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LONG-TERM CF6 ENGINE PERFORMANCE DETERIORATION - EVALUATION OF ENGINE S/N 451-479

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16. Abstract This report summarizes the performance testing and analytical teardown of CF6-6D engine serial number 451-479 at the General Electric Aviation Service Operation, Ontario, California. This United Airlines engine had completed its initial installation on DC-10 aircraft number N3029U. The investigative test program was conducted inbound prior to normal overhaul/refurbishment. The performance testing included an inbound test, a test following cleaning of the low pressure turbine airfoils, and a final test after leading edge rework and cleaning the stage one fan blades. The analytical teardown consisted of detailed disassembly inspection measurements and airfoil surface finish checks of the as received deteriorated hardware. Included in this report is a detailed analysis of the test cell performance data, a complete analytical teardown report with a detailed description of all observed hardware distress, and an analytical assessment of the performance loss (deterioration) relating measured hardware conditions to losses in both SFC (specific fuel consumption) and EGT (exhaust gas temperature).			
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TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
1.0 INTRODUCTION	1
2.0 OBJECTIVES	2
3.0 ENGINE HISTORY	3
4.0 SUMMARY OF EVENTS	4
5.0 451-479 PERFORMANCE SUMMARY	5
6.0 POSTTEST TEARDOWN RESULTS	17
6.1 High Pressure Compressor Section	17
6.1.1 HP Compressor Rotor Assembly	17
6.1.1.1 General Inspection	17
6.1.1.2 Rotor Land Rubs	17
6.1.1.3 Rotor Land Coating Condition	17
6.1.1.4 Blade Airfoil Condition	18
6.1.1.5 Blade Surface Finish	18
6.1.1.6 Rotating CDP Seal	19
6.1.2 High Pressure Compressor Stator Assembly	19
6.1.2.1 General Inspection	19
6.1.2.2 Condition of Variable Stator Bushings	20
6.1.2.3 Vane Airfoil Condition	20
6.1.2.4 Casing Rubs	20
6.1.2.5 Vane Surface Finish	21
6.1.3 Compressor Rear Frame	22
6.1.3.1 General	22
6.1.3.2 Combustor	22
6.1.3.3 Stationary CDP Seal, Forward	22
6.1.3.4 No. 4B Pressure Balance Seal Measurements	23
6.2 High Pressure Turbine Section	25
6.2.1 Stage 1 High Pressure Turbine Nozzle Assembly	25
6.2.1.1 General Inspection	25
6.2.1.2 Drop Dimension - CRF to Stage 1 Vanes	26
6.2.1.3 Vane Outer Platform Gap Measurements	26
6.2.1.4 Area Check (A_4)	27
6.2.1.5 Airfoil Surface Finish Checks	27
6.2.2 Stage 2 High Pressure Turbine Nozzle Assembly	28
6.2.2.1 General Inspection	28

TABLE OF CONTENTS (Continued)

<u>Section</u>	<u>Page</u>
6.2.2.2 Shroud Rubs and Condition of Bradelloy	28
6.2.2.3 Vane Condition	28
6.2.2.4 Spoolie Spring Washers	29
6.2.2.5 Nozzle Support	29
6.2.2.6 Interstage Seal Grooves	30
6.2.2.7 Stage 1 and Stage 2 Shroud Radii	30
6.2.3 High Pressure Turbine Rotor Assembly	33
6.2.3.1 General Inspection	33
6.2.3.2 HPTR Blade Airfoil Surface Finish	33
6.2.3.3 Rotor Blade Tip Measurements	34
6.2.3.4 HPT Blade Clearances	36
6.2.3.5 Thermal Shield Seal Teeth	36
6.2.3.6 Forward Shaft Seals Dimensions	37
6.3 Low Pressure Turbine Section	39
6.3.1 Turbine Midframes	39
6.3.1.1 General	39
6.3.1.2 LPT Pressure Balancing Seal	40
6.3.1.3 Stage 1 LPTN Vane Airfoil Surface Finish	40
6.3.2 Low Pressure Turbine Rotor	41
6.3.2.1 General Inspection	41
6.3.2.2 Dimensional Inspections	41
6.3.2.3 Airfoil Surface Finish Checks (RMS)	42
6.3.2.4 Rebuild	43
6.3.3 Low Pressure Turbine Stator Assembly	44
6.3.3.1 General Inspection	44
6.3.3.2 Airfoil Surface-Finish Checks	44
6.3.3.3 Rebuild	46
6.4 Fan Section	47
6.4.1 Fan Rotor	47
6.4.2 Fan Stator	48
6.4.3 Stage 1 Fan Blade Tip Clearances	48
6.4.3.1 Rotor Runout	48
6.4.3.2 Shroud Runout	51
6.4.3.3 Blade-to-Shroud Clearances	51
7.0 ANALYTICAL ASSESSMENT OF PERFORMANCE LOSSES	52
8.0 APPENDICES	60
8.1 Appendix A - Fuel Analysis	61

TABLE OF CONTENTS (Concluded)

<u>Section</u>	<u>Page</u>
8.2 Appendix B - Photographs	62
8.3 Appendix C - Log Sheets, Inbound Run	91
8.4 Appendix D - Log Sheets, Tests 2 and 3	97

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LIST OF ILLUSTRATIONS

<u>Figure</u>		<u>Page</u>
5-1.	CF6-6D Cruise Deterioration.	6
5-2.	CF6-6D Inbound Sea Level Deterioration.	7
5-3.	CF6-6D Inbound Sea Level Deterioration.	8
6-1.	LPTS Shroud and Interstage Seal Rub Impressions.	45
7-1.	General Electric CF6-6 Engine Cross Section.	56
8-1.	High Pressure Compressor Rotor (Cleaned), Missing Blades at Surface Finish Check.	63
8-2.	HP Compressor Rotor Stages 13 to 15 Land Coating.	64
8-3.	HP Compressor Stator Upper Overall Oil, Dirt, Rubs.	65
8-4.	HP Compressor Stator, Upper Stage 7 to OGV - Rubs.	66
8-5.	HP Compressor Stator, Lower Stage 9 to OGV - Rubs.	67
8-6.	Combustor, Overall Cracks.	68
8-7.	Combustor, Closeup Crack at 7 o'clock.	69
8-8.	Compressor Rear Frame, Forward Seals - Overall View, Installed.	70
8-9.	No. 4B Pressure Balance Seal, Overall View.	71
8-10.	Stage 1 HP Turbine Nozzle Assembly, Aft End, Overall View.	72
8-11.	Stage 1 HP Turbine Nozzle Assembly, Trailing Edge, Burnt/ Distorted Vanes.	73
8-12.	Stage 1 HP Turbine Nozzle Assembly Distress, Aft End.	74
8-13.	Stage 1 HP Turbine Nozzle, Typical Vane Distress.	75
8-14.	HP Turbine Nozzle Assembly, Overall View, Forward End.	76
8-15.	Stage 2 HP Turbine Nozzle, Damage Vane/Stage 1 Shroud.	77
8-16.	Stage 2 HP Turbine Nozzle Stage 2 Shroud Rub.	78
8-17.	HP Turbine Rotor, Overall View of Blades.	79
8-18.	HP Turbine Rotor, Blade Tip Rubs.	80
8-19.	Turbine Midframe Liner Distress.	81
8-20.	Profilometer Setup, LP Turbine Nozzle Segment, Concave Side.	82
8-21.	Profilometer Setup, LP Turbine Nozzle Segment, Convex Side.	83
8-22.	LP Turbine Rotor, Overall View.	84
8-23.	LP Turbine Stator Assembly, Overall View, One Casing.	85
8-24.	LP Turbine Stator Assembly, End View of Shroud and Seal Rubs.	86
8-25.	LP Turbine Stator Assembly, Stage 1 Shroud Rub Pattern.	87

LIST OF ILLUSTRATIONS (Concluded)

<u>Figure</u>	<u>Page</u>
8-26. Stage 1 Fan Blades Before/After Recontour.	88
8-27. Stage 1 Fan Shroud Ice Damage.	89
8-28. Fan Stator Aft Liner Ice Damage.	90

LIST OF TABLES

<u>Table</u>		<u>Page</u>
5-1.	451-479 Average Takeoff and Maximum Conditions.	9
5-2.	451-479 Stackup.	10
5-3.	451-479 Stackup.	12
5-4.	451-479 Stackup.	14
5-5.	EGT Harness Checks.	15
5-6.	451-479 Stackup.	16
7-1.	CF6-6 Influence Coefficients.	53
7-2.	CF6-6 Influence Coefficients.	54
7-3.	Analytical Assessment of 451-479 Losses.	55
7-4.	Analytical Assessment of Refurbished Airfoils.	58

SYMBOLS AND ACRONYMS

A ₄	Stage One High Pressure Turbine Nozzle Area
ALF	Aft Looking Forward
ASE	Airline Support Engineering
ASO	Aviation Service Operation
ASO/O	Aviation Service Operation/Ontario
B30	Forward Compressor Discharge Pressure Seal Clearance - reference Shop Manual, 72-00-00
B70	Aft Compressor Discharge Pressure Seal Clearance - reference Shop Manual, 72-00-00
B71	High Pressure Compressor Balance Piston Seal Clearance - reference Shop Manual, 72-00-00
B/P	Blue Print
BW	Blade Width
C27	Low Pressure Turbine Pressure Balance Seal Clearance - reference Shop Manual, 72-00-00
CDP	Compressor Discharge Pressure
CR	Cruise
CRF	Compressor Rear Frame
CW	Clockwise
DACO	Douglas Aircraft Company
DELTA	Delta
DETAC	Delta High Pressure Compressor Efficiency
DETALP	Delta Low Pressure System Efficiency
DETALPS	Delta Low Pressure System Efficiency
DFN1	Delta Net Thrust at Constant Fan Speed
Digital I	Instrument that Displays in Digits
DPARA	Delta Parasitics
DPARAS	Delta Parasitics
E12, E13	Fan Blade Tip Clearances - reference Shop Manual, 72-20-01
EGT	Exhaust Gas Temperature
EGT Margin	Exhaust Gas Temperature Margin
EPR	Engine Pressure Ratio
ETAC	High Pressure Compressor Efficiency

ETALPS	Low Pressure System Efficiency
ETAT	High Pressure Turbine Efficiency
F_N	Net Thrust
$F_{N@N1}$	Net Thrust at Constant Fan Speed
FBW	Full Blade Width
FIR	Full Indicated Runout
FWD	Forward
G1, G2, G3, G4, G5, G6	High Pressure Turbine Rotor Forward Shaft, Forward Seal Teeth
Gilmore	Tradename for Cell Meter Displaying Exhaust Gas Temperature
H1, H2, H3, H4, H5, H6	High Pressure Turbine Rotor Forward Shaft - Aft Seal Teeth
HP	High Pressure
HPC	High Pressure Compressor
HPS	High Pressure System
HPT	High Pressure Turbine
HPTN	High Pressure Turbine Nozzle
HPTR	High Pressure Turbine Rotor
HRS	Hours
ID	Inside Diameter
IGV	Inlet Guide Vane
IN	Inch
Dim "K"	Dimension "K", High Pressure Turbine Nozzle Support - reference Shop Manual, 72-52-00
LE, L/E	Leading Edge
LP	Low Pressure
LPS	Low Pressure System
LPT	Low Pressure Turbine
LPTN	Low Pressure Turbine Nozzle
LPTR	Low Pressure Turbine Rotor
LPTS	Low Pressure Turbine Stator
MAX	Maximum
M/C	Maximum Continuous
MM	Maintenance Manual
MRL	Maximum Repairable Limit

N1, N ₁	Fan Speed
NO.	Number
No. 4B	Number Four Ball Bearing
OGV	Outlet Guide Van
P ₃ , P3	Compressor Discharge Pressure
P ₄₉ , P49	Low Pressure Turbine INlet Pressure
PARAS	Parasitics
QEC	Quick Engine Connect
RAD	Radius
RMS	Root Mean Square
SFC	Specific Fuel Consumption
SFC Margin	Specific Fuel Consumption Margin
SL	Sea Level
S/M	Shop Manual
S/N	Serial Number
STG	Stage
SWECO	Vibratory Mill Cleaning Process
T ₃	Compressor Discharge Total Temperature
T _{5X}	Calculated Exhaust Gas Temperature
T/C	Thermocouple
TE	Trailing Edge
TMF	Turbine Mid Frame
TSN	Time Since New
T/O	Takeoff.
UA	United Airlines
V1, V2, V3, V4	High Pressure Turbine Rotor Thermal Shield Seal Teeth
WC16	Sixteenth Stage Cooling Air Flow
WF	Fuel Flow
Δ	Delta
η	Efficiency
η _c	High Pressure Compressor Efficiency
η _f	Fan Efficiency
η _t	High Pressure Turbine Efficiency
η _{2t}	Low Pressure Turbine Efficiency

1.0 INTRODUCTION

CF6-6D Engine S/N 451-479 was selected to be the first of a planned four Task IV (Long Term Performance Deterioration) engines, in accordance with the requirements outlined in the NASA-Lewis CF6 Jet Engine Diagnostics Program, Contract No. NAS3-20631. Log No. D11, dated March 11, 1977, describes the rationale and justification for selection of this engine. Included in that document, is a performance history of 451-479 including production acceptance test, aircraft trim run, first takeoff and cruise, and revenue service cruise trend data.

The test plan for this engine was defined in Log No. D12, dated March 11, 1977. Included in that document is a list of test objectives, a description of the basic CF6-6 engine, an itemized test plan schedule, detailed instructions for the designated performance tests, analytical teardown, refurbishment and reassembly instructions, and an instrumentation and facilities description for the General Electric Aviation Service Operation (ASO) Ontario, California CF6 Test Cell.

Log No. D13 describes the instrumentation required for the performance testing of the engine. Standard airline instrumentation was required to measure test cell engine performance. Additional low pressure turbine inlet pressure probes (P49) and high pressure compressor discharge temperatures (T3 rake) were requested and were used to ensure data consistency and accuracy.

This report summarizes all of the pertinent data generated during the course of the test plan, together with an analytical evaluation of the data. This report is a revision of the first 451-479 Task IV Engine Report dated July 29, 1977. Sections 5.0 (Performance Summary) and 7.0 (Analytical Assessment of Performance Losses) have been rewritten to reflect recent findings with regard to cruise to test cell performance correlations and errors in the analytical teardown hardware assessment.

2.0 OBJECTIVES

In accordance with the requirements outlined in the NASA-Lewis CF6 Jet Engine Diagnostics Program, Contract No. NAS3-20631, the following objectives were considered paramount for engine S/N 451-479, as well as for all future Task IV engines:

- Component analyses of long-term performance deterioration with regard to deterioration magnitude and apportionment to individual components.
 - High Pressure Compressor Efficiency
 - High Pressure Turbine Efficiency
 - Parasitics
 - Low Pressure (LP) System Efficiency
 - Thrust at Fan Speed
- Evaluation of LP turbine (LPT) performance restoration with regard to LPT vane and blade surface finish.
- Evaluation of fan performance restoration with regard to blade leading edge quality and airfoil surface cleanliness.
- Analysis of HP core losses (HP compressor, HP turbine, and parasitics) for use in correlating analytical teardown inspection results.
- Obtain data for the CF6 deterioration model in terms of both component and overall (EGT and SFC) performance.

3.0 ENGINE HISTORY

CF6-6D Engine S/N 451-479 was installed new on United Airlines DC-10-10 Aircraft No. N3029U (DACO #207) in the left wing location (Position No. 1). Subsequently, it was delivered to United Airlines in July 1975, with the engine still installed in its original position.

The United Airlines DC-10 route structure includes Chicago as a focal point, with routes, including intermediate stops, to the West Coast (Los Angeles, San Francisco, Portland, and Seattle) and Hawaii, and to the East Coast (Boston, New York, Washington, and Miami). The UA fleet includes 37 DC-10-10 aircraft.

Engine 451-479 was a CF6-6D "Task Force" engine (451-467 and up), which contained a number of performance and ruggedization improvements. The primary modifications included elliptical grinding of the HPT shrouds, shimming of the Stage 1 HPT nozzle, and increased cooling holes in the Stage 2 HPT nozzle support.

The engine was removed from the aircraft on March 16, 1977 to participate in the NASA-Lewis Diagnostics Program as the first Task IV engine. At that time, it had accumulated 4468 total hours and 1910 cycles. After removal of the QEC kit at UA, the engine was delivered to the General Electric Aircraft Service Operation (ASO), Ontario, California, on March 18.

4.0 SUMMARY OF EVENTS

Work Order No. 181460 was generated by ASO/O to fulfill the requirements of the Test Plan (Log No. D12). The program objectives were met in the following chronological sequence:

<u>Date</u>	<u>Event</u>
3-18-77	Engine arrived at Ontario. Incoming inspections performed and engine prepared for testing. Suspected faulty EGT T/C harness (lower left) replaced.
3-21-77	Engine set up in test cell. Initiated inbound test.
3-22-77	Completed inbound test. Engine returned to shop.
3-24-77	Initiated LPT disassembly and inspection checks.
4-1-77	Completed inspections and SWECO-cleaning of LPT blades and vanes.
4-15-77	Completed rebuild of engine.
4-19-77	Engine set up in test cell. Initiated retest, with cleaned LPT airfoils.
4-20-77	Completed test. Recontour and clean Stage 1 fan blades.
4-21-77	Completed test. Install original lower left EGT T/C harness.
4-21-77	Completed test. Engine returned to shop.
4-25-77	Initiated analytical teardown of core.
5-9-77	Completed core engine inspections.
5-17-77	Engine (in modules) returned to United Airlines.

5.0 451-479 PERFORMANCE SUMMARY

Performance testing of 451-479 consisted of three separate double-power calibrations. The three were an inbound test, a test following cleaning of the LPT blades and vanes, and final test following leading edge rework and cleaning of the Stage 1 fan blades. The data were consistent and repeatable with the exception of EGT which shifted 10° C cold between the inbound and post LPT performance tests.

The inbound test included two down-power calibrations. A grounded section (lower left) of the EGT harness was replaced prior to running the test. The calculated minus indicated EGT (ΔT_{5X}) level (5° F) was consistent with the outbound Evendale production power calibration (9° F) which indicates changing this segment had a negligible effect on the measured EGT.

The measured performance deterioration (production new to ASO/O inbound) was consistent with the level obtained for eight other inbound tests. Figure 5-1 presents aircraft cruise trend data as compared to these sample engines. Shown on these curves is a "fleet average" level which corresponds to the average cruise deterioration level of CF6-6D engines S/N 451-406 and up. Figures 5-2 and 5-3 present the inbound test cell deterioration levels for 451-479 and the other eight inbound engines. The "sea level fleet model" shown is based on sea level-to-altitude correlations of 0.7 for SFC, 0.8 for EGT, and 1.0 for WF (i.e., $\Delta \text{EGT at cruise} = 0.7 \times \Delta \text{EGT at sea level}$).

The inbound data are summarized in Tables 5-1 and 5-2. Almost all the measured component deterioration (inbound versus production acceptance) occurred in the HP turbine as presented below. Note that 1.3% of the 4.5% SFC deterioration is due to the "instant loss" at the aircraft manufacturer and not deterioration during revenue service.

-0.2%	ΔETAC	(HP Compressor Efficiency)
-4.3%	ΔETAT	(HP Turbine Efficiency)
0	ΔPARAS	(Core Engine Internal Leakages and Cooling Flows)
-0.1%	ΔETALPS	(LP System Efficiency)
+0.6%	FN@N1	(Thrust at Fan Speed)

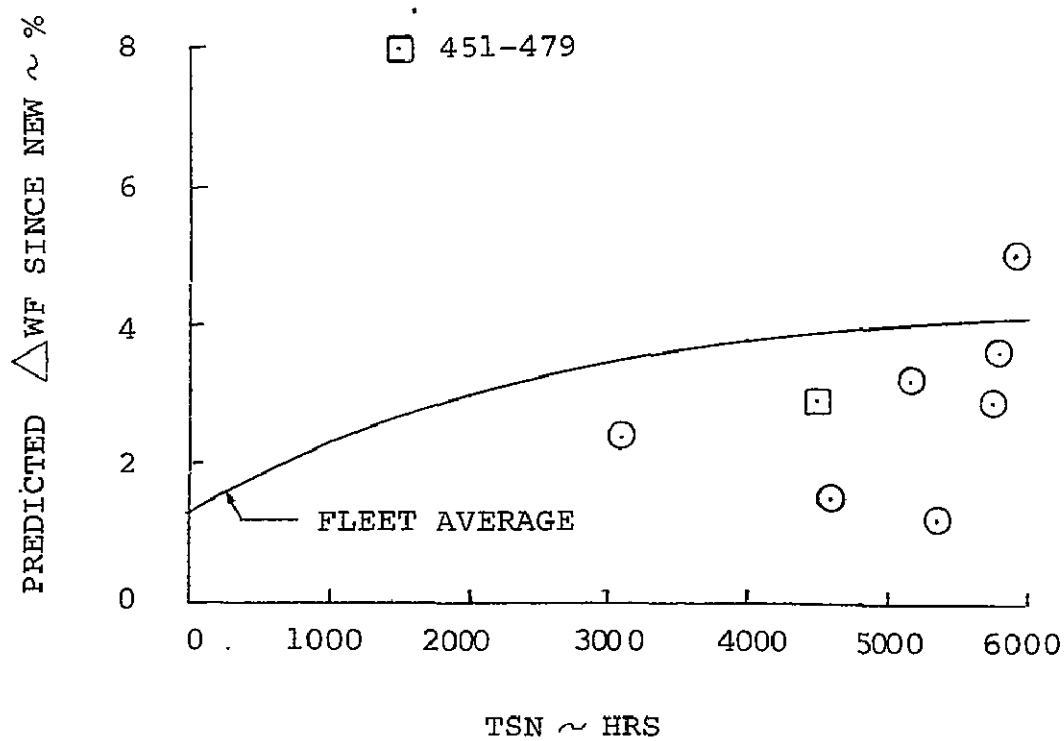
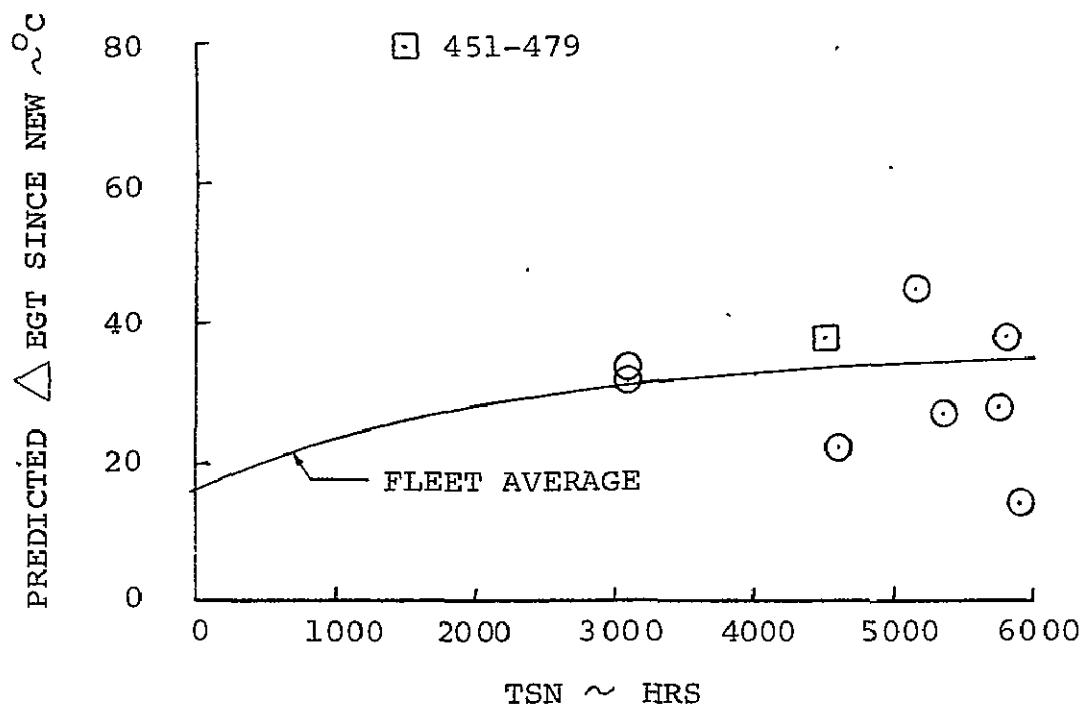


Figure 5-1. CF6-6D Cruise Deterioration.

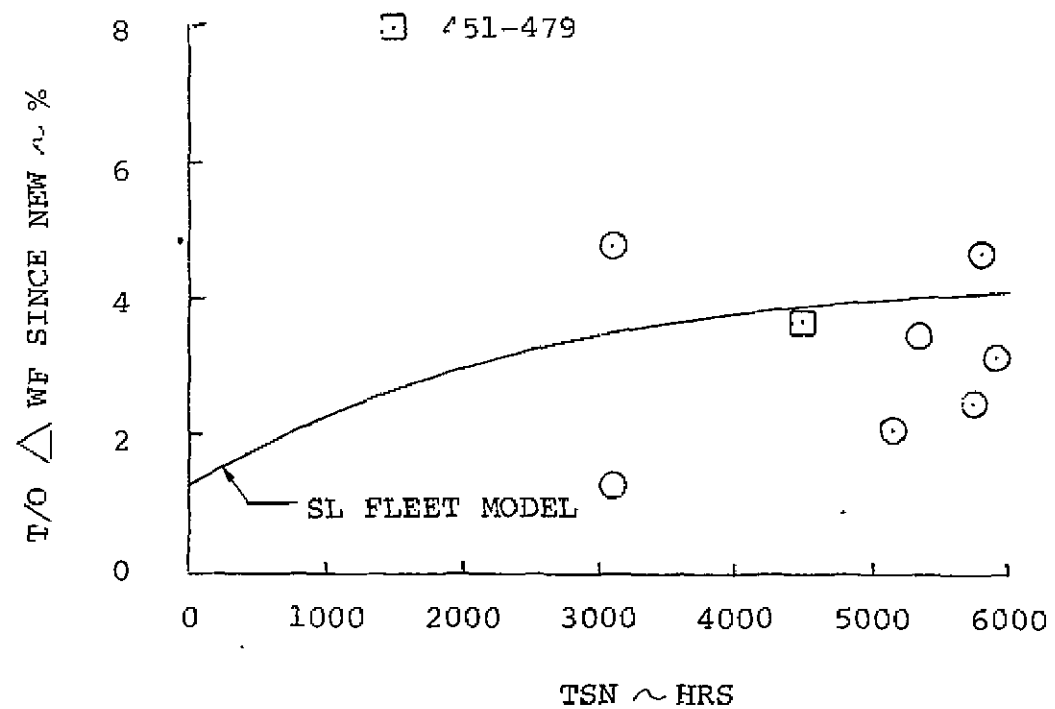
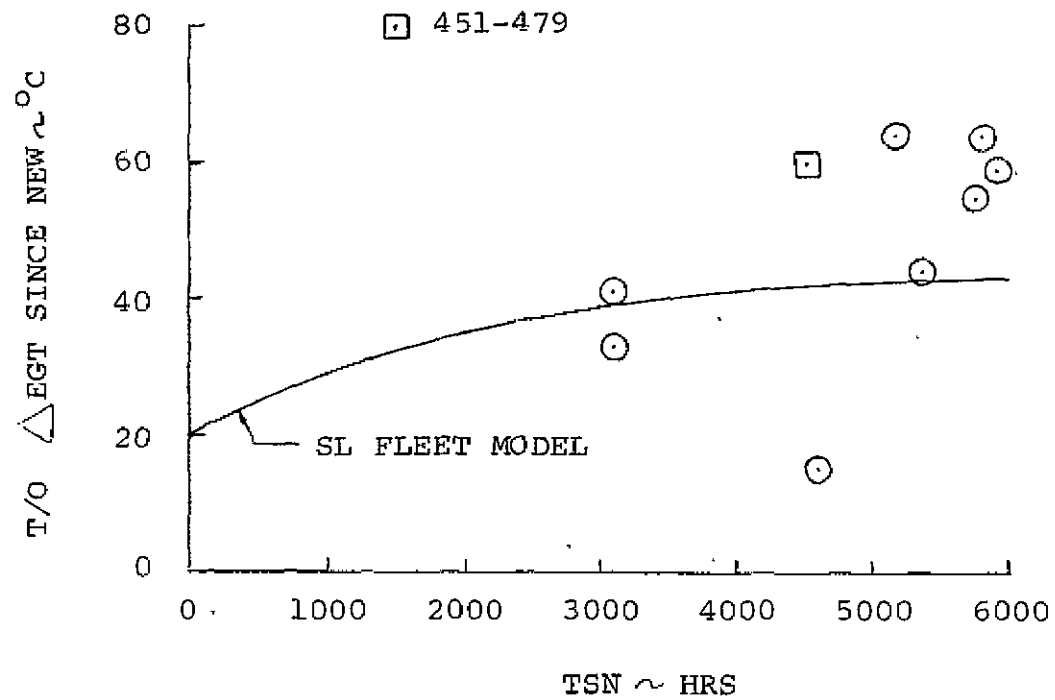


Figure 5-2. CF6-6D Inbound Sea Level Deterioration.

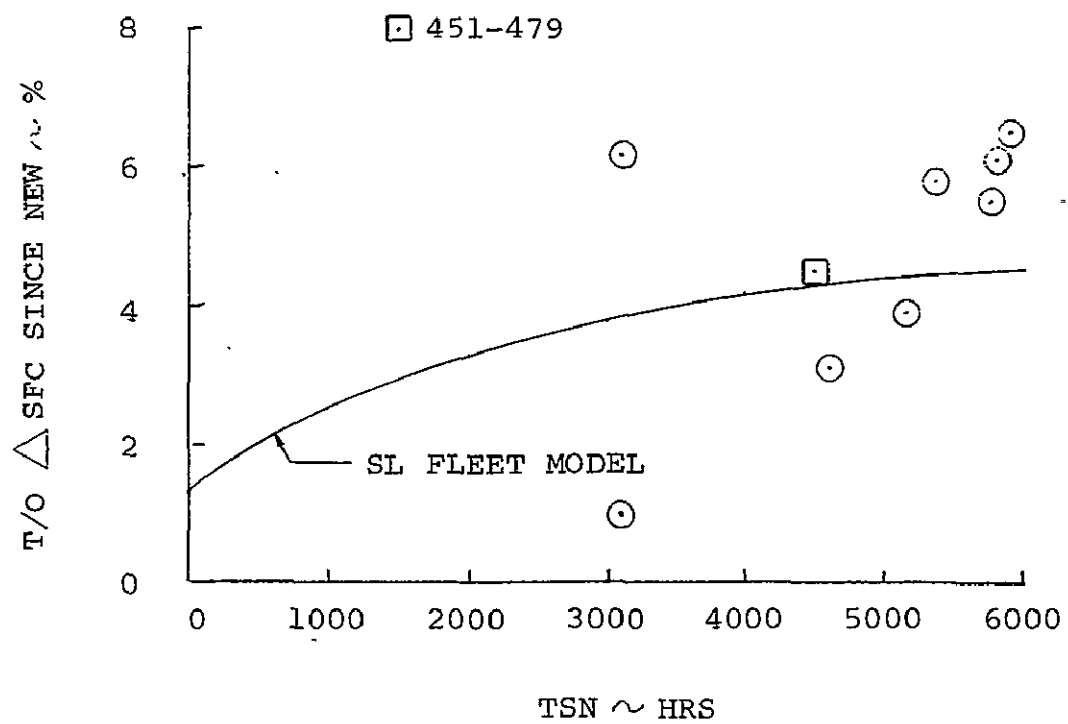


Figure 5-3. CF6-6D Inbound Sea Level Deterioration.

Table 5-1. 451-479 Average Takeoff and Maximum Conditions.

	<u>Production</u>	<u>Inbound</u>	<u>After LPT</u>	<u>After Fan</u>
Date	12-11-74	3-22-77	4-19-77	4-21-77
SFC Margin	1.0%	-3.5%	-3.7%	-3.2%
T/O Hot Day EGT	1566° F	1674° F	1656° F	1662° F
M/C Hot Day EGT	1503° F	1606° F	1590° F	1594° F
T/O Hot Day T ₅ X	1557° F	1668° F	1668° F	1670° F
M/C Hot Day T ₅ X	1493° F	1602° F	1603° F	1603° F
% DETAC ↑	-0.1	-0.3	-0.2	-0.4
% DETAT ↑	-1.1	-5.4	-5.5	-5.3
% DPARA Based on T ₅ X	-1.3	-1.4	-1.4	-1.5
% DETALP ↓	0.0	-0.1	-0.5	0.2
% DFN1 ↓	-0.7	-0.1	0.0	0.5
% DETAC ↑	-0.1	-0.3	-0.2	-0.4
% DETAT ↑	-1.0	-5.0	-4.3	-4.3
% DPARA Based on EGT	-1.4	-1.4	-1.3	-1.4
% DETALP ↓	0.1	0.1	0.3	0.9
% DFN1 ↓	-0.7	-0.1	0.0	0.6

Note: Stackup versus an average 1975 production engine. Inbound data includes "instant" loss at the aircraft manufacturer (1.3% SFC).

Table 5-2. 451-479 Stackup.

Run	Reading	SFC Margin	Hot Day EGT	Based on T_5X						Based on EGT				
				ΔT_5X	DETAC	DETAT	DPARAS	DETALPS	DFN1	DETAC	DETAT	DPARAS	DETALPS	DFN1
Production	9	0.9	1566	-9	-0.3	-0.8	-1.2	-0.1	-0.6	-0.3	-0.7	-1.2	-0.0	-0.6
$A_4 = 52.561$	10	1.0	1566	-9	0.2	-1.5	-1.5	0.1	-0.5	0.2	-1.3	-1.6	0.2	-0.5
	<u>11</u>	<u>1.1</u>	<u>1503</u>	<u>-10</u>	<u>-0.1</u>	<u>-1.1</u>	<u>-1.3</u>	<u>-0.1</u>	<u>-0.9</u>	<u>-0.1</u>	<u>-1.0</u>	<u>-1.4</u>	<u>-0.0</u>	<u>-0.9</u>
	AVG	1.0	1566/ 1503	-9	-0.1	-1.1	-1.3	-0.0	-0.7	-0.1	-1.0	-1.4	0.1	-0.7
Inbound	9	-3.6	1672	-7	-0.3	-5.4	-1.6	-0.5	0.0	-0.3	-5.2	-1.7	-0.3	0.0
$A_4 = 53.549$	10	-3.4	1672	1	-0.6	-5.5	-1.5	0.3	0.3	-0.6	-4.8	-1.5	0.7	0.3
	11	-3.2	1606	-6	-0.4	-4.8	-1.1	0.0	0.1	-0.4	-4.6	-1.1	0.2	0.1
	12	-3.7	1604	0	-0.1	-6.0	-1.8	-0.1	-0.2	-0.1	-5.4	-1.8	0.3	-0.2
	19	-3.3	1675	-8	-0.4	-5.4	-1.4	0.2	-0.2	-0.4	-5.2	-1.4	0.3	-0.2
	20	-3.6	1675	-7	-0.4	-5.1	-1.2	-0.4	-0.2	-0.4	-4.9	-1.2	-0.2	-0.2
	<u>21</u>	<u>-3.5</u>	<u>1606</u>	<u>-6</u>	<u>-0.1</u>	<u>-5.5</u>	<u>-1.3</u>	<u>-0.4</u>	<u>-0.5</u>	<u>-0.1</u>	<u>-5.2</u>	<u>-1.3</u>	<u>-0.2</u>	<u>-0.5</u>
	AVG	-3.5	1674/ 1606	-5	-0.3	-5.4	-1.4	-0.1	-0.1	-0.3	-5.0	-1.4	0.1	-0.1

+108° F	EGT@N1	(EGT at Fan Speed)
+111° F	T _{5X} @N1	(Calculated EGT at Fan Speed)
+4.5%	SFC@FN	(SFC at Thrust)

The measured performance stackup is presented using an A_4 of 53.594 sq. in. An attempt was made to measure A_4 but nine of the Stage 1 HPT vane segments were badly burned at the trailing edge. In addition, ballooning, cracking, and bowing of the nozzle vanes raised questions as to whether A_4 was assessed correctly. The resulting A_4 was obtained by extrapolating the measurable vane segments using tool 2C6846. A_4 , in conjunction with the measured HPT pressure ratio, is used to assess the performance tradeoff between parasitics and HPT efficiency. Furthermore, the condition of the TMF liner can affect the pressure (P49) as well as the temperature (EGT) measurement. Similarly, much effort has been placed in developing a simple, yet accurate, method of measuring compressor discharge temperature and pressure. A change in either parameter will result in a different component assessment as to the correct apportionment to compressor efficiency, turbine efficiency, and parasitics.

The test following the LPT airfoil cleaning also consisted of two down-power calibrations. The data indicated no improvement relative to the inbound run. In fact, the LP system efficiency worsened after the LPT work. The data analysis is slightly clouded due to a shift in indicated EGT. T_{5X} (calculated EGT), however, was consistent and was adequate for the component stackups. The performance data are summarized in Tables 5-1 and 5-3. The following component deltas were measured relative to the inbound run:

+0.1%	Δ ETAC
-0.1%	Δ ETAT
0	Δ PARAS
-0.4%	Δ ETALPS
+0.1%	FN@N1
-18° F	EGT@N1
0	T _{5X} @N1
+0.2%	SFC@FN

Table 5-3. 451-479 Stackup.

Run	Reading	SFC Margin	Hot Day EGT	Based on T_5X						Based on EGT				
				ΔT_5X	DETAC	DETAT	DPARAS	DETALPS	DFNL	DETAC	DETAT	DPARAS	DETALPS	DFNL
After LPT	11	-3.6	1656	10	-0.1	-5.3	-1.4	-0.4	0.5	-0.1	-4.2	-1.2	0.3	0.5
$A_4 = 53.549$	12	-3.4	1655	10	-0.2	-5.2	-1.4	-0.2	0.3	-0.2	-4.1	-1.2	0.4	0.3
	13	-3.6	1590	14	0.0	-5.6	-1.4	-0.3	0.2	0.0	-4.3	-1.2	0.5	0.2
	14.	-3.5	1590	15	-0.2	-5.6	-1.4	-0.1	0.1	-0.2	-4.3	-1.2	0.7	0.1
	21	-3.7	1657	12	-0.1	-6.3	-2.1	-0.4	-0.0	-0.1	-5.1	-1.9	0.4	-0.0
	22	-3.9	1656	15	-0.5	-4.8	-0.8	-0.6	-0.2	-0.5	-3.5	-0.7	0.2	-0.2
	23	-3.7	1591	7	-0.1	-5.2	-1.3	-1.0	-0.3	-0.1	-4.2	-1.2	-0.4	-0.3
	<u>24</u>	<u>-3.8</u>	<u>1590</u>	<u>15</u>	<u>0.0</u>	<u>-6.1</u>	<u>-1.7</u>	<u>-0.6</u>	<u>-0.4</u>	<u>0.0</u>	<u>-4.8</u>	<u>-1.6</u>	<u>0.2</u>	<u>-0.4</u>
	AVG	-3.7	1656/ 1590	12	-0.2	-5.5	-1.4	-0.5	0.0	-0.2	-4.3	-1.3	+0.3	0.0

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The double-power calibrations following the fan cleaning and leading edge rework showed a positive improvement in both SFC and thrust (0.5% SFC@FN and +0.5% FN@N1). There was no improvement in EGT@N1 because both airflow and fan efficiency increased. The performance data are summarized in Tables 5-1 and 5-4. The following component deltas were measured relative to the previous test:

-0.2%	Δ ETAC
+0.2%	Δ ETAT
+0.1%	Δ PARAS
+0.7%	Δ ETALPS
+0.5%	FN@N1
+6° F	EGT@N1
+2° F	T ₅ X@N1
-0.5%	SFC@FN

Following the fan test, a complete investigation was conducted to understand the indicated EGT shift. Table 5-5 summarizes the checks made to the harness and cell readout system. The checks revealed no discrepancies. The grounded section of EGT harness was reinstalled and check points were run to try and understand the EGT shift. There was no measurable difference in EGT or Δ T₅X (Table 5-6). An inspection following the last testing sequence showed one of the harness probe aspirator holes to be immersed in the cooler TMF liner. Due to the mechanical condition of the liner (cracks and two holes), buckling of the liner may have caused the indicated EGT shift.

Table 5-4: 451-479 Stackup.

Run	Reading	SPC Margin	Hot Day EGT	Based on T_5X						Based on EGT				
				ΔT_{5X}	DETAC	DETAT	DPARAS	DETALPS	DFN1	DETAC	DETAT	DPARAS	DETALPS	DFN1
After Fan	31	-3.4	1662	7	-0.6	-4.8	-1.0	-0.1	0.3	-0.6	-3.8	-0.9	0.5	0.3
$A_4 = 53.549$	32	-3.5	1658	2	-0.3	-4.9	-1.2	-0.6	-0.1	-0.3	-4.2	-1.2	-0.2	-0.1
	33	-3.4	1591	10	-0.3	-5.6	-1.7	-0.2	-0.1	-0.3	-4.5	-1.5	0.5	-0.1
	34	-2.7	1594	6	-0.1	-5.6	-1.6	0.6	0.5	-0.1	-4.7	-1.5	1.2	0.5
	39	-3.1	1663	6	-0.4	-5.9	-2.0	0.6	0.7	-0.4	-5.0	-1.9	1.2	0.7
	40	-3.0	1663	6	-0.5	-5.6	-1.9	0.6	0.8	-0.5	-4.8	-1.8	1.2	0.8
	41	-2.9	1594	8	-0.4	-4.9	-1.1	0.6	0.7	-0.4	-4.0	-1.0	1.2	0.7
	42	-3.5	1594	3	-0.5	-4.6	-1.1	-0.7	0.1	-0.5	-3.9	-1.1	-0.2	0.1
	43	-3.8	1659	16	-0.6	-5.2	-1.3	-0.2	0.7	-0.6	-3.8	-1.1	0.7	0.7
	44	-3.5	1665	16	-1.1	-5.1	-1.2	0.7	0.9	-1.1	-3.7	-1.1	1.6	0.9
	45	-2.7	1596	8	-0.1	-5.8	-1.8	0.9	1.1	-0.1	-4.8	-1.7	1.5	1.1
	<u>46</u>	<u>-3.4</u>	<u>1594</u>	<u>17</u>	<u>-0.2</u>	<u>-6.1</u>	<u>-1.8</u>	<u>0.3</u>	<u>0.6</u>	<u>-0.2</u>	<u>-4.7</u>	<u>-1.6</u>	<u>1.1</u>	<u>1.6</u>
	AVG	-3.2	1662/ 1594	9	-0.4	-5.3	-1.5	0.2	0.5	-0.4	-4.3	-1.4	0.9	0.6

Table 5-5. EGT Harness Checks.

1. Verify digital and cell meter (log sheets); indicate same EGT.
- 1a. Check same on previous run (if data are available).

After Next Run

2. Send calibration signal through cell system (at forward lead connection and read-out on Digital + Gilmore.
3. Visual EGT harness and leads for broken/damaged leads or connectors. Check that connectors are seated.
4. Check total EGT System (at forward lead connector) with Meggar per 77-21-01.
5. Disconnect forward and aft lead and disconnect T/C harness from aft lead.
 - Visual connectors for broken, missing, bent, or loose pins.
 - Check pin-pin and pin-casing per MM for
 - T/C harness (four sectors)
 - Forward lead
 - Aft lead

Check shop to see if anyone noted any discrepancy during disassembly and reassembly.

Table 5-6. 451-479 Stackup.

Run	Reading	SFC Margin	Hot Day EGT	Based on T ₅ X						Based on EGT				
				DELT ₅ X	DETAC	DETAT	DPARAS	DETALPS	DFN1	DETAC	DETAT	DPARAS	DETALPS	DFN1
Clean Harness	50	-3.4	1669	-3	-0.3	-5.1	-1.5	-0.2	0.9	-0.3	-4.6	-1.5	0.1	0.9
A ₄ = 53.549	51	-3.3	1594	10	0.1	-5.8	-1.6	0.1	0.5	0.1	-4.7	-1.5	0.8	0.5
	<u>52</u>	<u>-3.8</u>	<u>1596</u>	<u>13</u>	<u>-0.4</u>	<u>-4.6</u>	<u>-0.8</u>	<u>-0.6</u>	<u>0.7</u>	<u>-0.4</u>	<u>-3.4</u>	<u>-0.6</u>	<u>0.1</u>	<u>0.7</u>
	AVG	-3.5	1669/ 1595	7	-0.2	-5.2	-1.3	-0.2	0.7	-0.2	-4.2	-1.2	0.3	0.7
Old Harness	54	-3.7	1666	4	-0.5	-5.1	-1.4	-0.5	0.7	-0.5	-4.3	-1.4	0.0	0.7
A ₄ = 53.549	55	-3.4	1598	0	-0.1	-5.4	-1.7	-0.3	0.5	-0.1	-4.8	-1.7	0.1	0.5
	<u>56</u>	<u>-3.3</u>	<u>1596</u>	<u>7</u>	<u>-0.1</u>	<u>-5.4</u>	<u>-1.5</u>	<u>-0.1</u>	<u>0.8</u>	<u>-0.1</u>	<u>-4.5</u>	<u>-1.5</u>	<u>0.4</u>	<u>0.8</u>
	AVG	-3.5	1666/ 1597	4	-0.2	-5.3	-1.5	-0.3	0.7	-0.2	-4.5	-1.5	0.2	0.7

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6.0 POSTTEST TEARDOWN RESULTS

Upon completion of the test cell runs, the core engine was subjected to an analytical teardown inspection, the results of which are contained herein. During the course of the test program, the low pressure system had likewise been disassembled, cleaned, and inspected. These results are also included in this section.

The inspection results include observations concerning the hardware which were performance related, and do not imply that no other discrepancies existed.

6.1 HIGH PRESSURE COMPRESSOR SECTION

6.1.1 HP Compressor Rotor Assembly

6.1.1.1 General Inspection

Inspection of the HP compressor rotor revealed the spool and blades to be extremely dirty throughout, with a heavy deposit of oil mixed with the dirt in the forward end (through Stage 6). Some very mild aluminum splatter was noted on blades in Stages 12 and aft. A photograph of the rotor assembly was taken (Figure 8-1); however, it was not taken until after the rotor had been prematurely cleaned, erasing all evidence of the dirty condition.

6.1.1.2 Rotor Land Rubs

No vane-to-spool rubs were detected on any land. There was a new gouge, probably caused by a variable stator vane near the split line being out of position during disassembly.

6.1.1.3 Rotor Land Coating Condition

The coating of the compressor rotor lands was inspected with the following discrepancies noted (Figure 8-2 in Appendix B):

<u>Stage</u>	<u>Conditions</u>
15 and 16	100% missing
14	20/30% missing
13	30/40% missing
3 - 12	OK

6.1.1.4 Blade Airfoil Condition

Except for the dirt and oil previously noted, the airfoils were in excellent condition. There was no evidence of any nicked, or otherwise damaged blades. Blades in Stages 8 through 12, 15, and 16 showed some slight tip rub, as evidenced by the rubs noted on the compressor stator lands (see 6.1.2.4).

6.1.1.5 Blade Surface Finish

Two blades each from Stages 3 through 16 were removed for surface-finish checks, using a profilometer. Original plans also included blades in Stages 1 and 2 for these checks. However, to expedite the test plan, blades in these two stages were visually inspected and deemed to be about the same quality as blades in Stages 3 and 4; therefore, they were not removed from the rotor.

Surface-finish checks were taken at 15%, 50%, and 85% of blade height at:

- 10/15% of chord from leading edge on the suction side.
- 10/15% of chord from trailing edge on the pressure side.

Results were as follows (RMS μ inch):

Stage	← Convex →					← Concave →					Stage Overall Avg.
	Tip	Pitch	Root	Avg.	Stg. Avg.	Tip	Pitch	Root	Avg.	Stg. Avg.	
3	25	15	13	18		46	30	15	30		25
	21	19	21	20	19	50	26	15	30	30	
4	29	11	14	18		55	26	20	34		26
	20	15	15	17	17	55	35	20	37	35	
5	30	16	16	21		48	38	18	35		30
	30	24	18	24	22	46	44	25	38	37	
6	25	13	12	17		50	36	65	50		33
	26	17	21	21	19	44	46	45	45	47	
7	22	15	26	21		44	62	60	55		35
	25	15	25	22	21	42	30	50	41	48	
8	27	18	20	22		40	50	65	52		36
	30	20	20	23	23	40	40	59	46	48	
9	40	30	23	31		39	35	35	36		36
	34	34	29	32	32	39	42	50	44	40	
10	30	30	35	32		40	42	50	44		38
	27	35	40	34	33	37	40	45	41	42	
11	30	30	26	29		30	38	45	38		32
	35	30	20	28	29	37	40	25	34	36	
12	30	30	32	31		35	41	45	40		36
	30	25	27	27	29	40	38	55	44	42	

Stage	← Convex →					← Concave →					Stage Overall Avg.
	Tip	Pitch	Root	Avg.	Stg. Avg.	Tip	Pitch	Root	Avg.	Stg. Avg.	
13	30	23	22	25		35	37	40	37		
	35	26	25	29	27	45	40	38	41	39	33
14	30	32	24	29		37	40	50	42		
	27	23	20	23	26	30	40	33	34	38	32
15	34	40	27	34		40	37	40	39		
	41	30	25	32	33	35	30	45	37	38	36
16	27	28	24	26		45	33	40	39		
	31	60	60	50	38	32	22	32	29	34	36

Average blade surface finish = 33 RMS μ inch.

6.1.1.6 Rotating CDP Seal

Measurements of each of the CDP seal teeth were made, with the results as follows:

<u>Tooth</u>	<u>Max. Diameter</u>	<u>FIR</u>
I	18.130"	0.004"
H	17.931"	0.002"
G	17.731"	0.0015"
F	17.531"	0.001"
E	17.3305"	0.001"
D	17.131"	0.0015"

Resultant clearances can be found in 6.1.3.3, "Stationary CDP Seal Measurements."

6.1.2 High Pressure Compressor Stator Assembly

6.1.2.1 General Inspection

Inspection of the HP compressor stator assembly revealed a heavy mixture of oil and dirt in the forward stages, through Stage 6. The heaviest buildup accumulated on the IGV's and the IGV inner shrouds, and got progressively better from stage to stage. The remaining vanes, though not oily, were extremely dirty. There was a very mild splattering of aluminum on the Stage 13 vanes and OGV's. A photograph of the upper stator case can be seen in Appendix B, Figure 8-3.

6.1.2.2 Condition of Variable Stator Bushings

Variable stator bushings were generally in excellent condition. A total of 12 Stage 6 vanes were found to be slightly loose and only one vane in this stage revealed metal-to-metal contact. Stage 5 had three vanes which were slightly loose, but no metal-to-metal contact.

All of the Stage 3 vanes, in the lower case only, were on the loose side. This would seem to indicate that they had been initially assembled in this manner, since all other variable vanes in both casing halves exhibited the normal tightness.

6.1.2.3 Vane Airfoil Condition

Except for the oil and dirt, all airfoils were in excellent condition. No nicks or other discrepancies were noted on any vane.

6.1.2.4 Casing Rubs

Inspection of the stator case lands revealed the following blade tip-to-case rubs:

HP Compressor Casing Rubs - Upper (See Photo, Figure 8-4 in Appendix B)

<u>Stage</u>	<u>Depth</u>	<u>Width</u>	<u>Location</u>	<u>Remarks</u>
1-7	No Rub			
8	Kiss	FBW	12 o'clock	3" in length no depth
	.003	FBW	1 o'clock	1.3" in length
9	Kiss	FBW	9-10 o'clock	1.5" in length no depth
10	No rub			
11	Kiss	.5"	1 o'clock	2.5" in length no depth
12	Kiss	.4"	12 & 1 o'clock	.7" & 1.5" in length in aft case only. No depth
13	No rub			
14	No rub			
15	.005	FBW	10-11 o'clock	4.5" in length
	.003	FBW	12 o'clock	2.3" in length
	.005	FBW	1-2 o'clock	4.5" in length
16	.008	FBW	1-2 o'clock	4.5" in length

Note: FBW = Full Blade Width

HP Compressor Casing Rubs - Lower
(See Photo, Figure 8-5 in Appendix B)

<u>Stage</u>	<u>Depth</u>	<u>Width</u>	<u>Location</u>	<u>Remarks</u>
1-7	No rub			
8	Kiss	.050"	7-8 o'clock	6" in length, T/E
9	No rub			
10	Kiss	1/2 BW	7 o'clock	1.5" in length
11	No rub			
12	No rub			
13	No rub			
14	No rub			
15	Kiss	1/2 BW	5-7 o'clock	12" in length
	.003	FBW	8 o'clock	2.5" in length
16	.003	FBW	5-6 o'clock	3" in length

Note: FBW = Full Blade Width

6.1.2.5 Vane Surface Finish

Two vanes each from Stages 7 through OGV's were removed for surface-finish checks. Readings were taken with a profilometer at 15%, 50%, and 85% of vane height at:

- 10/15% of chord from LE on convex side.
- 10/15% of chord from TE on concave side.

Results are as follows (RMS- μ inch):

← Convex →					← Concave →					Stage	
Stage	Tip	Pitch	Root	Avg.	Stage Avg.	Tip	Pitch	Root	Avg.	Stage Avg.	Overall Avg.
7	25	40	40	35		130	70	65	88		
	35	35	35	35	35	140	65	70	92	90	63
8	65	60	55	60		75	60	45	60		
	70	75	55	68	64	85	70	65	73	67	65
9	40	40	35	38		75	45	55	58		
	55	40	45	47	43	65	55	50	57	58	50
10	40	45	40	42		60	50	50	53		
	40	35	40	38	40	50	50	50	50	52	46
11	30	35	30	32		40	50	50	47		
	30	35	30	32	32	55	40	40	45	46	39
12	35	40	35	37		60	50	60	57		
	25	25	35	28	33	50	40	55	48	53	43
13	35	35	40	37		45	55	55	52		
	35	35	45	38	38	50	45	55	50	51	44

Stage	← Convex →				← Concave →				Stage	
	Tip	Pitch	Root	Avg.	Stage Avg.	Tip	Pitch	Root	Avg.	Stage Overall Avg.
14	25	30	35	30		50	40	60	50	
	35	40	35	37	33	50	45	55	50	42
15	35	35	35	35		45	50	45	47	
	35	35	35	35	35	50	40	40	43	40
OGV	40	40	40	40		35	45	35	38	
	35	40	45	40	40	40	35	45	40	39

Average surface finish of vanes = 47 RMS μ inch.

6.1.3 Compressor Rear Frame

6.1.3.1 General

A cursory inspection of the compressor rear frame revealed no notable discrepancies. A more detailed inspection of the combustor and dimensional checks of the CDP seal and the 4B pressure balance seal (mini-nozzle) were performed, with results as follows:

6.1.3.2 Combustor

To expedite the work scope, the combustor was not removed from the rear frame, but rather visually inspected as installed. The combustor had its typical 1/4" to 1/2" cracks, inner and outer liners. The most noteworthy fault was the cracks originating at the inner liner's aft thimble louver at approximately the 7 o'clock location. This particular louver had cracked in four different directions of varying lengths (Figures 8-6 and 8-7 in Appendix B). The cracks were approximately 5/8", 1", and 2-1/2" in length and another about 2-1/4" long connecting with a 4-1/2" circumferential crack. The whole piece was bulged into the airstream approximately 5/8". There were six more of these thimble louvers with cracks ranging from 1/2" to 1-1/4" but these are considered insignificant with regard to performance.

6.1.3.3 Stationary CDP Seal, Forward

Measurements of each of the lands on the 4R CDP seal were taken and recorded. (A view of the forward CRF seals can be seen in Appendix B, Figure 8-8.) The results were as follows (all dimensions are in inches):

B30

Dia.	F1	F2	F3	F4	F5	F6
Max.	18.149	17.950	17.750	17.550	17.352	17.152
Min.	18.148	17.949	17.749	17.549	17.351	17.151
3	18.148	17.949	17.750	17.549	17.352	17.152
4	18.149	17.950	17.749	17.550	17.352	17.152
5	18.149	17.950	17.750	17.550	17.352	17.151
6	18.148	17.950	17.749	17.549	17.351	17.152
Avg.	18.148	17.949	17.749	15.549	17.352	17.152

Shop Manual Dimensional Requirements

Maximum	18.152	17.952	17.752	17.552	17.352	17.152
Minimum	18.148	17.948	17.748	17.548	17.348	17.148

Clearances determined from this data and that taken on the corresponding HPC rotor seal (6.1.1.6) were as follows:

B30

	1	2	3	4	5	6
Minimum	0.007	0.008	0.0085	0.0085	0.0095	0.0095
Maximum	0.0115	0.0105	0.010	0.010	0.011	0.011
Average	0.009	0.009	0.009	0.009	0.010	0.010

Overall average clearance = 0.0093

6.1.3.4 No. 4B Pressure Balance Seal Measurements

Diameter measurements of each land of each of the aft seals in the No. 4B pressure balance seal (mini-nozzle) were taken and are recorded below (dimensions are in inches). These are the seals that mate with the high pressure turbine rotor forward shaft seals. (A photograph of the mini-nozzle is contained in Appendix B, Figure 8-9.)

Forward Seal (Aft CDP Seal)

B70

Dia.	F1	F2	F3	F4	F5	F6
Max.	7.944	8.104	8.265	8.424	8.584	8.744
Min.	7.942	8.102	8.263	8.422	8.582	8.742
3	7.942	8.103	8.263	8.424	8.582	8.743
4	7.942	8.103	8.263	8.423	8.582	8.742
5	7.942	8.104	8.265	8.424	8.583	8.744
6	7.943	8.104	8.264	8.423	8.582	8.743
7	7.943	8.103	8.264	8.422	8.584	8.743
8	7.944	8.102	8.265	8.422	8.582	8.743
Avg.	(7.943)	8.103	8.264	8.423	8.583	8.743

Shop Manual Dimensional Requirements

Maximum	7.945	8.105	8.265	8.425	8.585	8.745
Minimum	7.942	8.102	8.262	8.422	8.582	8.742

Aft Seal (HPT Balance Piston Seal)

B-71

Dia.	F1	F2	F3	F4	F5	F6
Max.	10.443	10.622	10.778	10.942	11.105	11.260
Min.	10.442	10.616	10.770	10.939	11.098	11.249
3	10.442	10.616	10.772	10.940	11.100	11.249
4	10.443	10.617	10.771	10.940	11.098	11.255
5	10.442	10.621	10.773	10.941	11.099	11.258
6	10.443	10.622	10.770	10.941	11.101	11.260
7	10.443	10.620	10.770	10.939	11.104	11.258
8	10.443	10.620	10.778	10.942	11.105	11.262
Avg.	10.4225	10.619	10.773	10.9405	11.101	11.256

Shop Manual Dimensional Requirements

Maximum	10.446	10.606	10.766	10.926	11.086	11.246
Minimum	10.442	10.602	10.762	10.922	11.082	11.242

Resultant clearances between these seals and the corresponding rotating seals are contained in Section 6.2.3.6, "Forward Shaft Seal Dimensions."

6.2 HIGH PRESSURE TURBINE SECTION

6.2.1 Stage 1 High Pressure Turbine Nozzle Assembly

6.2.1.1 General Inspection

Visual inspection of the Stage 1 HPTN assembly revealed 13 vanes with some degree of burning on the trailing edge, while some 10 other vanes were bowed in the same area. (See photographs in Appendix B, Figures 8-10 through 8-13. Note that the position markings as viewed in the photographs are incorrect. Per B/P, the vane marked No. 18 is really Vane No. 1. From that point, the vanes should be marked in clockwise order. For orientation purposes, all references to vane position numbers in this report are per the actual position and not as depicted in the pictures.) As can be seen in the photographs, all vane distress emanated approximately from the center of the airfoils at the trailing edge, and continued radially outward and inward about the same amount for each particular vane.

All of the vanes that experienced the burning/distortion showed radial cracks of varying lengths on the concave side, depending on the severity of the distress. These cracks were located $3/8$ " to $1/2$ " forward of the trailing edge.

The leading edges of the vanes exhibited the normal minute cracks and splatter buildup, but all cooling holes appeared to be open. The same could be said for the concave face of the vanes; while the convex side was smooth, which is also normal. Surface finish checks of the airfoils were made on several vanes and are tabulated in 6.2.1.5, "Airfoil Surface Finish Checks."

The thermal shields, inside the vane platform ID, were distorted the full 360° circumference. Two bolt head covers, No. 2 (in line with Nozzles No. 5 and 6) and No. 12 (in line with Nozzles No. 45 and 46), were also heavily deformed.

The aft face of the Stage 1 vane outer hook showed contact 360° ; however, the first vane of each segment (CW, ALF) appeared to be marked heavier than the other.

The inspection also revealed (though it was not performance-related) that

five of the outer fishmouth seal tabs were burned away (three approximately 25% missing; one approximately 50% missing; one approximately 10% missing). There was also one inner fishmouth seal tab burned with approximately 40% missing.

6.2.1.2 Drop Dimension - CRF to Stage 1 Vanes

Drop dimensions from the CRF aft flange to the aft face of the Stage 1 vane outer hook were taken at 16 equally spaced locations, starting at 12 o'clock and working CW. The results were as follows:

1	4.868"	9	4.853"
2	4.860"	10	4.868"
3	4.864"	11	4.859"
4	4.850"	12	4.869"
5	4.858"	13	4.869"
6	4.856"	14	4.869"
7	4.853"	15	4.867"
8	4.856"	16	4.860"

Average = 4.861"

Note: This engine was equipped with the 0.020" shim (PPN 92570), which mounts between the CRF/Stage 2 nozzle flanges. Stackup of mating parts is contained in 6.2.2.5.

6.2.1.3 Vane Outer Platform Gap Measurements

Gaps between outer platforms on adjacent vanes were measured at 16 equally spaced locations and were as follows:

1	0.029"	9	0.029"
2	0.025"	10	0.029"
3	0.025"	11	0.032"
4	0.027"	12	0.030"
5	0.027"	13	0.032"
6	0.034"	14	0.035"
7	0.025"	15	0.027"
8	0.025"	16	0.027"

These are well within the shop manual limits of 0.015" min. and 0.045" max.

6.2.1.4 Area Check (A₄)

A check of the nozzle exit area was conducted with some difficulty. Due to the distress previously noted, it was impossible to obtain an accurate reading on some of the severely burned and distorted vanes. Measurements were taken of all the vanes that it was possible to measure, and data extrapolated to arrive at the final estimated A₄ of 53.960 sq. in.

Area check of each of the individual nozzles is as follows:

Nozzle No.	Area	Nozzle No.	Area	Nozzle No.	Area	Nozzle No.	Area
1	D	17	0.822	33	0.835	49	0.835
2	0.885	18	0.820	34	0.841	50	0.825
3	0.833	19	0.828	35	0.827	51	0.845
4	0.865	20	0.799	36	0.808	52	0.793
5	0.880	21	0.824	37	0.856	53	0.823
6	D	22	0.834	38	0.891	54	0.838
7	D	23	0.808	39	0.930	55	0.825
8	0.882	24	0.798	40	0.854	56	0.789
9	0.857	25	0.832	41	0.917	57	0.820
10	0.835	26	0.870	42	D	58	0.845
11	0.888	27	0.837	43	D	59	0.832
12	0.814	28	0.784	44	D	60	0.804
13	0.838	29	0.836	45	D	61	0.821
14	0.824	30	0.848	46	0.868	62	0.852
15	0.838	31	0.832	47	0.870	63	D
16	0.785	32	0.796	48	0.832	64	D

D = Distorted and/or Burned

6.2.1.5 Airfoil Surface Finish Checks

Three nozzle segments were removed from the assembly to check the airfoil surface finish. No problems were encountered in measuring the finish of the convex side; however, due to the curvature of the vane, it was not possible to set up the equipment to obtain all the desired measurements on the concave side. Measurements were taken at the pitchline at 10%, 50%, and 90% chord.

The following are the results of the surface finish measurements (RMS):

← Convex →					← Concave →			
Vane No.	Fwd.	Mid	Aft	Avg.	Fwd.	Mid	Aft	Avg.
1	45	65	60	57	170	---	250	210
	35	55	65	52		---	---	
2	50	40	35	42	180	---	280	230
	45	25	35	35		---	---	
3	35	35	65	45	170	---	500	335
	35	40	35	37		---	---	
Overall Average				44	258			

6.2.2 Stage 2 High Pressure Turbine Nozzle Assembly

6.2.2.1 General Inspection

A visual inspection of the Stage 2 high pressure turbine nozzle, as assembled, produced no surprising results. It proved to be about as expected for an assembly with this amount of running time (see photograph, Figure 8-14, for an overall view of the assembly). The more noteworthy results of the inspections are covered in the following paragraphs.

6.2.2.2 Shroud Rubs and Condition of Bradelloy

The Stage 1 shrouds were very rough and eroded/oxidized. One shroud (No. 17) had an irregular shaped piece missing, approximately 1" x 1-1/2" (see photograph in Appendix B, Figure 8-15). This was the only missing section.

Additional roughness was noted on the shrouds due to burning, located axially in the center of several of the pieces. Burned areas averaged approximately 3/8" x 1-1/2" on each of 13 shrouds with only three parts showing any depth ($\approx 0.010"/0.020"$).

The Stage 2 shrouds had light erosion/oxidation, with no missing pieces. All shrouds were heavily rubbed, with a more recent rub, approximately 1" x 1-1/2", noted on shroud No. 1 (see photograph, Figure 8-16, in Appendix B).

6.2.2.3 Vane Condition

The vanes were in excellent condition with no burning noted on any of them. One vane, immediately behind Stage 1 Shroud No. 17, did show some type of impact damage in the center third of the leading edge (see photograph,

Figure 8-15 in Appendix B). None of the cooling holes showed indications of being clogged.

6.2.2.4 Spoolie Spring Washers

During the course of the visual inspections, eight spoolie spring washers were observed to be missing. Seven others were so badly worn that they were easily removed with no effort. All others were also worn to the extent that no more spring was left in them; however, they were still secured in place.

6.2.2.5 Nozzle Support

Inspection of the forward face of the support that mates to the Stage 1 nozzle vanes, showed good contact the full 360° circumference. All of the support cooling holes appeared to be open.

Drop checks from the forward face of the aft flange to the forward face of the lugs that support the Stage 1 vane outer hook (Dim. "K" in S/M) were taken at 16 equally spaced locations, starting at 12 o'clock, CW. The dimensions were as follows:

1	4.858"	9	4.863"
2	4.860"	10	4.861"
3	4.861"	11	4.856"
4	4.867"	12	4.858"
5	4.864"	13	4.857"
6	4.865"	14	4.857"
7	4.869"	15	4.858"
8	4.857"	16	4.862"
Average		4.861"	
Shop Dim.		4.857"/4.861"	
Service Limits		4.853"/4.865"	

Corresponding dimensions from the CRF aft flange to the aft face of the Stage 1 vane outer hook also average 4.861" (Reference 6.2.1.2, "Drop Dimension - CRF to Stage 1 Vanes"). However, this engine incorporated the 0.020" shim between the Stage 2 support mounting flange and the CRF aft flange. Therefore, the actual gap averaged 0.020".

6.2.2.6 Interstage Seal Grooves

The grooves in each of the interstage seal lands were measured at 12, 3, 6, and 9 o'clock positions. Measurements were obtained by rubbing a piece of chalk across the groove, and measuring the resultant protrusion. Following are the results:

	1		2		3		4	
Location	Width	Depth	Width	Depth	Width	Depth	Width	Depth
12 o'clock	0.126	0.070	0.120	0.062	0.110	0.055	0.100	0.055
3 o'clock	0.135	0.090	0.135	0.075	0.110	0.080	0.105	0.060
6 o'clock	0.135	0.040	0.155	0.055	0.150	0.070	0.136	0.042
9 o'clock	0.125	0.055	0.130	0.055	0.130	0.052	0.125	0.052
Average	0.130	0.064	0.135	0.062	0.125	0.064	0.119	0.052

Note: All readings are in inches.

6.2.2.7 Stage 1 and Stage 2 Shroud Radii

The Stage 2 high pressure turbine nozzle assembly was restrained on its aft flange on the fixture normally used for shroud grind, and the entire assembly centered on the inspection table. Stage 1 and 2 shrouds were measured at axial locations approximately 1/2" from LE and 1/4" from TE at each end and at the center of each shroud. Measurements at each of these locations consisted of a diameter check at the 12 o'clock position and runouts relative to this point at each of the other positions.

Stage 1 Shroud Runout Data

Shroud No.	<u>1/2" from LE</u>			<u>1/4" from TE</u>		
	1	2	3	1	2	3
1	0	4	-1	0	5	5
2	2	3	2	10	9	3
3	8	10	10	4	14	13
4	11	25	15	18	25	17
5	15	12	3	18	25	17
6	18	18	14	16	27	24
7	16	18	14	16	21	20
8	19	23	20	24	25	24
9	23	23	15	25	28	22
10	17	13	8	24	25	16
11	8	8	6	16	15	12
12	5	6	4	12	15	13
13	3	5	2	12	12	10
14	-2	3	3	11	13	10
15	3	9	14	5	15	20
16	13	19	20	20	25	29
17	13	23	13	25	30	17
18	18	17	15	22	27	22
19	15	15	10	23	23	18
20	13	13	10	12	18	17
21	11	10	5	14	19	17
22	8	9	5	16	16	11
23	6	6	5	14	13	12
24	6	8	0	13	13	6

All readings are in mils and are positive, unless otherwise indicated.

	Leading	Trailing
Diameter at 12 o'clock	33.288	33.275
Radius at 12 o'clock	16.643	16.632
Minimum Radius	16.641	16.632
Maximum Radius	16.668	16.662
Average Radius	16.653	16.649

Stage 2 Shroud Runout Data

Shroud No.	<u>1/2" from LE</u>			<u>1/4" from TE</u>		
	1	2	3	1	2	3
1	0	0	0	0	1	-3
2	-1	-2	3	1	3	0
3	3	7	8	-1	7	4
4	6	10	8	4	7	1
5	8	9	7	4	5	1
6	5	9	4	1	6	-7
7	2	7	4	-7	5	2
8	4	12	10	2	8	6
9	9	15	10	3	8	5
10	7	10	5	4	0	-6
11	1	6	6	-6	-4	-3

All readings are in mils and are positive, unless otherwise indicated.

	Leading	Trailing
Diameter at 12 o'clock	34.595"	34.605"
Radius at 12 o'clock	17.293"	17.300"
Minimum Radius	17.291"	17.293"
Maximum Radius	17.308"	17.308"
Average Radius	17.299"	17.301"

6.2.3 High Pressure Turbine Rotor Assembly

6.2.3.1 General Inspection

An overall visual inspection of the HTPR assembly showed it to be in good condition. No discrepancies were noted in any of the spool parts (disks, shafts, seals, etc.). There appeared to be a heavy Stage 2 blade-to-shroud rub, as evidenced by the discoloration at the tips of all blades, accompanied by tip burrs the full blade width. Except for the slight deposit buildup at the leading edge, convex side, the Stage 2 airfoils were smooth.

Stage 1 blades also exhibited some rubbing, but not as much as Stage 2; no burrs were noted on the blade tips. The typical heavy deposits and roughness were seen on the concave surface of the airfoil, with the convex side being smooth.

Photographs of the HTPR can be seen in Appendix B, Figures 8-17 and 8-18.

The Stage 1 and Stage 2 blade retainer wire seals were in many small pieces. These were removed and returned to Evendale. Inspection of the pieces revealed good contact between the seals and the blades.

6.2.3.2 HPTR Blade Airfoil Surface Finish

Three blades from each stage were removed to check the surface finish of the airfoils by use of a profilometer. Measurements were taken on each side at 10%, 50%, and 90% of the blade chord. Following are the results of these inspection checks (RMS μ inch):

		← Convex →				← Concave →			
Stage	Blade No.	Fwd	Mid	Aft	Avg	Fwd	Mid	Aft	Avg
1	1	110	45	45	67	75	105	195	125
	2	130	50	30	70	50	160	150	120
	3	150	50	50	83.3	55	150	170	125
	Average				73.5				123
2	1	80	40	40	53.3	35	40	70	48.3
	2	120	40	31	63.7	40	31	60	43.7
	3	130	32	41	67.7	80	37	70	62.3
	Average				61.5				51.5

6.2.3.3 Rotor Blade Tip Measurements

The HPT rotor was set up in a lathe bed and the blades shimmed per the shop manual. Runouts at two axial locations (0.100" from both the leading edge and the trailing edge) of each blade, together with the maximum blade radius of each stage, were taken and recorded. Following are the detailed data.

Stage 1 HPTR Blade Runout Data

No.	Fwd	Aft	No.	Fwd	Aft	No.	Fwd	Aft	No.	Fwd	Aft
1	11	6	28	8	3	55	10	10	82	12	9
2	9	2	29	8	1	56	11	11	83	13	10
3	10	7	30	8	3	57	10	8	84	10	9
4	7	4	31	10	3	58	11	9	85	13	10
5	8	5	32	9	3	59	13	9	86	10	9
6	5	4	33	10	2	60	11	9	87	11	8
7	9	6	34	9	4	61	13	13	88	10	9
8	7	4	35	7	1	62	11	8	89	10	8
9	12	7	36	8	5	63	14	10	90	9	9
10	10	4	37	9	1	64	12	12	91	8	6
11	6	1	38	9	3	65	10	9	92	9	7
12	8	2	39	12	4	66	12	10	93	13	8
13	13	5	40	11	4	67	13	10	94	10	8
14	13	0	41	7	3	68	12	12	95	16	10
15	11	6	42	11	6	69	16	12	96	11	9
16	7	3	43	11	5	70	13	16	97	16	12
17	11	2	44	9	6	71	12	9	98	9	7
18	9	0	45	10	4	72	11	8	99	18	11
19	11	3	46	10	12	73	12	10	100	10	5
20	10	0	47	15	12	74	11	10	101	18	10
21	11	3	48	7	9	75	12	8	102	10	4
22	9	2	49	11	9	76	10	9	103	19	14
23	16	11	50	9	9	77	13	10	104	10	7
24	6	4	51	9	8	78	11	8	105	14	12
25	10	2	52	11	11	79	11	8	106	7	7
25	9	3	53	11	7	80	12	8	107	12	9
27	9	3	54	11	13	81	12	8	108	9	7

0 = 16.569 in. = Maximum Blade Radius

Other readings are in mils and are negative

Fwd. Max. = 16.564 in.	Min. = 16.550 in.	Avg. = 16.558 in.
Aft Max. = 16.569 in.	Min. = 16.553 in.	Avg. = 16.562 in.

Stage 2 HPTR Blade Runout Data

No.	Fwd	Aft	No.	Fwd	Aft	No.	Fwd	Aft	No.	Fwd	Aft
1	10	3	30	8	2	59	13	4	88	10	5
2	7	4	31	10	1	60	12	6	89	11	5
3	7	2	32	6	2	61	10	3	90	11	7
4	8	7	33	11	2	62	12	8	91	14	3
5	8	1	34	6	1	63	11	3	92	11	4
6	8	5	35	11	2	64	11	6	93	12	5
7	7	0	36	6	1	65	14	5	94	10	6
8	7	4	37	10	1	66	11	3	95	11	4
9	7	2	38	7	1	67	13	3	96	10	4
10	8	6	39	11	2	68	12	6	97	12	3
11	8	1	40	8	2	69	14	6	98	9	4
12	7	3	41	12	2	70	11	5	99	12	4
13	8	1	42	7	0	71	14	6	100	9	5
14	7	4	43	11	2	72	11	6	101	12	4
15	7	1	44	9	2	73	13	4	102	9	4
16	6	3	45	12	3	74	11	6	103	14	4
17	8	0	46	8	3	75	14	4	104	11	5
18	6	2	47	9	2	76	14	7	105	14	4
19	7	0	48	9	5	77	14	5	106	10	2
20	7	3	49	9	1	78	11	5	107	12	2
21	9	0	50	9	5	79	14	6	108	9	1
22	8	1	51	12	3	80	10	5	109	14	6
23	7	0	52	8	3	81	14	5	110	8	4
24	6	2	53	11	4	82	10	4	111	13	6
25	9	1	54	9	5	83	14	4	112	8	3
26	7	4	55	12	1	84	11	4	113	10	1
27	10	1	56	11	3	85	16	6	114	7	0
28	6	0	57	10	3	86	11	6	115	9	1
29	10	1	58	10	8	87	13	5	116	9	5

0 = 17.223 in. = Maximum Blade Radius

Other readings are in mils and are negative.

Fwd. Max. = 17.217 in.	Min. = 17.207 in.	Avg. = 17.213 in.
Aft Max. = 17.223 in.	Min. = 17.215 in.	Avg. = 17.220 in.

6.2.3.4 HPT Blade Clearances

Calculated clearances, as derived from the blade tip measurements and the shroud dimensions (Section 6.2.2.7) were as follows:

Stage No.	B/P in.	Min. in.	Max. in.	Avg. in.	ΔB/P in.
1 (LE)	0.072	0.077	0.118	0.095	+0.023
1 (TE)	0.072	0.063	0.109	0.087	+0.015
1 (Avg)	0.072	0.070	0.114	0.091	+0.019
2 (LE)	0.075	0.074	0.101	0.086	+0.011
2 (TE)	0.075	0.070	0.093	0.081	+0.006
3 (Avg)	0.075	0.072	0.097	0.084	+0.009

6.2.3.5 Thermal Shield Seal Teeth

While in the lathe bed, measurements were taken of the HPTR thermal shield seal teeth, in the same manner as taken on the forward shaft seals.

Runout	V1	V2	V3	V4
1	0	0	0	0
2	0	0	0	0
3	0	0.5	1.0	0
4	0	0.5	1.5	1.5
5	0	0.5	1.5	1.5
6	1.5	2.0	2.0	1.0
7	0.5	1.0	1.0	2.0
8	0	1.5	2.0	2.0
9	1.0	1.5	3.0	2.5
10	1.5	2.5	3.0	3.5
11	2.0	3.0	3.5	2.0
12	2.0	3.0	3.0	2.0

0 = Max. Rad = 13.316 13.238 13.157 13.029

Resultant diameters are as follows:

Maximum	26.632"	26.475"	26.313"	26.056"
Minimum	26.628"	26.471"	26.309"	26.053"
Average	26.630"	26.473"	26.311"	26.055"

6.2.3.6 Forward Shaft Seals Dimensions

While in the lathe bed, the maximum radius of each tooth of each forward shaft seal was recorded, together with the runouts at 12 equally spaced locations. In the following tabulations, 0 = maximum tooth radius; all other readings are in mils, and are negative.

Forward Shaft Forward Seal

Runout	G1	G2	G3	G4	G5	G6
1	1.0	2.0	0.0	1.0	2.0	0
2	0	3.0	1.0	3.0	1.5	2.0
3	0	1.0	0	2.5	0.5	2.0
4	0	1.0	0	0	0.5	1.0
5	1.0	2.0	0	1.0	2.0	1.0
6	1.5	1.0	1.5	3.0	1.0	2.0
7	1.0	1.0	0	1.0	0	1.5
8	0.5	2.0	0	1.0	0.5	1.0
9	0	1.5	0	1.0	0	1.0
10	0.5	1.0	0.5	1.0	0	1.0
11	1.0	0	0	2.0	0.5	1.0
12	1.5	1.0	0	1.0	0	0.5

0 = Max. Rad. =	3.952"	4.042"	4.121"	4.200"	4.283"	4.361"
Min. Rad. =	3.9505"	4.039"	4.1195"	4.197"	4.281"	4.359"

Calculated Diameters

Maximum	7.904"	8.082"	8.242"	8.399"	8.565"	8.721"
Minimum	7.901"	8.079"	8.241"	8.396"	8.563"	8.719"
Average	7.902"	8.081"	8.242"	8.397"	8.564"	8.720"

Shop Manual Dimensions

Maximum	7.909"	8.087"	8.250"	8.410"	8.570"	8.730"
Minimum	7.899"	8.083"	8.246"	8.406"	8.566"	8.726"
MRL*	7.864"	8.048"	8.211"	8.371"	8.531"	8.691"

* MRL = Maximum Repairable Limits

Using stationary seal data from 6.1.3.4, clearances were determined to be:

B70

	1	2	3	4	5	6
Maximum	0.022"	0.013"	0.013"	0.015"	0.011"	0.013"
Minimum	0.019"	0.009"	0.010"	0.011"	0.008"	0.010"
Average	0.021"	0.011"	0.011"	0.013"	0.010"	0.012"

Overall Average Clearance = 0.013" vs 0.010" stackup of production hardware.

Forward Shaft Aft Seal

Runout	H1	H2	H3	H4	H5	H6
1	8.0	8.0	7.0	6.0	6.0	3.0
2	6.0	6.5	5.0	5.0	6.0	3.0
3	2.0	1.0	1.0	2.0	2.5	2.0
4	1.0	4.0	3.0	4.5	2.0	2.0
5	6.5	8.0	7.0	9.0	7.0	3.0
6	7.0	7.0	6.0	6.5	7.5	6.0
7	5.0	5.0	4.0	2.5	2.5	2.0
8	1.5	3.5	2.5	3.0	2.0	1.0
9	5.5	5.5	4.5	4.5	4.5	2.0
10	2.0	2.5	1.0	2.0	2.5	1.0
11	0	0	0	0	0	0
12	4.5	4.5	3.0	4.0	3.0	0.5

0 = Max. Rad. =	5.214"	5.298"	5.378"	5.457"	5.536"	5.614"
Min. Rad. =	5.206"	5.290"	5.371"	5.448"	5.5285"	5.608"

Calculated Diameters

Maximum	10.425"	10.589"	10.752"	10.907"	11.067"	11.225"
Minimum	10.415"	10.583"	10.745"	10.904"	11.062"	11.222"
Average	10.420"	10.587"	10.749"	10.906"	11.064"	11.224"

Shop Manual Dimensions

Maximum	10.417"	10.587"	10.747"	10.907"	11.067"	11.227"
Minimum	10.413"	10.583"	10.743"	10.903"	11.063"	11.223"
MRL*	10.378"	10.548"	10.708"	10.868"	11.028"	11.188"

*MRL = Maximum Repairable Limits

Using stationary seal data from 6.1.3.4, clearances were determined to be:

B71

	1	2	3	4	5	6
Maximum	0.015"	0.021"	0.018"	0.023"	0.024"	0.022"
Minimum	0.007"	0.010"	0.007"	0.013"	0.013"	0.011"
Average	0.011"	0.016"	0.012"	0.017"	0.019"	0.016"

Overall Average Clearance = 0.015" vs 0.010" stackup of production hardware.

6.3 LOW PRESSURE TURBINE SECTION

One of the most important objectives of the NASA-Lewis Diagnostics Program is to evaluate low pressure turbine (LPT) performance restoration. In accordance with this, following the inbound performance test, the LPT module was removed from the engine and disassembled into its major components for various inspection checks, and for cleaning of the blades and vanes.

Upon completion of this activity, the module was rebuilt and reinstalled on the engine. This was followed by a test cell run to measure the change in engine and component performance. While the work was being performed on the LPT section, the rest of the engine was not disturbed. This was done so that any performance changes could be attributed only to the refurbishment of the LPT blade and vane surface finish, and not to some unrelated activity.

During the core analytical teardown, the LPT module was removed from the engine and set aside with no further disassembly. In time it was returned to United Airlines "as is" - together with the engine modules and other hardware.

Following are the results of the LPT module analytical teardown and refurbishment.

6.3.1 Turbine Midframes

6.3.1.1 General

Visual inspection of the turbine midframe revealed two holes (3/4" dia. and approximately 1" x 2-1/2") in the inner liner aft of Strut No. 2; one hole on each side of the strut (see photograph, Figure 8-18 in Appendix B). Aft of Strut No. 2, there was a 4" circumferential crack in the liner, and another circumferential crack approximately 9" long was observed in the liner

behind Strut No. 3.

The aft outer seal had numerous cracks and several missing pieces. A number of cracks were also noted on the Stage 1 nozzle outer support ring.

No attempt was made to repair or to replace any of the discrepant parts. Any change of hardware at this time could have clouded any subsequent data taken to analyze the LP system per the test plan.

It was the consensus of opinion that none of the noted faults were serious enough to imperil the engine during the remaining planned tests. Therefore, after all the inspection checks were complete, the TMF was re-assembled to the package together with all the original hardware "as is." The test program was completed without incident.

After removal of the LPT module during the core analytical teardown, the TMF liner was visually inspected, as viewed from the forward end, and no further crack progression was noted. It was noted during this inspection that the buckling of the liner had caused one EGT T/C probe aspirator hole to be immersed in the cooler TMF liner cavity. Another was partially immersed. Possibly this could have been the reason for the inconsistent EGT indicated readings, recorded during the several tests conducted.

6.3.1.2 LPT Pressure Balancing Seal

An eight-point diameter measurement of the LPT pressure balance seal produced the following results:

- | | |
|------------|------------|
| 1. 19.054" | 5. 19.055" |
| 2. 19.049" | 6. 19.052" |
| 3. 19.053" | 7. 19.049" |
| 4. 19.049" | 8. 19.051" |

Average = 19.052"; S/M = 19.050"/19.054"

Average clearance (C27) to the rotating seal (see 6.3.2.2) was calculated to be 0.032" vs 0.031" stackup of new production hardware.

6.3.1.3 Stage 1 LPTN Vane Airfoil Surface Finish

The airfoils of the end vanes of two Stage 1 LPT nozzle vane segments

were inspected after removal from the TMF. The profilometer and associated hardware used for these surface-finish checks were supplied by Airline Support Engineering (ASE), Evendale. A typical setup of this equipment can be seen in Figures 8-20 and 8-21 in Appendix B.

Following the inspection, these vanes together with all the other Stage 1 vanes were SWECO-cleaned for two hours. Vane segment S/N B0631, one of the two that had been inspected, was subjected to six more hours of cleaning to determine if a longer cleaning cycle would further improve the surface finish. A recheck of the previously inspected airfoils was then made to ascertain the net improvement. The vanes in S/N B0631 did appear to clean up more than the other; but it is felt that a more detailed test is required to establish the optimum amount of the time required for the cleaning cycle.

For comparison purposes, the results of the Stage 1 vane airfoil surface-finish checks have been grouped with similar data acquired on the vane airfoils in the other stages of the LPT section (see 6.3.3.2, "Airfoil Surface Finish Checks"). The measurements were taken 0.45"/0.50" from the leading edge (LE) and the trailing edge (TE) on each side; tip readings were taken 0.50" below the outer platform.

6.3.2 Low Pressure Turbine Rotor

6.3.2.1 General Inspection

A visual inspection of the LPT rotor assembly showed it to be in excellent condition. No discrepancies were observed on any of the spool parts. Blades were rough and dirty, typical of blades which have this amount of running time. A photograph of the rotor assembly can be found in Appendix B, Figure 8-22, showing it mounted in the lathe bed for the inspection checks.

6.3.2.2 Dimensional Inspections

The LPT rotor was set up in a lathe bed on the No. 6 and the No. 7 journals for radial measurements of the blade tip shroud seal serrations, each stage; of the air seal teeth, each stage; and of the pressure balance seal teeth. The results are as follows:

LPTR Blades

	← Forward →			← Aft →		
Stage	Max. Rad.	Min. Rad.	FIR	Max. Rad.	Min. Rad.	FIR
1	24.133	24.121	0.012	24.129	24.118	0.011
2	24.090	24.084	0.006	24.115	24.109	0.006
3	24.093	24.082	0.011	24.106	24.098	0.008
4	24.118	24.103	0.015	24.119	24.106	0.013
5	24.120	24.101	0.019	24.113	24.100	0.013

Interstage Seals

	← Forward →			← Aft →		
1	18.191	18.188	0.003	N/A		
2	18.005	18.001	0.004	18.004	18.002	0.002
3	16.851	16.846	0.005	16.850	16.836	0.014
4	15.579	15.575	0.004	15.583	15.580	0.003
5	14.216	14.213	0.003	14.223	14.215	0.008

Pressure Balance Seal

Tooth

F-1	9.495	9.491	0.004
-2	9.497	9.493	0.004
-3	9.497	9.493	0.004
-4	9.497	9.493	0.004
-5	9.497	9.493	0.004

6.3.2.3 Airfoil Surface Finish Checks (RMS)

After the lathe bed inspections, two blades per stage were removed from the rotor for airfoil surface finish checks. Following these checks, all blades were removed from the rotor and SWECCO-cleaned for two hours. The surface finish was then rechecked on the same blades as previously checked.

The following is a tabulation of these surface finish inspections: dirty (D), clean (C), and the differences (Δ). All readings were taken 0.10"/0.15" from LE and TE, each side. Tip readings were taken 0.50" below the blade's outer platform.

			← Convex →					← Concave →		
Stage	S/N	Condi- tion	Tip		Pitch		Avg	Pitch		
			LE	TE	LE	TE		LE	TE	Avg
1	D1249	D	140	70	80	75	91	70	100	85
		C	100	45	60	75	70	60	80	70
		Δ	40	25	20	0	21	10	20	15
1	B7746	D	130	65	85	*55	93	55	65	60
		C	85	65	55	*65	68	50	50	50
		Δ	45	0	30	*-	25	5	15	10
2	A1774	D	130	80	65	55	83	55	65	60
		C	100	45	45	35	56	45	55	50
		Δ	30	35	20	20	26	10	10	10
2	A3139	D	140	60	60	65	81	60	60	60
		C	75	40	50	50	54	55	60	57
		Δ	65	20	10	15	27	5	0	3
3	Z0168	D	90	75	70	45	70	65	55	60
		C	80	60	55	30	56	45	50	47
		Δ	10	15	15	15	14	20	5	13
3	Z0710	D	90	85	60	60	74	65	70	67
		C	55	45	40	40	45	50	40	45
		Δ	35	40	20	20	29	15	30	22
4	Y6830	D	90	80	60	75	76	70	70	70
		C	70	35	25	45	44	45	55	50
		Δ	20	45	35	30	32	25	15	20
4	Y3666	D	90	70	65	60	71	65	70	68
		C	70	50	35	45	50	55	65	60
		Δ	20	20	30	15	21	10	5	7
5	X4917	D	70	50	40	55	54	70	50	60
		C	45	30	25	30	32	30	25	27
		Δ	25	20	15	25	21	40	25	32
5	X2121	D	90	60	55	60	66	65	55	60
		C	80	30	40	35	46	60	40	50
		Δ	10	30	15	25	20	5	15	10
Avg.	Rotor	D					76			65
		C					52			51
		Δ					24			14

Note: *Evidently one and/or the other reading is in error; both omitted from the averages.

6.3.2.4 Rebuild

Following the cleaning and surface finish checks, the blades were reinstalled in the spool per position marks (as identified during disassembly). The rotor was then reassembled to the package for the next series of tests.

6.3.3 Low Pressure Turbine Stator Assembly

6.3.3.1 General Inspection

Visual inspection of the LP turbine stator assembly showed it to be in good condition. Rub patterns on the shrouds and seals were typical of those observed in the past. (See photographs in Appendix B, Figures 8-23, 8-24, and 8-25.) Casteone impressions were made of the maximum depth rub pattern visually observed in each casing half for all shrouds and interstage seals. A sketch of each of these is shown in Figure 6-1.

The impressions are in the files of ASE Engineering, and no further action is planned for them unless some future testing in the program indicates a need for further study.

6.3.3.2 Airfoil Surface-Finish Checks

Two vane segments, each stage, were removed and the surface finish of each of the end vane airfoils, each segment, was inspected. The remaining segments were then removed and all vanes were SWECO-cleaned for two hours. The previously inspected airfoils were rechecked to determine the effect of the cleaning.

The following is a tabulation of these surface inspections: dirty (D), clean (C), and the difference (Δ). All measurements were taken 0.45"/0.50" from the leading edge and from the trailing edge, each side. Tip readings were taken 0.050" below the outer platform.

Note: Stage 1 vane data (though part of the TMF module) are included here for ease of comparison with the vanes in the rest of the low pressure turbine assembly.

SEALS



Stg. 1 (TMF)



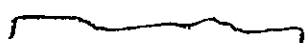
Stg. 2 - Lower



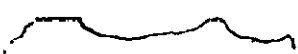
Stg. 2 - Upper



Stg. 3 - Lower



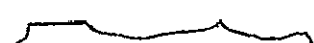
Stg. 3 - Upper



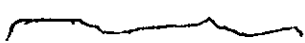
Stg. 4 - Lower



Stg. 4 - Upper

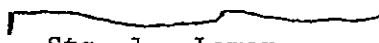


Stg. 5 - Lower



Stg. 5 - Upper

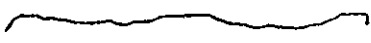
SHROUDS



Stg. 1 - Lower



Stg. 1 - Upper



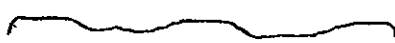
Stg. 2 - Lower



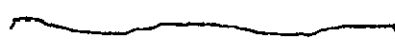
Stg. 2 - Upper



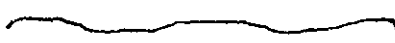
Stg. 3 - Lower



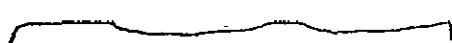
Stg. 3 - Upper



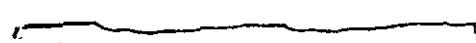
Stg. 4 - Lower



Stg. 4 - Upper



Stg. 5 - Lower



Stg. 5 - Upper

Figure 6-1. LPTS Shroud and Interstage Seal Rub Impressions.

Stage	S/N	Condi- tion	← Convex →					← Concave →		
			Tip		Pitch		Avg	Pitch		Avg
			LE	TE	LE	TE		LE	TE	
1	B0631	D	120	80	110	90	100	110	110	110
		C	75	35	65	50	56	60	75	67
		Δ	45	45	45	40	44	50	35	43
1	A9567	D	100	75	95	85	89	90	90	90
		C	70	60	70	45	61	55	60	57
		Δ	30	15	25	40	28	35	30	33
2	B0180	D	150	110	120	90	117	110	105	107
		C	80	50	65	45	60	85	35	60
		Δ	70	60	55	45	57	25	70	47
2	B0164	D	125	120	105	60	102	85	80	82
		C	50	40	50	45	46	66	40	47
		Δ	75	80	55	15	56	30	40	35
3	T2369	D	90	110	75	65	85	100	75	88
		C	50	55	45	30	45	70	50	60
		Δ	40	55	30	35	40	30	25	28
3	T2157	D	120	100	80	70	93	85	80	82
		C	55	50	40	35	45	65	45	55
		Δ	65	50	40	35	48	20	35	27
4	V1998	D	110	85	70	50	79	65	70	68
		C	60	45	35	20	40	35	35	35
		Δ	50	40	35	30	39	30	35	33
4	U6005	D	130	110	95	65	100	80	100	90
		C	90	70	45	45	62	45	45	45
		Δ	40	40	50	20	38	35	55	45
5	V3698	D	105	95	65	80	86	70	70	70
		C	70	65	35	50	55	45	50	47
		Δ	35	30	30	30	31	25	20	23
5	V3647	D	125	85	80	75	91	85	75	80
		C	85	60	50	40	59	50	35	42
		Δ	40	25	30	35	32	35	40	38
Avg.	Stator	D					94			87
		C					53			52
		Δ					41			35

6.3.3.3 Rebuild

Upon completion of the cleaning and surface-finish checks, the low pressure turbine stator assembly was reassembled using all the original hardware. The cases were included in the rebuild of the LPT module for resumption of the test plan.

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6.4 FAN SECTION

Another objective of the NASA-Lewis Diagnostics Program is the evaluation of fan performance restoration with regard to blade leading edge quality and airfoil surface cleanliness. The fan section performance deterioration is believed to be primarily attributed to changes in the fan blade leading edge due to FOD, erosion, etc., and due to buildup of dirt on the airfoil.

To determine the performance effects for the fan section components, the following method was employed: The test cell run after the LPT blade and vane refurbishment served as a baseline for subsequent tests. Following this run, the Stage 1 blades were removed, cleaned, and the leading edges recontoured per Shop Manual. Another test cell run was then conducted. Since no other changes were made to the engine during this time period, the performance improvements achieved were attributed to the fan blade refurbishment. Figure 8-26 in Appendix B compares a recontoured blade with one that had not yet been reworked.

Upon completion of these tests, the core analytical teardown was begun with no further activity on the fan section. Disassembly, as required, was conducted in order to prepare the fan module for shipment back to United Airlines with the other engine modules.

The following are the results of the fan section analytical teardown and refurbishment.

6.4.1 Fan Rotor

When the engine was received from United Airlines, a visual inspection showed 21 Stage 1 fan blades had tiny, insignificant nicks on the leading edges, the majority of which were in the blade outer panel. Otherwise, the blades were in good condition with no large dirt buildups.

Leading edge contour was such that during the test plan, when the blades were reconditioned for test evaluation purposes, only minor rework using Tool 2C7546 was required to bring the contour into limits. See photograph, Figure 8-26, in Appendix B, depicting one blade before and another blade after re-contour. The pressure side radius was already in limits, so no hand-blending was necessary on any of the blades.

Visual inspection of the Stage 2 blades, through the Stage 1 fan blades and vanes, showed them to be in excellent condition with no nicks, dents, etc.

6.4.2 Fan Stator

The Stage 1 open faced, aluminum honeycomb shroud exhibited typical ice damage. There were approximately 30 pock marks distributed through the full 360° circumference and located in the path of the blades. The typical size indentation was approximately 3/8" x 1-1/2", with the honeycomb mashed to a depth of 0.050"/0.080". In addition, there were many superficial markings the full width and circumference of the shroud. See photograph, Figure 8-27 in Appendix B, which shows a typical section of the damaged shroud.

The midring shroud (Stage 2), as viewed through the Stage 1 fan blades and vanes, appeared to be in excellent condition. No missing pieces were noted, other than approximately a 1/2" square piece at 1 o'clock. Some light rubs were noted at various locations throughout the circumference, but these are normal. This shroud was still of the abradable material, which has since been replaced by open face, aluminum honeycomb in later production CF6-6 engines and in many updated field engines.

Stage 1 fan blade OGV's also were in excellent condition. There was some slight damage on the leading edge of the aft stator case linings. This too can be attributed to ice damage. A photograph showing the worst observed damage can be found in Appendix B, Figure 8-28.

6.4.3 Stage 1 Fan Blade Tip Clearances

6.4.3.1 Rotor Runout

The clearance between the shroud and each Stage 1 fan blade was measured at the 6 o'clock position at both the E12 and the E13 locations. The detailed data are as follows:

Clearances at E12

<u>Blade No.</u>	<u>Clearance</u>	<u>Blade No.</u>	<u>Clearance</u>
1	0.170	20	0.160
2	0.168	21	0.162
3	0.150	22	0.160
4	0.165	23	0.150
5	0.170	24	0.168
6	0.165	25	0.160
7	0.155	26	0.170
8	0.170	27	0.160
9	0.168	28	0.155
10	0.165	29	0.170
11	0.160	30	0.163
12	0.160	31	0.152
13	0.170	32	0.163
14	0.165	33	0.160
15	0.170	34	0.167
16	0.155	35	0.160
17	0.165	36	0.145
18	0.165	37	0.180
19	0.165	38	0.160
Average Clearance =		0.163"	
Smallest Clearance =		0.145"	
Average E12 Rotor			
Runout =		0.018" vs 0.014" Maximum Per B/P	

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Clearances at E13

<u>Blade No.</u>	<u>Clearance</u>	<u>Blade No.</u>	<u>Clearance</u>
1	0.160	20	0.155
2	0.161	21	0.155
3	0.153	22	0.165
4	0.165	23	0.152
5	0.162	24	0.155
6	0.145	25	0.155
7	0.150	26	0.160
8	0.165	27	0.155
9	0.172	28	0.153
10	0.170	29	0.155
11	0.168	30	0.160
12	0.153	31	0.150
13	0.165	32	0.155
14	0.170	33	0.145
15	0.163	34	0.155
16	0.145	35	0.147
17	0.157	36	0.150
18	0.146	37	0.165
19	0.155	38	0.155

Average Clearance = 0.157"

Smallest Clearance = 0.145"

Average E13 Rotor
Runout = 0.012" vs 0.014" Maximum Per B/P

6.4.3.2 Shroud Runout

Using the blades with the smallest clearances at E12 (#36) and at E13 (#33) locations, clearances were measured to the shroud at 12 equally spaced locations starting at 12 o'clock and working CW, ALF.

Clearances at E12 (B/P = 0.145" Min.)

<u>Position No.</u>	<u>Clearance</u>	<u>Position No.</u>	<u>Clearance</u>
12 o'clock	0.150	6 o'clock	0.145
1	0.140	7	0.153
2	0.130	8	0.155
3	0.130	9	0.157
4	0.139	10	0.150
5	0.142	11	0.145

Average = 0.145"

Clearances at E13 (B/P = 0.145" Min.)

<u>Position No.</u>	<u>Clearance</u>	<u>Position No.</u>	<u>Clearance</u>
12 o'clock	0.145	6 o'clock	0.145
1	0.135	7	0.150
2	0.125	8	0.160
3	0.125	9	0.165
4	0.135	10	0.163
5	0.145	11	0.155

Average = 0.146"

6.4.3.3 Blade-to-Shroud Clearances

Using the aforesaid information, the Stage 1 fan blade tip clearances were determined to be as follows:

	<u>E12</u>	<u>E13</u>	<u>B/P</u>
Minimum	0.130"	0.125"	0.145" min.
Maximum	0.192"	0.192"	-
Average	0.163"	0.158"	0.163" max.

7.0 ANALYTICAL ASSESSMENT OF PERFORMANCE LOSSES

The 451-479 detailed analytical teardown inspections and measurements were evaluated resulting in a performance stackup using influence coefficients listed in Tables 7-1 and 7-2. The coefficients are based on current "best estimate" of hardware effects on engine performance and may be updated based on information learned during the NASA-Lewis CF6 Jet Engine Diagnostics Program. The performance stackup (Table 7-3) relative to new engine performance, is based on the analytical teardown inspections summarized in the 451-479 engine report. (See Section 6.0.) The first column (assessment) is based on the analytical measurements and influence coefficients, while the second column (measured) is based on the measured test cell performance deltas between the Evendale production test and the Ontario inbound test. (See Section 5.0.)

Note that the core engine stackup (HPC efficiency, HPT efficiency, and parasitics) is significantly different from the measured component analysis. Much of this discrepancy is due to the problems noted in Section 5.0. A slight error in A_4 , T_3 , P_3 , or EPR can alter the component assessment significantly.

The 3.23% SFC assessment compares well with the 4.5% measured deltas, which means approximately 72% of the SFC losses have been accounted for. However, the 54° F EGT assessment (as compared to a 108° F measured delta) indicates a problem in evaluating the EGT loss. As stated earlier, the influence coefficients are "best estimates" which may be modified based on the results of the Diagnostics Program. In addition, the analytical analysis obviously does not address to all the possible loss mechanisms. For instance, no method has yet been devised to completely assess the Stage 1 HPT nozzle assembly. Losses due to vane surface-finish deterioration can and are assessed; but beyond that, no influence coefficients are available to cover other detrimental conditions. Conditions such as ballooning, bowing, or burning of vanes, in addition to the size of the gap/interference fit between the Stage 2 HPT nozzle support forward flange and the Stage 1 vane outer flange, cannot be assessed. An excessive gap would result in cooling air

Table 7-1. CF6-6 Influence Coefficients.

Component	Description	°F EGT	$\frac{\% \text{ SFC}}{\text{T/O CR.}}$	
<u>HPT</u>				
Rotor Blades	Surface finish rms μ in. for 0.1% η_t			
Stage 1	Suction 26 μ in. Pressure 330	2	0.08	0.06
Stage 2	Suction 32	2	0.08	0.06
Shrouds	Surface finish Tip clearance for 1% η_t			
Stage 1	30 mils	21	0.85	0.62
Stage 2	50 mils	21	0.85	0.62
Interstage Seal	20 mils = 0.15% η_t	3	0.12	0.09
Rotating				
Stationary				
Stator Vanes	Surface finish rms μ in. for 0.1% η_t			
Stage 1	Suction 20 Pressure 140	2	0.08	0.06
Stage 2	Suction 28 Pressure 240	2	0.08	0.06
Both Nozzles	None			
Bal. Piston Seal	33 mils = 0.1% WC16 to HP	18	0.72	0.54
Rotating				
Stationary				
<u>LPT</u>				
Nozzles				
Stage 1				
Stage 2				
Stage 3				
Stage 4				
Stage 5				
Rotor Blades	60 μ in. surface finish blades and vanes*			
Stage 1	= 0.41% η_{2t}	3.0	0.31	0.26
Stage 2	= 0.29% η_{2t}	2.1	0.22	0.18
Stage 3	= 0.18% η_{2t}	1.3	0.13	0.11
Stage 4	= 0.10% η_{2t}	0.7	0.07	0.06
Stage 5	= 0.02% η_{2t} 1.00% η_{2t}	0.1 7.2	0.01 0.74	0.01 0.62
Shrouds	40 mils tip seal clear			
Stage 1	= 0.28% η_{2t}	2.0	0.21	0.18
Stage 2	= 0.20% η_{2t}	1.4	0.15	0.13
Stage 3	= 0.15% η_{2t}	1.1	0.11	0.09
Stage 4	= 0.11% η_{2t}	0.8	0.08	0.07
Stage 5	= 0.06% η_{2t} 0.80% η_{2t}	0.4 5.7	0.04 0.59	0.04 0.51
Interstage Seals				
Rotating	20 mils clear			
Stage 1				
Stage 2	= 0.25% η_{2t}	1.8	0.19	0.16
Stage 3	= 0.14% η_{2t}	1.0	0.10	0.09
Stage 4	= 0.15% η_{2t}	0.7	0.07	0.06
Stage 5	= 0.05% η_{2t} 0.54% η_{2t}	0.4 3.9	0.04 0.40	0.03 0.34

*Pressure (concave) surface values weighted at 1/4
Suction (convex) surface values weighted at 3/4

Table 7-2. CF6-6 Influence Coefficients.

Component	Description	° F EGT	T SFC	
			T/O	CR.
Interstage Seals				
Stationary				
Stage 1				
Stage 2				
Stage 3				
Stage 4				
Stage 5				
Bal. Piston Seal	51 mils = 0.1% WC16 to LP from HP	2	0.25	0.2
Rotating				
Stationary				
CDP SEALS				
Fwd. Seal	19 mils = 1% WC16 to HP	18	0.72	0.54
Rotating				
Stationary				
Aft Seal	33 mils = 1% WC16 to HP	18	0.72	0.54
Rotating				
Stationary				
COMPRESSOR-ALL PARTS				
Rotor Blades	Dirt buildup, damage, L/E irregularity Tip Clear avg. 10 mils tighter throughout compressor = 1% nc Breakdown - 10 mils each stage: Blade to case: Stage 1-4 0.05% nc Stage 5-16 0.49% nc Vane to spool: Stage 3-7 0.13% nc Stage 8-15 0.33% nc Total 1.00% nc Surface finish: 6 rms μ in. = 0.1% nc 33% of blades eroded on each stage, Stage 5 on back = 0.7% nc 50% = 1.0% nc			
		1	0.04	0.03
		9.3	0.37	0.25
		2.5	0.10	0.07
		6.3	0.25	0.18
		19.0	0.75	0.54
		2	0.08	0.03
Compressor Casings	Leaking variable stator bushings			
Stator Vanes	Surface finish: 10 rms μ in. = 0.1%	2	0.08	0.03
FAN				
Vanes	Surface finish:			
Stage 2	87 rms μ in. = 0.1% nf	0.6	0.07	0.05
OGV - Inner	87 rms μ in. = 0.1% nf	0.6	0.07	0.05
OGV - Outer	80 rms μ in. = 0.1% nf	0.6	0.07	0.05
Fan Rotor Blades				
Stage 1	Tip clear 35 mils = 0.6% nf Surface finish: 27 rms μ in. = 0.1% nf	3.6	0.42	0.30
		0.6	0.07	0.05
Stage 2	Tip clear 40 mils = 0.3% nf 22 rms μ in. 0.1% nf	1.8	0.21	0.15
		0.6	0.07	0.05

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Table 7-3. Analytical Assessment of 451-479 Losses.

	Assessment			Measured	
	η	EGT	SFC	EGT	SFC
HP Compressor	0.74%	14° F	0.55%	4° F	0.2%
Blade Surface Finish (18 RMS μ in.)	0.30				
Vane Surface Finish (34 RMS μ in.)	0.34				
Rotor Land Coating (10 mils)	0.10				
HP Turbine	1.22%	26° F	1.04%	99° F	4.2%
Stage 1 Nozzle Surface Finish	0.10				
Stage 1 Blade Surface Finish	0.06				
Stage 2 Blade Surface Finish	0				
Stage 1 Blade Tip Clearance (+ 19 mils)	0.63				
Stage 2 Blade Tip Clearance (+ 9 mils)	0.18				
Burned Stage 1 Nozzles (9 segments)	0.20				
Stage 1 Shroud Roughness	0.05				
Parasitics	0.24%	4° F	0.17%	0	0
Aft CDP Seal (+ 3 mils-Rotating)	0.09				
Balance Piston Seal (+ 5 mils-Stationary)	0.15				
Forward CDP Seal (0)	0				
LPT Pressure Balance Seal (+ 1 mil)	0				
LP System	2.03%	10° F	1.47%	5° F	0.1%
Rotor Clearance	0.10%	0.7° F	0.07%		
Stage 2 (+ 14 mils)	0.07				
Stage 3 (+ 7 mils)	0.02				
Stage 5 (+ 3 mils)	0.01				
I/S Seal Clearance	0.10%	0.7° F	0.07%		
Stage 2 (+ 4 mils)	0.05				
Stage 3 (+ 4 mils)	0.03				
Stage 4 (+ 1 mil)	0				
Stage 5 (+ 8 mils)	0.02				
Blade Airfoil Surface Finish	0.57%	4° F	0.42%		
Stage 1	0.29				
Stage 2	0.15				
Stage 3	0.07				
Stage 4	0.05				
Stage 5	0.01				
Vane Airfoil Surface Finish	0.56%	4° F	0.41%		
Stage 1	0.23				
Stage 2	0.21				
Stage 3	0.07				
Stage 4	0.04				
Stage 5	0.01				
Stage 1 Fan Blade LE Cleanliness	0.70%	0° F	0.50%		
Total		54° F	3.23%	108° F	4.5%

See Figure 7-1 for Engine Cross Section.

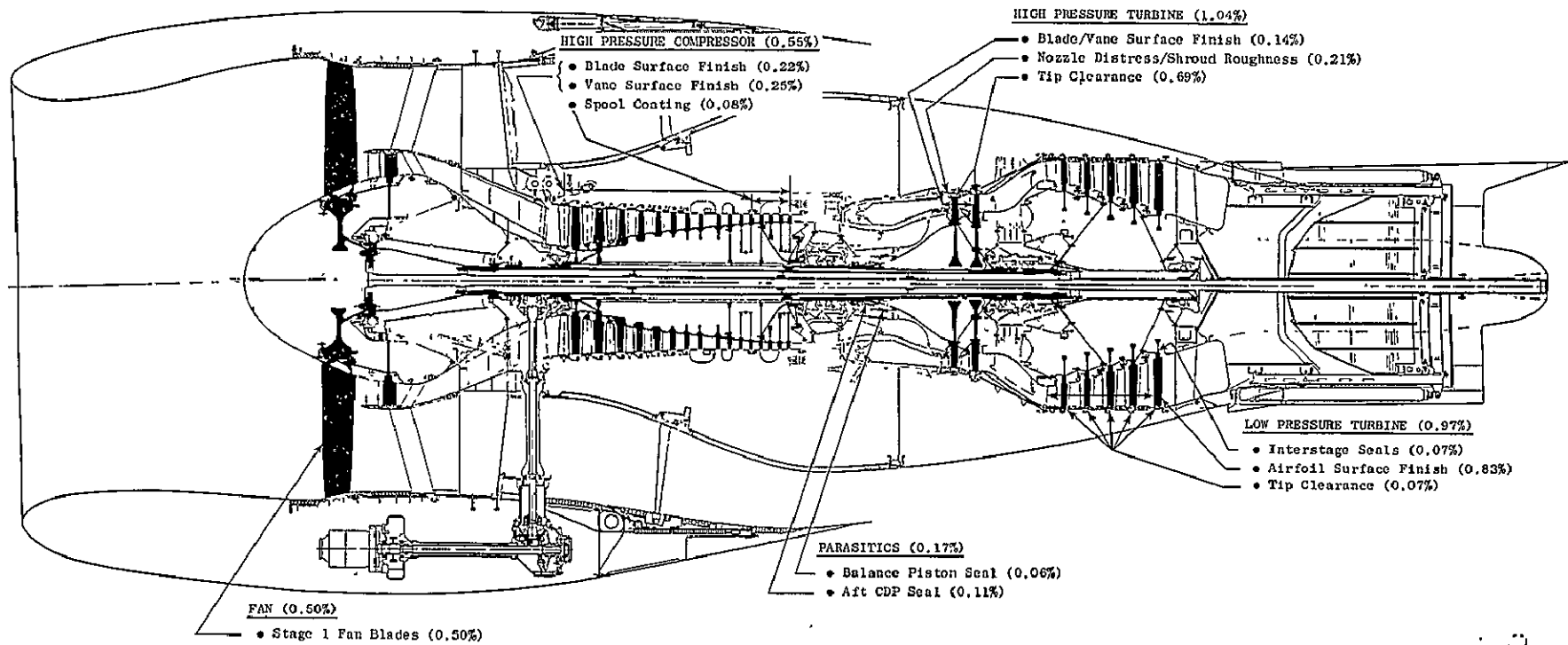


Figure 7-1. General Electric CF6-6 Engine Cross Section.

leakage between the flanges; whereas an extreme interference fit would cause the vanes to be tilted forward, resulting in uneven loading, which also would allow leakage between the flanges. During the Performance Restoration Program for 451-337 in early 1975, back-to-back engine tests were conducted to compare the original hardware versus a new Stage 1 HPT nozzle assembly. A 1.2% improvement in SFC was realized; however, it should be noted that the new Stage 1 HPT nozzle assembly incorporated shims to reduce vane to Stage 2 support interference and the Stage 2 HPTN support flange was reworked to 63 RMS finish. Calculations during the buildup revealed a one mil average interference between the nozzle vane outer flange and the Stage 2 support. Effort is planned as part of this program at a later date to address to this condition.

The Stage 1 fan blades with regard to blade leading edge contour and airfoil surface cleanliness is another example of hardware that cannot be analytically assessed as to performance loss. For this reason, the testing sequence included back-to-back tests comparing performance levels of the blades in the "as-received" condition vs performance levels of the blades after cleaning the airfoils and reworking the leading edges. An 0.5% improvement in SFC was demonstrated and is included in the analytical assessment of losses (Table 7-3).

Other potential areas that do not lend themselves to assessment include the dirt buildup on the HPC airfoils and leakage paths throughout the engine (variable stator bushings, split line flanges, and piping flanges).

The Test Program also included back-to-back tests comparing low pressure turbine performance with blade and vane airfoils in the "as-received" condition versus the same blades and vanes after having been cleaned by the SWECO method. (See Section 6.3.) Airfoil surface finish of two each blades and vanes (each stage) were measured both before and after cleaning, as recorded in 6.3.2.3 and 6.3.3.2.

The analytical assessment of the losses caused by surface-finish deterioration, as compared to original manufacturing requirements, is contained in Table 7-3. Table 7-4 shows the assessment of the performance recovered by

Table 7-4. Analytical Assessment of Refurbished Airfoils.

	<u>η</u>	<u>EGT</u>	<u>SFC</u>
Blade Airfoil Surface Finish	0.35%	2.5° F	0.26%
Stage 1	0.14		
Stage 2	0.10		
Stage 3	0.06		
Stage 4	0.04		
Stage 5	0.01		
Vane Airfoil Surface Finish	0.69%	5.0° F	0.51%
Stage 1	0.25		
Stage 2	0.25		
Stage 3	0.12		
Stage 4	0.06		
Stage 5	0.01		
Total	1.04%	7.5° F	0.77%

cleaning of the airfoils. As can be seen, 0.83% SFC loss was assessed and 0.77% was regained; or, in other words, 93% of the SFC assessment for airfoil surface finish deterioration was recovered as a result of the refurbishment. These figures tend to substantiate the cleaning method; however, more sampling should be undertaken to further prove the process. The measured improvement due to cleaning the airfoils, however, was negligible as reported in Section 5.0. This tends to indicate that the LPT airfoil surface finish influence coefficients must be reevaluated since an 0.8% improvement in LPT efficiency was expected.

When comparing the analytical assessment to the measured performance deterioration, it must be realized that some of the designated hardware deterioration may have occurred prior to running the Evendale performance acceptance test. The seal break-in run and engine accels may cause some of the seal and blade clearances to open prior to running the performance test. For the purpose of this analysis, however, it is assumed that all the losses occur after the official production acceptance test.

8.0 APPENDICES

8.1 APPENDIX A - FUEL ANALYSIS

8.2 APPENDIX B - PHOTOGRAPHS

8.3 APPENDIX C - LOG SHEETS, INBOUND RUN

8.4 APPENDIX D - LOG SHEETS, TESTS 2 AND 3

8.1 APPENDIX A - FUEL ANALYSIS

GENERAL  ELECTRIC

EVENDALE PLANT
CINCINNATI, OHIO 45215

• SUBJECT

FUEL ANALYSIS

May 5, 1977

J. Smith

M.D. F117

MAIL DROP M82

DIAL COMM 8 * 332 3743

COPIES:



Following are the results of fuel analysis by the Bearings/Gears & Fuels/
Lubes Lab

Sample Identification:

1. "Sample #1" (Composite of two) CF6-6D #451-479
2. "Sample #2" (Composite of three) " "
3. _____

Hydrogen:

1. 13.95%
2. 13.89%
3. _____

Sulfur:

1. 0.136%
2. 0.136%
3. _____

Net Heat by Precision Bomb:

1. 18602 Btu/#
2. 18600 Btu/#
3. _____

Comments Specific gravity:

Sample #1 .7885 @ 60°F
Sample #2 .7876 @ 60°F


J. M. Fausz

8.2 APPENDIX B - PHOTOGRAPHS

The photographs listed below are included in this report and were selected to support discussions. Other photographs, not included in this report, are available in the CF6 Diagnostics Field Engineering files.

Figure

- 8-1. High Pressure Compressor Rotor (Cleaned), Missing Blades at Surface Finish Check.
- 8-2. HP Compressor Rotor Stages 13 to 15 Land Coating.
- 8-3. HP Compressor Stator Upper Overall Oil, Dirt, Rubs.
- 8-4. HP Compressor Stator, Upper Stage 7 to OGV - Rubs.
- 8-5. HP Compressor Stator, Lower Stage 9 to OGV - Rubs.
- 8-6. Combustor, Overall Cracks.
- 8-7. Combustor, Closeup Crack at 7 o'clock.
- 8-8. Compressor Rear Frame, Forward Seals - Overall View, Installed.
- 8-9. No. 4B Pressure Balance Seal, Overall View.
- 8-10. Stage 1 HP Turbine Nozzle Assembly, Aft End, Overall View.
- 8-11. Stage 1 HP Turbine Nozzle Assembly, Trailing Edge, Burnt/Distorted Vanes.
- 8-12. Stage 1 HP Turbine Nozzle Assembly Distress, Aft End.
- 8-13. Stage 1 HP Turbine Nozzle, Typical Vane Distress.
- 8-14. HP Turbine Nozzle Assembly, Overall View, Forward End.
- 8-15. Stage 2 HP Turbine Nozzle, Damage Vane/Stage 1 Shroud.
- 8-16. Stage 2 HP Turbine Nozzle Stage 2 Shroud Rub.
- 8-17. HP Turbine Rotor, Overall View of Blades.
- 8-18. HP Turbine Rotor, Blade Tip Rubs.
- 8-19. Turbine Midframe Liner Distress.
- 8-20. Profilometer Setup, LP Turbine Nozzle Segment, Concave Side.
- 8-21. Profilometer Setup, LP Turbine Nozzle Segment, Convex Side.
- 8-22. LP Turbine Rotor, Overall View.
- 8-23. LP Turbine Stator Assembly, Overall View, One Casing.
- 8-24. LP Turbine Stator Assembly, End View of Shroud and Seal Rubs.
- 8-25. LP Turbine Stator Assembly, Stage 1 Shroud Rub Pattern.
- 8-26. Stage 1 Fan Blades Before/After Recontour.
- 8-27. Stage 1 Fan Shroud Ice Damage.
- 8-28. Fan Stator Aft Liner Ice Damage.

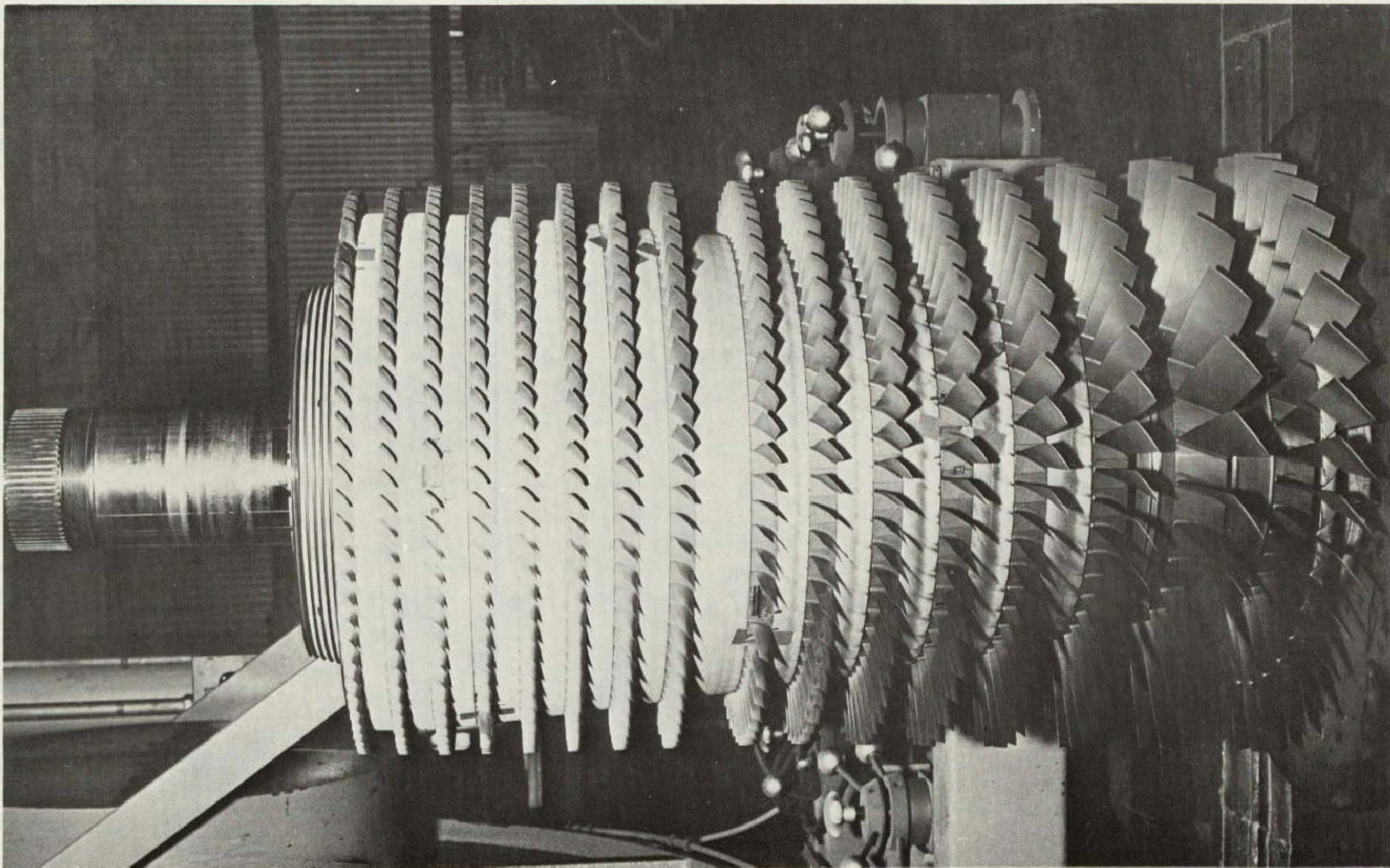


Figure 8-1. High Pressure Compressor Rotor (Cleaned), Missing Blades
at Surface Finish Check.

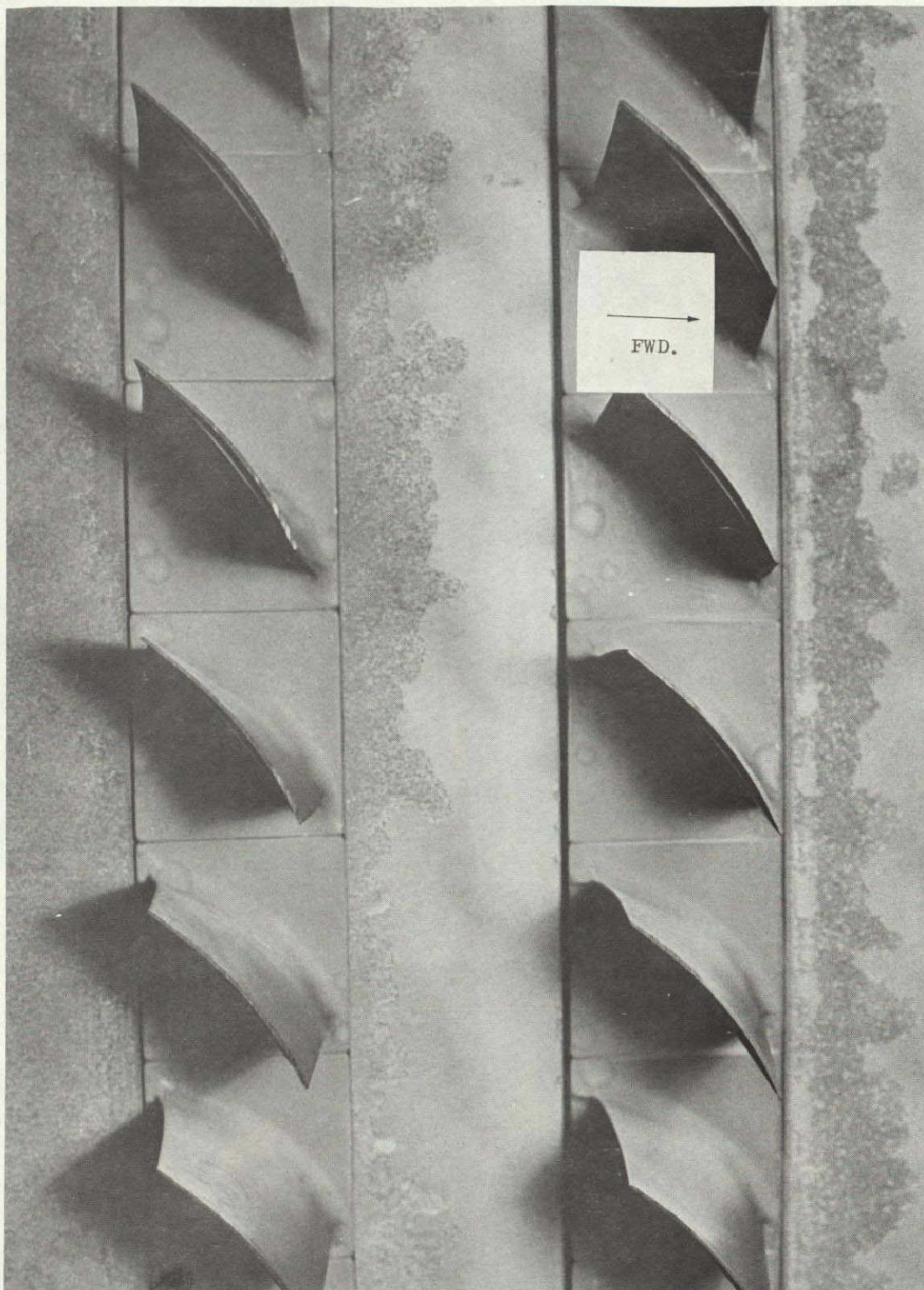


Figure 8-2. HP Compressor Rotor Stages 13 to 15 Land Coating.

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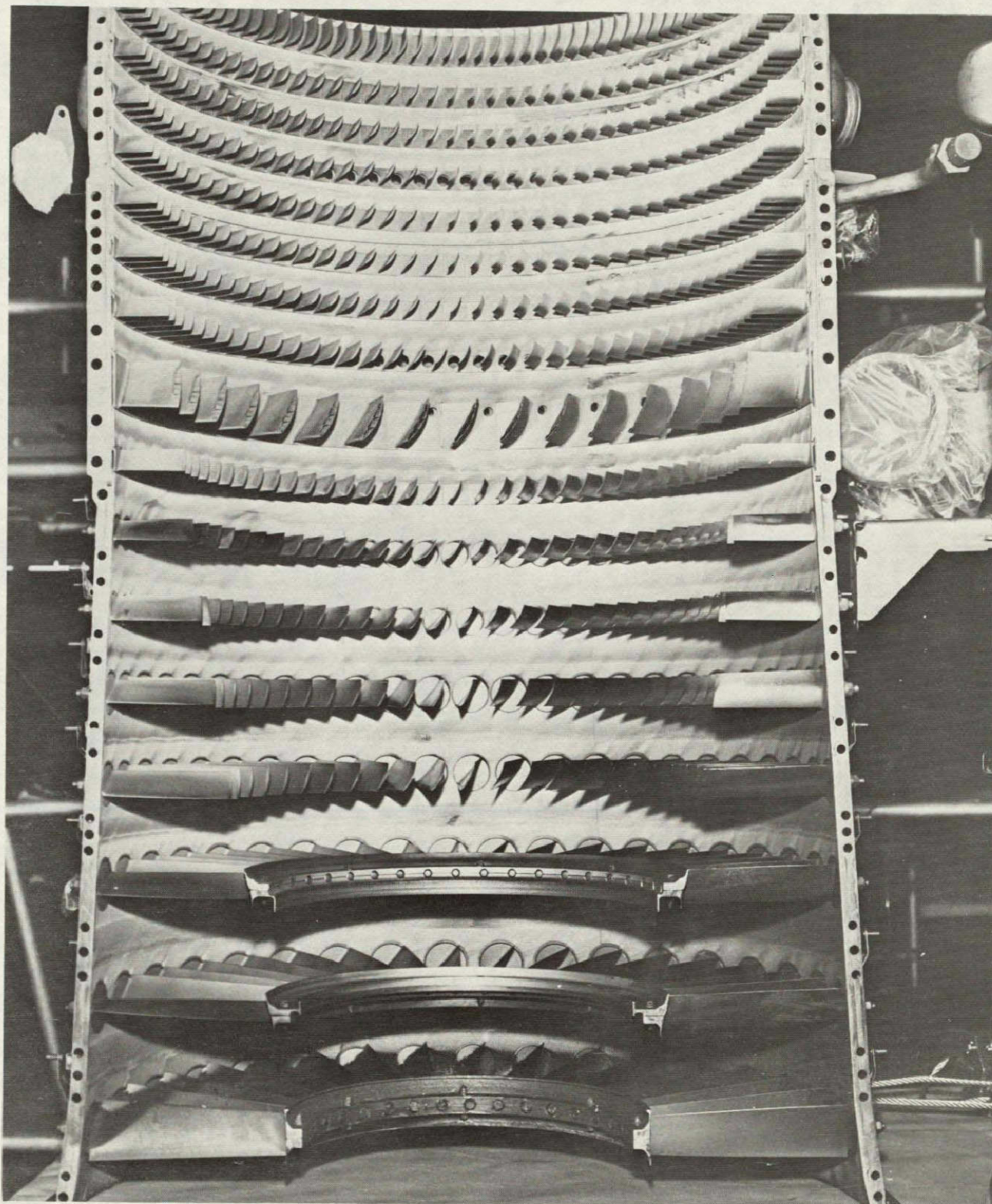


Figure 8-3. HP Compressor Stator Upper Overall Oil, Dirt, Rubs.

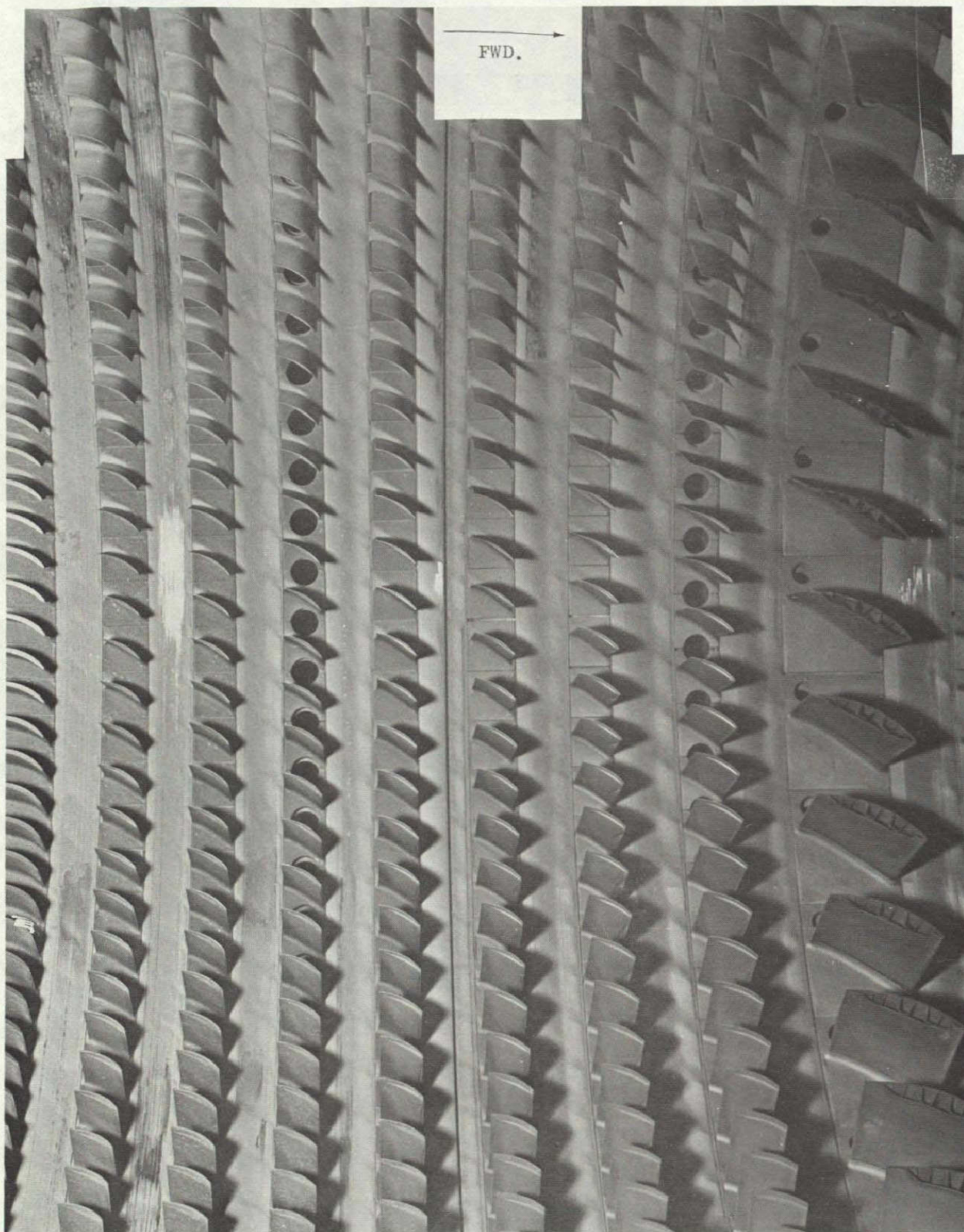


Figure 8-4 . HP Compressor Stator, Upper Stage 7 to OGV - Rubs.

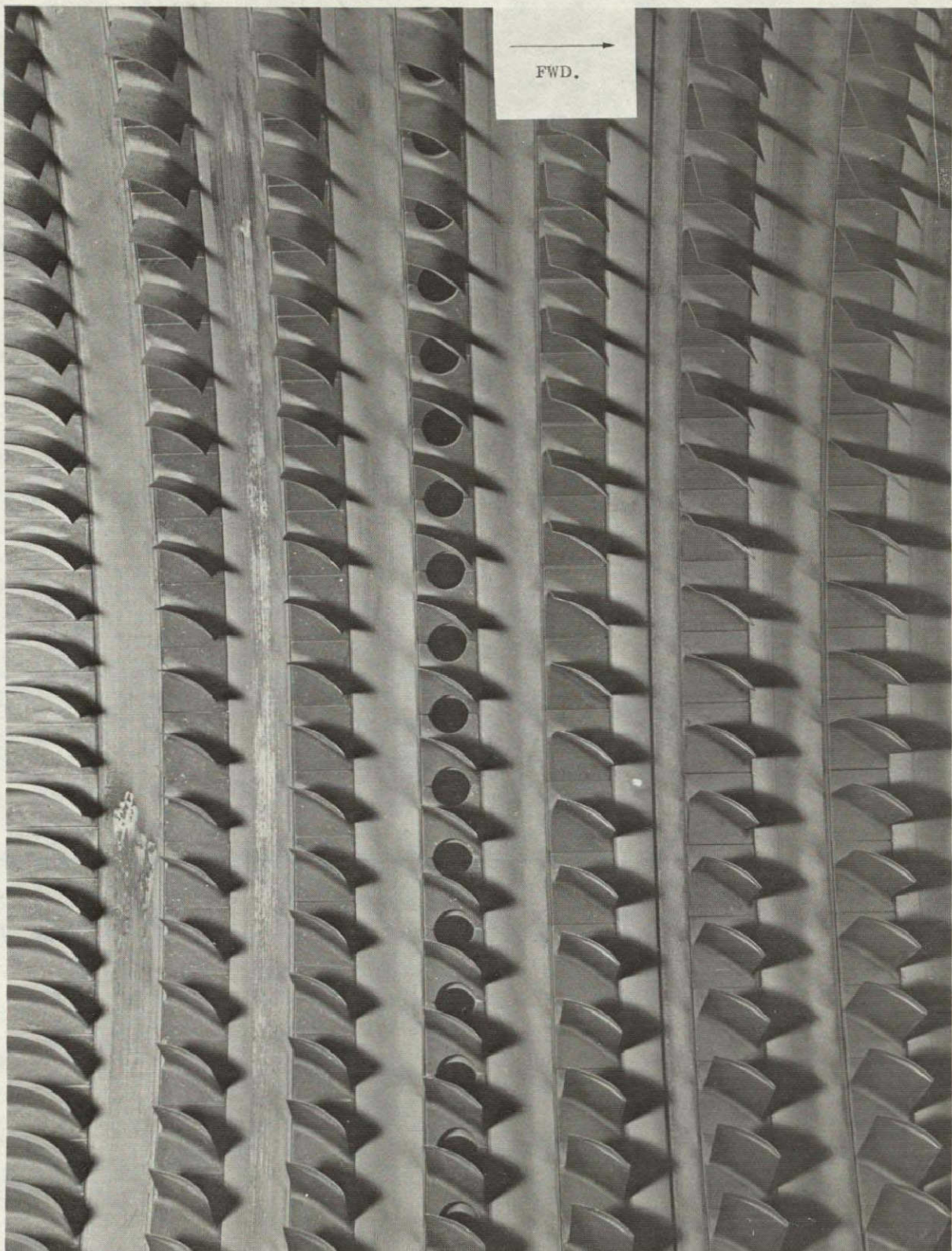


Figure 8-5. HP Compressor Stator, Lower Stage 9 to OGV - Rubs.

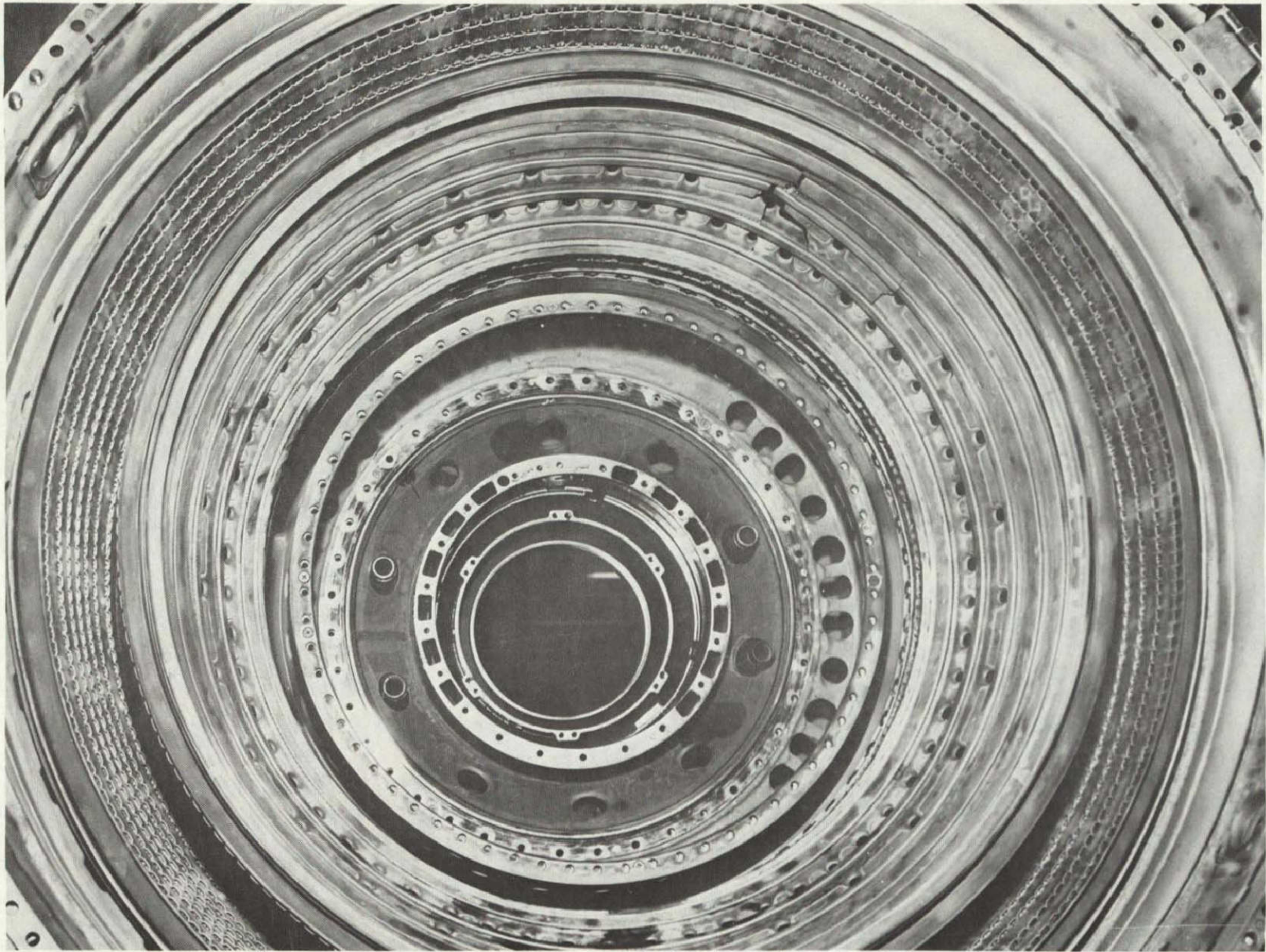


Figure 8-6. Combustor, Overall Cracks.

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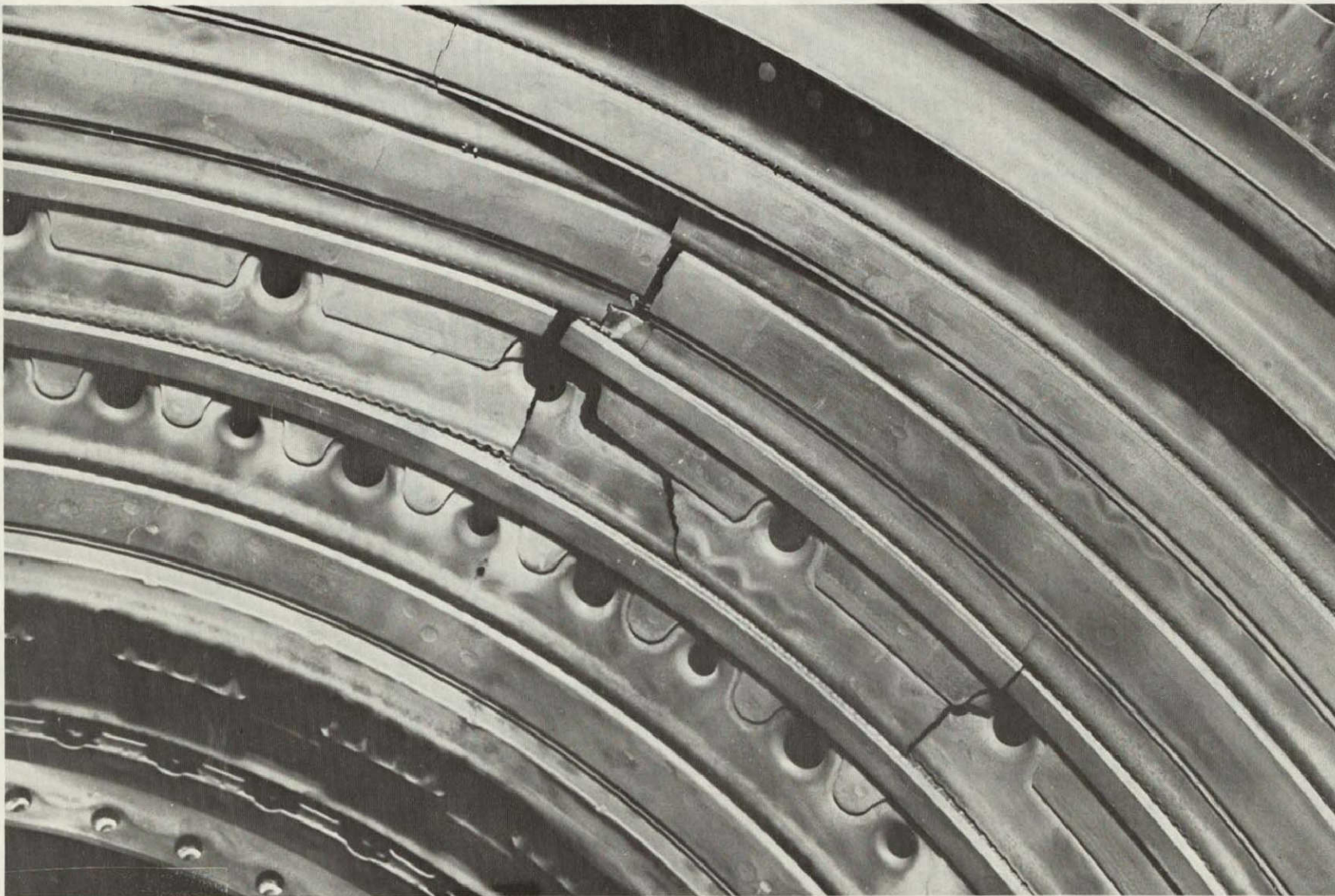


Figure 8-7. Combustor, Closeup Crack at 7 o'clock.

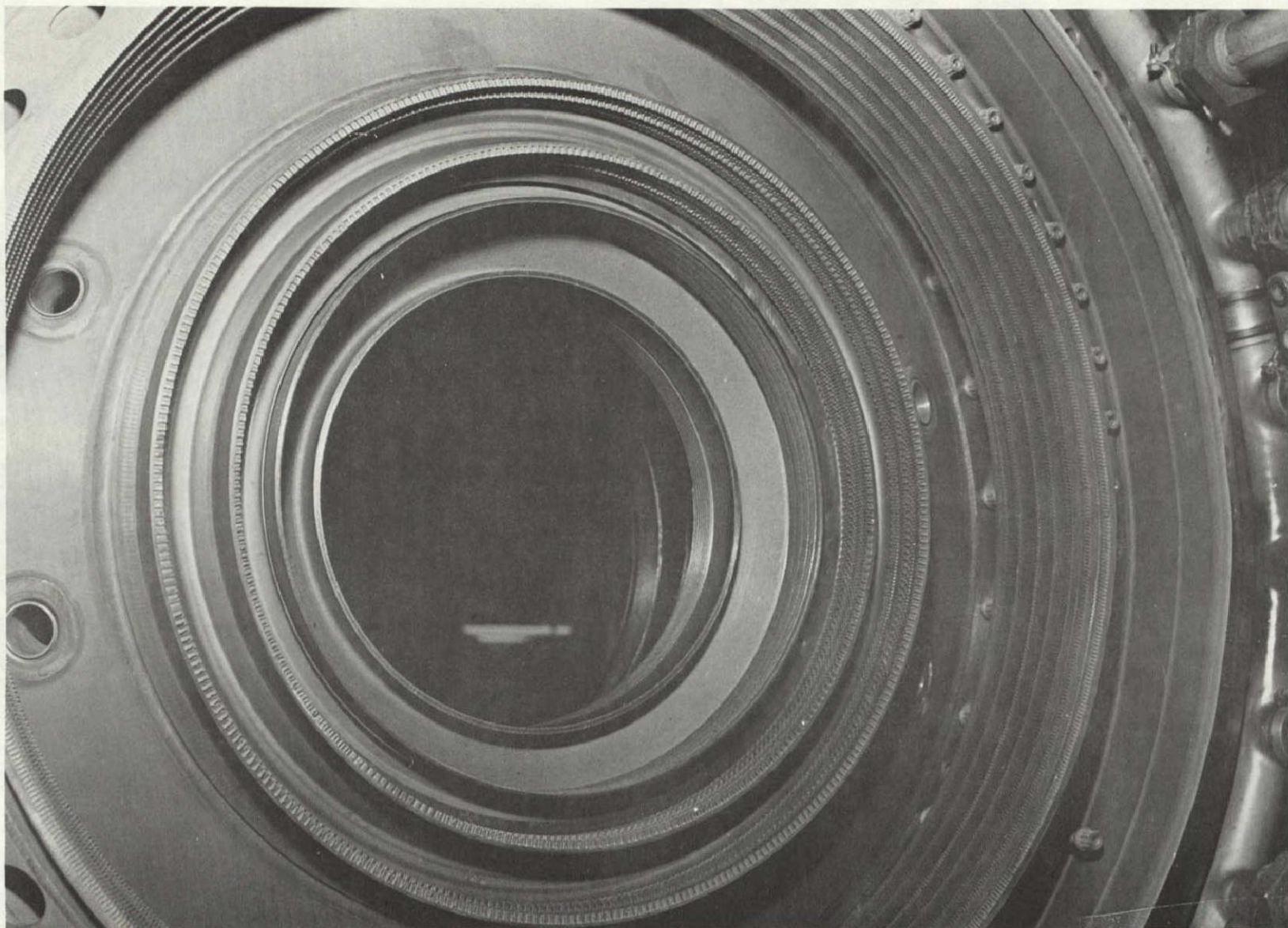


Figure 8-8. Compressor Rear Frame, Forward Seals - Overall View, Installed.

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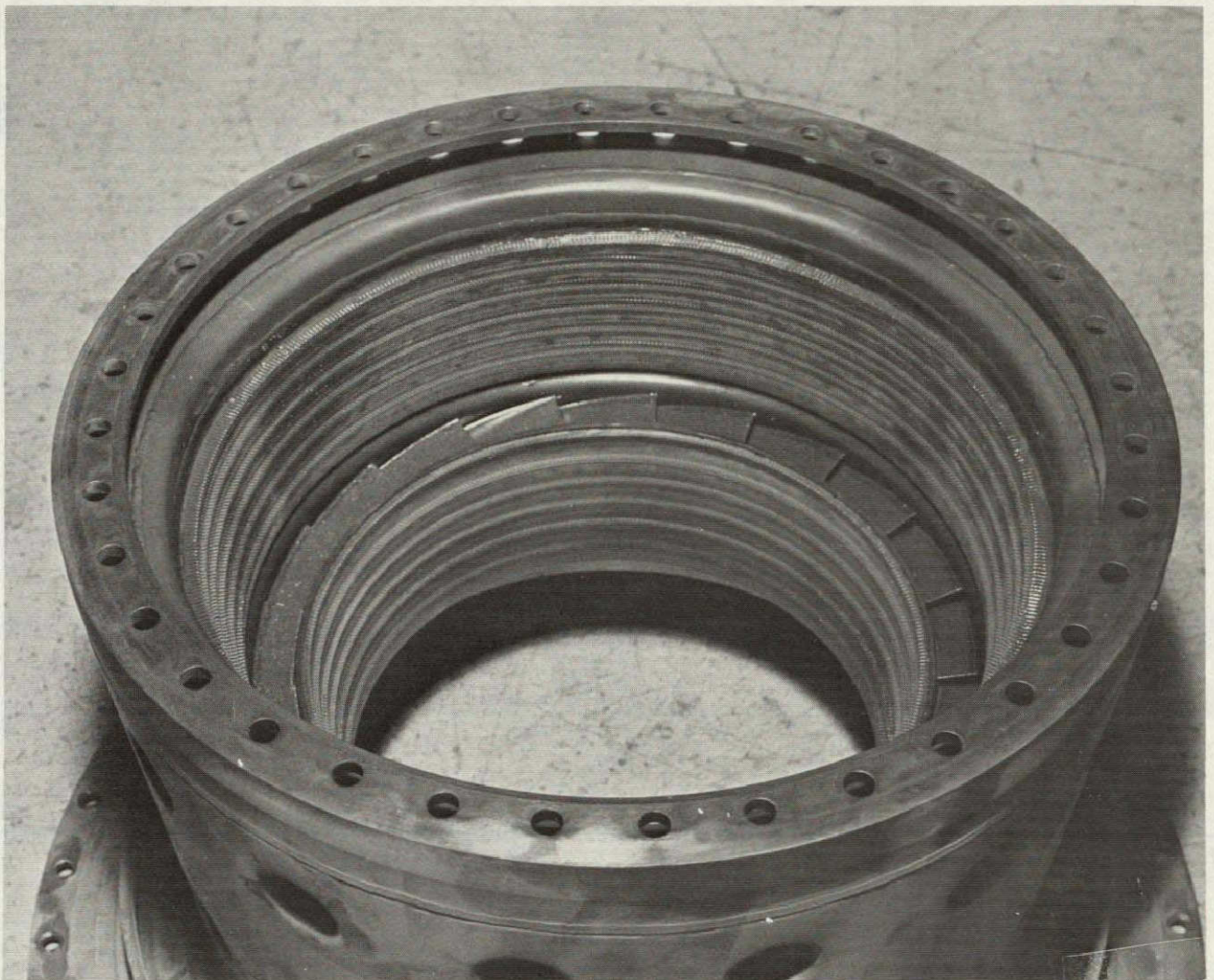


Figure 8-9. No. 4B Pressure Balance Seal, Overall View.

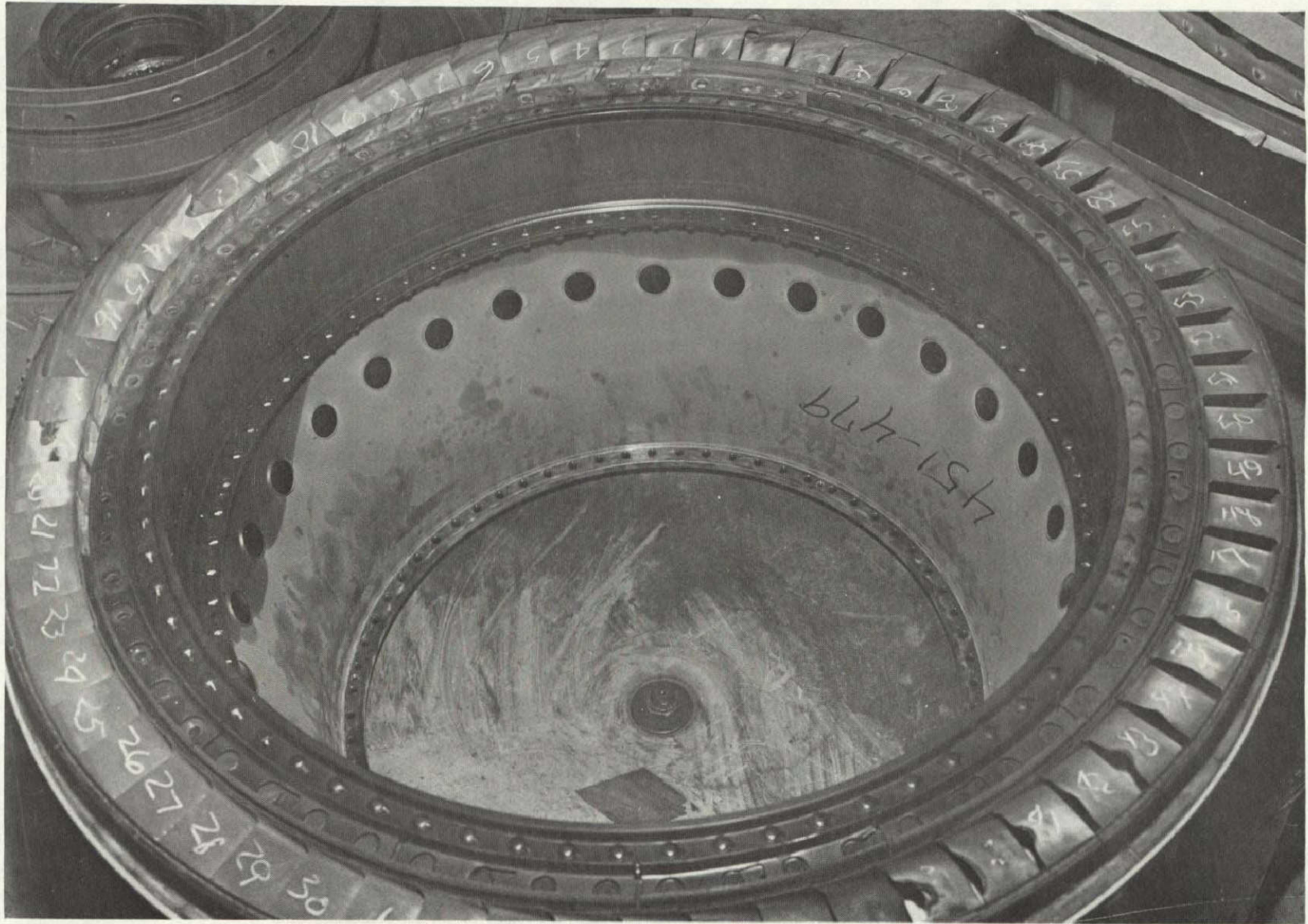


Figure 8-10. Stage 1 HP Turbine Nozzle Assembly, Aft End, Overall View.



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Figure 8-11. Stage 1 HP Turbine Nozzle Assembly, Trailing Edge, Burnt/Distorted Vanes.

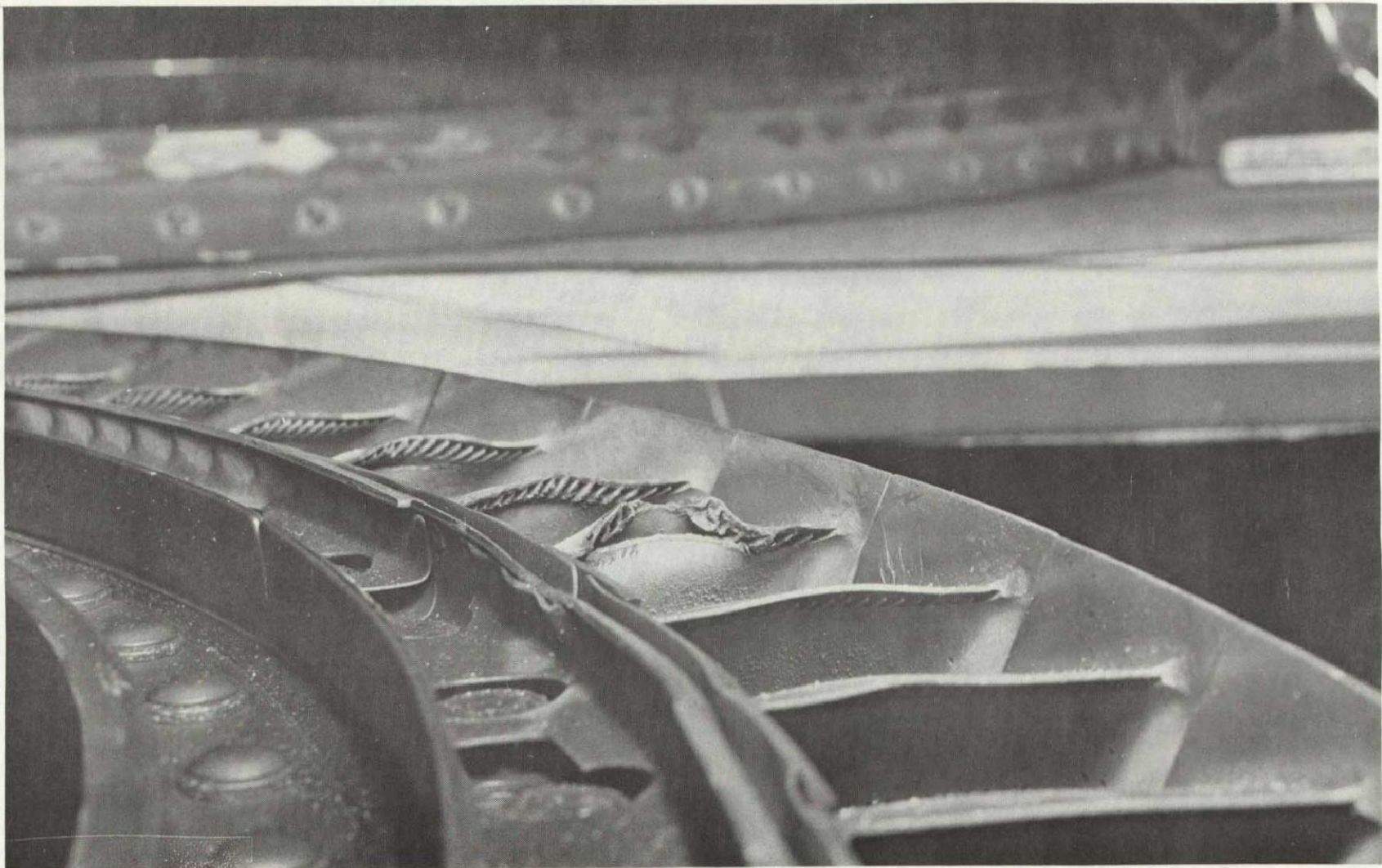
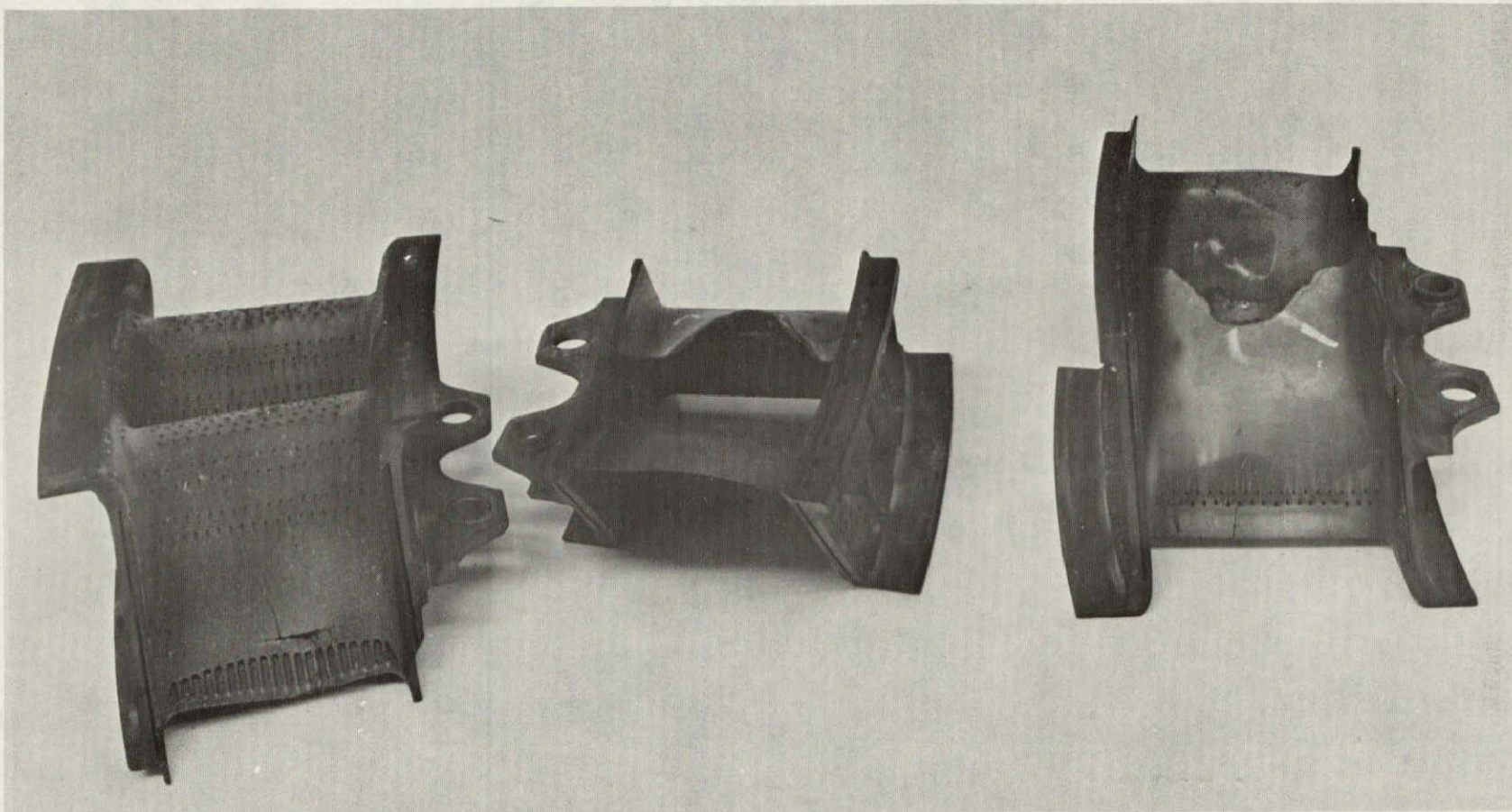


Figure 8-12. Stage 1 HP Turbine Nozzle Assembly Distress, Aft End.



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Figure 8-13. Stage 1 HP Turbine Nozzle, Typical Vane Distress.

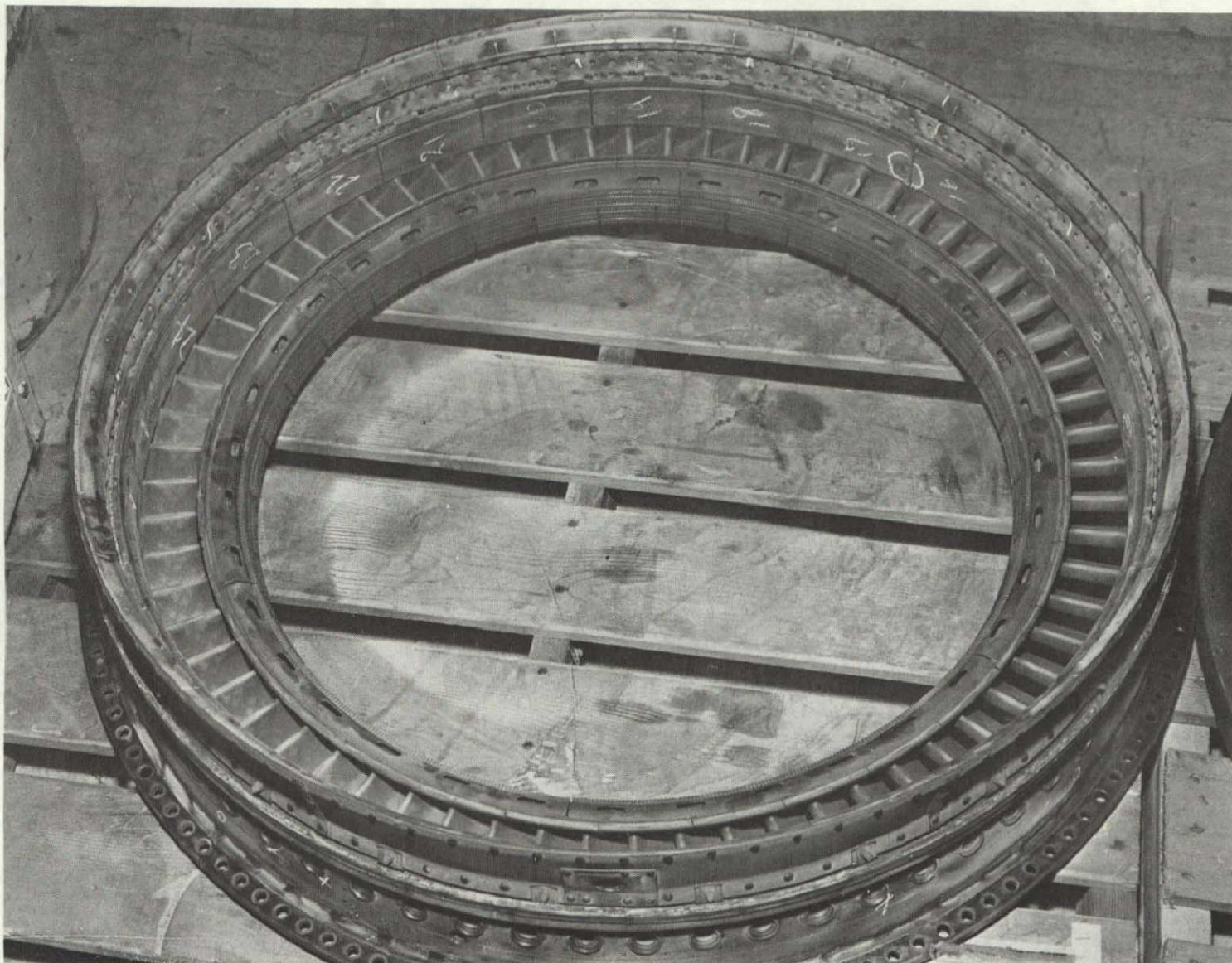


Figure 8-14. HP Turbine Nozzle Assembly, Overall View, Forward End.

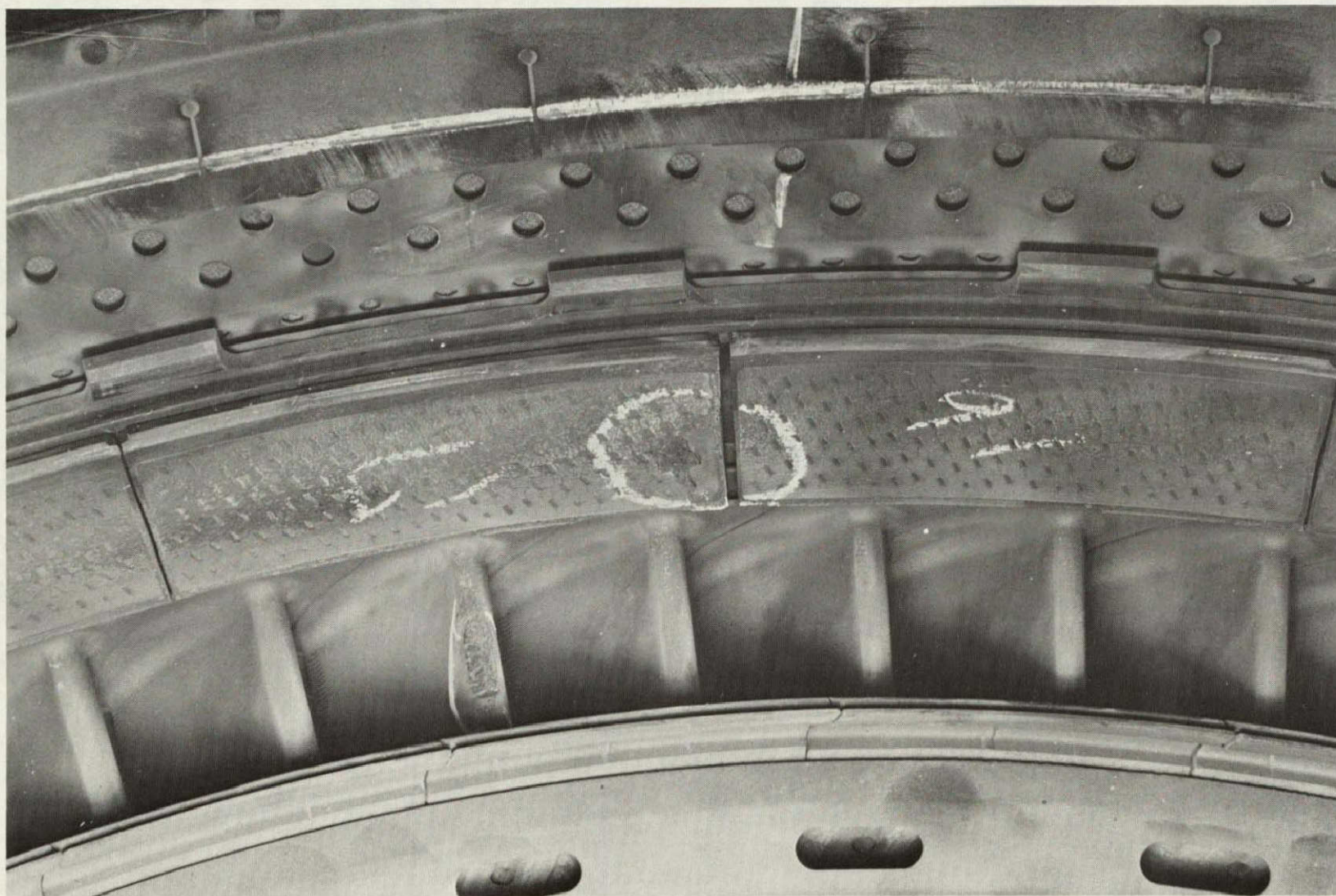


Figure 8-15 . Stage 2 HP Turbine Nozzle, Damage Vane/Stage 1 Shroud.

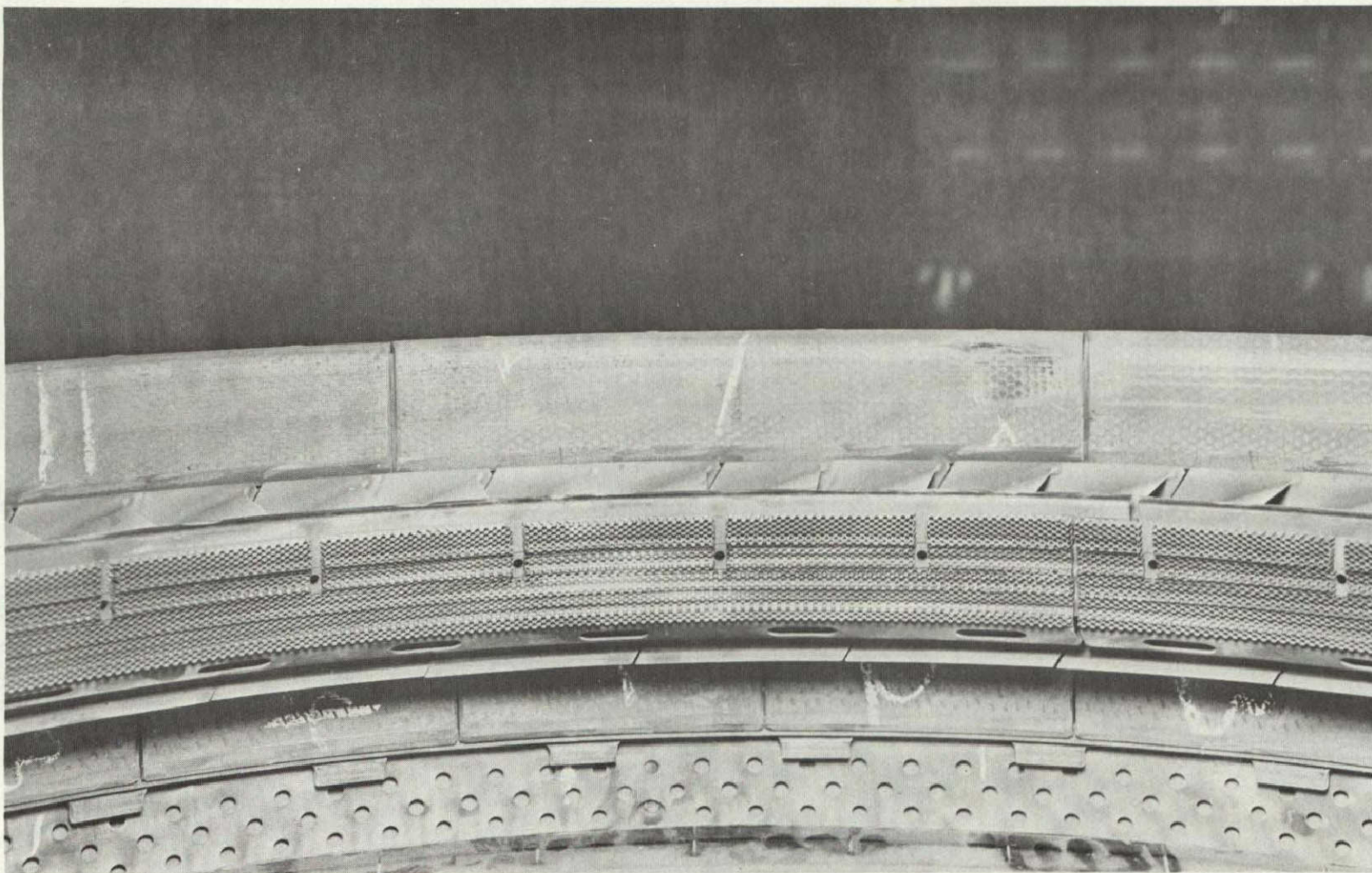


Figure 8-16. Stage 2 HP Turbine Nozzle Stage 2 Shroud Rub.

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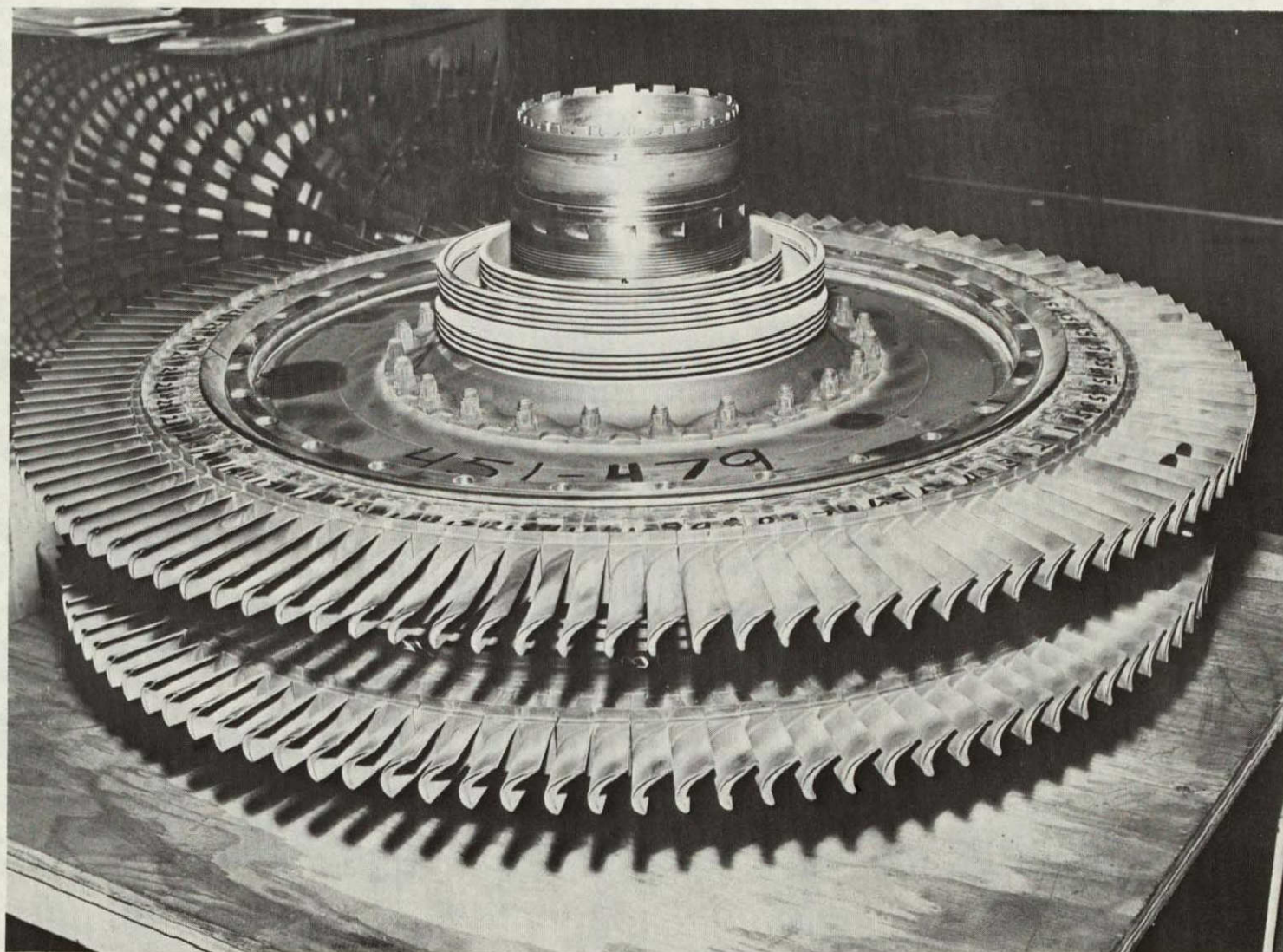


Figure 8-17. HP Turbine Rotor, Overall View of Blades.

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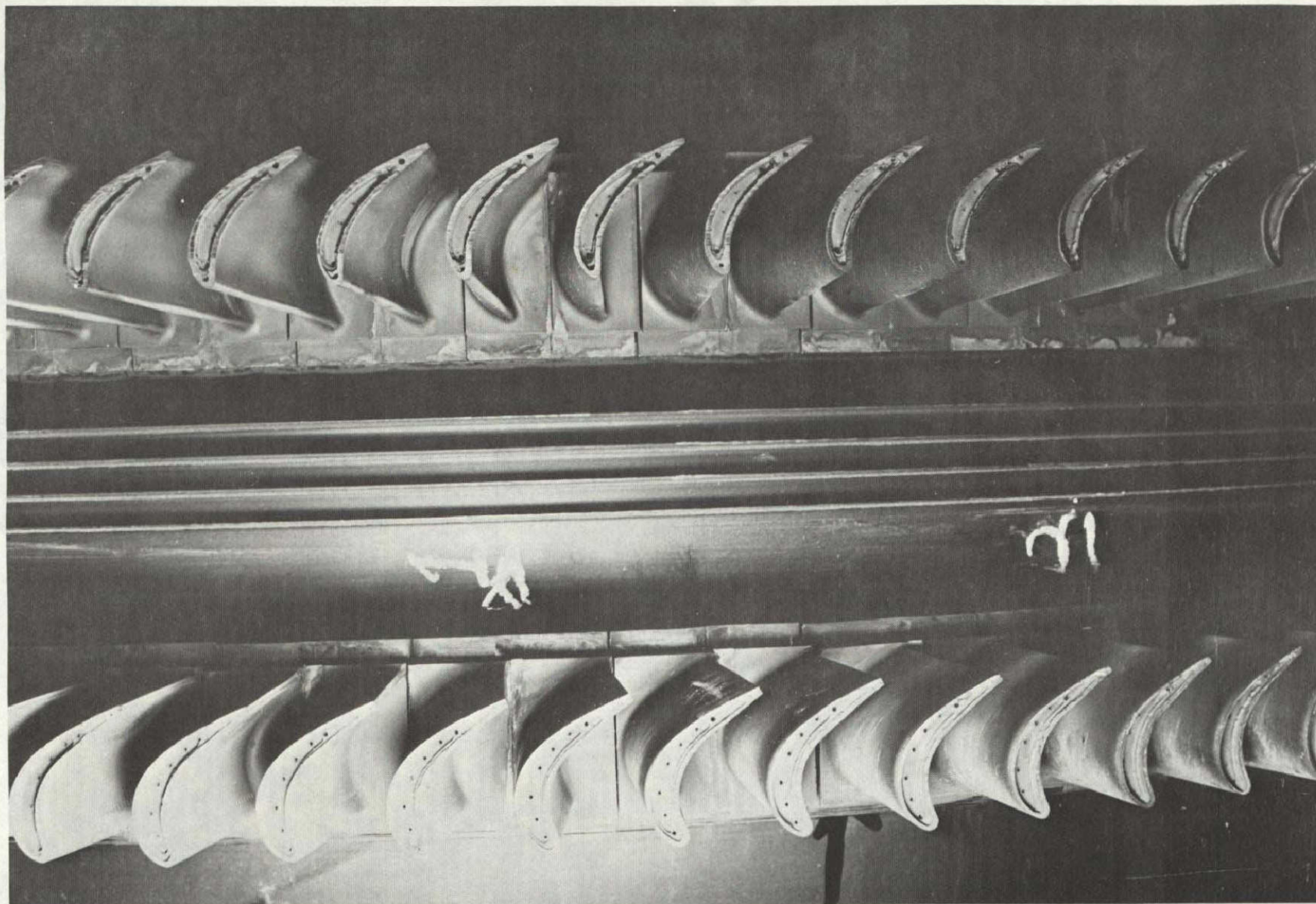


Figure 8-18. HP Turbine Rotor, Blade Tip Rubs.

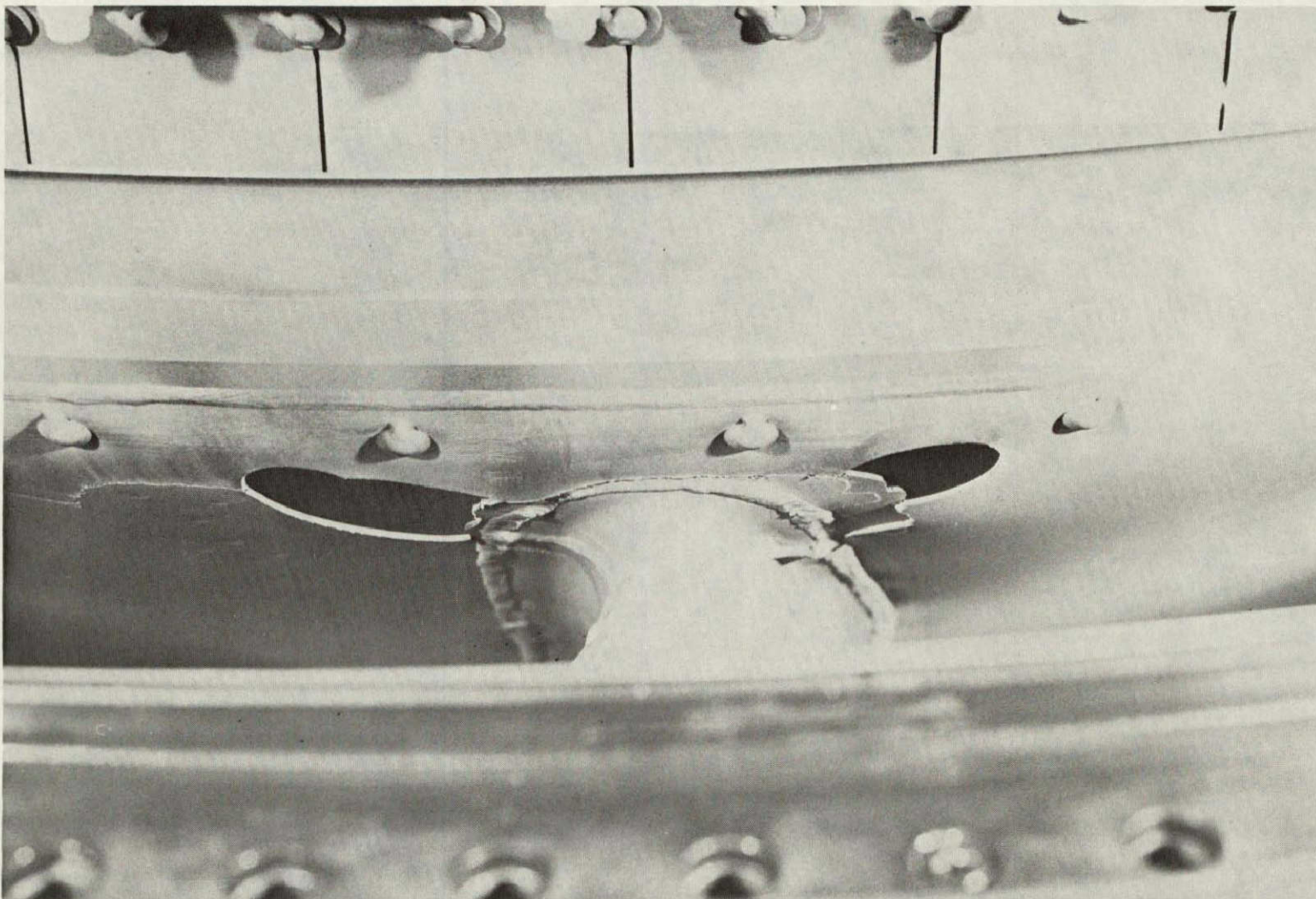


Figure 8-19. Turbine Mid Frame Liner Distress.

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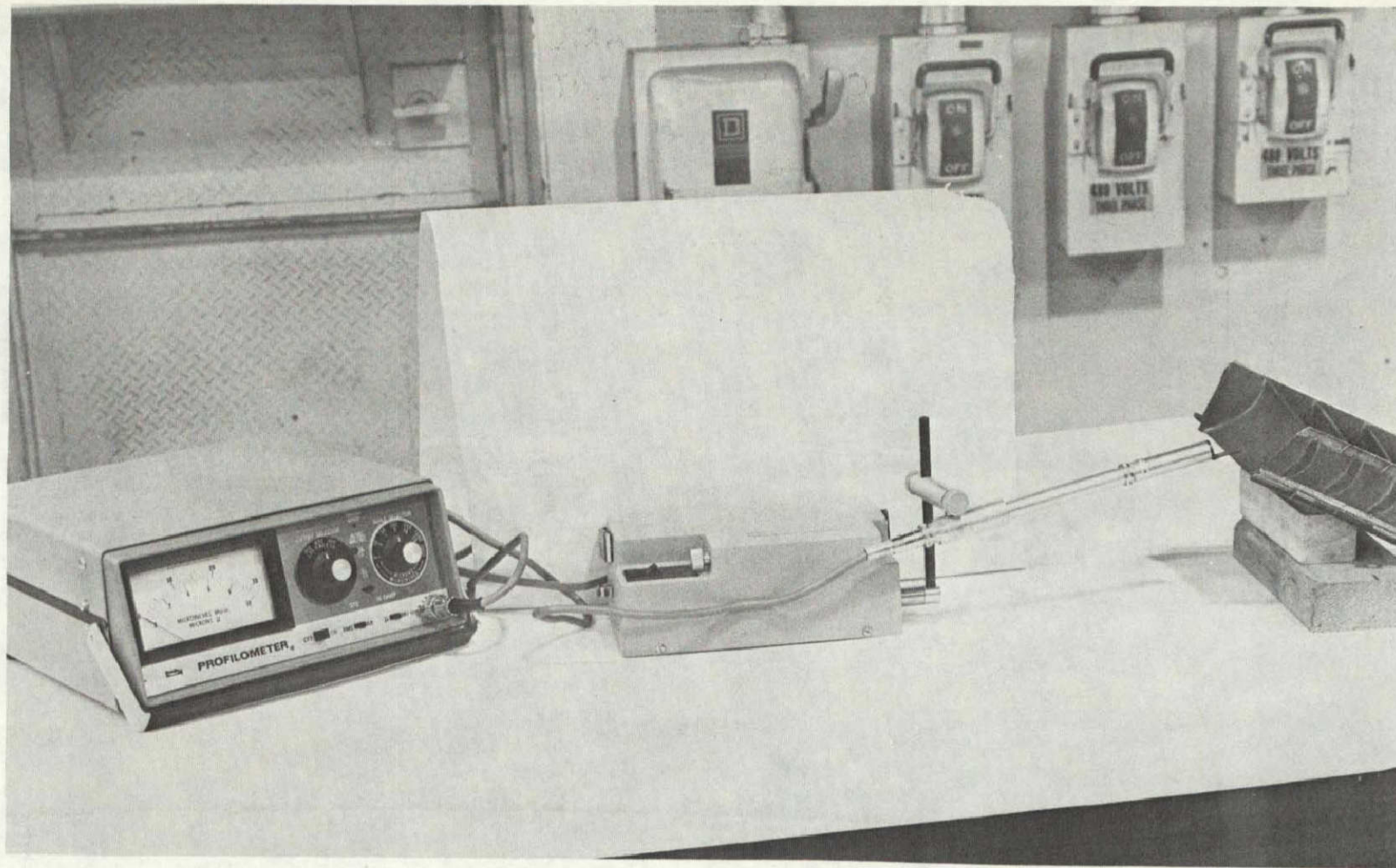
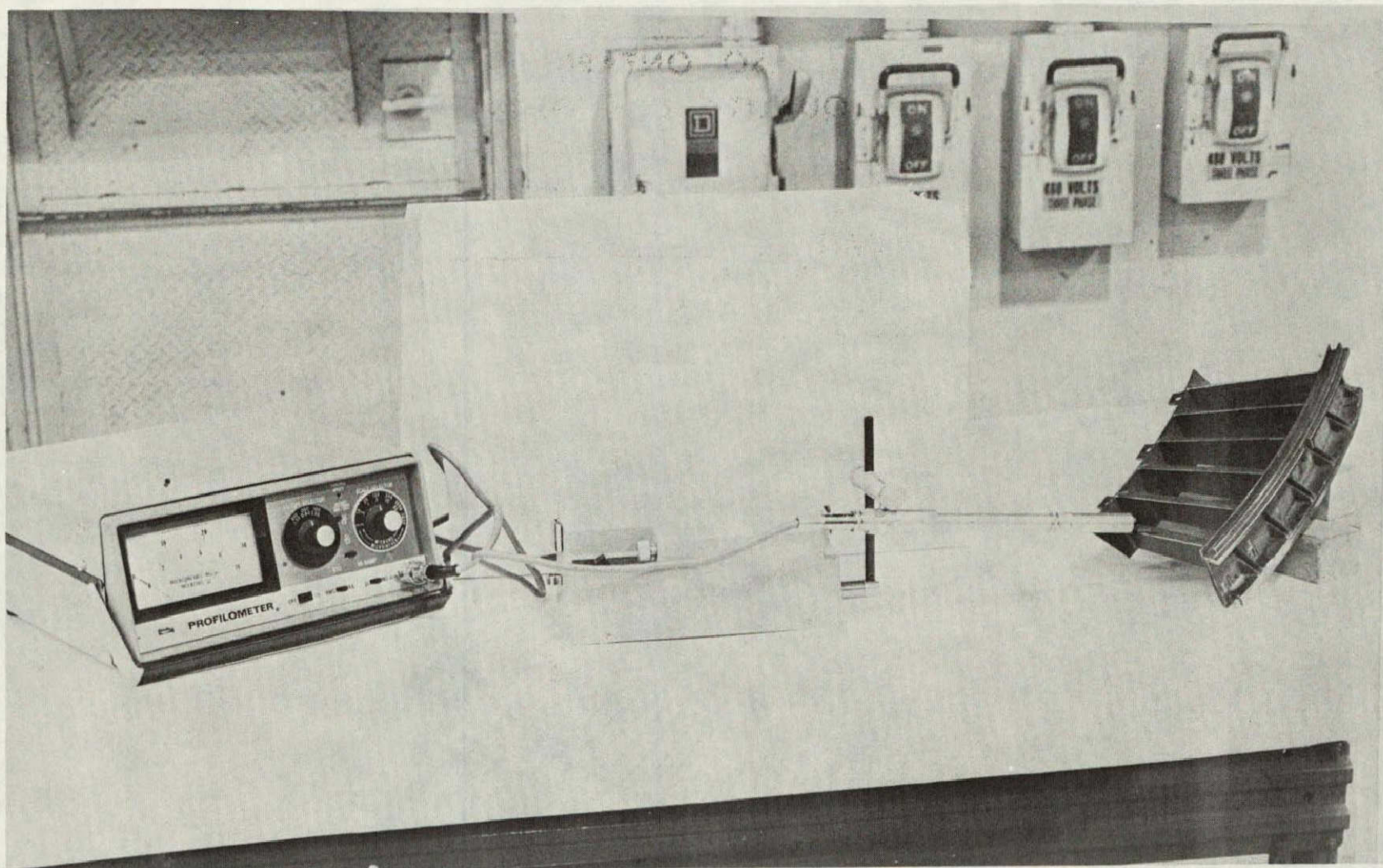


Figure 8-20. Profilometer Setup, LP Turbine Nozzle Segment, Concave Side.



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Figure 8-21. Profilometer Setup, LP Turbine Nozzle Segment, Convex Side.

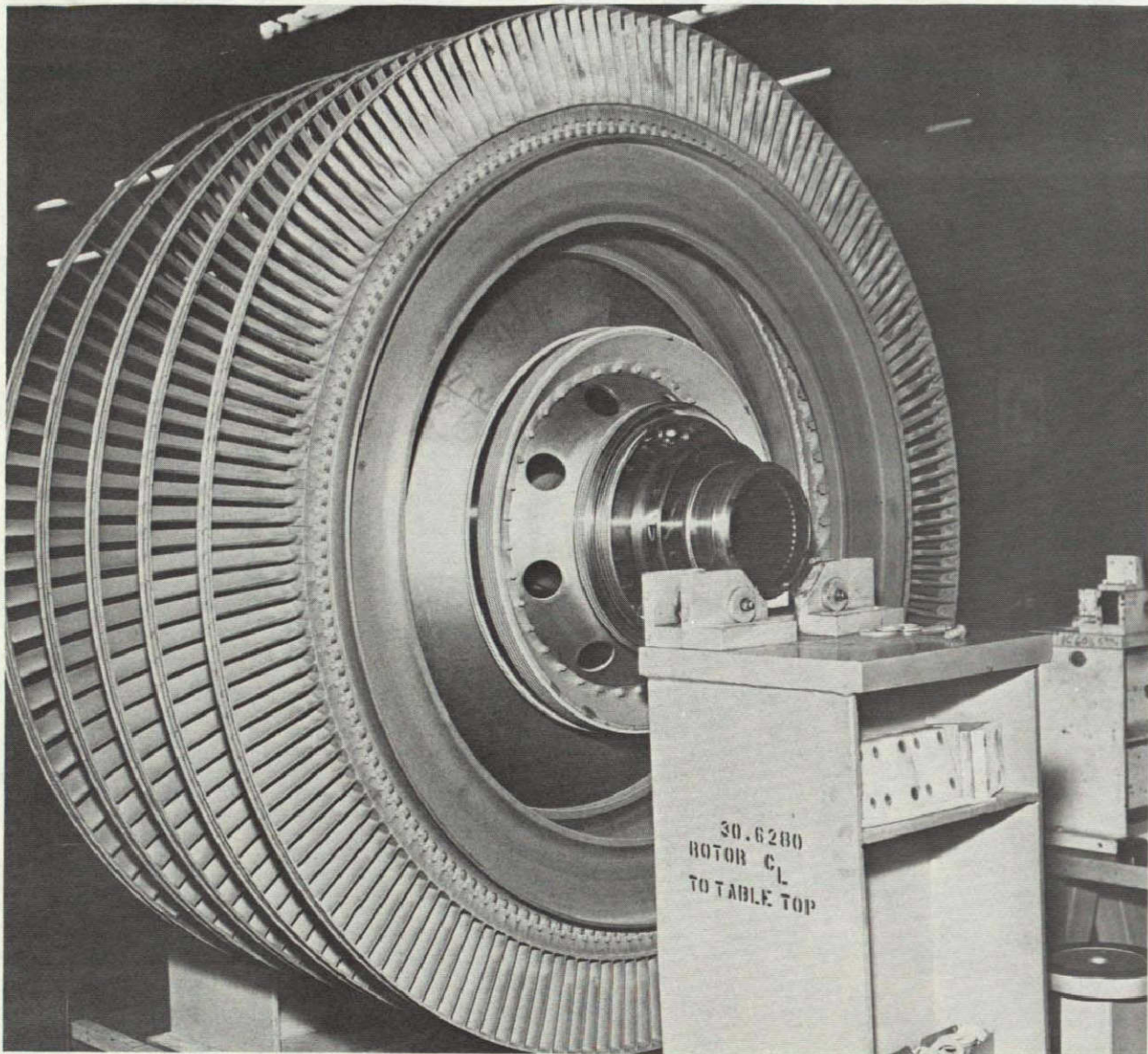
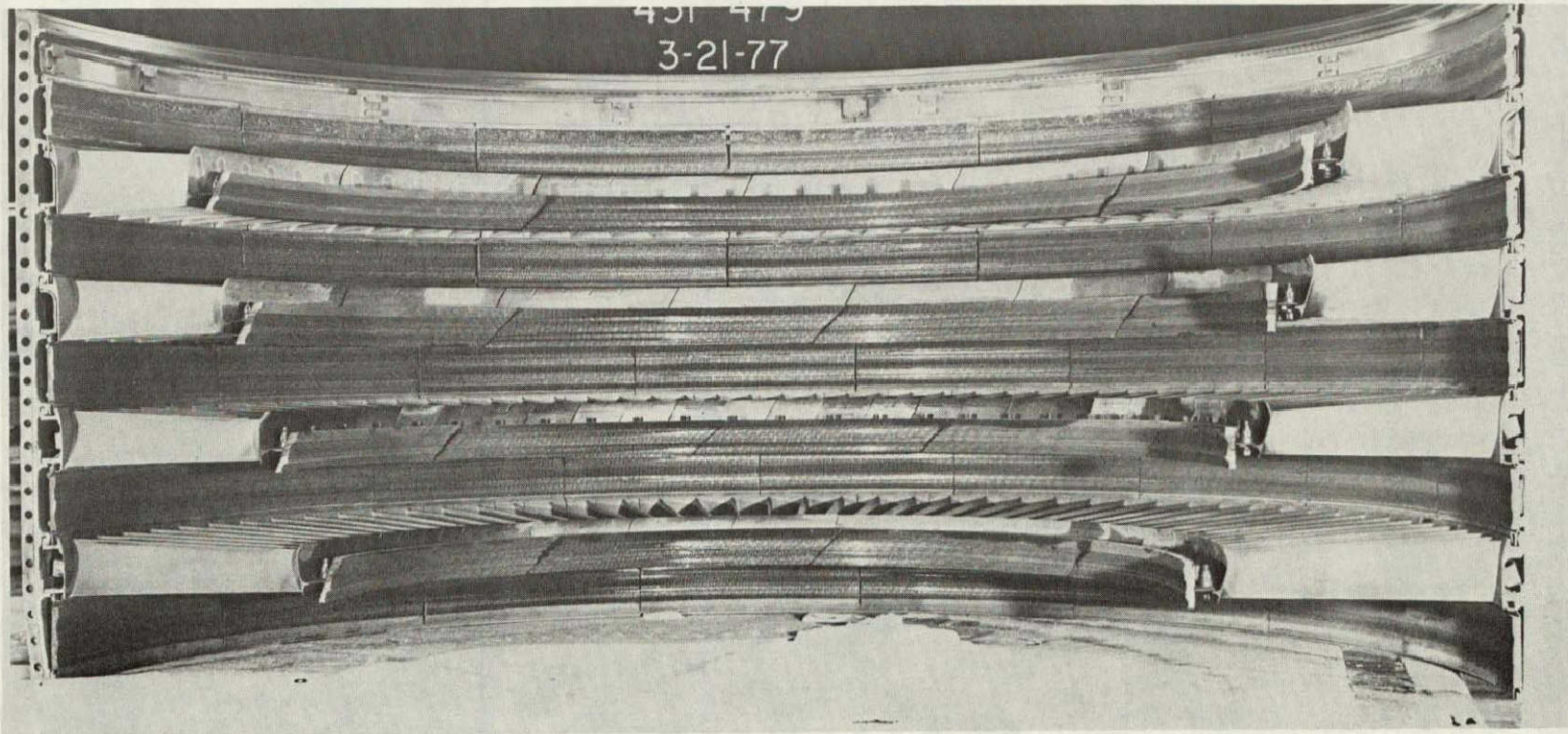


Figure 8-22. LP Turbine Rotor, Overall View.



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Figure 8-23. LP Turbine Stator Assembly, Overall View, One Casing.

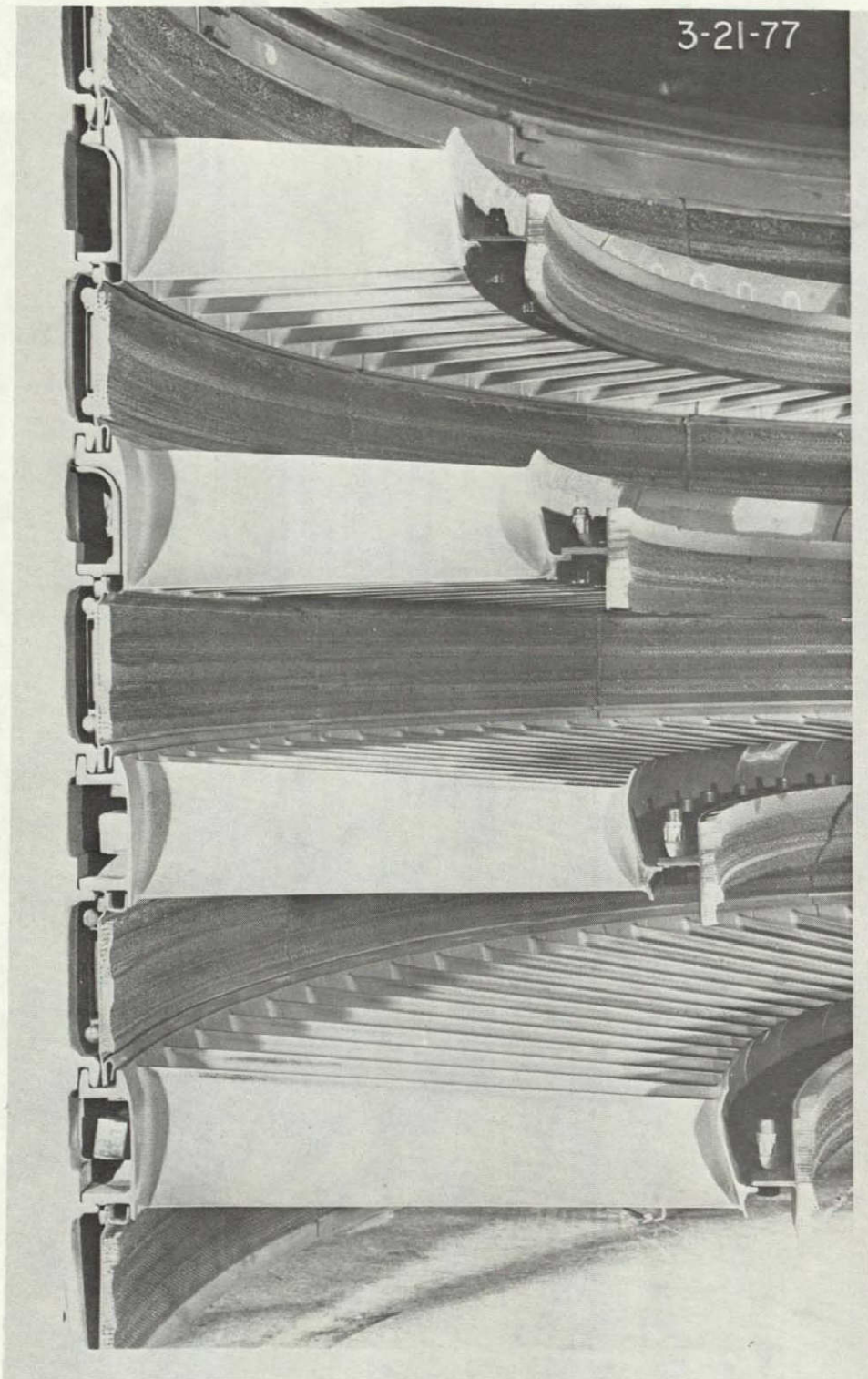
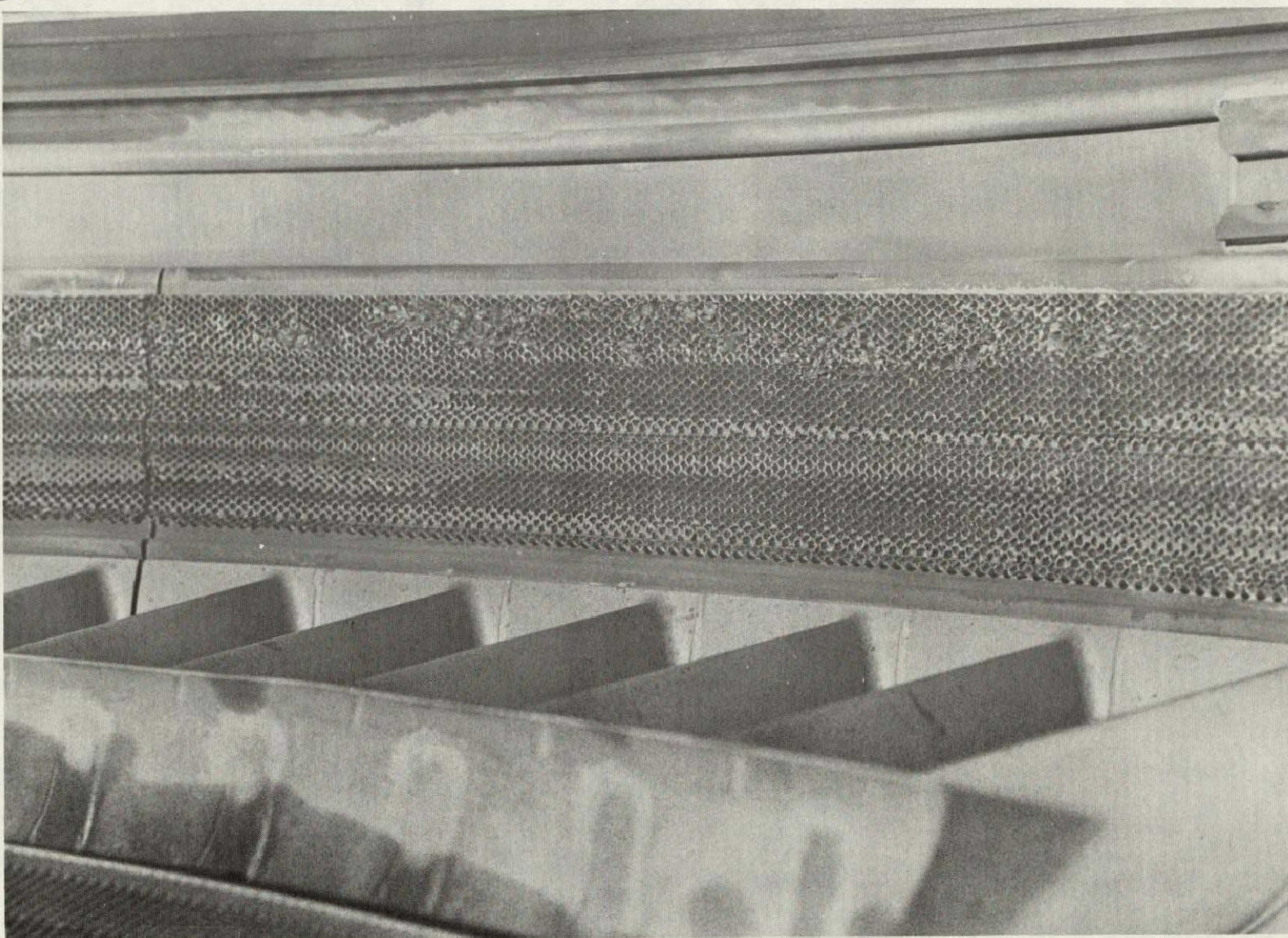


Figure 8-24. LP Turbine Stator Assembly, End View of Shroud and Seal Rubs.



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Figure 8-25. LP Turbine Stator Assembly, Stage 1 Shroud Rub Pattern.

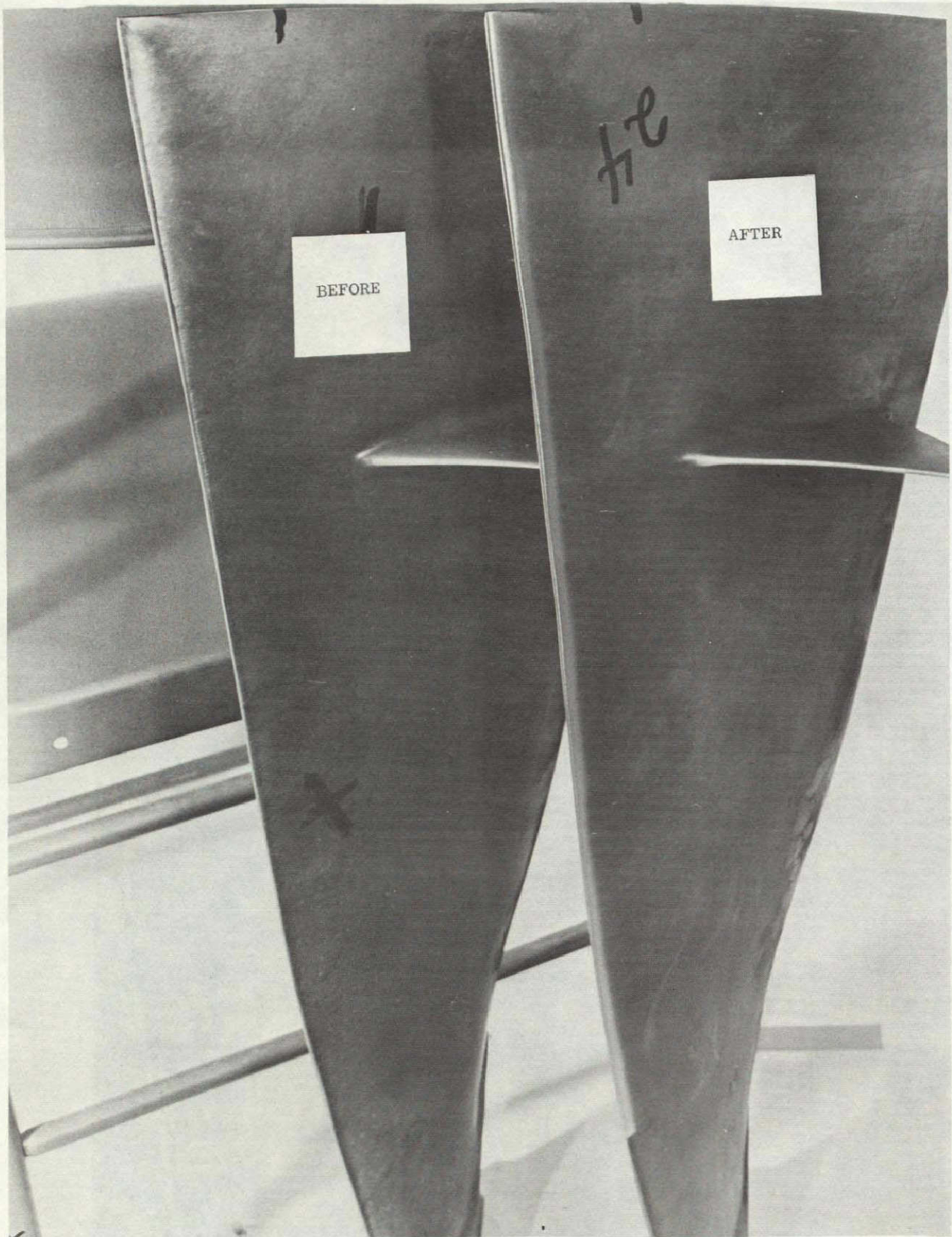


Figure 8-26. Stage 1 Fan Blades Before/After Recontour.

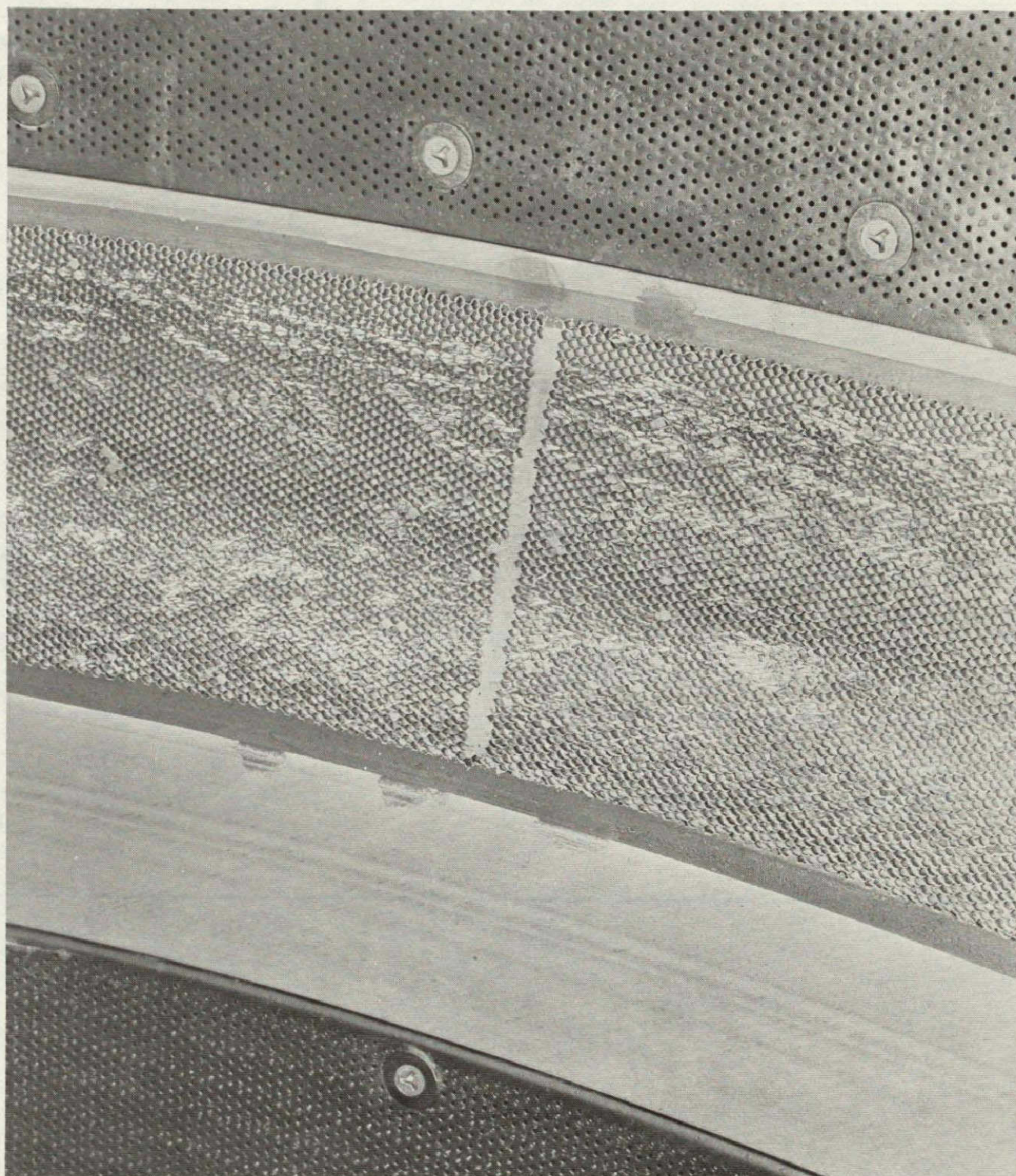


Figure 8-27. Stage 1 Fan Shroud Ice Damage.

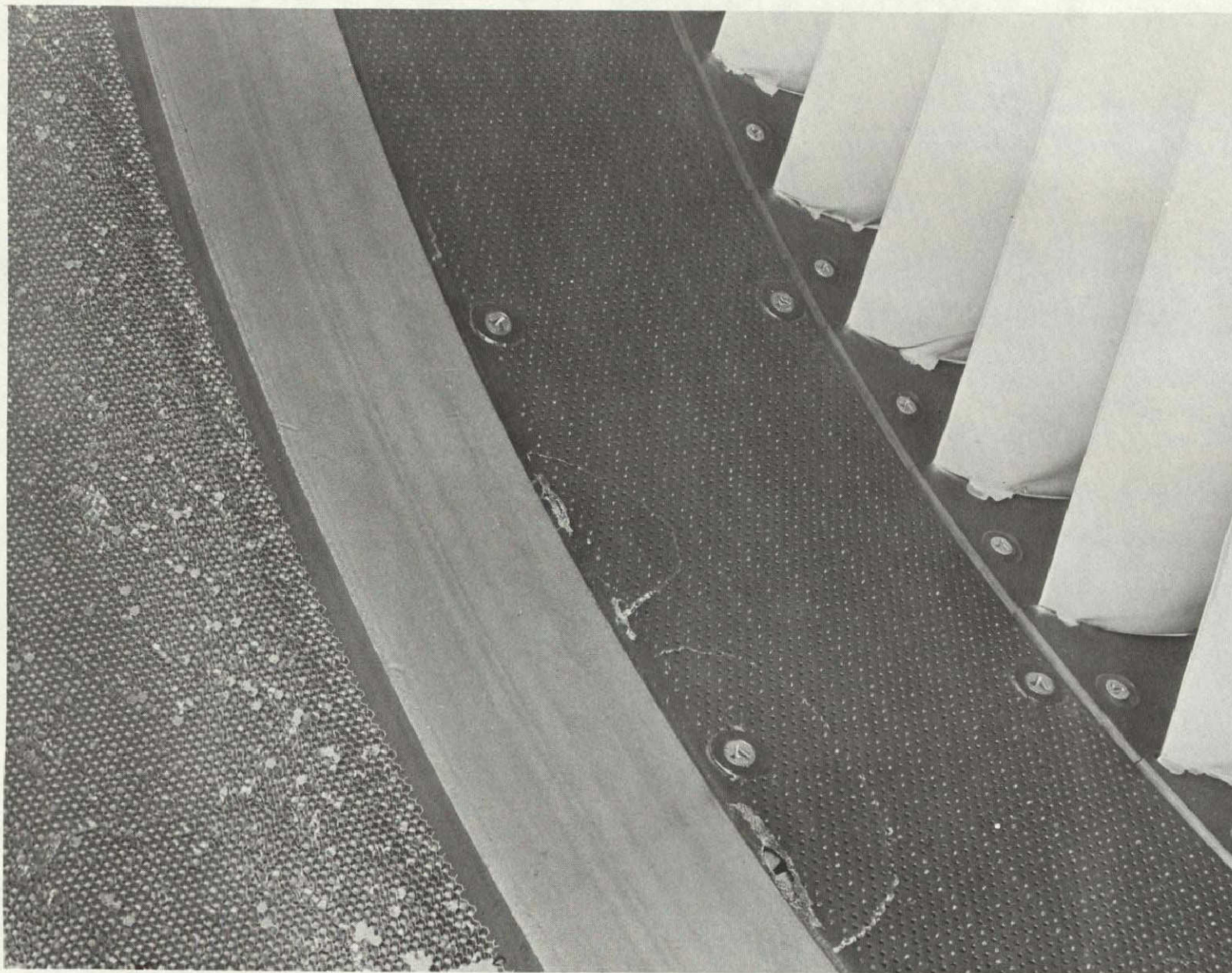


Figure 8-28 . Fan Stator Aft Liner Ice Damage.

8.3 APPENDIX C - LOG SHEETS, INBOUND RUN

[illegible]

CF - 6 / TF-39
GENERAL ELECTRIC COMPANY
ONTARIO, CALIFORNIA

Nature of Test _____
Sheet 2 of 5 Sheets

Date 3-22-77
Operator DYE
Inspector NEUBAUER

RUN NO. _____

A - VIBRATION CONDITIONS				OIL TYPE 2350				FUEL TYPE JP-4				NO OF STARTS																									
TIME	PRESS	TEMP	W	D	START	TIME	OIL WT	TIME	OIL WT	MODEL NO	WORK ORDER	CUSTOMER	LAST READING NO																								
14:00	38.920		57.75		START					CF6-6D	181460	NRSP	181460																								
			39.65		END																																
					CONSUM																																
ALT IN FT 1000												OVER CRUISE AUGMENTED GENERAL ELECTRIC ACCEPTANCE DATE																									
START NO	READING NO	TIME HRS	SPEED		LUBE OIL				FUEL				T ₂	T ₃	T ₅	THRUST LBS	VGV VOLTS	STATOR BETA VOLTS	PT ₅ LPT INLET PSIG	RECUP CAV "HG	SUMP VENT PRESS PSIG	CDP PSIG	B/M WALL "H ₂ O	CELL TOTAL "H ₂ O	FRONT CELL STATIC "H ₂ O	REAR CELL "H ₂ O	VIBRATION						FUEL USED	TOTAL RUN TIME			
			CORE	FAN	TEMP		PRESS.		INLET PRESS PSIG	INLET TEMP °F	FLOW																FAN IN °F	COT °F	EGT °F	FAN					CORE		
					N ₂ RPM	N ₁ RPM	INLET °F	SCAV °F			INLET PSIG	FILTER ΔP PSID																		MAIN PPH	VAR PPH	NO 1 BRG			TMF	T _{RM}	NO 1 BRG
758	5	1301	ACCEL TO 75%																																		
759	5	1304	918	3134			151	105	53.1				1350	74		1442	2780	865	1132	256	3.4	258															
760	5	1308	ACCEL TO MC										1320																								
761	5	1311	9647	3442			149	217	57.1	6.9	22	66	2741	3278	776	968	1554	3500	865	1132	256	3.4	258														
762	5	1319	ACCEL TO T.O.																																		
763	5	1321	DECEL TO FLT. IDLE																																		
764	5	1324	SLOW ACCEL TO 3451 N1																																		
765	5	1326	SLOW DECEL TO FLT. IDLE																																		
766	5	1330	SWITCH TO GRD. IDLE																																		
767	5	1336	SLOW ACCEL TO T.O.																																		
768	5	1339	9737	3512			149	217	57.1	6.9	22	66	2741	3278	776	968	1554	3500	865	1132	256	3.4	258														
769	5	1340	SLOW DECEL TO FLT. IDLE																																		
770	5	1346	SWITCH TO GRD. IDLE																																		
771	5	1408	SHUT DOWN - COAST DOWN																																		

9706552

QC - 149 - 1 FORM CE# TEST 2

REV. 8-75

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OF POOR QUALITY

CF - 6 / TF-39
GENERAL ELECTRIC COMPANY
ONTARIO, CALIFORNIA

Nature of Test _____
Sheet 4 of 5 Sheets

Date, 3-22-77
Operator LOCKIE
Inspector CIMPLEN

RUN NO _____

[illegible]

● 代笔秘书办文程序

QC - 149 - 1 FORM CF4 TEST 1

REV 5 75

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OF POOR QUALITY

AIRCRAFT TURBINE TEST LOG SHEET																				Gas Turbine Serial No. <u>457-429</u>									
Operator <u>LOCKIE</u> Inspector <u>CLIMARELLI</u>										CF-6, TF-35 GENERAL ELECTRIC COMPANY ONTARIO, CALIFORNIA										Nature of Test Sheet <u>5</u> of <u>5</u> Sheets									
ATMOSPHERIC CONDITIONS										OIL TYPE										FUEL TYPE									
TIME	PRESS	TEMP	W	D	START	END	CONSUM	SP GR	TEMP	TIME	OIL WT.	TIME	OIL WT.	LHV	CONSUM	SP GR	TEMP	MODEL NO.	WORK ORDER	CUSTOMER	NO OF STARTS	LAST READING NO	TOTAL RUNNING TIME	OVER CRUISE	AUGMENTED	GENERAL ELECTRIC ACCEPTANCE DATE			
ALT IN FT. <u>1000</u>																													
START NO	READING NO	TIME HRS	SPEED	THROTTLE ANGLE	LUBE OIL	FUEL	T ₂	T ₃	T ₅	THRUST LBS	VIN	STATOR BETA	LPT INLET	RECUP CAV	SUMP VENT	P ₅₂	FRONT	FRONT	REAR	VIBRATION						FUEL USED	TOTAL TIME		
		CORE FAN			TEMP	PRESS	INLET PRESS	INLET TEMP	FLOW	FAN IN	CGT	EGT					RM WALL	CELL TOTAL	CELL STATIC	CELL STATIC	NO 1 TRM	NO 1 TRM	NO 1 TRM	NO 1 TRM					
		H ₂	H ₁		INLET	SCAV	INLET FILTER	INLET PRESS	MAIN	VAR							IN ₂	CELL	CELL	CELL	NO 1 TRM	NO 1 TRM	NO 1 TRM	NO 1 TRM					
		RPM	RPM		°F	°F	PSIG	PSIG	PPH	PPH	°F	°F	°F				"H ₂ O	"H ₂ O	"H ₂ O	"H ₂ O	DRG	TRM	TRM	TRM					
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8.4 APPENDIX D - LOG SHEETS, TESTS 2 AND 3

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OF POOR QUALITY

Date <u>4-19-77</u>		AIRCRAFT TURBINE TEST LOG SHEET										Gas Turbine Serial No. <u>451-479</u>																							
Inspector <u>Lockie</u>		GENERAL ELECTRIC COMPANY ONTARIO, CALIFORNIA										Nature of test _____ Sheet <u>3</u> of <u>10</u> sheets																							
Model No. <u>CF6-6D</u>		WORK ORDER <u>181460</u>										CUSTOMER _____																							
NO OF STARTS _____		LAST READING NO. _____										TOTAL RUNNING TIME _____																							
OVER CRUISE _____		AUGMENTED _____										GENERAL ELECTRIC ACCEPTANCE DATE _____																							
START NO	TIME	SPEED	LUBE OIL	FUEL	T ₂	T ₃	T ₅	THRUST	VOLTS	STATOR	PT	RECUP	SUMP	PS ₂	FRONT	FRONT	REAR	VIBRATION																	
		CORE	FAN	THROTTLE	TEMP	PRESS	INLET	INLET	INLET	TEMP	FLOW	FAN	DOT	DOT	IN	OUT	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT						
13	1327	1831	4594	3429	152	221	56	310	24	70	1350	1350	68	440	1565	3530	54	55	2	3.6	3.25	3.18	50	3	2	2	2	7	2.65	1.6	1.3	1.4	1.4	1.5	2.0
14	1334	1834	4594	3430	152	221	56	410	24	70	1360	1360	68	447	1566	3531	53	55	4	3.6	3.25	3.18	50	6	2	2	2	7	2.65	1.6	1.4	1.4	1.5	1.9	
15	1346	1840	4449	3321	153	217	54	810	26	70	1240	1240	67	915	1503	3264	67	51	0	3.2	3.05	2.94	45	9	2	1	2	6	2.5	1.5	1.1	1.1	1.4	1.6	1.5
16	1343	1445	3321	152	216	54	810	26	70	12390	12390	66	932	1502	3260	66	51	2	3	2	3.05	2.96	46	2	2	15	7	65	2.55	1.5	1.0	1.1	1.4	1.6	1.6
17	1447	1451	4193	3125	154	213	52	310	29	70	10290	10290	66	861	1394	3771	94	43	5	2.5	2.45	2.60	38	8	1	35	2	3	2.35	1.5	1.0	1.4	1.7	1.4	
18	1454	1491	3121	153	211	52	310	29	70	10300	10300	66	861	1393	3773	95	43	6	2.5	2.65	2.59	38	8	1	9	2	25	2.25	1.5	1.0	1.4	1.7	1.4		
19	1504	1520	740	164	200	60	4	5	39	69	480	470	65	346	735	160	430	2	0	0.05	2.3	2.2	11	12	13	1	1	1	1	1	1	1	1	1	
20	1512	0	0	165	152	13	0	0	69	0	0	67	187	346	450	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
11/15/77 @ 159° Check T5 harness for continuity & ground check -																																			

CF - 6 / TI-39
GENERAL ELECTRIC COMPANY
ONTARIO, CALIFORNIA

Nature of Test _____
Sheet 7 of 16

Date 4-19-77

2. order Scapic
 3. section Campelli

RUN NO _____

REMARKS

QC - 165 - 1 FORM C-4 TEST

REV 3'S

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AIRCRAFT TURBINE TEST LOG SHEET

CF-6 / TF-39
GENERAL ELECTRIC COMPANY
ONTARIO, CALIFORNIA

Gas Turbine Serial No. 451-479

Nature of Test _____
Sheet 5 of 16 tests

RUN NO. _____

Date 4-19-77
 Location Lockport
 Technician Morelli

MODEL NO. CF6-6D
 WORK ORDER 181460
 CUSTOMER _____

NO. OF STARTS _____
 LAST READING NO. _____
 TOTAL RUNNING TIME _____
 OVER CRUISE _____
 AUGMENTED _____
 GENERAL ELECTRIC ACCEPTANCE DATE _____

NO. OF TESTS	ALTIMETER NO.	TIME HRS	SPEED		THROTTLE ANGLE	LUBE OIL				FUEL				T ₂	T ₃	T ₅	T ₈	T ₉	T ₁₀	T ₁₁	T ₁₂	T ₁₃	T ₁₄	T ₁₅	T ₁₆	T ₁₇	T ₁₈	T ₁₉	T ₂₀	T ₂₁	T ₂₂	T ₂₃	T ₂₄	T ₂₅	T ₂₆	T ₂₇	T ₂₈	T ₂₉	T ₃₀	T ₃₁	T ₃₂	T ₃₃	T ₃₄	T ₃₅	T ₃₆	T ₃₇	T ₃₈	T ₃₉	T ₄₀	T ₄₁	T ₄₂	T ₄₃	T ₄₄	T ₄₅	T ₄₆	T ₄₇	T ₄₈	T ₄₉	T ₅₀	T ₅₁	T ₅₂	T ₅₃	T ₅₄	T ₅₅	T ₅₆	T ₅₇	T ₅₈	T ₅₉	T ₆₀	T ₆₁	T ₆₂	T ₆₃	T ₆₄	T ₆₅	T ₆₆	T ₆₇	T ₆₈	T ₆₉	T ₇₀	T ₇₁	T ₇₂	T ₇₃	T ₇₄	T ₇₅	T ₇₆	T ₇₇	T ₇₈	T ₇₉	T ₈₀	T ₈₁	T ₈₂	T ₈₃	T ₈₄	T ₈₅	T ₈₆	T ₈₇	T ₈₈	T ₈₉	T ₉₀	T ₉₁	T ₉₂	T ₉₃	T ₉₄	T ₉₅	T ₉₆	T ₉₇	T ₉₈	T ₉₉	T ₁₀₀	T ₁₀₁	T ₁₀₂	T ₁₀₃	T ₁₀₄	T ₁₀₅	T ₁₀₆	T ₁₀₇	T ₁₀₈	T ₁₀₉	T ₁₁₀	T ₁₁₁	T ₁₁₂	T ₁₁₃	T ₁₁₄	T ₁₁₅	T ₁₁₆	T ₁₁₇	T ₁₁₈	T ₁₁₉	T ₁₂₀	T ₁₂₁	T ₁₂₂	T ₁₂₃	T ₁₂₄	T ₁₂₅	T ₁₂₆	T ₁₂₇	T ₁₂₈	T ₁₂₉	T ₁₃₀	T ₁₃₁	T ₁₃₂	T ₁₃₃	T ₁₃₄	T ₁₃₅	T ₁₃₆	T ₁₃₇	T ₁₃₈	T ₁₃₉	T ₁₄₀	T ₁₄₁	T ₁₄₂	T ₁₄₃	T ₁₄₄	T ₁₄₅	T ₁₄₆	T ₁₄₇	T ₁₄₈	T ₁₄₉	T ₁₅₀	T ₁₅₁	T ₁₅₂	T ₁₅₃	T ₁₅₄	T ₁₅₅	T ₁₅₆	T ₁₅₇	T ₁₅₈	T ₁₅₉	T ₁₆₀	T ₁₆₁	T ₁₆₂	T ₁₆₃	T ₁₆₄	T ₁₆₅	T ₁₆₆	T ₁₆₇	T ₁₆₈	T ₁₆₉	T ₁₇₀	T ₁₇₁	T ₁₇₂	T ₁₇₃	T ₁₇₄	T ₁₇₅	T ₁₇₆	T ₁₇₇	T ₁₇₈	T ₁₇₉	T ₁₈₀	T ₁₈₁	T ₁₈₂	T ₁₈₃	T ₁₈₄	T ₁₈₅	T ₁₈₆	T ₁₈₇	T ₁₈₈	T ₁₈₉	T ₁₉₀	T ₁₉₁	T ₁₉₂	T ₁₉₃	T ₁₉₄	T ₁₉₅	T ₁₉₆	T ₁₉₇	T ₁₉₈	T ₁₉₉	T ₂₀₀	T ₂₀₁	T ₂₀₂	T ₂₀₃	T ₂₀₄	T ₂₀₅	T ₂₀₆	T ₂₀₇	T ₂₀₈	T ₂₀₉	T ₂₁₀	T ₂₁₁	T ₂₁₂	T ₂₁₃	T ₂₁₄	T ₂₁₅	T ₂₁₆	T ₂₁₇	T ₂₁₈	T ₂₁₉	T ₂₂₀	T ₂₂₁	T ₂₂₂	T ₂₂₃	T ₂₂₄	T ₂₂₅	T ₂₂₆	T ₂₂₇	T ₂₂₈	T ₂₂₉	T ₂₃₀	T ₂₃₁	T ₂₃₂	T ₂₃₃	T ₂₃₄	T ₂₃₅	T ₂₃₆	T ₂₃₇	T ₂₃₈	T ₂₃₉	T ₂₄₀	T ₂₄₁	T ₂₄₂	T ₂₄₃	T ₂₄₄	T ₂₄₅	T ₂₄₆	T ₂₄₇	T ₂₄₈	T ₂₄₉	T ₂₅₀	T ₂₅₁	T ₂₅₂	T ₂₅₃	T ₂₅₄	T ₂₅₅	T ₂₅₆	T ₂₅₇	T ₂₅₈	T ₂₅₉	T ₂₆₀	T ₂₆₁	T ₂₆₂	T ₂₆₃	T ₂₆₄	T ₂₆₅	T ₂₆₆	T ₂₆₇	T ₂₆₈	T ₂₆₉	T ₂₇₀	T ₂₇₁	T ₂₇₂	T ₂₇₃	T ₂₇₄	T ₂₇₅	T ₂₇₆	T ₂₇₇	T ₂₇₈	T ₂₇₉	T ₂₈₀	T ₂₈₁	T ₂₈₂	T ₂₈₃	T ₂₈₄	T ₂₈₅	T ₂₈₆	T ₂₈₇	T ₂₈₈	T ₂₈₉	T ₂₉₀	T ₂₉₁	T ₂₉₂	T ₂₉₃	T ₂₉₄	T ₂₉₅	T ₂₉₆	T ₂₉₇	T ₂₉₈	T ₂₉₉	T ₃₀₀	T ₃₀₁	T ₃₀₂	T ₃₀₃	T ₃₀₄	T ₃₀₅	T ₃₀₆	T ₃₀₇	T ₃₀₈	T ₃₀₉	T ₃₁₀	T ₃₁₁	T ₃₁₂	T ₃₁₃	T ₃₁₄	T ₃₁₅	T ₃₁₆	T ₃₁₇	T ₃₁₈	T ₃₁₉	T ₃₂₀	T ₃₂₁	T ₃₂₂	T ₃₂₃	T ₃₂₄	T ₃₂₅	T ₃₂₆	T ₃₂₇	T ₃₂₈	T ₃₂₉	T ₃₃₀	T ₃₃₁	T ₃₃₂	T ₃₃₃	T ₃₃₄	T ₃₃₅	T ₃₃₆	T ₃₃₇	T ₃₃₈	T ₃₃₉	T ₃₄₀	T ₃₄₁	T ₃₄₂	T ₃₄₃	T ₃₄₄	T ₃₄₅	T ₃₄₆	T ₃₄₇	T ₃₄₈	T ₃₄₉	T ₃₅₀	T ₃₅₁	T ₃₅₂	T ₃₅₃	T ₃₅₄	T ₃₅₅	T ₃₅₆	T ₃₅₇	T ₃₅₈	T ₃₅₉	T ₃₆₀	T ₃₆₁	T ₃₆₂	T ₃₆₃	T ₃₆₄	T ₃₆₅	T ₃₆₆	T ₃₆₇	T ₃₆₈	T ₃₆₉	T ₃₇₀	T ₃₇₁	T ₃₇₂	T ₃₇₃	T ₃₇₄	T ₃₇₅	T ₃₇₆	T ₃₇₇	T ₃₇₈	T ₃₇₉	T ₃₈₀	T ₃₈₁	T ₃₈₂	T ₃₈₃	T ₃₈₄	T ₃₈₅	T ₃₈₆	T ₃₈₇	T ₃₈₈	T ₃₈₉	T ₃₉₀	T ₃₉₁	T ₃₉₂	T ₃₉₃	T ₃₉₄	T ₃₉₅	T ₃₉₆	T ₃₉₇	T ₃₉₈	T ₃₉₉	T ₄₀₀	T ₄₀₁	T ₄₀₂	T ₄₀₃	T ₄₀₄	T ₄₀₅	T ₄₀₆	T ₄₀₇	T ₄₀₈	T ₄₀₉	T ₄₁₀	T ₄₁₁	T ₄₁₂	T ₄₁₃	T ₄₁₄	T ₄₁₅	T ₄₁₆	T ₄₁₇	T ₄₁₈	T ₄₁₉	T ₄₂₀	T ₄₂₁	T ₄₂₂	T ₄₂₃	T ₄₂₄	T ₄₂₅	T ₄₂₆	T ₄₂₇	T ₄₂₈	T ₄₂₉	T ₄₃₀	T ₄₃₁	T ₄₃₂	T ₄₃₃	T ₄₃₄	T ₄₃₅	T ₄₃₆	T ₄₃₇	T ₄₃₈	T ₄₃₉	T ₄₄₀	T ₄₄₁	T ₄₄₂	T ₄₄₃	T ₄₄₄	T ₄₄₅	T ₄₄₆	T ₄₄₇	T ₄₄₈	T ₄₄₉	T ₄₅₀	T ₄₅₁	T ₄₅₂	T ₄₅₃	T ₄₅₄	T ₄₅₅	T ₄₅₆	T ₄₅₇	T ₄₅₈	T ₄₅₉	T ₄₆₀	T ₄₆₁	T ₄₆₂	T ₄₆₃	T ₄₆₄	T ₄₆₅	T ₄₆₆	T ₄₆₇	T ₄₆₈	T ₄₆₉	T ₄₇₀	T ₄₇₁	T ₄₇₂	T ₄₇₃	T ₄₇₄	T ₄₇₅	T ₄₇₆	T ₄₇₇	T ₄₇₈	T ₄₇₉	T ₄₈₀	T ₄₈₁	T ₄₈₂	T ₄₈₃	T ₄₈₄	T ₄₈₅	T ₄₈₆	T ₄₈₇	T ₄₈₈	T ₄₈₉	T ₄₉₀	T ₄₉₁	T ₄₉₂	T ₄₉₃	T ₄₉₄	T ₄₉₅	T ₄₉₆	T ₄₉₇	T ₄₉₈	T ₄₉₉	T ₅₀₀	T ₅₀₁	T ₅₀₂	T ₅₀₃	T ₅₀₄	T ₅₀₅	T ₅₀₆	T ₅₀₇	T ₅₀₈	T ₅₀₉	T ₅₁₀	T ₅₁₁	T ₅₁₂	T ₅₁₃	T ₅₁₄	T ₅₁₅	T ₅₁₆	T ₅₁₇	T ₅₁₈	T ₅₁₉	T ₅₂₀	T ₅₂₁	T ₅₂₂	T ₅₂₃	T ₅₂₄	T ₅₂₅	T ₅₂₆	T ₅₂₇	T ₅₂₈	T ₅₂₉	T ₅₃₀	T ₅₃₁	T ₅₃₂	T ₅₃₃	T ₅₃₄	T ₅₃₅	T ₅₃₆	T ₅₃₇	T ₅₃₈	T ₅₃₉	T ₅₄₀	T ₅₄₁	T ₅₄₂	T ₅₄₃	T ₅₄₄	T ₅₄₅	T ₅₄₆	T ₅₄₇	T ₅₄₈	T ₅₄₉	T ₅₅₀	T ₅₅₁	T ₅₅₂	T ₅₅₃	T ₅₅₄	T ₅₅₅	T ₅₅₆	T ₅₅₇	T ₅₅₈	T ₅₅₉	T ₅₆₀	T ₅₆₁	T ₅₆₂	T ₅₆₃	T ₅₆₄	T ₅₆₅	T ₅₆₆	T ₅₆₇	T ₅₆₈	T ₅₆₉	T ₅₇₀	T ₅₇₁	T ₅₇₂	T ₅₇₃	T ₅₇₄	T ₅₇₅	T ₅₇₆	T ₅₇₇	T ₅₇₈	T ₅₇₉	T ₅₈₀	T ₅₈₁	T ₅₈₂	T ₅₈₃	T ₅₈₄	T ₅₈₅	T ₅₈₆	T ₅₈₇	T ₅₈₈	T ₅₈₉	T ₅₉₀	T ₅₉₁	T ₅₉₂	T ₅₉₃	T ₅₉₄	T ₅₉₅	T ₅₉₆	T ₅₉₇	T ₅₉₈	T ₅₉₉	T ₆₀₀	T ₆₀₁	T ₆₀₂	T ₆₀₃	T ₆₀₄	T ₆₀₅	T ₆₀₆	T ₆₀₇	T ₆₀₈	T ₆₀₉	T ₆₁₀	T ₆₁₁	T ₆₁₂	T ₆₁₃	T ₆₁₄	T ₆₁₅	T ₆₁₆	T ₆₁₇	T ₆₁₈	T ₆₁₉	T ₆₂₀	T ₆₂₁	T ₆₂₂	T ₆₂₃	T ₆₂₄	T ₆₂₅	T ₆₂₆	T ₆₂₇	T ₆₂₈	T ₆₂₉	T ₆₃₀	T ₆₃₁	T ₆₃₂	T ₆₃₃	T ₆₃₄	T ₆₃₅	T ₆₃₆	T ₆₃₇	T ₆₃₈	T ₆₃₉	T ₆₄₀	T ₆₄₁	T ₆₄₂	T ₆₄₃	T ₆₄₄	T ₆₄₅	T ₆₄₆	T ₆₄₇	T ₆₄₈	T ₆₄₉	T ₆₅₀	T ₆₅₁	T ₆₅₂	T ₆₅₃	T ₆₅₄	T ₆₅₅	T ₆₅₆	T ₆₅₇	T ₆₅₈	T ₆₅₉	T ₆₆₀	T ₆₆₁	T ₆₆₂	T ₆₆₃	T ₆₆₄	T ₆₆₅	T ₆₆₆	T ₆₆₇	T
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Date: 4-26-77

Inspector: DJE

In Dept: NUMBER

AIRCRAFT TURBINE TEST LOG SHEET

CF-6 / TF-40
GENERAL ELECTRIC COMPANY
ONTARIO, CALIFORNIA

Gas Turbine Serial No. 551-420
Nature of Test: _____
Sheet 6 of 16 ends

RUN NO: _____

START NO.	TIME	SPEED	CORE	FAN	THROTTLE ANGLE	LUBE OIL				FUEL				T ₂	T ₃	T ₅	THRUST LBS	VIB VOLTS	STATOR DE-FA	LPT INLET	PT ₅	RECOUP	SUM VENT	PRESS	CDP	P ₅	B M WALL	FRONT CELL TOTAL	PI.ONT	REAR	VIBRATION						DISC TEMP	1/2" AS RND	
						TEMP	PRESS	INLET	INLET	FLOW	FAN	CDT	EGT																		NO. 1	TMF	TPM	NO. 1	TMF	TPM			
HR	MIN	SEC	IN	OUT	IN	INLET	SCAV	INLET	FILTER	INLET	INLET	MAIN	VAR	FAN	CDT	EGT	THRUST	VIB	STATOR	LPT	PT	RECOUP	SUM	PRESS	CDP	P ₅	B M	FRONT	PI.ONT	REAR	NO. 1	TMF	TPM	NO. 1	TMF	TPM	DISC	1/2"	
1	00:18																																						
2	00:23																																						
3	00:26																																						
4	00:29																																						
5	00:34																																						
6	00:37																																						
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8	00:44																																						
9	00:47																																						
10	00:50																																						
11	00:54																																						
12	00:59																																						

REMARKS:

1. 00:18 - DELTA TO MCR.

2. 00:23 - T3 = 921 946 921 919 934

3. 00:26 - T3 = 928 947 923 921 933

4. 00:29 - DELTA TO MCR.

5. 00:34 - T3 = 906 930 898 894 907

6. 00:37 - T3 = 906 922 894 896 906

7. 00:39 - DELTA TO T3 = 958

8. 00:44 - T3 = 856 869 850 847 856

9. 00:47 - T3 = 855 869 849 846 855

10. 00:50 - DELTA TO FLT. T3 = 856

11. 00:54 - DELTA TO GRD. T3 = 856

12. 00:59 - DELTA TO GRD. T3 = 856

13. 00:59 - DELTA TO GRD. T3 = 856

14. 00:59 - DELTA TO GRD. T3 = 856

15. 00:59 - DELTA TO GRD. T3 = 856

16. 00:59 - DELTA TO GRD. T3 = 856

17. 00:59 - DELTA TO GRD. T3 = 856

18. 00:59 - DELTA TO GRD. T3 = 856

19. 00:59 - DELTA TO GRD. T3 = 856

20. 00:59 - DELTA TO GRD. T3 = 856

21. 00:59 - DELTA TO GRD. T3 = 856

22. 00:59 - DELTA TO GRD. T3 = 856

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24. 00:59 - DELTA TO GRD. T3 = 856

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CF - 6 / TF-29
GENERAL ELECTRIC COMPANY
ONTARIO, CALIFORNIA

Nature of Test _____
Sheet 10 of 10 Sheets

Date 4-21-77
Operator Loke
Inspector Colmorelli

RUM NO. _____

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