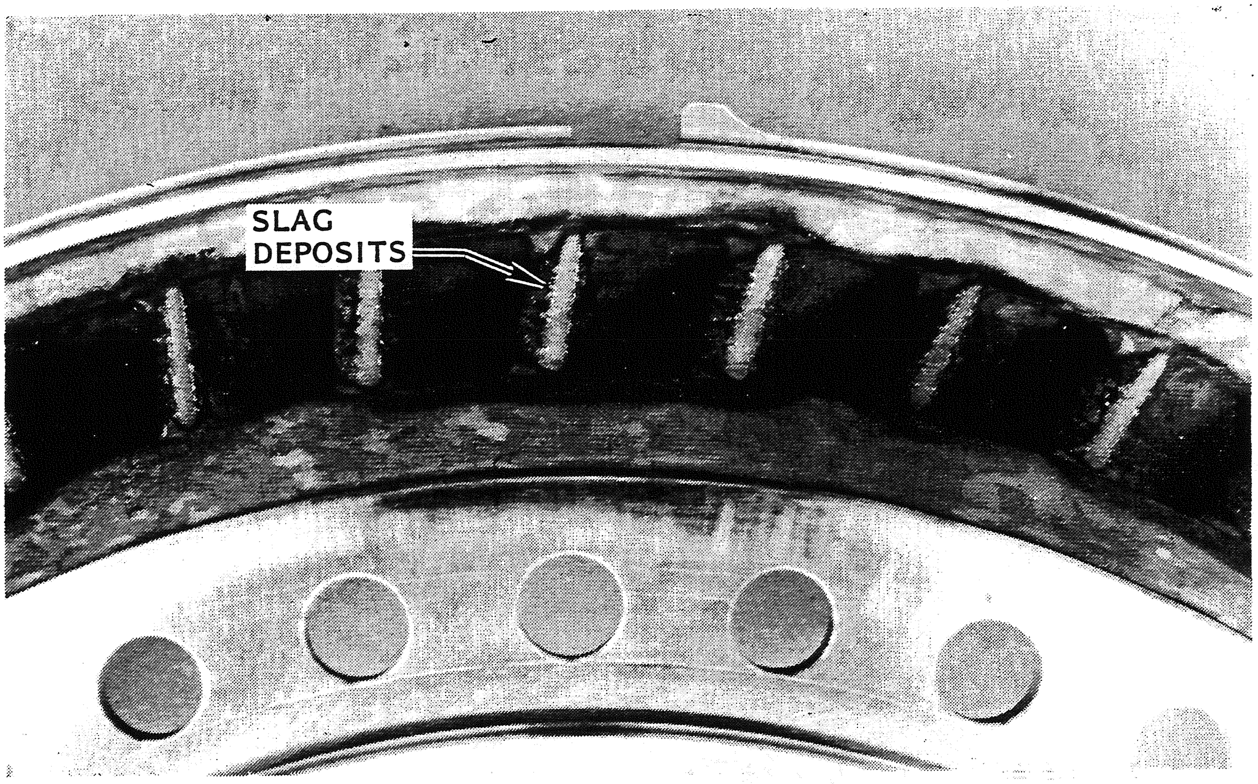


Figure 2-35. HPOTP First-Stage Nozzle, Acceptable Slag Deposits (Typical)

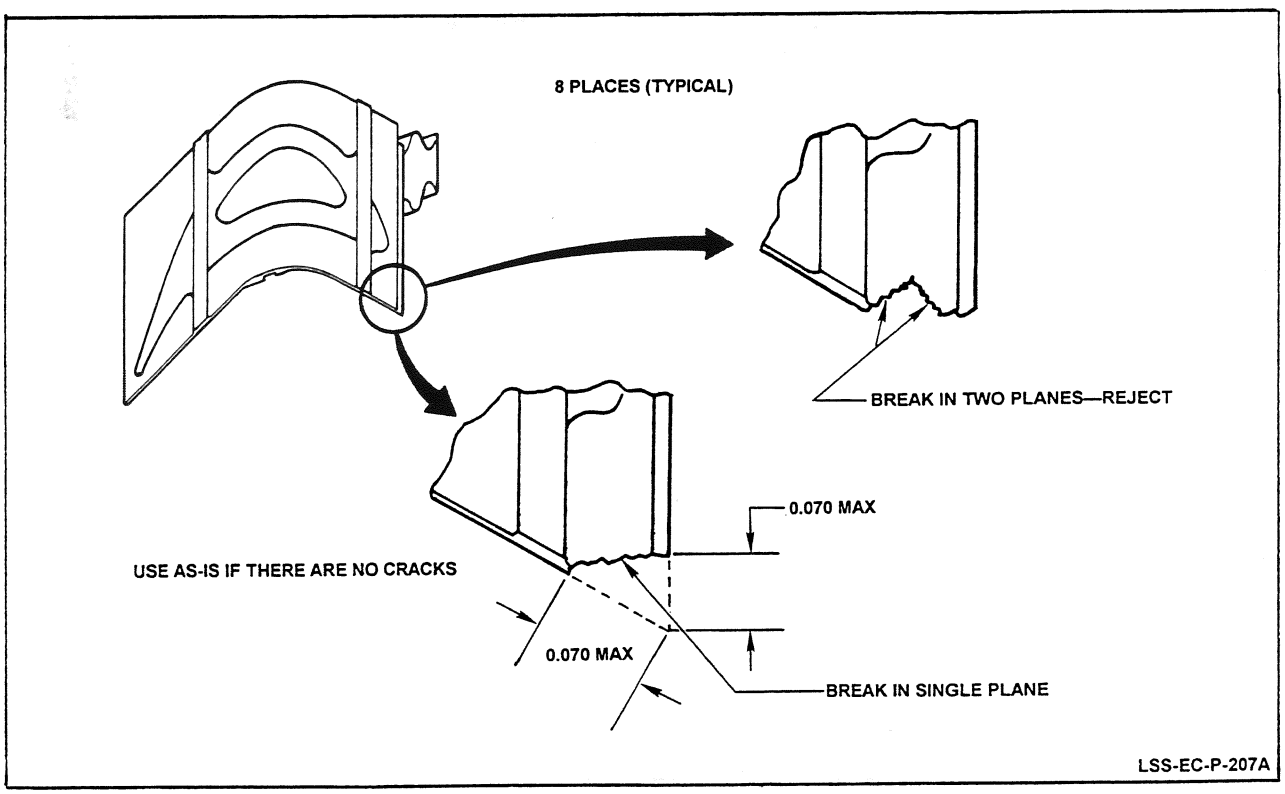


Figure 2-36. HPOTP First-Stage Turbine Blade Shroud Chipping (Examples)

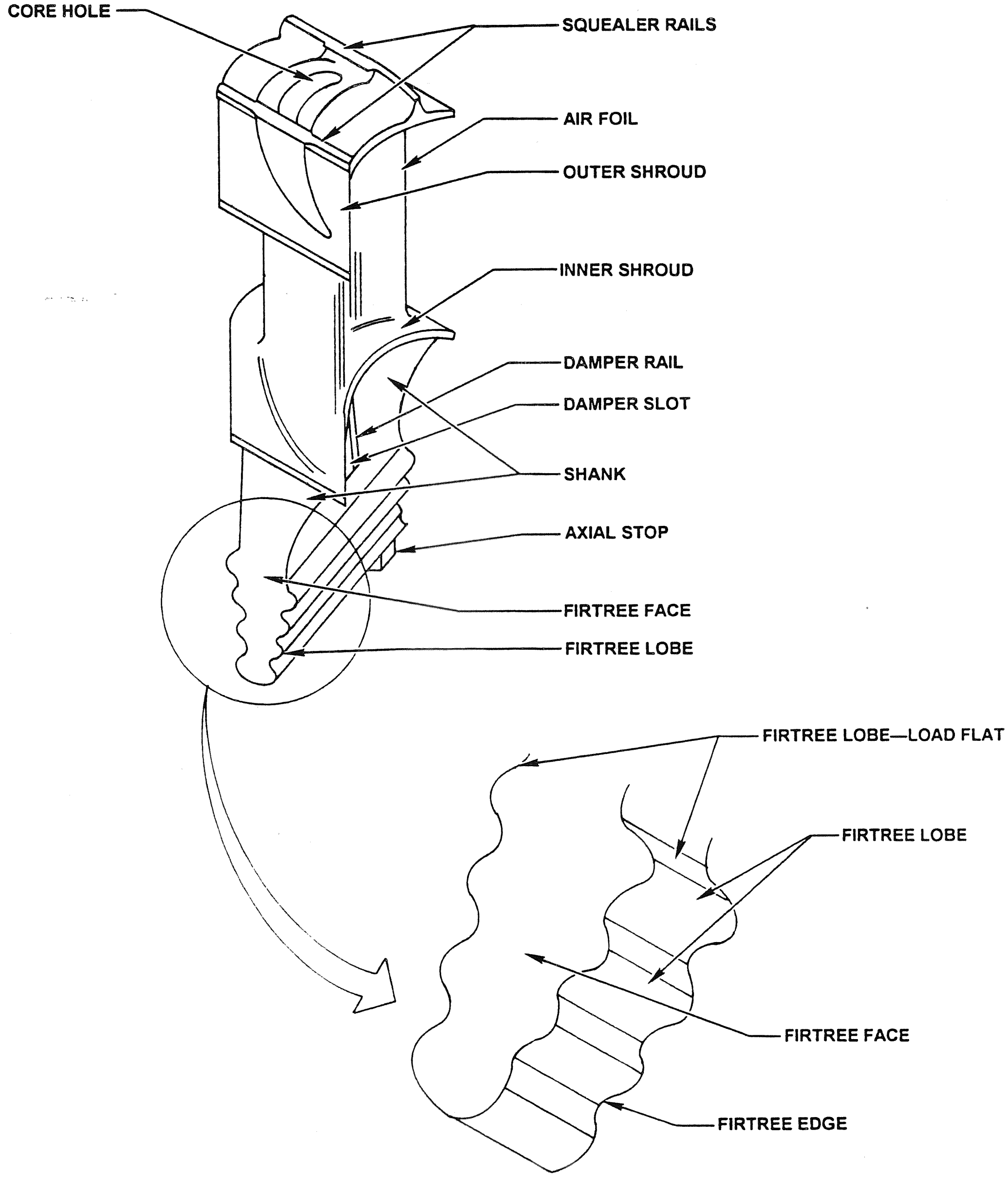


Figure 2-37. HPOTP Erosion and Slag Deposits

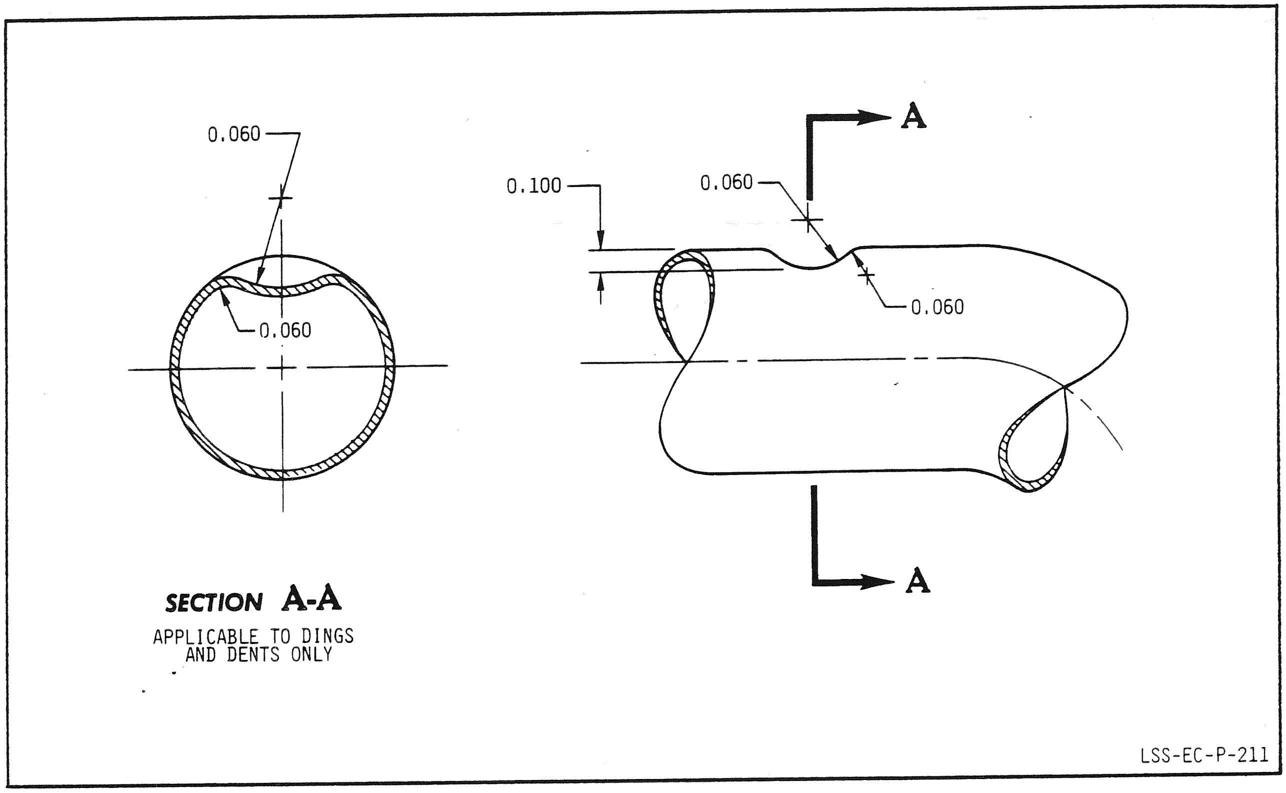


Figure 2-38. Drain Line Dent Inspection Guidelines

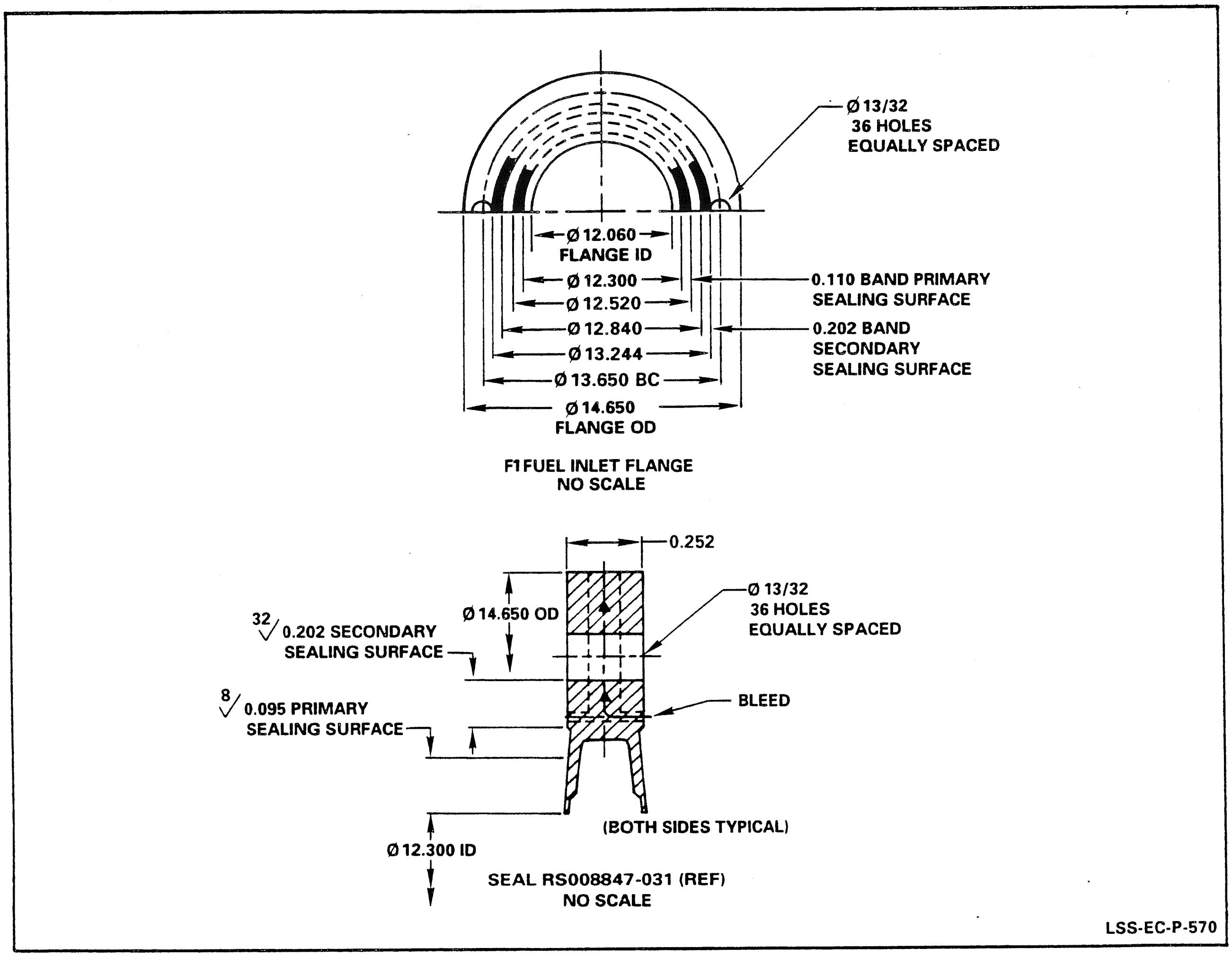


Figure 2-39. F1 Fuel Inlet Flange Sealing Surfaces

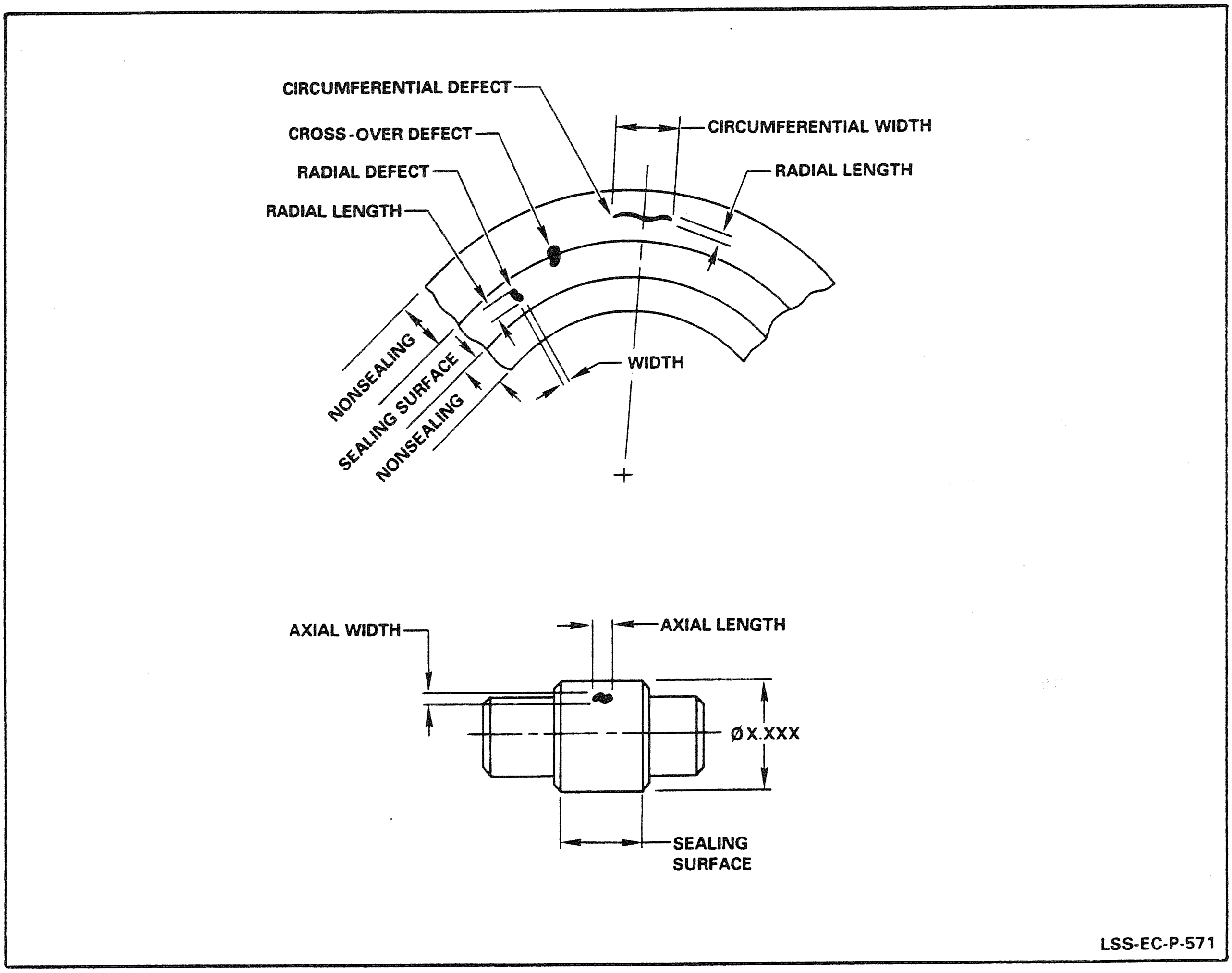


Figure 2-40. Surface Defects

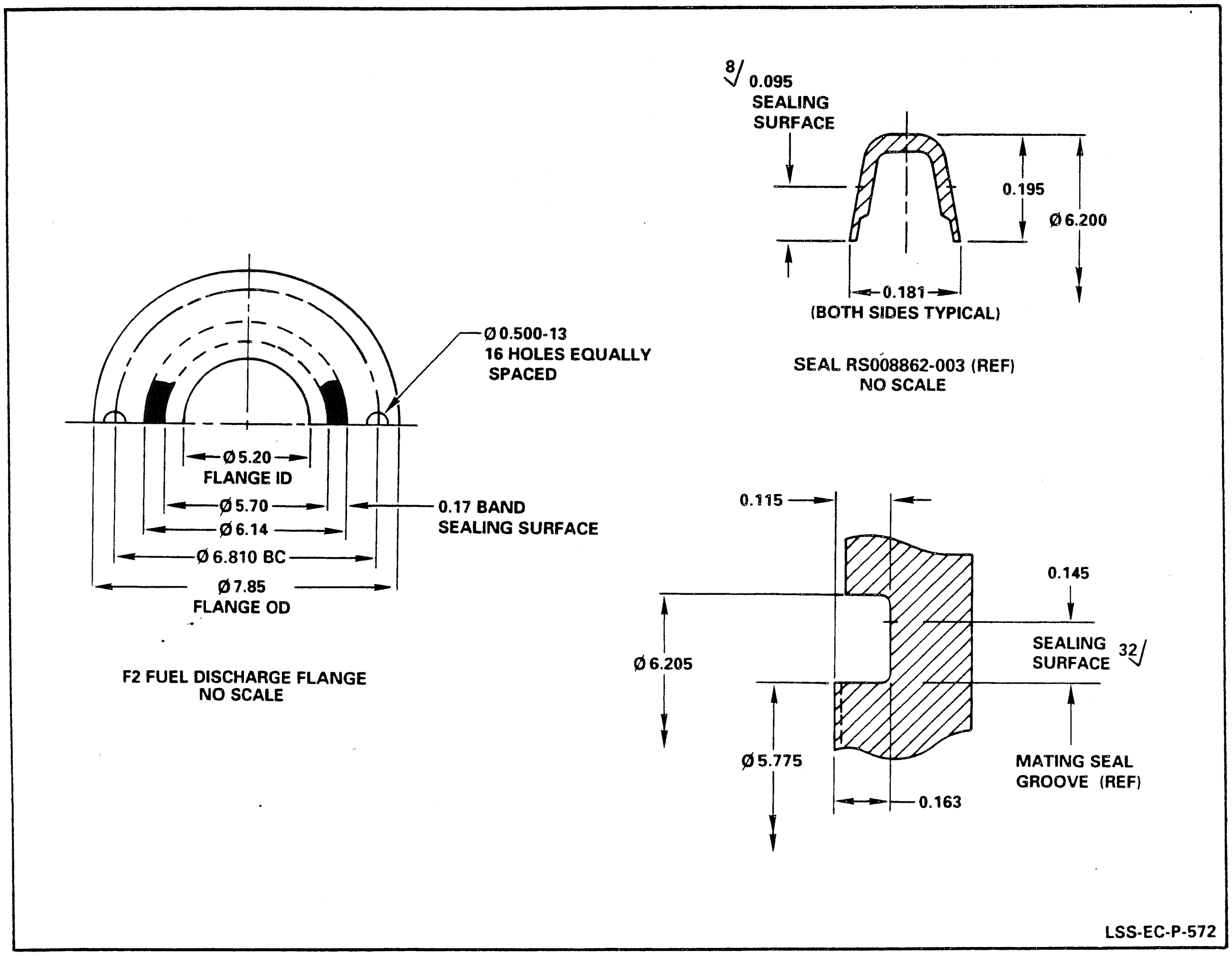


Figure 2-41. F2 Fuel Discharge Flange Sealing Surfaces

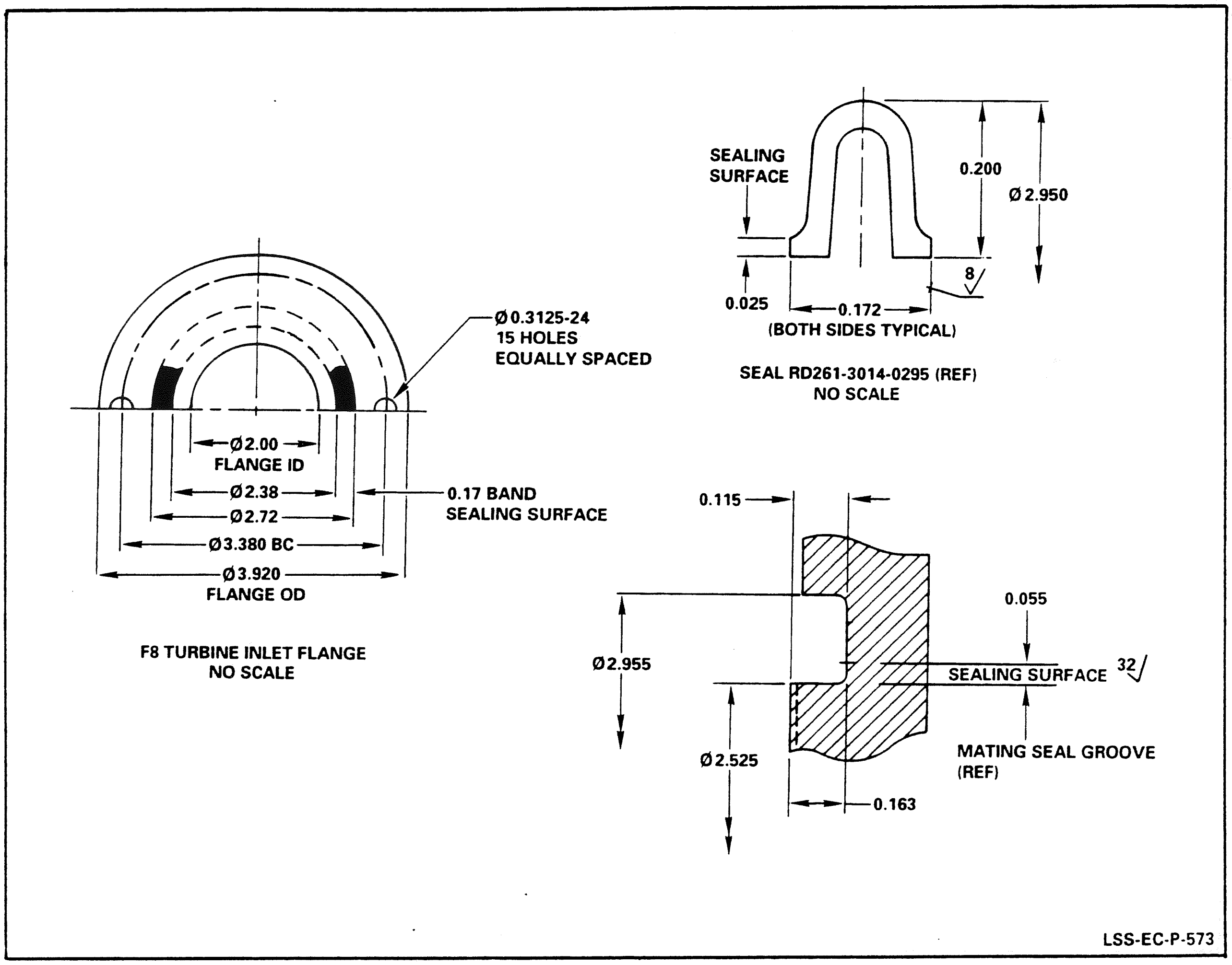


Figure 2-42. F8 Turbine Inlet Flange Sealing Surfaces

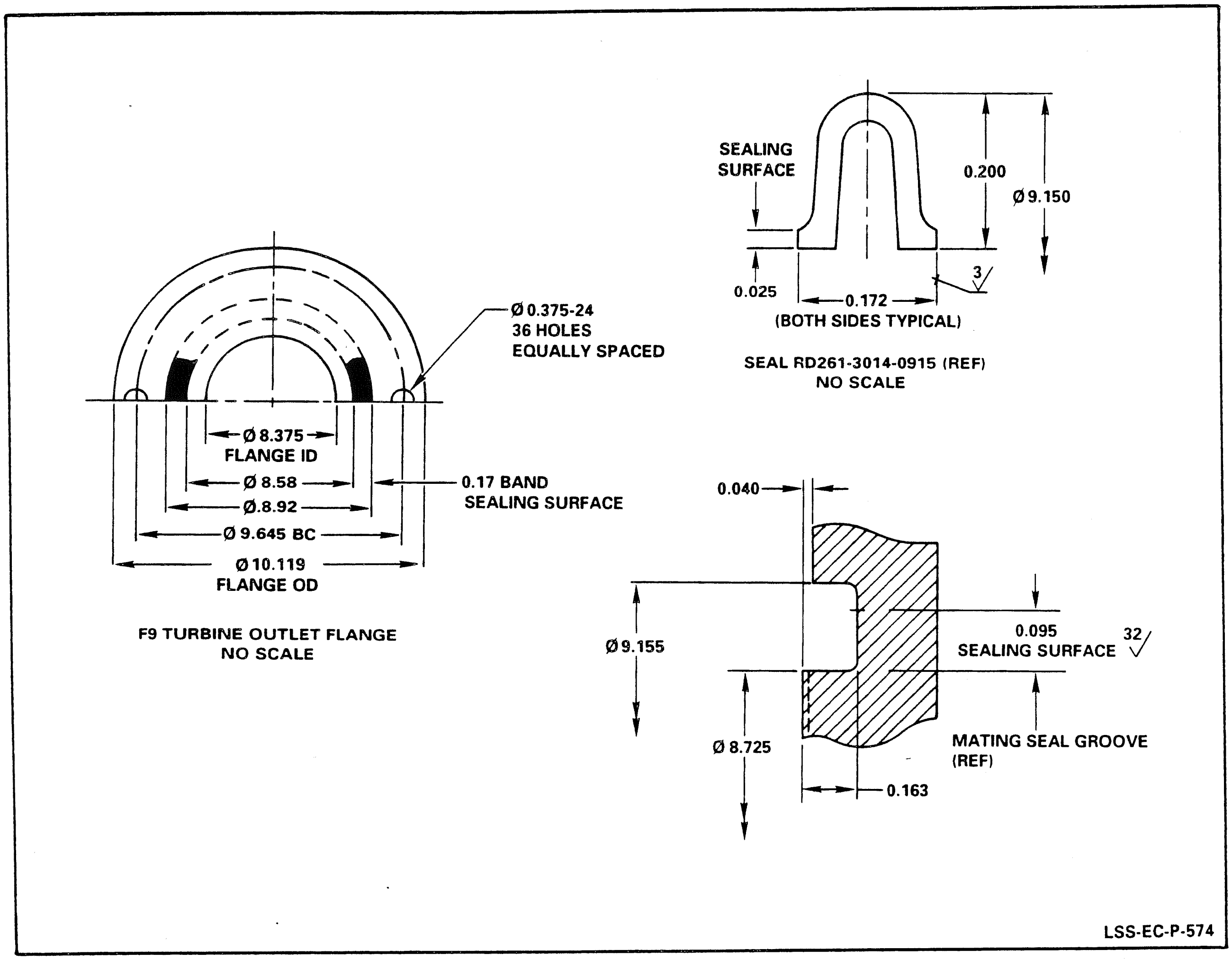


Figure 2-43. F9 Turbine Discharge Flange Sealing Surfaces

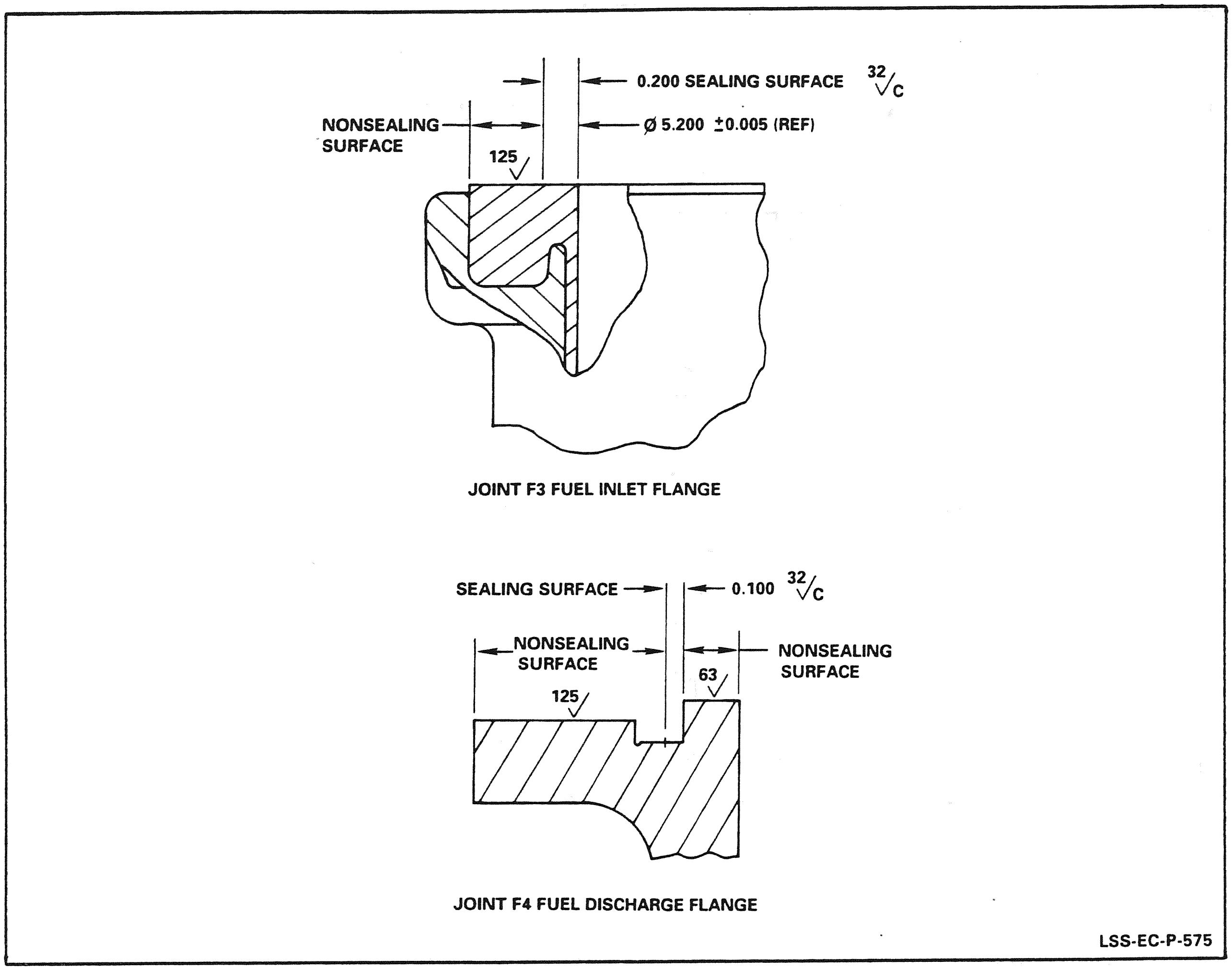


Figure 2-44. Extend Seal Surfaces

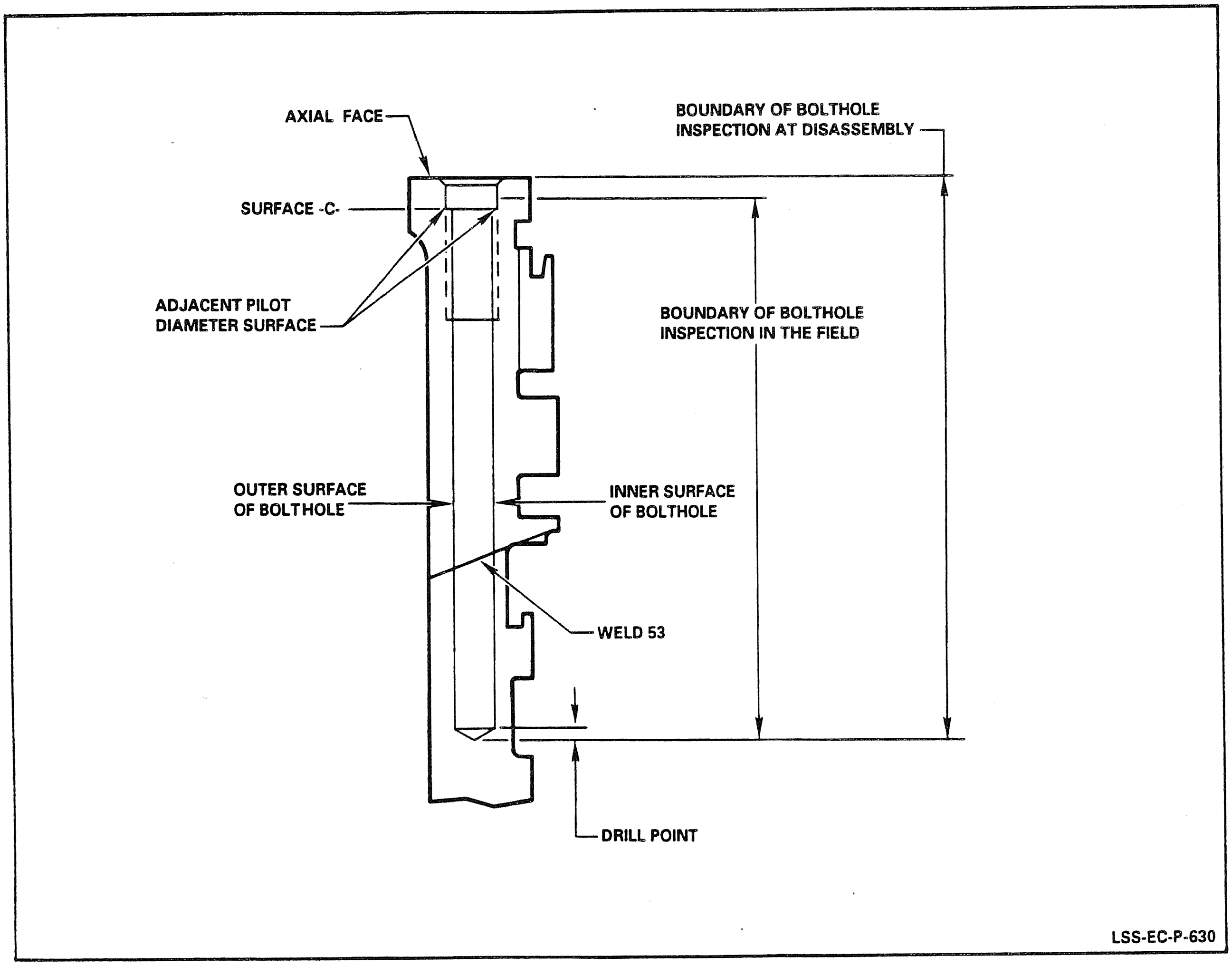


Figure 2-45. Cracks - Turbine Inner Ring Boltholes

SECTION III

INSPECTION CRITERIA
FOR
HEAT EXCHANGER

SECTION III

CHANGE RECORD

REV/ CHG	DATE	CHANGE SUMMARY	PAGE EFFECT	RCN/CCBD
PRELIM	3/6/85	PRELIMINARY FOR OMRSD REVIEW/ APPROVAL CYCLE	ALL	RCN MV6596 (RELEASED FOR REVIEW 8/26/85)
BASIC	3/6/85	BASIC SECTION RELEASED	ALL	RCN MV6596 (APPROVED 9/26/85)
REV	8/10/87	UPDATED SECTION TO THE LATEST REQUIREMENTS	ALL	RCN MV8301 (APPROVED 7/28/88)
CHG 1	7/5/89	UPDATED SECTION TO THE LATEST REQUIREMENTS	3-3/ 3-4, 3-5	CCBD NO. ME3-00-7675 (APPROVED 6/29/89)
REV	11/1/89	UPDATED SECTION TO THE LATEST REQUIREMENTS	3-3/ 3-4, 3-5	CCBD NO. ME3-00-7909 (APPROVED 9/29/89)
REV	10/25/90	UPDATED SECTION TO THE LATEST REQUIREMENTS	None	CCBD NO. ME3-AA-5445 (APPROVED 6/20/89)
REV	2/10/92	UPDATED SECTION TO THE LATEST REQUIREMENTS	3-3 THRU 3-5	SPECIFICATION RF0001-053 REVISION E-1 (APPROVED 10/30/91)
REV	5/29/92	UPDATED SECTION TO THE LATEST REQUIREMENTS	3-3/ 3-4, 3-7	SPECIFICATION RF0001-053 REVISION F-4 (APPROVED 5/19/92)
REV	7/31/92	UPDATED SECTION TO THE LATEST REQUIREMENTS OF RF0001-053	3-3/ 3-4	SPECIFICATION RF0001-053 REVISION G (APPROVED 8/13/92)
REV	11/5/92	UPDATED SECTION TO THE LATEST REQUIREMENTS OF RF0001-053	3-3/ 3-4	SPECIFICATION RF0001-053 REVISION G-1 (APPROVED 11/17/92)

SECTION III

CHANGE RECORD (continued)

REV/ CHG	DATE	CHANGE SUMMARY	PAGE EFFECT	RCN/CCBD
REV	2/16/93	UPDATED SECTION TO THE LATEST REQUIREMENTS OF RF0001-053	3-5/ 3-6	SPECIFICATION RF0001-053 REVISION G-2 (APPROVED 2/16/93)
REV	3/10/93	UPDATED SECTION TO THE LATEST REQUIREMENTS OF RF0001-053	3-5/ 3-6	SPECIFICATION RF0001-053 REVISION G-3 (APPROVED 3/16/93)

SECTION III

INSPECTION CRITERIA FOR HEAT EXCHANGER

3.1 SCOPE

This section contains inspection criteria for the SSME heat exchanger. (Refer to table 3-1.)

3.2 OMRSD

The hardware condition limitation of the inspection criteria supports the OMRSD requirements listed below. Hardware conditions that are within these limitations require no further action or rework. Hardware conditions resulting from operational degradation that do not meet these limitations shall be processed through the PR/MR system.

V41BU0.040	INTERNAL INSPECTION OF SSME COMPONENTS
V41BU0.082	SSME OPB INSPECTIONS WITH HPOTP REMOVED
V41BU0.115	SSME HEAT EXCHANGER INSPECTION
V41BU0.125	SSME HEX VISUAL INSPECTION

3.3 APPLICABLE DOCUMENTS

The following documents are listed as source reference only.

SPECIFICATIONS

Rockwell International

	REV	
RF0001-053	G-3	Space Shuttle Main Engine Inspection Criteria
RL00289	D-3	SSME Heat Exchanger, Overhaul/Recycle/Repair Requirements
RL00409	E	Heat Exchanger Assembly Final Checkout

TABLE 3-1. SSME HEAT EXCHANGER INSPECTION CRITERIA (Sheet 1 of 3)

Condition	Hardware Condition Limit
Heat exchanger primary tube wear (See figures 3-1 and 3-2.)	As verified by eddy current test, wall thinning shall not exceed 0.0045 inch.
Nicks, scratches, gouges, dents, and dings: (See figures 3-1 and 3-2.)	
On heat exchanger coil external	Depth shall not exceed 0.001 inch on secondary tubes and not to exceed 0.0005 inch on primary tube. Dents with sharp creases shall be rejected. Well-rounded dents less than 0.024-inch deep on the secondary tube are acceptable. Dents on primary tube may be repaired per RF0001-025. All dings are not acceptable.
In heat exchanger bypass tubing external surfaces	Depth shall not exceed 0.002 inch.
Individual tube vertical and radial movement with respect to dimples on bracket channels (See figures 3-1 and 3-2.)	Movement at three consecutive bracket locations is acceptable (if subsequent adjacent bracket locations do not exceed 0.005 inch), provided the movements are not greater than 0.030 inch at one of the brackets and not greater than 0.010 inch at the other two brackets.
Clearances:	
Movement of coil tubes at each bracket with respect to dimples on the bracket channels	Movement at three consecutive bracket locations is acceptable (if subsequent adjacent bracket locations are tight) provided movements are not greater than 0.030 inch at one of the brackets nor 0.010 inch at other two brackets.
Between inlet tube and any part of bracket No. 8 (See figure 3-3.)	Clearance shall be 0.100 inch minimum except for a minimum clearance of 0.065 inch between tube and outer channel.

TABLE 3-1. SSME HEAT EXCHANGER INSPECTION CRITERIA (Sheet 2 of 3)

Condition	Hardware Condition Limit
Between inlet tube and any part of hole where it passes through hot gas manifold liner (See figure 3-4.)	Clearance shall be 0.025 inch minimum.
Between outlet tubes and any part of hole where tubes pass through hot gas manifold liner (See figure 3-4.)	Clearance shall be 0.025 inch minimum.
Between upper outlet tube where it bends to go through liner, and tube that crosses above it (See figure 3-4.)	Clearance shall be 0.030 inch minimum.
Between each outlet tube and any part of bracket No. 1 (See figure 3-3.)	Clearance shall be 0.040 inch minimum.
Between bifurcation joint ball and inner row of coils	Clearance shall be 0.020 inch minimum.
Looseness of brackets on coil pack	Total side-to-side movement of less than 0.20 inch (using light hand pressure) is acceptable.
Cracks:	
Cracks in accessible bracket welds	Visible cracks not acceptable.
Cracks in turning vane edges and corner radii	Visible cracks not acceptable.
Cracks in inlet port gusset welds	Visible cracks not acceptable.
Cracks in the RS008811 weld ⚠1 ID	Visible cracks (as determined by borescope inspection) are not acceptable.
Turning vane vertical movement at each pin location	Vertical movement under finger pressure shall not exceed 0.010 inch.
Damage to coil bracket inward facing legs by HPOTP	Bending is not acceptable.

TABLE 3-1. SSME HEAT EXCHANGER INSPECTION CRITERIA (Sheet 3 of 3)

Condition	Hardware Condition Limit
Primary tube internal contamination	Visual contamination (as determined by borescope inspection) is not acceptable.
Primary tube dents at brackets	Dents (as determined by borescope inspection) are not acceptable.
Bypass orifice support clamp wire mesh breaking and/or falling out	Breaking/falling out particles of wire mesh is not acceptable.

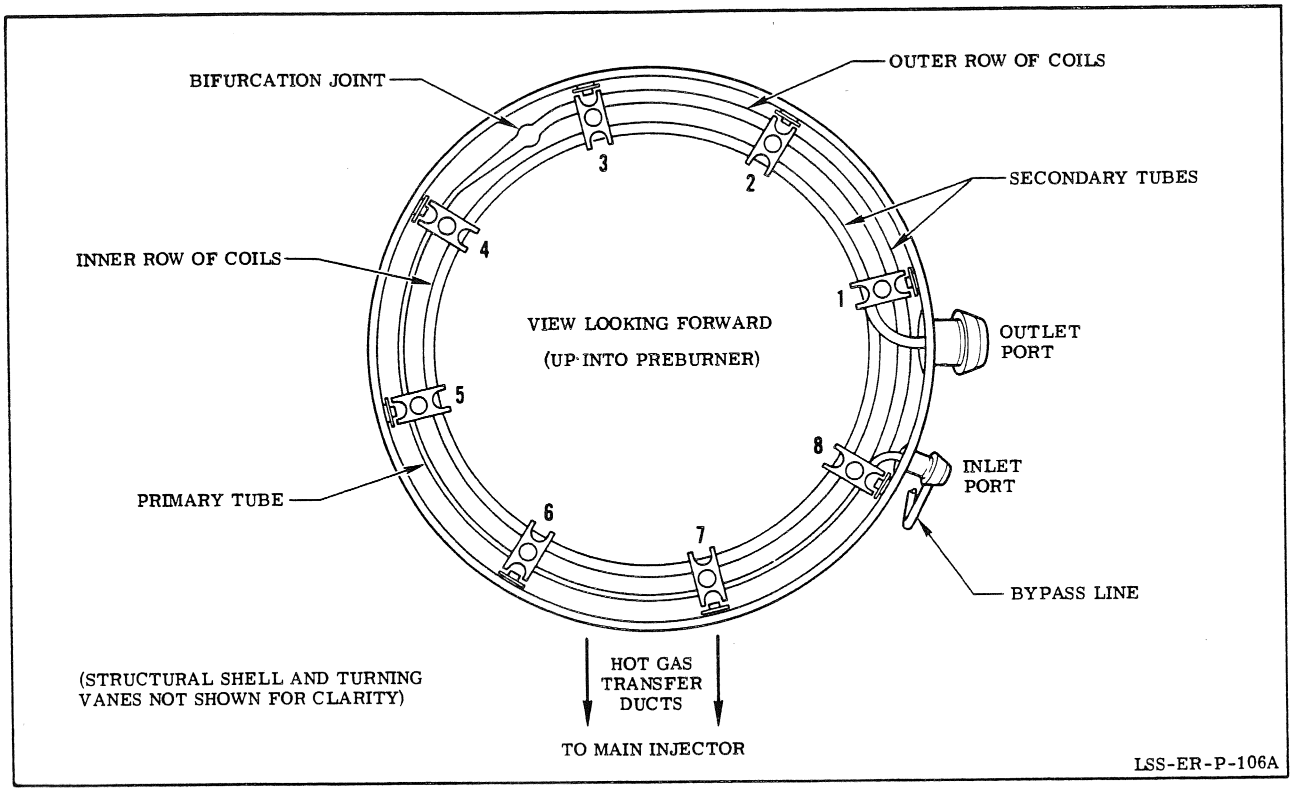


Figure 3-1. Heat Exchanger Coil Bracket Number Orientation

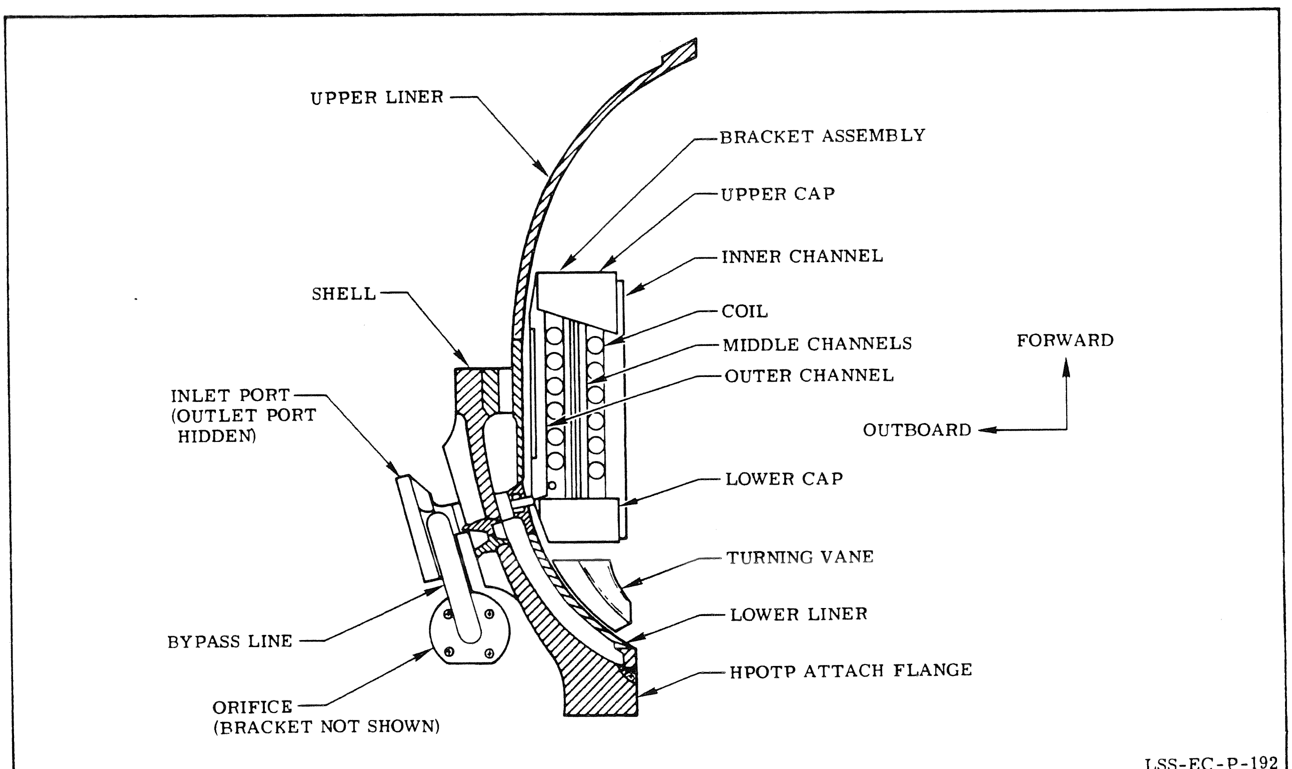


Figure 3-2. Heat Exchanger Major Components Identification

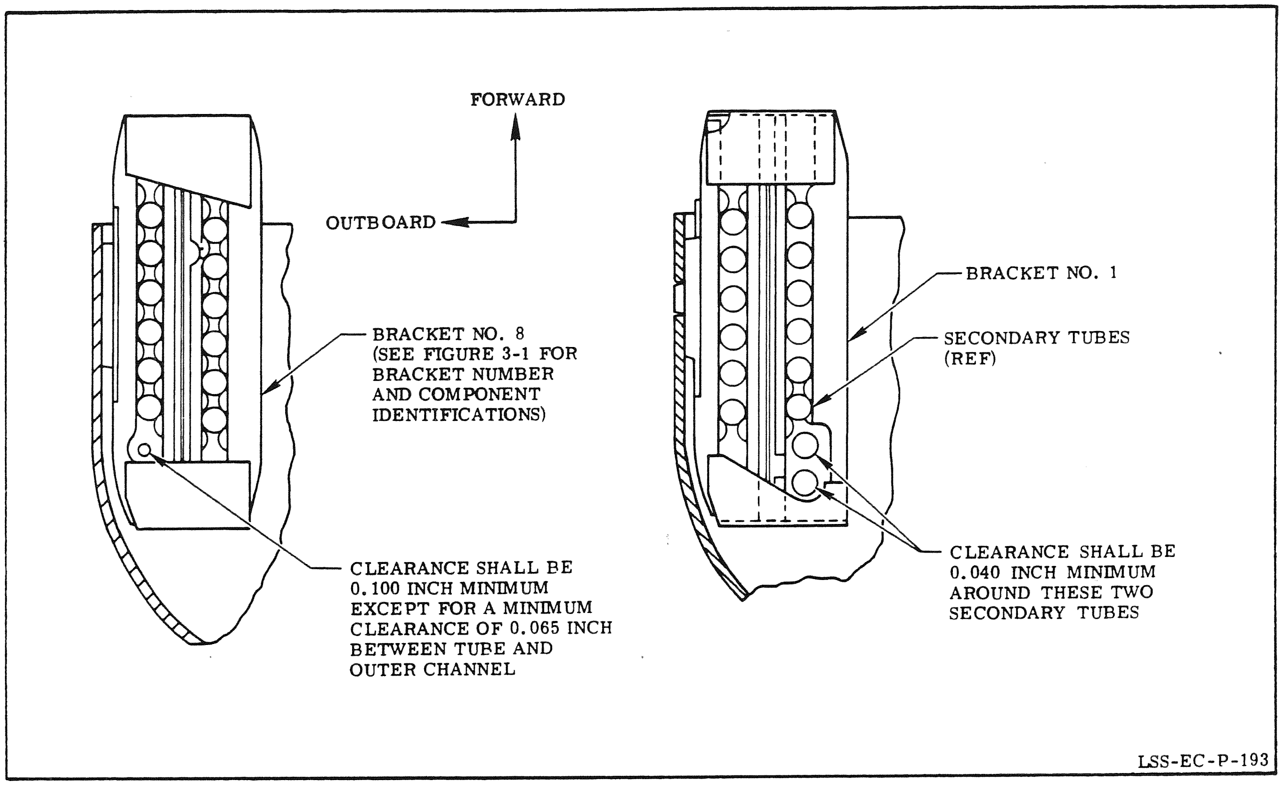


Figure 3-3. Secondary and Primary Tube Clearance at Brackets No. 1 and 8

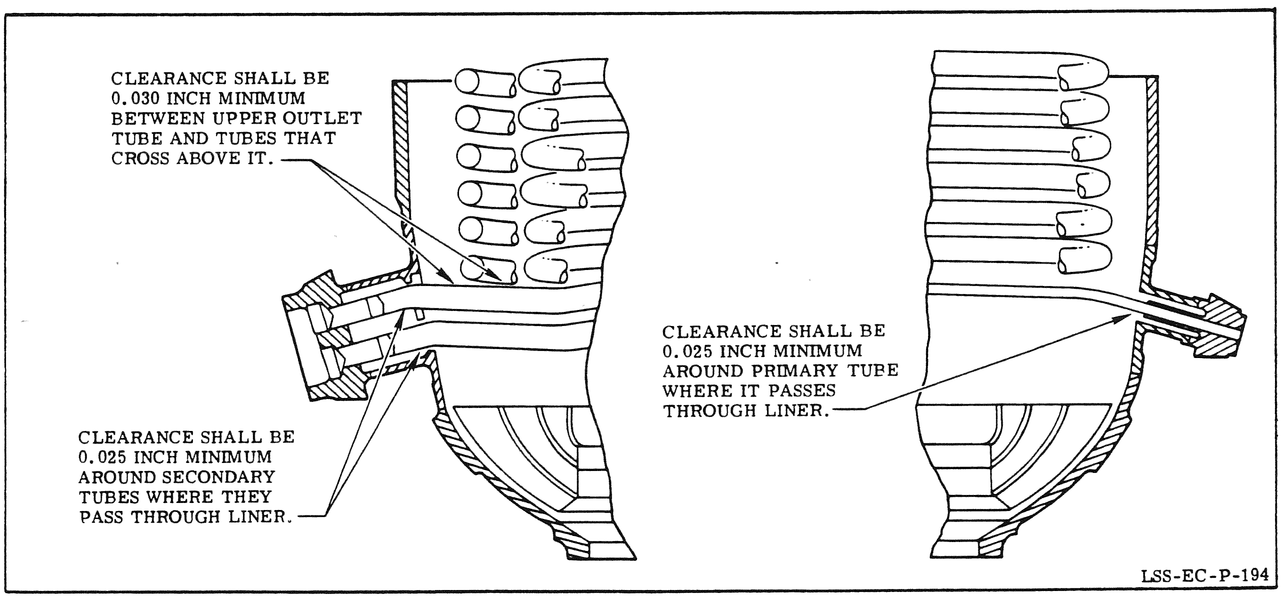


Figure 3-4. Primary Tube, Secondary Tube Clearance at Liner and Clearance of Tubes Crossing Over Outlet Tube

SECTION IV

INSPECTION CRITERIA
FOR
DUCTS, LINES, AND VALVES

SECTION IV

CHANGE RECORD

REV/ CHG	DATE	CHANGE SUMMARY	PAGE EFFECT	RCN/CCBD
PRELIM	3/6/85	PRELIMINARY FOR OMRSD REVIEW/ APPROVAL CYCLE	ALL	RCN MV6596 (RELEASED FOR REVIEW 8/26/85)
BASIC	3/6/85	BASIC SECTION RELEASED	ALL	RCN MV6596 (APPROVED 9/26/85)
REV	8/10/87	UPDATED SECTION TO THE LATEST REQUIREMENTS	ALL	RCN MV8301 (APPROVED 7/28/88)
CHG 1	7/5/89	UPDATED SECTION TO THE LATEST REQUIREMENTS	4-3, 4-4	CCBD NO. ME3-00-7675 (APPROVED 6/29/89)
REV	11/1/89	UPDATED SECTION TO THE LATEST REQUIREMENTS	4-23 thru 4-26	CCBD NO. ME3-00-7909 (APPROVED 9/29/89)
CHG 4	10/24/90	UPDATED SECTION TO THE LATEST REQUIREMENTS	4-4, 4-9, 4-11, 4-12, 4-17, 4-26	CCBD NO. ME3-00-9101 (APPROVED 10/24/90)
REV	10/25/90	UPDATED SECTION TO THE LATEST REQUIREMENTS	NONE	CCBD NO. ME3-AA-5445 (APPROVED 6/20/89)
REV	2/10/92	UPDATED SECTION TO THE LATEST REQUIREMENTS	4-3 THRU 4-5, 4-8 THRU 4-12, 4-22 THRU 4-26	SPECIFICATION RF0001-053 REVISION E-1 (APPROVED 10/30/91)

SECTION IV

CHANGE RECORD (continued)

REV/ CHG	DATE	CHANGE SUMMARY	PAGE EFFECT	RCN/CCBD
REV	5/29/92	UPDATED SECTION TO THE LATEST REQUIREMENTS	4-3, 4-5 THRU 4-12, 4-14, 4-15	SPECIFICATION RF0001-053 REVISION F-4 (APPROVED 5/19/92)
REV	7/31/92	UPDATED SECTION TO THE LATEST REQUIREMENTS OF MCR 729	4-5, 4-7 THRU 4-30	SPECIFICATION RF0001-053 REVISION G (APPROVED 8/13/92)
REV	11/5/92	UPDATED SECTION TO THE LATEST REQUIREMENTS OF RF0001-053	4-5	SPECIFICATION RF0001-053 REVISION G-1 (APPROVED 11/17/92)
REV	2/16/93	UPDATED SECTION TO THE LATEST REQUIREMENTS OF RF0001-053	4-5, 4-6, 4-17	SPECIFICATION RF0001-053 REVISION G-2 (APPROVED 2/11/93)
REV	3/10/93	UPDATED SECTION TO THE LATEST REQUIREMENTS OF RF0001-053	4-5, 4-7	SPECIFICATION RF0001-053 REVISION G-3 (APPROVED 3/16/93)

SECTION IV

INSPECTION CRITERIA FOR DUCTS, LINES, AND VALVES

4.1 SCOPE

This section contains inspection criteria for SSME ducts and lines, including the nickel plate insulation and liquid air insulation joint closures. (Refer to table 4-1.)

4.2 OMRSD

The hardware condition limitation of the inspection criteria supports the OMRSD requirements listed below. Hardware conditions that are within these limitations require no further action or rework. Hardware conditions resulting from operational degradation that do not meet these limitations shall be processed through the PR/MR system.

V41BU0.030	PERFORM SSME COMPONENTS EXTERNAL INSPECTION
V41BU0.033	SSME FUEL SYSTEM

4.3 APPLICABLE DOCUMENTS

The following documents are listed as source reference only.

SPECIFICATIONS

<u>Rockwell International</u>

<u>Rockwell International</u>

	REV	
RF0001-053	G-3	Space Shuttle Main Engine Inspection Criteria
RF0001-024	C	Small Line and Tube Assembly, Standard Repair of
RF0001-039	B	Major Duct Details, Standard Repair of
RL00059	E-1	SSME Overhaul/Recycle/Repair Requirements
RF0004-027	A	Sealing Surface Requirements
RL00293	C-2	Flex Line, Overhaul/Recycle/Repair Requirements
RL00327	E	SSME Rigid Duct Assemblies, Overhaul/Recycle/ Repair Requirements

	REV	
RL00328	C-1	SSME Articulating Duct Assembly, Overhaul/Recycle/ Repair Requirements
RL00330	C-1	SSME Rigid Line Assemblies, Overhaul/Recycle/ Repair Requirements
RL00471	C	Flex Joint Assemblies, Overhaul/Recycle/Repair Requirements
RL00925	B	High Pressure Fuel Duct, R007026, Installation and Inspection Requirements
RL01071	NC-1	High Pressure Fuel Duct R035533, Installation and Inspection Requirements

TABLE 4-1. SSME DUCTS AND LINES INSPECTION CRITERIA (Sheet 1 of 12)

Definitions (ECP 1218)

Erosion - Wearing away of the blade parent material. This normally occurs in the airfoil region of the blade.

Imbedded Material - A particle that has imbedded itself in the parent material of the blade.

Scratch, Nick, or Gauge - A damaged area in which material has been removed or moved, resulting in a decrease in wall thickness.

Spalling - Flaking, scaling, or delamination of material.

Slag - Melted material deposited on the surface of the blade.

Smeared Material - A smear of material on the blade surface that is left after a deposit of soft material contacts the blade.

Splatter - A deposit of material on the blade surface, most commonly used when describing gold.

TABLE 4-1. SSME DUCTS AND LINES INSPECTION CRITERIA (Sheet 2 of 12)

Condition	Hardware Condition Limit
A. Rigid Lines (Refer to table 4-2 for applicability.)	
1. Tubing surface irregularities:	
Nicks, scratches, gouges, pits, and/or similar damage	Nicks and/or similar damage that does not exceed 15 percent of nominal wall thickness in depth and has a minimum fillet radius of 0.030 inch is acceptable, provided that a minimum of 85 percent of the wall thickness is maintained. (Refer to table 4-2.)
Dents and clamp marks	Dents and clamp marks that do not exceed 10 percent of nominal tubing OD are acceptable (figure 4-1, item D_1) if the following criteria are satisfied: Minimum fillet radius (figure 4-1, items R_2 and R_4) at base of dent is as follows: Depth of Dent (D_1) — Minimum Fillet Radius (R_2 and R_4) 0 - 0.020 — 0.010 0.020 - 0.040 — 0.030 0.040 - 0.060 — 0.060 0.060 and deeper — 0.125 Minimum fillet radius (figure 4-1, items R_1 and R_3) is 2 times nominal wall thickness. All radii less than 0.125 inch, formed as a result of a dent or clamp installation, shall be penetrant-inspected in accordance with RA0115-116, Type IVC.

TABLE 4-1. SSME DUCTS AND LINES INSPECTION CRITERIA (Sheet 3 of 12)

Condition	Hardware Condition Limit
A. Rigid Lines (continued)	
2. Flanges: (See figure 4-2.)	
Nicks, scratches, gouges, pits, and/or similar damage	Nicks and/or similar damage to external areas (except sealing surface areas) that has a maximum surface area of 0.02 square inch and a maximum depth of 0.030 inch with a minimum fillet radius of 0.030 inch (except on valves) is acceptable, provided that a minimum of 85 percent of the wall thickness is maintained in the damaged area. There is a limit of two damaged areas per machined part, a minimum of 0.50 inch apart. Sealing Surface Areas - Designated sealing surface areas shall be free of nicks, scratches, or other imperfections that will impair the sealing function. Tube Stub Area - Nicks and/or similar damage that does not exceed 15 percent of nominal wall thickness in depth and has a minimum fillet radius of 0.030 inch is acceptable, provided that a minimum of 85 percent of the wall thickness is maintained. (Refer to table 4-2.) Tube stub area shall not be bent more than 3 degrees as a result of assembly or handling. Bent areas shall be penetrant-inspected in accordance with RA0115-116, Type IVC. Fillet Radii Area - shall be maintained per drawing requirements.
Raised Material	Raised material above the level of original surface contour shall be removed.

TABLE 4-1. SSME DUCTS AND LINES INSPECTION CRITERIA (Sheet 4 of 12)

Condition	Hardware Condition Limit
A. Rigid Lines (continued)	
3. Critical rigid lines	The following rigid line assemblies shall be considered critical hardware, and all discrepancies determined to be in excess of the limits allowed by RA0102-003 shall be cause for rejection and dispositioned, in accordance with Quality Assurance procedures:
	Rigid Bleed Valve Line RS007041 Fuel Tank Repress Line RS007046 FPB ASI LOX Supply Line RS007186 OPB ASI LOX Supply Line RS007187 LOX Boost Pump Disch Press Line RS007363 OPB ASI Fuel Supply Line R0010751 FPB ASI Fuel Supply Line R0010752 MCC ASI Fuel Supply Line R0010758 HPFTP Disch Press Line R0019552 MCC Drying Purge Line R0019585
4. Tape-wrapped sections:	
Nicks, cuts, and missing tape	Nicks, cuts, or missing tape RB0135-029 on emergency shutdown lines are not acceptable.
B. Flex Lines	
1. Flex hose braid:	
Broken or chafed wires within 1 inch of braid retaining collar	Broken wires are not acceptable. Chafed wires with less than 30 percent of material removed are acceptable.
Broken wires within a carrier (See figure 4-3.)	Maximum of one broken wire within one carrier is acceptable. Maximum of 6 broken wires within entire flex section is allowable. Broken wires within 2 adjacent parallel carriers are not acceptable.

TABLE 4-1. SSME DUCTS AND LINES INSPECTION CRITERIA (Sheet 5 of 12)

Condition	Hardware Condition Limit
B. Flex Lines (continued)	
Bulged or kinked braid (See figure 4-4.)	Bulges not exceeding diameter of braid retaining collar are acceptable. Severe bulging or kinking is not acceptable.
2. Flanges:	
Nicks, scratches, gouges, pits, and/or similar damage	Nicks and/or similar damage equal to or less than 0.004 inch in depth or width is acceptable provided that there are no sharp edges or raised material within the defect. Fillet Radii Area - shall be maintained per drawing requirements. Sealing Surface Areas - Designated sealing surface areas shall be free of nicks, scratches, or other imperfections that will impair the sealing function.
C. Rigid Ducts (Refer to table 4-3 for applicability.)	
1. Tubing surface irregularities:	
Nicks, scratches, gouges, pits, and/or similar damage	Nicks and/or similar damage that does not exceed 5 percent of nominal wall thickness in depth and has a minimum fillet radius of 0.060 inch is acceptable. (Refer to table 4-3.)

TABLE 4-1. SSME DUCTS AND LINES INSPECTION CRITERIA (Sheet 6 of 12)

Condition	Hardware Condition Limit
C. Rigid Ducts (continued)	
Dents	Dents that do not exceed 5 percent of nominal tubing OD are acceptable, provided that the minimum fillet radius (figure 4-1, items R_2 and R_4) at the base of dent is as follows:

Depth of Dent (D_1)	Minimum Fillet Radius (R_2 and R_4)
0 - 0.020	0.050
0.020 - 0.040	0.100
0.040 - 0.060	0.150
0.060 and deeper	0.250

Condition	Hardware Condition Limit
	The minimum allowable fillet radii R_1 and R_3 (figure 4-1) shall be twice the nominal wall thickness.
	All radii less than 0.250 inch shall be penetrant-inspected in accordance with RA0115-116, Type IVC.
Arc burns	Arc burns are not acceptable.
Cracks	Cracks are not acceptable.
2. Flanges: (See figure 4-5.)	
Nicks, scratches, gouges, pits, and/or similar damage	Tube Stub Area - Nicks and/or similar damage that does not exceed 5 percent of nominal wall thickness in depth and has a minimum radius of 0.060 inch is acceptable.
	Fillet Radii Area - shall be maintained per drawing requirements.
	Flange Periphery - Nicks and/or similar damage that does not exceed 0.030 inch in depth and has a minimum radius of 0.060 inch is acceptable.

TABLE 4-1. SSME DUCTS AND LINES INSPECTION CRITERIA (Sheet 7 of 12)

Condition	Hardware Condition Limit
C. Rigid Ducts (continued)	
	Flange Face - Nicks and/or similar damage that is less than 0.002 inch deep, has an area no greater than 0.020 square inch, and is without raised material located inboard or outboard of the designated sealing surface area is acceptable. Designated sealing surface areas shall be free of nicks, scratches, or other imperfections that will impair sealing function.
3. Raised Material	Raised material above the level of original surface contour shall be removed.
4. HPF duct alinement:	
Duct flange gap	To find the maximum allowable measurements for duct gap or offset, calculate the angulation using the following formula: F4 Flange: Angulation $TAN^{-1} \frac{\text{MAX. GAP - MIN. GAP}}{6.68}$ F5 Flange: Angulation $TAN^{-1} \frac{\text{MAX. GAP - MIN. GAP}}{6.41}$
Average flange gap	Average of four measured gaps (equally spaced and including the maximum and minimum gaps, taken at the OD of flange) minus the flange step height per the following formula: F4 Flange: Average GAP = Average OD Gap - 0.035 F5 Flange: Average GAP = Average OD Gap - 0.048

TABLE 4-1. SSME DUCTS AND LINES INSPECTION CRITERIA (Sheet 8 of 12)

Condition	Hardware Condition Limit
C. Rigid Ducts (continued)	
Allowable gap	To find the allowable average gap, use figures 4-6 or 4-8 for joint F4 and figures 4-7 or 4-9 for joint F5. Using the appropriate figure, plot the calculated angulation and measured offset to determine the maximum allowable average gap.
Allowable offset	To find the allowable offset, use figures 4-6 or 4-8 for joint F4 and figures 4-7 or 4-9 for joint F5. Using the appropriate figure, plot the calculated angulation and average gap to determine the maximum allowable offset.
5. Controller coolant duct segments (RS007356)	Acceptability of duct segment shall be in accordance with Specification RL00059.
D. Articulating Ducts (Refer to table 4-3 for applicability.)	
1. Tubing surface irregularities:	
Nicks, scratches, gouges, pits, and/or similar damage	Nicks and/or similar damage that does not exceed 5 percent of nominal wall thickness in depth and has a minimum fillet radius of 0.060 inch is acceptable. (Refer to table 4-3.)

TABLE 4-1. SSME DUCTS AND LINES INSPECTION CRITERIA (Sheet 9 of 12)

Condition	Hardware Condition Limit
D. Articulating Ducts (continued)	
Dents	Dents that do not exceed 5 percent of nominal tubing OD are acceptable, provided that the minimum fillet radius (figure 4-1, items R_2 and R_4) at the base of dent is as follows: Depth of Dent (D_1) — Minimum Fillet Radius (R_2 and R_4) 0 - 0.020 — 0.050 0.020 - 0.040 — 0.100 0.040 - 0.060 — 0.150 0.060 and deeper — 0.250 The minimum allowable fillet radii R_1 and R_3 (figure 4-1) shall be twice the nominal wall thickness. All radii less than 0.250 inch shall be penetrant-inspected in accordance with RA0115-116, Type IVC.
Arc burns	Arc burns are not acceptable.
Cracks	Cracks are not acceptable.
2. Flanges: (See figure 4-5.)	
Nicks, scratches, gouges, pits, and/or similar damage	Tube Stub Area - Nicks and/or similar damage that does not exceed 5 percent of nominal wall thickness in depth and has a minimum radius of 0.060 inch is acceptable. Fillet Radii Area - shall be maintained per drawing requirements. Flange Periphery - Nicks and/or similar damage that does not exceed 0.030 inch in depth and has a minimum radius of 0.060 inch is acceptable.

TABLE 4-1. SSME DUCTS AND LINES INSPECTION CRITERIA (Sheet 10 of 12)

Condition	Hardware Condition Limit
D. Articulating Ducts (continued)	
	Flange Face - Nicks and/or similar damage that is less than 0.002 inch deep, has an area no greater than 0.020 square inch, and is without raised material located inboard or outboard of the designated sealing surface area is acceptable. Designated sealing surface areas shall be free of nicks, scratches, or other imperfections that will impair sealing function.
3. Raised Material	Raised material above the level of original surface contour shall be removed.
E. Articulating Duct Bellows	
1. Dents:	
In other than critical regions. (See figure 4-10 for location of critical regions.)	Depth shall not exceed 0.010 inch. Indentations less than 10 percent of material thickness are not considered dents. Dents within these limits are not affected by length.
In critical regions. (See figure 4-10 for locations of critical regions.)	Dents are acceptable if corners are well rounded and do not exceed 0.005 inch in depth maximum. Maximum acceptable length shall be in accordance with figure 4-10.
2. Nicks and scratches	Figure 4-10 lists maximum acceptable depth limits by various combinations or orientation, location, and material thickness. Select combination that applies to defect being evaluated. See figure 4-10 for location of critical regions.

TABLE 4-1. SSME DUCTS AND LINES INSPECTION CRITERIA (Sheet 11 of 12)

Condition	Hardware Condition Limit
E. Articulating Duct Bellows (continued)	
3. Cracks	Cracks are not acceptable.
4. Pits	Depth shall not exceed 0.002 inch for material thicknesses of 0.012 inch, or greater than 0.001 inch for material thicknesses less than 0.012 inch.
5. Arc burns	Arc burns are not acceptable.
F. Duct Bellows Vacuum Jacket Port Neck	
Cracks	Cracks are not acceptable.
G. Fuel System Nickel Plate Insulation	
1. Cracks, punctures, or pin holes	Cracks, punctures, or pin holes are not acceptable.
2. Dents and blisters	Dents are acceptable providing dent does not decrease thickness of foam to less than 0.25 inch. Blisters are acceptable providing they are not cracked, punctured, or contain pin holes.
3. Dents (fuel feed and fuel bleed system ducts only)	Dents, depressions, gouges, pits, and/or similar damage not exceeding 25 percent in depth of the minimum insulation thickness in the discrepant area, or not exceeding 4 inches in length in any direction, are acceptable.
4. Separation of nickel plating at closeout to duct parent metal	Separation is not acceptable.

TABLE 4-1. SSME DUCTS AND LINES INSPECTION CRITERIA (Sheet 12 of 12)

Condition	Hardware Condition Limit
H. Liquid Air Insulators	
1. Surface damage	Any damage that penetrates surface of insulator is not acceptable.
2. Cracks	Cracks are not acceptable.
3. Debonding	Debonding is not acceptable.
I. Identification/Flow Tape (ECP 1225)	
1. Nicks, cuts, and missing pieces	Nicks, cuts, and missing pieces of tape are acceptable, as long as the tape is legible. Nicks, cuts, and missing pieces of tape are not acceptable for flight engine delivery to KSC.
Debonded or missing tape	Debonded or missing tape is not acceptable.
Discolored or melted tape	Discolored or melted tape in the GOX repressurization system is acceptable, as long as the tape is legible. Discolored or melted tape in the GOX repressurization system is not acceptable for flight engine delivery to KSC.

TABLE 4-2. SSME ENGINE SYSTEMS LINE INFORMATION (Sheet 1 of 3)

ITEM	DRAWING	TUBING OD x WT	TUBING MATERIAL	MAX OPER PRESS. (PSI)	SERVICE	FUNCTION
1	RS007103	0.375 x 0.042	Inco 625	650	GN_2/LOX	Main injector purge
2	RS007107	0.250 x 0.028	321 CRES	15	Hyd	Drain
3	RS007111	1.500 x 0.035	321 CRES	15	Fuel	Secondary turbine drain
4	RS007113	0.500 x 0.035 0.750 x 0.035	321 CRES	30	Fuel	HPFT drain
5	RS007114	0.250 x 0.028	321 CRES	15	LOX	MOV drain
6	RS007116	0.250 x 0.028	321 CRES	15	LOX	OPOV drain
7	RS007117	0.250 x 0.028	321 CRES	15	LOX	FPOV drain
8	RS007118	1.500 x 0.035	Inco 625	38	HG	Primary turbine drain
9	RS007119	0.500 x 0.035	Inco 625	3,500	Hyd	CCV and OPOV hydraulic supply
10	RS007120	0.500 x 0.035	Inco 625	3,500	Hyd	MFV and FPOV hydraulic supply
11	RS007121	0.500 x 0.028	321 CRES	270	Hyd	MFV and FPOV hydraulic supply
12	RS007122	0.500 x 0.028	321 CRES	270	Hyd	CCV and OPOV hydraulic return
13	RS007123	0.375 x 0.028	321 CRES	100	He	Intermediate seal purge
14	RS007124	0.250 x 0.028	321 CRES	800	He	OPOV - emergency shutdown
15	RS007125	0.250 x 0.028	321 CRES	800	He	MOV and FPOV - emergency shutdown
16	RS007126	0.250 x 0.028	321 CRES	800	He	FPOV - emergency shutdown
17	RS007127	0.250 x 0.028	321 CRES	800	He	Oxidizer bleed valve control
18	RS007128	0.250 x 0.028	321 CRES	800	He	Fuel bleed valve control
19	RS007130	0.375 x 0.042	Inco 625	800	He/Fuel	Fuel system purge
20	RS007132	0.625 x 0.028	321 CRES	650	GN_2	Main supply
21	RS007133	0.750 x 0.035	321 CRES	800	He	PCA supply
22	RS007134	0.375 x 0.042	Inco 625	650	GN_2	OPB purge
23	RS007135	0.375 x 0.042	Inco 625	650	GN_2	Oxidizer dome purge
24	RS007150	0.250 x 0.028	321 CRES	215	Fuel	LPFT drain
25	RS007163	1.500 x 0.035	321 CRES	15	Oxid	HPOT drain
26	RS007171	0.250 x 0.028	321 CRES	800	He	MFV - emergency shutdown

TABLE 4-2. SSME ENGINE SYSTEMS LINE INFORMATION (Sheet 2 of 3)

ITEM	DRAWING	TUBING OD x WT	TUBING MATERIAL	MAX OPER PRESS. (PSI)	SERVICE	FUNCTION
27	RS007172	0.375 x 0.035	321 CRES	800	GN_2	PB purge
28	RS007212	0.500 x 0.035	Inco 625	3,500	Hyd	MLV supply
29	RS007215	0.500 x 0.028	321 CRES	270	Hyd	MLV return
30	RS007270	0.750 x 0.035	321 CRES	800	He	He supply
31	RS007271	0.250 x 0.028	321 CRES	800	He	Fuel bleed valve control
32	RS007283	0.500 x 0.035	321 CRES	800	He/GOX	Pogo accumulator supply
33	RS007284	0.500 x 0.035	321 CRES	800	He	Accumulator precharge
34	RS007285	0.250 x 0.049	321 CRES	4,128	GOX	GCV GOX supply
35	RS007286	0.500 x 0.028	321 CRES	800	He	Accumulator He supply
36	RS007287	0.250 x 0.028	321 CRES	800	He	GOX valve control
37	RS007288	0.250 x 0.028	321 CRES	800	He	RIV control
38	RS007289	0.250 x 0.028 0.375 x 0.028	321 CRES	170	Oxid	Pogo drain
39	RS007297	1.250 x 0.035	321 CRES	800	GOX/He	Pogo recirculation
40	RS007365	0.250 x 0.049	321 CRES	430	LOX	Instr (BA01A)
41	RS007367	0.250 x 0.049	321 CRES	4,131	GOX	Instr (H02)
42	RS007368	0.375 x 0.035	321 CRES	650	GN_2	HPV warmant
43	RS007369	0.250 x 0.049	321 CRES	4,000	GOX	RIV override
44	RS007371	0.250 x 0.049	321 CRES	3,620	Hot gas	Instr (CG1P)
45	RS010427	0.250 x 0.028	321 CRES	200	Fuel	LPFT drain
46	RS010439	1.125 x 0.035	321 CRES	650	LOX	Pogo recirculation valve
47	R0010747	0.375 x 0.042	Inco 625	650	GN_2/LOX	FPB ASI purge
48	R0010760	0.250 x 0.049	321 CRES	3,500	Hot gas	Instr MCC press
49	R0010828	0.375 x 0.042	Inco 625	650	GN_2	OPB ASI purge
50	R0010938	0.750 x 0.035 1.000 x 0.035 1.250 x 0.035	321 CRES	15	Fuel	Component drain
51	R0010939	0.250 x 0.028	321 CRES	15	Fuel	CCV drain
52	R0010940	0.250 x 0.028	321 CRES	15	Fuel	MFV drain
53	R0011626	0.250 x 0.028	321 CRES	18	Hot gas	Instr primary turbine seal drain
54	R0011628	0.250 x 0.028	321 CRES	15	Fuel	Instr secondary turbine seal drain
55	R0011935	0.250 x 0.028	321 CRES	80	LOX	HPV drain
56	R0011936	0.250 x 0.028	321 CRES	800	He	Pogo - emergency shutdown

TABLE 4-2. SSME ENGINE SYSTEMS LINE INFORMATION (Sheet 3 of 3)

ITEM	DRAWING	TUBING		MAX OPER	SERVICE	FUNCTION
		OD x WT	MATERIAL	PRESS. (PSI)		
57	R0019349	0.250 x 0.028	321 CRES	80	Oxid	AFV drain
58	R0019353	0.250 x 0.028	321 CRES	800	He	CCV - emergency shutdown
59	R0019421	0.875 x 0.035 1.000 x 0.035	321 CRES	80	Oxid	Component drain
60	R0019422	0.250 x 0.028	321 CRES	15	Fuel	Fuel drain purge
61	R0019431	0.375 x 0.035	Inco 625	3,800	GN_2 Hot gas	HPFTP purge
62	R0019438	0.250 x 0.028	321 CRES	15	Hyd	OPOV drain
63	R0019439	0.250 x 0.028	321 CRES	15	Hyd	FPOV drain
64	R0019440	0.250 x 0.028	321 CRES	15	Hyd	MFV lower drain
65	R0019481	0.250 x 0.028	321 CRES	15	Hyd	MFV upper drain
66	R0019550	0.250 x 0.049	321 CRES	4,790	Oxid	Instr. (B04dI)
67	R0019554	0.250 x 0.049	321 CRES	215	Fuel	Instr.
68	R0019561	0.625 x 0.028	321 CRES	650	GN_2	Main supply
69	R0019565	0.250 x 0.028	321 CRES	800	He	CCV - emergency shutdown
70	R0017310	0.500 x 0.035	321 CRES	350	Hot gas	MCC burst diaphragm drain

TABLE 4-3. SSME ENGINE SYSTEMS DUCT INFORMATION

ITEM	DRAWING	TUBING OD x WT	TUBING MATERIAL	MAX OPER PRESS. (PSI)	SERVICE	FUNCTION
1	RS007015	4.006 x 0.203 2.906 x 0.148 2.406 x 0.203	Inco 718	550	Oxygen	Supply liquid oxygen to HPOTP
2	RS007016	1.375 x 0.188	Inco 718	4,050	Oxygen	Oxygen tank pressurant
3	RS007018	Insulated	21-6-9 CRES	320	Hydrogen	Supply hydrogen to HPFTP
4	RS007021	4.330 x 0.165 4.296 x 0.148 2.848 x 0.174	Inco 718	4,650	Oxygen	Supply liquid oxygen to MOV
5	RS007026	Insulated	Titanium	7,100	Hydrogen	Supply hydrogen to MFV
6	RS007029	2.540 x 0.120	Inco 718	4,500	Oxygen	Supply liquid oxygen to HPOTP preburner
7	RS007031	2.250 x 0.138 2.250 x 0.127	Inco 718	8,100	Oxygen	Supply liquid oxygen to preburners-fuel side
8	RS007032	1.535 x 0.219 2.250 x 0.134	Inco 625 Inco 718	8,100	Oxygen	Supply liquid oxygen to preburners-oxygen side
9	RS007034	2.360 x 0.180 2.406 x 0.203	Inco 903	5,600	Hydrogen	Supply hydrogen to LPFTP turbine drive
10	RS007035	2.540 x 0.120 2.630 x 0.165 2.660 x 0.180	Inco 718	4,650	Oxygen	Supply liquid oxygen to LPOTP turbine
11	RS007037	3.060 x 0.180 2.996 x 0.148	Inco 903	3,800	Hydrogen	LPFTP turbine discharge
12	RS007043	Insulated	21-6-9 CRES	30	Hydrogen	High-pressure fuel bleed system
13	RS007168	Insulated	21-6-9 CRES	30	Hydrogen	High-pressure fuel bleed system
14	R035533	Insulated	Inco 718	7,100	Hydrogen	Supply hydrogen to MFV
15	RS007356	2.00 x 0.020	6061-T4 Al ALY TBG	1	Nitrogen or air	Controller coolant/ CCVA warmant

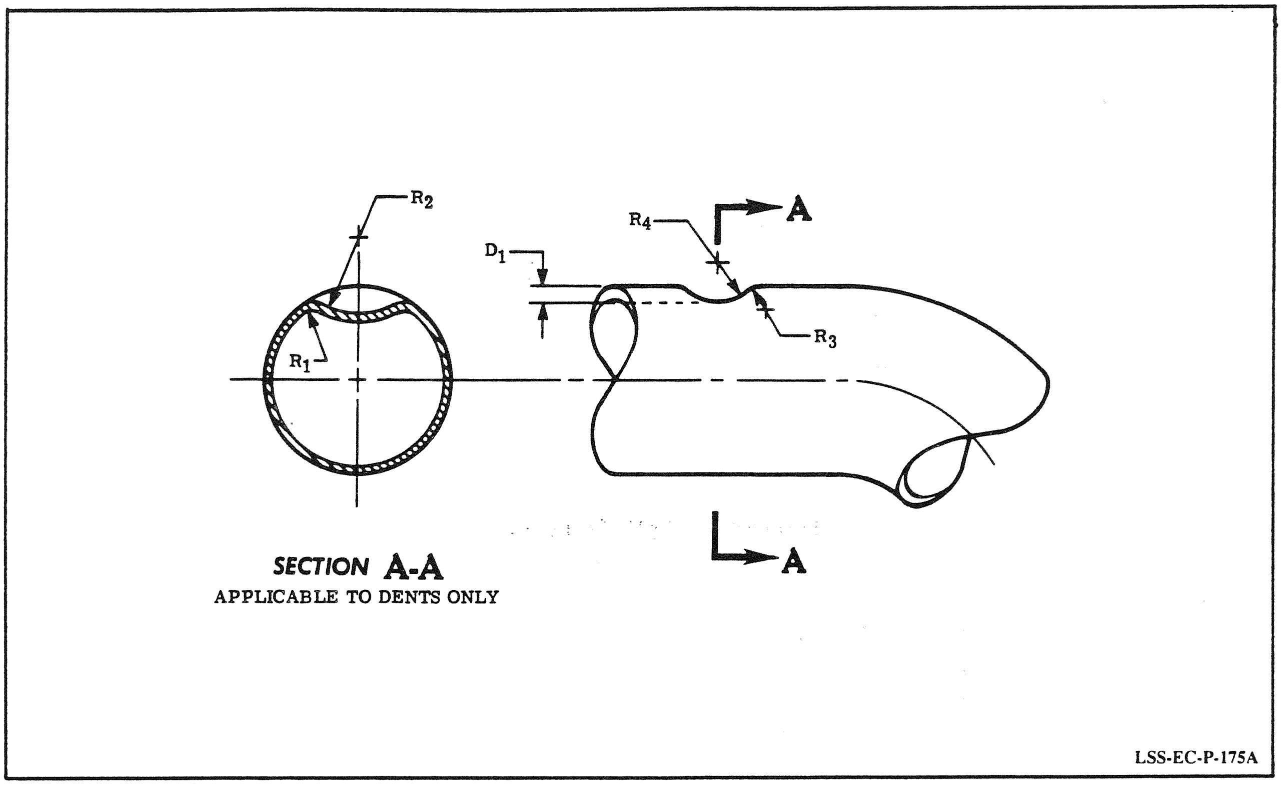


Figure 4-1. Rigid Tube Dent Description

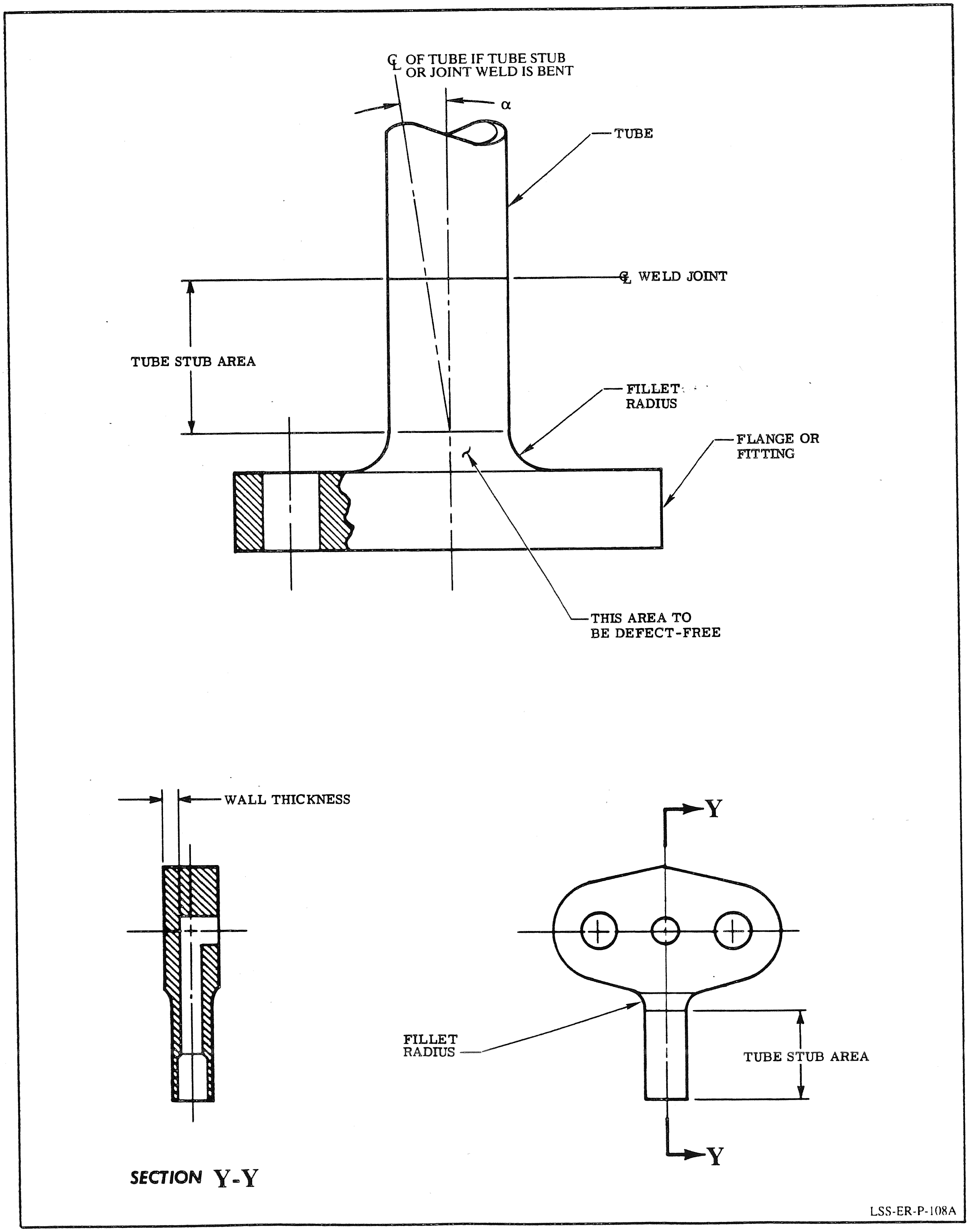


Figure 4-2. Typical Flange Fillet-Radius Areas

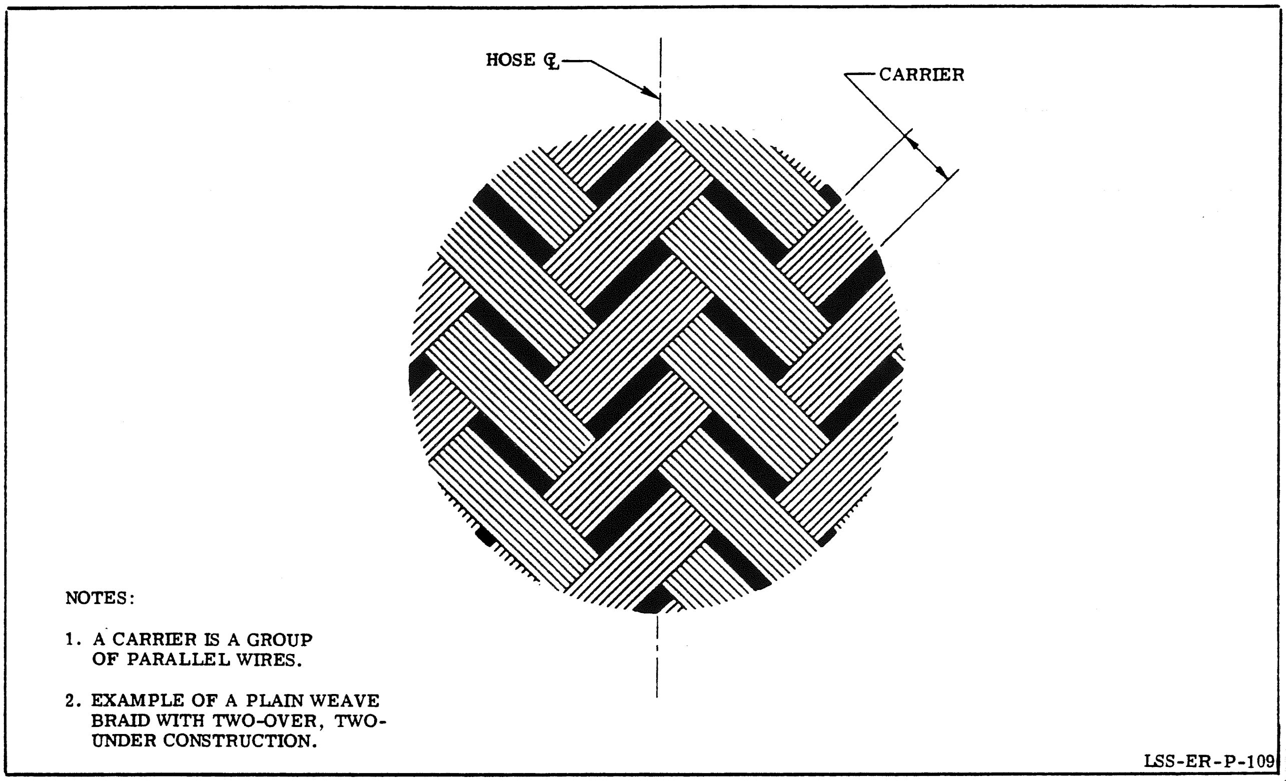


Figure 4-3. Flex Line Braid Definition

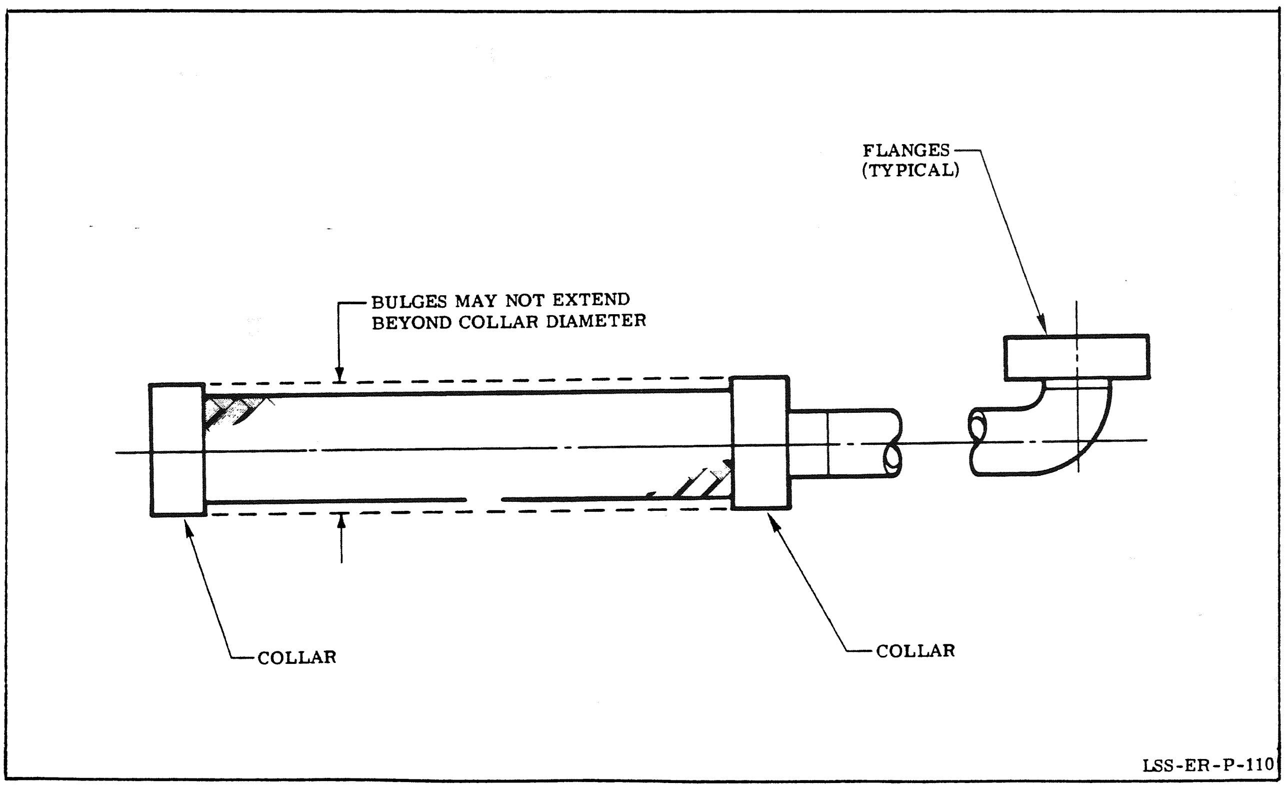


Figure 4-4. Flex Line Braid Bulge Limitations

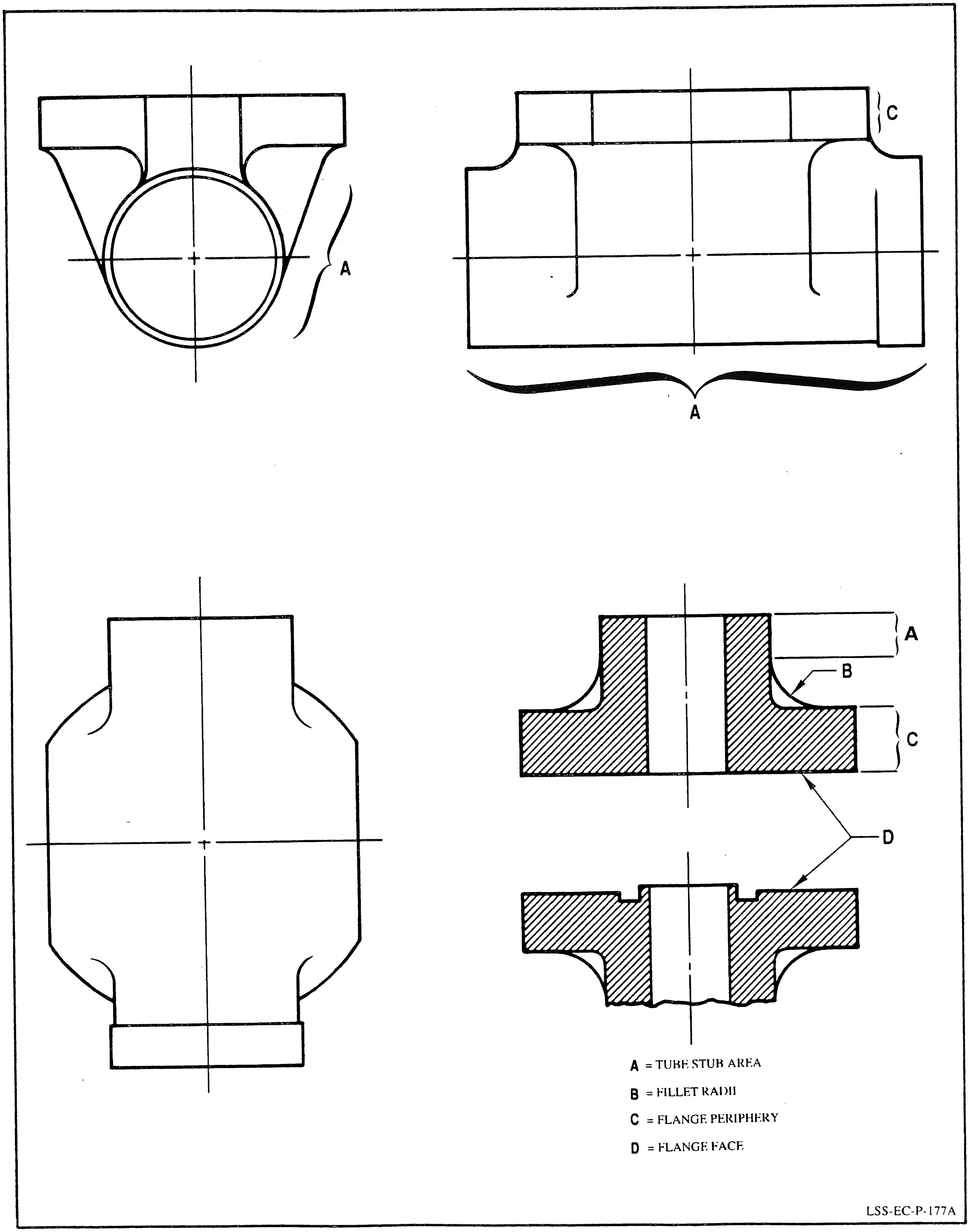
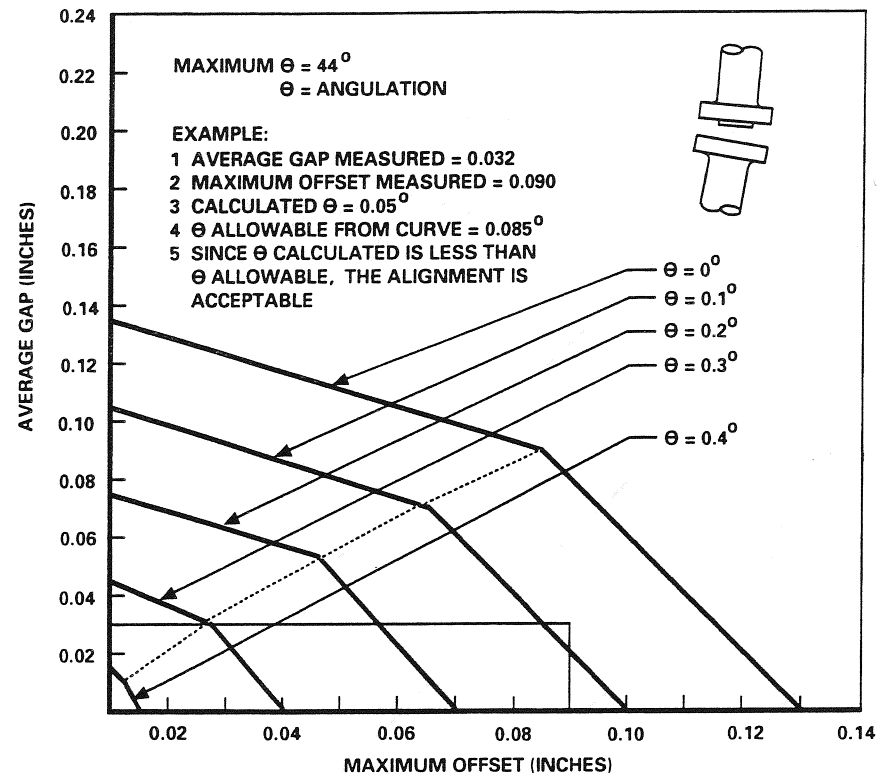


Figure 4-5. Duct Flange Description - Typical



NOTE: THIS CHART DOES NOT PROVIDE JOINT ANGULARITY WITH GIVEN GAP AND OFFSET. ALL THREE COMPONENTS OF ALIGNMENT MUST BE KNOWN TO ESTABLISH ACCEPTABILITY USING THIS CHART.

LSS-EC-P-576

Figure 4-6. High Pressure Fuel Duct Joint F4 (Free State Measurement)

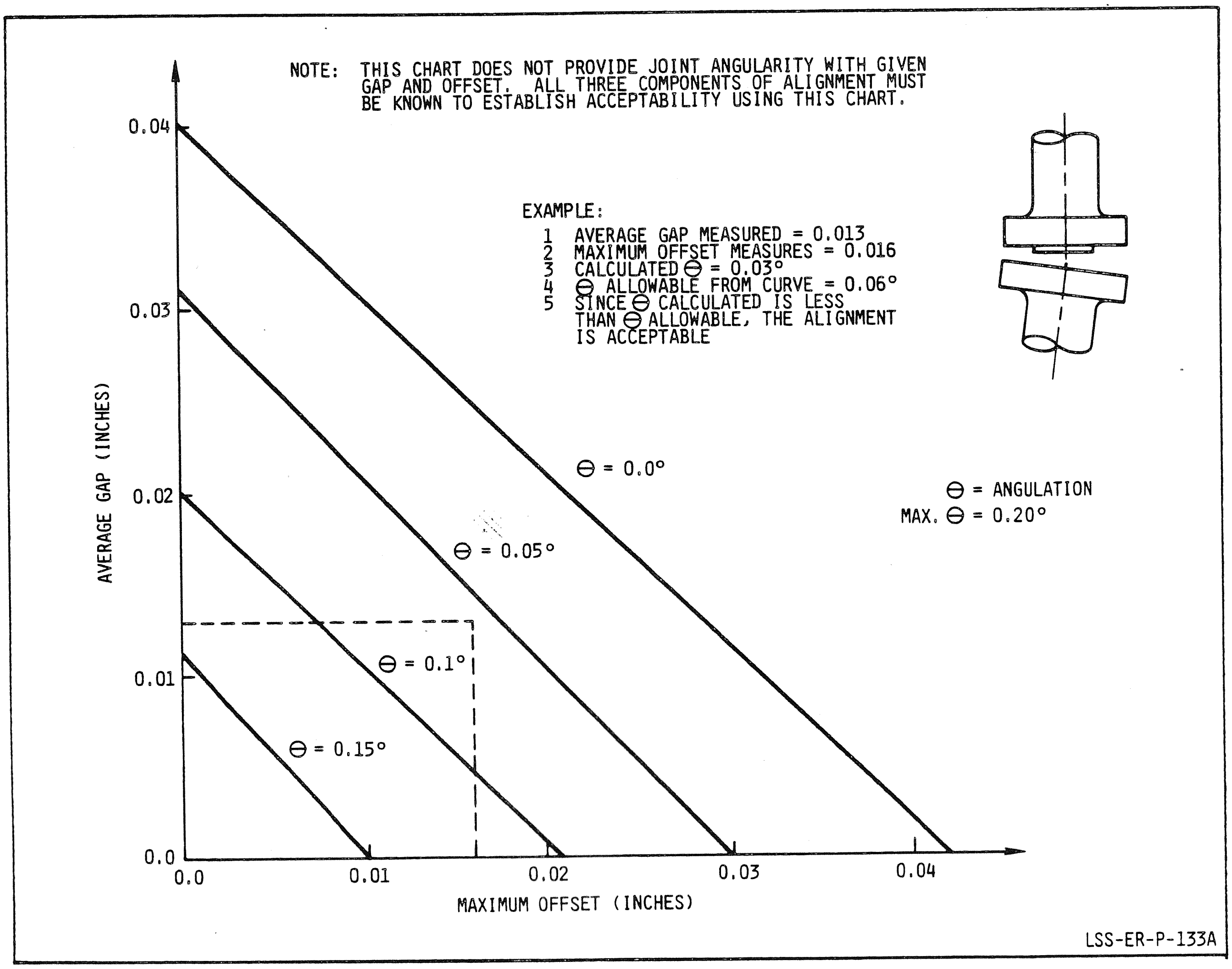


Figure 4-7. HP Fuel Duct Joint F5 (Free State Measurement)

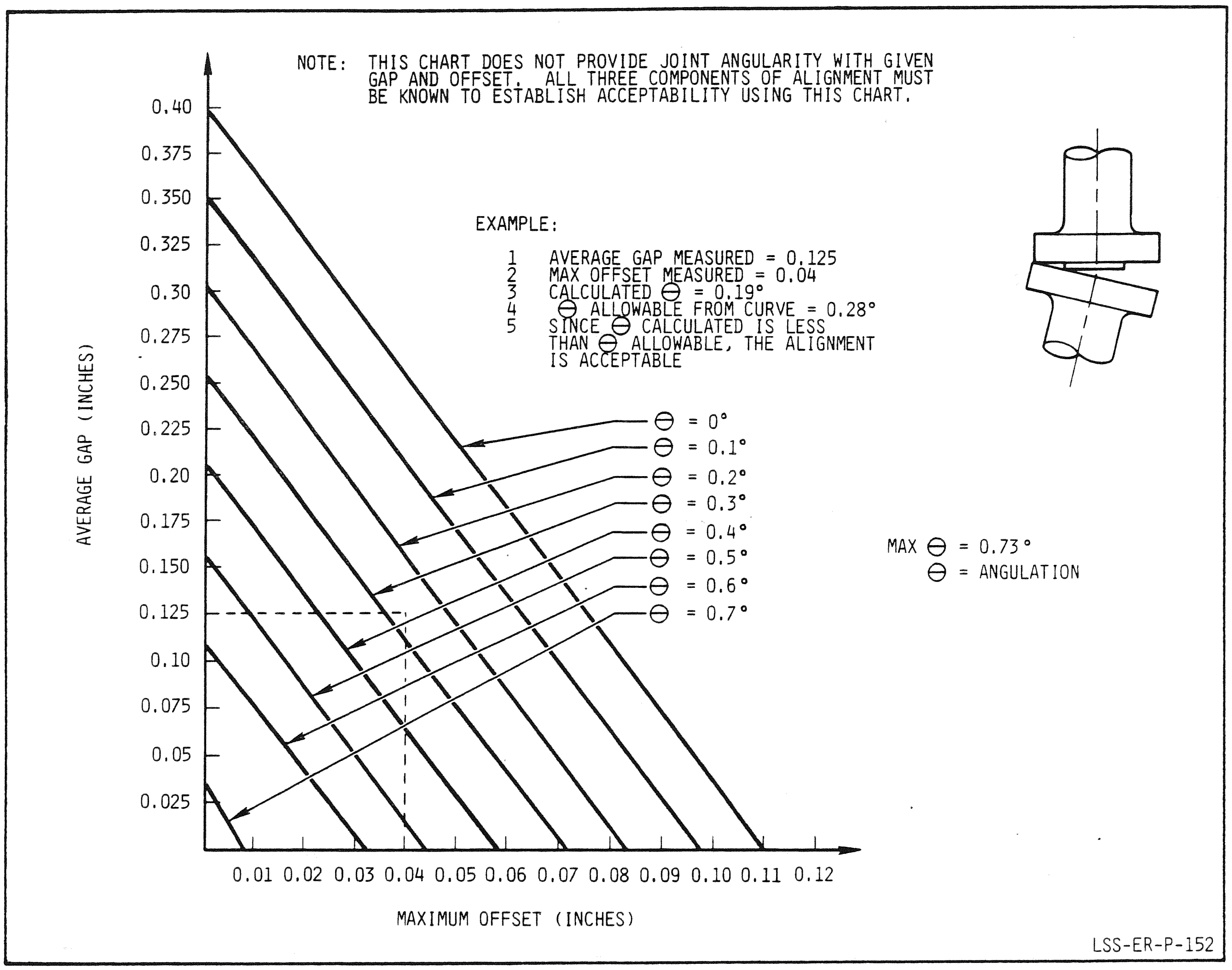


Figure 4-8. HP Fuel Duct (Inco 718) Joint F4 (Free State Measurement)

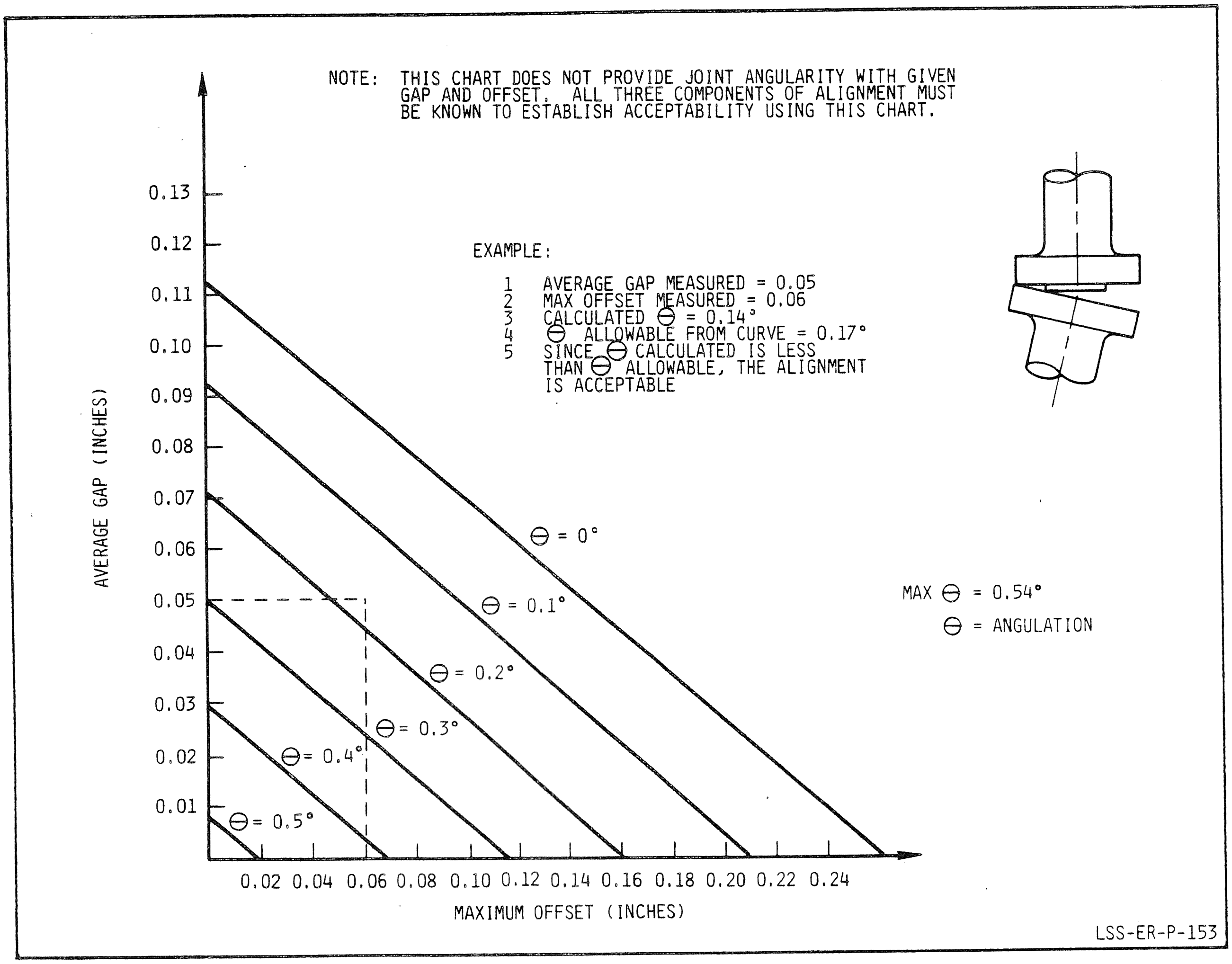


Figure 4-9. HP Fuel Duct (Inco 718) Joint F5 (Free State Measurement)

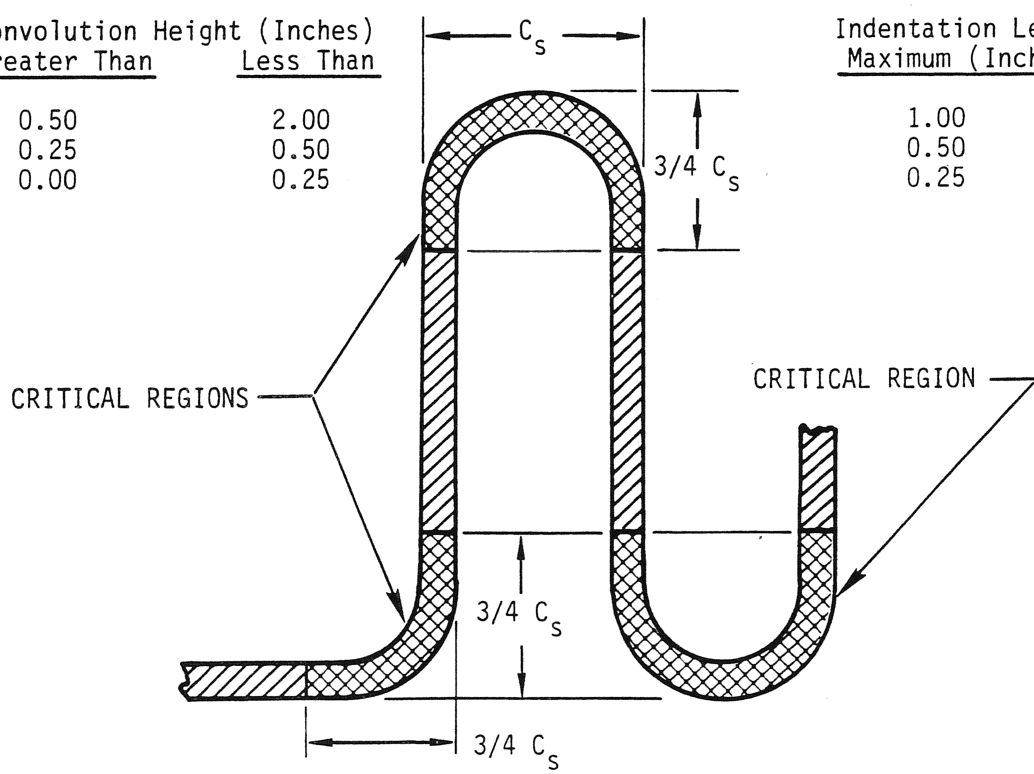
NICKS AND SCRATCHES:

Critical Region	Critical Orientation[a]	Material Thickness (Inches) <0.012	Material Thickness (Inches) >0.012	Depth (Inches)
Yes	Yes		X	0.001
Yes	Yes	X		0.0005
Yes	No		X	0.002
Yes	No	X		0.001
No	Yes		X	0.002
No	Yes	X		0.001
No	No		X	0.002
No	No	X		0.001

(a) Applies to scratch-type irregularities which are 45 degrees or less to the plane of the convolutions. The plane of the convolutions is normal to the bellows centerline.

DENTS IN CRITICAL REGIONS:

Convolution Height (Inches) Greater Than	Convolution Height (Inches) Less Than	Indentation Length Maximum (Inches)
0.50	2.00	1.00
0.25	0.50	0.50
0.00	0.25	0.25



LSS-EC-P-94

Figure 4-10. Bellows Damage Limits for Nicks, Scratches, and Dents

SECTION V

INSPECTION CRITERIA
FOR
AVIONICS

SECTION V

CHANGE RECORD

REV/ CHG	DATE	CHANGE SUMMARY	PAGE EFFECT	RCN/CCBD
PRELIM	3/6/85	PRELIMINARY FOR OMRSD REVIEW/ APPROVAL CYCLE	ALL	RCN MV6596 (RELEASED FOR REVIEW 8/26/85)
BASIC	3/6/85	BASIC SECTION RELEASED	ALL	RCN MV6596 (APPROVED 9/26/85)
REV	8/10/87	UPDATED SECTION TO THE LATEST REQUIREMENTS	ALL	RCN MV8301 (APPROVED 7/28/88)
CHG 1	7/5/89	UPDATED SECTION TO THE LATEST REQUIREMENTS	5-3, 5-9	CCBD NO. ME3-00-7675 (APPROVED 6/29/89)
REV	11/1/89	UPDATED SECTION TO THE LATEST REQUIREMENTS	5-15/ 5-16	CCBD NO. ME3-00-7909 (APPROVED 9/29/89)
REV	10/25/90	UPDATED SECTION TO THE LATEST REQUIREMENTS	NONE	CCBD NO. ME3-AA-5445 (APPROVED 6/20/89)
REV	2/10/92	UPDATED SECTION TO THE LATEST REQUIREMENTS	5-3, 5-9 THRU 5-10, 5-12 THRU 5-14	SPECIFICATION RF0001-053 REVISION E-1 (APPROVED 10/30/91)
CHG 1	2/27/92	UPDATED SECTION TO THE LATEST REQUIREMENTS	5-11, 5-12	SPECIFICATION RF0001-053 REVISION E-1 (APPROVED 10/30/91)
REV	5/29/92	UPDATED SECTION TO THE LATEST REQUIREMENTS	5-3, 5-4, 5-9	SPECIFICATION RF0001-053 REVISION F-4 (APPROVED 5/19/92)
REV	6/24/92	UPDATED SECTION TO THE LATEST REQUIREMENTS	5-3, 5-13	SPECIFICATION RF0001-053 REVISION F-5 (APPROVED 7/21/92)

SECTION V

CHANGE RECORD (continued)

REV/ CHG	DATE	CHANGE SUMMARY	PAGE EFFECT	RCN/CCBD
REV	11/5/92	UPDATED SECTION TO THE LATEST REQUIREMENTS	5-5, 5-15	SPECIFICATION RF0001-053 REVISION G-1 (APPROVED 11/17/92)
REV	2/16/93	UPDATED SECTION TO THE LATEST REQUIREMENTS OF RF0001-053	5-5, 5-6	SPECIFICATION RF0001-053 REVISION G-2 (APPROVED 2/11/93)
REV	3/10/93	UPDATED SECTION TO THE LATEST REQUIREMENTS OF RF0001-053	5-5	SPECIFICATION RF0001-053 REVISION G-3 (APPROVED 3/16/93)

SECTION V

INSPECTION CRITERIA FOR AVIONICS

5.1 SCOPE

This section contains inspection criteria for the SSME avionics including harnesses, sensors, igniters, main engine controller, FASCOS controller, and hydraulic actuator wireways. (Refer to table 5-1.)

5.2 OMRSD

The hardware condition limitation of the inspection criteria supports the OMRSD requirements listed below. Hardware conditions that are within these limitations require no further action or rework. Hardware conditions resulting from operational degradation that do not meet these limitations shall be processed through the PR/MR system.

V41BUO.030 PERFORM SSME COMPONENTS EXTERNAL INSPECTION

5.3 APPLICABLE DOCUMENTS

The following documents are listed as source reference only.

SPECIFICATIONS

Rockwell International

	REV	
RF0001-053	G-3	Space Shuttle Main Engine Inspection Criteria
RF0001-008	C	Braided Harness, Standard Repair of
RF0001-116	-	Spline Teeth, Actuator Body, Standard Repair
RL00294	G-1	Armored Harnesses, Overhaul/Recycle/Repair Requirements
RL00295	G	Conventional Harnesses, Overhaul/Recycle/Repair Requirements
RL00296	E-2	Integral Igniter, Overhaul/Recycle/Repair Requirements
RL00297	D-2	Temperature-Resistance Type Transducer, Overhaul/Recycle/Repair Requirements

	REV	
RL00363	G-1	Lightning Braided Harnesses, Overhaul/Recycle/ Repair Requirements
RL00645	C	Controller, Overhaul/Recycle/Repair Requirements
RL00842	-2	FASCOS, Overhaul/Recycle/Repair Requirements

Hydraulic Research

41003720		Overhaul/Recycle Specification, Preburner Valve Actuator
41003730		Overhaul/Recycle Specification, Main Oxidizer & Main Fuel Valve Actuator
41003740		Overhaul/Recycle Specification, Chamber Coolant Valve Actuator

TABLE 5-1. SSME AVIONIC COMPONENTS INSPECTION CRITERIA (Sheet 1 of 9)

Condition	Hardware Condition Limit
A. Armored and Lightning Braided Harnesses	
1. Loose braid or disrupted braid pattern	Acceptable unless tubing beneath braid is visible in an area equal to or greater than 1 percent of total surface area in 3 linear inches of harness and whose largest diameter is not greater than 0.150 inch.
2. Broken strands or carriers in armor braid	Random individual broken strands are acceptable provided they are clipped off flush with braid surface. Sealing of such strands is not required. Broken carriers are acceptable provided that at any one point is no more than two complete carriers are broken and no more than five such points are present in any 2-foot length of harness. These broken carriers are to be clipped off flush to harness surface. Sealing of such carriers is not required.
3. Dents and raised braid	Dents, bends, and risers are acceptable up to 20 percent of cable diameter.
4. Heat shrinkable overmold defects	Surface defects, such as small blisters (1/8-inch diameter or less), minor nicks, holes, scratches, or impressions are acceptable. Cut or severely damaged overmold is not acceptable.
5. Thermal protective boots	Same as overmold limits.

TABLE 5-1. SSME AVIONIC COMPONENTS INSPECTION CRITERIA (Sheet 2 of 9)

Condition	Hardware Condition Limit
A. Armored and Lightning Braided Harnesses (continued)	
6. Heat-shrinkable silicone rubber tubing defects	Slight surface defects, such as small blisters (1/8-inch diameter or less), minor nicks, scratches, or impressions are acceptable. Tubing containing cuts 1 inch in length or less may be repaired provided that harness insulation has not been damaged and no more than two cuts are present in 1 foot of harness.
7. Birdcaging (neckdown) behind connector adapter	Acceptable if reduction in diameter is less than 10 percent and ramp under braid has not been sheared. Harnesses that are limber (flexible as compared to other sections of harness that are same diameter) behind adapter and have braid necked down are not acceptable.
B. Conventional Harnesses	
1. Lacing cord damage	Broken cord sections are not acceptable. Slippage of dimension, frayed end ties, and fraying from wear are acceptable.
2. Wire (conductor) damage	Cut or nicked insulation on individual conductors is not acceptable. Minor abrasion is acceptable.
3. Cable jacket damage	Cable jacket may be cut through but no more than a single carrier of shield braid may be cut through in same area. Jacket and braid damaged areas shall not exceed one area in 6 inches of cable.

TABLE 5-1. SSME AVIONIC COMPONENTS INSPECTION CRITERIA (Sheet 3 of 9)

Condition	Hardware Condition Limit
C. Electrical Connectors, All Components (Table 5-2)	
1. Connector shell defects	If walls around safety wire holes in threaded plug coupling nuts are broken, plug is acceptable if an undamaged safety wire hole is available and satisfactory safety wire installation can be made. Connector shells, including coupling and clamping nuts that are broken, cracked, bent, or corroded are not acceptable.
2. Bent pins or sockets	Bent pins or sockets in connectors with removable pins and sockets are not acceptable. Glass or ceramic sealed connectors with bent contacts sizes 14 or larger are not acceptable. Glass or ceramic sealed connectors with pins, sizes 16 or smaller: bent pins may be straightened if the pin contains only one bend less than 20 degrees with respect to the connector axis. (See figure 5-1.) One individual pin may not be straightened more than 5 times. Record is maintained in the engine log book.
3. Cracked contacts or glass header	Not acceptable if detected with 7-power magnification or less. Crazing of glass meniscus about the pin is acceptable.
4. Unseated contacts	Connectors with removable contacts with unseated pins or sockets: contacts may be reseated followed by a 4-7 pound compression test to verify contact retention.
5. Pin corrosion and plating damage	Corrosion and plating damage is not acceptable.

TABLE 5-1. SSME AVIONIC COMPONENTS INSPECTION CRITERIA (Sheet 4 of 9)

Condition	Hardware Condition Limit
C. Electrical Connectors, All Components (continued)	
6. Connector finish defects	Minor surface burnishes or scratches are acceptable. Damage that exceeds one-half connector-metal thickness is not acceptable.
7. Obliterated connector markings	Markings that have been removed due to application and removal of torque-lock material are acceptable.
8. Hydraulic actuator connector stains or deposits	Stains and/or deposits inside of connectors is acceptable, provided they are not located in the area of contact between the connector and mating connector.
D. Sensors	
1. Damaged sensing probe, hot gas temperature sensors	Minor surface defects, grit blasting, erosion, discoloration, etc, is acceptable. Minor defects are defined as any defect less than 0.010 inch in depth; width and length of defect is not a factor. Minor surface defects, 0.25 inch outside of weld or fillet radius of flange are acceptable. Any defect in weld or fillet radius of flange is not acceptable. Cracks are not acceptable.
2. Evidence of moisture around hot gas temperature sensors	Moisture (water droplets) found during sensor removal prior to engine drying is acceptable.
3. Damaged sensing probe/port, all sensors except hot gas temperature sensors	Dents, dings, scratches, erosion, or cracks are not acceptable. Clogged pressure sensor inlet holes are not acceptable.

TABLE 5-1. SSME AVIONIC COMPONENTS INSPECTION CRITERIA (Sheet 5 of 9)

Condition	Hardware Condition Limit
D. Sensors (continued)	
4. Damaged threaded surfaces	Damaged threaded surfaces are not acceptable. NOTE: If damage does not exceed an equivalent circumference of 50 percent of one thread, the threads may be reworked.
E. Spark Igniters (See figure 5-2.)	
1. Discoloration, erosion, and blisters on copper	Discoloration is acceptable. Erosion of 90 percent of the surface area is acceptable (no depth restriction, ie erosion, can penetrate the copper face). All cracks are acceptable (no depth, length, or width restrictions). Multiple cracks of the copper face are acceptable. Delamination of the copper face is not acceptable.
2. Discoloration and cracks of the Inconel tip (at the surface beneath the copper face and also the tip internal diameter)	Discoloration is acceptable. Cracks greater than 0.125 inch in length (no depth restriction) are not allowed. Multiple cracks not allowed.
3. Cracks, chips, and discoloration of secondary ceramic insulator (outermost ceramic nearest tip)	Discoloration is acceptable. All cracks and chipouts, regardless of quantity and size, are acceptable as long as the secondary insulator, or portion thereof, maintains isolation of the secondary electrode from the Inconel (625) tip.
4. Damage to secondary floating electrode	Surface pitting and discoloration is acceptable. Melting or other deformation, which results in a short circuit or evidence of a short circuit, is not acceptable. Shifting causing the electrode to be off-axis (ie, not parallel to the Inconel tip and copper face) is not allowed. Chipouts greater than 270 degrees of undiscernible depth are not acceptable.

TABLE 5-1. SSME AVIONIC COMPONENTS INSPECTION CRITERIA (Sheet 6 of 9)

Condition	Hardware Condition Limit
E. Spark Igniters (continued)	
5. Damage to primary ceramic insulator	Discoloration is acceptable. Cracks, quantity greater than 6, are not acceptable. Total area of cracks and chipouts shall not exceed 15 degrees.
6. Damage to primary electrode	Surface pitting and grey or black discoloration is acceptable.
7. Damage to threaded surfaces	Damaged threaded and sealing surfaces are not acceptable.
8. Dry film lubricant coating	Dry-film-lubricant wear on threads and load-bearing surface (outside seal groove) is acceptable.
F. Main Engine Controller	
1. Damaged surface finish	Missing paint or scratches in paint that are less than 0.060-inch deep and of any width are acceptable.
2. Damaged fins	Bent fins that are not cracked and do not touch adjacent fins are acceptable.
3. Dented pressurization valve cover	Burrs and displaced metal are not acceptable. Dents in pressurization valve cover are acceptable if depression does not touch valve.
4. Exposure to Firex	Exposure to high-pressure water is acceptable provided all connector receptacles are cleaned/dried after exposure.
5. Exposure to radiation	Exposure up to 5 Roentgen dose, measured at nearest point on controller ($\pm$30 degrees) from source is acceptable.

TABLE 5-1. SSME AVIONIC COMPONENTS INSPECTION CRITERIA (Sheet 7 of 9)

Condition	Hardware Condition Limit
F. Main Engine Controller (continued)	
6. Bent pins	Bent pins may be straightened if pin contains only one bend less than 20 degrees with respect to connector axis (straightened pins will require inspection of plating for integrity).
7. Pin discoloration and missing gold plating	Discoloration or missing gold plating exceeding 15 percent of pin contact area is not acceptable.
G. FASCOS Controller	
1. Damaged surface finish	Missing paint or scratches in paint that are less than 0.060-inch deep and of any width are acceptable.
2. Dented pressurization valve cover	Dents in pressurization valve cover are acceptable if depression does not touch valve.
3. Exposure to Firex	Exposure to high-pressure water is acceptable provided all connector receptacles are cleaned/dried after exposure.
4. Bent pins	Bent pins may be straightened if pin contains only one bend less than 20 degrees with respect to connector axis (straightened pins will require inspection of plating for integrity).
5. Pin discoloration and missing gold plating	Discoloration or missing gold plating exceeding 15 percent of pin contact area is not acceptable.

TABLE 5-1. SSME AVIONIC COMPONENTS INSPECTION CRITERIA (Sheet 8 of 9)

Condition	Hardware Condition Limit
H. Hydraulic Actuators	
1. Actuator wireways:	
Cover breaks	Tears, cuts, pinholes in the outer wireway covering (black Teflon) are acceptable on part number actuators RES1008-5112, -6109, -7313, -8115 and subs, provided the damage does not extend through the wireway inner core.
Kinks	All wireway kinks are acceptable, provided there is no unacceptable break in the covering.
Clamping rubber defects	Defects are acceptable, provided rubber is present between the wireway and the clamp steel.
Contact between fittings	Contact between fittings on adjacent wireways is acceptable, provided no wear is evident.
Loose fittings	Loose fittings are acceptable, provided the safety wire is not damaged.
Rusted fittings	Surface rust is acceptable. Severe rusting with structural deterioration of the fitting is not acceptable.
2. Damaged safety wire lugs	Bent lugs that are not used are acceptable.
3. Damaged safety wire	Damaged or imperfect safety wire is not acceptable.
4. Label damage	Damage to labels on servocomponents, RVDTs and actuator body are acceptable provided that the part number and serial number are legible.

TABLE 5-1. SSME AVIONIC COMPONENTS INSPECTION CRITERIA (Sheet 9 of 9)

Condition	Hardware Condition Limit
H. Hydraulic Actuators (continued)	
5. Loose rust in actuator to valve coupling cavity	Small amounts of loose rust that can be removed from the actuator coupling cavity is acceptable.
6. Damaged spline teeth	Damaged spline teeth are acceptable if less than 5 percent (volume) of each tooth is damaged. Repair raised material in accordance with Specification RF0001-116.
7. Damaged helical inserts	Damaged inserts are not acceptable.
8. Pin plug potting damage	Missing or damaged potting such that moisture could enter the pin plug is not acceptable.
9. Actuator burst diaphragm (without protective bracket):	
Scratches, nicks, and gouges	Scratches, nicks, and gouges less than 0.002-inch deep on the flanges or barrel are acceptable, as long as there is no damage to the diaphragm coin area.
	Scratches, nicks, gouges, or evidence of impact on the diaphragm coin area are not acceptable.
10. Cover (part number R055302):	Bends or deformations are acceptable provided they do not affect the coined area of the diaphragm.
Scratches, nicks, gouges, bends, or deformation	Scratches, nicks, or gouges are acceptable provided there is no penetration through the cover.
I. Hydraulic filter	
Damaged helical insert	Damaged inserts are not acceptable.

TABLE 5-2. ELECTRICAL CONNECTOR PIN RECORD

SPACE SHUTTLE ACCEPTANCE DATA PACKAGE
ELECTRICAL CONNECTOR PIN RECORD

ENGINE P/N ________

MODEL SSME ________ TYPE OF REPAIR BENT ELECTRICAL CONNECTOR PINS ________ ENGINE S/N ________

PHYSICAL LOCATION		HARNESS P/N	HARNESS S/N	NO. OF TIMES BENT	ACCUM. NO. OF TIMES BENT	ALLOW. NO. OF TIMES BENT	REMAINING NO. OF TIMES BENT	DATE	INSPECTION
CONNECTOR REFERENCE DESIGNATION P OR J NUMBER	PIN DESIGNATION								
						5			

REQUIREMENT SOURCE RL10014 ________ IDENTIFICATION METHOD CHARTED ________

REPAIR LIMITATION REQUIREMENT: ANY ONE PIN SHALL NOT BE STRAIGHTENED MORE THAN FIVE (5) TIMES

PAGE ____ OF ____

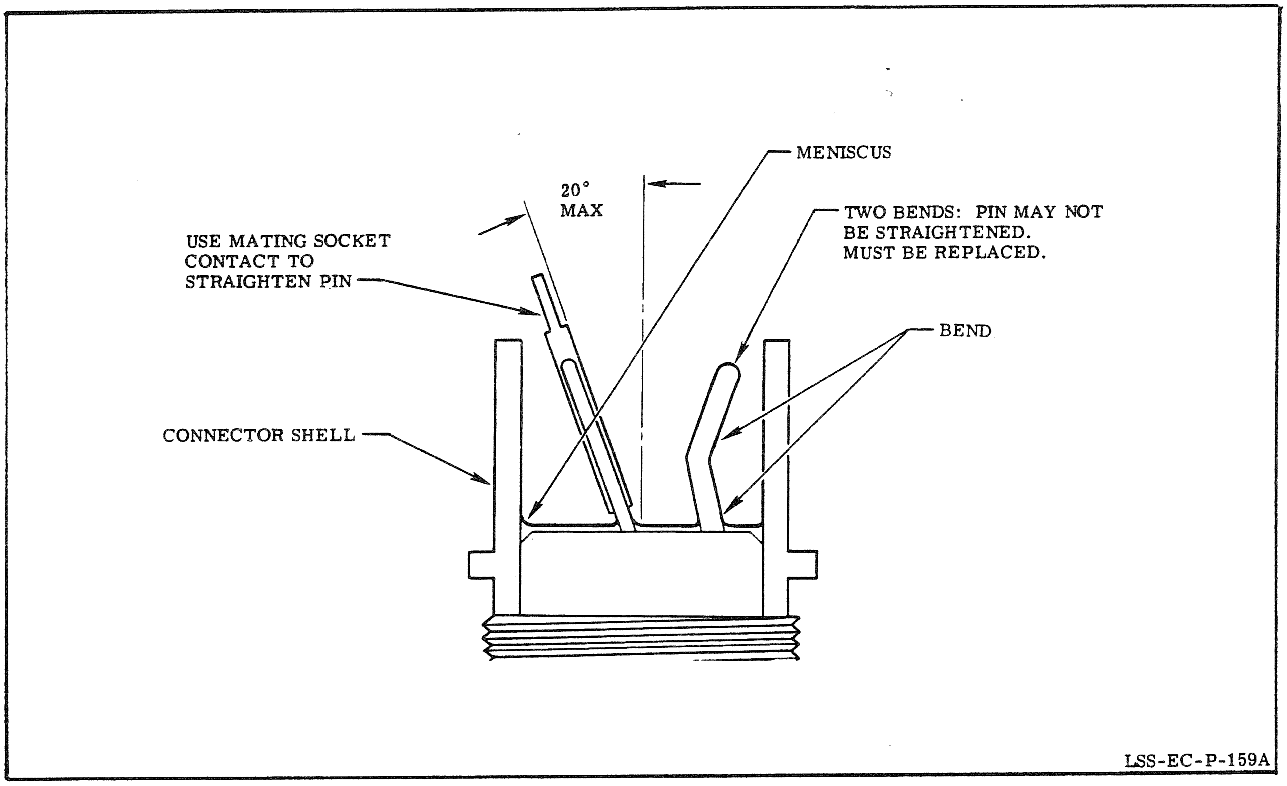


Figure 5-1. Connector Bent Pin Limits

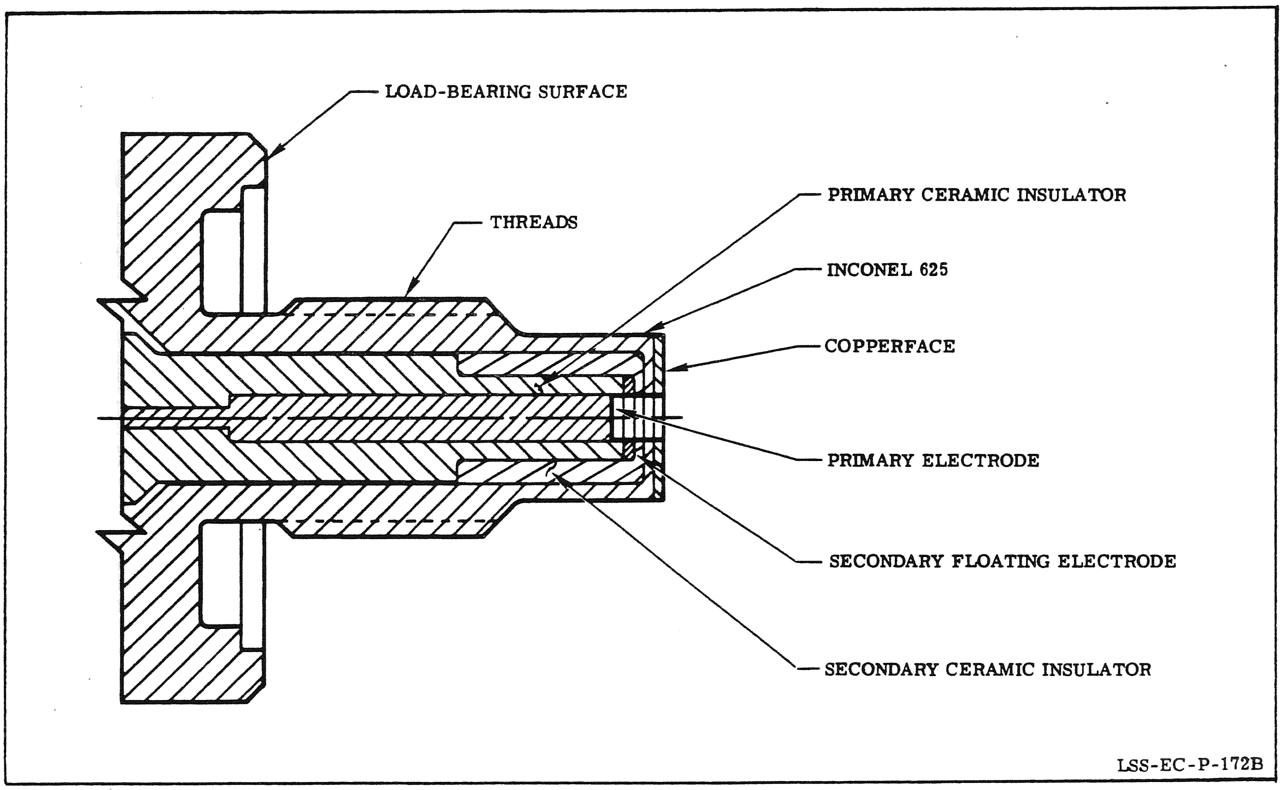


Figure 5-2. Spark Igniter