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

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Final report. Project Manager, J. A. Ziemianski and Technical Adviser, R. P. Dengler, both of Energy Conservative Engines Office, NASA Lewis Research Center, Cleveland, Ohio 44135.

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 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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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
DELT	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
ηc	High Pressure Compressor Efficiency
ηf	Fan Efficiency
ηt	High Pressure Turbine Efficiency
$\eta 2t$	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:

Date	Event
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., ΔEGT at cruise = 0.7 x ΔEGT 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)

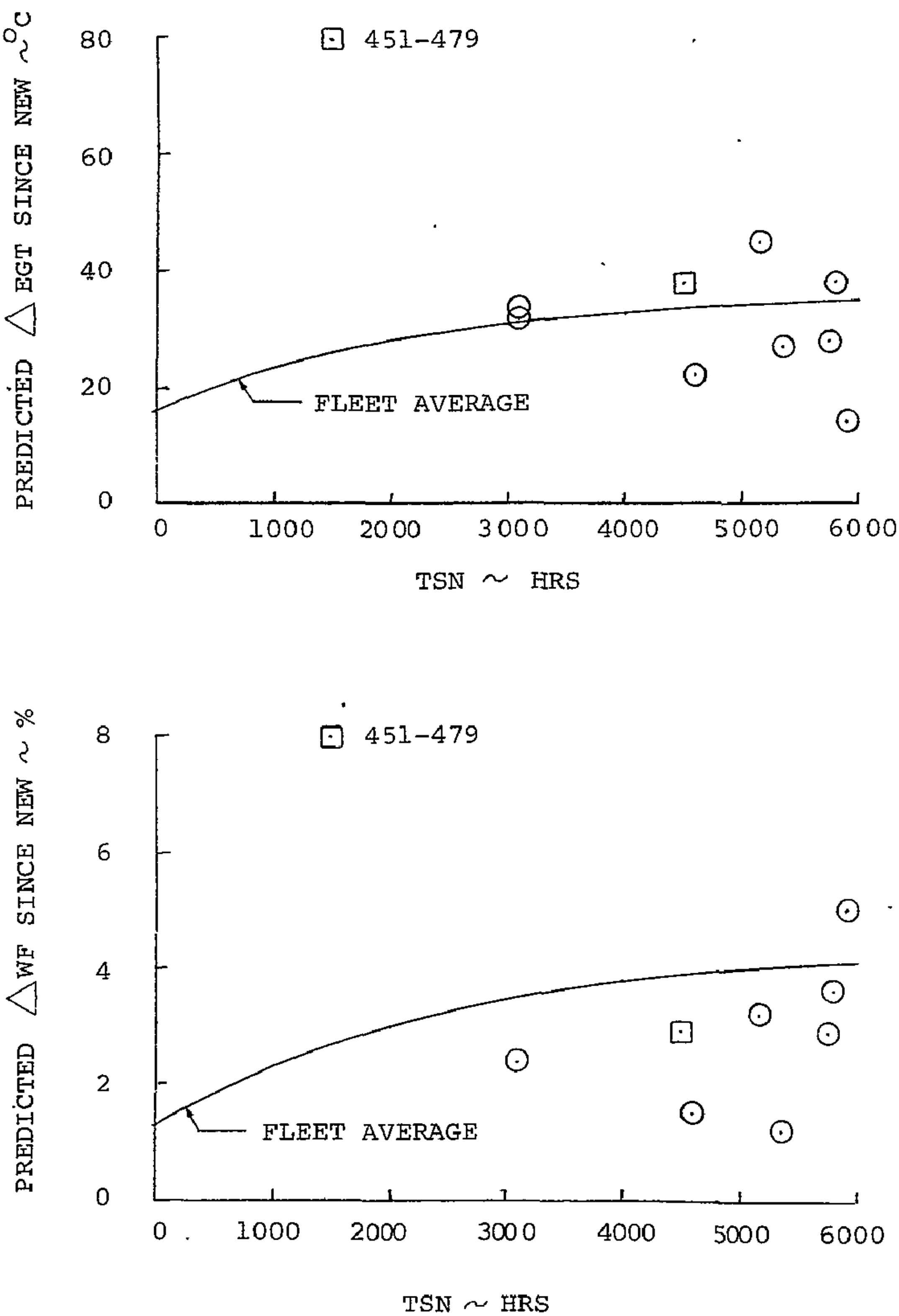

Figure 5-1. CF6-6D Cruise Deterioration.

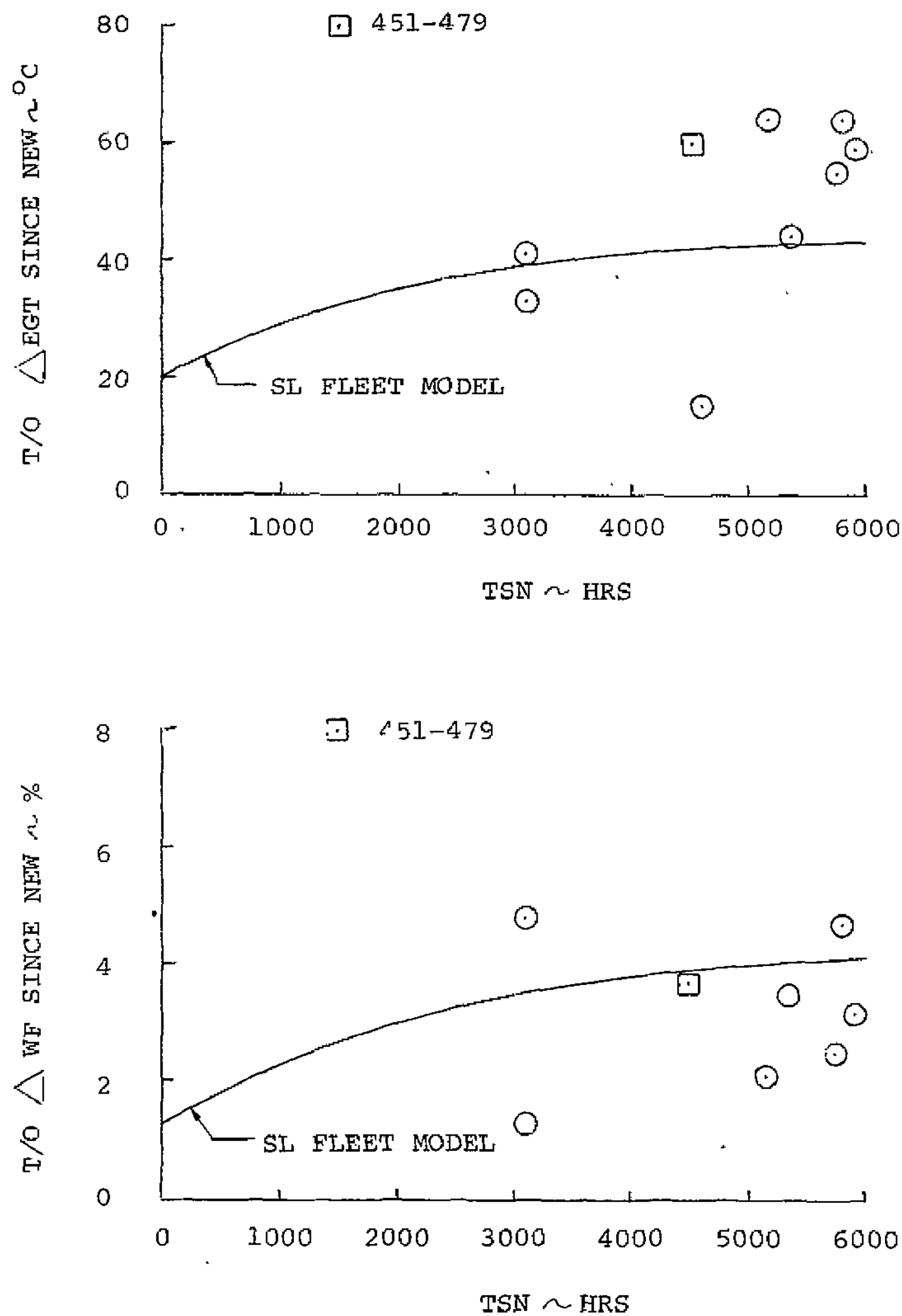

Figure 5-2. CF6-6D Inbound Sea Level Deterioration.

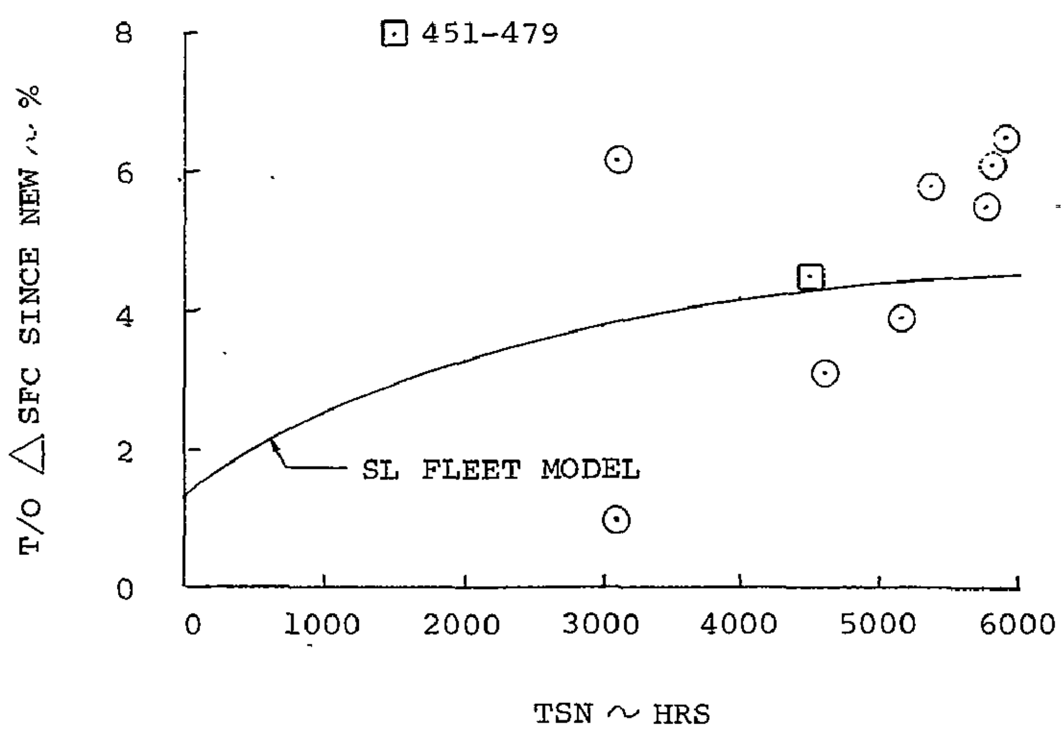

Figure 5-3. CF6-6D Inbound Sea Level Deterioration.

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

		Production	Inbound	After LPT	After Fan
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_5X		1557° F	1668° F	1668° F	1670° F
M/C Hot Day T_5X		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_5X	-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.

				Based on T_5X						Based on EGT				
Run	Reading	SFC Margin	Hot Day EGT	$DELT_5X$	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
	11	1.1	1503	-10	-0.1	-1.1	-1.3	-0.1	-0.9	-0.1	-1.0	-1.4	-0.0	-0.9
	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
	21	-3.5	1606	-6	-0.1	-5.5	-1.3	-0.4	-0.5	-0.1	-5.2	-1.3	-0.2	-0.5
	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%	ΔETAC
-0.1%	ΔETAT
0	ΔPARAS
-0.4%	ΔETALPS
+0.1%	FN@N1
-18° F	EGT@N1
0	T_5X@N1
+0.2%	SFC@FN

Table 5-3. 451-479 Stackup.

					Based on T_5X					Based on EGT				
Run	Reading	SFC Margin	Hot Day EGT	$DELT_5X$	DETAC	DETAT	DPARAS	DETALPS	DFN1	DETAC	DETAT	DPARAS	DETALPS	DFN1
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
	24	-3.8	1590	15	0.0	-6.1	-1.7	-0.6	-0.4	0.0	-4.8	-1.6	0.2	-0.4
	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

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%	ΔETAC
+0.2%	ΔETAT
+0.1%	ΔPARAS
+0.7%	ΔETALPS
+0.5%	FN@N1
+6° F	EGT@N1
+2° F	T_5X@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 ΔT_5X (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	SFC Margin	Hot Day EGT	$DELT_5X$	Based on T_5X					Based on EGT				
					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
	46	-3.4	1594	17	-0.2	-6.1	-1.8	0.3	0.6	-0.2	-4.7	-1.6	1.1	1.6
	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.

					Based on T_5X					Based on EGT				
Run	Reading	SFC Margin	Hot Day EGT	$DELT_5X$	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
	52	-3.8	1596	13	-0.4	-4.6	-0.8	-0.6	0.7	-0.4	-3.4	-0.6	0.1	0.7
	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
	56	-3.3	1596	7	-0.1	-5.4	-1.5	-0.1	0.8	-0.1	-4.5	-1.5	0.4	0.8
	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

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):

Stage	Conditions
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):

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

	Convex					Concave					Stage
Stage	Tip	Pitch	Root	Avg.	Stg. Avg.	Tip	Pitch	Root	Avg.	Stg. Avg.	Overall 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:

Tooth	Max. Diameter	FIR
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)

Stage	Depth	Width	Location	Remarks
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)

Stage	Depth	Width	Location	Remarks
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					Stage	Overall
Stage	Tip	Pitch	Root	Avg.	Avg.	Tip	Pitch	Root	Avg.	Avg.	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

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

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 (A_4)

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 A_4 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):

Vane No.	Convex Fwd.	Convex Mid	Convex Aft	Convex Avg.	Concave Fwd.	Concave Mid	Concave Aft	Concave 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 (≃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.	1/2" from LE 1	2	3	1/4" from TE 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.	1/2" from LE			1/4" from TE		
	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 HPTR 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

	G1	G2	G3	G4	G5	G6
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

	G1	G2	G3	G4	G5	G6
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 reassembled 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

Stage	Forward Max. Rad.	Forward Min. Rad.	Forward FIR	Aft Max. Rad.	Aft Min. Rad.	Aft 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

Stage	Forward Max. Rad.	Forward Min. Rad.	Forward FIR	Aft Max. Rad.	Aft Min. Rad.	Aft FIR
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 SWECO-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		
		Condi-	Tip		Pitch			Pitch		
Stage	S/N	tion	LE	TE	LE	TE	Avg	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.

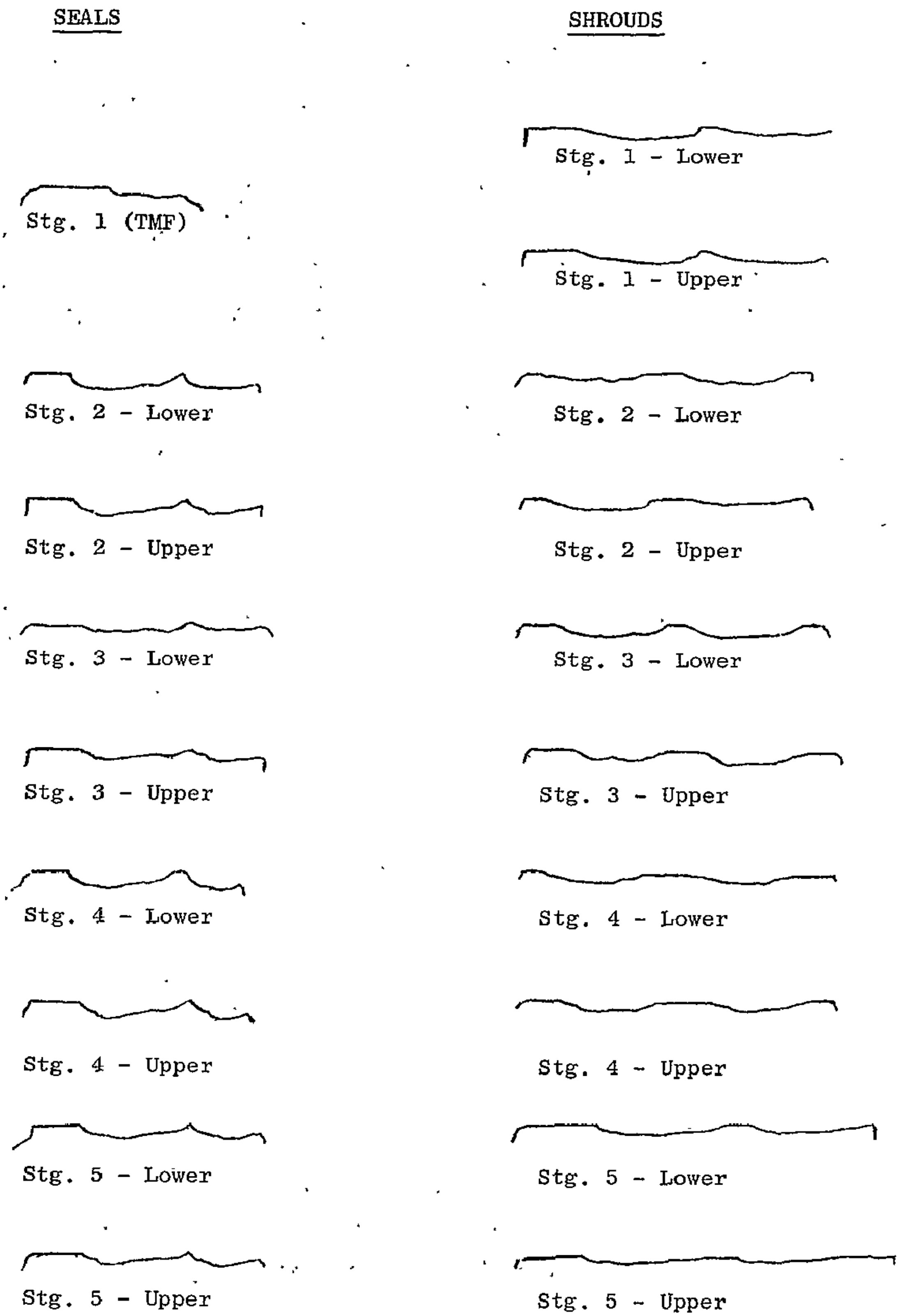

Figure 6-1. LPTS Shroud and Interstage Seal Rub Impressions.

			Convex					Concave		
		Condi-	Tip		Pitch			Pitch		
Stage	S/N	tion	LE	TE	LE	TE	Avg	LE	TE	Avg
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.

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 recontour. 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

Blade No.	Clearance	Blade No.	Clearance
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

Clearances at E13

Blade No.	Clearance	Blade No.	Clearance
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

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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.)

Position No.	Clearance	Position No.	Clearance
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.)

Position No.	Clearance	Position No.	Clearance
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:

	E12	E13	B/P
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	% SFC T/O	% SFC CR.
HPT				
Rotor Blades	Surface finish rms μ in. for 0.1% ηt			
Stage 1	Suction 26 μ in.	2	0.08	0.06
	Pressure 330	2	0.08	0.06
Stage 2	Suction 32	2	0.08	0.06
Shrouds	Surface finish Tip clearance for 1% ηt			
Stage 1	30 mils	21	0.85	0.62
Stage 2	50 mils	21	0.85	0.62
Interstage Seal	20 mils = 0.15% ηt	3	0.12	0.09
Rotating				
Stationary				
Stator Vanes	Surface finish rms μ in. for 0.1% ηt			
Stage 1	Suction 20	2	0.08	0.06
	Pressure 140	2	0.08	0.06
Stage 2	Suction 28	2	0.08	0.06
	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				
LPT				
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% η2t	3.0	0.31	0.26
Stage 2	= 0.29% η2t	2.1	0.22	0.18
Stage 3	= 0.18% η2t	1.3	0.13	0.11
Stage 4	= 0.10% η2t	0.7	0.07	0.06
Stage 5	= 0.02% η2t	0.1	0.01	0.01
	1.00% η2t	7.2	0.74	0.62
Shrouds	40 mils tip seal clear			
Stage 1	= 0.28% η2t	2.0	0.21	0.18
Stage 2	= 0.20% η2t	1.4	0.15	0.13
Stage 3	= 0.15% η2t	1.1	0.11	0.09
Stage 4	= 0.11% η2t	0.8	0.08	0.07
Stage 5	= 0.06% η2t	0.4	0.04	0.04
	0.80% η2t	5.7	0.59	0.51
Interstage Seals Rotating	20 mils clear			
Stage 1				
Stage 2	= 0.25% η2t	1.8	0.19	0.16
Stage 3	= 0.14% η2t	1.0	0.10	0.09
Stage 4	= 0.15% η2t	0.7	0.07	0.06
Stage 5	= 0.05% η2t	0.4	0.04	0.03
	0.54% η2t	3.9	0.40	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	% SFC T/O	% SFC 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	Dirt buildup, damage, L/E irregularity			
Rotor Blades	Tip Clear avg. 10 mils tighter throughout compressor = 1% ηc			
	Breakdown - 10 mils each stage:			
	Blade to case:			
	Stage 1-4 0.05% ηc	1	0.04	0.03
	Stage 5-16 0.49% ηc	9.3	0.37	0.25
	Vane to spool:			
	Stage 3-7 0.13% ηc	2.5	0.10	0.07
	Stage 8-15 0.33% ηc	6.3	0.25	0.18
	Total 1.00% ηc	19.0	0.75	0.54
	Surface finish: 6 rms μ in. = 0.1% ηc	2	0.08	0.03
	33% of blades eroded on each stage, Stage 5 on back = 0.7% ηc 50% = 1.0% ηc			
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% ηf	0.6	0.07	0.05
OGV - Inner	87 rms μ in. = 0.1% ηf	0.6	0.07	0.05
OGV - Outer	80 rms μ in. = 0.1% ηf	0.6	0.07	0.05
Fan Rotor Blades				
Stage 1	Tip clear 35 mils = 0.6% ηf	3.6	0.42	0.30
	Surface finish: 27 rms μ in. = 0.1% ηf	0.6	0.07	0.05
Stage 2	Tip clear 40 mils = 0.3% ηf	1.8	0.21	0.15
	22 rms μ in. 0.1% ηf	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.

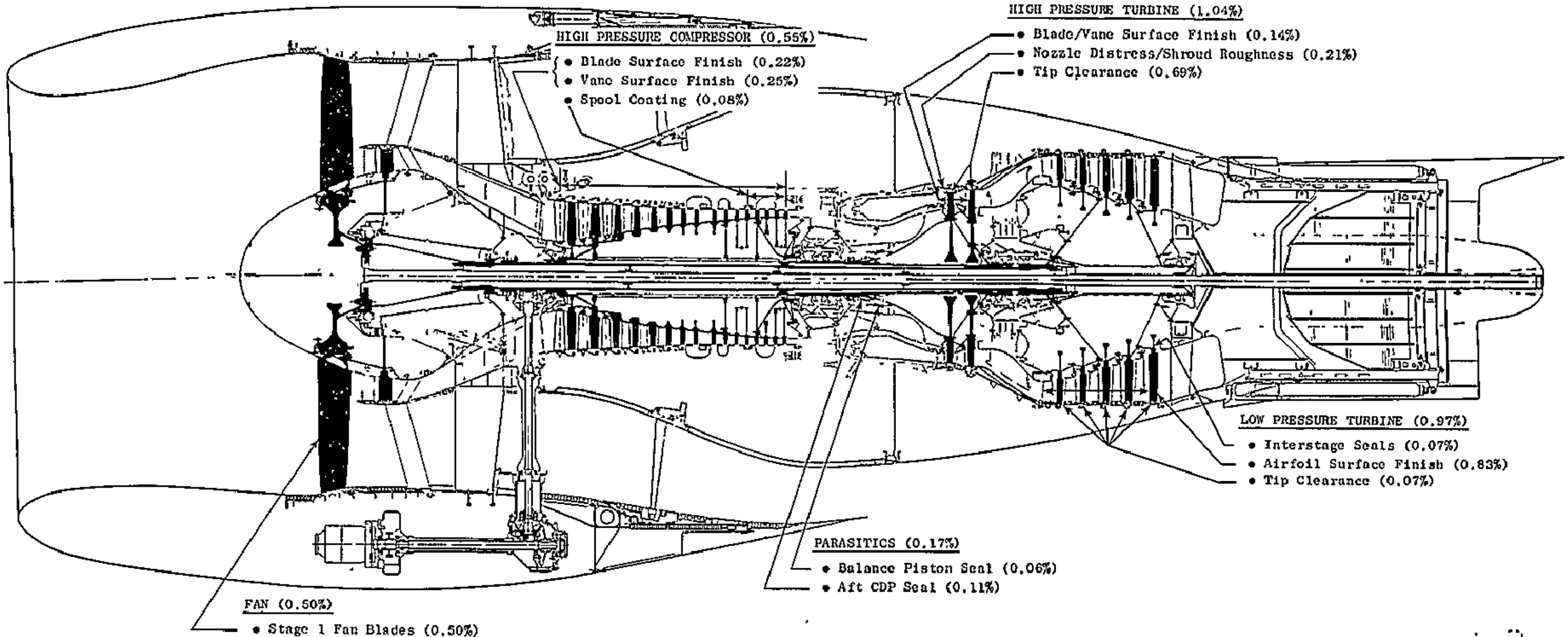

Figure 7-1. General Electric CF6-6 Engine Cross Section.

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.

	η	EGT	SFC
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

MAIL DROP M82
DIAL COMM 8 * 332 3743
COPIES:

SUBJECT
FUEL ANALYSIS

May 5, 1977

J. Smith
M.D. F117

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

Jack 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

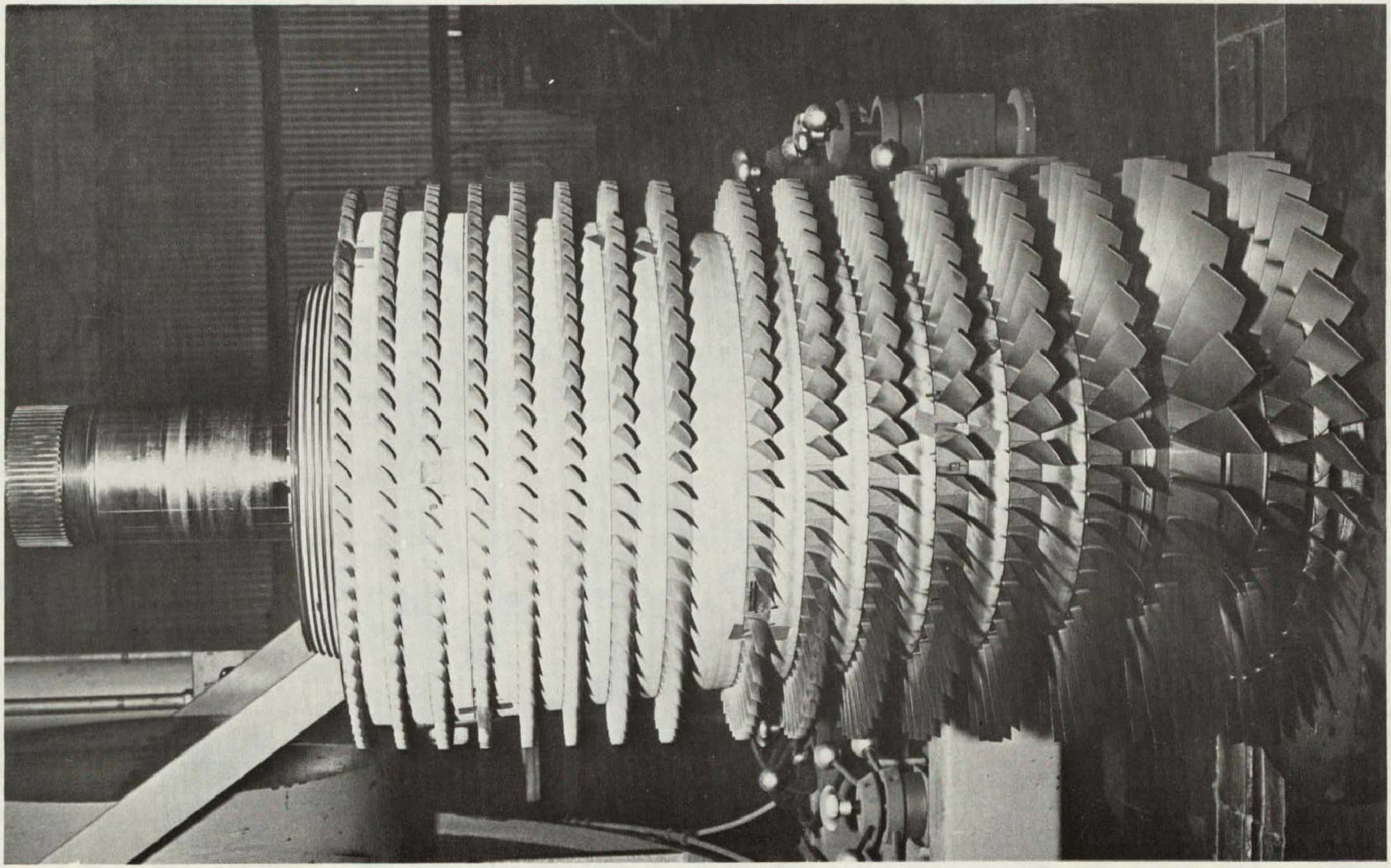

Figure 8-1. High Pressure Compressor Rotor (Cleaned), Missing Blades at Surface Finish Check.

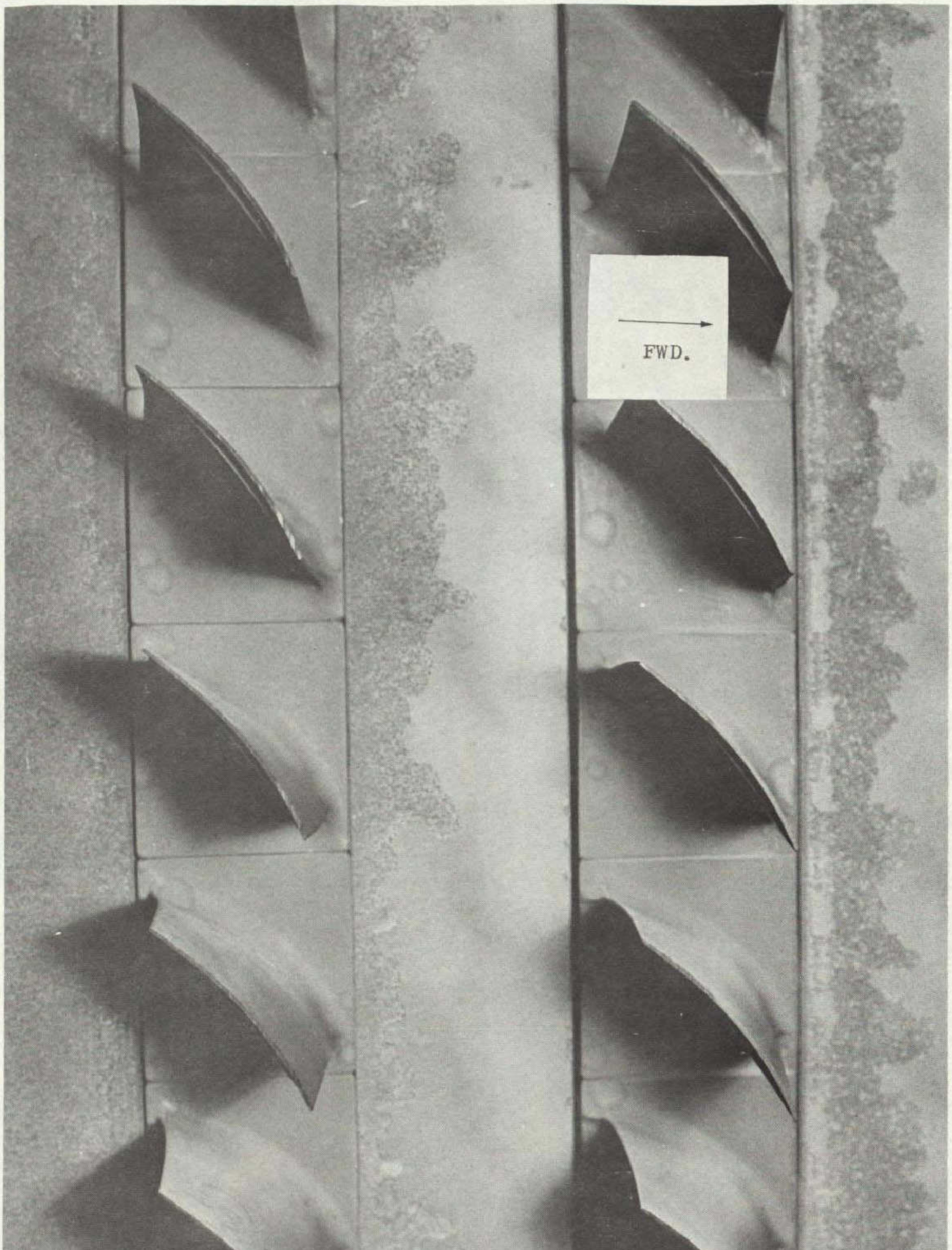

Figure 8-2. HP Compressor Rotor Stages 13 to 15 Land Coating.

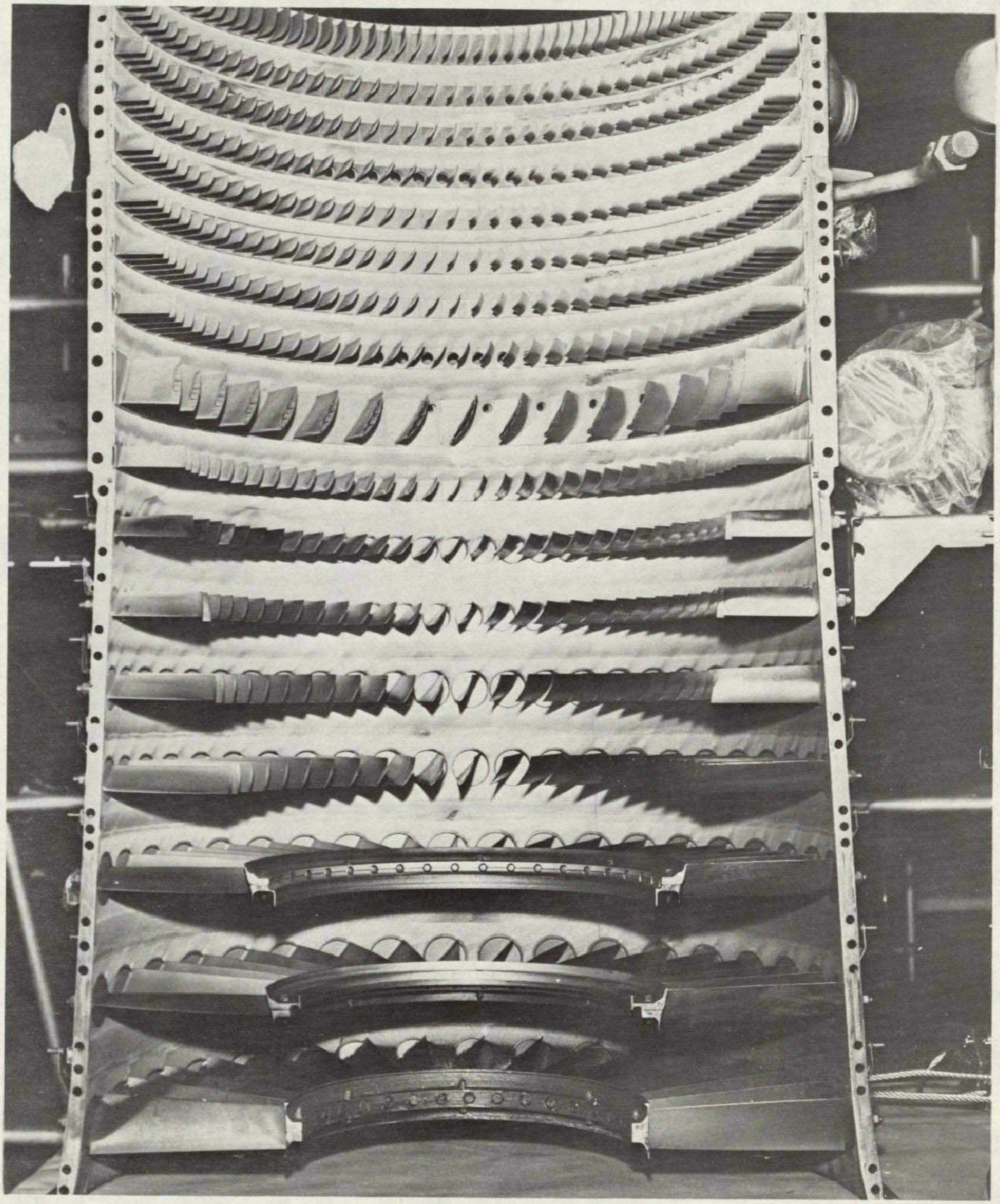

Figure 8-3. HP Compressor Stator Upper Overall Oil, Dirt, Rubs.

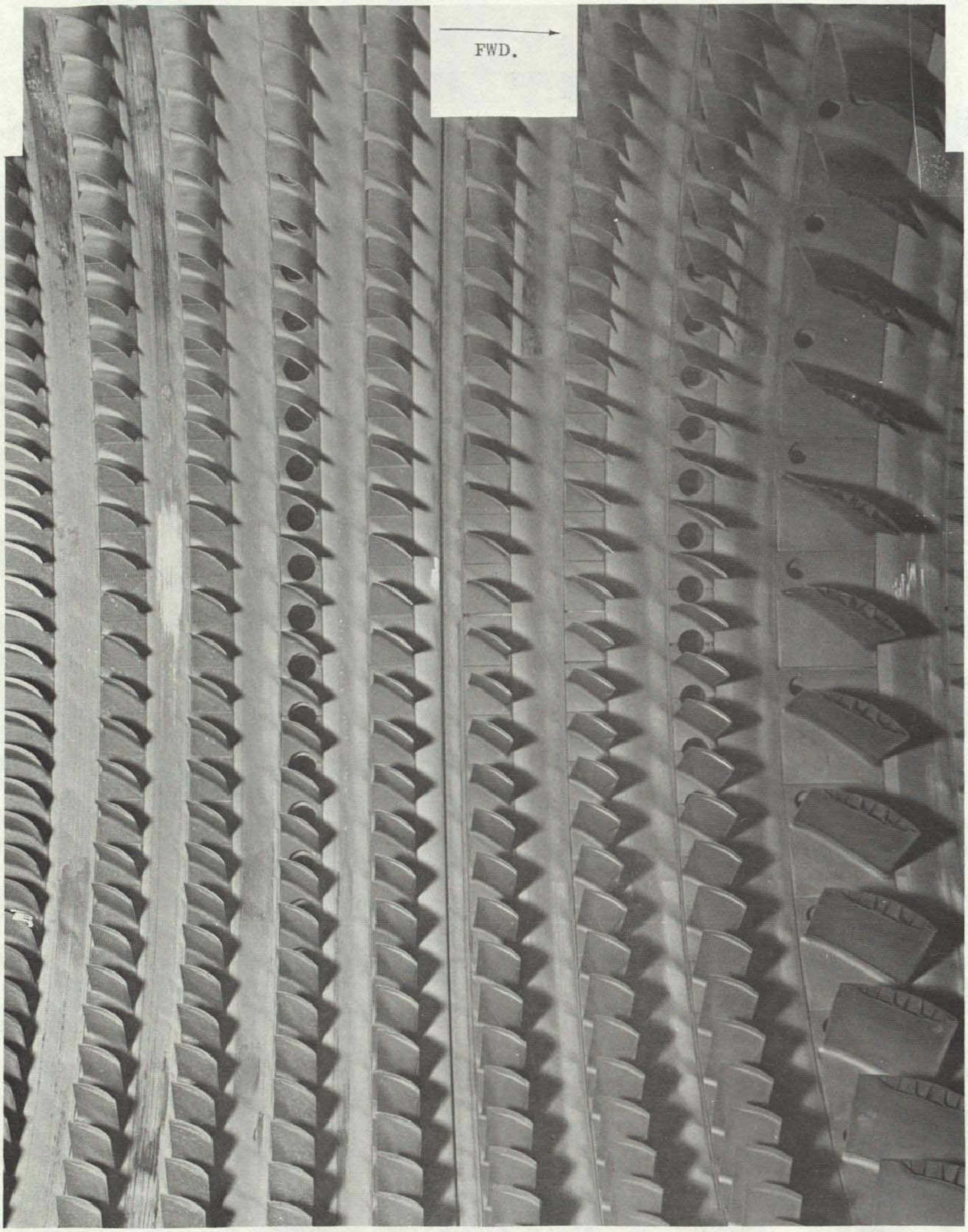

Figure 8-4. HP Compressor Stator, Upper Stage 7 to OGV - Rubs.

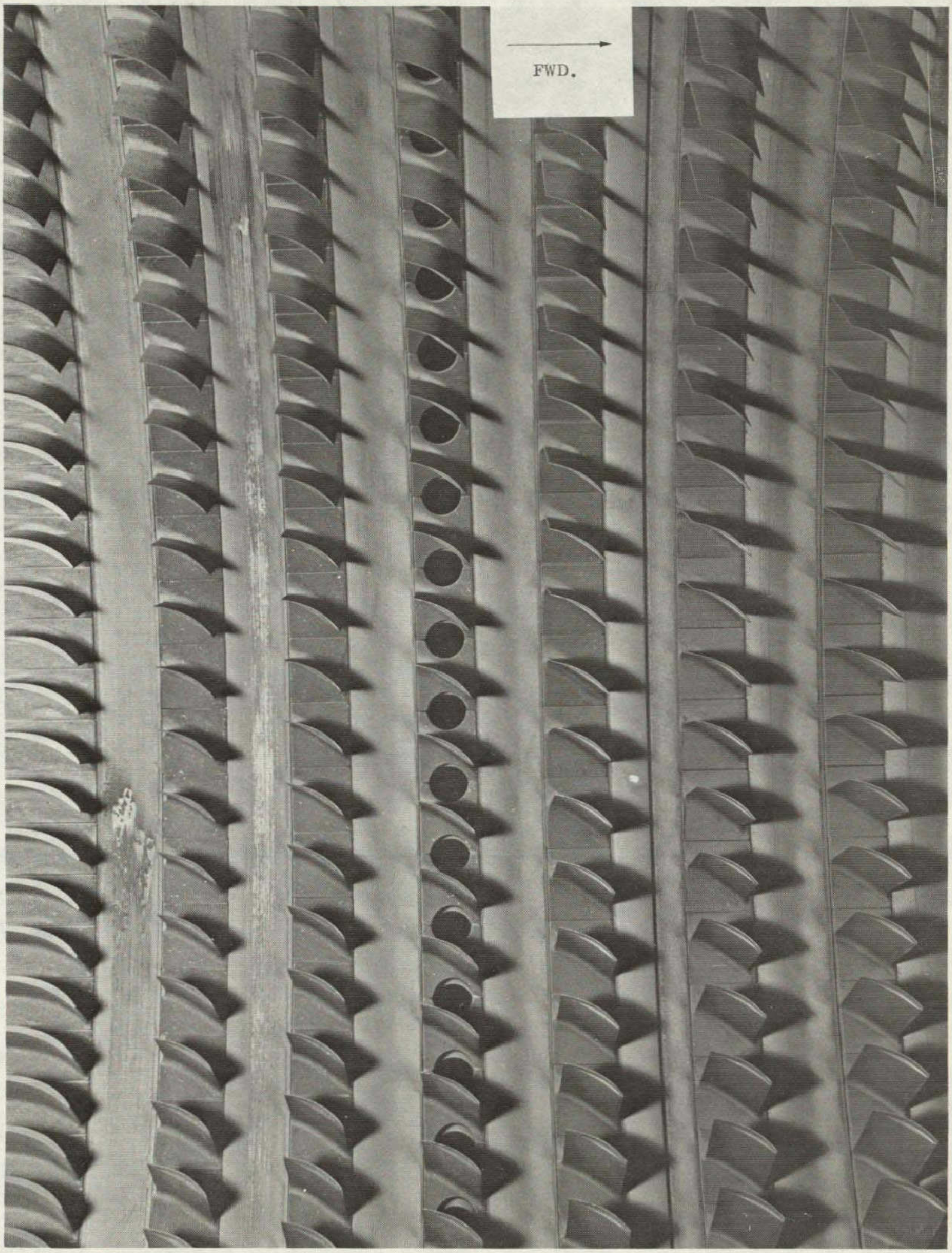

Figure 8-5. HP Compressor Stator, Lower Stage 9 to OGV - Rubs.

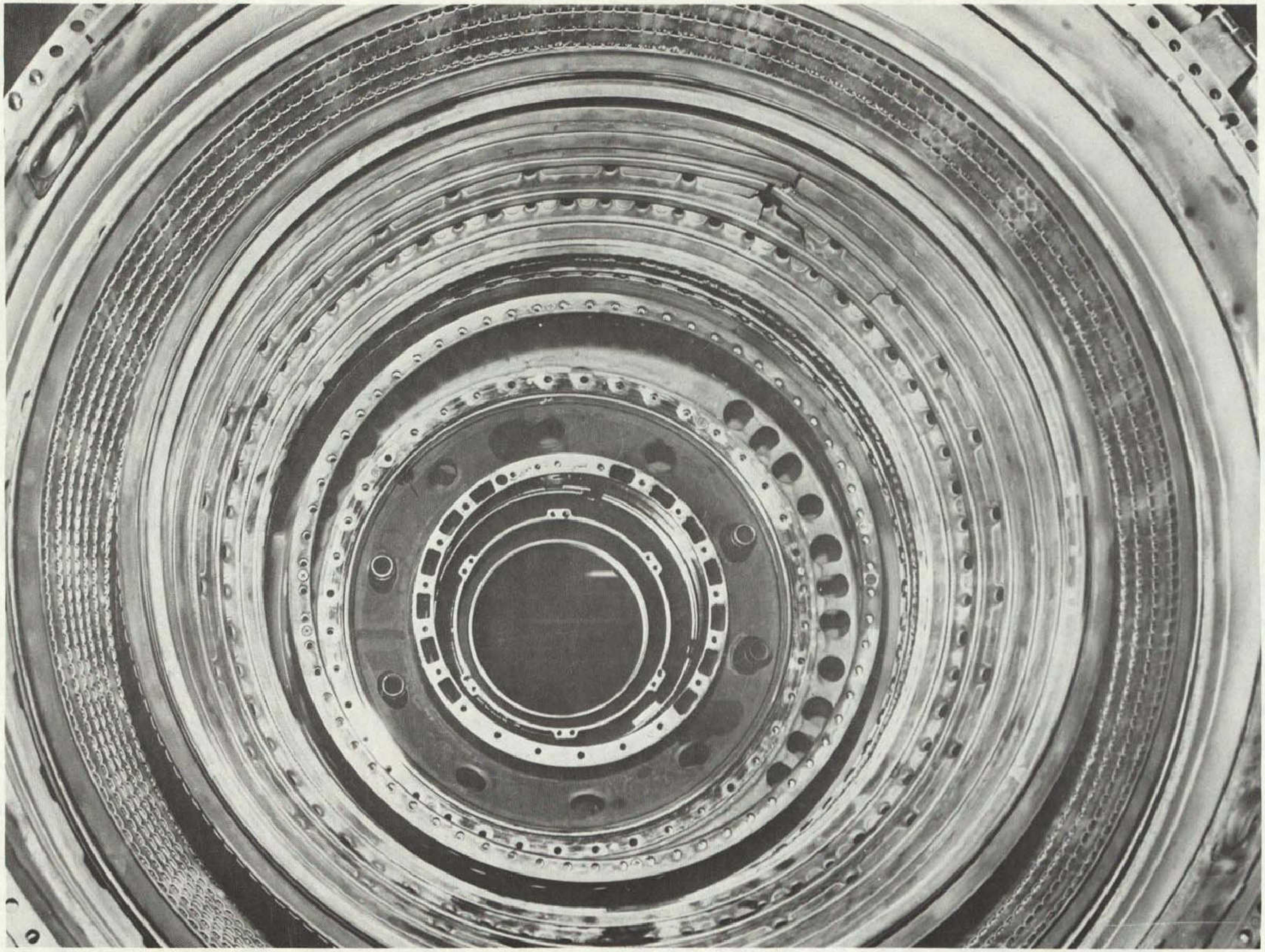

Figure 8-6. Combustor, Overall Cracks.

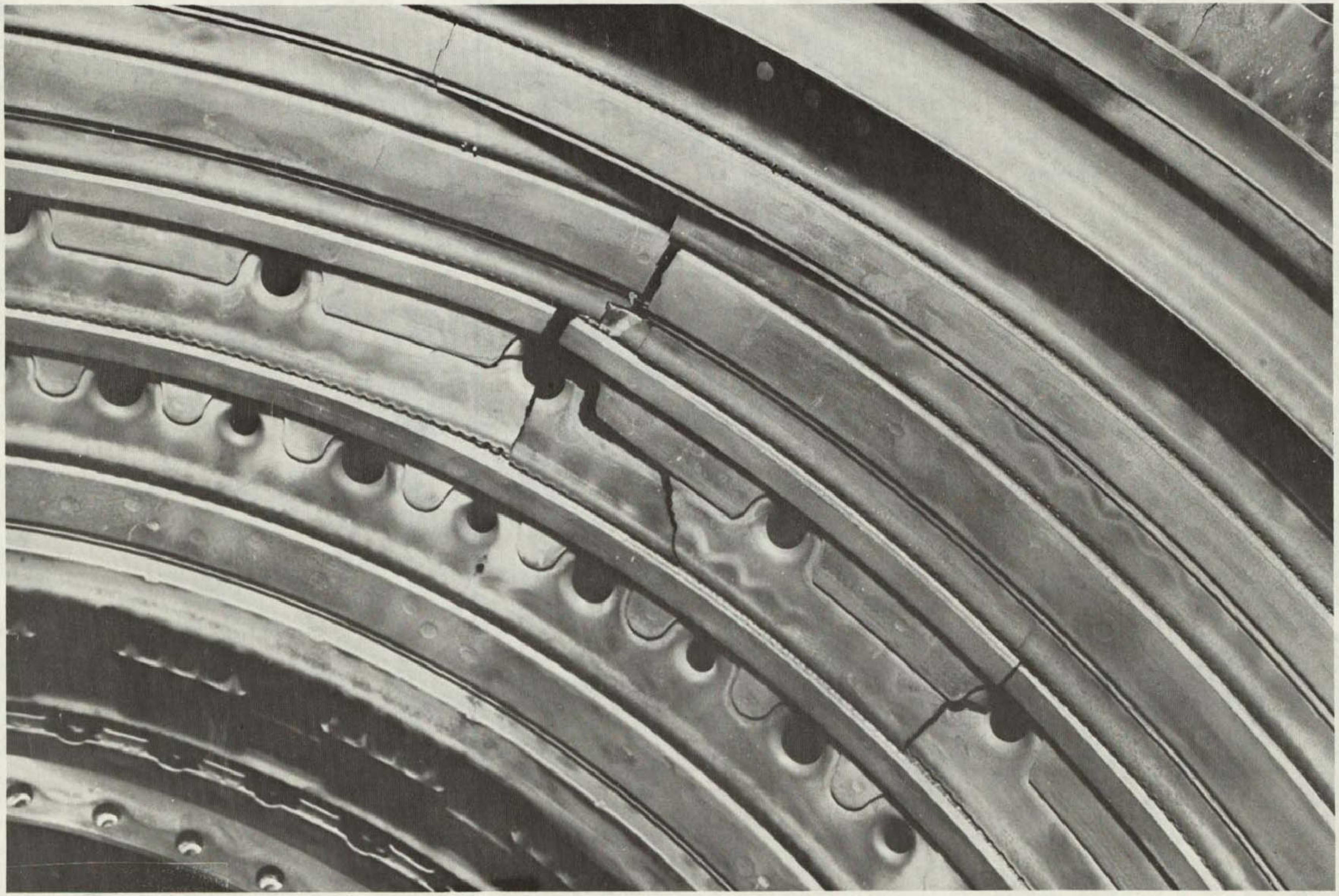

Figure 8-7. Combustor, Closeup Crack at 7 o'clock.

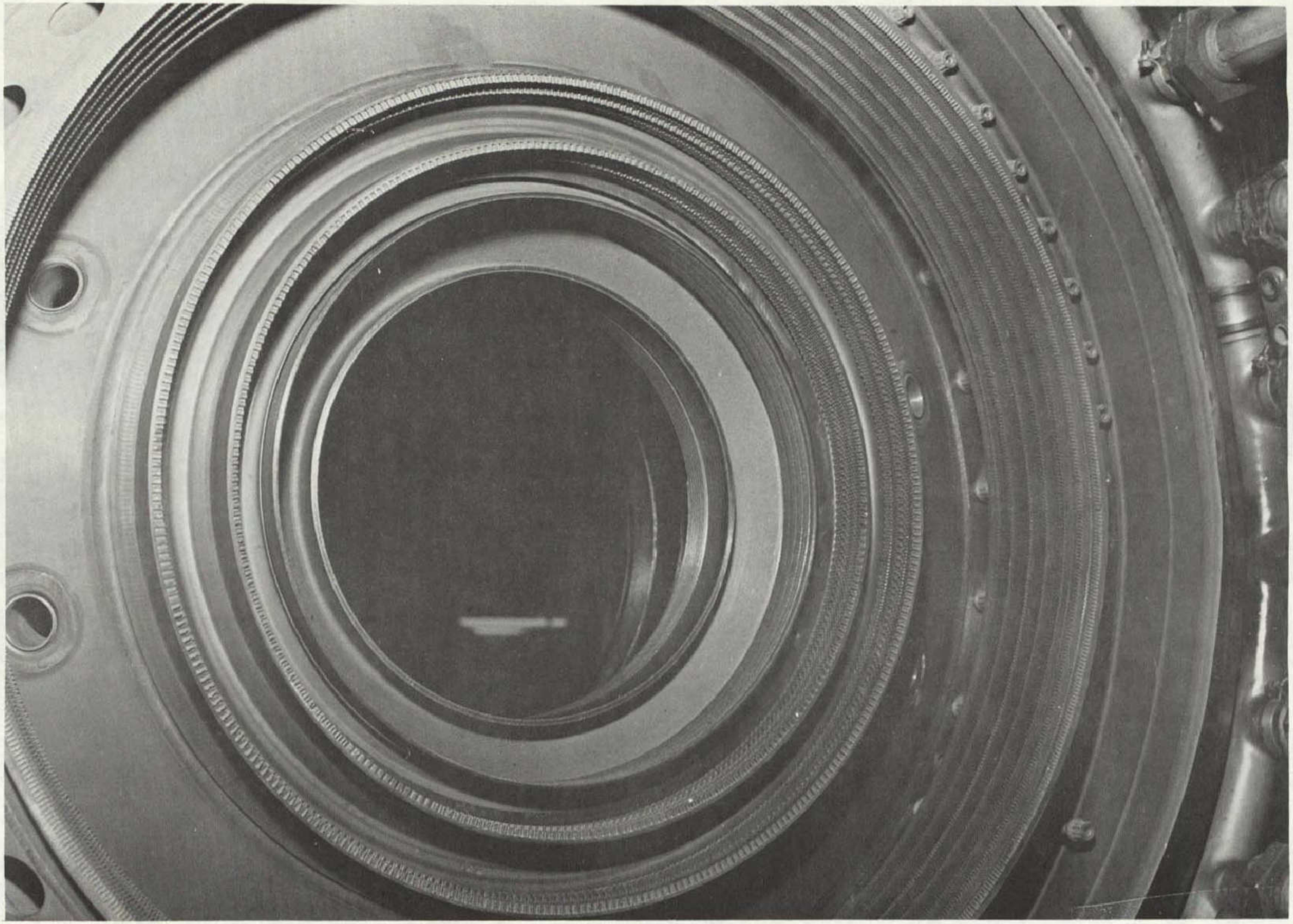

Figure 8-8. Compressor Rear Frame, Forward Seals - Overall View, Installed.

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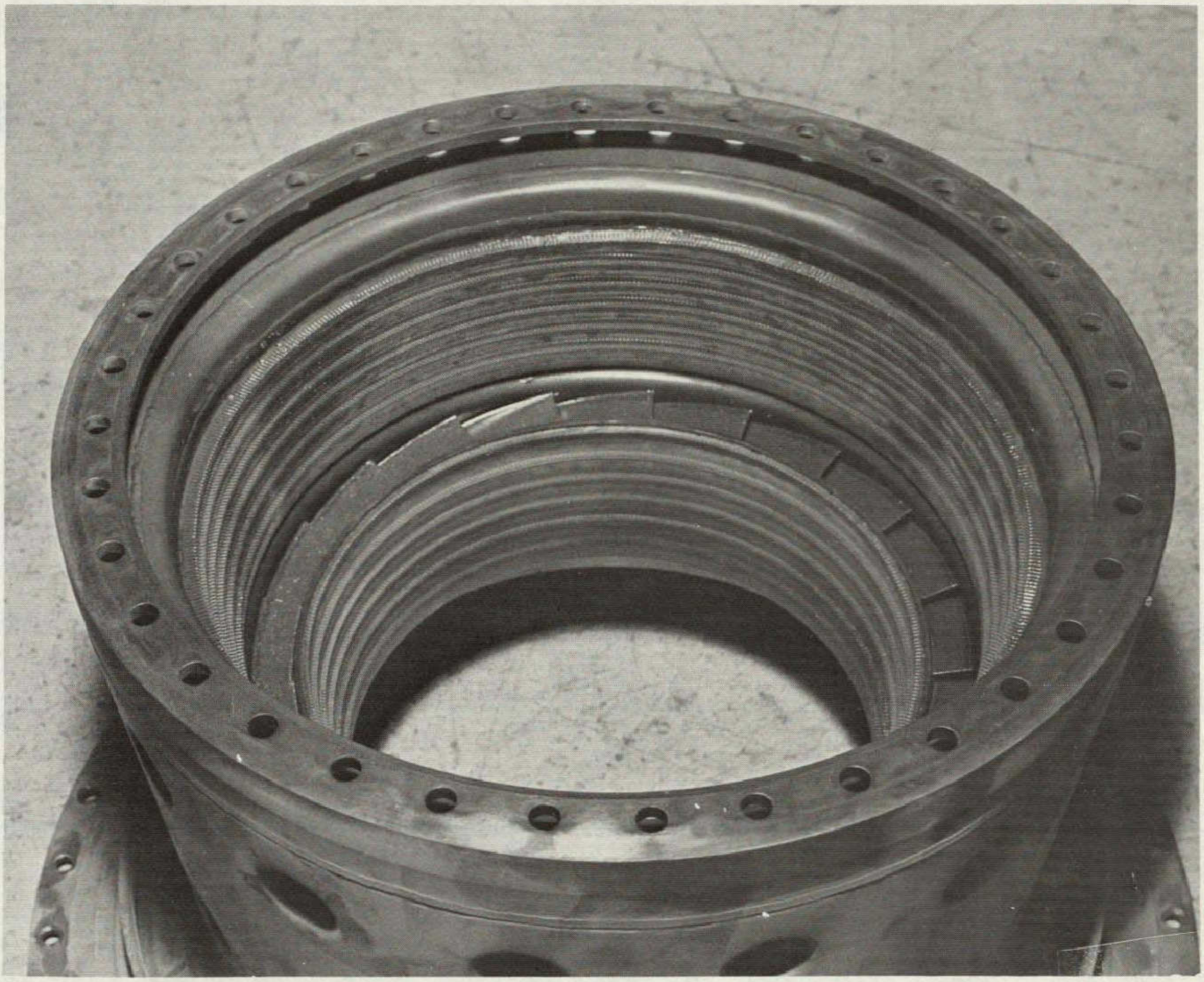

Figure 8-9. No. 4B Pressure Balance Seal, Overall View.

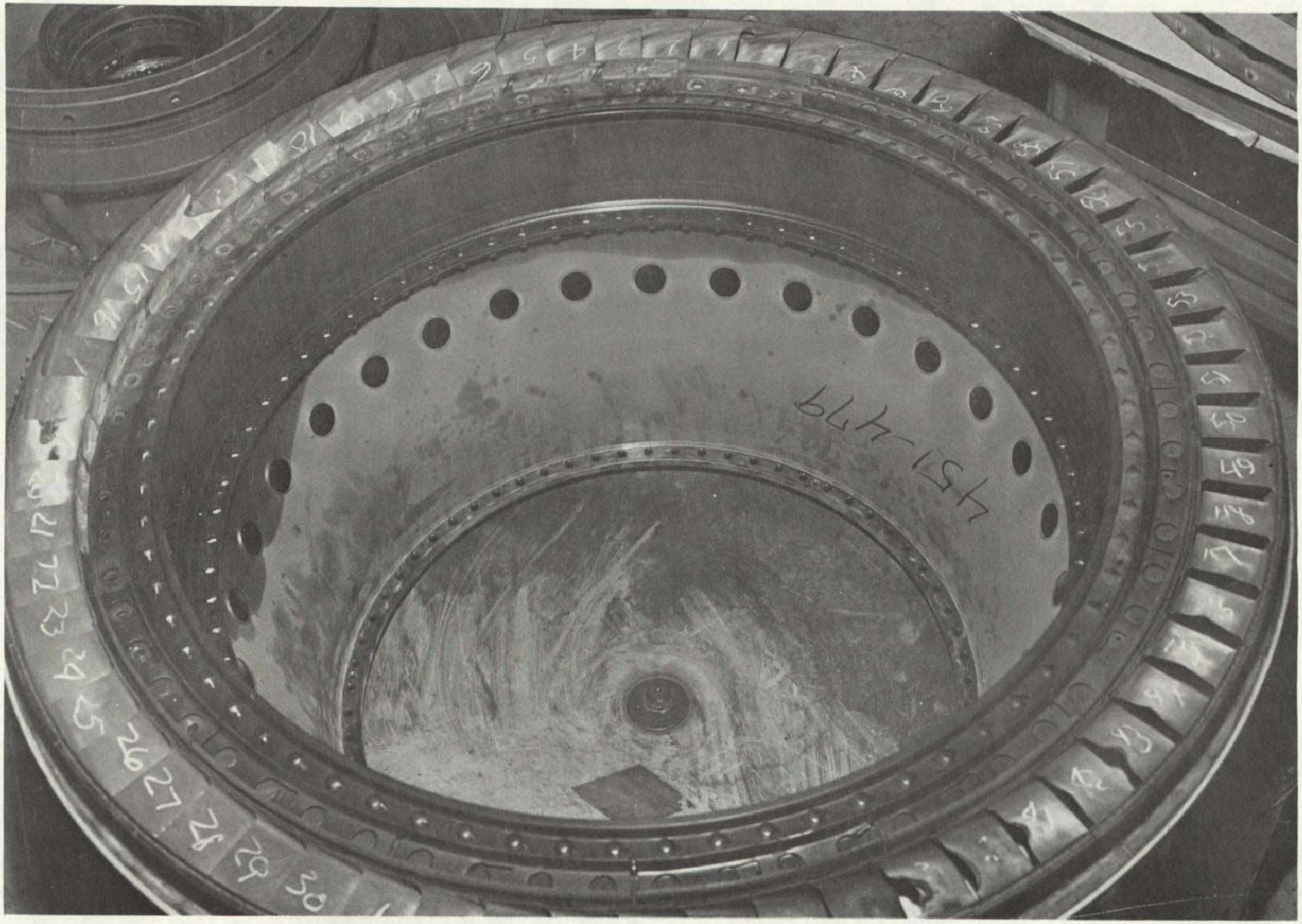

Figure 8-10. Stage 1 HP Turbine Nozzle Assembly, Aft End, Overall View.

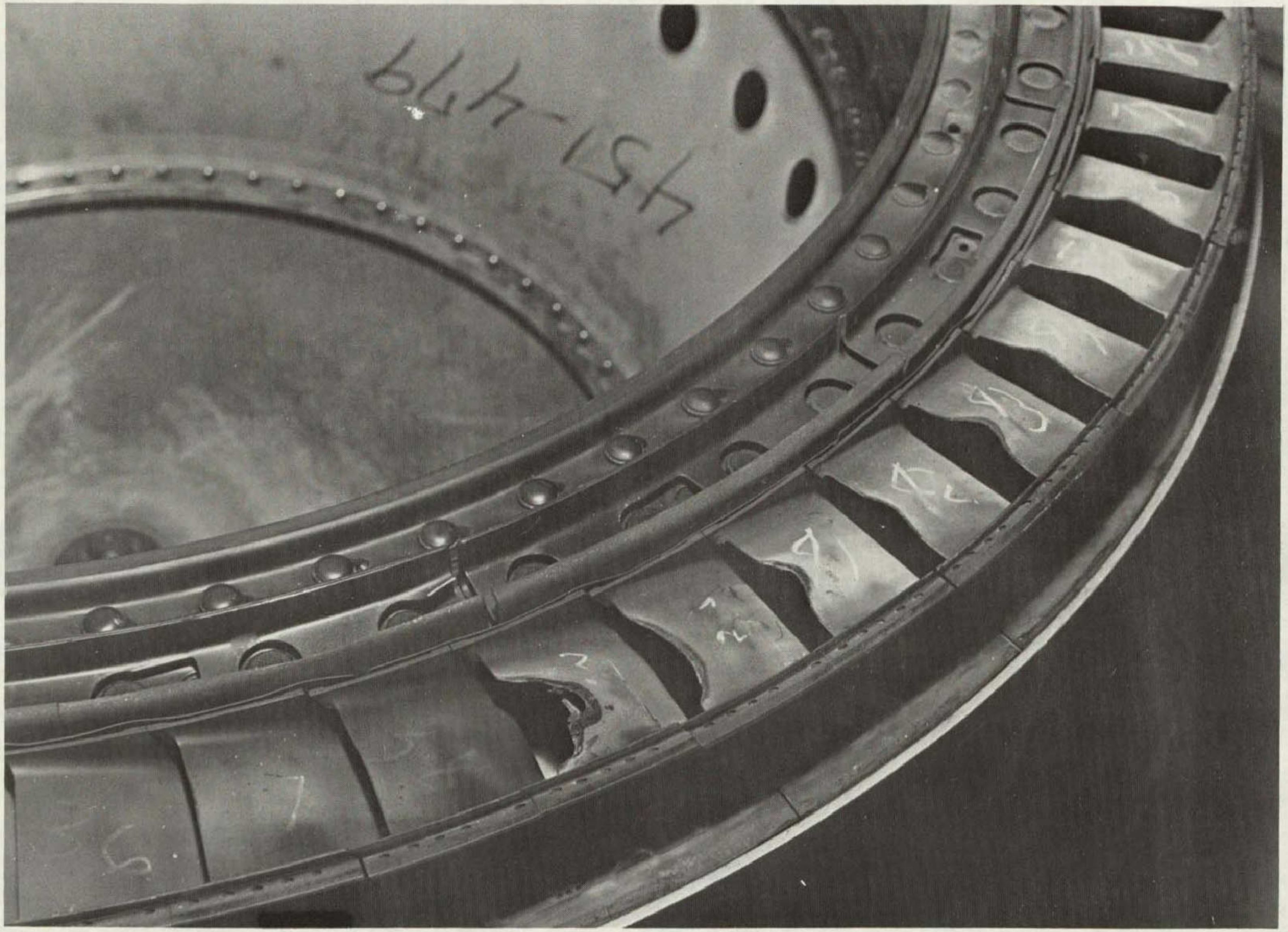

Figure 8-11. Stage 1 HP Turbine Nozzle Assembly, Trailing Edge, Burnt/Distorted Vanes.

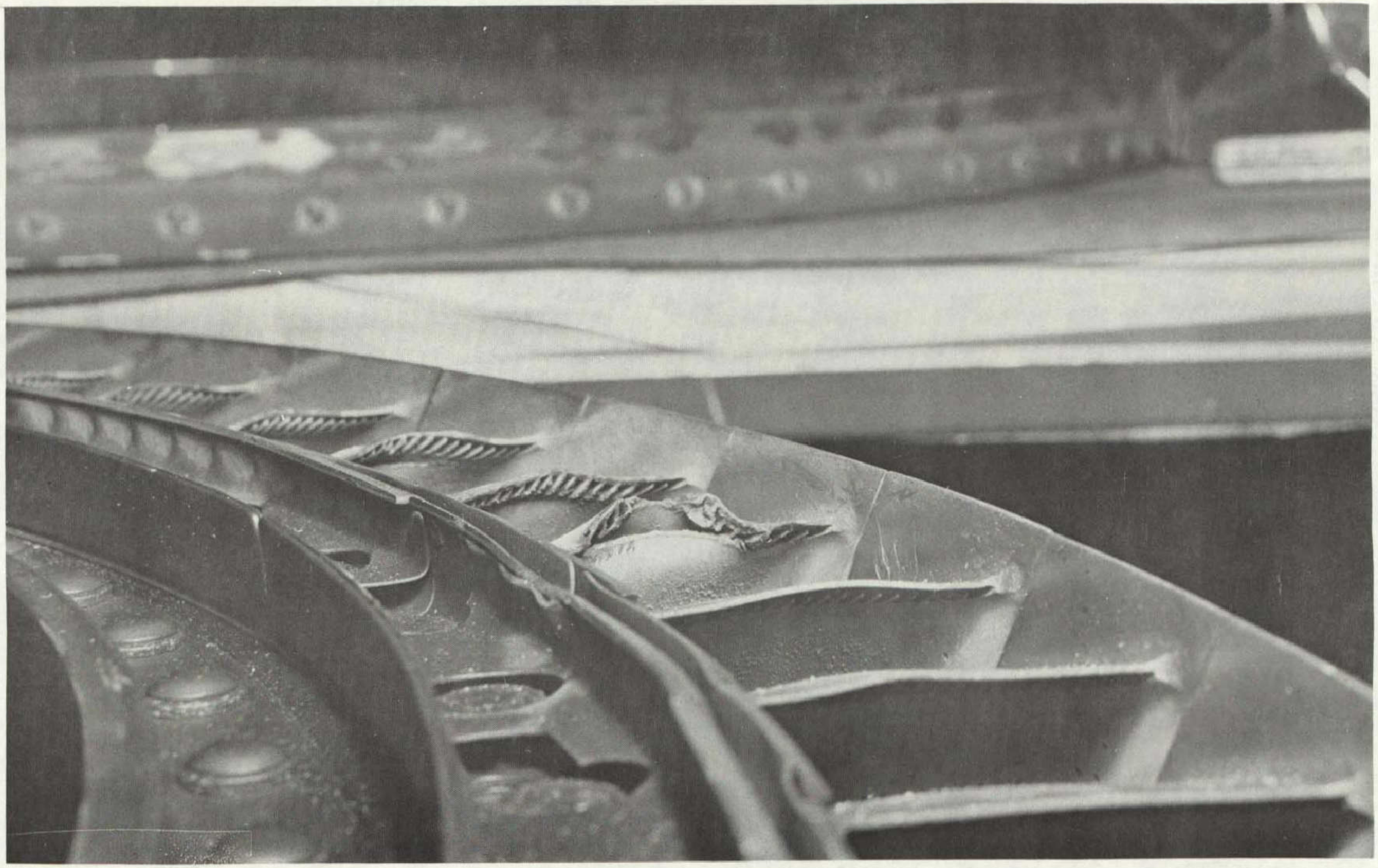

Figure 8-12. Stage 1 HP Turbine Nozzle Assembly Distress, Aft End.

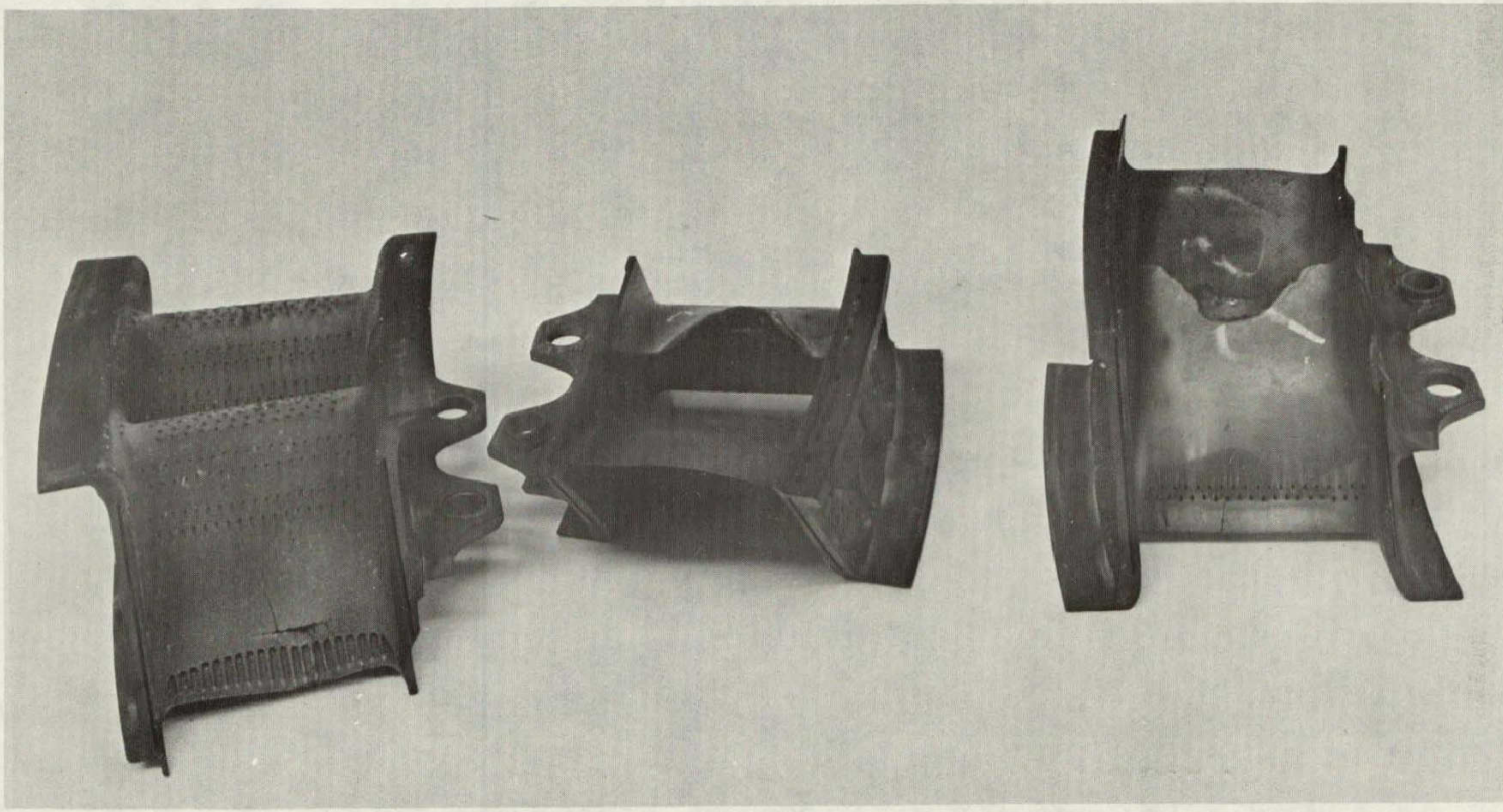

Figure 8-13. Stage 1 HP Turbine Nozzle, Typical Vane Distress.

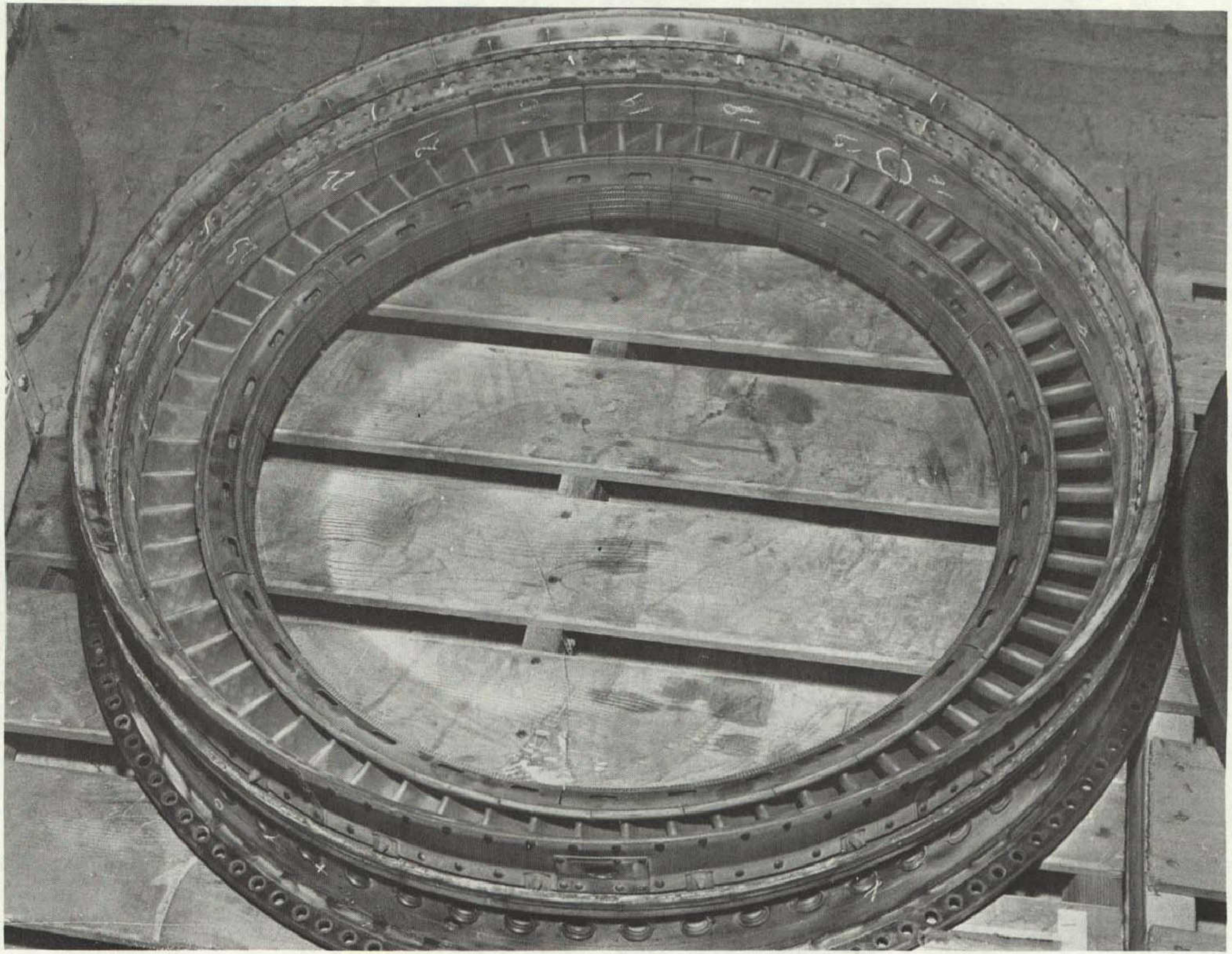

Figure 8-14. HP Turbine Nozzle Assembly, Overall View, Forward End.

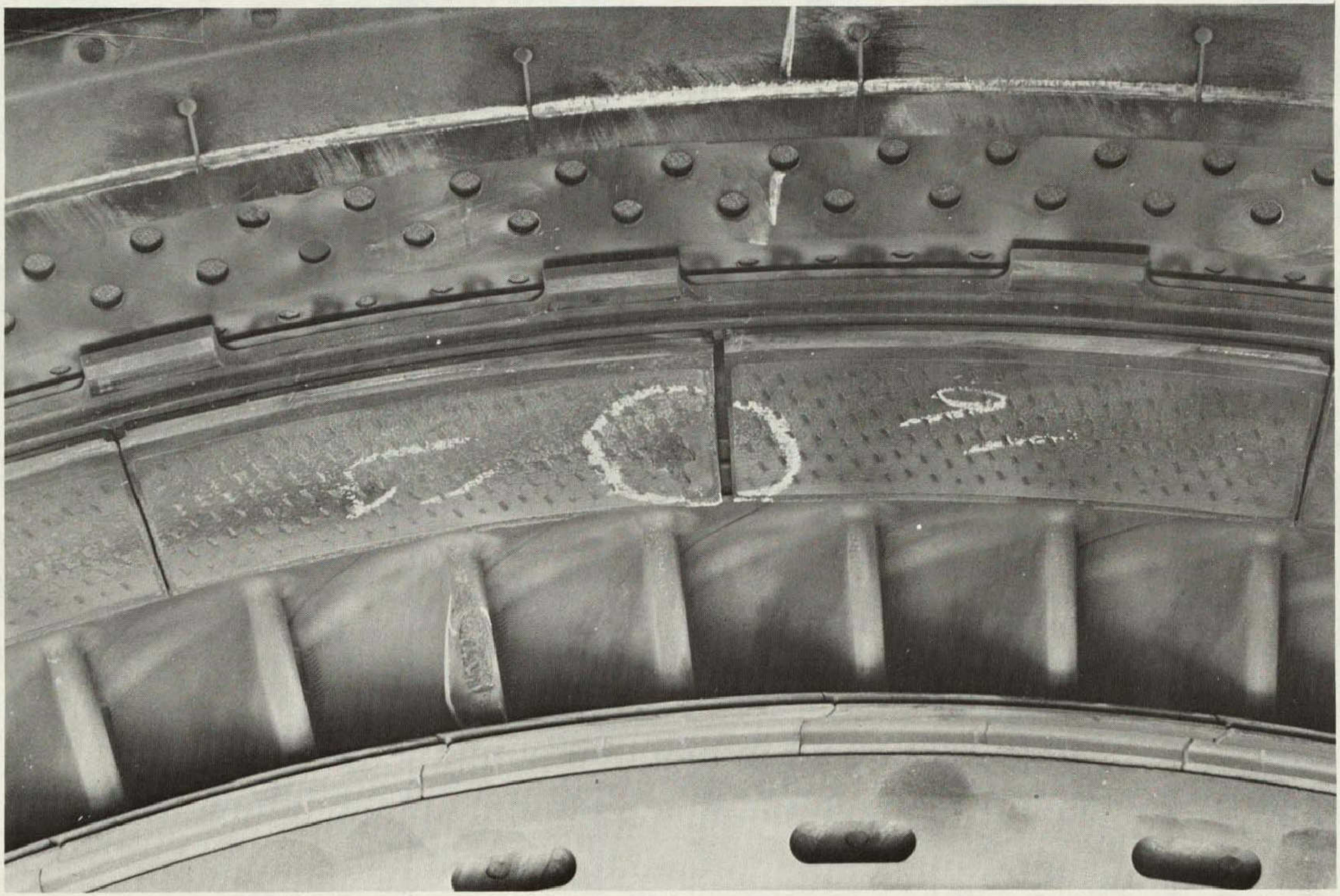

Figure 8-15 . Stage 2 HP Turbine Nozzle, Damage Vane/Stage 1 Shroud.

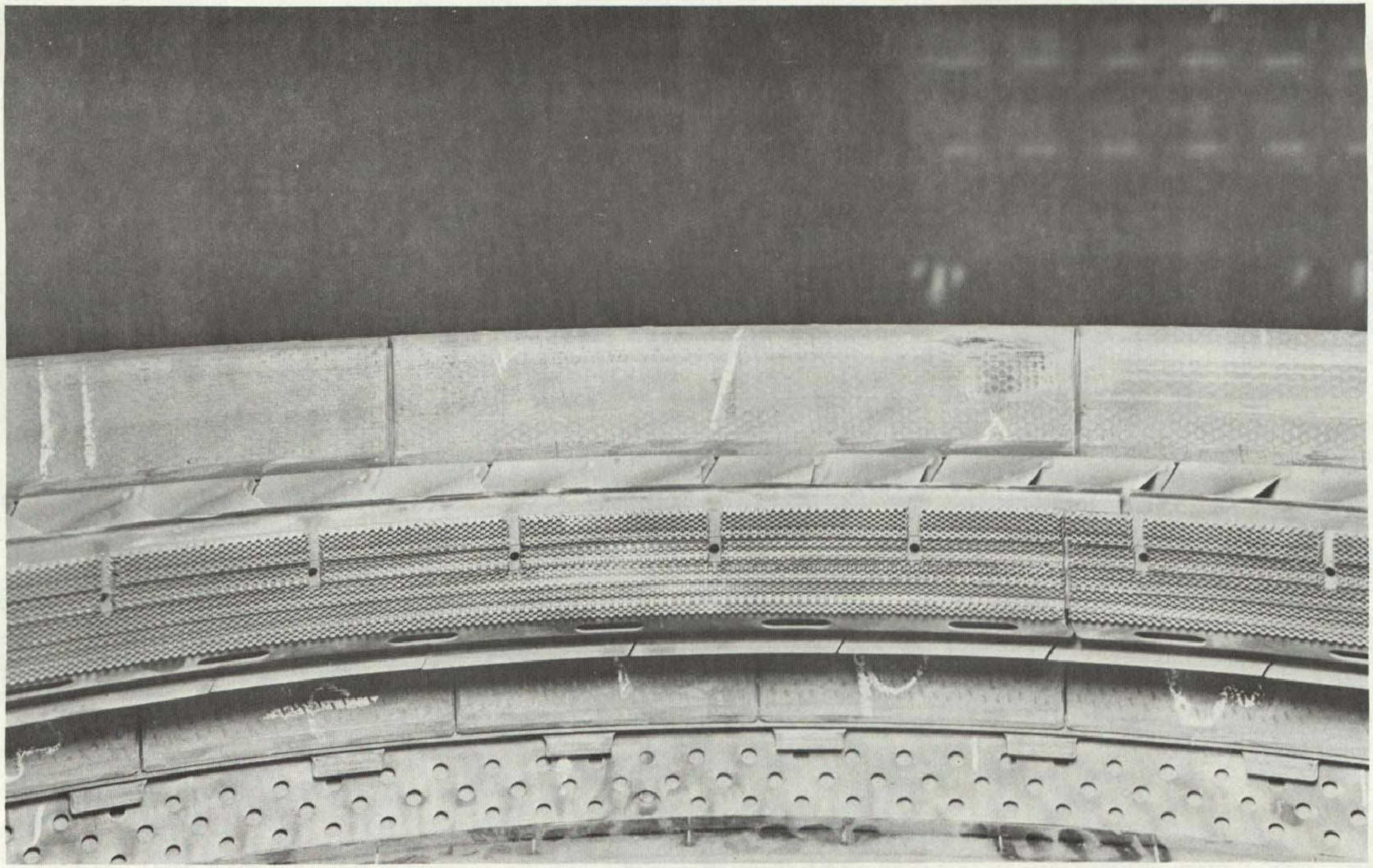

Figure 8-16. Stage 2 HP Turbine Nozzle Stage 2 Shroud Rub.

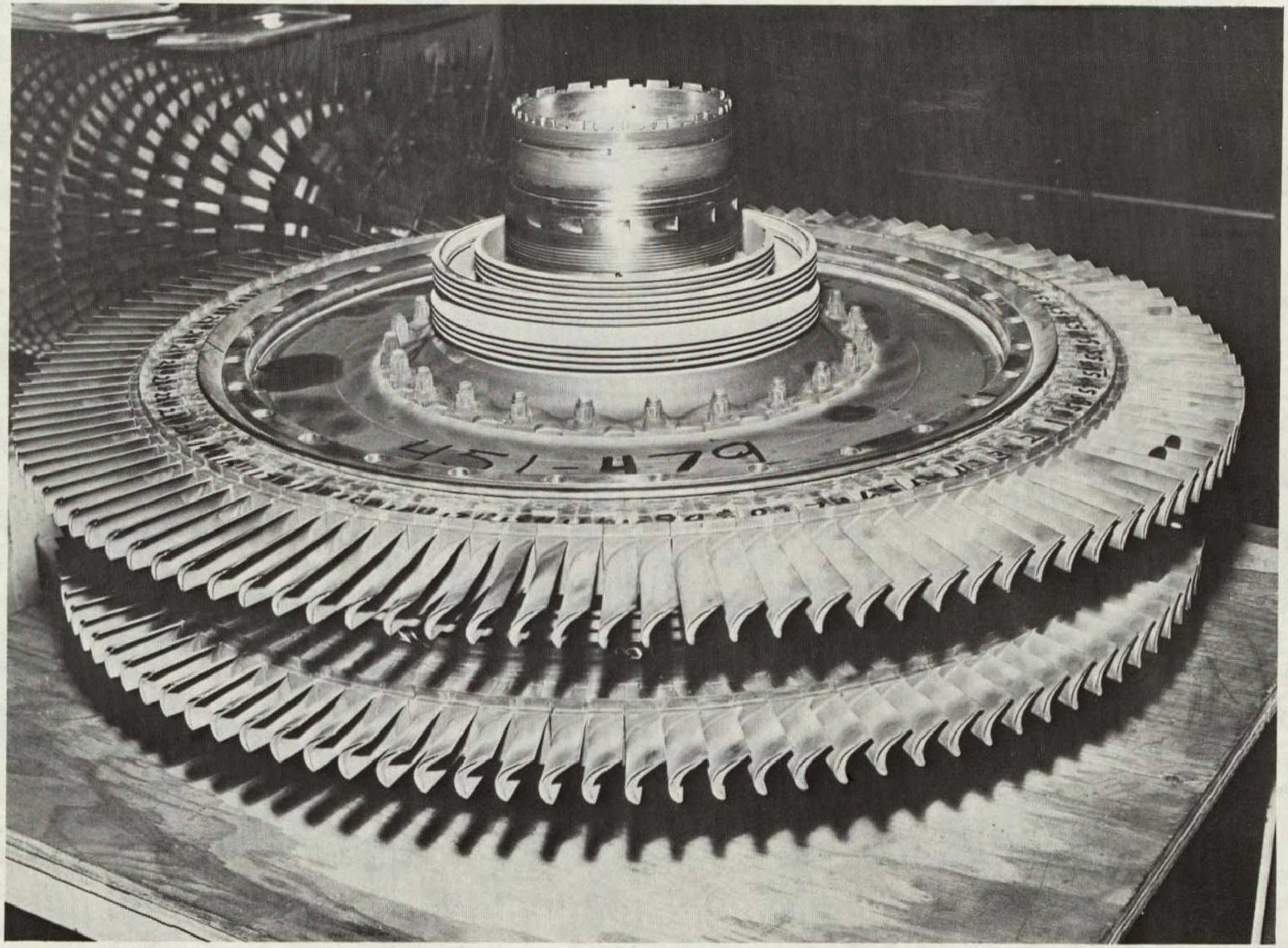

Figure 8-17. HP Turbine Rotor, Overall View of Blades.

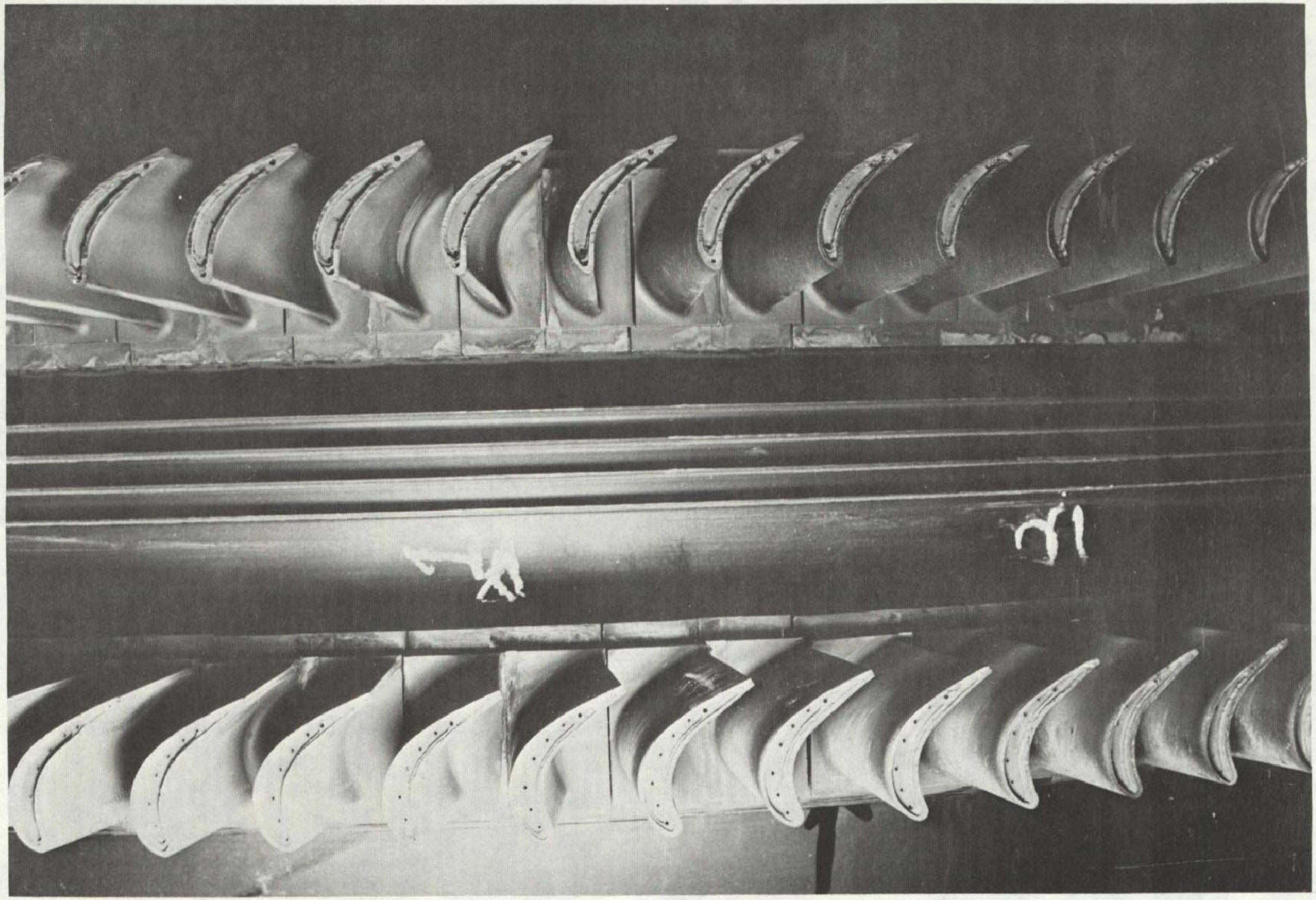

Figure 8-18. HP Turbine Rotor, Blade Tip Rubs.

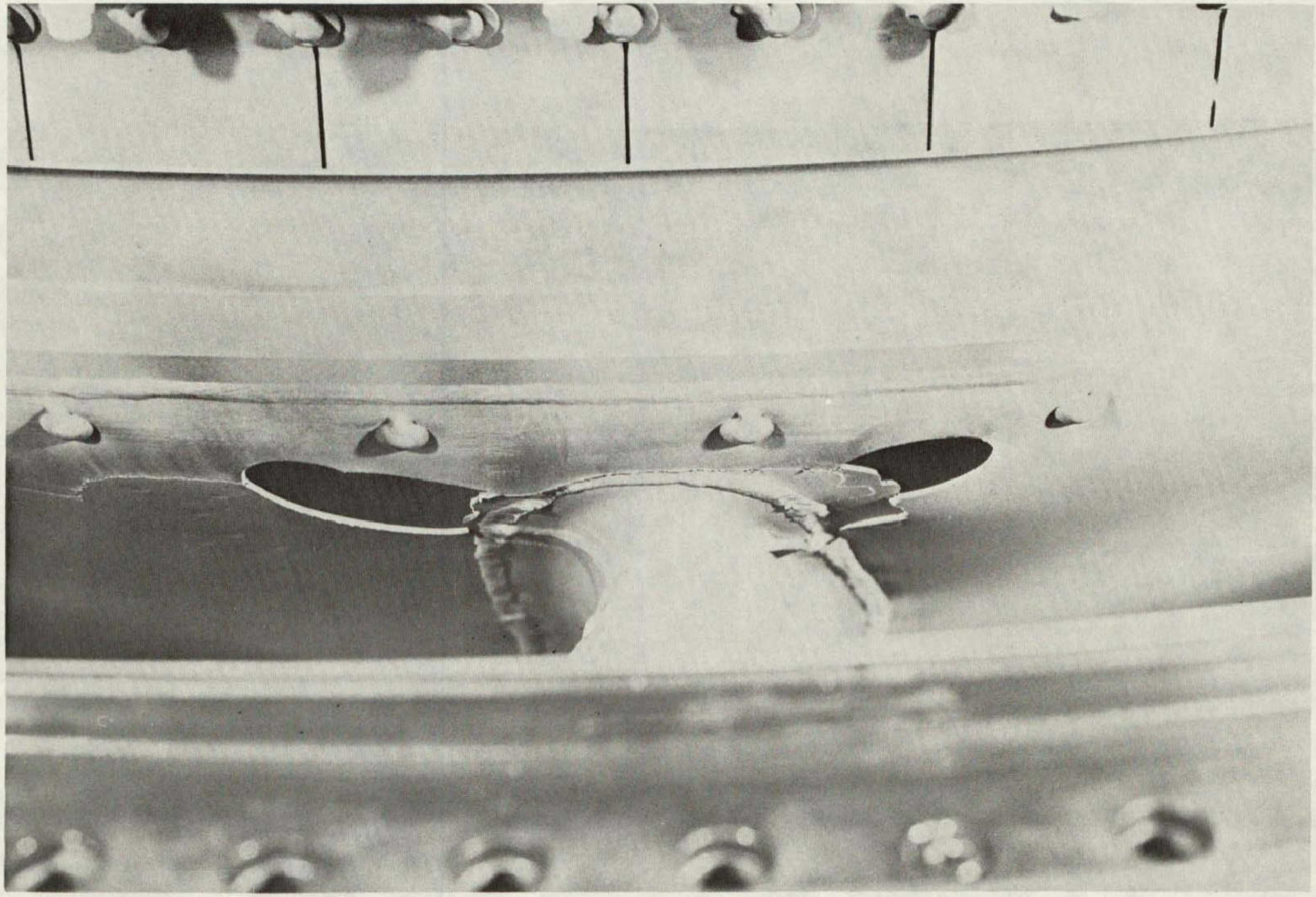

Figure 8-19. Turbine Mid Frame Liner Distress.

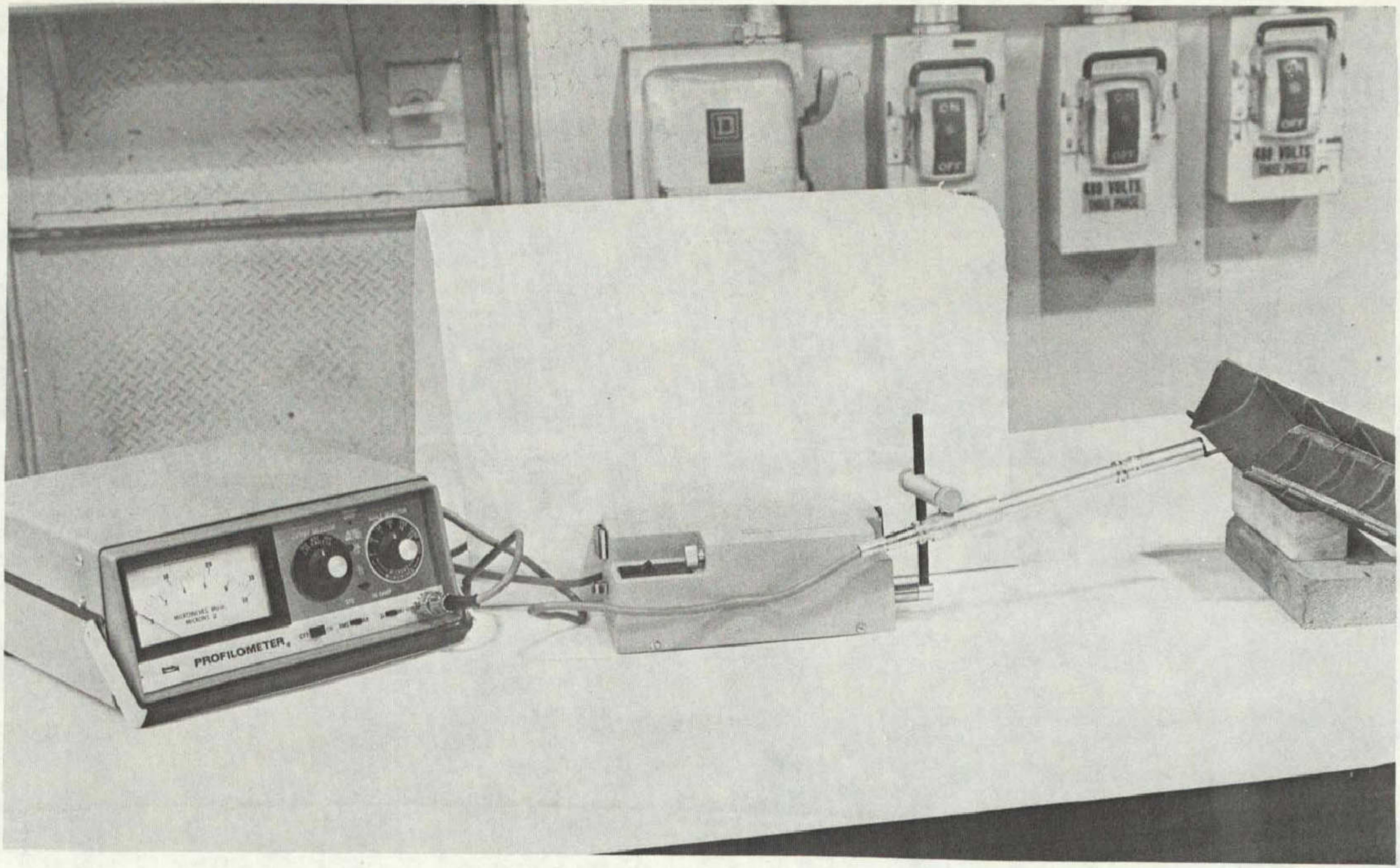

Figure 8-20. Profilometer Setup, LP Turbine Nozzle Segment, Concave Side.

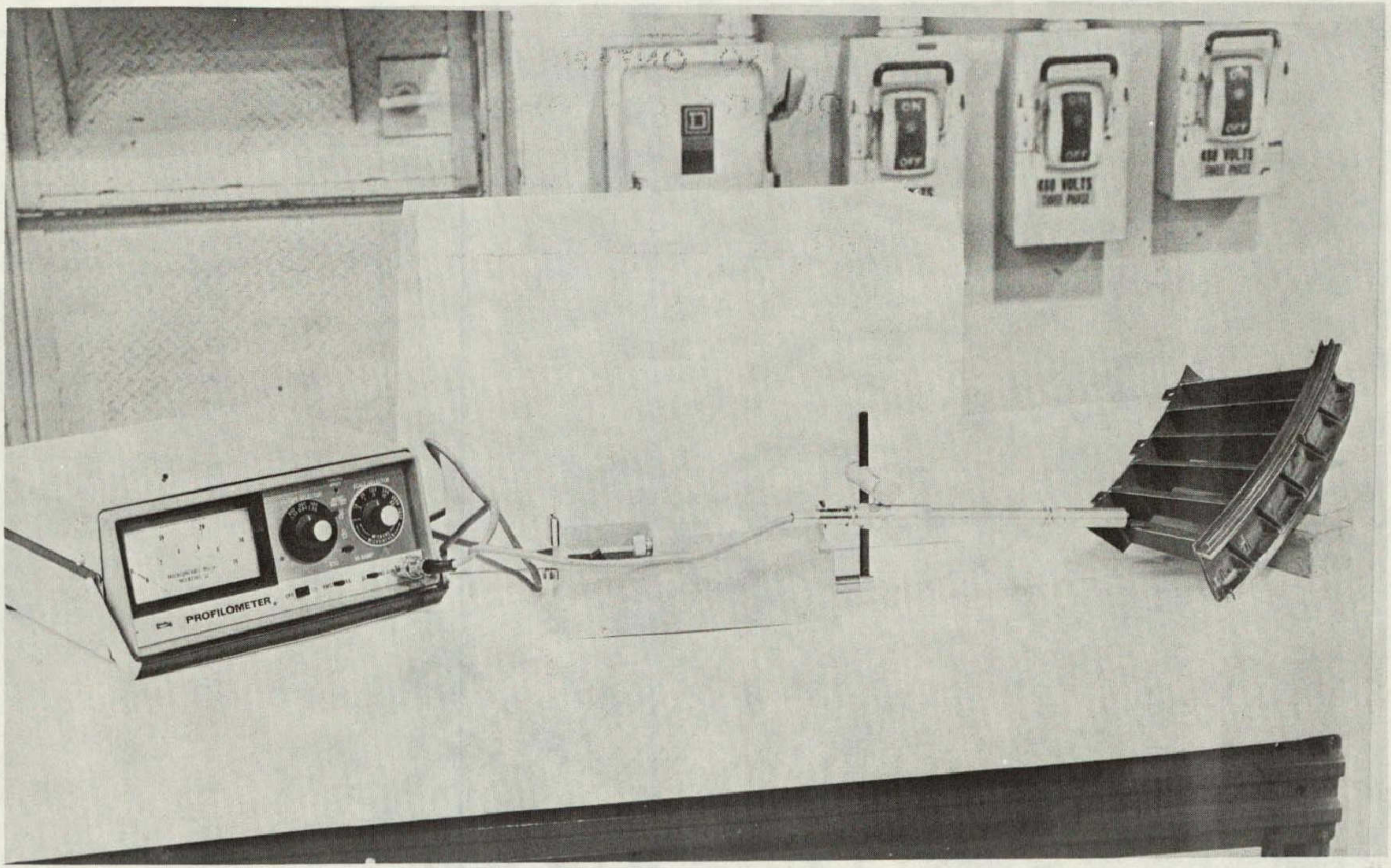

Figure 8-21. Profilometer Setup, LP Turbine Nozzle Segment, Convex Side.

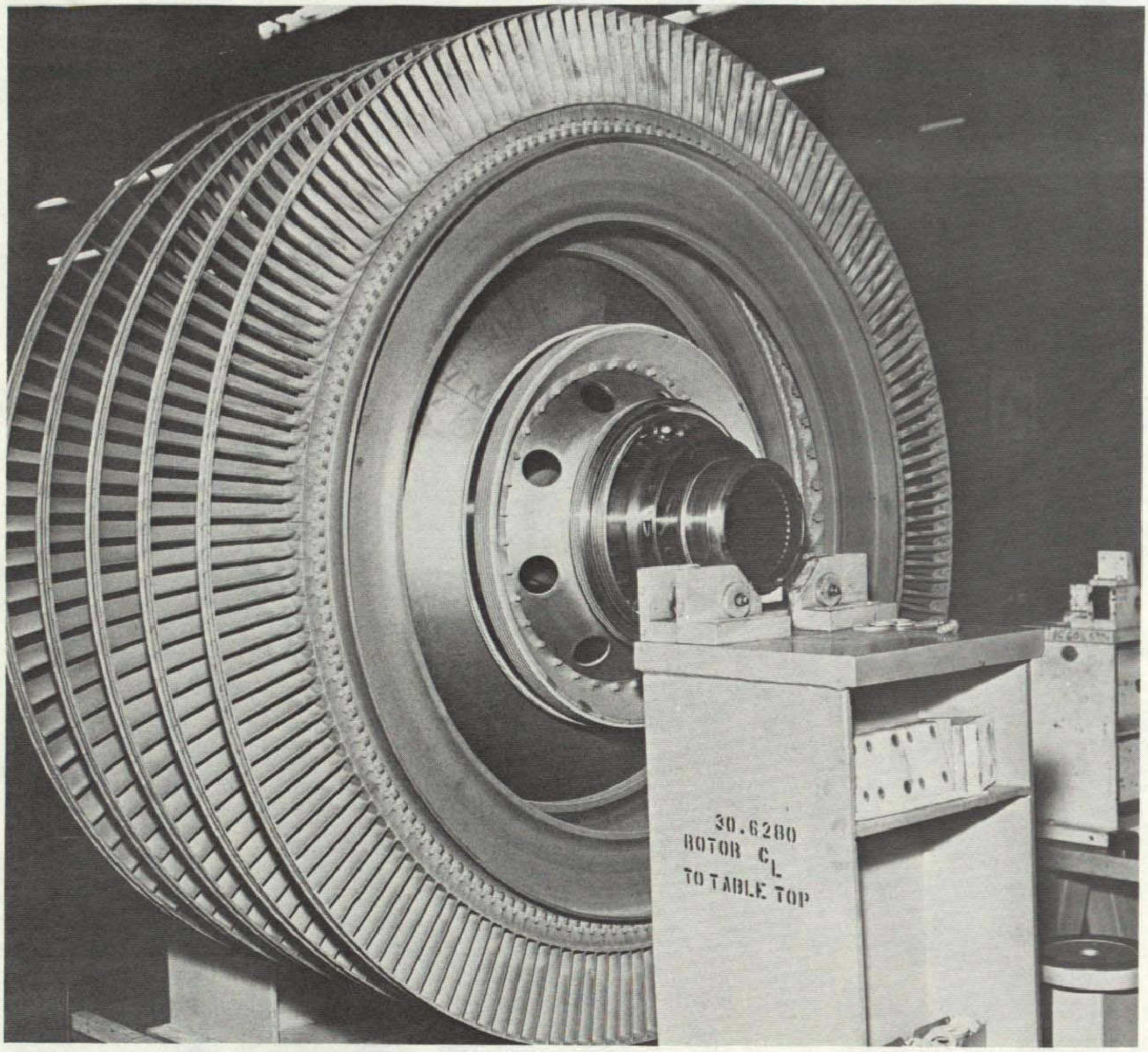

Figure 8-22. LP Turbine Rotor, Overall View.

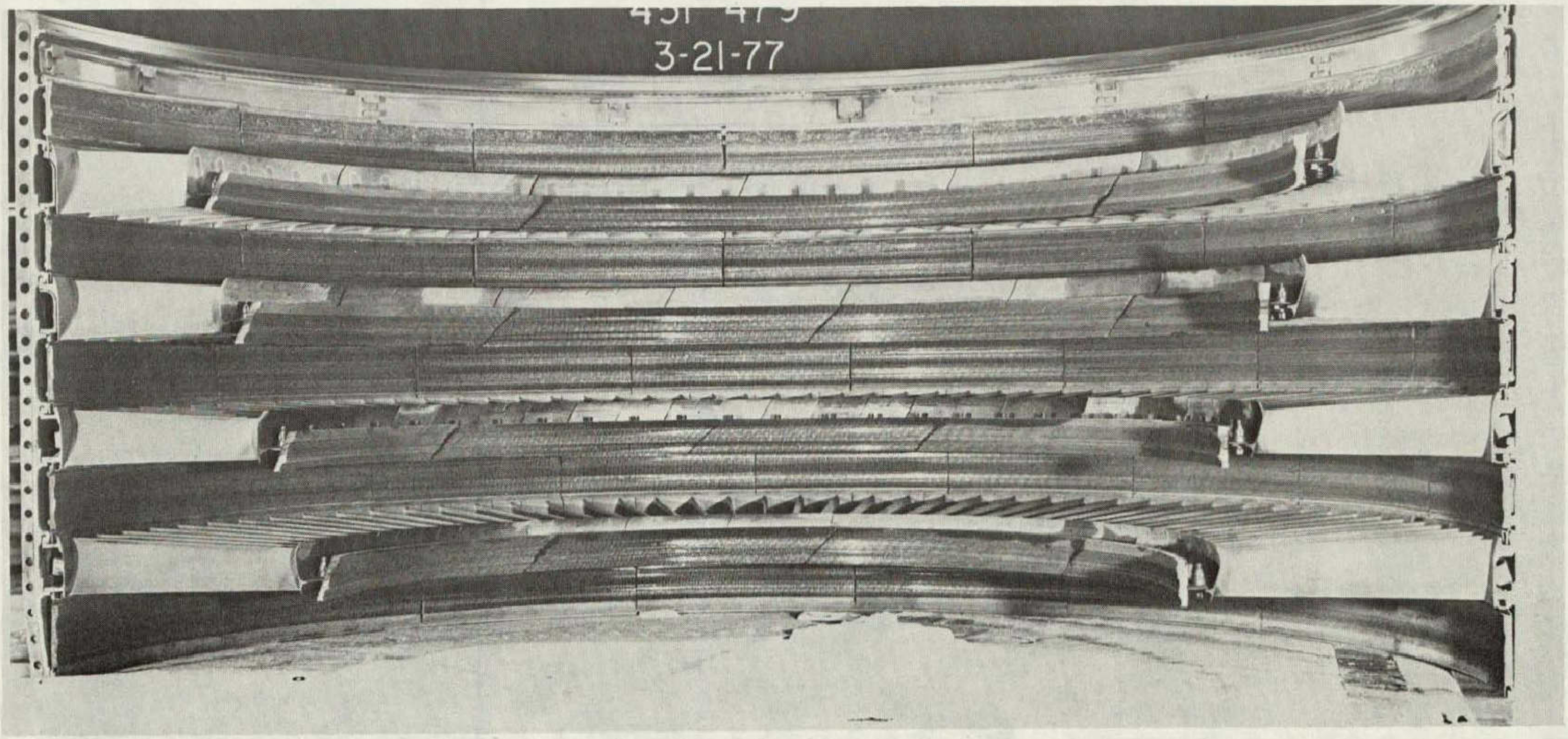

Figure 8-23. LP Turbine Stator Assembly, Overall View, One Casing.

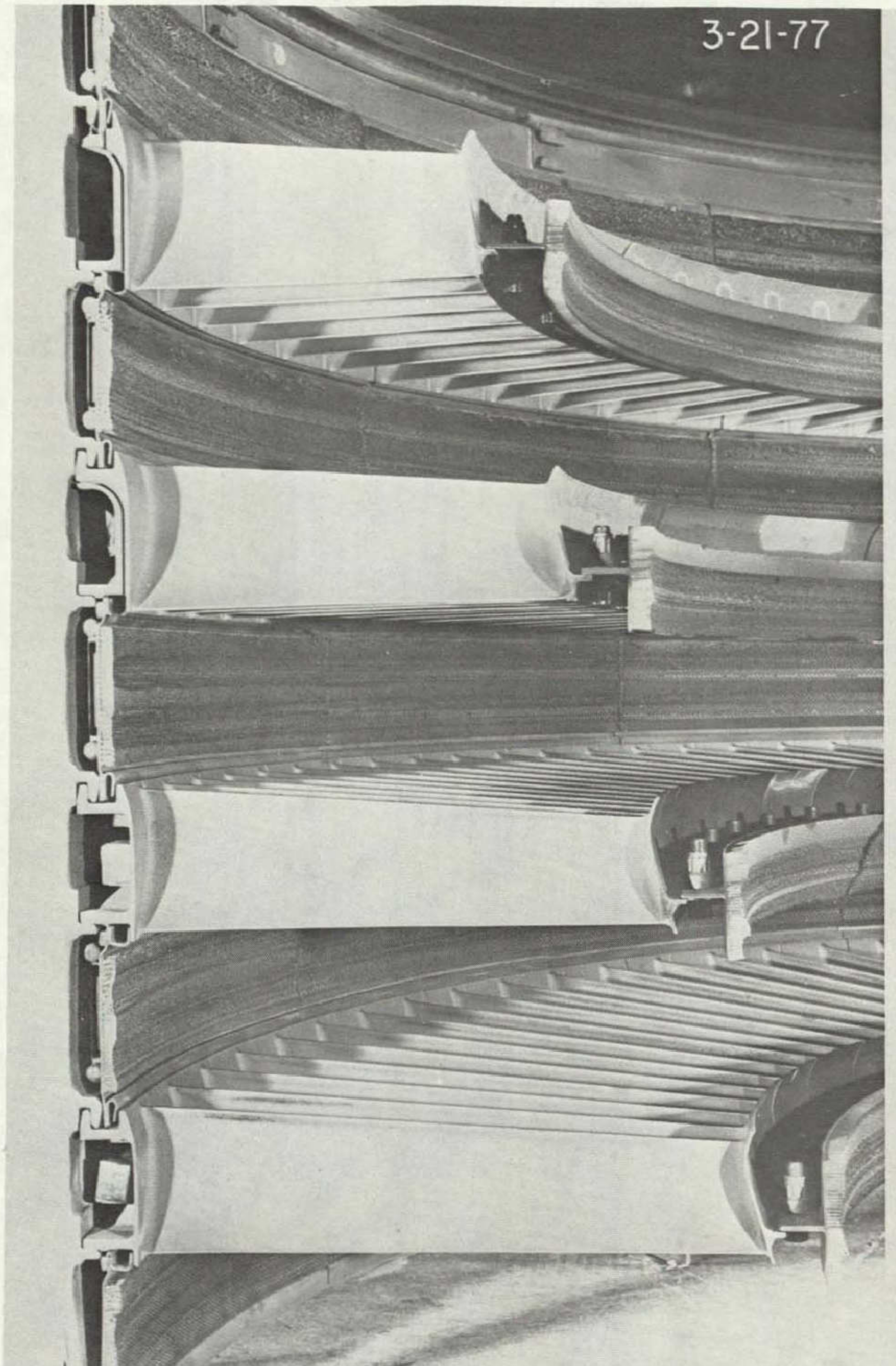

Figure 8-24. LP Turbine Stator Assembly, End View of Shroud and Seal Rubs.

C-2

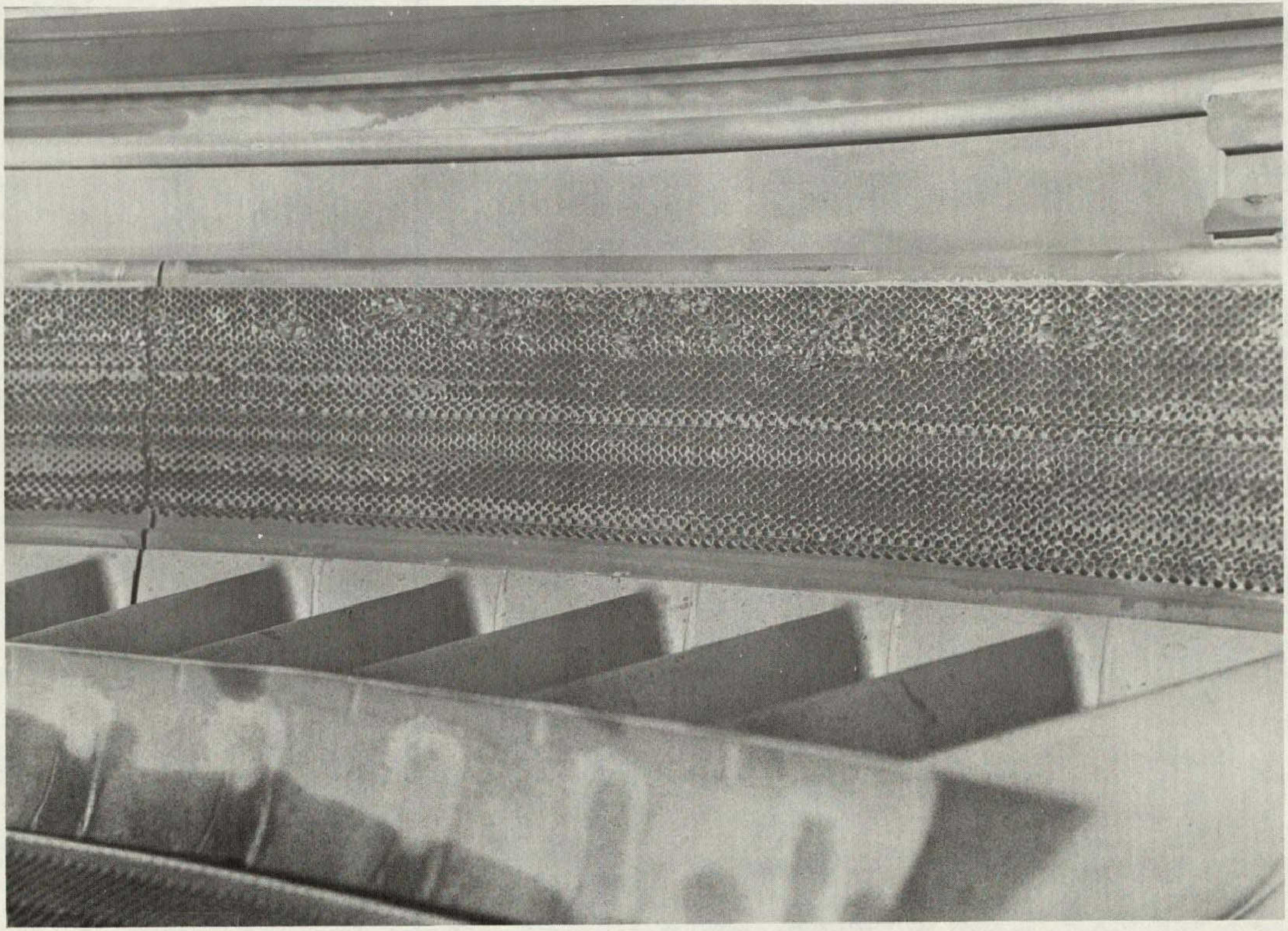

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Figure 8-25. LP Turbine Stator Assembly, Stage 1 Shroud Rub Pattern.

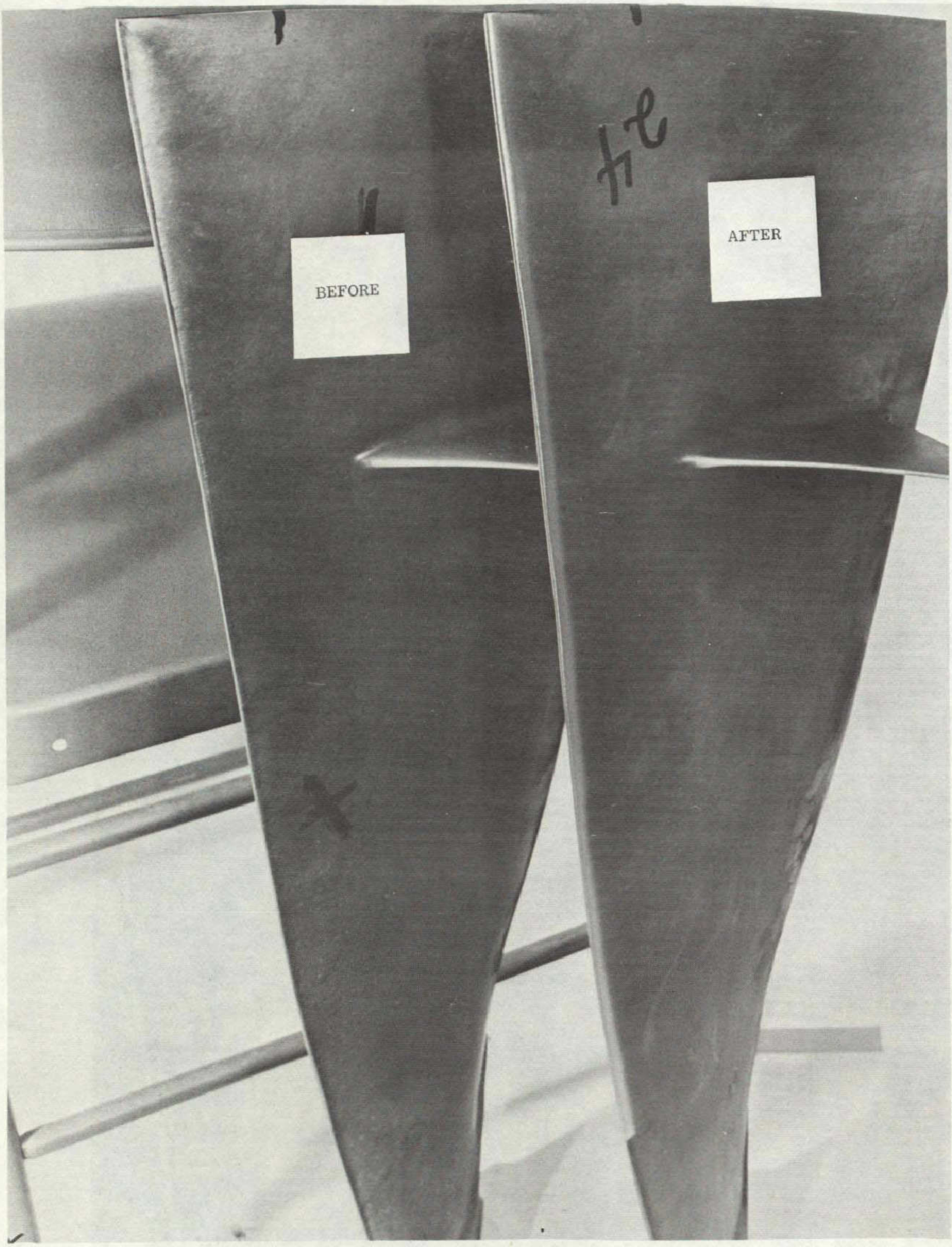

Figure 8-26. Stage 1 Fan Blades Before/After Recontour.

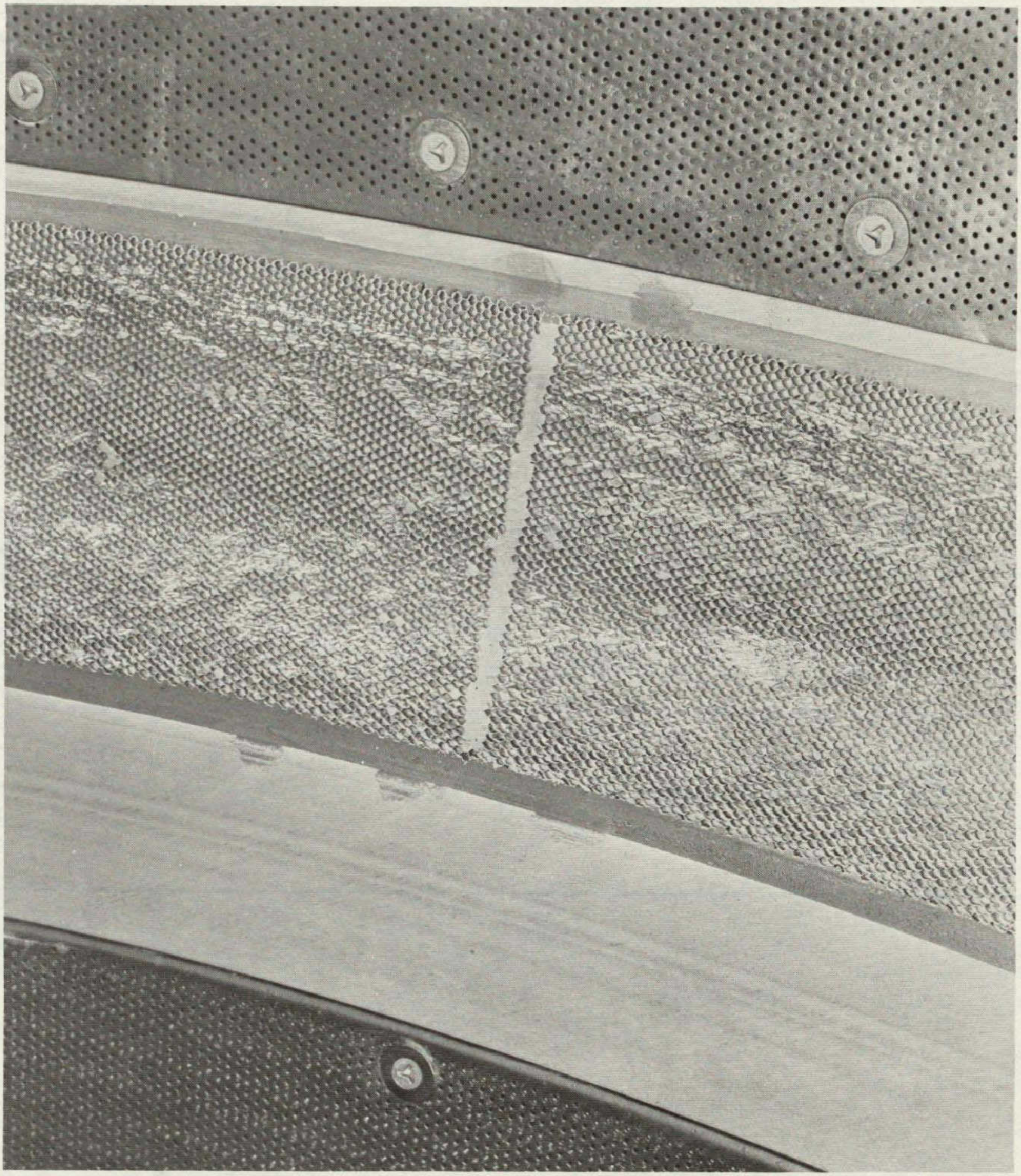

Figure 8-27. Stage 1 Fan Shroud Ice Damage.

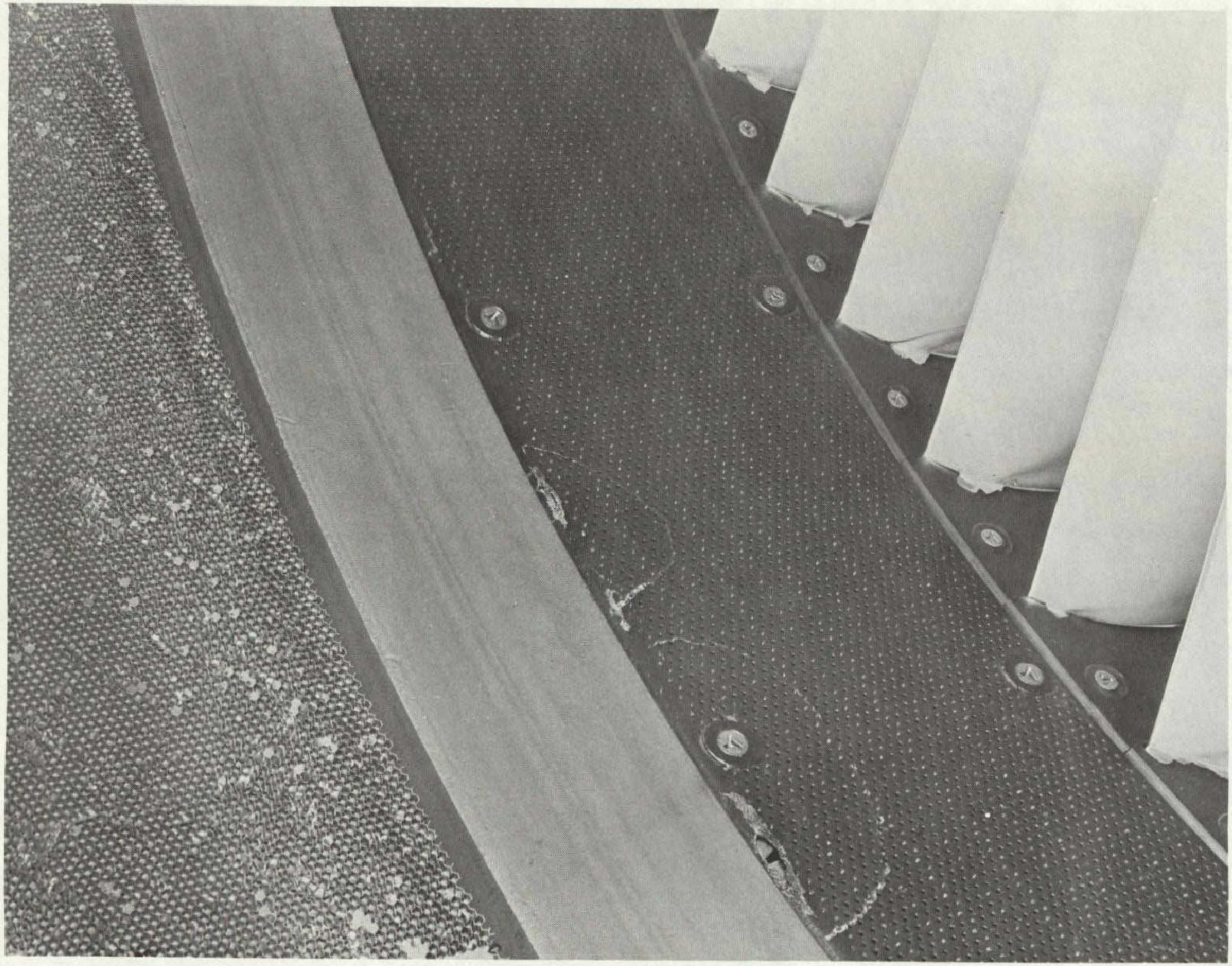

Figure 8-28. Fan Stator Aft Liner Ice Damage.

8.3 APPENDIX C - LOG SHEETS, INBOUND RUN

AIRCRAFT TURBINE TEST LOG SHEET

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

Date 3-22-77
Operator DYE
Inspector NEUBAUER

Gas Turbine Serial No. 451-479
Nature of Test
Sheet 1 of 5 Sheets
RUN NO 1

ATMOSPHERIC CONDITIONS				
TIME	PRESS	TEMP	W	D
13:00	28.955"		59	72
			44 GRS.	
ALT IN FT. 1000				

OIL TYPE 2380	TIME	OIL WT	TIME	OIL WT
START	1900	- 3 qts low @ 155°F		
END	2011	- 3.4 qts low @ 154°F		
CONSUM	.708 PPH			

FUEL TYPE JP-4
LHV:
CONSUM: 4435 gal
SP GR: .784 .7824
TEMP.: 70 74

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

NO OF STARTS 4
LAST READ NG NO 28
TOTAL RUNNING TIME 3 hrs 55 min
OVER CRUISE
AUGMENTED
GENERAL ELECTRIC ACCEPTANCE DATE

Start No	Reading No	Time Hrs	Speed Core N_2 RPM	Speed Fan N_1 RPM	Throttle Angle	Lube Oil Temp Inlet °F	Lube Oil Temp Scav °F	Lube Oil Press Inlet PSIG	Lube Oil Filter ΔP PSID	Fuel Inlet Press PSIG	Fuel Inlet Temp °F	Fuel Flow Main PPH	Fuel Flow Var PPH	T_2 Fan In °F	T_3 CDT °F	T_5 EGT °F	Thrust Lbs.	VBV Volts	Stator Beta Volts	PT_5 LPT Inlet PSIG	Recoup Cav "HG	Sump Vent Press PSIG	CDP PSIG	Ps_2 B H Wall "H_2O	Front Cell Total "H_2O	Front Cell Static H_2O	Rear Cell Static H_2O	Vibration Fan No 1 Brg	Vibration Fan TMF	Vibration Fan TRH	Vibration Core No 1 Brg	Vibration Core TMF	Vibration Core TRH				Fuel Used	Total Run Time
			PRE-START MOTORING:- CORE 1377 RPM; FAN RPM; S.A.P.: 39 PSIG; WF= 680 PPH; T3= 71°																																			
			L.O.P.= 13 PSIG; STOPCOCK: OK- COAST DOWN: CORE= 2-27 ; FAN= 4-55																																			
			OIL TANK LEVEL: - 4 QTS LOW -																																			
2E:30		11:05	0	0	0	69	65	0	0	80	69	0	0	70	76	75	+160	-0-	465	0	0	0	0	0	0	0	0	0	0	0	0	0	0					
1		11:19	MAX START T5= 935 TIME TO IDLE= 31 SEC, T2= 71 FIRED AT CORE 2332 RPM, FAN 191 RPM, WF= 656 PPH,																																			
			#1 IGN:- L.O.P.= 26 PSIG-																																			
	1	11:23	5657	759	-0-	115	139	25.3	5.5	37	66	1050	1040	74	308	780	1630	-0-	4.33	1.5	.01	.1	22.1	-0-	.1	.1	.1	.2	.3	.1	.1	.6	.1					
			GRD IDLE SPEEDS:- OK- OIL PRESS. OK- 57.3 PSID-																																			
		11:27	SHUT DOWN- STOPCOCK- OK- COAST DOWN- CORE= 3-0 FAN= 5-25																																			[illegible]
			OIL TANK LEVEL= -2.2 QTS @ 128°																																			
2E:30		1331	0	0	0	89	77	0	0	70	87	0	0	73	165	160	+130	-0-	464	0	0	0	0	0	0	0	0	0	0	0	0	0	0					[illegible]
2		11:35	MAX START T5= 974°F TIME TO IDLE= 29 SEC; FIRED AT CORE 2371 RPM, FAN 120 RPM, WF= 610 PPH,																																			
			T2= 73, L.O.P= 25 PSIG, S.A.P.: 39 PSIG, # 2 IGN:																																			
GRD IDLE	2	12:38	5680	761	-0-	130	137	24.8	5.5	37	75	1060	1050	73	309	782	1680	-0-	4.34	1.5	.01	.1	33	-0-	.1	.1	.1	1.0	.5	.8	.5	1.2	1.1					
			LEAK CHECK:- OK-																																			
		12:41	SWITCH TO FLT. IDLE																																			
FLT IDLE	3	12:43	7347	1243								1800		74		816	3960	-0-	3.61	5.1			55					.7	.9	1.5	.5	1.8	.7					
		12:45	FLT. IDLE SPEEDS- OK-																																			
		12:45	SWITCH TO GRD IDLE-																																			
		12:49	ACCEL TO 25%-																																			
25%	3	12:52	8126	1960		162	135	39.9				3490		75.4		942	9560		2.45	150			110					.5	1.0	.6	.2	1.1	.3					
		12:56	ACCEL TO 50%-																																			
50%	4	12:59	8753	2651		157	196	76.9				6490		74		1197	17850		1.50	29		1.4	181					.8	1.2	.8	.2	.8	.9					

REMARKS:
Oil press @ T.O. Rdg # 4 = 55.55 PSID, (Speed = 9632 RPM, Temp = 145°F, Jump = 3.25 PSIG, Obs press = 57.8 PSIG)

QC-169-1 FORM CF6 TEST 1
REV 1 76

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AIRCRAFT TURBINE TEST LOG SHEET

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

Date 3-22-77
Operator Dye
Inspector Neubauer

Run No. ______

Gas Turbine Serial No 451-479
Nature of Test ______
Sheet 2 of 5 Sheets

ATMOSPHERIC CONDITIONS				
TIME	PRESS	TEMP	W	D
14:00	28.920		57	75
			-39	GRS
ALT IN FT. 1000				

OIL TYPE 2380	TIME	OIL WT	TIME	OIL WT
START				
END				
CONSUM				

FUEL TYPE JP-4
LHV ______
CONSUM. ______
SP. GR. ______
TEMP ______

MODEL NO CF6-6D
WORK ORDER 181460
CUSTOMER NASA

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

START NO	READING NO	TIME HRS	SPEED CORE N_2 RPM	SPEED FAN N_1 RPM	THROTTLE ANGLE	LUBE OIL TEMP INLET °F	LUBE OIL TEMP SCAV °F	LUBE OIL PRESS. INLET PSIG	LUBE OIL PRESS. FILTER ΔP PSID	FUEL INLET PRESS PSIG	FUEL INLET TEMP °F	FUEL FLOW MAIN PPH	FUEL FLOW VAR PPH	T_2 FAN IN °F	T_3 CDT °F	T_5 EGT °F	THRUST LBS	VBV VOLTS	STATOR BETA VOLTS	PT_5 LPT INLET PSIG	RECOUP CAV "HG	SUMP VENT PRESS PSIG	CDP PSIG	P_{S2} B/M WALL "H2O	FRONT CELL TOTAL "H2O	FRONT CELL STATIC H2O	REAR CELL STATIC H2O	VIBRATION FAN NO 1 BRG	VIBRATION FAN TMF	VIBRATION FAN TRH	VIBRATION CORE NO 1 BRG	VIBRATION CORE TMF	VIBRATION CORE TRH			FUEL USED	TOTAL RUN TIME
		1301	ACCEL TO 75%.																																		
75%	5	13:04	9125	3134		151	205	53.1				10350		74		1442	27700	-0-	.865	113.2	2.56	2.4	258					.6	.9	1.2	.35	.8	1.5				
		13:08	ACCEL TO M.C.									13400																									
M.C.	6	13:11	9647	3442	-0-	149	217	57.1	6.9	22	66	12710	3678	74.6	968	1594	35001	-0-	.53	55.2	3.5	3.2	318	-0-	2.25	2.7	2.7	.7	1.2	1.9	.4	1.1	1.65				
		1319	ACCEL TO T.O. * OIL PRESS. = 55.9 PSID. AT M.C.																																		
T.O.	7	1321	DECEL TO FLT. IDLE SLOWLY.																																		
		1324	SLOW ACCEL TO 3451 N1 UNABLE TO REACH TARGET																																		
		13:26	SLOW DECEL TO FLT. IDLE																																		
		13:30	SWITCH TO GRD. IDLE. * ADJ. CELL THROTTLE																																		
		1336	SLOW ACCEL TO T.O. ALTERNATE NF TACH SPEED WITHIN 2 RPM.																																		
T.O.	7	13:39	9737	3512	-0-	OUT	219	58.3	7.2	20	67	14620	14620	74	988	1634	37130	-0-	.44	58.6	3.9	3.3	332	-0-	2.5	3.0	3.0	.7	.6	1.1	.4	.7	.7				
		1340	SLOW DECEL TO FLT. IDLE																																		
		1346	SWITCH TO GRD. IDLE. * CHANGED OIL DISCH. TEMP. PROBE. SUBSTANTIAL OIL LOSS. OIL CONSUMPTION CHECK NOT VALID.																																		
		14:08	SHUT DOWN. COAST DOWN ENG. = 3-05 DYNO. 5-05																																		
			OIL TANK LEVEL = -2.5 QTS @ 163° = +3.6 QTS CORR.																																		7/41
	ZERO	1438	0	0	-0-	158	135	0	0	0	84	0	0	76	189	349	±410	-0-	4.66	0	0	0	0	0	0	0	0	0	0	0	0	0	0			1354	7/41
	ZERO	1710	0	0	—	73	69	0.4	0	0	78	0	0	70	152	119	±460	—	4.66	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
3		1714	Max start T5 = 952 °F fired @ 2561 RPM Sump = 38 Psig. T2 = 69 °F																																		
			Wf = 610 PPH Lod = 29 PSIG Time to idle = 29 sec #1 ign.																																		
	8	1717	564	759	—	148	154	22.4	9	39	79	1030	1030	68	299	774	±80	—	4.33	1.6	0	.05	23	/				3	.6	.1	.1	.6	.1				

REMARKS

QC-189-1 FORM CF6 TEST 2
REV 8.75

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AIRCRAFT TURBINE TEST LOG SHEET

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

Date 3-22-77
Operator DYE — LOCKIE
Inspector NEWBAUER—CIMORELLI

Gas Turbine Serial No 451-479
Nature of Test ____
RUN NO ____
Sheet 3 of 5 Sheets

ATMOSPHERIC CONDITIONS				
TIME	PRESS	TEMP	H	D
1728	29.91	Abs	56 / 48%	67
ALT IN FT	1000			

OIL TYPE 2380	TIME	OIL WT.	TIME	OIL WT
START				
END				
CONSUM				

FUEL TYPE JP-4
LHV ____
CONSUM ____
SP. GR. .783 .7810
TEMP. 68° 74°

MODEL NO CF6-6D
WORK ORDER 181460
CUSTOMER ____

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

START NO.	READING NO	TIME HRS	SPEED CORE N_2 RPM	SPEED FAN N_1 RPM	THROTTLE ANGLE	LUBE OIL TEMP. INLET °F	LUBE OIL TEMP. SCAV °F	LUBE OIL PRESS INLET PSIG	LUBE OIL PRESS FILTER ΔP PSID	FUEL INLET PRESS PSIG	FUEL INLET TEMP °F	FUEL FLOW MAIN PPH	FUEL FLOW VAR PPH	T_2 FAN IN F	T_3 CDT °F	T_5 EGT °F	THRUST LBS	VBV VOLTS	STATOR BETA VOLTS	PT_5 LPT INLET PSIG	RECOUP CAV "HG	SUMP VENT PRESS PSIG	CDP PSIG	P_{S2} B/M WALL "H_2O	FRONT CELL TOTAL "H_2O	FRONT CELL STATIC H20	REAR CELL STATIC H20	VIBRATION FAN NO 1 BRG	VIBRATION FAN TMF	VIBRATION FAN TRM	VIBRATION CORE NO. 1 BRG	VIBRATION CORE TMF	VIBRATION CORE TRM			FUEL USED	TOTAL RUN TIME
		1720				Slow accel to MC for soak period																															
		1727				accel to T.O. for performance																															
T.O.	9	1732	9632	3469	—	145	217	57.8	9	22	67	14170	14170	65	959	1598	36510	—	.46	58.0	3.8	3.25	326	—	2.4	3.0	2.85	.6	1.0	2.1	.4	1.0	1.6				
T.O.	10	1736	9634	3468	—	146	217	57.8	9	22	66	14170	14160	65	958	1596	36530	—	.46	57.8	3.75	3.25	327	—	2.35	2.95	2.85	.6	1.3	1.6	.4	1.0	1.7				
		1739				Decel to MC																															
MC	11	1743	9559	3413	—	146	216	56.9	9	24	66	13510	13509	64	942	1566	35120	—	.51	55.5	3.5	3.15	316	—	2.3	2.9	2.8	.6	1.2	1.6	.4	1.0	1.9				
MC	12	1746	9558	3415	—	146	217	56.0	9	24	66	13570	13510	63	941	1565	35140	—	.51	55.7	3.6	3.15	317	—	2.4	2.9	2.8	.6	1.2	1.8	.4	1.1	1.85				
		1748				Decel to MCR																															
MCR	13	1752	9420	3312	—	148	214	55.4	9	27	66	12310	12310	63	912	1510	32520	—	.63	51.5	3.1	2.95	296	—	2.2	2.6	2.55	.5	1.1	1.6	.4	1.2	1.6				
MCR	14	1755	9417	3309	—	147	213	55.4	9	27	66	12340	12340	63	912	1509	32570	—	.63	51.6	3.2	2.9	297	—	2.15	2.65	2.55	.5	1.1	1.5	.4	1.2	1.6				
		1758				Decel to 75%																															
75%	15	1802	9157	3106	—	150	208	52.9	9	30	66	10170	10170	62	856	1399	27580	—	.92	43.8	2.45	2.5	260	—	1.85	2.2	2.25	.8	.8	1.1	.3	1.35	1.1				
75%	16	1805	9155	3107	—	149	208	53.0	9	30	66	10220	10210	62	856	1400	27580	—	.93	43.7	2.5	2.45	259	—	1.85	2.2	2.2	.6	.7	1.2	.3	1.3	1.15				
		1807				Slow decel to flt. idle																															
		1811				at switch to grd. idle																															
	17	1813	5593	758	—	185	198	20.7	7	40	66	4170	4160	61	292	739	1640	—	4.30	2.0	.05	.05	23	—	.11	.13	.14	.2	.3	.1	.1	.1	.2				
						Leak check																															
		1817				Shut down, dump ok, coast down, Core = 3 min 15 sec Fan = 5 min 12 sec																															7/44
	2220	1823	0	0	—	163	147	0.0	0	0	63	0	0	62	180	318	410	—	4.65	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
						oil level @ 3.0 @ 155°F																															

REMARKS:

QC-169-1 FORM CF6 TEST 1
REV 5.75

AIRCRAFT TURBINE TEST LOG SHEET

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

Operator: Lockie   Date: 3-22-77
Inspector: Cimorelli

Gas Turbine Serial No. 451-479
Nature of Test ______
RUN NO ______
Sheet 4 of 5 Sheets

ATMOSPHERIC CONDITIONS				
TIME	PRESS	TEMP	W	D
1914	28.945	Abs	54	59
			54 grains	
ALT. IN FT 1000				

OIL TYPE: START / END / CONSUM — TIME / OIL WT. / TIME / OIL WT.

FUEL TYPE
LHV
CONSUM
SP. GR. .784 .7808
TEMP 66 74°

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

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

START NO	READING NO	TIME HRS	SPEED CORE N_2 RPM	SPEED FAN N_1 RPM	THROTTLE ANGLE	LUBE OIL TEMP. INLET °F	LUBE OIL TEMP. SCAV °F	LUBE OIL PRESS INLET PSIG	LUBE OIL PRESS FILTER ΔP PSID	FUEL INLET PRESS PSIG	FUEL INLET TEMP °F	FUEL FLOW MAIN PPH	FUEL FLOW VAR PPH	T_2 FAN IN °F	T_3 CDT °F	T_5 EGT °F	THRUST LBS.	VBV VOLTS	STATOR BETA VOLTS	PT_5 LPT INLET PSIG	RECOUP CAV "HG	SUMP VENT PRESS PSIG	CDP PSIG	P_{S2} D M WALL "H_2O	FRONT CELL TOTAL "H_2O	FRONT CELL STATIC H_2O	REAR CELL STATIC H_2O	VIBRATION FAN NO. 1 BRG	VIBRATION FAN TMF	VIBRATION FAN TRH	VIBRATION CORE NO. 1 BRG.	VIBRATION CORE TMF	VIBRATION CORE TRH	FUEL USED	TOTAL RUN TIME
	ZERO	1858	C	0	—	108	79	1.0	0	0	61	0	0	62	188	228	±420	—	4.65	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
4		1900				Max start T5 = 954 °F lited @ 2341 RPM SAP = 31 PSIG T2 = 62 °F																													
						Wf = 600 PPH Pod = 24 PSIG Time to idle = 29 SEC # 2 ign.																													
	18	1903	5590	755	—	161	170	22.1	7	39	63	1000	1000	59	286	749	1670	—	4.32	1.6	.05	.05	23	—	.11	.12	.13	.4	.4	.3	.2	.5	.2		
						Leak check —																													
		1905				slow accel to MC for soak period —																													
		1914				accel to T.O. for performance																													
T.O.	19	1918	9555	3441	—	143	212	57.9	9	23	66	14070	14080	57	939	1578	36485	—	.46	57.8	3.8	3.25	326	—	2.3	2.9	2.8	.6	1.1	2.1	.4	1.2	1.7		
T.O.	20	1920	9553	3446	—	144	214	57.9	9	22	66	14050	14060	57	939	1577	36490	—	.46	57.8	3.8	3.25	327	—	2.3	2.85	2.75	.6	1.1	1.8	.4	1.2	1.8		
		1923				decel to MC																													
MC	21	1927	9474	3391	—	144	213	56.9	9	24	66	13320	13310	57	922	1543	34780	—	.52	55.3	3.55	3.1	316	—	2.2	2.8	2.7	.6	1.2	1.6	.4	1.1	1.9		
MC	22	1930	9471	3386	—	144	212	56.9	9	24	66	13310	13320	57	923	1444	34910	—	.52	55.4	3.55	3.15	315	—	2.2	2.75	2.7	.6	1.1	1.7	.4	1.2	1.85		
		1932				Decel to MCR																													
MCR	23	1936	9347	3291	—	145	209	55.9	9	26	66	12200	12200	57	895	1491	32470	—	.64	51.5	3.2	2.9	296	—	2.1	2.6	2.55	.5	1.2	1.3	.4	1.1	1.7		
MCR	24	1938	9347	3293	—	145	208	56.0	9	26	66	12210	12240	57	896	1492	32550	—	.64	51.5	3.2	2.9	295	—	2.15	2.65	2.5	.5	1.1	1.4	.4	1.0	1.6		
		1941				Decel to 75%																													
75%	25	1945	9105	3094	—	147	205	53.1	9	30	66	10150	10130	57	843	1385	27610	—	.92	43.9	2.45	2.5	260	—	1.85	2.25	2.2	.6	.8	1.0	.3	1.3	1.1		
75%	26	1948	9105	3097	—	147	204	53.1	9	30	66	10160	10160	57	843	1386	27630	—	.92	43.9	2.5	2.45	259	—	1.8	2.25	2.2	.6	.7	1.1	.3	1.45	1.1		
		1951				Decel to flt. idle																													
	27	1953	7224	1264										57		759		—										.4	.8	.85	.2	1.35	.6		
		1955				Decel to gnd idle																													
	28	1958	5554	751	—	181	192	21.0	7	40	65	970	960	57	285	730	1630	—	4.30	2.0	.05	.05	23	—	.1	.11	.13	.2	.4	.2	.1	.3	.1		

REMARKS

QC-168-1 FORM CF6 TEST 1
REV 5 75

ORIGINAL PAGE IS OF POOR QUALITY

AIRCRAFT TURBINE TEST LOG SHEET

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

Date 3-22-77
Operator Leckie
Inspector Cimorelli

RUN NO

Gas Turbine Serial No 451-479
Nature of Test
Sheet 5 of 5 Sheets

ATMOSPHERIC CONDITIONS — TIME, PRESS, TEMP, W, D
ALT IN FT. 1000

OIL TYPE — START, END, CONSUM; TIME, OIL WT., TIME, OIL WT

FUEL TYPE — LHV, CONSUM, SP GR, TEMP.

MODEL NO. CF6-6D
WORK ORDER 181460
CUSTOMER

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

START NO	READING NO	TIME HRS	SPEED CORE N_2 RPM	SPEED FAN N_1 RPM	THROTTLE ANGLE	LUBE OIL TEMP INLET °F	LUBE OIL TEMP SCAV °F	LUBE OIL PRESS INLET PSIG	LUBE OIL PRESS FILTER ΔP PSID	FUEL INLET PRESS PSIG	FUEL INLET TEMP. °F	FUEL FLOW MAIN PPH	FUEL FLOW VAR PPH	T_2 FAN IN °F	T_3 CDT °F	T_5 EGT °F	THRUST LBS	VBV VOLTS	STATOR BETA VOLTS	PT_5 LPT INLET PSIG	RECOUP CAV "HG	SUMP VENT PRESS PSIG	CDP PSIG	P_{S2} R M WALL "H2O	FRONT CELL TOTAL "H2O	FRONT CELL STATIC H20	REAR CELL STATIC H20	VIBRATION FAN NO 1 BRG	VIBRATION FAN TMF	VIBRATION FAN TRH	VIBRATION CORE NO 1 BRG	VIBRATION CORE TMF	VIBRATION CORE TRH			FUEL USED	TOTAL RUN TIME
		2000				accel to T.O (2 min accel)																															
		2002				decel to flt. idle																															
		2006				Switch to gnd. idle																															
		~~2008~~				~~[illegible]~~ leak check																															
		2011				Shut down, dump ok, coast down core = 3 min 14 sec fan = 5 min 11 sec																															3/55
	ZERO		0	0	—	159	143	14	0	0	41	6	0	57	175	324	400	—	4.64	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
						oil @ -3.4 qt low @ 154°																															
																												fuel used 4435 gal.									
						All filters, finger screens & mag plug checked - ok -																															
						Under - cowl leakage check - ok -																															

REMARKS

QC-169-1 FORM CF6 TEST 1
REV 3 76

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8.4 APPENDIX D - LOG SHEETS, TESTS 2 AND 3

AIRCRAFT TURBINE TEST LOG SHEET

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

Date 7-19-77
Operator DW
Inspector NEWTRAVER

Run No 2

Gas Turbine Serial No. 451-479
Nature of Test 90-75
Sheet 1 of 10 Sheets

ATM SPH COND.				
TIME	PRESS	TEMP	W	D
14:25	28.920		55	81
		22 CPS-		
ALT IN FT 1000				

OIL TYPE 2380	TIME	OIL WT	TIME	OIL WT
START	13:50	-3595 @ 135°	= -3.55	
END	14:41	-3395 @ 175°	= -3.45	
CONSUM		NONE -		

FUEL TYPE JP-4		
LHV		
CONSUM	9668	
SP GR	.780	.7804
TEMP	75°	74°

MODEL NO CF6-6D
WORK ORDER 181460
CUSTOMER NASA

NO OF STARTS 8
LAST READING NO. 57
TOTAL RUNNING TIME 6 HRS 37 min
OVER CRUISE
AUGMENTED
GENERAL ELECTRIC ACCEPTANCE DATE

START NO.	READING NO.	TIME HRS	SPEED CORE N_2 RPM	SPEED FAN N_1 RPM	THROTTLE ANGLE	LUBE OIL TEMP INLET °F	LUBE OIL TEMP SCAV °F	LUBE OIL PRESS. INLET PSIG	LUBE OIL PRESS. FILTER ΔP PSID	FUEL INLET PRESS PSIG	FUEL INLET TEMP °F	FUEL FLOW MAIN PPH	FUEL FLOW VAR PPH	T_2 FAN IN °F	T_3 CDT °F	T_5 EGT °F	THRUST LBS	VBV VOLTS	STATOR BETA VOLT.	PT_5 LPT INLET PSIG	RECOUP CAV "HG	SUMP VENT PRESS PSIG	CDP PSIG	P_{S2} O/W WALL "H2O	FRONT CELL TOTAL "H2O	FRONT CELL STATIC H2O	REAR CELL STATIC H2O	VIBRATION FAN NO 1 BRG	FAN TMF	FAN TRH	CORE NO 1 BRG	CORE TMF	CORE TRH
			CRK-START MOTORING:- Core 2617 RPM; Fan 147 RPM, WF: 630 PPH, T5= 79 S.O.P.- 39 PSIG L.O.P: 13 PSIG																														
			STARTCHECK- OK- COAST DOWN- Core: 2:33 Fan 3+																														
			OIL TANK LEVEL = -4973 Low - CLOSED FAN COWL DOORS-																														
	GRD	13:12	0	0	⊕	70	72	0	0	8	96	0	0	79	83	80	+/30	⊕	4.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1		13:15	MAX START T5= 948°F TIME TO IDLE= 32 SEC- T2= 78 FIRED AT CORE= 2376 RPM, FAN 180 RPM, WF= 586 PPH,																														
			S.O.P.= 39 PSIG- #1 IGN SYSTEM-																														
	1	13:20	5693	764	⊕	142	145	23.1	6	36	82	1006	1040	80	316	785	1590	⊕	4.33	2.5	.1	.1	22.5	1.9	.1	.1	.1	.1	.3	.1	.1	.3	.1
			LEAK CHECK: OK L.O.P.= 55.1 PSID GRD IDLE SPEEDS= OK-																														
		13:26	SHUT DOWN- CORE= 3-11 FAN= 5+ 05																														
			OIL TANK LEVEL= -3973 LOW @135°																														
	GRD	13:47	0	0	⊕	135	126	0	0	75	90	0	0	80	189	305	+/440	⊕	4.67	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2		13:54	MAX START T5= 998°F TIME TO IDLE= 30 SEC- T2= FIRED AT CORE 2177 RPM, FAN 177 RPM, S.O.P.= 39 PSIG																														
			WF= 580 PPH #2 IGN. L.O.D.= 24 PSIG-																														
GRD IDLE	2	13:53	5725	769	⊕	145	150	32.3	6	36	83	1030	1040	79.1	316	779	1680	⊕	4.33	2.5	.1	.1	22.5	1.9	.1	.1	.1	.2	.4	.1	.1	.7	.2
		13:54	SWITCH TO FLT IDLE, FLT IDLE SPEEDS - OK-																														
FLT IDLE	3	13:56	7248	1260	⊕	157	165	33.2				1780	1770	79.2		821	3880	⊕	3.64	5.0	.2	.25	53					.5	1.0	1.2	.6	1.3	2.0
		13:58	ACCEL TO 25%-																														
25%	4	14:02	8371	1740		172	195	38.9	—			3130	3120	78		940	9320		3.50	4.5	.6	.5	108					.3	.7	1.1	.2	1.3	3.0
		14:03-	DECEL TO FLT. IDLE-																														
		14:07	ACCEL TO 50%-																														
50%	5	14:10	8818	2676		164	204	46.2				6670	6670	79		1208	18200		1.50	29	1.4	1.5	184					.7	.7	1.3	0.3	1.5	1.6
		14:13	ACCEL TO 75%-																														
75%	6	14:16	9357	3167		156	213	52.3				10680	10680	78		1453	28200		.87	44	2.5	2.6	262					.5	.8	1.5	.4	1.0	1.0

REMARKS DDC #8 TAKEOFF,- 9763 RPM, L.O.P.= 57.1 PSI @155°, Sump= 3.4 PSI= 55.2 0 PSID.

QC-169-1 FORM CF6 TEST 1
REV 3 75

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AIRCRAFT TURBINE TEST LOG SHEET

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

Date 4-19-77
Operator D/E
Inspector H. BAKER
RUN NO.

Gas Turbine Serial No 451-479
Nature of Test
Sheet 2 of 16 Sheets

ATMOS. TIME	PRESS	TEMP	W	D	OIL TYPE 2380	TIME	OIL WT.	TIME	OIL WT
1614	28.905	Abs	54	71	START				
			35 grains		END				
					CONSUM				
ALT. IN FT 1000									

FUEL TYPE JP4
LHV:
CONSUM
SP. GR. .782 .7820
TEMP. 74

MODEL NO CF6-6D
WORK ORDER 181460
CUSTOMER

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

START NO	READING NO	TIME HRS	SPEED CORE N_2 RPM	SPEED FAN N_1 RPM	THROTTLE ANGLE	LUBE OIL TEMP INLET °F	LUBE OIL TEMP SCAV °F	LUBE OIL PRESS INLET PSIG	LUBE OIL PRESS FILTER ΔP PSID	FUEL INLET PRESS PSIG	FUEL INLET TEMP °F	FUEL FLOW MAIN PPH	FUEL FLOW VAR PPH	T_2 FAN IN °F	T_3 CDT °F	T_5 EGT °F	THRUST LBS	VBV VOLTS	STATOR BETA VOLTS	PT_5 LPT INLET PSIG	RECOUP CAV "HG	SUMP VENT PRESS PSIG	COP PSIG	PS_2 B M WALL "H2O	FRONT CELL TOTAL "H2O	FRONT CELL STATIC H2O	REAR CELL STATIC H2O	VIBRATION FAN NO 1 BRG	FAN TMF	FAN TRH	CORE NO 1 BRG	CORE TMF	CORE TRH			FUEL USED	TOTAL RUN TIME
		1418	ACCEL TO MAX CONT																																		
F.	7	1421	9685	3448		154	222	56.4				13680	13670	79		1597	35000	-0-	55	55	3.5	3.3	314					.7	1.4	1.1	.4	1.1	1.3				
		1422	ACCEL TO T.O. — ALTERNATE TORCH SPEED OK — OIL PRESS. = 55.2 PSID.																																		
T.O.	8	1424	9763	3518	-0-	155	235	57.1	2.5	20	71	14590	14530	78	987	1630	36940	-0-	.48	57.9	3.7	3.4	329	52.9	2.3	2.9	2.9	.8	1.5	1.2	.4	1.1	1.5				
		1426	SLOW DECEL TO GEN. GRD. IDLE																																		
		1432	SWITCH TO GRD. IDLE																																		
GRD IDLE	9	1434	5707	751	-0-	200	214	19.7	4	36	73	980	990	80	315	758	1670	-0-	4.31	2.0	.1	.1	24	2.0	.1	.1	.1	.1	.4	.1	.1	.5	.1				
			LEAK CHECK: — ACCESSORY GEAR BOX WET WITH OIL — LEAK AT GENERATOR PAD.																																		
		1441	SHUT DOWN — COAST DOWN — CORE = 3-22 FAN = 4-40																																		
[illegible]																																				819	[illegible]
			OIL TANK LEVEL = — 2.2 9.15 @ 175° = — 3.45 CORR.																																		
	T:50	1800	0	0	/	80	78	0.2	0	0	80	0	0	73	160	126	±490	/	4.66	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
3		1804	max start T5 = 967 °F fired @ 2442 RPM SAP = 38 PSIG T2 = 73 °F																																		
			Wf = 650 PPH Pod = 277 PSIG Time to idle = 30 sec # 1 ign																																		
	10	1807	5665	741	/	147	155	22.2	8	38	82	1010	990	71	303	758	1710	/	4.34	1.6	0	.05	23					.2	.4	.1	.1	1.1	.2				
			LEAK check —																																		
		1812	slow accel to MC for soak period																																		
		1819	accel to T.O.																																		
I.	11	1823	9670	3482	/	152	222	57.2	9	21	70	14270	14260	70	963	1596	36560	/	.49	57.4	3.8	3.35	327	52.5	2.25	2.8	2.75	.5	1.4	1.4	.5	1.4	1.6				
											T3 = 967 982 958 956 968																										
TO	12	1825	9671	3484	/	152	221	57.1	10	22	70	14270	14270	69	963	1595	36419	/	.49	57.5	3.8	3.35	326	52.6	2.26	2.8	2.75	.1	1.5	1.5	.5	1.4	1.5				
											T3 = 965 980 957 954 968																										

REMARKS

OC-1654-1 FORM CF6 TEST 1

ORIGINAL PAGE IS OF POOR QUALITY

AIRCRAFT TURBINE TEST LOG SHEET

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

Date 4-19-77
Operator Jockie
Inspector Cimorelli

Gas Turbine Serial No. 451-479
Nature of test
Sheet 3 of 10 sheets
RUN NO

ATMOS	AIR COND.				OIL TYPE					FUEL TYPE
TIME	PRESS	TEMP	W	D		TIME	OIL WT	TIME	OIL WT	
					START					LHV
					END					CONSUM.
					CONSUM					SP GR
ALT IN FT 1000										TEMP.

MODEL NO CF6-6D
WORK ORDER 181460
CUSTOMER

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

	START NO	READ NO.	TIME HRS.	SPEED CORE N_2 RPM	SPEED FAN N_1 RPM	THROTTLE ANGLE	LUBE OIL TEMP INLET °F	LUBE OIL TEMP SCAV °F	LUBE OIL PRESS INLET PSIG	LUBE OIL PRESS FILTER ΔP PSID	FUEL INLET PRESS PSIG	FUEL INLET TEMP °F	FUEL FLOW MAIN PPH	FUEL FLOW VAR PPH	T_2 FAN IN °F	T_3 CDT °F	T_5 EGT °F	THRUST LBS.	VDV VOLTS	STATOR BETA VOLTS	PT_5 LPT INLET PSIG	RECOUP CAL "HG	SUMP VENT PRESS PSIG	CDP PSIG	P_{S2} B M WALL "H2O	FRONT CELL TOTAL H2O	FRONT CELL STATIC H2O	REAR CELL STATIC H2O	VIBRATION FAN NO 1 BRG	VIBRATION FAN TMF	VIBRATION FAN TRF	VIBRATION CORE NO 1 BRG	VIBRATION CORE THF	VIBRATION CORE TRH			FUEL USED	TOTAL RUN TIME
			1827						Decel	To	MC																											
MC		13	1831	9594	3429	✓	152	221	56.3	10	24	70	13570	13580	68	948	1565	35530	—	.54	55.2	3.6	3.25	318	50.3	2.2	2.7	2.65	.6	1.3	1.4	.4	1.5	2.0				
													T3 =	950	965	942	939	952																				
MC		14	1834	9594	3430	—	152	221	56.4	10	24	70	13690	13690	68	947	1566	35510	—	.53	55.4	3.6	3.25	318	50.6	2.2	2.7	2.65	.6	1.4	1.4	.5	1.6	1.9				
													T3 =	950	965	940	938	952																				
			1836						Decel	To	MCR																											
MCR		15	1840	9449	3321	✓	153	217	54.8	10	26	70	12420	12420	67	915	1503	32640	—	.67	51.0	3.2	3.05	294	45.9	2.1	2.6	2.5	.5	1.1	1.1	.4	1.6	1.5				
													T3 =	917	934	910	907	920	—																			
MCR		16	1843	9445	3321	✓	152	216	54.8	10	26	70	12390	12330	66	932	1502	32660	—	.66	51.2	3.2	3.05	296	46.2	2.15	2.65	2.55	.5	1.0	1.1	.4	1.6	1.6				
													T3 =	917	934	909	907	918																				
			1847						Decel	To		75 %																										
75%		17	1851	9193	3125	✓	154	213	52.3	10	29	70	10290	10270	66	861	1394	27710	—	.94	43.5	2.5	2.65	260	38.8	1.85	2.3	2.25	.5	.8	1.0	.4	1.7	1.4				
													T3 =	864	878	856	854	864																				
75%		18	1854	9191	3121	—	153	211	52.3	10	29	70	10300	10300	66	861	1393	27730	—	.95	43.6	2.5	2.65	259	38.8	1.9	2.25	2.25	.5	.8	1.0	.4	1.7	1.4				
													T3 =	864	877	856	853	864																				
			1857				slow		Decel		To		flt	idle																								
			1901					switch		To		grd	idle																									
		19	1904	5624	740	—	184	200	20.4	5	39	69	980	970	65	396	735	1600	—	4.30	2.0	0	.05	23	2.2	.11	12	.13	.1	.3	.1	.1	.2	.1				
			1907						Shut down,		dump ok,		coast down,		Core = 3 min 17 sec														Fan = 4 min 55 sec									3.75
		1500	1912	0	0	✓	165	152	1.3	0	0	69	0	0	67	187	346	450	—		0	0	0	0	0	0	0	0	C	0	0	0	0	0				
													oil	Level @	—	3.4	@	159°																				
									check T5 harness for continuity & ground check —																													

REMARKS

QC-169-1 FORM CF6 TEST 1
REV 3 76

ORIGINAL PAGE IS
OF POOR QUALITY

Date 4-19-77

Operator Leakie

Inspector Cimarelli

AIRCRAFT TURBINE TEST LOG SHEET

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

Gas Turbine Serial No 451-479
Nature of Test ______
Sheet 7 of 10 sheets
RUN NO ______

TIME	BARO PRESS	RELATIVE HUMIDITY	TEMP W	TEMP D
2140	28.99	Lbs	50	59
				39 grains

ALT IN FT 1000

OIL TYPE	TIME	OIL WT.	TIME	OIL WT
START				
END				
CONSUM				

FUEL TYPE ______
CHV ______
CONSUM ______
SP GR .781 .7798
TEMP 71° 74°

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

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

START NO	READING NO	TIME HRS	SPEED CORE N_2 RPM	SPEED FAN N_1 RPM	THROTTLE ANGLE	LUBE OIL TEMP INLET °F	LUBE OIL TEMP SCAV °F	LUBE OIL PRESS INLET PSIG	LUBE OIL FILTER ΔP PSID	FUEL INLET PRESS PSIG	FUEL INLET TEMP °F	FUEL FLOW MAIN PPH	FUEL FLOW VAR PPH	T_2 FAN IN °F	T_3 CDT °F	T_5 EGT °F	THRUST LBS	VPV VOLTS	STATOR BETA VOLTS	PT_5 LPT INLET PSIG	RECOUP CAV	SUMP VENT PRESS PSIG	CDP PSIG	P_{S2} DM WALL	FRONT CELL TOTAL H_2O	FRONT CELL STATIC H_2O	REAR CELL STATIC H_2O	VIBRATION FAN NO. 1 BRG	VIBRATION FAN TMF	VIBRATION FAN TRF	VIBRATION CORE NO. 1 BRG	VIBRATION CORE TMF	VIBRATION CORE TRF			FUEL USED	STALL [illegible]
	7-110	2123	0	0	—	77	72	0.8	0	0	61	0	0	67	169	133	+480	/	4.61	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
4		2125				mix start T5 = 952 °F									fixed @ 2509 RPM						SAP = 37.6 PSIG							T2 = 62 °F									
							Δf =							Δd = 28 3 PSIG						Time To idle = 30 SEC																	
	20	2128	5617	736	—	148	156	23.0	6	38	65	1010	1010	64	291	740	1710	/	4.33	1.6	0	.05	23	2.0	.06	.08	.04	.4	.4	.2	.1	.4	.4				
											LEAK check —																										
		2131				slow accel To MC for soak period																															
		2144				accel To T.O.																															
T.O.	21	2145	564	3446	—	147	215	57.3	9	22	69	14140	14140	57	934	1560	36840	/	.48	57.6	3.8	3.35	329	52.8	2.15	2.9	2.75	.7	1.2	1.3	.4	1.3	1.6				
											T3 =	925	952	928	925	938																					
T.O.	22	2148	4566	3442	—	147	214	57.3	9	22	69	14130	14150	57	934	1559	36860	/	.48	57.5	3.85	3.35	329	53	2.15	2.05	2.75	.7	1.3	1.6	.4	1.4	1.9				
											T3 =	935	951	927	926	939																					
		2151				Decel To MC																															
MC	23	2155	4476	3344	—	148	214	56.3	9	24	69	13340	13370	56	916	1524	35260	/	.54	55.8	3.6	3.25	318	50.6	2.15	2.8	2.7	.5	1.2	1.1	.4	1.7	1.35				
											T3 =	918	934	910	902	916	29820	/																			
MC	24	2158	4474	3379	—	148	214	56.3	9	24	69	13150	13110	56	916	1523	35230	/	.54	55.2	3.6	3.20	316	50.2	2.15	2.7	2.55	.5	1.1	1.5	.4	1.7	1.6				
											T3 =	917	934	910	908	920																					
		2200				DECEL To MCR																															
MCR	25	2204	4362	3294	—	149	211	55.0	9	26	69	12220	12210	56	893	1475	32620	/	.66	51.3	3.2	3.0	296	46.1	2.05	2.6	2.40	.6	1.1	1.1	.4	1.7	1.8				
											T3 =	892	908	885	884	896																					
CR	[illegible]	2207	4361	3295	—	148	211	55.0	9	26	69	12340	12340	56	892	1476	32670	/	.65	51.5	3.2	3.0	298	46.6	2.05	2.55	2.5	.5	1.0	1.4	.4	1.7	1.7				
											T3 =	893	911	886	885	896																					

REMARKS

QC-169-1 FORM CF6 TEST 1
REV 5/75

ORIGINAL PAGE IS
OF POOR QUALITY

AIRCRAFT TURBINE TEST LOG SHEET

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

Date 4-19-77
Operator Seckin
Inspector Simorelli

RUN NO. ____

Gas Turbine Serial No 451-479
Nature of Test ____
Sheet 5 of 10 sheets

ATMOSPHERIC CONDITIONS					OIL TYPE	TIME	OIL WT	TIME	OIL WT
TIME	PRESS	TEMP.	W	D					
07:55	27.16		50	63	START				
			33 CPS.		END				
					CONSUM.				
ALT IN FT	1000								

FUEL TYPE ____
LHV ____
CONSUM ____
SP GR .782 .7804
TEMP. 70 74

MODEL NO CF6-6D
WORK ORDER 181460
CUSTOMER ____

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

START NO	READING NO	TIME HRS	SPEED CORE N_2 RPM	SPEED FAN N_1 RPM	THROTTLE ANGLE	LUBE OIL TEMP INLET °F	LUBE OIL TEMP SCAV °F	LUBE OIL PRESS INLET PSIG	LUBE OIL PRESS FILTER ΔP PSID	FUEL INLET PRESS PSIG	FUEL INLET TEMP °F	FUEL FLOW MAIN PPH	FUEL FLOW VAR PPH	T_2 FAN IN °F	T_3 CDT °F	T_5 EGT °F	THRUST LBS	VBV VOLTS	STATOR BETA VOLTS	PT_5 LPT INLET PSIG	RECOUP CAV "HG	SUMP VENT PRESS PSIG	CDP PSIG	P_{s2} B M WALL "H2O	FRONT CELL TOTAL "H2O	FRONT CELL STATIC H2O	REAR CELL STATIC H2O	VIBRATION FAN NO 1 BRG	VIBRATION FAN TMF	VIBRATION FAN TRH	VIBRATION CORE NO 1 BRG	VIBRATION CORE TMF	VIBRATION CORE TRH			FUEL USED	TOTAL RUN TIME
		2210					Decel			To	75%																										
15[illegible]	2	2214	4107	3090	/	150	207	52.4	8	29	69	10130	10130	56	837	1361	27670	/	.94	43.5	2.5	2.6	260	38.8	1.8	2.25	2.1	.6	.9	1.0	.3	1.8	1.6				
											T3=	839	854	833	831	841																					
15[illegible]	23	2217	4107	3087	/	150	206	52.5	8	29	69	10140	10130	56	838	1361	27160	/	.94	43.4	2.5	2.55	260	38.7	1.75	2.25	2.15	.5	.8	1.2	.35	1.8	1.5				
											T3=	841	854	833	831	841	[illegible]	/																			
		2220				slow	Decel			To	flt	idle																									
		2224					Switch			To	grd	idle																									
	24	2226	5564	735	/	185	196	20.7	5	39	68	950	950	57	286	719	1660	/	4.29	2.0	0	.05	23	2.2	.11	.13	.14	.1	.3	.1	.1	.4	.1				
											leak	check -																									
		2229					Shutdown			dump	OK		Coast		down		Core =		3 min		17 sec			Fan =		5 min +										4137	3/59
2200		2235	0	0	/	161	146	1.5	0	0	65	0	0	59	171	328	420	/	4.65	0	0	0	0	0	0	0	0	0	0	.0	0	0	0				
											oil	level	@		- 3.0 qt	low	@	154°																			
		*		STAGE 1		FAN	BLADES			REMOVED,			REWORKED			PER		INSTRUCTIONS,				REINSTALLED.															
		4-21-77																																			
ZERO		07:40	0	0	0	57	58	0	0	0	54	0	0	60	64	60	460	0	4.65	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
5		07:45	MAX START			T5 =	878°F		TIME TO IDLE =								T2 =	60		FIRED AT			CORE-2338			RPM,		FAN		130			RPM				
			# 1 IGN					SAP =			39	PSIG. -					LOP =	41.9	PSIG -				W/F		630	PPH -											
	20	07:48	6596	734	0	121	133	357	54	36	58	1030	1030	59	287	741	1710	0	4.33	1.6	.1	.1	23	1.9	.1	.1	.1	.1	.4	.1	.1	.5	.1				
		07:55				SLOW	ACCEL		TO	M.C.							SOAK	PERIOD. -																			
		08:02				ACCEL	TO	TAKE	OFF																												
TO	21	08:10	9576	3441	0	147	216	56.9	6	21	48.8	11190	11190	60.2	939	1568	[illegible]	0	.50	57.5	3.9	3.35	328	52.4	2.2	2.7	2.7	.8	1.5	1.2	.4	1.7	1.9				
						T3 =	~~[illegible]~~	~~[illegible]~~	~~[illegible]~~	~~[illegible]~~	~~[illegible]~~																										
TO	[illegible]	08:15	9572	3444	0 7	148	215	56.7		31	48.7	11110	11130	60.6	939	1525	[illegible]	0	.51	57.5	3.8	3.35	326	52.0	2.2	2.7	2.7	.8	1.5	1.4	.4	1.7	1.8				

REMARKS
T3 = 957 941 934 931 943

QC-869-1 FORM CF6 TEST 1
REV 8-75

AIRCRAFT TURBINE TEST LOG SHEET

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

Date 4-26-77
Operator DYE
Inspector NIWBAUER

Gas Turbine Serial No. 451-429
Nature of Test
Run No.
Sheet 6 of 16 sheets

ATMOSPHERIC CONDITIONS					OIL TYPE 2380					FUEL TYPE JP-4		MODEL NO. CF6-6D	NO. OF STARTS
TIME	PRESS	TEMP	W	D		TIME	OIL WT.	TIME	OIL WT.			WORK ORDER 181460	LAST READING NO.
07:55	29.16		50	63	START					LHV		CUSTOMER	TOTAL RUNNING TIME
			33CPS		END					CONSUM			OVER CRUISE
08:55	29.16		51	64	CONSUM					SP GR	.782 / .7804		AUGMENTED
ALT IN		1000	54	4RS						TEMP	70 / 74		GENERAL ELECTRIC ACCEPTANCE DATE

START NO.	READING NO.	TIME HRS	SPEED CORE N_2 RPM	SPEED FAN N_1 RPM	THROTTLE ANGLE	LUBE OIL TEMP INLET °F	LUBE OIL TEMP SCAV °F	LUBE OIL PRESS INLET PSIG	LUBE OIL PRESS FILTER ΔP PSID	FUEL INLET PRESS PSIG	FUEL INLET TEMP °F	FUEL FLOW MAIN PPH	FUEL FLOW VAR PPH	T_2 FAN IN F	T_3 CDT F	T_5 EGT °F	THRUST LBS	VBV VOLTS	STATOR BETA VOLTS	PT_5 LPT INLET PSIG	RECOUP CAV "HG	SUMP VENT PRESS PSIG	CDP PSIG	P_{S2} BM WALL "H2O	FRONT CELL TOTAL "H2O	FRONT CELL STATIC H2O	REAR CELL STATIC H2O	VIBRATION FAN NO. 1 BRG	VIBRATION FAN TMF	VIBRATION FAN TRH	VIBRATION CORE NO. 1 BRG	VIBRATION CORE TMF	VIBRATION CORE TRH			FUEL USED	TOTAL RUN
		08:18	DECEL TO M.C.-																																		
M	13	08:23	9517	3397	0	148	216	56.0	6.5	21.5	68.7	13490	13680	61	929	1543	35570	0	.55	55.5	3.7	3.2	317	51.1	2.15	2.7	2.7	.7	1.5	1.4	.4	1.8	1.8				
					T3 =	931	946	931	919	934																											
MC	3/1	08:26	9519	3460	0	0	0	0	0	0	68.7	13660	13760	61.6	930	1544	35590	0	.54	55.5	0	0	319	58.8	2.15	2.7	2.7	.6	1.5	1.4	.4	1.8	1.8				
					T3 =	928	947	923	921	933																											
		08:29	DECEL TO MCR.																																		
MCR	5	08:34	9395	3305	0	150	214	54.5	6	24	68.7	12490	12470	61.6	904	1492	34250	0	.67	51.5	2.65	3.1	298	76.4	2.1	2.5	2.5	.6	1.1	1.1	.4	1.8	1.5				
					T3 =	906	920	898	894	907																											
MCR	6	08:37	9395	3302	0						68.8	12460	12430	62.1	903	1490	32600	0	.68	51.5			297	76.4	2.1	2.5	2.5	.6	1.2	1.2	.4	1.8	1.5				
					T3 =	906	922	894	896	906																											
		08:39	DECEL TO 75%-																																		
75%	7	08:44	9158	3161	0	153	211	51.7	6	24	69.6	10350	10350	64.3	853	1385	27900	0	.94	44	2.6	2.85	261	39	1.85	2.2	2.2	.6	1.1	.9	.4	1.8	1.4				
					T3 =	856	869	850	847	856																											
		08:47	9158	3107							69	10310	10330	63.8		1385	27840				DELETE READINGS - RAN OUT OF TAPE																
					T3 =	855	869	849	846	855																											
		08:48 -	DECEL TO FLT. IDLE																																		
		08:51	SWITCH TO GRD. IDLE-																																		
		08:54	SHUT DOWN- COAST DOWN CORE = 3-10 FAN = 4-35																																		
	20	08:59	0	0	0	170	170	0	0	85	68	0	0	64	193	336	±00	0	4.63	0	0	0	0	0	0	0	0	0	0	0	0	0	0			5968	7/3
			- ADDED FUEL -																																		

REMARKS

QC-165-1 FORM CFE REV. 1

ORIGINAL PAGE IS OF POOR QUALITY

AIRCRAFT TURBINE TEST LOG SHEET

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

Date 4-21-77
Operator DJE
Inspector NEUBAUER

RUN NO. ____

Gas Turbine Serial No 451-472
Nature of Test ____
Sheet 7 of 10 Sheets

ATMOSPHERIC CONDITIONS					OIL TYPE 2380					FUEL TYPE JP-4	
TIME	PRESS	TEMP	W	D		TIME	OIL WT	TIME	OIL WT.		
09:30	29.165		53	68	START					LHV	
			34 GRS		END					CONSUM	
					CONSUM					SP. GR	.7835 .7809
ALT IN FT 1000										TEMP	70 74

MODEL NO: CF6-6D
WORK ORDER 181460
CUSTOMER ____

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

START NO.	READING NO.	TIME HRS.	SPEED CORE N_2 RPM	SPEED FAN N_1 RPM	THROTTLE ANGLE	LUBE OIL TEMP INLET °F	LUBE OIL TEMP SCAV °F	LUBE OIL PRESS INLET PSIG	LUBE OIL PRESS FILTER ΔP PSID	FUEL INLET PRESS PSIG	FUEL INLET TEMP °F	FUEL FLOW MAIN PPH	FUEL FLOW VAR PPH	T_2 FAN IN °F	T_3 CDT °F	T_5 EGT °F	THRUST LBS	VBV VOLTS	STATOR BETA VOLTS	PT_5 LPT INLET PSIG	RECOUP CAV "Hg	SUMP VENT PRESS PSIG	CDP PSIG	Ps_2 B M WALL "H2O	FRONT CELL TOTAL "H2O	FRONT CELL STATIC H20	REAR CELL STATIC H20	VIBRATION FAN NO 1 BRG	VIBRATION FAN TMF	VIBRATION FAN TRH	VIBRATION CORE NO 1 BRG	VIBRATION CORE TMF	VIBRATION CORE TRH			FUEL USED	TOTAL RUN TIME
					T3 =		202	224	264	211	216																										
	2(90	09:26	0	0	θ	133	96	0	0	20	68.2	0	0	66	306	338	+400	θ	46.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0			5909	7/8
		09:21	MAX START T5 = 999°							TIME TO IDLE = 30 SEC						T2 =				FIRED AT CORE 2227 RPM,								FAN 140 RPM.									
			Wf = 580 PPH,				S.O.P = 39 PSIG.								L.O.P = 2.2 PSIG -							#1 IGN -															
	38	09:23	5658	743	θ	165	176	213	5	35	68.5	1020	1000	67	298	747	1660	θ	4.32	1.5	.1	.1	3.3	2	.1	.1	.1	.2	.4	.2	.6	1.2	.5				
		09:27	ACCEL TO M.C.							SOAK PERIOD																											
	A.P.	09:34	ACCEL TO T.O.																																		
T.O.	39	09:39	9462	3482	4	149	220	57.1	7	20	68.4	14510	14510	68	962	1601	37300	4	.46	58.4	3.9	3.4	332	53.5	2.15	2.8	2.75	.7	1.5	1.3	.5	1.3	1.7				
					T3 =	964	980	957	954	968																											
T.O	A.P. 40	09:42	9460	3477							68.4	14440	14440	68.4	962	1599	37620	4	.47	58.2			331	53.3	2.1	2.8	2.8										
					T3 =	965	982	956	955	967																											
	F.F.	09:44	DECEL TO M.C.																																		
MC	41	09:49	9591	3424	4	151	220	56.1	7	22	68.3	13690	13620	68.9	950	1570	35390	4	.53	55.5	3.6	3.3	320	56.9	2.1	2.7	2.7	.7	1.5	1.4	.4	1.7	2.2				
					T3 =	952	966	942	939	953																											
MC	42	09:52	9591	3423								13740	13730	68.9	949	1570	35400	4	.53	55.5			319	56.5	2.1	2.7	2.7										
					T3 =	950	967	941	938	954																											
		09:56	ACCEL TO T.O.																																		
T.O	43	10:00	9498	3492	4	150	221	57.1	6	20	68	14650	14680	69.9	970	1611	37260	4	.45	58.6	3.9	3.5	335	54	2.2	2.8	2.8	.8	1.5	1.2	.4	1.5	1.6				
					T3 =	972	988	962	962	977																											
T	44	10:03	9708	3497								14670	14640	76.3	971	1615	37500	θ	.44	59.0			334.5	54.1													
					T3 =	972	988	964	961	975																											
		10:05	DECEL TO M.C.																																		

REMARKS

Date 4-21-77

Operator DJF

Inspector HEIBRUER

AIRCRAFT TURBINE TEST LOG SHEET

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

Gas Turbine Serial No. 451-472

Nature of Test ____

RUN NO ____

Sheet 8 of 10 Sheets

ATMOSPHERIC CONDITIONS					OIL TYPE 2380					FUEL TYPE JP-4
TIME	PRESS	TEMP	W	D		TIME	OIL WT	TIME	OIL WT	
10:16	29.16		50	72	START					LHV
	29.10		57	81	END					CONSUM
			30 CRS.		CONSUM.					SP GR .7825 .7809
ALT. IN FT: 1000										TEMP 70 74

MODEL NO. CF6-6D

WORK ORDER 181460

CUSTOMER ____

NO. OF STARTS ____

LAST READING NO. ____

TOTAL RUNNING TIME ____

OVER CRUISE ____

AUGMENTED ____

GENERAL ELECTRIC ACCEPTANCE DATE ____

START NO.	READING NO.	TIME HRS.	SPEED CORE N_2 RPM	SPEED FAN N_1 RPM	THROTTLE ANGLE	LUBE OIL TEMP INLET °F	LUBE OIL TEMP SCAV °F	LUBE OIL PRESS INLET PSIG	LUBE OIL PRESS FILTER ΔP PSID	FUEL INLET PRESS PSIG	FUEL INLET TEMP. °F	FUEL FLOW MAIN PPH	FUEL FLOW VAR PPH	T_2 FAN IN F	T_3 CDT °F	T_5 EGT °F	THRUST LBS	VBV VOLTS	STATOR BETA VOLTS	PT_5 LPT INLET PSIG	RECOUP CAV "HG	SUMP VENT PRESS PSIG	CDP PSIG	P_{S_2} B M WALL "H2O	FRONT CELL TOTAL "H2O	FRONT CELL STATIC H2O	REAR CELL STATIC H2O	VIBRATION FAN NO 1 BRG	VIBRATION FAN TMF	VIBRATION FAN TRH	VIBRATION CORE NO 1 BRG	VIBRATION CORE TMF	VIBRATION CORE TRH			FUEL USED	TOTAL RUN TIME
MP	45	1009	9?64	3433	—	151	222	56.9	7	22	68.3	13750	13730	71.3	952	1572	35300	4	.54	55.2	3.6	3.3	320	50.5	2.1	2.6	2.6	.7	1.5	1.3	.4	1.7	2.1				
			T3=	954	970	947	945	958																													
MC	46	1012	9663	3416							68.3	13630	13630	71.9	954	1573	35350		.54	55.2			318	50.5	2.1	2.6	2.6										
			T3=	955	970	946	943	956																													
		10:14 DECEL TO MCR-																																			
MCR	47	10:18	9473	3334		151	221	54.5	7	21	68.5	12640	12640	72.6	1519	929	33052	4	.65	52	3.3	3.2	298	46.9	2.1	2.5	2.5	.7	1.2	1.4	.4	1.7	1.9				
			T3=	931	948	925	918	932																													
		10:20 DECEL TO 75%-																																			
75%	48	1021	9272	3129	—	155	217	51.5	6	26	68.5	10410	10410	71.9	876	1414	27450	4	.95	44	2.6	2.7	262	39.5	1.8	2.25	2.25	.6	1.2	.8	.3	1.8	1.5				
			T3=	840	892	871	869	879																													
		1026 DECEL TO FLT. IDLE																																			
		1030 SWITCH TO GRD IDLE																																			
		1032 SHUT DOWN- PED DUMP- OK - COAST DOWN = CORE = 3.55 FAN = 5-47																																			
7PPD		1036	0	0	—	176	174	0	0	80	69.6	0	0	72.2	215	370	+/00	4	4.63	0	0	0	0	0	0	0	0	0	0	0	0	0	0			7959:5/23	
		CHECKED EGT HARNESS RESISTANCE -OK-																																			
7:30		14:33	0	0	—	80	80	0	0	0	93.7	0	0	80.1	147	116	+470	4	4.63	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
7		14:40 MAX START T5= 978°F TIME TO IDLE 30SEC T3: FIRED AT CORE 2392 RPM, FAN 120 RPM,																																			
		Wf's 620 pph S.P.P.= 39 psig L.O.P.= 30 PSIG #1 IGN.																																			
	49	14:43	5740	1720	—	140	147	23	6	35	90.8	1050	1040	80.5	322	787	1720	4	4.35	2.0	.1	.1	13	2.0	.1	.1	.1	.3	.4	.1	.2	.6	.2				
				T3=	372	322	321	322	323																												
		14:44 ACCEL TO M.C. 5 min. SOAK PERIOD - T5= 1605°																																			
		P.P. 14:54 ACCEL TO TAKE OFF																																			
T.O.	50	14:57	9718	3531	—	154	223	57.4	6	18	71.1	14900	14900	77.5	994	1646	37500	4	.48	58.9	3.9	3.5	332	54	2.4	2.9	2.9	.8	1.4	1.4	.5	.8	1.4				

REMARKS

~~T3 = 9?? 9??~~

T3: 992 988 980 998 1010

QC-189-1 FORM CF6 TEST
REV 5 75

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OF POOR QUALITY

AIRCRAFT TURBINE TEST LOG SHEET

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

Date 4-21-77
Operator D.?
Inspector [illegible]

Gas Turbine Serial No. 451-477
Nature of Test
Sheet 9 of 10 Sheets
RUN NO.

ATMOSPHERIC CONDITIONS				
TIME	PRESS	TEMP	W	D
15:10	29.10			
			53	79
16:30	29.10	Abs	20	400
ALT IN FT	1000			

OIL TYPE: 2380

	TIME	OIL WT	TIME	OIL WT
START				
END				
CONSUM				

FUEL TYPE: JP-4
LHV
CONSUM
SP GR
TEMP

MODEL NO: CF6-6D
WORK ORDER 181460
CUSTOMER

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

START NO.	READING NO.	TIME HRS	SPEED CORE N_2 RPM	SPEED FAN N_1 RPM	THROTTLE ANGLE	LUBE OIL TEMP INLET °F	LUBE OIL TEMP SCAV °F	LUBE OIL PRESS. INLET PSIG	LUBE OIL PRESS. FILTER ΔP PSID	FUEL INLET PRESS PSIG	FUEL INLET TEMP °F	FUEL FLOW MAIN PPH	FUEL FLOW VAR PPH	T_2 FAN IN °F	T_3 CDT °F	T_5 EGT °F	THRUST LBS	VBV VOLTS	STATOR BETA VOLTS	PT_5 LPT INLET PSIG	RECOUP CAV "HG	SUMP VENT PRESS PSIG	CDP PSIG	P_{S2} B M WALL "H_2O	FRONT CELL TOTAL "H_2O	FRONT CELL STATIC H_2O	REAR CELL STATIC H_2O	VIBRATION FAN NO. 1 BRG	VIBRATION FAN TMF	VIBRATION FAN TRH	VIBRATION CORE NO. 1 BRG	VIBRATION CORE TMF	VIBRATION CORE TRH			FUEL USED	TOTAL RUN TIME
		1458	DECEL TO M.C.																																		
T	51	1502	9676	3445	ϕ	156	226	559	7	22	707	13740	13730	78.6	970	1594	31900	ϕ	.58	57.9	3.6	3.3	317	50.3	2.2	2.7	2.7	.7	1.5	1.4	.5	1.3	2.5				
			T3 =		969	962	955	973	988																												
MC	52	1505	9671	3434	ϕ	156	226	556	7	22	705	13720	13710	79.0	970	1593	35000	ϕ	.57	55	3.6	3.3	316	50.2	2.2	2.7	2.7										
			T3 =		968	962	955	~~98~~	987																												
		1507	DECEL TO FLT IDLE																																		
		1511	SWITCH TO GRD. IDLE																																		
		1515	SHUT DOWN - PED DUMP OK - COAST DOWN CORE = 3-15 FAN = 4-30																																		
	SD	1520	0	0	ϕ	181	179	0	0	79	76	0	0	78.5	315	360	+440	ϕ	4.65	0	0	0	0	0	0	0	0	0	0	0	0	0	0			8773 [illegible]	
			OIL - [illegible] @ 173°																																		
			REMOVED BOTTOM LEFT THERMOCOUPLE HARNESS - P/N = 9055M41P01 S/N CDB 06216																																		
			INSTALLED ORIGINAL " " " P/N 9055M21P01 S/N CDB 05550																																		
			NOTE: T/C IS REJECTED ON INCOMING INSPECTION																																		
			closed cell doors All drains secured																																		
	SD	1620	0	0	✓	107	85	0.2	0	0	83	0	0	77	229	214	+460	—	4.65	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
8		1622	MAX start T5 = 998°F fired @ 2533 RPM SAP = 38 PSIG																																		
			T2 = 77°F Wf = 610 PPH lod = 23 PSIG Time to idle = 31 SEC																																		
	53	1625	5704	748	✓	123	182	20.4	8	38		1020	1020	77	320	769	1710	—	4.34	16	0	.05	23	21	13	.13	.14	.15	.35	.2	.6	1.1	.35				
			leak check -																																		
		1627	slow accel to MIC for soak period -																																		
		1635	accel to Take-off																																		
	54	1638	9749	3507	✓	154	225	56.9	10	21	69	14610	14610	76	988	1630	37114	✓	.48	58.4	3.85	3.4	330	53.3	2.3	2.9	4.85	1.1	1.6	1.1	.5	1.3	1.8				
													T3 =	984	978	971	990	1001																			

REMARKS

AIRCRAFT TURBINE TEST LOG SHEET

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

Date 4-21-77
Operator Locklie
Inspector Cimorelli

Gas Turbine Serial No 451-474
Nature of Test ______
Sheet 10 of 10 Sheets
RUN NO. ______

AT. (OSP)	EHC CONT.	FLONT			
TIME	PRESS	TEMP.	W	D	
ALT. IN FT	1000				

OIL TYPE	TIME	OIL WT	TIME	OIL WT.
START				
END				
CONSUM				

FUEL TYPE ______
LHV ______
CONSUM. ______
SP. GR. ______
TEMP ______

MODEL NO CF6-6D
WORK ORDER 151460
CUSTOMER ______

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

START NO	STAT NO	TIME, HRS	SPEED CORE N_2 %RPM	SPEED FAN N_1 RPM	THROTTLE ANGLE	LUBE OIL TEMP INLET °F	LUBE OIL TEMP SCAV °F	LUBE OIL PRESS INLET PSIG	LUBE OIL PRESS FILTER ΔP PSID	FUEL INLET PRESS PSIG	FUEL INLET TEMP °F	FUEL FLOW MAIN PPH	FUEL FLOW VAR PPH	T_2 FAN IN °F	T_3 CDT °F	T_5 EGT °F	THRUST LBS.	VOV VOLTS	STATOR BETA VOLTS	PT_5 LPT INLET PSIG	RECOUP CAV "HG	SUMP VENT PRESS PSIG	CDP PSIG	P_{S2} B/M WALL "H2O	FRONT CELL TOTAL "H2O	FRONT CELL STATIC H2O	REAR CELL STATIC H2O	VIBRATION FAN NO 1 BRG.	VIBRATION FAN TMF	VIBRATION FAN TRH	VIBRATION CORE NO 1 BRG	VIBRATION CORE TMF	VIBRATION CORE TRH			FUEL USED	TOTAL RUN TIME
		1640					Decel To 4110																														
	5	1644	9.74	3451	/	154	224	56.2	10	23	69	3860	3870	76	971	1547	35660	/	.55	56.1	3.6	3.3	319	50.8	2.25	2.35	2.7	1.0	1.5	1.2	.4	1.4	2.4				
												T3=	969	963	956	972	986																				
	56	1648	9.74	3450	/	154	225	56.2	10	23	69	3860	3830	76	971	1546	35630	/	.55	56.2	3.6	3.3	319	51.0	2.3	2.8	2.7	1.0	1.4	1.2	.4	1.5	2.4				
												T3=	968	962	956	973	987																				
		1650				slow Decel To flt. idle																															
		1656				Decel To grd idle																															
	57	1658	5690	748	/	198	211	19.8	8	39	70	970	980	76	323	766	1680	/	4.31	2.0	0	.05	23	2.3	.12	.13	.14	.1	.4	.1	.1	.7	.1				
							LEAK CHECK																													966	
		1701				Shut down, dump OK, coast down, Core = 3 min 20 sec Fan = 4 min 57 sec																															1.35
ZERO			0	0	/	176	163	0.6	0	0	74	0	0	76	201	352	±440	—	4.66	0	0	0	0	0	0	0	0	0	0	0	0	0	0				1

oil level @ -5 qt low @ 110°
All filters, finger screens & mag plug checked - OK -
under cowl leakage check - OK.

REMARKS:

QC-168-1 FORM CF6 TEST 1
REV 5 75

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