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FEASIBILITY OF BURNING EMULSIFIED FUEL IN A 7LM100 ENGINE

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February 1968

U. S. ARMY AVIATION MATERIEL LABORATORIES
FORT EUSTIS, VIRGINIA

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FLIGHT PROPULSION DIVISION

GENERAL ELECTRIC COMPANY

CINCINNATI, OHIO

U S ARMY MATERIEL COMMAND

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This report was prepared by General Electric Company, Cincinnati, Ohio, under the terms of Contract DAAJ02-67-C-0038. It consists of a study to determine the feasibility of burning emulsified JP-4 fuel in a GE 7LM100 gas turbine engine.

The results of this study indicate that it is feasible to operate the 7LM100 engine on emulsified JP-4 fuel. Several areas in which further research is needed are brought out.

The information in this report will be utilized in the pursuance of further research in the area of fuel emulsions.

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Prepared by

Flight Propulsion Division
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Cincinnati, Ohio

For

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ABSTRACT

Much investigation and aircraft engine operation have been accomplished in developing a "safe" fuel that will not explode in its stored condition when exposed to a spark, but which will give identical engine performance when used in place of fuels being burned today. The Bell air cushion vehicle engine, a General Electric LM100, was tested on the latest emulsified "safe" JP-4 fuel (WSX-7165). Engine starts and operation were about the same with emulsified JP-4 fuel as with plain JP-4 except that running time was limited on emulsified fuel because of fuel nozzle clogging. Clogging was caused by dirtier-than-normal fuel and by an iron deposit that formed on the fuel nozzles and fuel nozzle screens.

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LIST OF SYMBOLS

AD	Alloy depletion
CDP-(P_3)	Compressor discharge pressure, psi
C/S	Cross section
GO	General oxidation
IGO	Intergrannular oxidation
L/E	Leading edge
mg/gal	Milligrams per gallon
N_f	Free power turbine speed, rpm
N_g	Gas generator speed, rpm
PPH	Pounds per hour
psia	Pounds per square inch absolute
psig	Pounds per square inch gage
TFC	Thermal fatigue crack
T_2	Compressor inlet temperature, ^oF
T_5	Power turbine inlet temperature, ^oF
T_6	Power turbine downstream temperature, ^oF
W_f	Weight flow, fuel

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INTRODUCTION

TEST OBJECTIVE

The objective of the test was to determine the feasibility of burning emulsified fuel in a General Electric LM100 gas turbine. Starting, acceleration, and steady-state characteristics of the engine were compared on liquid JP-4 and emulsified JP-4. The engine was also inspected before and after test to determine what, if any, deleterious effects resulted from burning emulsified fuel.

Emulsified fuel offers several advantages over liquid fuels from a safety viewpoint. Emulsified fuel burns much slower and has a higher open-cup flash point. It has a low rate of vaporization, since it stays in a jelly-like form until sheared through pumps and filters prior to entering the engine combustion chamber.

LM100 ENGINE

The LM100 gas turbine is an industrialized version of the T-58, the major difference being its controls. The engine used for the test was a 7LM100PD101 that had been returned for overhaul. This engine had accumulated 329 hours of service in Vietnam in an air cushion vehicle.

The 7LM100PD101 fuel system consists of a flight (T-58) fuel pump, high-pressure filter, flow divider, and fuel nozzles. An industrial fuel metering valve and stopcock are used. Lube oil is cooled in an oil-to-fuel engine-mounted heat exchanger.

DESCRIPTION OF TEST INSTALLATION

The test stand used a dynamometer that consisted of the compressor portion of an aircraft turbosupercharger to absorb the engine output horsepower. A means of varying the load was provided by a damper valve in the supercharger inlet. Temperature rise across this unit was monitored as an indication of engine performance. Actual engine performance was based on N_g, T_5, and CDP. Figure 1 shows this test stand.

Fuel was supplied to the engine from a pressurized stainless-steel tank. Initial emulsified fuel testing was done with the standard engine high-pressure fuel filter. After approximately 4 hours of testing, engine fuel manifold pressure started rising with fixed engine conditions. When it was evident that the pressure was not going to stabilize, the engine was shut down and the fuel filter was inspected for contamination. This filter was completely clogged and was in a bypass condition, allowing the fuel nozzles to be unprotected. The fuel nozzles were replaced, and a 46-micron filter was installed close to the fuel pump inlet. Fuel and lube temperatures were also monitored so that the effectiveness of the engine lube-oil-to-fuel heat exchanger could be evaluated. Overspeed and over-temperature protective devices were incorporated in the test installation to shut the engine down automatically in the event that one of these conditions existed.

DISCUSSION

TESTING

Prior to the testing, a hot-section inspection of the engine was performed. Figures 2 through 6 show the results of this inspection. New fuel manifold assemblies and two new first-stage turbine blades were installed. An overhauled fuel metering valve was installed so that corrosion could be monitored. Otherwise, only those parts necessary to run the engine safely were replaced at this time.

The test consisted of making comparisons of starting, acceleration, and steady-state characteristics on JP-4 and WSX-7165 emulsified fuel. Testing included:

1. Start and acceleration calibration runs on JP-4.

2. Start and acceleration test runs on WSX-7165 emulsified fuel.

Testing of the engine on emulsified fuel was to the following schedule:

1. Operating for 5 minutes at 1200°F T_5.

2. Operating at 1175°F T_5 for 1-1/2 hours.

3. Operating at 1050°F T_5 for 25 minutes.

4. Repeating steps 1, 2, and 3 as fuel supply permitted.

A total of 11 hours 37 minutes running time was accumulated during the test. Of this total, 9 hours 32 minutes was on emulsified fuel.

A flowmeter calibrated on emulsified fuel was not provided for this test. The following method was used to compare engine fuel consumption rate of JP-4 and emulsified fuel:

1. Determine the known operating time on emulsified fuel at each particular condition.

2. Calculate the total amount of JP-4 fuel that would have been used at each condition.

3. Determine the total amount of JP-4 fuel that would have been used for the total running time on emulsified fuel.

4. Compare this total with the actual total amount of emulsified fuel used.

TEST RESULTS

Engine performance on emulsified fuel was identical to that on JP-4 with the exception of light (backfire) explosions. These explosions were heard during starting, transit, and steady-state conditions. Transit and steady-state explosions were audible and accompanied by an irratically indicated T_5 and streaks of flame in the exhaust. These explosions were not numerous and were probably caused by blobs of emulsified fuel burning downstream of the combustor.

After 4 hours 18 minutes (3 hours 17 minutes on emulsified fuel), the fuel manifolds were changed because of high fuel manifold pressure. This was caused by the fuel nozzles' clogging on dirty fuel (see Figures 7, 8, and 9). Bench checks showed five secondary fuel nozzles not flowing at inlet pressures up to 500 psig. All nozzles were dirty and clogged to some extent. Two secondary nozzles had collapsed nozzle filter screens. This is shown in Figures 10 and 11. Also, globs of emulsified fuel were dribbling out of these nozzles, as shown in Figures 13 and 14. A white crystal-like residue was also found (see Figures 15 and 16) on the nozzles. Figures 17, 18, and 19 are typical of the condition of the other fuel nozzles in the first set.

The second set of manifolds was in much better condition at the end of the test. A slave filter had been added to the fuel supply system when the manifolds were changed. These nozzles were about 35 percent clogged at the end of the test. There was some white residue around the nozzle orifices, but there were no blobs of fuel. The nozzles had been operated on JP-4, whereas the first set had been operating on emulsified fuel prior to shutdown. Clogging of the first set of fuel nozzles was caused by contaminated fuel. Figures 21 through 28 show typical fuel nozzles from the second set.

Fuel nozzles from the second set were disassembled, and a reddish deposit was found on the screens and in the nozzle areas. This deposit was inadvertently cleaned from the second set of nozzles prior to obtaining a sample for chemical analysis. However, there was a similar coating in the first set of nozzles in addition to all the other contaminant.

A sample of this reddish deposit was analyzed and found to be primarily iron, with traces of aluminum, calcium, chromium, copper, magnesium, manganese, nickel, lead, silicon, and titanium. Flow check of the second set of nozzles after ultrasonic cleaning restored them to pre-test condition

Laboratory analysis revealed that the fuel contained sand, a large amount of fiber, and large pieces of material that appeared to be gray paint. The contamination level was 17.8 mg/gal. MIL-T-5624G allows 8 mg/gal for liquid JP-4.

Comparison of the fuel consumption of WSX-7165 and the expected fuel flow on liquid JP-4 revealed the fuel flows to be essentially the same. The expected fuel consumption on liquid JP-4 for known engine conditions was 829 pounds. The actual amount of WSX-7165 fuel burned during the comparison was approximately 825 pounds. Data from this test are given in the table.

ESTIMATED FUEL CONSUMPTION

Power Setting T_5 (°F)	Running Time (min)	Estimated JP-4 Consumption (lb)
1180	20	205
1170	10	100
1165	10	97.5
1060	7	58
1140	5	45.5
1125	29	295
745 (idle)	12	28

The engine-mounted lube-oil-to-fuel heat exchanger was sufficient for the test. Comparisons showed that the lube oil temperature drop across the heat exchanger was considerably less on emulsified fuel than on liquid JP-4 shown by the data sheets in Appendix II.

Figures 29 through 36 are pictures of the hot-section parts after test. A blue coloring on most of the hot-section parts was analyzed and found to be a cobalt-based material. It is surmised that the cobalt came from hot-section materials, as each component that was coated incorporated a high percentage of cobalt. The coloring did not show on the second-stage nozzle or on the power turbine buckets. The second-stage nozzle material is 713 (B50T1239), and the power turbine buckets are A286. The blue-colored coating did not adhere to these two metals. See Appendix VIII.

Analysis of the first-stage buckets from pre-test to post-test condition showed no apparent change as a result of emulsified fuel operation. The one bucket that had experienced 300 hours of Vietnam operation plus the emulsified fuel test was in the same general condition as the two that were analyzed prior to this test. The new coated bucket installed prior to the test showed the coating to be in good condition at post-test time, with general oxidation estimated at 0.5 to 1.0 percent. Also, the coated bucket showed a trace of alloy depletion, but nothing was found in the analysis of the coated or uncoated bucket that could be identified as being of a destructive nature caused by operation with emulsified fuel.

PROBLEMS

Fuel Nozzles

Fuel nozzle coking may be a problem in achieving required nozzle life if emulsified fuel is supplied to the fuel nozzles. The primary fuel nozzles were coked the heaviest. This suggests that spray characteristics with emulsified fuel are much poorer at lower pressure drops across the fuel nozzles. The secondary nozzles, which operate only above 185-psi fuel manifold pressure, showed much less coking. Coking was aggravated by dirty fuel's clogging the nozzles.

Since emulsified fuel must be pumped to move, it will not drain after shutdown but will stay in the nozzle and coke. Secondary fuel nozzles showed signs of this, since they do not flow below 185-psi manifold pressure. Figures 18 and 19 show coking on the secondary nozzles which can be attributed to high-temperature no-flow conditions.

Fuel Drains

Emulsified fuel will not flow through the engine drains. If a start is aborted or the engine fails to light off, fuel could accumulate in the combustor. Then, if a second start is initiated and the engine lights, this accumulation of fuel might also ignite and a dangerous overtemperature condition could exist.

Backfires

The backfire-type explosions with simultaneous streaks of flame in the exhaust were probably caused by the fuel's not burning in the combustor. If emulsified fuel is supplied to the fuel nozzle, a redesign will be required. Redesign of the fuel system to de-emulsify the fuel completely before it reaches the nozzles may be more attractive.

It is suspected that a change in T_5 profile occurred as a result of fuel nozzle clogging. No damage resulted from this suspected change, nor was there any sign of deterioration of hot-section parts. This assumption is based on variations of the T_5-T_6/N_g-T_5 relationships and on a rise in fuel manifold pressure as a function of time.

Contamination

Emulsified fuel will pick up and hold all impurities that it comes in contact with. These impurities must be filtered out. The fuel system must therefore be kept very clean or designed to be compatible with the contamination. Testing had to be suspended to change clogged fuel filters.

CONCLUSIONS

Based on the results of this test, the following conclusions are drawn:

1. The LM100 engine and fuel control system used in conjunction with the Bell air cushion vehicle are capable of short-duration operation using WSX-7165 emulsified fuel.

2. Engine starting on emulsified fuel creates no problems, and fuel consumption rate is very close to that of JP-4 under the same steady-state conditions.

3. Although no lube temperature problems were encountered in this test, lube temperature drop across the oil cooler indicated that emulsified fuel will not be as efficient a cooling medium as liquid JP-4.

4. The LM100 fuel system will experience no adverse corrosion problems from short-duration operation on WSX-7165 emulsified fuel under average conditions.

5. The LM100 engine and fuel system would require extensive tests, such as fuel nozzle and component combustion tests, and probably design changes in some areas before they could be released for operation on WSX-7165 emulsified fuel for extended periods.

RECOMMENDATIONS

1. Since the results of this test indicate satisfactory short-duration (4 to 6 hours) operation for the LM100 engine and fuel system supplied by the General Electric Company, it is recommended that a similar test be conducted on an engine installed in an air cushion vehicle to determine the feasibility of operation in conjunction with the craft fuel system that is presently in use with standard JP fuels. This test would dictate the changes necessary in the total system and could be a prelude to any tests that might be conducted in aircraft applications.

2. An LM100 component combustor test is recommended to determine flame pattern and differences in combustor operation between straight JP-4 fuel and WSX-7165 emulsified fuel. Combustor operation should also be compared using new fuel nozzles versus nozzles that have operated from 4 to 6 hours and experienced the 35 to 40 percent restriction noted with the second set of nozzles used in this test.

3. Experiments and tests are recommended to determine the feasibility of developing a cleaning fluid that might be injected periodically into the fuel system to clean fuel nozzles of the deposits that cause clogging with extended operation on WSX-7165 emulsified fuel.

4. It is recommended that methods to de-emulsify the fuel completely, prior to injection into the fuel nozzle manifolds, be investigated. This would certainly preclude the backfires, would stop blobs of emulsified fuel from being spewed into the combustion section, and would eliminate the engine drain problem. It appears that the fuel must be completely de-emulsified by the time that it reaches the fuel nozzles; otherwise, a redesign will be required.

5. A test on a <u>new</u> LM100 engine with a <u>new</u>, <u>clean</u> fuel system operated with <u>clean</u> emulsified fuel is recommended. This would eliminate the uncertainty that presently exists as to why and where the contamination and blue-colored coating came from on the engine that has just completed testing.

6. It is recommended that hot-section materials be tested to determine what deleterious effects (i. e., alloy depletion, oxidation, etc.) result from burning emulsified fuel.

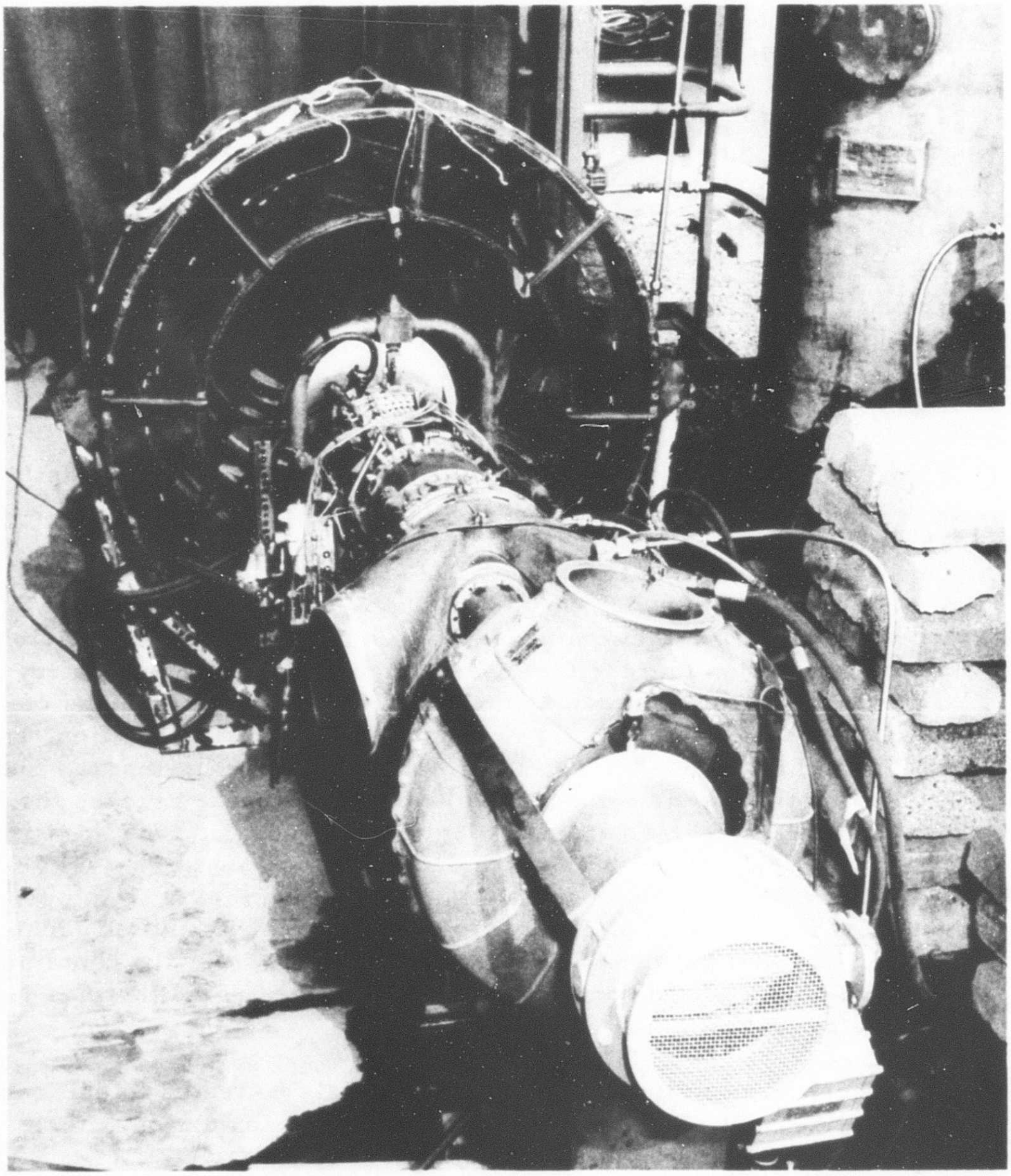


Figure 1. Test Stand.

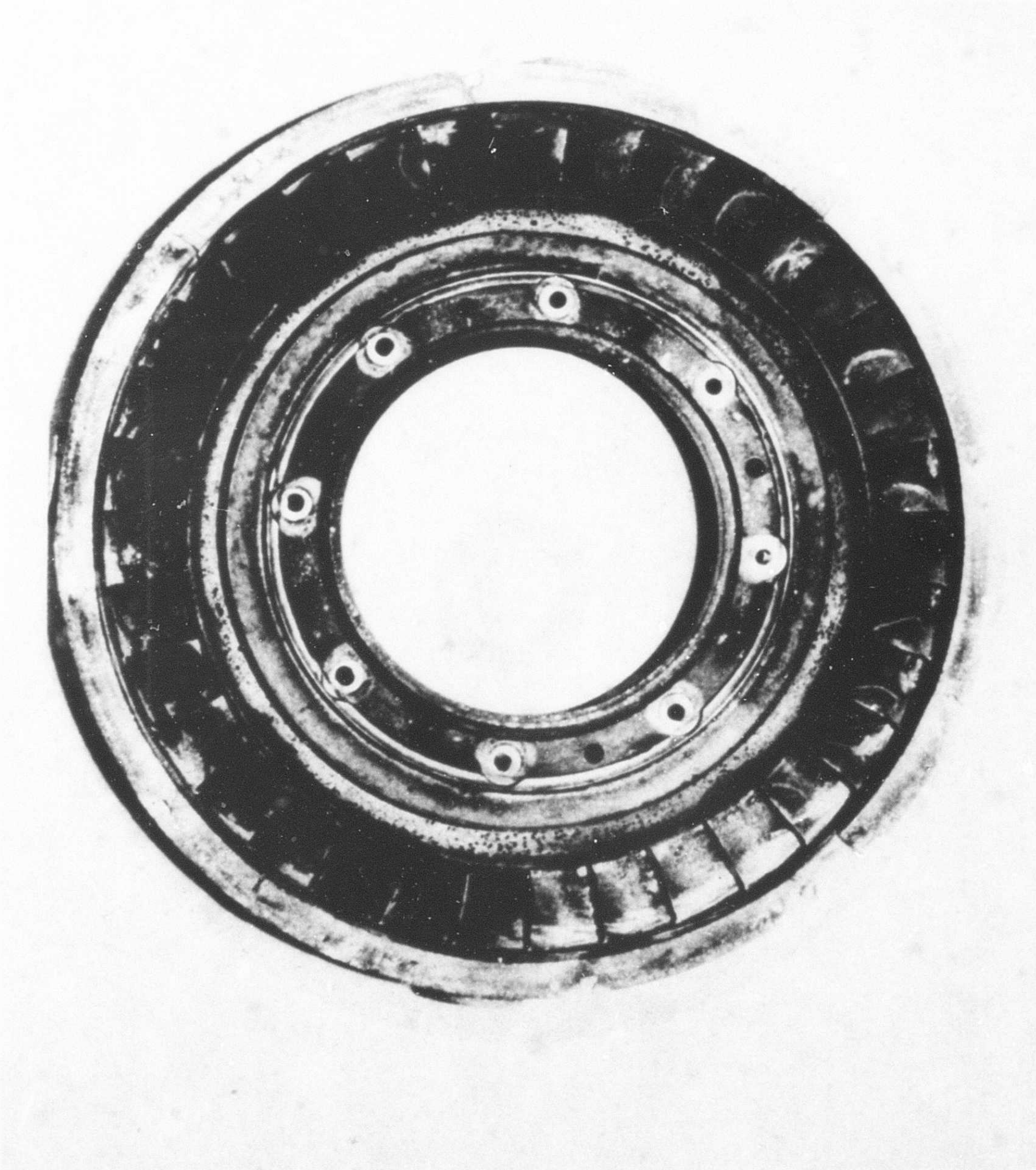


Figure 2. First-Stage Nozzle, Pre-Test Condition.

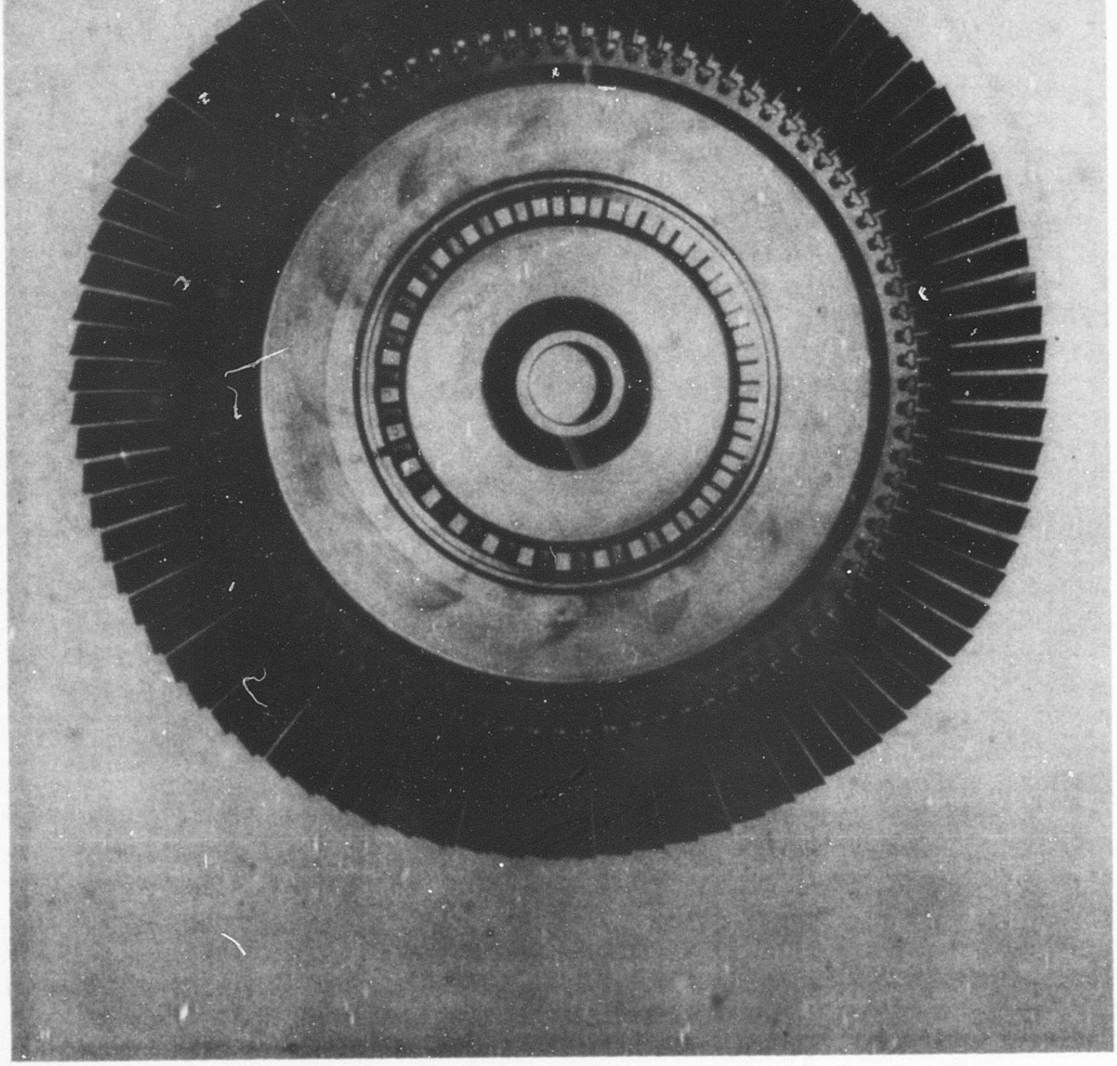


Figure 3. First-Stage Turbine Wheel, Pre-Test Condition.

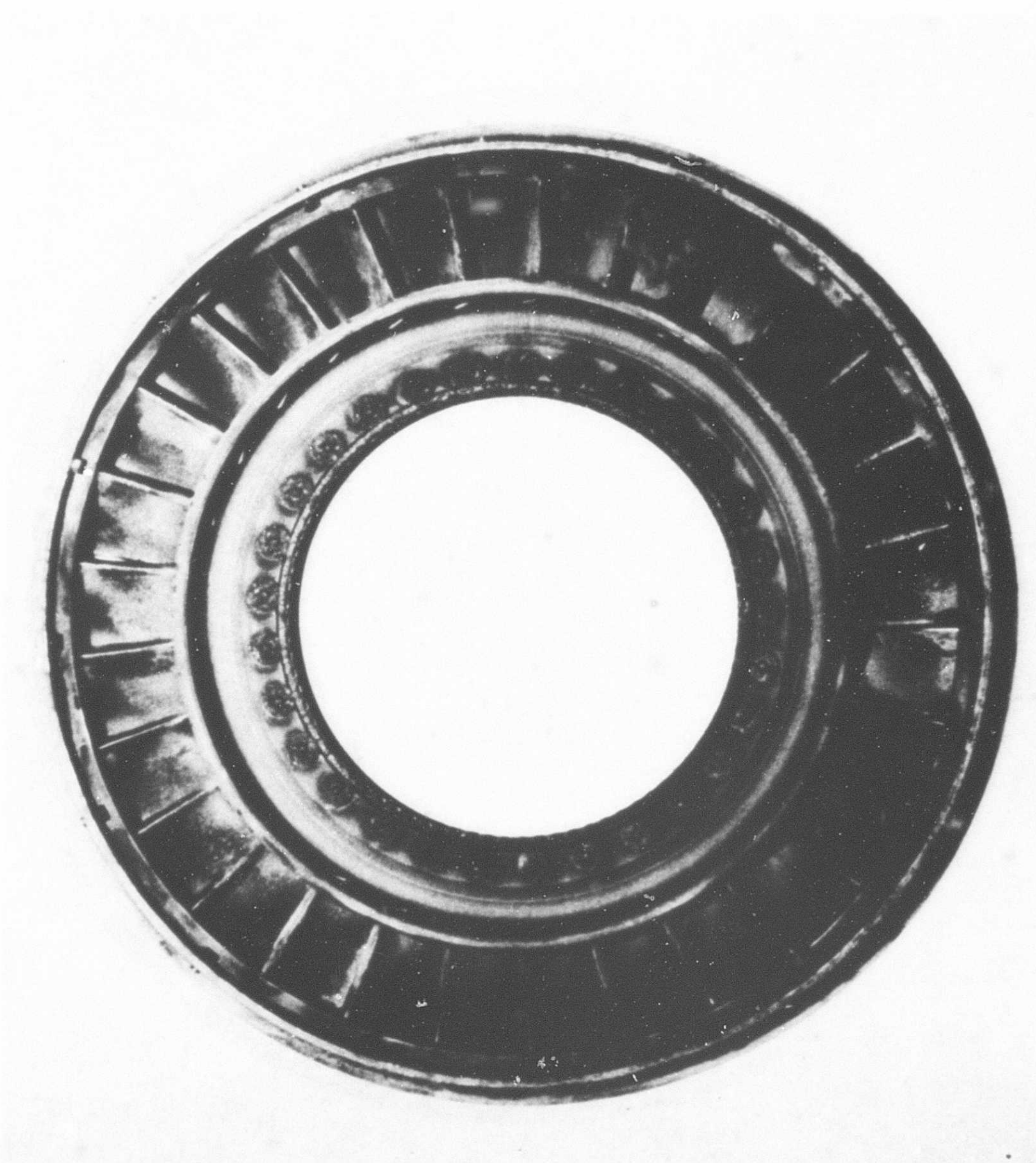


Figure 4. Second-Stage Nozzle Before Test, Leading Edge.

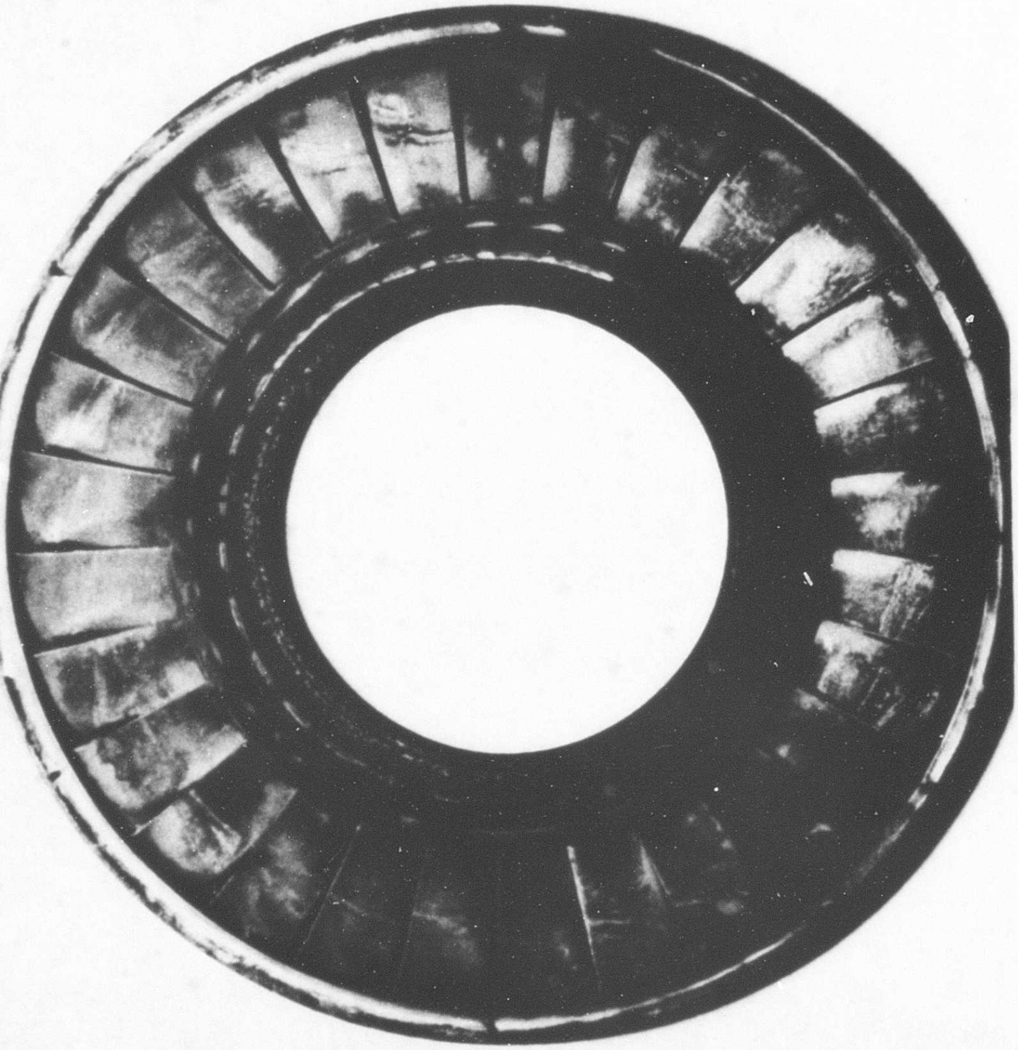


Figure 5. Second-Stage Nozzle Before Test, Trailing Edge.

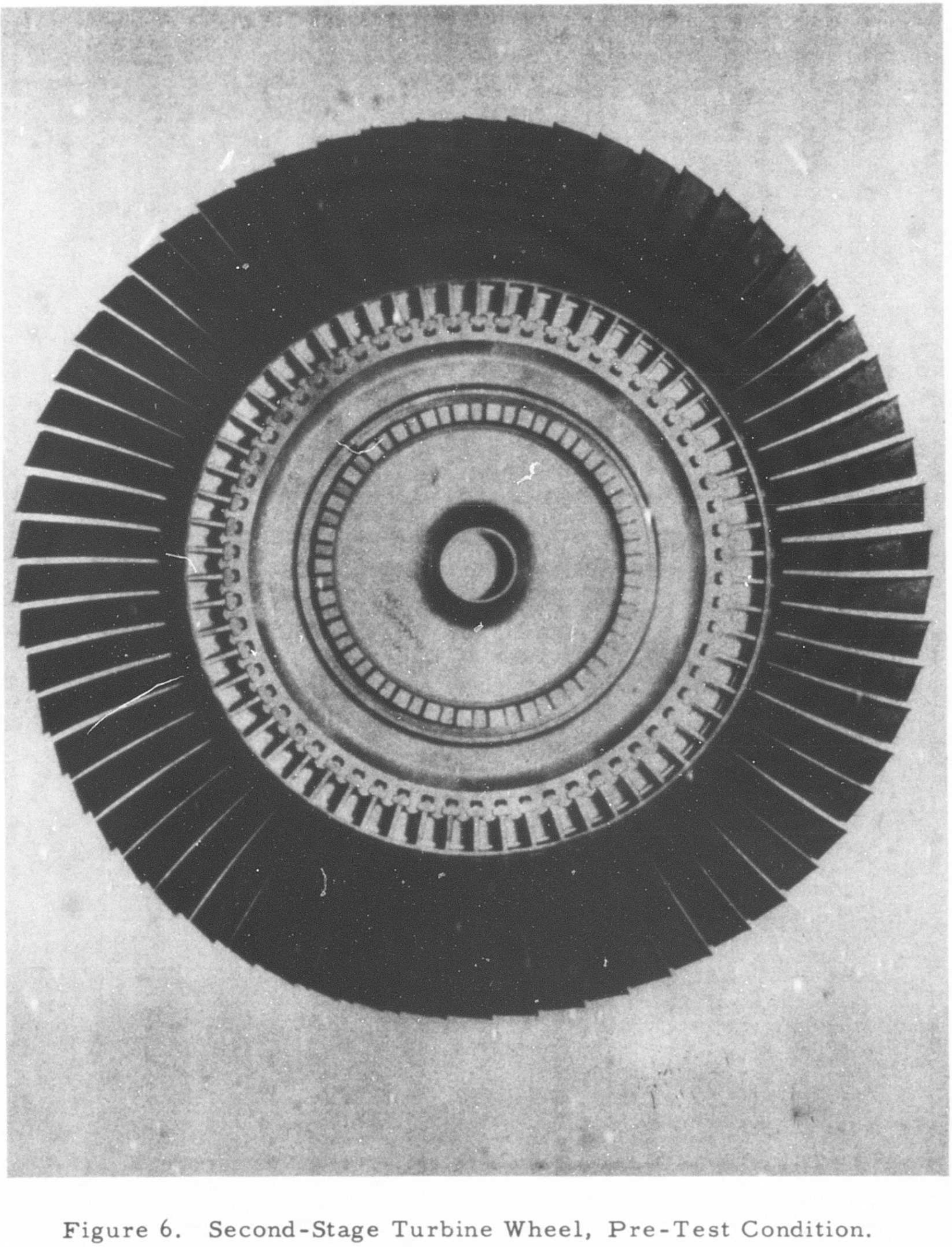


Figure 6. Second-Stage Turbine Wheel, Pre-Test Condition.

Figure 7. Clogged Secondary Fuel Nozzle (Upstream View).

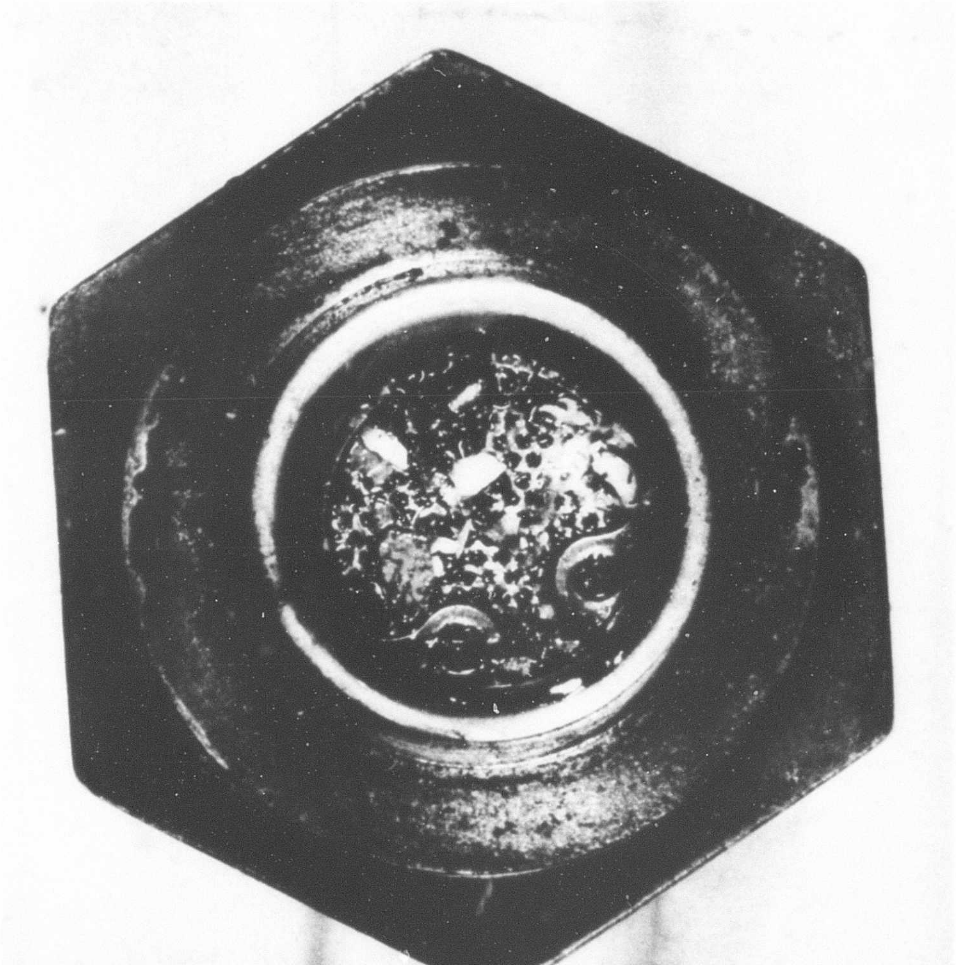


Figure 8. Clogged Primary Fuel Nozzle (Upstream View).

Figure 9. Clogged Primary Fuel Nozzle (Upstream View).

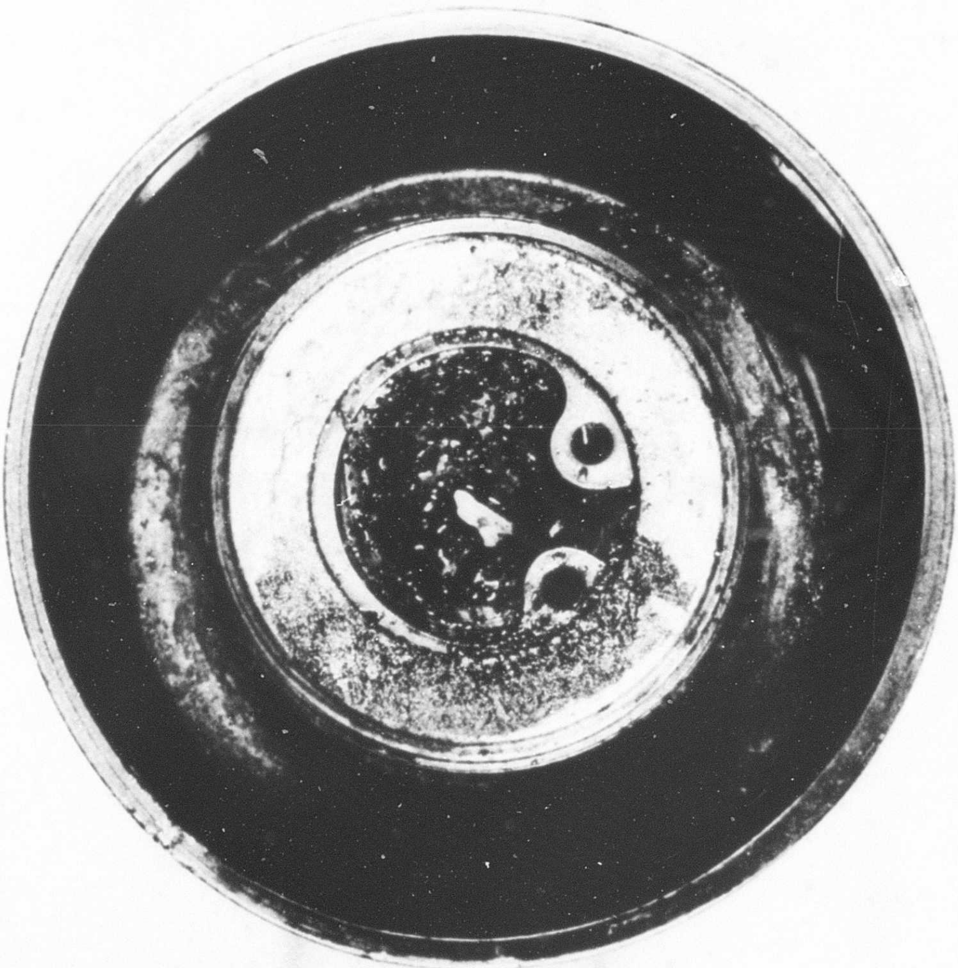


Figure 10. Clogged Secondary Fuel Nozzle With Collapsed Filter Screen (Upstream View).

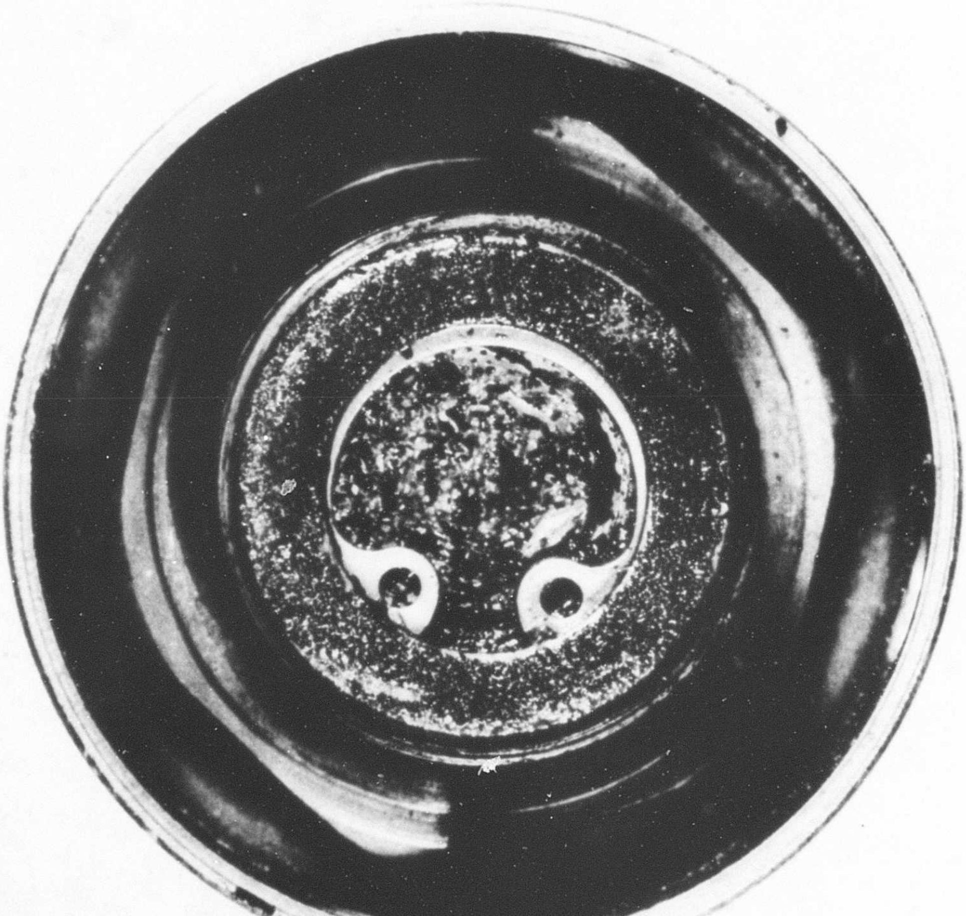


Figure 11. Clogged Secondary Fuel Nozzle With Collapsed Filter Screen (Upstream View).

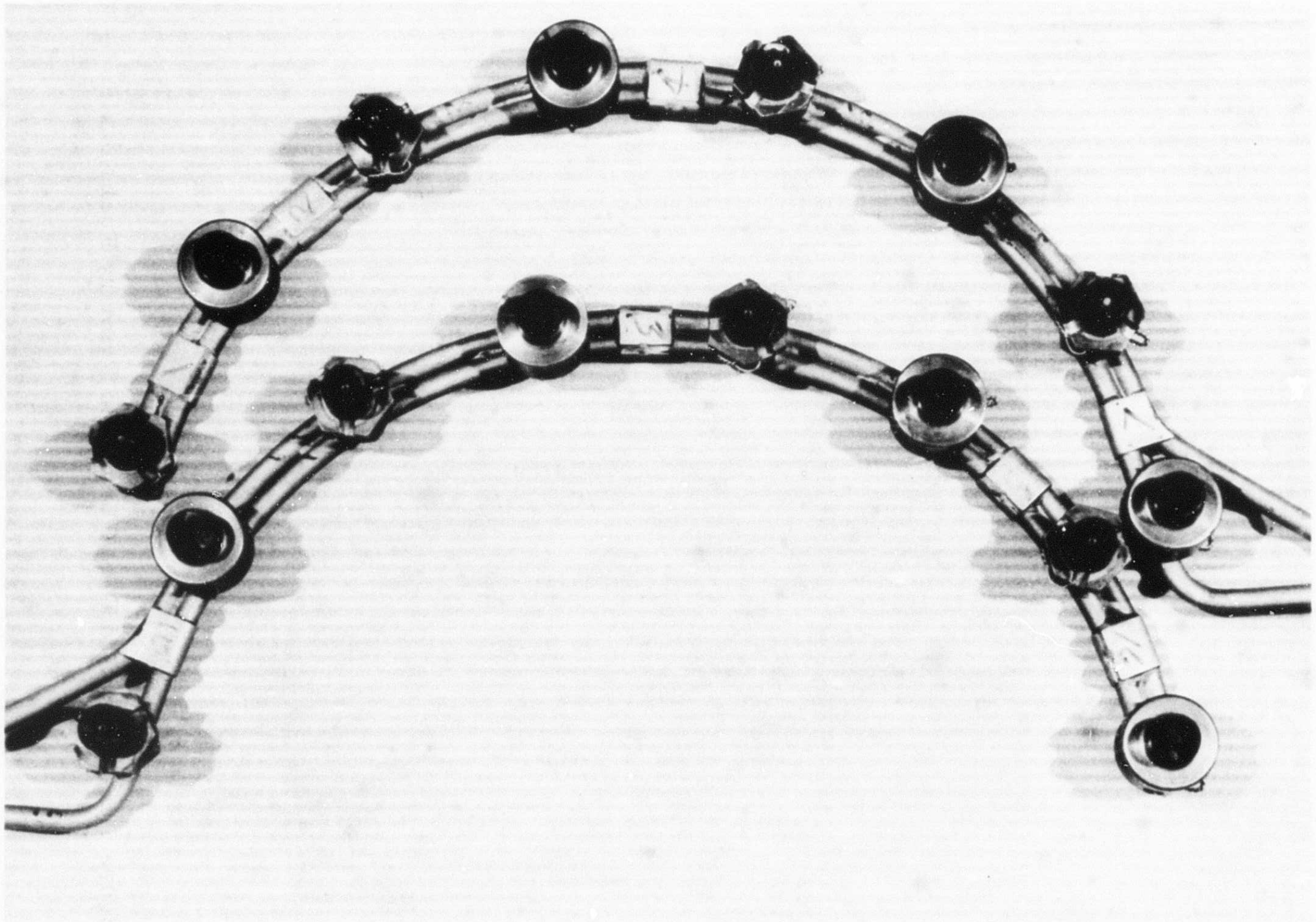


Figure 12. First Set of Fuel Nozzles.

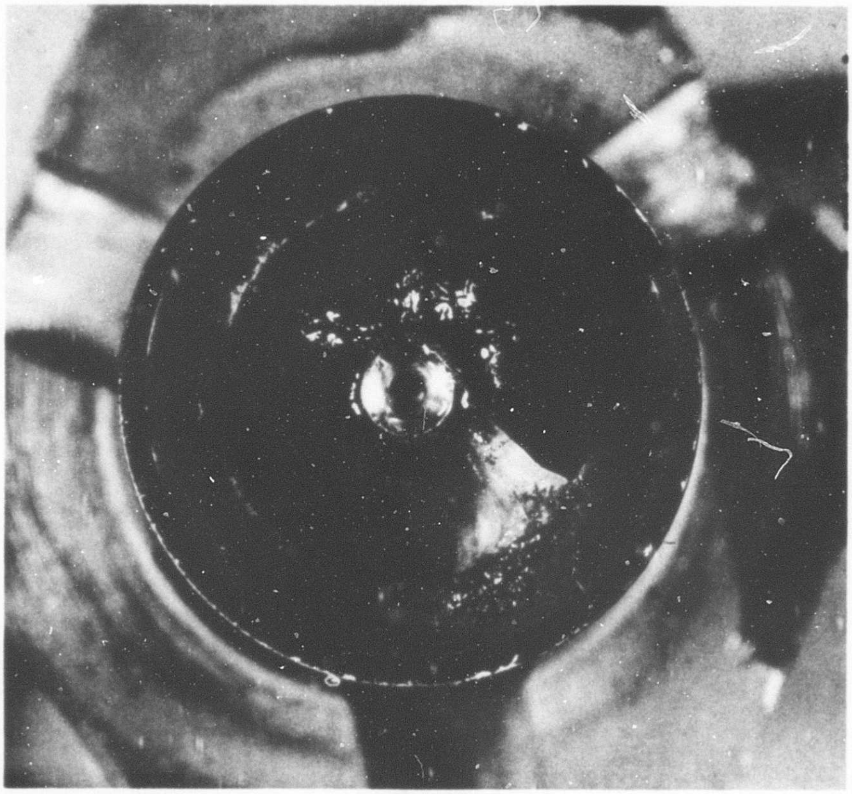


Figure 13. Emulsified Fuel Clinging to Primary Fuel Nozzle.

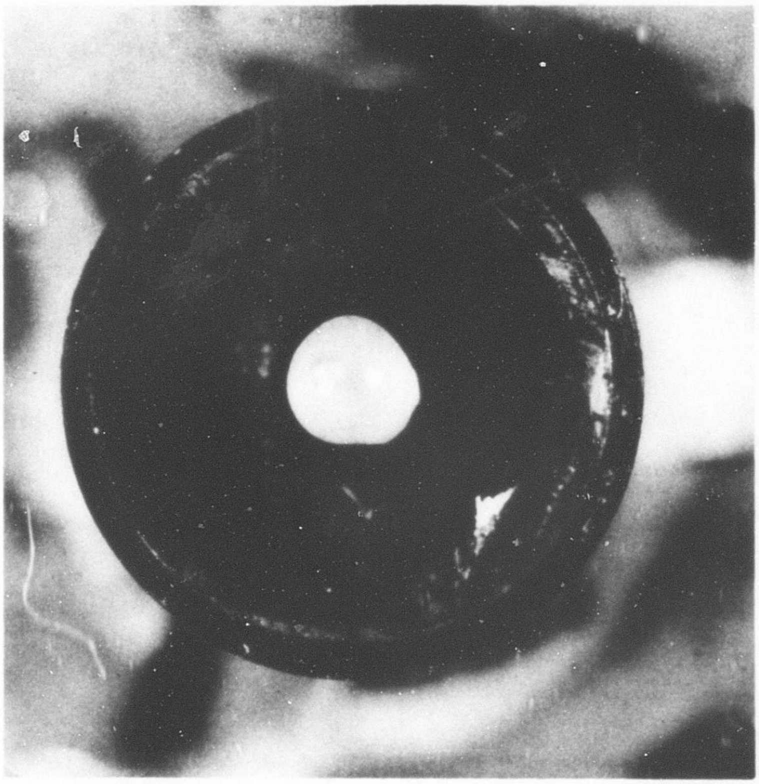


Figure 14. Emulsified Fuel on Primary Fuel Nozzle After Shutdown.

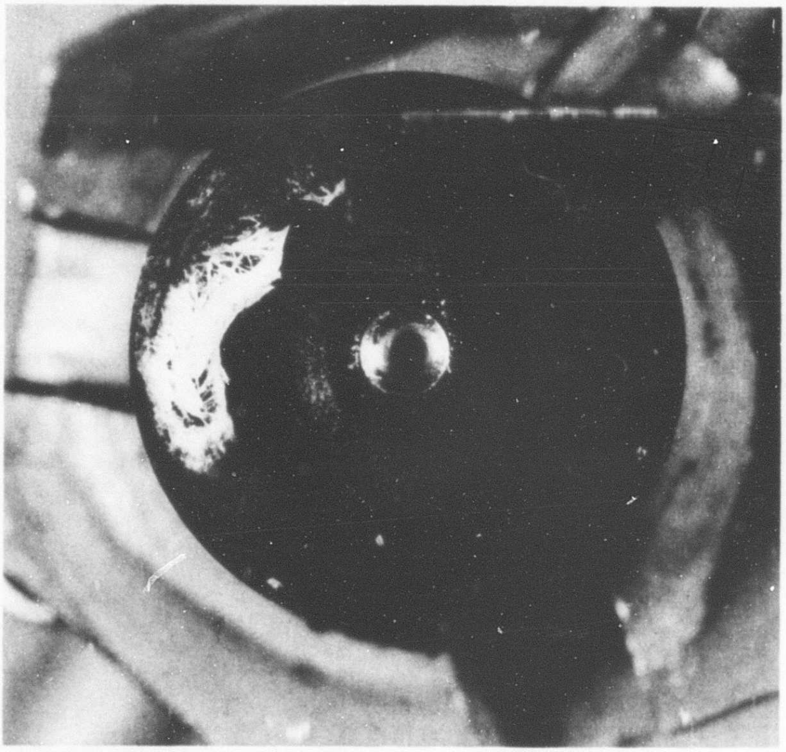


Figure 15. White Residue Found on Fuel Nozzles.

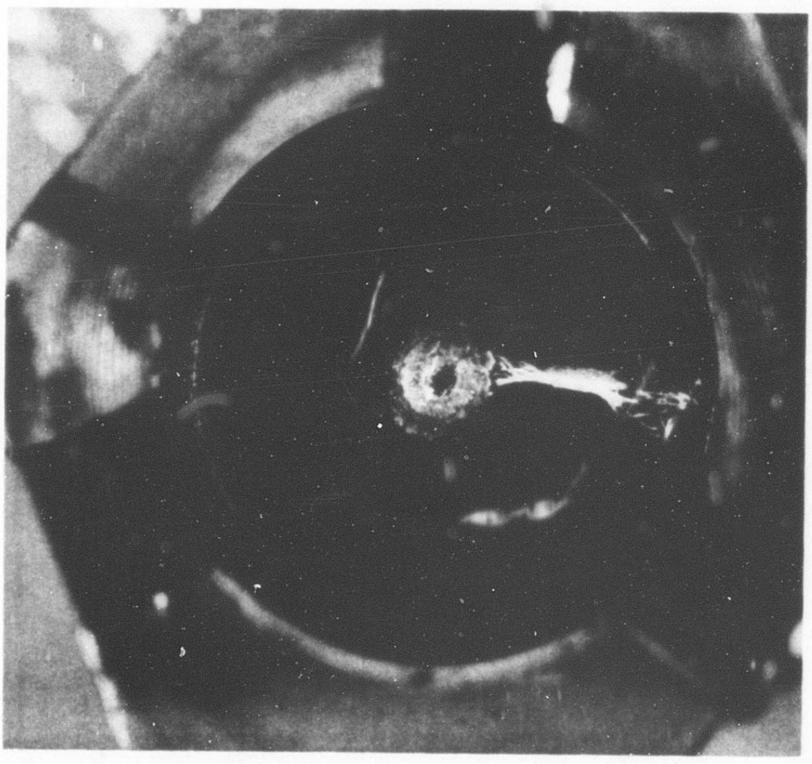


Figure 16. White Residue Found on Fuel Nozzles.

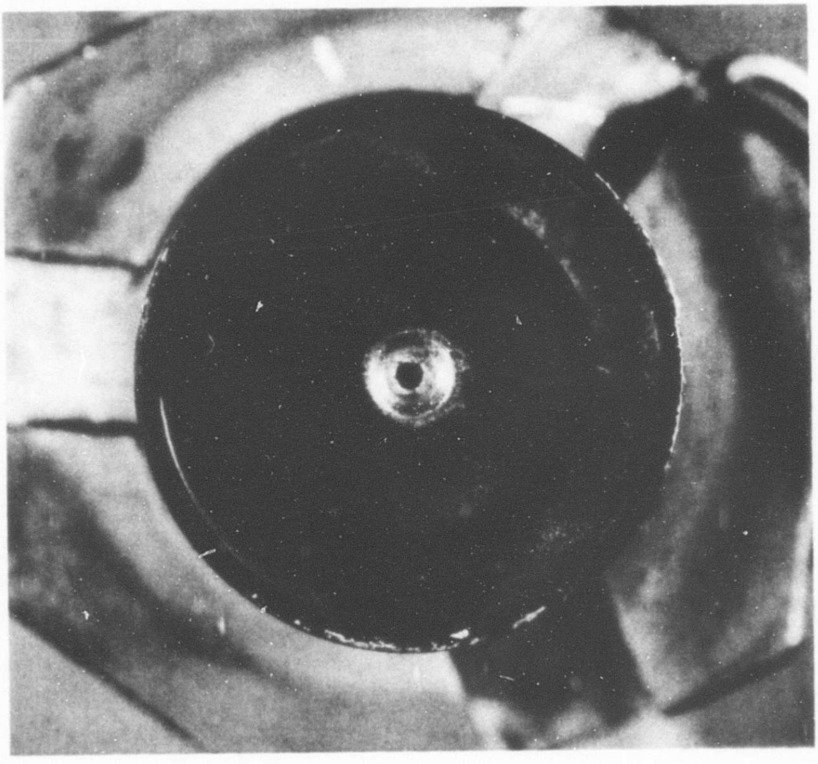


Figure 17. Primary Fuel Nozzle Coking.

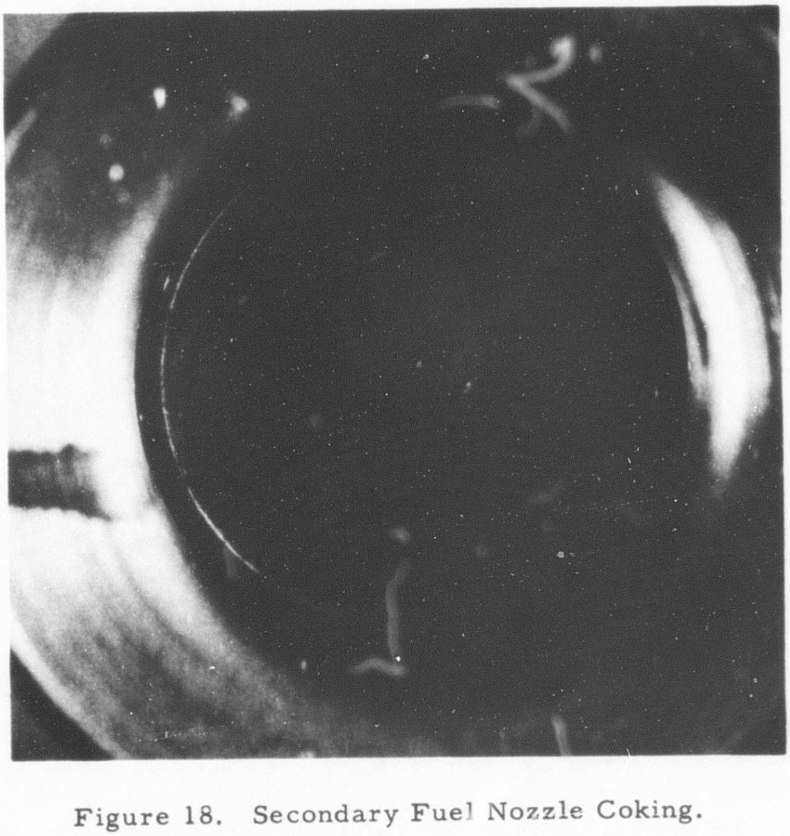


Figure 18. Secondary Fuel Nozzle Coking.

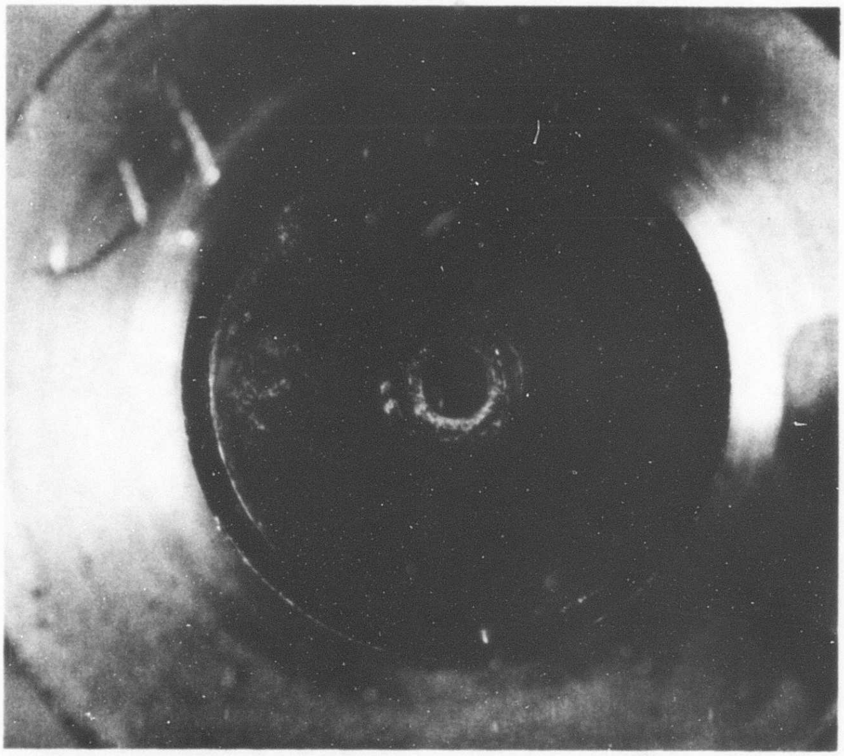


Figure 19. Secondary Fuel Nozzle Coking.

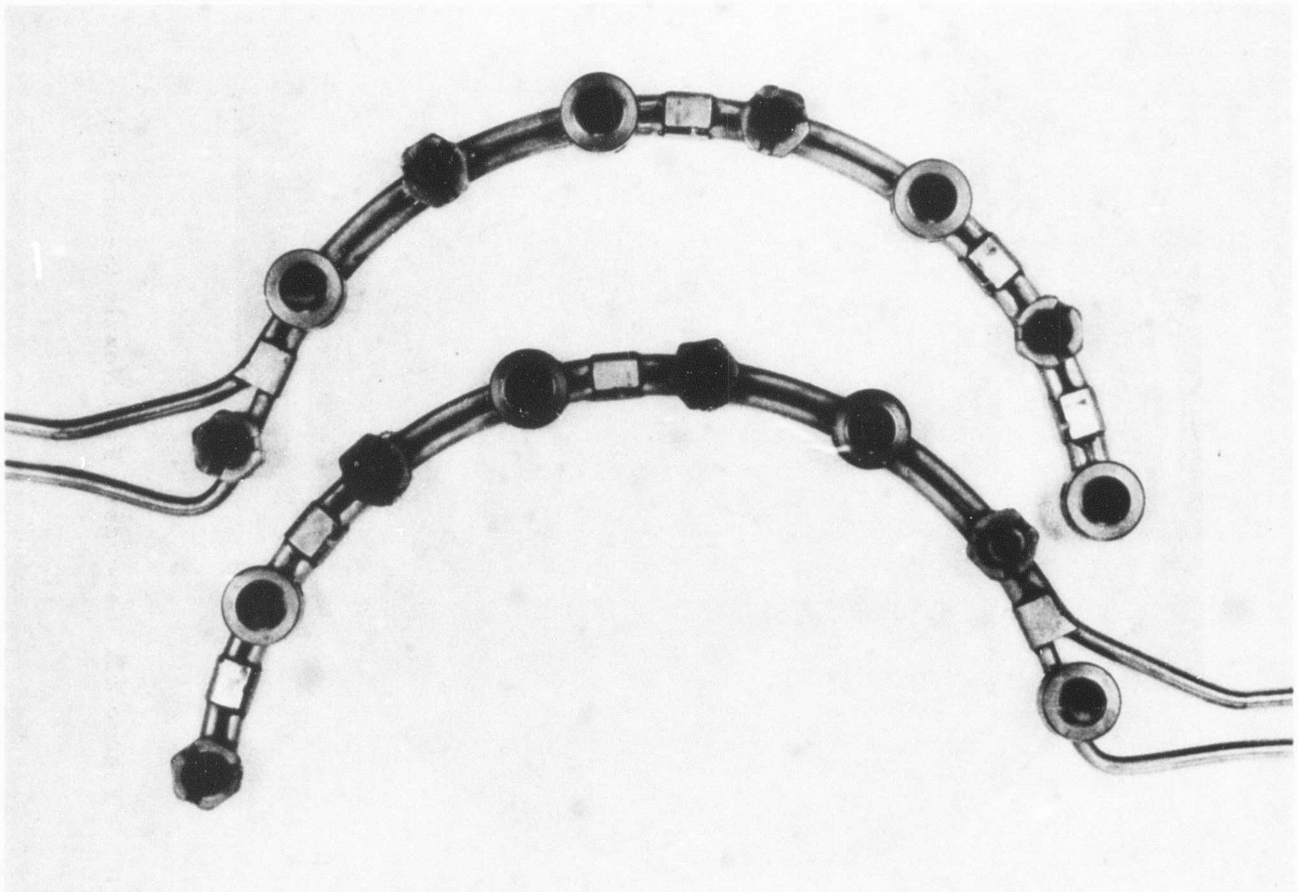


Figure 20. Secondary Set of Fuel Nozzles After Test.

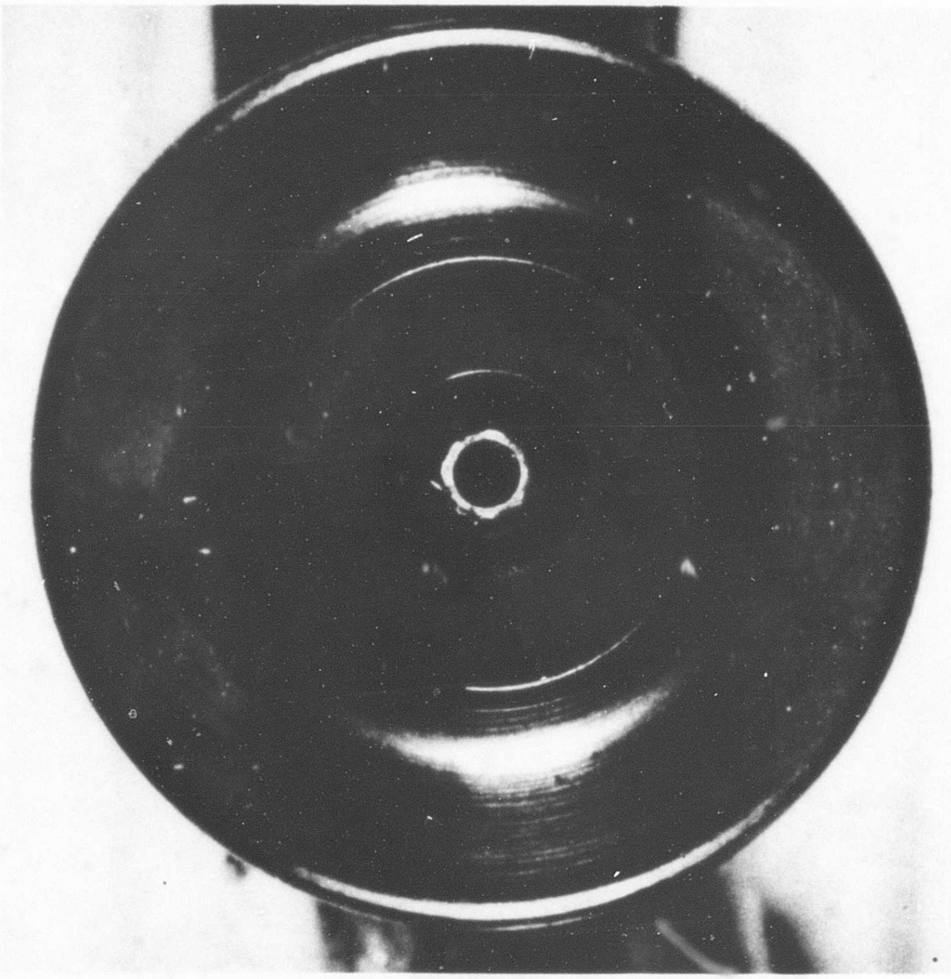


Figure 21. Secondary Fuel Nozzle (Second Set).

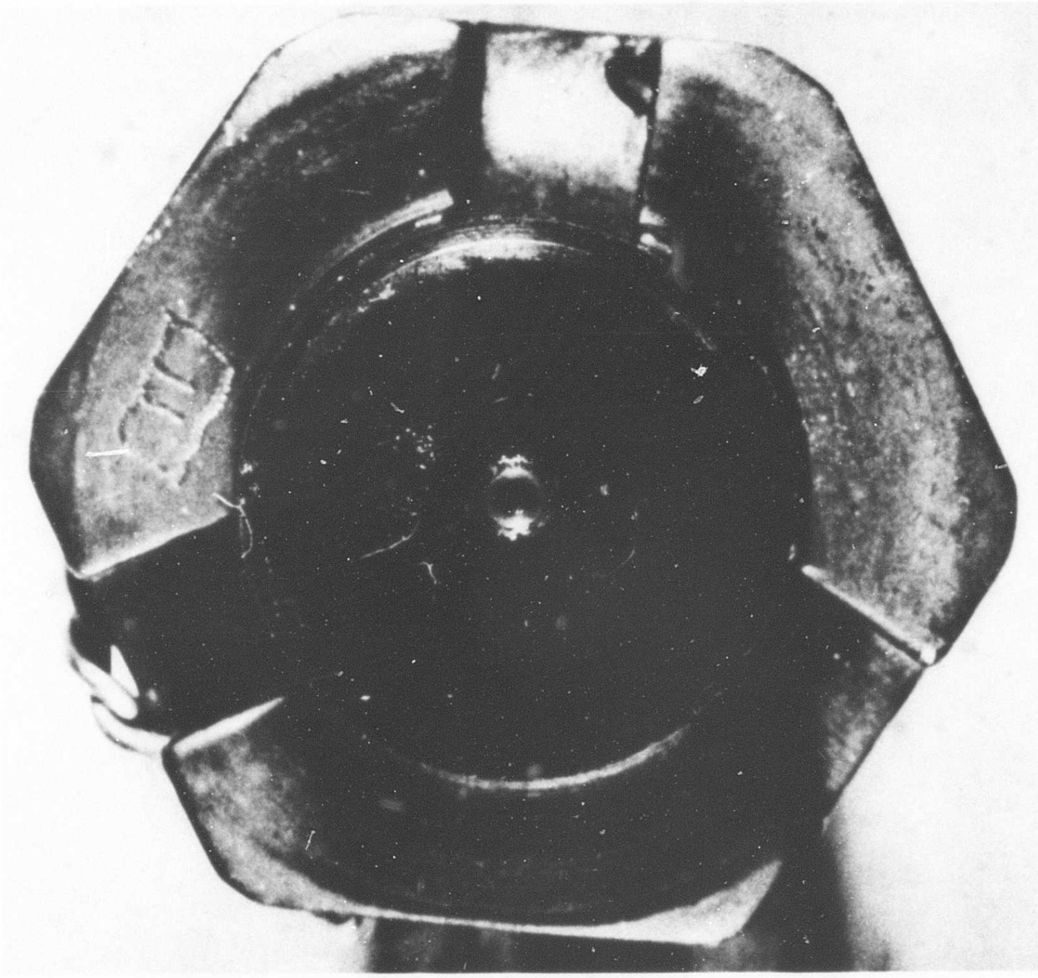


Figure 22. Primary Fuel Nozzle (Second Set).

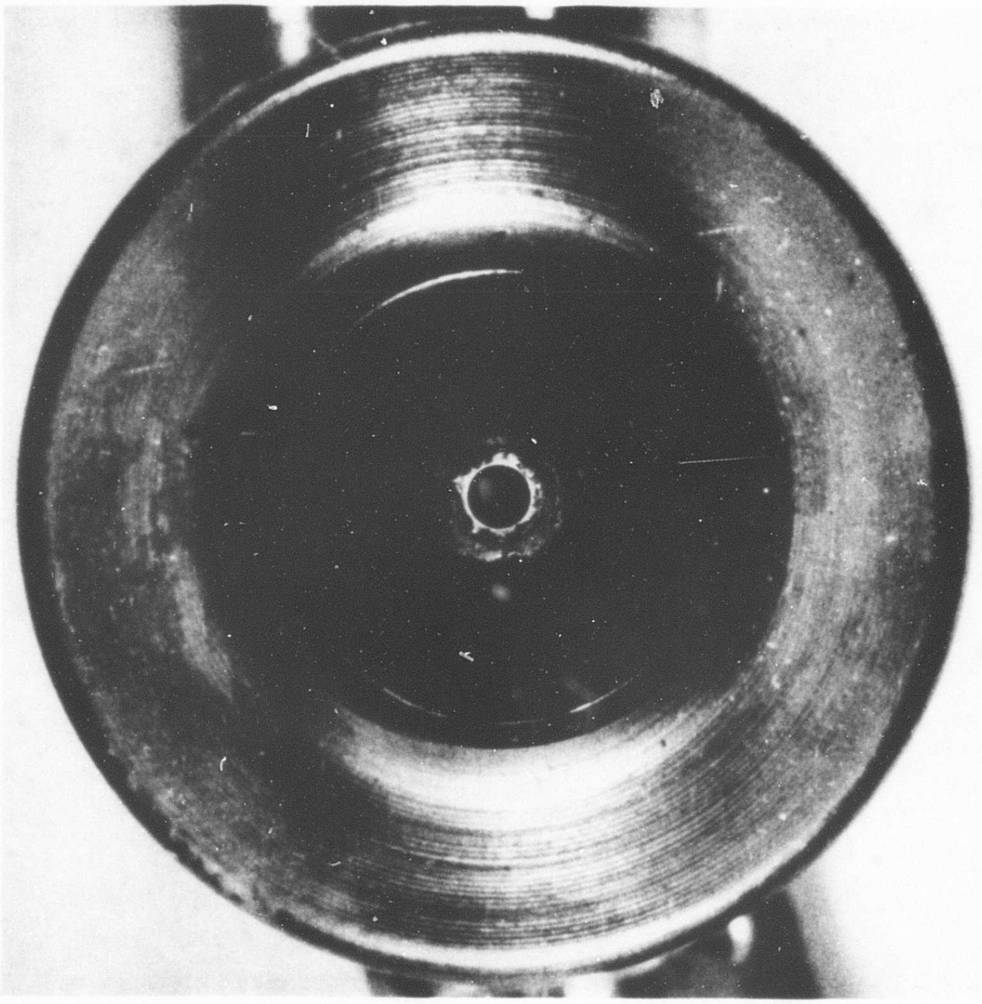


Figure 23. Secondary Fuel Nozzle (Second Set).

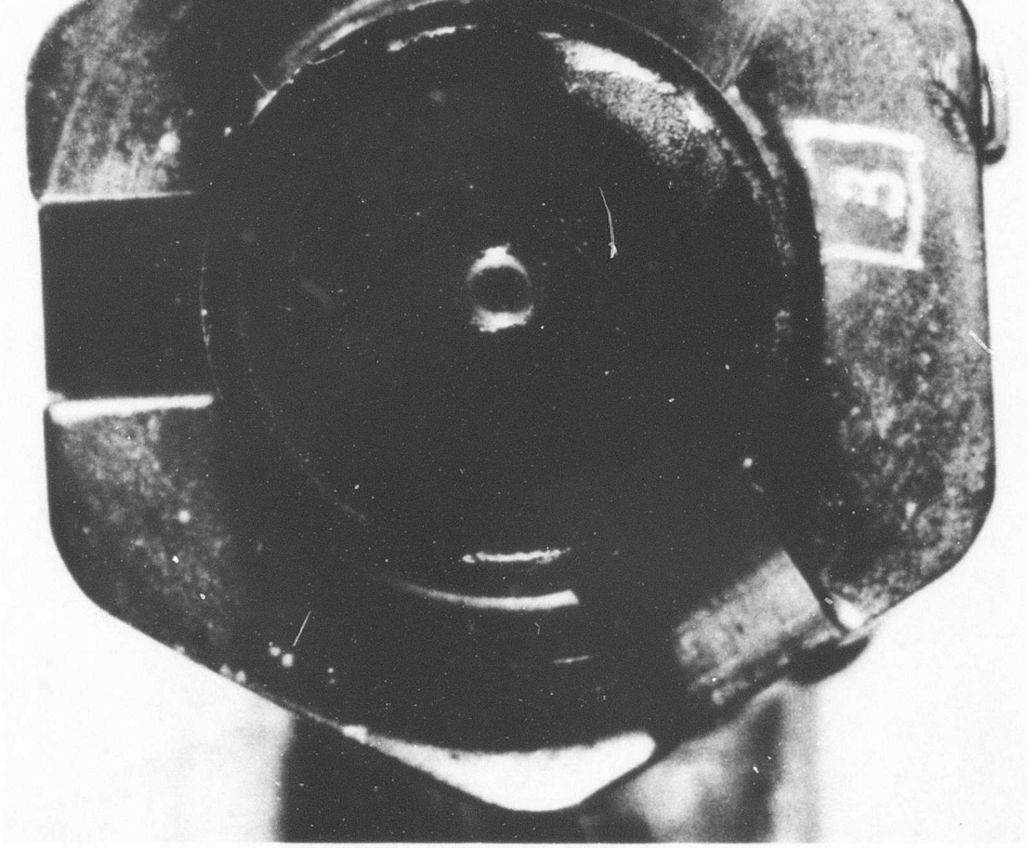


Figure 24. Primary Fuel Nozzle (Second Set).

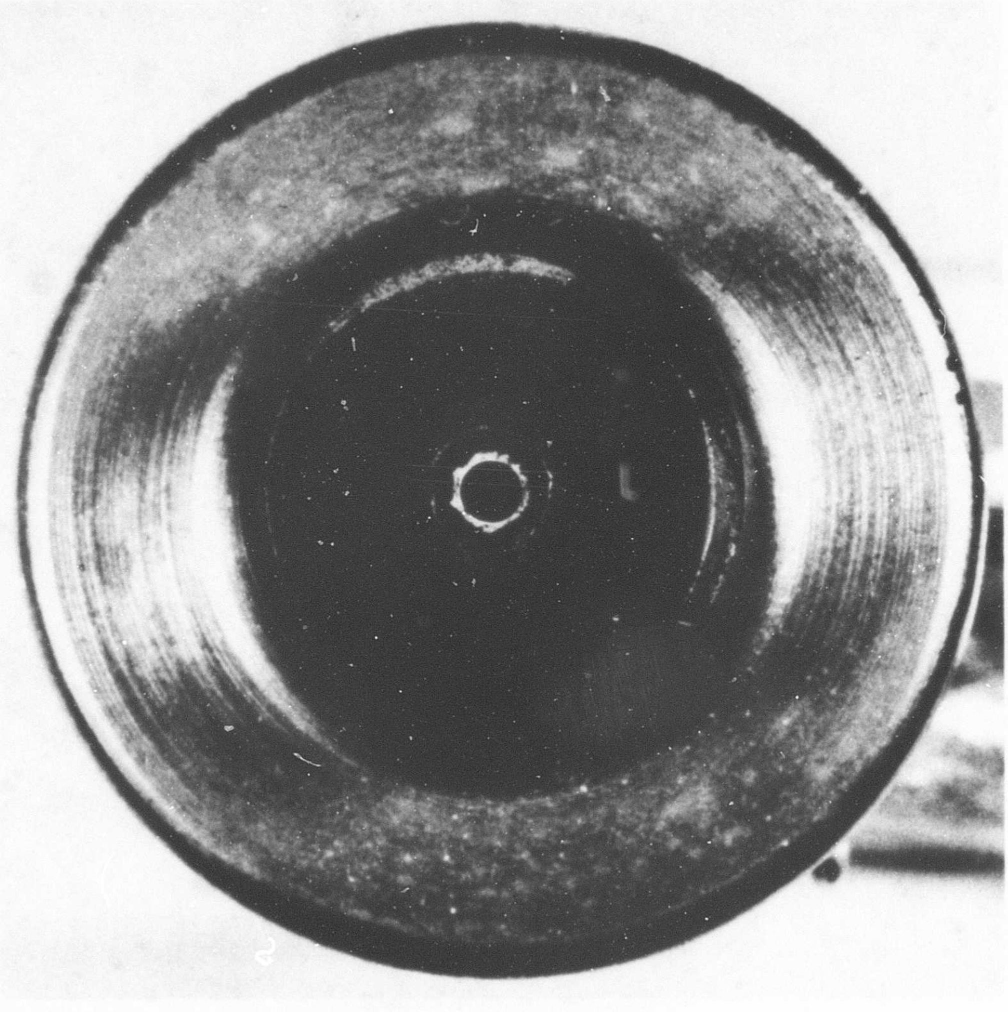


Figure 25. Secondary Fuel Nozzle (Second Set).

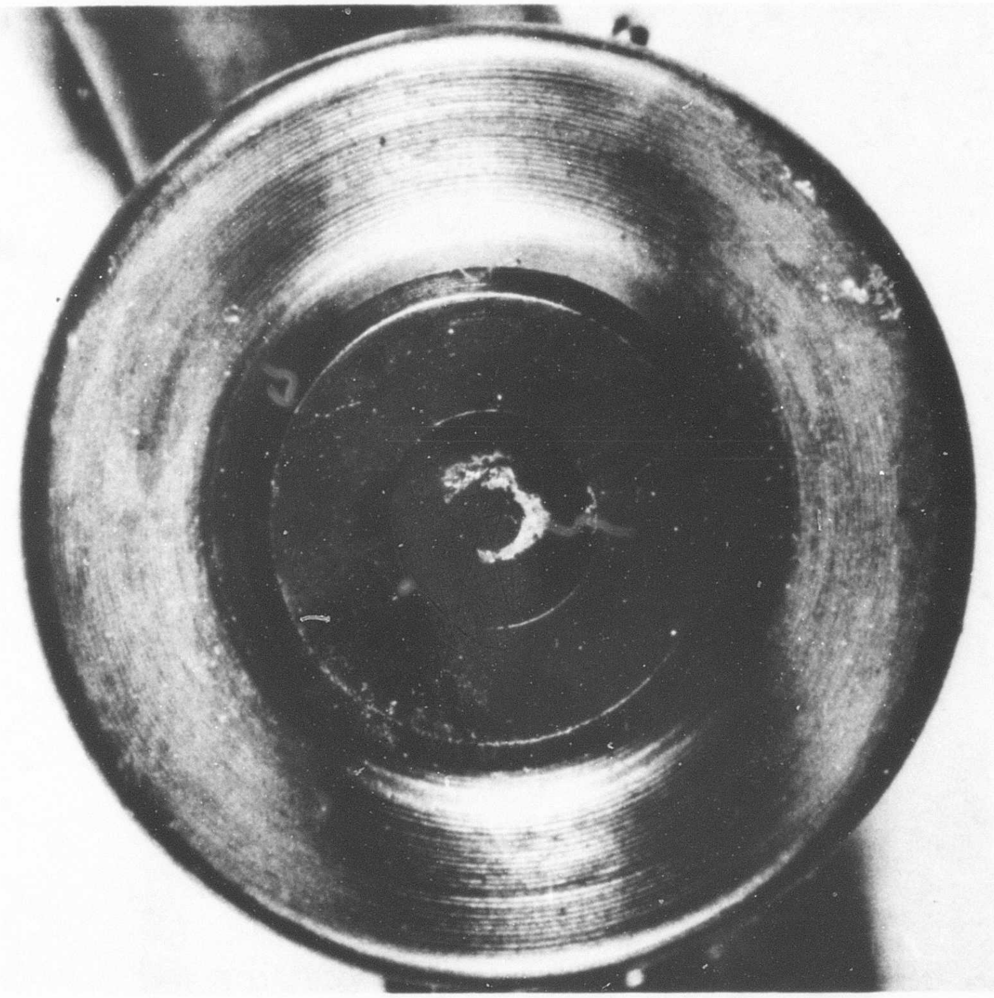


Figure 26. Secondary Fuel Nozzle (Second Set).

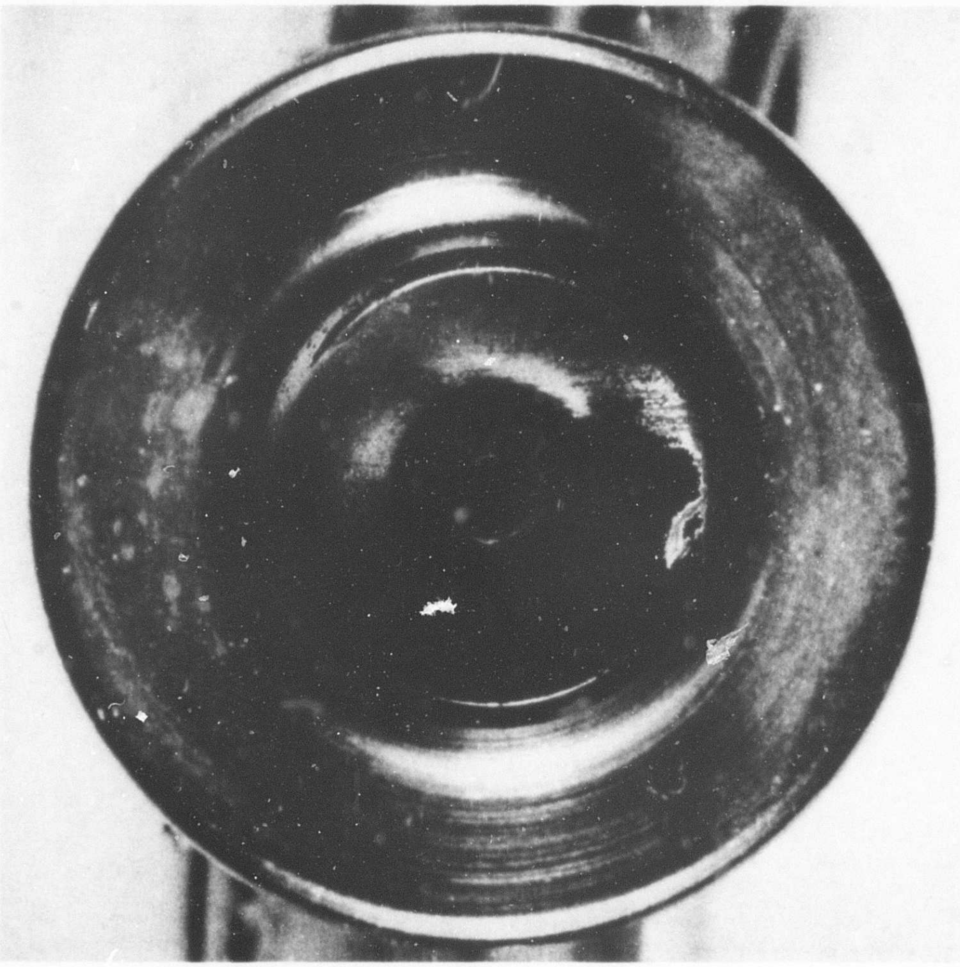


Figure 27. Secondary Fuel Nozzle (Second Set).

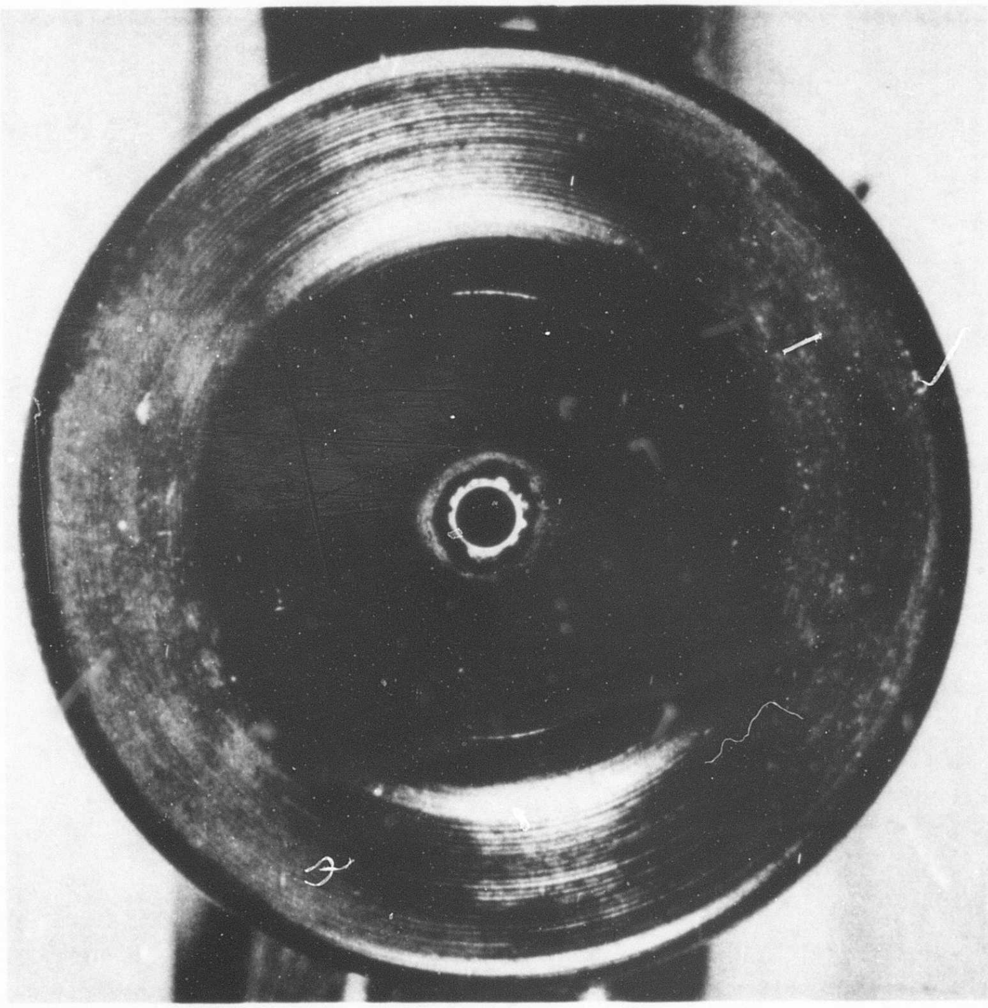


Figure 28. Secondary Fuel Nozzle (Second Set).

Figure 29. First-Stage Nozzle, Leading Edge, Post-Test Condition.

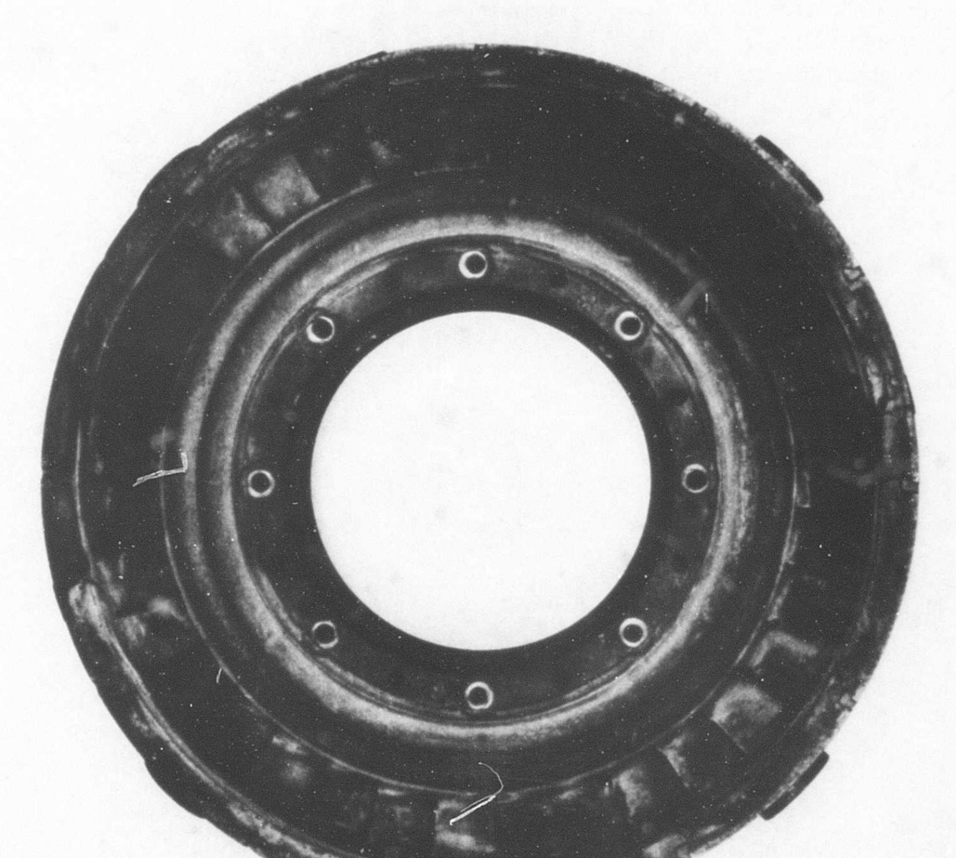


Figure 30. First-Stage Nozzle, Trailing Edge, Post-Test Condition.

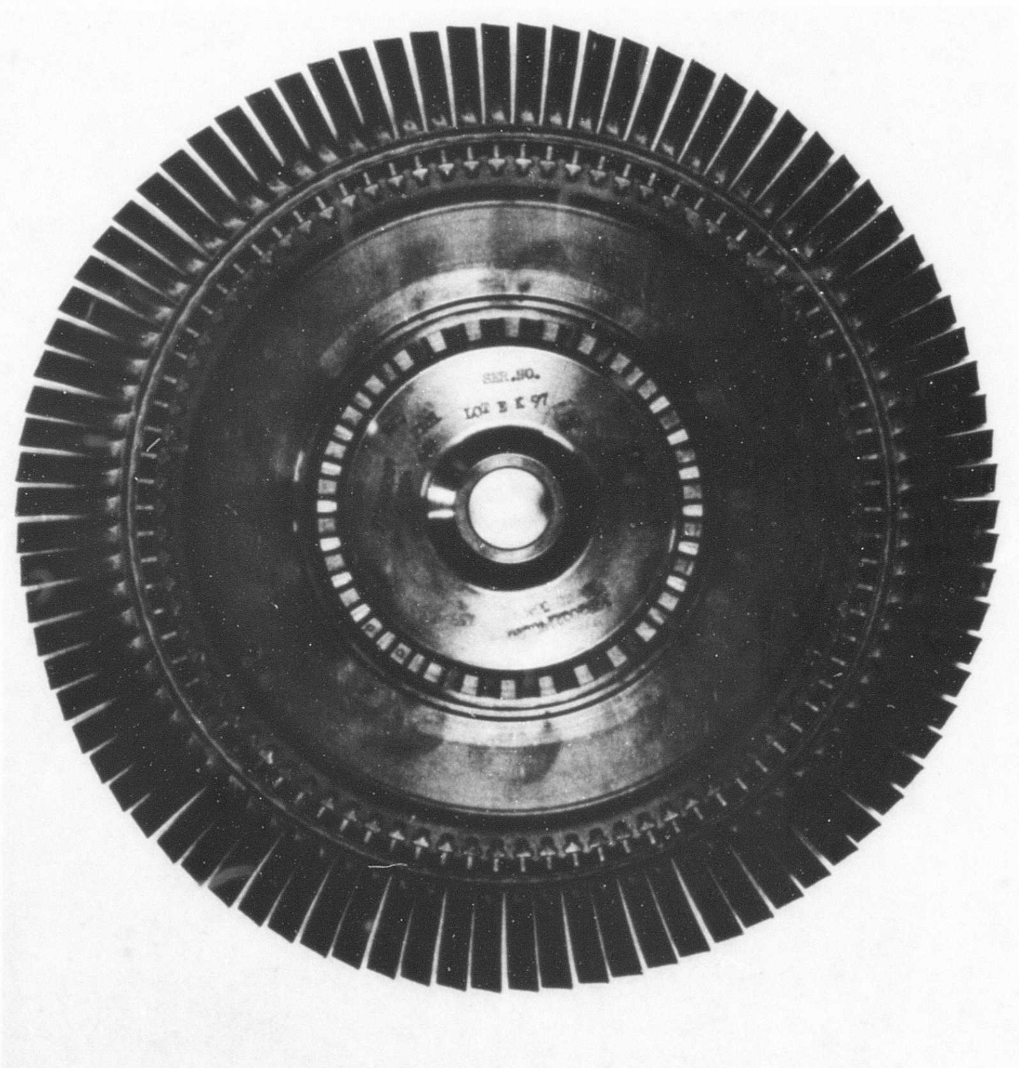


Figure 31. First-Stage Turbine Wheel, Post-Test Condition.

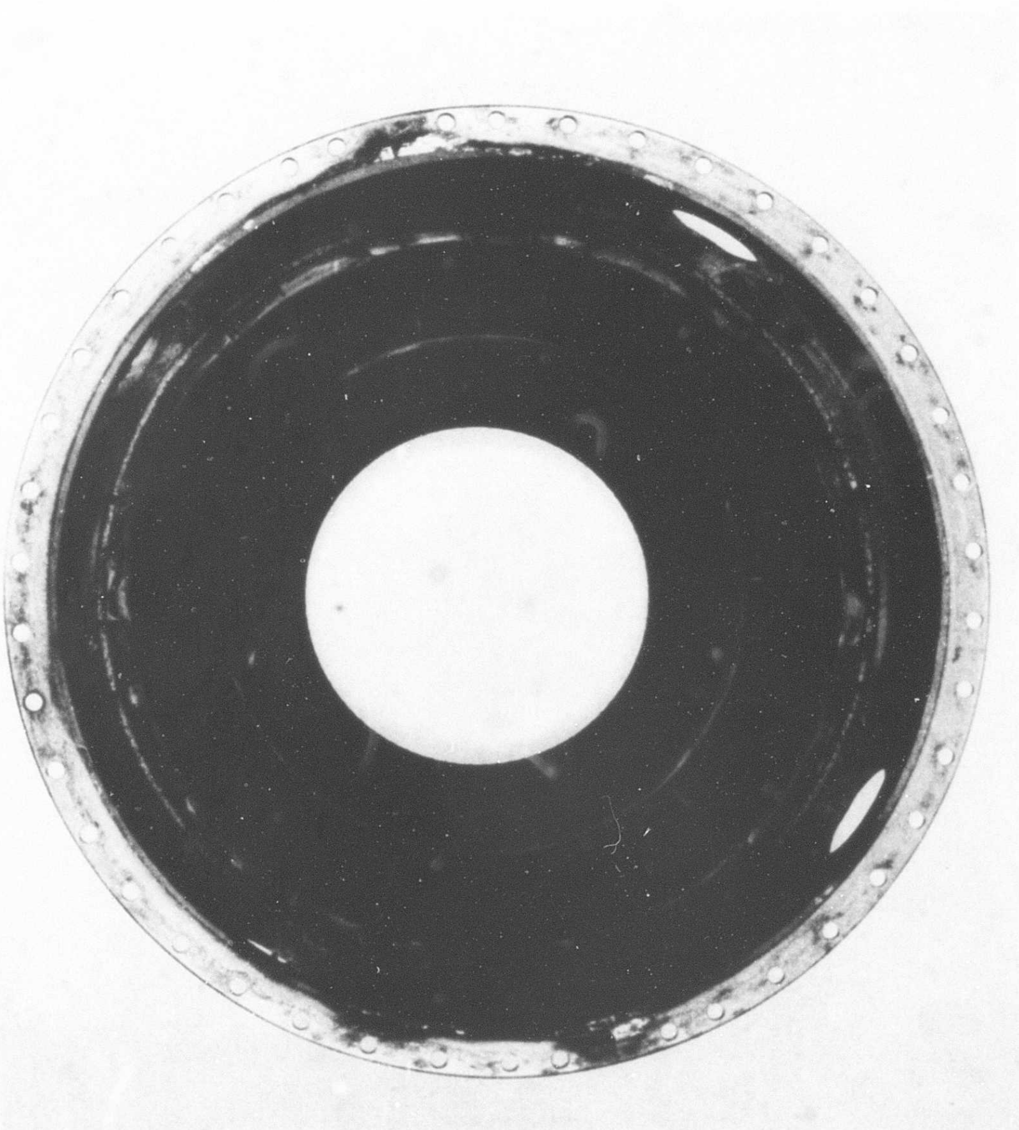


Figure 32. Second-Stage Nozzle, Leading Edge, and Second-Stage Shrouds, Post-Test Condition.

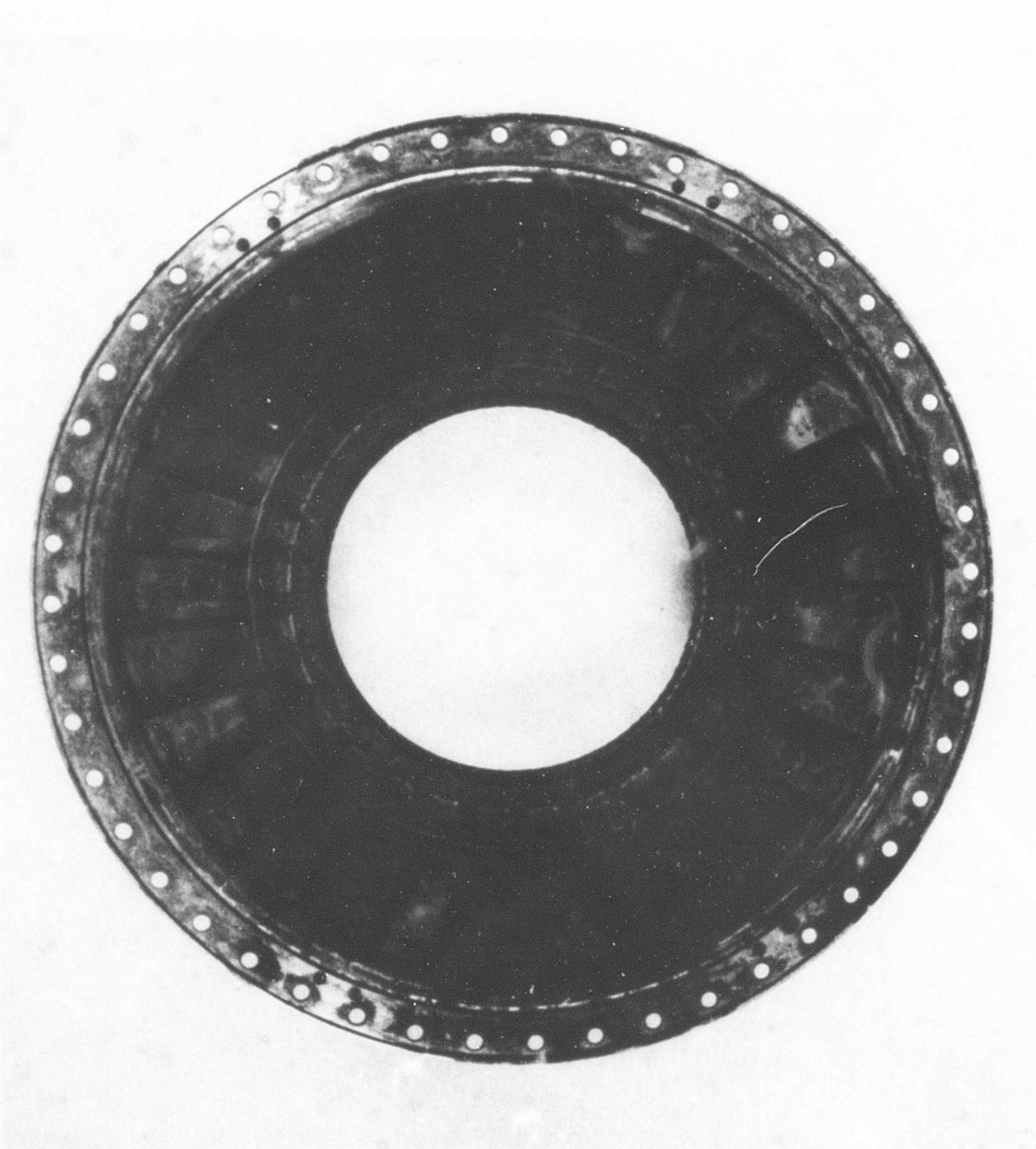


Figure 33. Second-Stage Nozzle, Trailing Edge, Post-Test Condition.

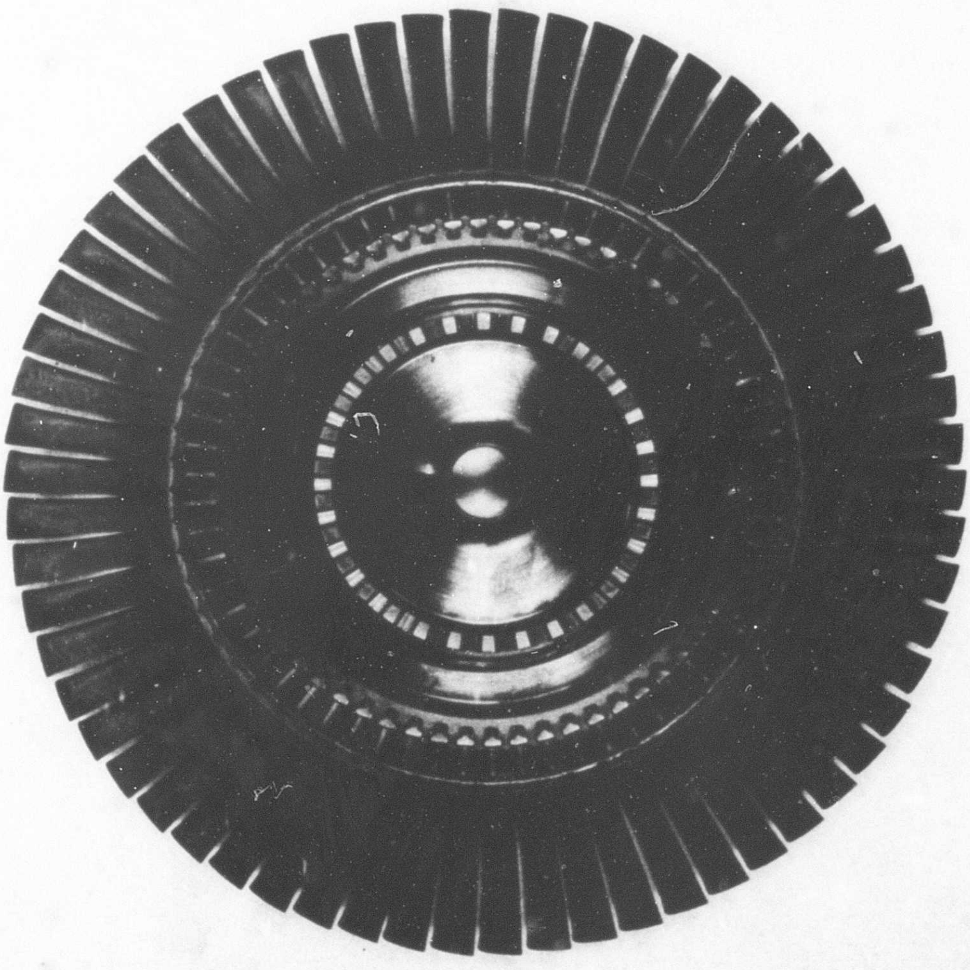


Figure 34. Second-Stage Turbine Wheel, Post-Test Condition.

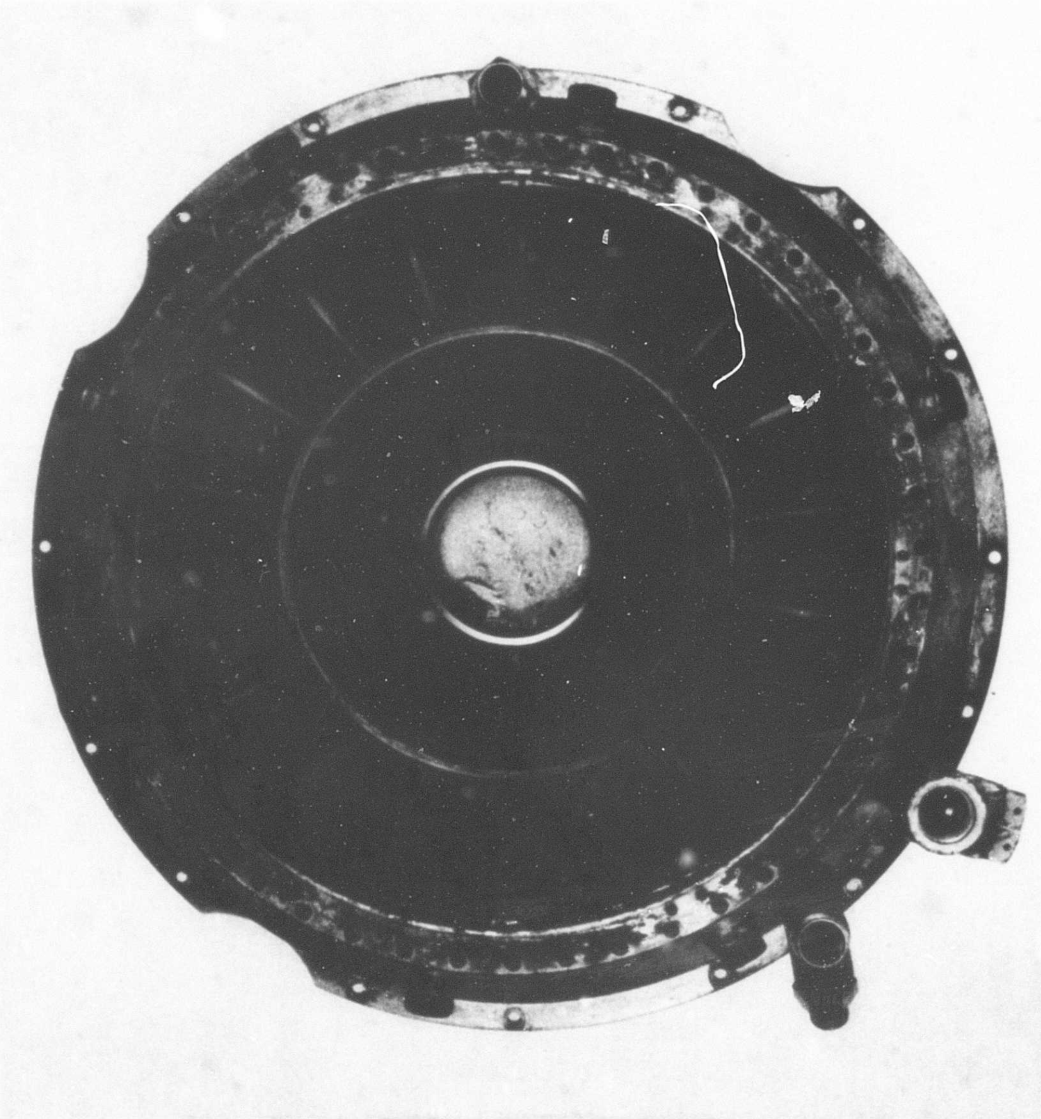


Figure 35. Third-Stage Nozzle Leading Edge, Post-Test Condition.

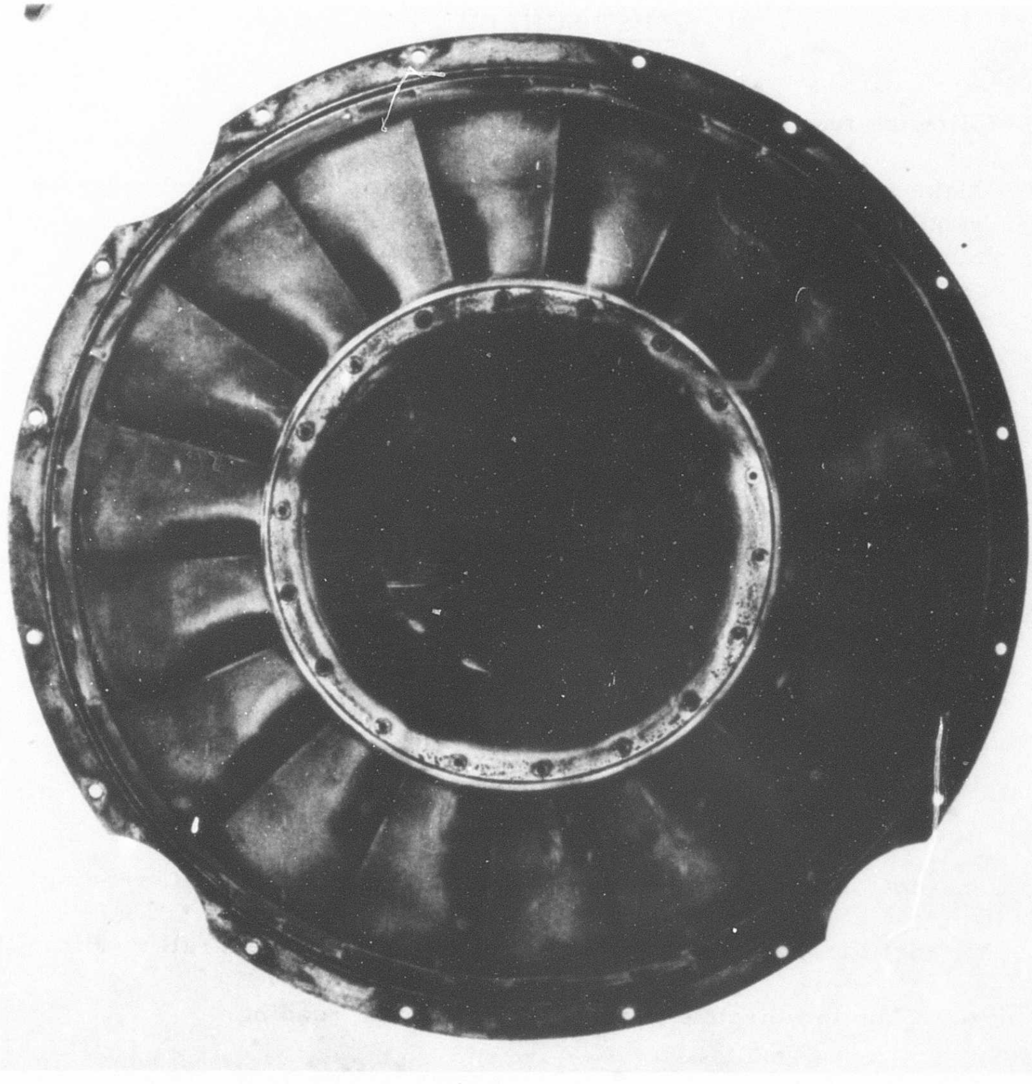


Figure 36. Third-Stage Nozzle, Trailing Edge, Post-Test Condition.

APPENDIX I

TEST SCHEDULE

The following testing was performed:

1. Make a start under engineering supervision on JP-4 and make any required adjustments. Make three to five starts to assure consistent starting time and T_5 readings.

2. Set 975° - 1000°F T_5 and record T_5, N_g, N_f, and T_2. Limit throttle movement so that it cannot be moved beyond the T_5 point. Chop to idle and throttle burst to this point three times. Measure acceleration time with a stop watch.

3. Set T_5 at 1175°F and record T_5, N_g, and T_2 (reduce T_5 so as to limit N_f to 19,500 if necessary). Limit throttle burst to this point three times. Measure acceleration time with a stop watch.

4. Perform the following tests:

   a. Adjust the throttle to obtain T_5 = 1175°F, N_f = 19,500 and take a full reading.

   b. Adjust the throttle to obtain T_5 = 1200°F; do not exceed 21,000 N_f or 26,300 N_g. Take a full reading.

   c. Set the throttle to obtain T_5 = 1125°F and take a full reading.

   d. Set the throttle to obtain T_5 = 1050°F and take a full reading.

   e. Chop the throttle to idle and take a full reading.

5. Shut the engine down and switch to emulsified fuel.

6. Disconnect the fuel supply line from the engine fuel filter to the flow divider end and place it so that fuel will be collected in a container.

7. Disconnect the inlet to the engine fuel pump and operate the emulsified fuel boost pump until nonaerated fuel is present; then reconnect the line.

8. Open the stopcock and crank the engine until emulsified fuel flows from the flow divider inlet line or until over 1 gallon of fuel has been collected. (Caution: observe starter limitations.)

9. Reconnect the flow divider inlet line and make an engine start on emulsified fuel. Power turbine inlet temperature readings may dictate a change in fuel flow adjustments for starting on emulsified fuel.

10. Repeat step 1 on emulsified fuel.

11. Check gas generator speed versus T_2 and power turbine inlet temperature to assure that tuning is consistent with that set in step 1. Note any differences on the log sheet.

12. Repeat steps 3 and 4 using emulsified fuel.

13. Repeat the following cycle until a total of 6 hours of operation has been completed:

    a. Operate for 5 minutes at a power turbine inlet temperature of 1200°F or with power turbine maximum speed at 21,000 rpm, whichever is reached first.

    b. Operate for 1-1/2 hours at a power turbine inlet temperature of 1175°F.

    c. Operate for 25 minutes at a power turbine inlet temperature of 1050°F.

14. Repeat steps 1, 2, and 3.

15. Repeat step 4 using emulsified fuel.

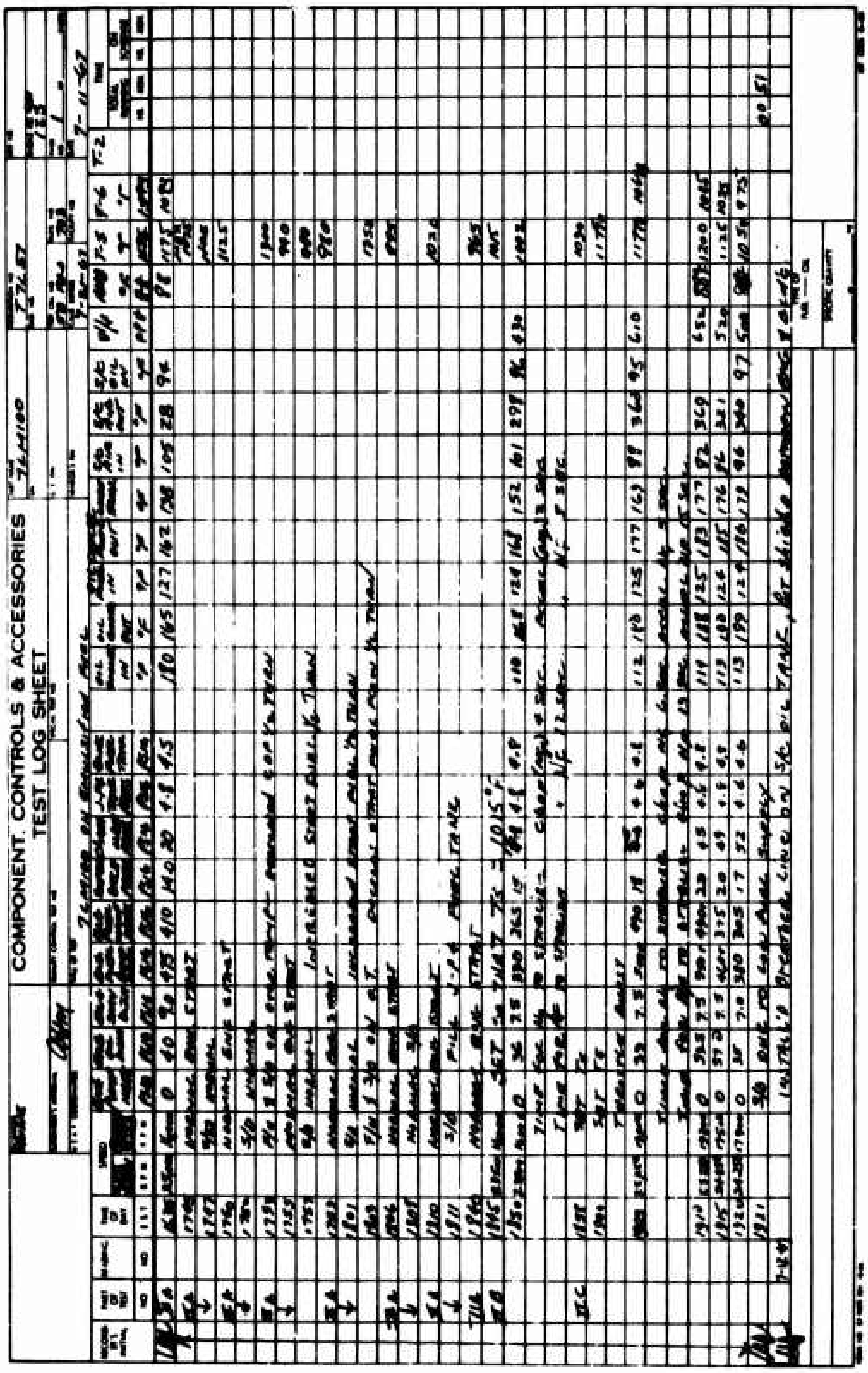
16. Shut the engine down and switch to JP-4 fuel.

17. Start the engine and operate for 30 minutes at a power turbine inlet temperature of 1175°F or with N_f = 19,500 rpm.

18. Repeat steps 1 and 4.

19. Remove the engine from the test cell and flush with JP-4 all facilities that were exposed to emulsified fuel.

APPENDIX II
TEST LOG SHEETS



COMPONENT, CONTROLS & ACCESSORIES TEST LOG SHEET

COMPONENT, CONTROLS & ACCESSORIES TEST LOG SHEET

Part name: 7LM100
Requisition no.: T7667
Test cell no.: 38 Pad · Spec no.: 703 · Date: 7-31-67
Work order no.: 125 · Page no.: 2 · Date: 7-12-67
Supervisor's approval: [signature]
Type of test: 7LM100 ON EMULSIFIED FUEL

Recorder's Initial	Part of Test No	Reading No	Time of Day EST	Speed RPM	Speed RPM	Eng. Pump Inlet PSIG	Eng Oil Disch PSIG	Eng Scav Disch PSIG	Eng Fuel PSIG	PSIG	PSIG	PSIG	JP-4 PSIG	PSIG	ΔP	Oil Cooler In °F	Oil Cooler Out °F	Oil Cooler Fuel In °F	Oil Cooler Fuel Out °F	Lube Tank °F	Surge Air In °F	Surge Air Out °F	Oil In °F	Amb Air °F	T-5 °F	T-6 °F	T-2 °F	Fuel Flow PPH	Total Running HR	Total Running MIN	On Schedule HR	On Schedule MIN
[illegible]		7-13-67	1025			NORMAL START																			925				00	51		
			1028	1836	7000	0	28	8.0	205	160	5.0	0	5.0	4.3		115	121	117	120	85	90	143	85	81	725	705	85		01	01		
[illegible]			1035			NORMAL S/D — PURGE OUT OF JP-4 & FILL FUEL LINES WITH EMUL. FUEL																										
			1100			5 PSIG TANK PRESSURE SUPPLIED ENGINE PUMP INLET EMULSIFIED FUEL																										
			1130			A 30 SEC. ENGINE CRANK SUPPLIED EMULSIFIED FUEL TO THE FLOW DIVIDER — APPROX 50% EMUL. & 50% JP4																										
[illegible]			1145			* NORMAL START ON EMUL. FUEL																			910				01	01		
			1149			S/D NORMAL ~~START~~																							01	05		
			1150			FLU & S/D ON OT (THIS WAS A HOT START)																			1310				↓	↓		
			1154			FLU & S/D ON OT — REDUCED START BY 1/4 TURN																			1250							
			1155	18500	7,550	NORMAL START																			945				01	05		
[illegible]			1200			0	21.5	7.0	215	165	4.0	0	6.6	5.0		111	138	107	120	115	99	142	90	86	710	750	92					
			1201			NORMAL S/D																							01	11		
[illegible]			1430			NORMAL START																			890	~~765~~						
[illegible]			1439			IDLE																			775	765						
[illegible]			1440	18300	6,900	0	24.5	6.5	210	160	3.0	0	6.6	5.0		132	131	114	114	116	107	136	[illegible]		765	760	93	—				
[illegible]			1444			S/D LOSS OF 24 VOLT POWER (110 TO NOBATRON CHARGER)																							01	17		
[illegible]			1445			NORMAL START																			1010							
[illegible]			1454	23900	15,150	0	34.5	8.0	300	265	14.0	0	6.5	5.0		172	166	116	131	137	108	254	95		995	945	82					
[illegible]			1500			TIME FOR NG TO STABILIZE → CHOP NG 5 SEC ACCEL NG 4 SEC																										
[illegible]			↓			" " NF " " → " NF 10 SEC " NF 10 SEC																										
[illegible]			1514			NORMAL S/D COULD NOT RUN STABLE ABOVE 1040/1050 °F (T-5)																							01	46		
[illegible]			1526			NORMAL START (ADJ FUEL RELIEF VALVE 1 TURN CLOCKWISE)																			1035							
[illegible]			1528			S/D NORMAL REPLACED -8 FUEL INLET LINE TO -10 IN SIZE																							01	48		
[illegible]			1608			NORMAL START																			945							
			1610			TIME FOR NG TO STABILIZE CHOP NG = 6 SEC ACCEL NG = 7 SEC																			1175							
[illegible]			1612			" " NF TO STABILIZE " NF 9 SEC " NF 10 SEC																										
[illegible]			1614	25000	19000	0	36.5	7.0	570	485	20	0	7.2	5.8	77	201	189	117	146	179	[illegible]	362	94	88	1170	1082	92					
[illegible]			1625	25300	19300	0	37.0	7.0	610	525	20	0	7.2	5.5	796	220	206	116	149	181	105	385	94		1185	1105	91		2	0	5	

NOTES: * ALL RUN TIME FROM THIS POINT ON EMULSIFIED FUEL

Type of fuel — oil

Specific gravity

COMPONENT, CONTROLS & ACCESSORIES TEST LOG SHEET

Part name: 76M100 | Serial no.: 77657 | No.: 125 | Sheet 3 | Date: 7-13-67 | 7-21-67 | 8022

Type of test: 7LM100 ENGINE ON EMULSIFIED FUEL

Record Initial	Part of Test No	Reading No	Time of Day EST	Speed RPM	Speed RPM	[illegible] PSIG	Ext Oil [illegible] PSIG	Eng Scav [illegible] PSIG	[illegible] PSIG	[illegible] PSIG	[illegible] PSIG	[illegible] Inlet PSIG	JP [illegible] PSIG	[illegible] PSIG	C_p/ρ	Oil In °F	Oil Out °F	[illegible] Fuel In °F	[illegible] Fuel Out °F	[illegible] Tank °F	[illegible] Air In °F	[illegible] Air Out °F	[illegible] Oil In °F	Amb Air °F	T-5 °F	T-6 °F	T-2 °F	Fuel Flow PPH	Total Running Hr	Total Running Min	On Schedule Hr	On Schedule Min
[illegible]	·	[illegible]	1635	29750	18000	0	24.5	7.0	540	440	17.0	0	72	5.8	74	228	213	117	151	138	95	340	101	86	1125	1060	[illegible]	—	2	15		
[illegible]			1640	23500	16000	0	33.0	7.0	410	330	20.0	0	72	5.8	65	229	217	114	146	99	93	297	103	96	1055	1010	91	—				
[illegible]			1642			Normal S/D (Fill fuel tank to 50 gal level)																										
[illegible]			1715			Normal start																			895							
[illegible]			1716	28,300	19,300	0	37.0	7.5	560	465	20.0	0	7.10	5.4	75.5	210	197	117	147	188	95	380	99	90	1180	1057	94	—				
[illegible]			1735	28,250	19,500	0	36.5	7.5	625	520	20	0	7.10	5.4	79.0	240	226	122	152	207	95	395	106	90	1170	1075	90	—				
[illegible]			1745	28,250	19,400	0	36.0	7.5	630	530	20	0	7.10	5.4	79.0	246	233	126	156	216	[illegible]	385	108	91	1165	1070	88	—				
[illegible]			*1752	20,150	16,700	0	32.5	7.5	470	385	20	0	7.10	5.5	67	250	238	124	152	222	93	315	110	90	1060	1003	92	—				
						Chop to idle and [illegible] accelerated to 1175° T5																										
[illegible]			1757	25,150	19,100	0	35.0	7.5	610	505	19	0	7.10	5.5	77.5	252	236	125	160	225	96	374	109	90	1140	1060	92	—				
[illegible]			1825			Accel to 1175° T5																										
[illegible]			1826	25,500	19,600	0	36.0	7.5	950	830	20	0	7.0	5.4	80.5	258	241	133	168	229	100	383	109	88	1125	1070	89	—				
[illegible]			1835	18,700	7,500	0	20.0	5.5	255	180	4.0	0	7.0	5.5	22.5	247	238	190	186	231	108	157	109	88	670	745	89		↓	↓		
[illegible]			1838			NORMAL S/D (Fuel pump disch creeping to 1400 psig fuel manifold [illegible])																							4	18		
[illegible]	7-13-67					Add 2½ drums of fuel																										
[illegible]	↓					Changed fuel manifolds & install'd [illegible]-flex (-24) hose & 40 micron filter in inlet to fuel pump, fill'd syst with fuel before F/U!																										
[illegible]	7-14-67		1005			Normal start																			855				4	18		
[illegible]			1048			Normal S/D tightened [illegible] & C/case bolts																							4	21		
[illegible]			1125			Normal start																			990				↓	↓		
[illegible]			[illegible]	19000	6700	0	26.0	7.5	210	160	4.0	0	7.4	6.3	21	125	124	111	116	83	105	132	74	73	725	700	82					
↓						Accel to 1200 °F T-5										147	142	112	124	110	95	364	77	70	1205	1044	74					
[illegible]			1135	26000	13550	0	43	9.0	600	490	22	0.0	[illegible]	5.8	92	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓					
↓						Decel to 1175 °F T-5																										
[illegible]			1142	29750	18,900	0	39.0	9.0	525	420	20	0	7.3	5.8	79	176	167	108	130	138	95	357	79	70	1175	1030	74					
[illegible]			1210	29,750	18,800	0	34.5	8.5	550	445	19	0	11.3	10.0	78.5	225	210	113	144	192	77	345	98	[illegible]	1165	1036	71.5					
[illegible]			1240	25,750	18,900	0	34.0	7.5	550	445	18	0	11.3	10	78.5	237	220	109	145	206	[illegible]	355	101	72.0	1180	1045	76.0	[illegible]				
[illegible]			1310			DECELL to 1050 T-5																										
[illegible]			1310	23,150	15,300	0	30	7.0	350	280	13	0	13.7	12.0	62.5	231	214	103	145	205	83	260	101	72.0	[illegible]	[illegible]	76.5					
			1315	12,900	6,800	0	28.5	5.5	205	157	4.0	0	12.3	12.8	20.5	217	208	109	154	205	84	131	110	72.0	700	695	77.0		↓	↓		
[illegible]			1318			NORMAL S/D (Took 2 drums to fill tank) F/O press erratic																							6	14		

NOTES:
* No change in throttle position between these readings.
* Eng lost speed & T-5 (took read @ this condition)

Type of fuel — oil

Specific gravity

COMPONENT, CONTROLS & ACCESSORIES TEST LOG SHEET

Part Name: 7LM100 — Requisition No.: T7L57 — Phone No.: 125
Test Log No.: 58 FAA — Base No.: 703 — Sheet No. 4
Date Started: 7-21-67 — Facility No.: 2022 — Date: 7-18-67
Title of Test: 7LM100 ENGINE ON EMULSIFIED FUEL

Record by Initial	Part of Test	Reading No.	Time of Day	Speed (RPM)	Speed (RPM)	Pump Inlet PSIG	Eng Oil PSIG	Eng Scav PSIG	Eng Fuel PSIG	Fuel Manif PSIG	PSIG	PSIG	J-P4 Tank PSIG	PSIG	C_{D_P} PSI	In °F	Out °F	Fuel In °F	Fuel Out °F	Tank °F	Air In °F	Air Out °F	Oil In °F	Amb Air °F	T-5 °F	T6 °F	T-2 °F	Flow PPH	Total Running HR	Total Running MIN
	7-18		1348			NORMAL START																			955				6	14
			1350			S/D TRIED TO SET 1050 T-5 COULD NOT REACH 1050 T-5 (CHANGED FUEL FILTER)																							6	16
			1413			F/U & S/D ON STALL CONDITIONS																			1125				↓	↓
			1415			F/U & S/D ON STALL CONDITIONS																			1200					
			1416			F/U & S/D ON STALL CONDITIONS ADJ START AIR FLOW) ¼ TURN																			1205					
			1420			F/U & S/D ON " " ADJ " " " THE OTHER WAY ½ TURN																			1265					
			1423			NORMAL START																			940				6	16
			1425			ACCEL TO 1050 T-5																								
			1425	23500	14500	0	33	7.5	395	275	13.0	0	10.4	90	64.5	194	185	108	131	166	80	250	94	75	1050	925	76.0			
			1448	23500	15000	0	32.5	7.0	365	285	13.0	0	10.7	9.9	63.0	213	209	108	134	193	80	270	90	75	1050	985	77.0			
			1455			ACCEL TO 1200 °F T-5																								
			1455	25250	18400	0	37.0	7.5	610	505	20	0	10.7	9.8	82.0	223	213	112	143	199	85/87	375	90	75	1205	1075	79.0			
			1500			DECEL TO 1175 °F T-5																								
			1500	24900	17800	0	35.5	7.0	555	455	19	0	10.6	11.0	78.5	234	218	111	142	203	100	350	91	76	1175	1050	76.5
			1530	24900	17750	0	35.0	7.0	560	460	19	0	N.L.	10.6	79.2	240	224	113	143	213	90/95	348	100	74	1170	1050	74.0			
			1600	24900	17800	0	35.0	7.0	565	470	19	0	10.0	11.5	79.5	240	223	[illegible]	145	213	[illegible]	345	100	74	1170	1065	76.0			
			1620	24850	17800	0	35.0	7.0	595	495	19	0	9.8	20.6	79.5	238	220	[illegible]	146	211	105	350	101	75	1175	1075	78.0			
			1630			DECEL TO 1050 °F T-5																								
			1630	23550	15700	0	31.5	7.0	390	308	16	0	9.8	22.5	64.0	234	218	106	146	211	94/95	270	101	76	1055	1005	78.0		↓	↓
			1642			S/D ENGINE NOT GETTING FUEL (TANK IS FULL) - (INLET FILTER DIRTY) CHANG'D FILTER																							8	35
	7-21	1.	1854			F/U - NORMAL START 7 SEC TO LITE OFF																			870					
			1855			S/D - NORMAL																								
		2.	1856			F/U - NORMAL START 6½ SEC TO LITE OFF																			860					
			1857			S/D NORMAL																								
		3.	1858			F/U - NORMAL START 7 SEC TO LITE OFF																			870					
			1859	18000	6900	0	20.5	5.0	195	160	3.0	0	10	9.0	18.5	165	162	OUT	157	166	90	120	90	72	735	725	73			
			1905			SET 975-1000 °F T-5																								
						GG CHOP TO IDLE FROM 1000 °F T5 (3 TIMES) @ 9 SEC, 9 SEC, 9 SEC.																								
			↓			GG IDLE TO 1000 °F T-5 3 TIMES @ 6 SEC, 7 SEC, 6 SEC																							↓	↓
			1910	22300	14650																				1010		73		8	51
						RUNNING CONT ON LOG SHEET #5																								

NOTES:

Type of Fuel — Oil:
Specific Gravity:

COMPONENT. CONTROLS & ACCESSORIES TEST LOG SHEET

Recorder: [illegible]
Supervisor's Approval: [illegible]
U.S.A.F. Coordinator:
Quality Control Test No:
Special Test No:
Title of Test: 7LM100 ENGINE ON EMULSIFIED FUEL
Part Name: 7LM100
S/N:
C.E. P/N:
Requisition No: T7657
Test Cell No: 50 AMS
Bldg No: 703
Calib. Expires: 7-21-67
Facility No: 3022
Engine No: 125
Page No: 5 of
Date: 7-18-67

Record by Initial	Part of Test	Reading	Time of Day	Speed	Speed	Eng Pump Inlet	Eng Oil Disch	Eng Scav Disch	Eng Fuel Pump Disch	Eng Fuel Manifold	Oil Disch	Oil Inlet	JP-4 Tank	Emul Fuel Tank	C_{ρ}	Oil Cooler In	Oil Cooler Out	Emulsion Fuel In	Emulsion Fuel Out	Lube Oil Tank	Supercharger Air In	Supercharger Air Out	Supercharger Oil In	Amb Air	T-5	T-6	T-2	Fuel Flow	Total Running	Total Running	On Schedule	On Schedule
	NO	NO	EST	RPM	RPM	PSIG	PSIA	PSIG	PSIG	PSIG	PSIG	PSIG	PSIG	PSIG	PSI	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F		HR	MIN	HR	MIN
[illegible]			1813	24950	18200		SET 1175°F T-5																		1175		72		8	54		
[illegible]			↓				1175 T5 TO IDLE – 10.5 SEC – 8.3 SEC – 8.5 SEC (3 TIMES)																						↓	↓		
[illegible]			1815				IDLE TO 1175 T5 – 5 SEC – 4 SEC – 4.6 SEC (3 TIMES)																						↓	↓		
[illegible]			1828				SET 1200°F T-5																		1200		71		↓	↓		
[illegible]							1200°F T-5 TO IDLE – 11 SEC – 8 SEC – 7.5 SEC																						↓	↓		
[illegible]			1825	25750	19000		IDLE TO 1200°F T-5 – 6.2 SEC – 5.5 SEC – 5.8 SEC																						↓	↓		
[illegible]			1828	25750	19000	0	36	20	620	515	20	0	12.5	11.2	71.5	220	204	OUT	144	188	—	354	90	70	1205	1100	71		↓	↓		
[illegible]			1835	17500	6600	0	19	5.5	215	160	3	0	12.3	11.3	19.8	215	206	—	157	190	95/85	132	91	71	690	715	71		↓	↓		
[illegible]			1836				NORMAL S/D																						9	17		
[illegible]	7-15-67		0900				NORMAL START																		800				↓	↓		
[illegible]			0905	23850	16,000	0	44	9.0	335	275	15	0	11.5	10.5	60.5	114	111	OUT	100	72	←	225	65	68	1055	985	74					
[illegible]			0910	23700	17,600	0	43.5	8.5	460	365	18	0	11.5	10.4	70.5	130	126	—	111	82	—	333	66	70	1129	1055	73					
[illegible]			0915	24300	19,000	0	41.5	8.5	550	440	20	0	11.5	10.4	75.0	152	145	—	119	107	—	385	71	68	1175	1095	78					
[illegible]			0917	24550	18,300	0	41.0	9.0	600	490	21	0	11.5	10.3	78.5	162	155	—	124	121	—	396	75	68	1200	1100	81					
[illegible]			0922	24450	18,800	0	38.0	9.0	580	470	19	0	11.5	10.3	78.0	186	174	—	132	149	—	392	88	70	1175	1095	78					
[illegible]			0950	24500	18,900	0	35.0	8.0	660	550	19	0	12.5	11.0	76.5	227	209	—	145	196	—	392	100	73	1170	1140	80					
[illegible]			0955	17250	6,300	0	18.0	5.0	215	170	3	0	12.5	11.0		212	203	—	153	198	—	140	100	75	705	765	81					
[illegible]			0955				S/D NORMAL																						10	12		
[illegible]			1012				START NORMAL									205	191	—	137	187	78	294	96	71	730	[illegible]	77		↓	↓		
[illegible]			1018	23100	16,300	0	32	6.5	440	350	19	0	12.5	11.8	63	↓	↓		↓	↓	↓	↓	↓	↓	1050	↓	↓					
[illegible]			1020	24000	17500	0	34	6.5	580	475	16	0	12.6	11.5	71.5	212	203	—	137	187	70	305	96	71	1130	1110	77					
[illegible]			1020				S/D ERRATIC F/P PRESS ADDED 1½ DRUMS of FUEL TO TANK																						10	20		
[illegible]			1045				NORMAL START																		805				↓	↓		
[illegible]			1050	24150	19000	0	34.5	7.0	625	525	19	0	12	9.0	73.0	208	193	—	140	176	140	410	93	74	1175	1160	77					
[illegible]			1053	24550	19500	0	35.0	7.0	722	620	19	0	12.3	10.0	78	214	200	—	140	178	95/100	382	93	72	1205	1188	78					
									660	550															1175	1175						
[illegible]			1055	17350	6600	0	18.0	5.0	228	175	3	0	12.5	11.0	18.5	204	197	—	148	187	135/140	170	92	74	720	775	82					
[illegible]			1058				S/D NORMAL SWITCH FROM EMULSIFIED FUEL TO JP-4																						10	33		
[illegible]			1230				E/A NORMAL START J-P4 FUEL																		795				↓	↓		
[illegible]			1235	24,200	18,800	0	37	7.5	650	530	19	80	~~32~~	3.2	74	188	177	—	137	151	119/115	378	88	73	1175	1170	79		10	38		
	7-18-67									CONT ON LOG SHEET #6														~~73~~	~~470~~				↓	↓		

NOTES:

TYPE OF FUEL — OIL

SPECIFIC GRAVITY

COMPONENT CONTROLS & ACCESSORIES
TEST LOG SHEET

Model	7LM100
Designation	T7L67
Engine No.	125
Test Cell No.	58 P&O
Bldg. No.	703
Cal. Date	7-21-67
Facility No.	2022
Page No.	6
Date	7-18-67
Title	7LM100 ENGINE ON EMULSIFIED FUEL

Time	Speed	Speed	PSIG	PSIG	PSIG	PSIG	PSIG	PSIG	PSIG	.106 Tank PSIG	PSIG	C_D P PSI	Oil Cooler In °F	Oil Cooler Out °F	Oil Cooler Fuel Out °F	Oil Cooler Fuel In °F	Lube Oil Tank °F	Supercharger Air In °F	Supercharger Air Out °F	Supercharger Oil In °F	Amb. Air °F	T-5 °F	T-6 °F	T-2 °F	Fuel Flow PPH	Total Running HR	Total Running MIN	On Schedule HR	On Schedule MIN
1250	[illegible]	[illegible]	0	36	7.5	[illegible]	565	19	0	6.2	3.2	755	214	192	—	165	176	160	426	96	74	1175	1200	88	560	10	53		
			SET 975-1000°F T-5										210									985	1090						
1258	[illegible]	[illegible]	0	310	7.5	385	295	19	0	6.0	4.0	58	210	189	—	171	182	122	280	98	74	985	1080	80	420				
1305				IDLE TO [illegible] T-5 4 SEC 3.8 SEC 4.2 SEC																									
1310	[illegible]	[illegible]	0	355	7.5	785	580	20	0	5.8	4.0	7.6	215	188	—	167	180	125	410	96	74	1180	1180	82	600				
1313	[illegible]	[illegible]	0	31.5	7.5	445	350	19	0	6.5	4.0	61	211	188	—	172	182	110	305	93	72	1050	1110	74	450				
1318	[illegible]	[illegible]	0	33.5	7.5	555	460	17	0	6.5	4.0	69.5	213	188	—	170	183	147	385	95	74	1125	1150	78	530				
1322	[illegible]	[illegible]	0	350	7.5	665	545	17	0	5.8	4.0	70.5	215	190	—	171	180	85	370	96	74	1175	1185	78	590				
1325	[illegible]	[illegible]	0	36.0	7.5	790	610	19	0	5.6	4.0	78.0	217	190	—	171	181	63	360	96	75	1200	1185	73	625				
1330	[illegible]	2000	0	200	5.5	205	175	3	0	6.0	4.0	20.5	198	187	—	183	183	126	160	97	75	700	750	78	—	11	33		
1330				NORMAL S/D																						11	33		
1332				NORMAL START OPEN S/C TO LITE OFF 3.5 SEC																		875				↓	↓		
1333				NORMAL S/D																						11	34		
1334				NORMAL START OPEN S/C TO LITE OFF 3.0 SEC																		870				↓	↓		
1336				NORMAL S/D																						11	35		
1336				NORMAL START OPEN S/C TO LITE OFF 2.2 SEC																		885				↓	↓		
13[illegible]				NORMAL S/D																						11	37		

NOTES:

TYPE OF FUEL — OIL

SPECIFIC GRAVITY

APPENDIX III
PRE-TEST HOT-SECTION INSPECTION, ENGINE S/N 125, TURBINE SECTION

STATOR

1. First-stage nozzle - All partitions corroded; 14 cracked on trailing edge.

2. Second-stage nozzle - Five partitions cracked on leading edge (3 o'clock position); badly discolored; shows signs of hot corrosion.

3. Third-stage nozzle - Coking on aft face; visually good.

4. First-stage casing - One dump tube pad has a bolt seized and broken off; internal cooling tubes plugged; otherwise, visually good.

5. Second-stage casing - Visually good.

ROTOR

1. Forward shaft - Visually good; normal discoloration.

2. Cooling plates - Some corrosion; extensive discoloration; not visually warped or otherwise damaged.

3. First-stage wheel - Some evidence of hot corrosion on buckets.

4. Second-stage wheel assembly - Some evidence of hot corrosion.

5. Coupling shaft - Visually good.

6. Tie bolt - Good.

APPENDIX IV
INSPECTION REPORT ON EMULSIFIED FUEL TEST MANIFOLD ASSEMBLIES, ENGINE S/N 125

BACKGROUND

Running time: 4 hours 18 minutes

Time on JP-4: 1 hour 1 minute

Time on emulsified fuel: 3 hours 17 minutes

These manifold assemblies were removed from the engine because of suspected clogging indicated by high fuel manifold pressure.

VISUAL INSPECTION

White crystal-like deposits were found on four primary nozzles. Coking was evident on primary and secondary nozzles. The coking was apparently caused by dribbling. The primary nozzles were coked the heaviest. Globs of fuel were hanging on two primary nozzles.

The nozzle strainer completely clogged in two secondary nozzles. All strainers were dirty. Contamination appeared to be chips of paint, sand, and wood (same type of contamination found in fuel filter).

FLOW CHECK

Five secondary nozzles clogged at 500 psig. All others were dribbling heavily.

APPENDIX V
POST-TEST HOT-SECTION INSPECTION OF EMULSIFIED FUEL, ENGINE S/N 125

Test time: 11 hours 37 minutes

Time on emulsified fuel: 9 hours 37 minutes

1. First-stage nozzle - Leading edge oxidized; blue deposit on part exposed to primary air; some white salt-like deposits; does not appear to have deteriorated during test.

2. Second-stage nozzle - Brownish deposit on trailing edge; no blue deposit; otherwise, same as pre-test.

3. Third-stage nozzle - Blue color; otherwise, no change in appearance.

4. First-stage buckets - Heavy blue deposit covering both sides.

5. Second-stage buckets - Heavy blue deposit.

6. Third-stage buckets - White salt-like deposits; otherwise, no change.

7. Cooling plates 1 and 2 - White deposits on cooling air side.

8. Combustion liner - Some carbon deposits close to fuel nozzle; essentially as before test.

9. Fuel manifolds - Coking on all nozzles; primaries coked the most; much better than first set; no globs of emulsified fuel seen.

10. Fuel control valve S/N 704043 - Some small globs of emulsified fuel still present; no signs of corrosion or scale.

11. Flow divider S/N CGW 1842 - Emulsified fuel clinging to springs; a black (varnish-like) deposit on nozzle end of temperature valve; no corrosion.

12. Fuel pump S/N PE2552X - No corrosion or wear; visually OK.

APPENDIX VI
PRELIMINARY REPORT, LM100 FIRST-STAGE TURBINE BLADES

RESULTS

Blade	View	Condition			
		AD (mils)	IGO	TFC	GO (mils)
#1 (uncoated)*	C/S	0.2	None	None	0.5
	L/E	0.5	None	None	1.0 - 1.5
#2 (coated)**	C/S	Trace	None	None	0.5 - 1.0
#3 (uncoated)***	C/S	0.5 - 0.6	None	None	1.0
	L/E	2.0	None	None	2.0

*(1) No appreciable sulfidation
(2) Contour irregular

**(1) C/S: 1.0 mil coating
(2) Surface - regular
(3) No appreciable sulfidation

***(1) C/S and L/E: irregular surface indicative of erosion
(2) No appreciable sulfidation

CONCLUSION

The general condition of all three blades was good.

APPENDIX VII
SPECTROGRAPHIC ANALYSIS

Engineering Department
Materials Development Laboratory Operation
Analytical Chemistry Unit

SUBMITTED BY P. Linko K148

NAME ORGANIZATION BLDG. EXT.

DATE REC'D 8-24-67 DATE REPORTED 8-28-67 ACCOUNT NO. MYD02

SAMPLE HISTORY & MATERIAL DESCRIPTION Materials on T58

Secondary Fuel Nozzle Run on Emulsified Fuel

3319A - Red Deposit

3319B - Loose Material on Screen

TYPE OF ANALYSIS DESIRED: SEMI-QUANTITATIVE___
QUANTITATIVE___ QUALITATIVE X

REPORT OF ANALYSIS: MAJOR = 100-10%; MINOR = 10-1%;
TRACE (T) 1-0%

	3319A	3319B		3319A	3319B
Ag	O	T	Mn	T	T
Al	T	Minor	Mo	O	O
B	O	O	Na	O	O
Ba			Ni	T	Minor
Be	O	O	Pb	T	T
Bi			Si	T	Minor
Ca	T	T	Sn		T
Cb	O	O	Sr	O	T
Cd			Ti	T	Minor
Co	O	O	V	O	O
Cr	T	T	W		
Cu	T	T	Y		
Fe	Major	Major	Zn		T
K			Zr	O	O
Mg	T	T			

R. J. Yoder

APPENDIX VIII
FUEL ANALYSIS

The emulsified fuel submitted for analysis has been investigated and the following noted:

1. The emulsion was broken into two phases by the addition of acetone: an emulsifier phase and a JP-4 acetone phase. Subsequently, the acetone phase was separated again into two components: an α and a β phase.

2. The α and β phases were analyzed spectrographically. The JP-4 and acetone phases showed almost no contamination; the emulsifier phase showed a strong phosphorus indication.

3. The blue deposits on a nozzle of X-40 which were exposed to combustion gases of the emulsified fuel were examined by X-ray diffraction and spectroscopy. In X-ray, the deposits showed evidence (not very conclusive) that the scale contained cobalt phosphate. The spectroanalysis identified cobalt and phosphorus in the scale.

4. Samples of L605 and X-40 heated in contact with Na_3PO_4 at 1800°F for a short time (1/2 hour) showed a blue deposit. Normally, these alloys do not show these deposits at this temperature and time interval.

5. Samples of L605 and X-40 were heated in contact with emulsifier obtained from the emulsified fuel. After 1/2 hour at 1800°F, a blue deposit was observed. The samples of X-40 and L605 were sectioned. Pitting was observed under the coked emulsifier.

These data indicate that:

1. The emulsifier in the emulsified fuel contains phosphorus, but its precise mode of chemical composition is uncertain. As the emulsifier had not appeared in the acetone phase, it must be polar in character. An organic phosphate compound would behave in this fashion.

2. The presence of phosphorus in the oxidation scale of the nozzle is unusual.

3. Inorganic compounds and the emulsifier both corrode L605 and X-40 but to different degrees, the inorganic salt Na_3PO_4 being the most corrosive in the short test.

4. The smaller the concentration of phosphorus, the slower the corrosion; but without phosphorus, the presence of the blue oxide in a short test time does not occur.

5. It is reasonable to assume that the heavy corrosion noted on the nozzle was caused by the phosphorus in the emulsifier.

6. Emulsified fuels *per se* need not be considered as corrosive, at least based on the data obtained in these tests. The culprit appears to be the *type* of emulsifier rather than the physical state of the fuel.

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Security Classification

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13. ABSTRACT

Much investigation and aircraft engine operation have been accomplished in developing a "safe" fuel that will not explode in its stored condition when exposed to a spark, but which will give identical engine performance when used in place of fuels being burned today. The Bell air cushion vehicle engine, a General Electric LM100, was tested on the latest emulsified "safe" JP-4 fuel (WSX-7165). Engine starts and operation were about the same with emulsified JP-4 fuel as with plain JP-4 except that running time was limited on emulsified fuel because of fuel nozzle clogging. Clogging was caused by dirtier-than-normal fuel and by an iron deposit that formed on the fuel nozzles and fuel nozzle screens.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Fuel						
Emulsified Fuel						
7LM100 Engine						
JP-4						
Emulsified JP-4						
Safe Fuel						
Aircraft Fuel						
Fuel Nozzles						