VOLUME I

JANUARY 1963

X353-5B PROPULSION SYSTEM FLIGHTWORTHINESS TEST REPORT

GENERAL ELECTRIC

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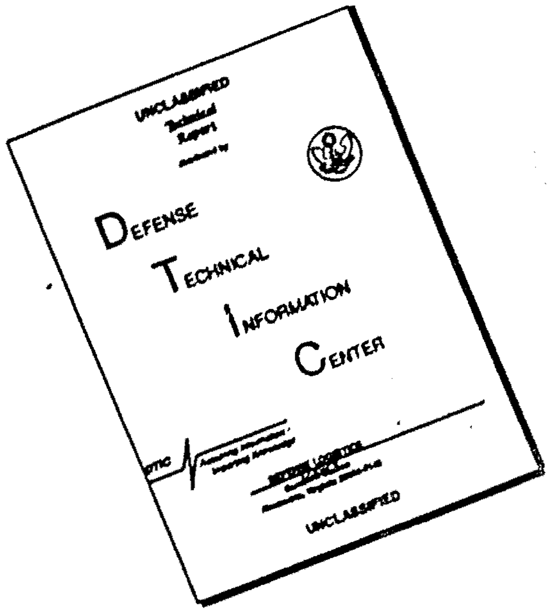

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LIFT FAN FLIGHT RESEARCH AIRCRAFT PROGRAM

CONTRACT DA 44-177-TC-715

X353-5B PROPULSION SYSTEM

FLIGHTWORTHINESS TEST REPORT

JANUARY, 1963

VOLUME I

Prepared By:

GENERAL ELECTRIC COMPANY

Flight Propulsion Laboratory Department

Cincinnati 15, Ohio

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Section A

S U M M A R Y

A. SUMMARY

An X353-5B propulsion system comprised of two J85-GE-5 turbojet engines without afterburners, two X353-5B diverter valves, one X353-5 lift fan and one X376 pitch trim control fan was assembled and tested in accordance with Contract DA 44-177-TC-715 Specifications 112, 113, 114 and 115.

This report, prepared in three volumes, is submitted to the U.S. Army (TRECOM) in accordance with Specifications 114 and 115 to form the basis for establishing a flightworthiness rating for this propulsion system with the objective of insuring that it has a sufficient durability and reliability to permit experimental flight test.

The specified testing was completed. The J85 gas generators were unaffected by the presence of the X353-5B propulsion system. The diverter valves and the pitch fan met or exceeded performance requirements at all operating conditions. The lift fan met or exceeded performance requirements at all but one condition (single engine lift).

There were only minor discrepancies found in the diverter valve and pitch fan hardware at disassembly. The lift fan had considerable damage resulting from the shedding of a small metal tab from the rotor during the last endurance cycle of the test. Lift fan aluminum inlet vanes and exit louvers were of generally poor manufacturing quality and did not satisfactorily complete the test.

The General Electric Company recommends a flightworthiness rating be assigned to the X353-5B propulsion system upon satisfactory completion of a 10-hour penalty test of new lift fan inlet vanes and exit louvers.

Volume I presents the main report including the test analysis and recommendations.

Volume II is a supplement containing photographs of the detailed hardware review and inspection certificates.

Volume III is available at the General Electric Company for review but has not been prepared in multiple copies. It contains the official test log sheets and all associated test data as well as test plans, schedules, instrumentation specifications, operation limits, maintenance records, calibration data, and performance evaluation and computation results.

B. TEST VEHICLE DESCRIPTION

1. COMPONENT DESCRIPTIONS

Diverter Valves: The diverter valves were assembled conforming to drawings 4012001-937L (left hand - Figure I-1) and 4012001-938R (right hand). The units were assembled using hardware from a previous 29-hour assurance test. The valve actuation system used was not flight-type hardware and is not considered part of the rating test vehicle.

The test valve serial numbers assigned are:

Left-hand	003L (installation position #1)
Right-hand	004R (installation position #2)

Figure I-2A shows the diverter valve prior to test and trial assembled to a YJ85-5 engine. Figure I-2B views the test actuation.

Lift Fan: The lift fan was assembled in accordance with Specification 124 (Assembly Instructions) and drawing 4012001-941G1 (Figure I-3). The test fan was a left-hand fan (counter-clockwise rotation looking from the top). The assembly was the second buildup for this set of parts which had previously accumulated 23 hours of operation in assurance tests. The only new parts incorporated for this buildup were one (1) fan blade, the forward torque band, and all carrier retainer pins and covers.

The test fan serial number assigned is 003L. Figure I-4A shows the assembled lift fan prior to test. Figure I-4B is a view from the bottom side showing the exit louver assembly.

Pitch Fan: The pitch fan was assembled in accordance with Specification 124 (Assembly Instructions) and drawing 4012001-940G1

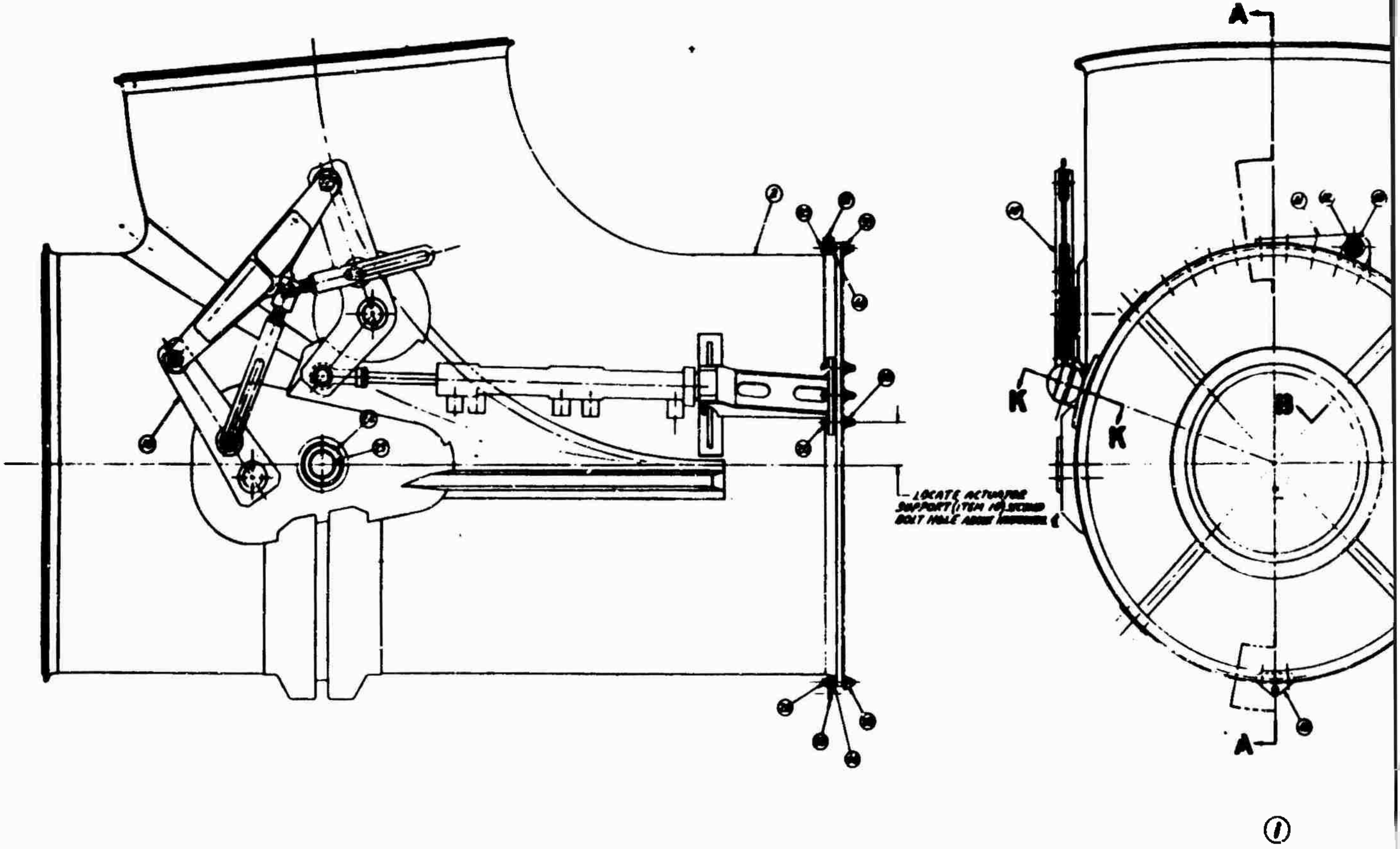

Figure I-1. Assembly Diverter Valve, Le

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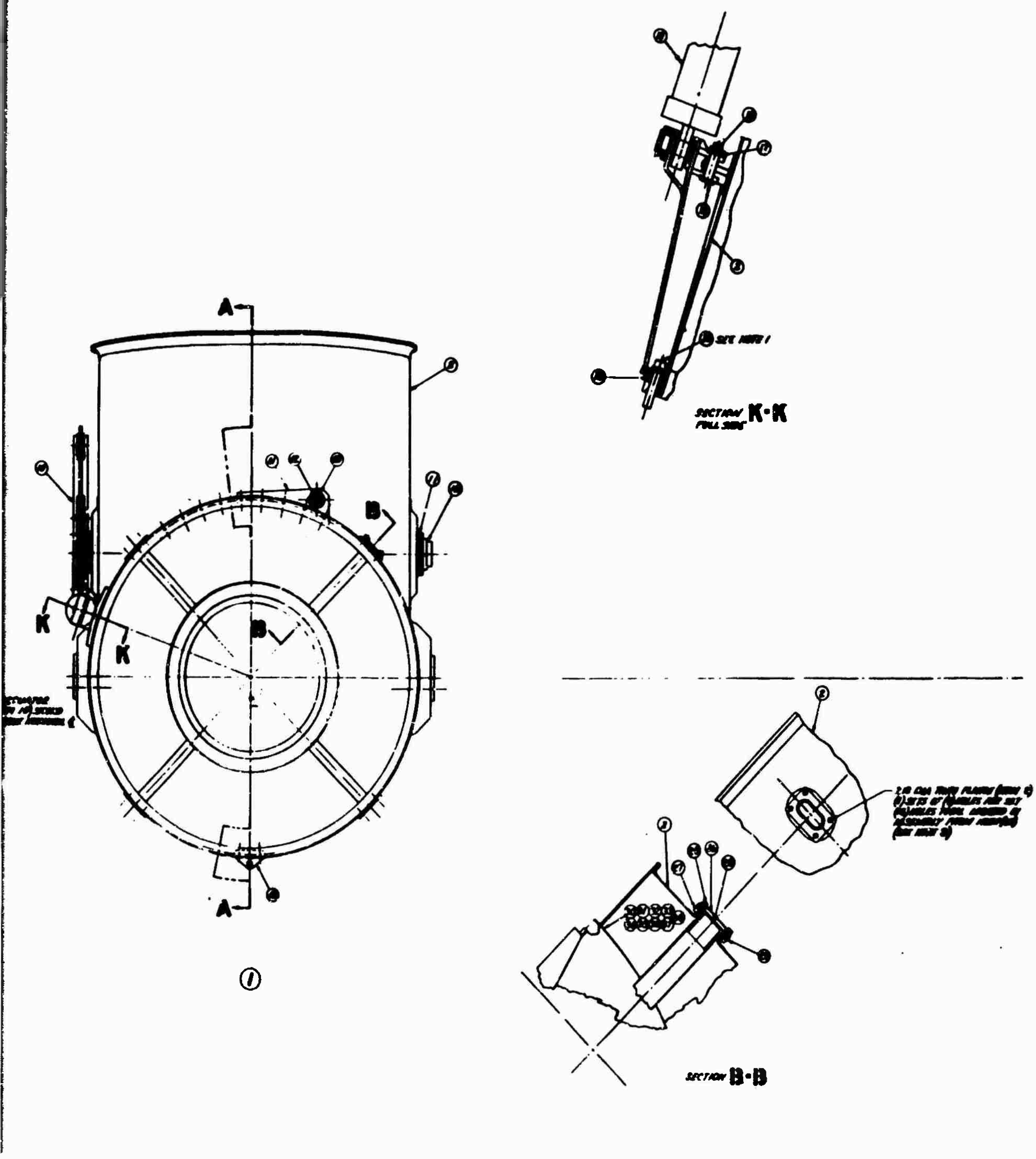


Assembly Diverter Valve, Left Hand

Sheet 1 of 2

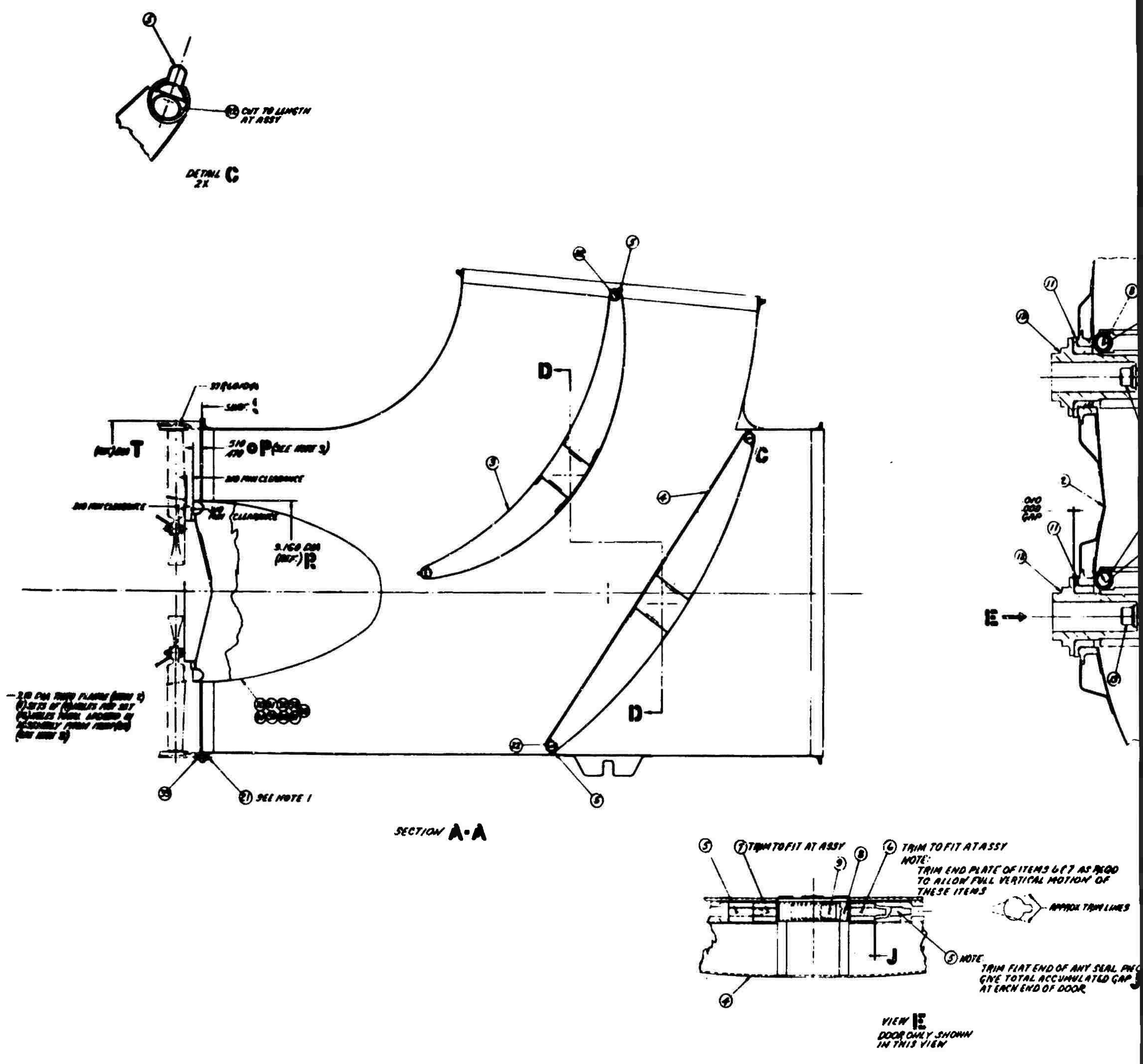
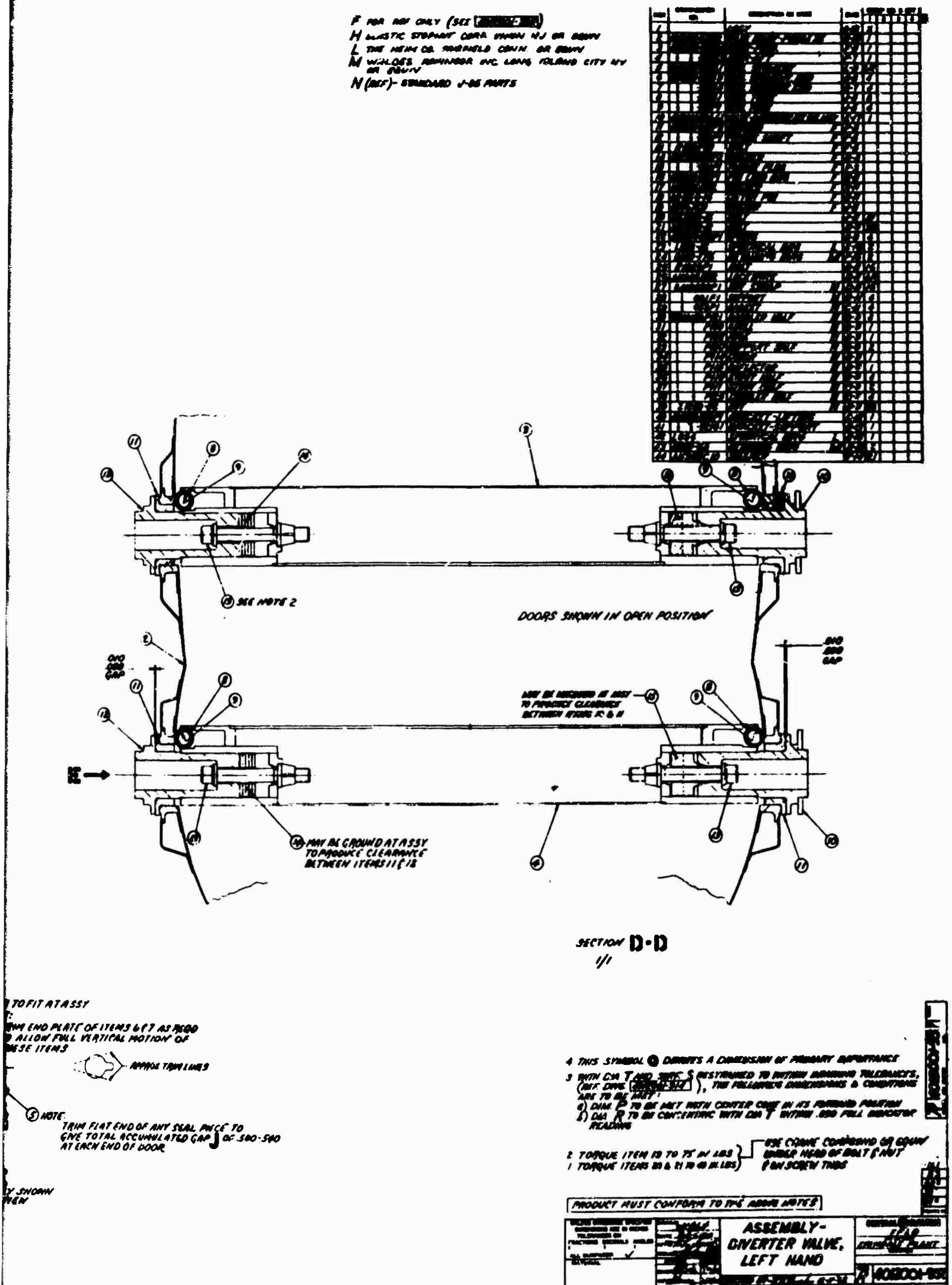


Figure I-1. Sheet 2 of 2


F FOR REF ONLY (SEE [redacted])
N (REF)- STANDARD J-85 PARTS
DOORS SHOWN IN OPEN POSITION
MAY BE GROUND AT ASSY TO PRODUCE CLEARANCE BETWEEN ITEMS 11 & 12
SECTION D-D
1/1
TO FIT AT ASSY
ALLOW FULL VERTICAL MOTION OF
APPROX TRIM LINES
5 NOTE:
TRIM FLAT END OF ANY SEAL PIECE TO GIVE TOTAL ACCUMULATED GAP J OF .500-.540 AT EACH END OF DOOR
4 THIS SYMBOL ● DENOTES A DIMENSION OF PRIMARY IMPORTANCE
3 WITH DIA T AND (REF DWG [redacted]), THE FOLLOWING DIMENSIONS & CONDITIONS ARE TO BE MET:
a) DIM. P TO BE MET WITH CENTER IN ITS POSITION
b) DIA R TO BE CONCENTRIC WITH DIA T WITHIN .010 FULL INDICATOR READING
2 TORQUE ITEM 19 TO 75 IN LBS
1 TORQUE ITEMS 20 & 21 TO 40 IN.LBS
PRODUCT MUST CONFORM TO THE ABOVE NOTES
ASSEMBLY-
DIVERTER VALVE,
LEFT HAND

1. Sheet 2 of 2

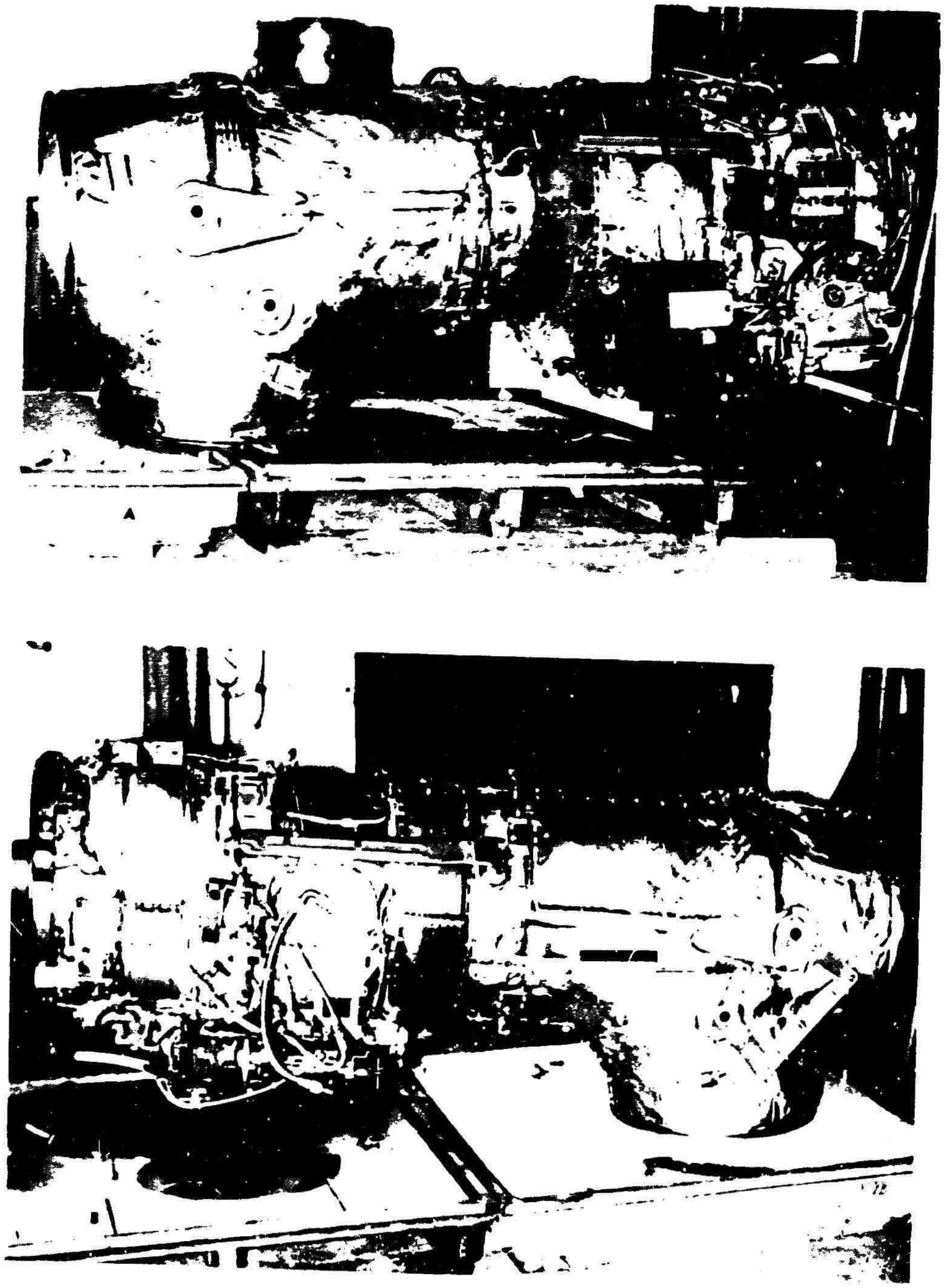


Figure I-2. A. Diverter Valve Assembly Before Test (Trial Assembly With YJ85-5 Engine)

B. Diverter Valve Assembly Before Test (Showing Test Actuation)

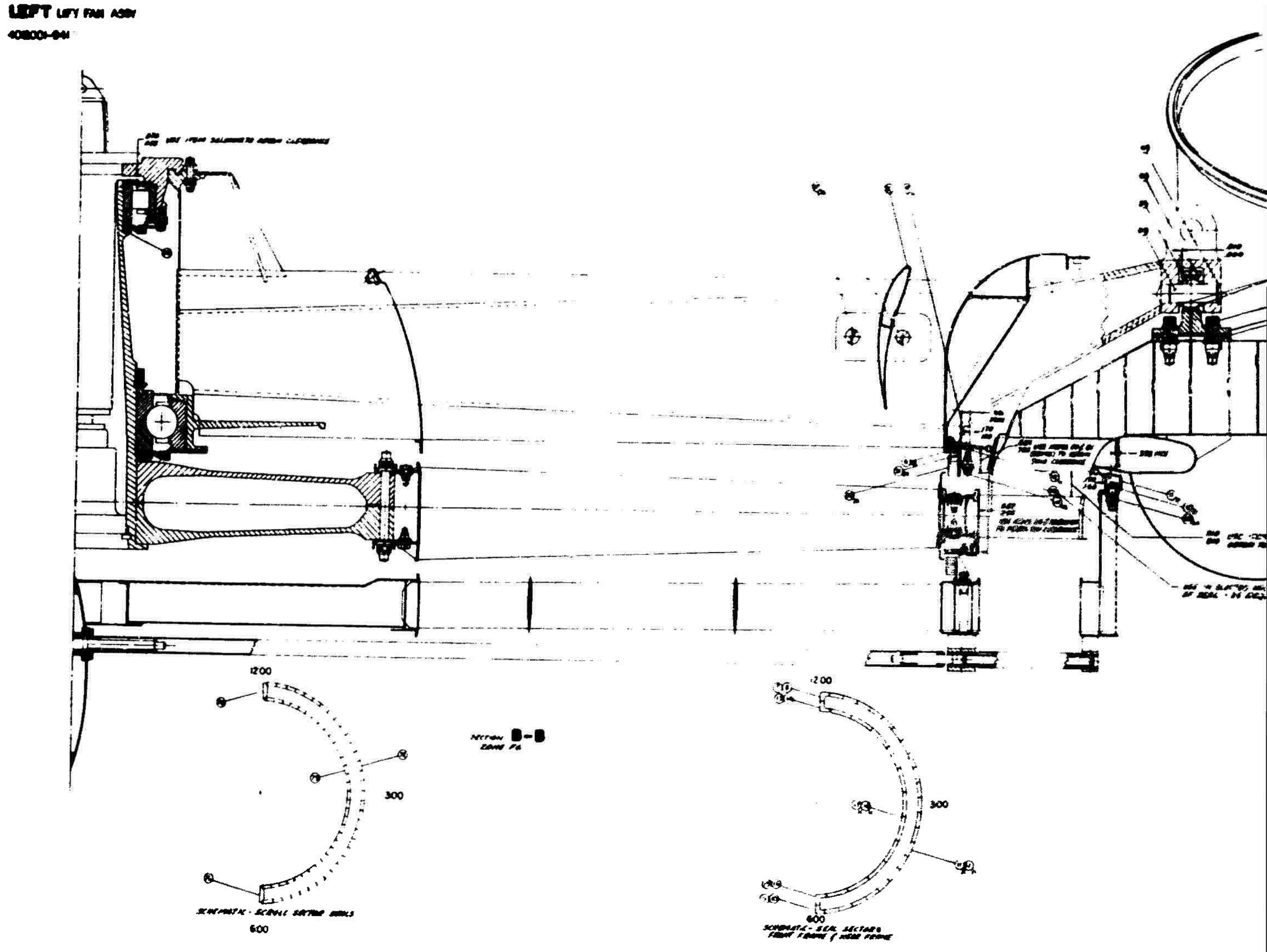
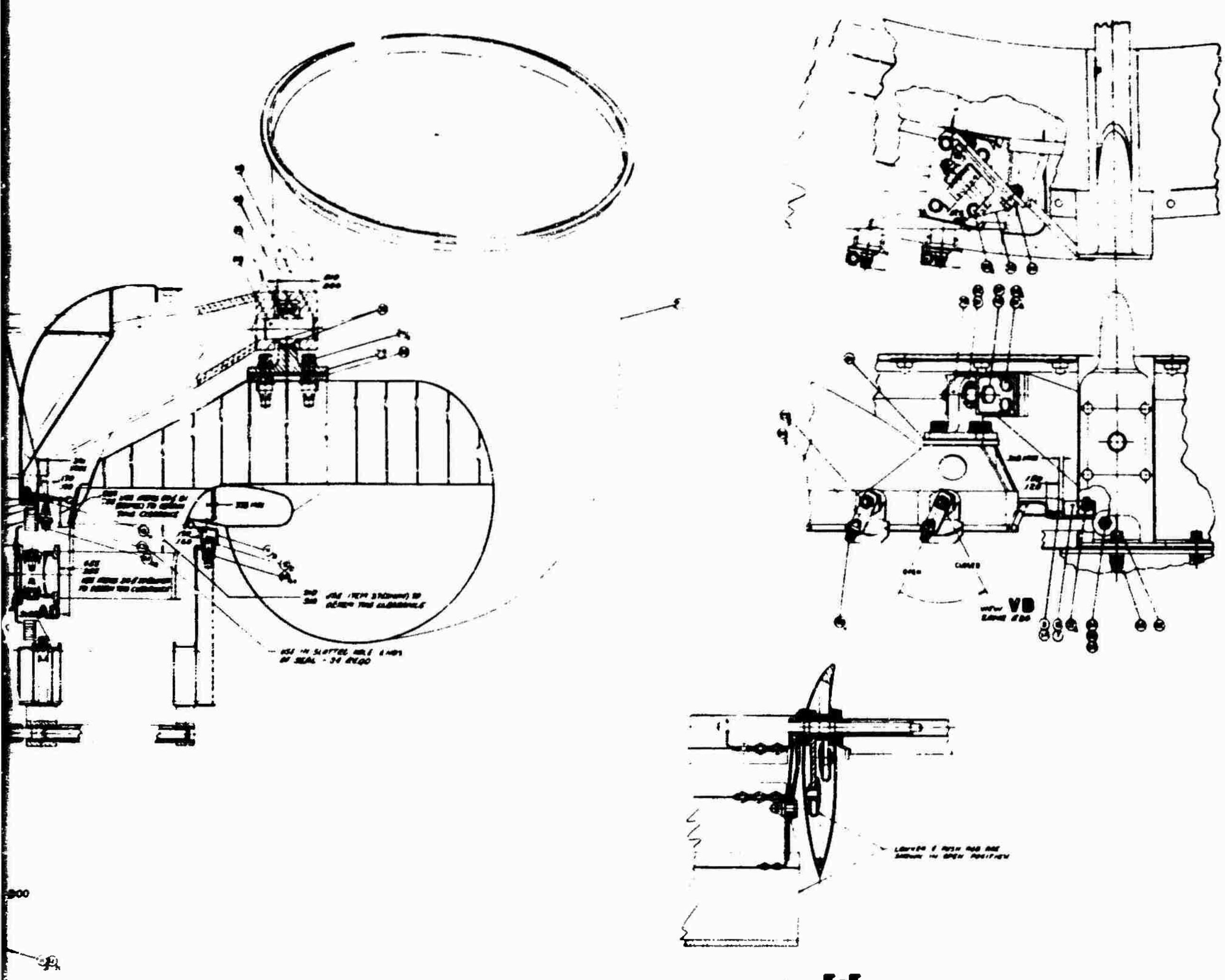


Figure I-3. Lift Fan Basic Assembly - Left

Sheet 1 of 4



an Basic Assembly - Left (X353-5B)

Sheet 1 of 4

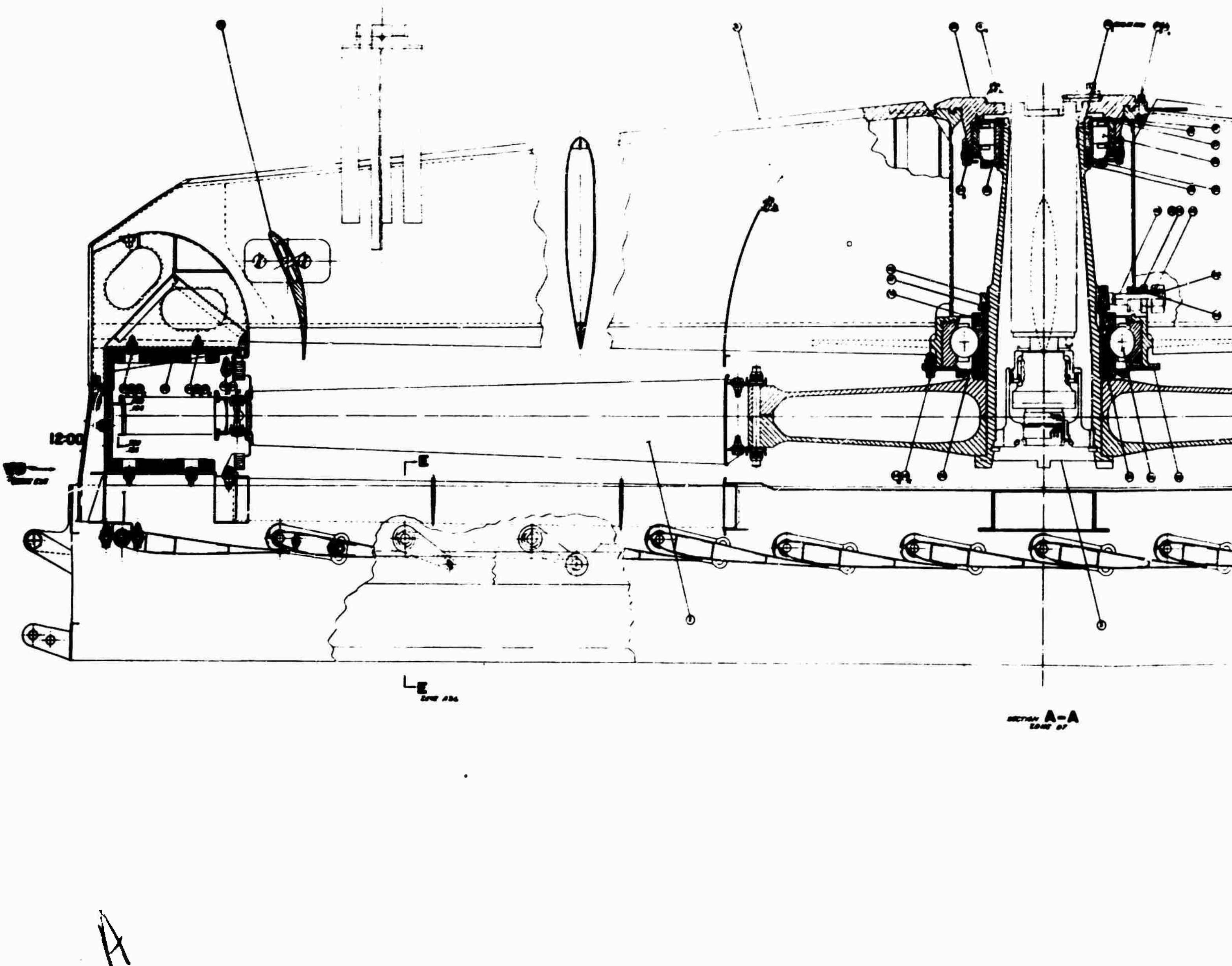


Figure I-3. Sheet 2 of 4

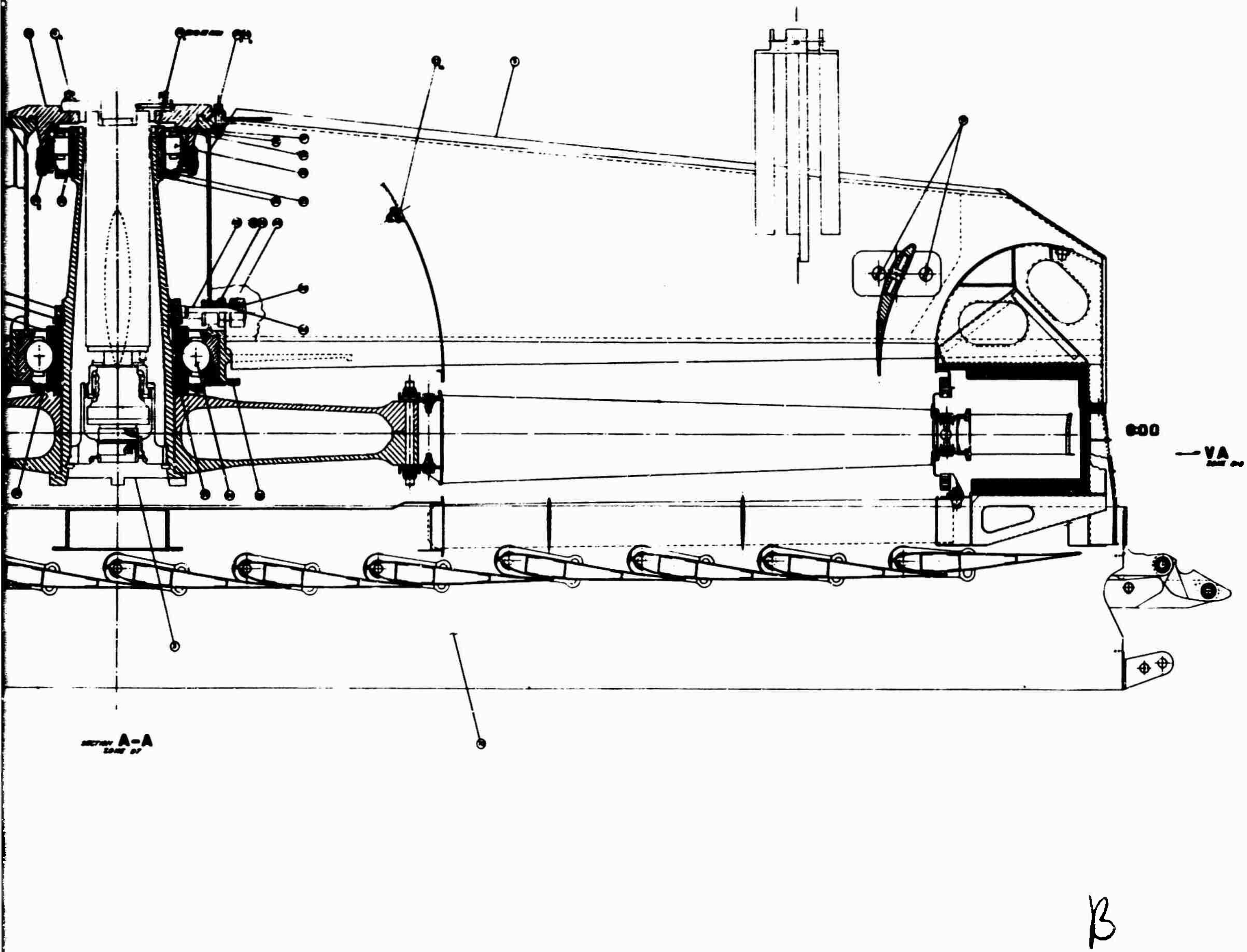
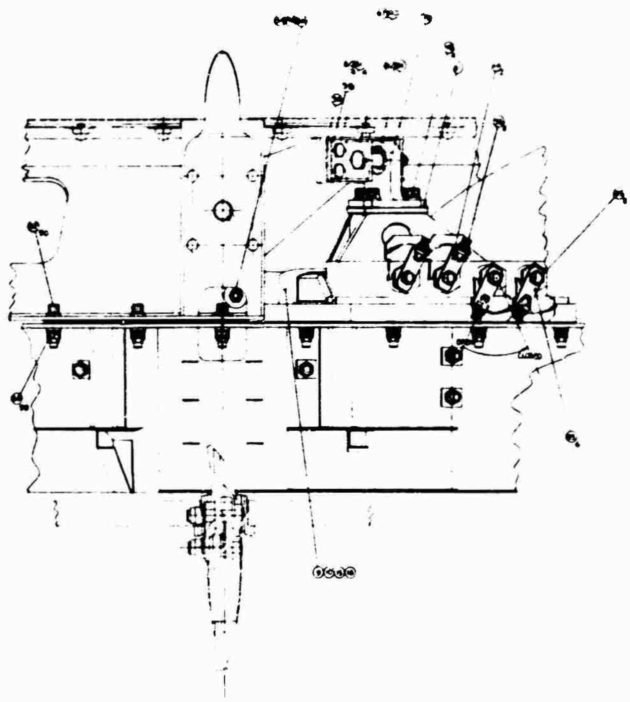
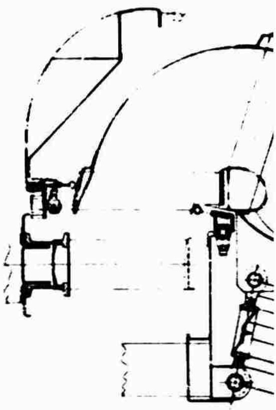


Figure I-3. Sheet 2 of 4



VIEW VA



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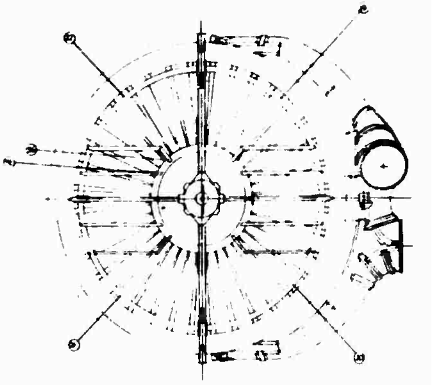

TOP PLAN VIEW

Figure I-3. Sheet

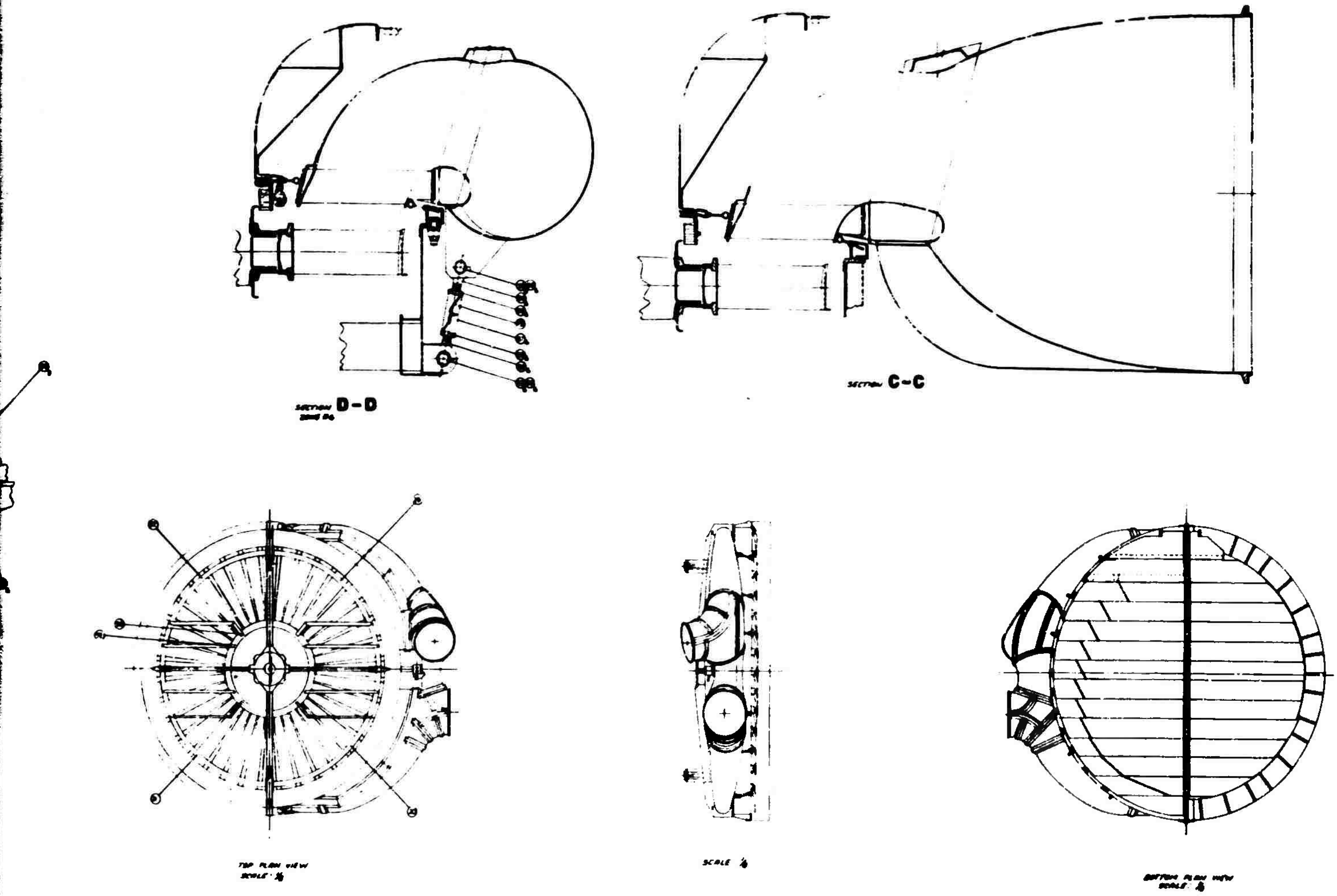

Figure I-3. Sheet 3 of 4

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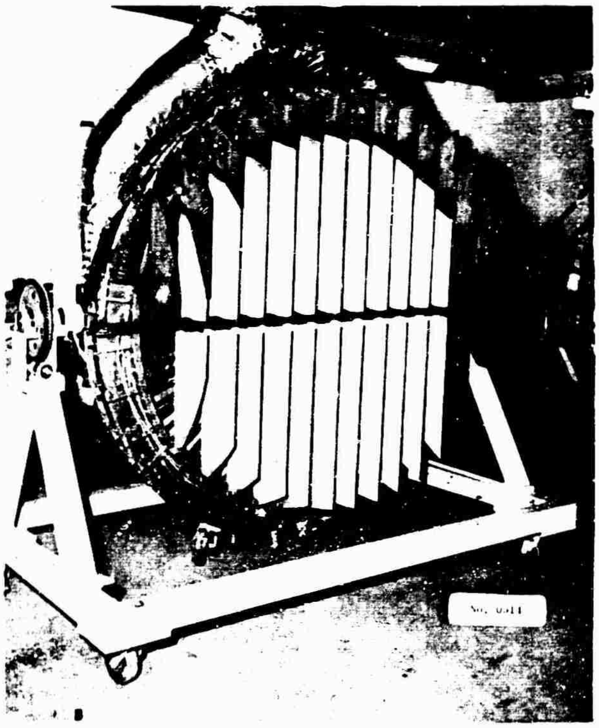


Figure I-4. A. Lift Fan Assembly Before Test

B. Lift Fan Assembly Before Test Showing Exit Louvers

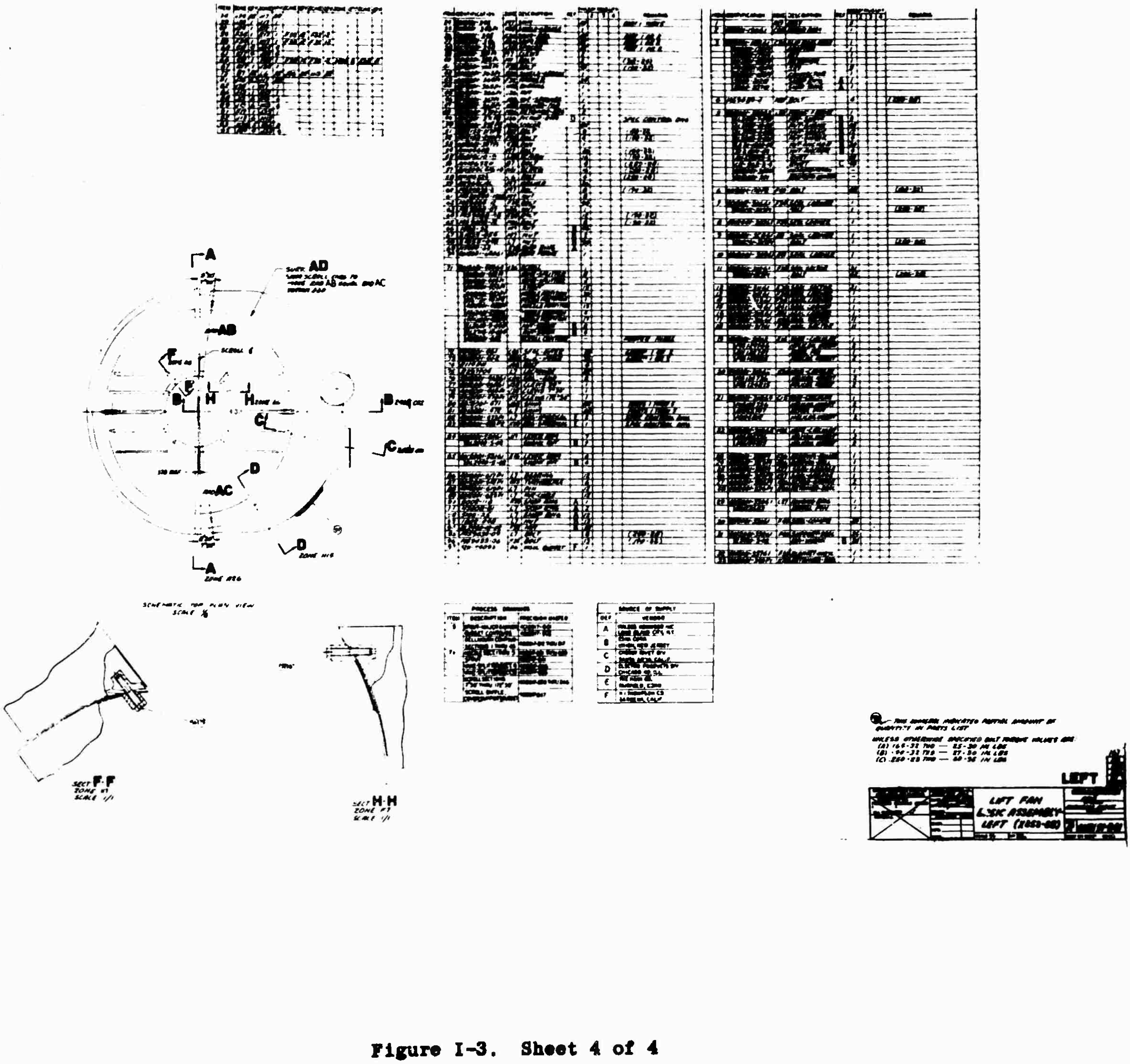


Figure I-3. Sheet 4 of 4

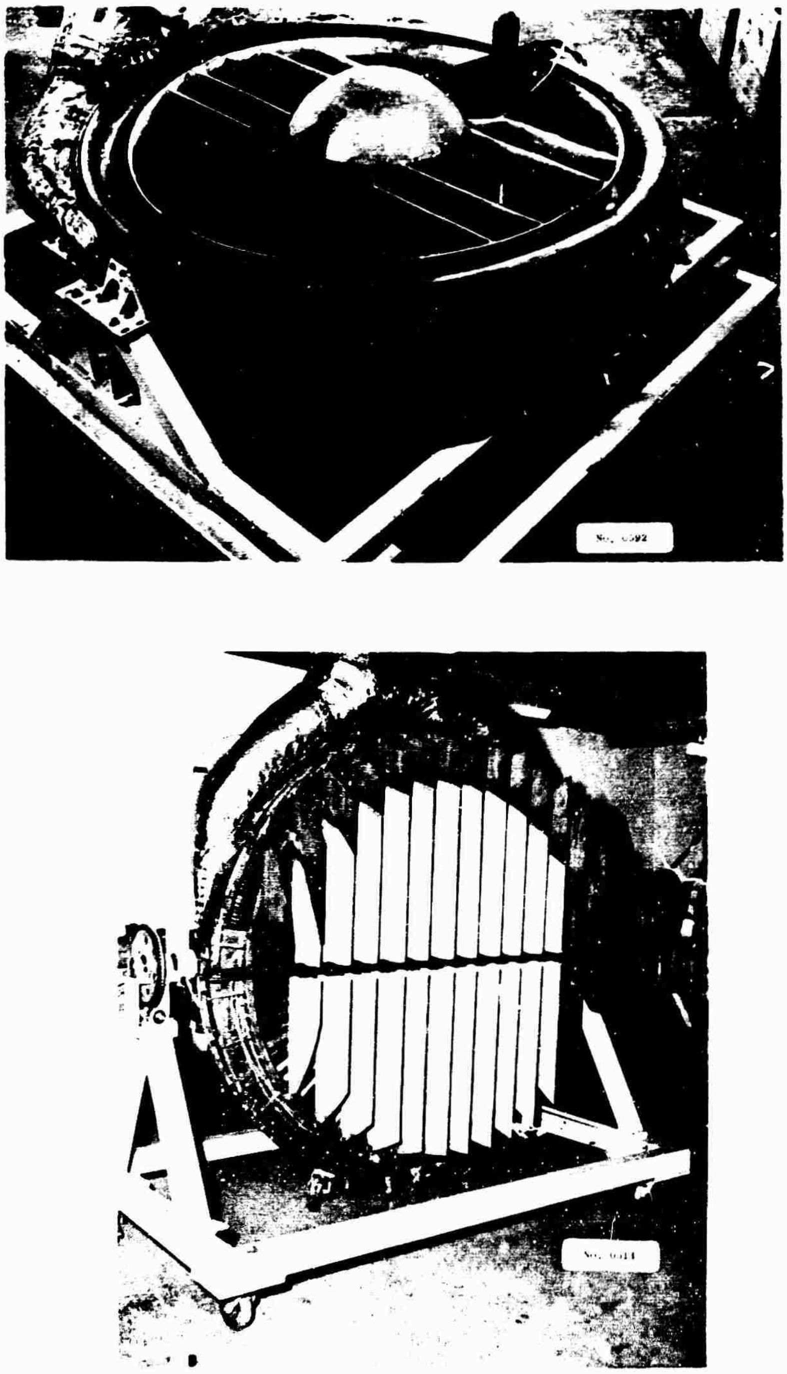


Figure I-4. A. Lift Fan Assembly Before Test

B. Lift Fan Assembly Before Test Showing Exit Louvers

(Figure I-5). Eight hours assurance testing were accomplished with this hardware prior to this second buildup. The X376 has a right hand direction of rotation (clockwise looking from the top).

Based on the assurance testing the following changes to the configuration were incorporated for the rating test:

1. A .100" layer of fibrefrax slurry was applied to the front frame outer surface in the active arc region of the fan for insulation. The slurry was air cured.
2. A fibrefrax gasket enclosed in metal foil was added between the front frame and scroll center mounts for insulation.
3. Spacers were used between the front frame flange and honeycomb air seals to increase rotor to rear frame axial clearance. Part number 4012001-374 has been assigned to the spacers.
4. Metal strips (.020") were used to bridge across the outer scroll seal ends to prevent gas leakage.
5. Four aluminum strips were inserted in the honeycomb air seals (extending beyond the honeycomb surface into the rotor) to measure axial and radial movement of the rotor during test (part of research instrumentation).

The test fan serial number assigned is 001. Figure I-6 shows the assembled fan prior to test.

Overspeed Limiter: The overspeed limiter was demonstrated with the flight type electronics package but with a substitute device (P_{S3} bleed) for the throttle linkage actuator mechanism. The signal from the package was used to open a valve which was "teed off" the engine control P_{S3} line. This reduced the P_{S3} signal to the engine fuel control causing the engine to cut back about 2% in speed.

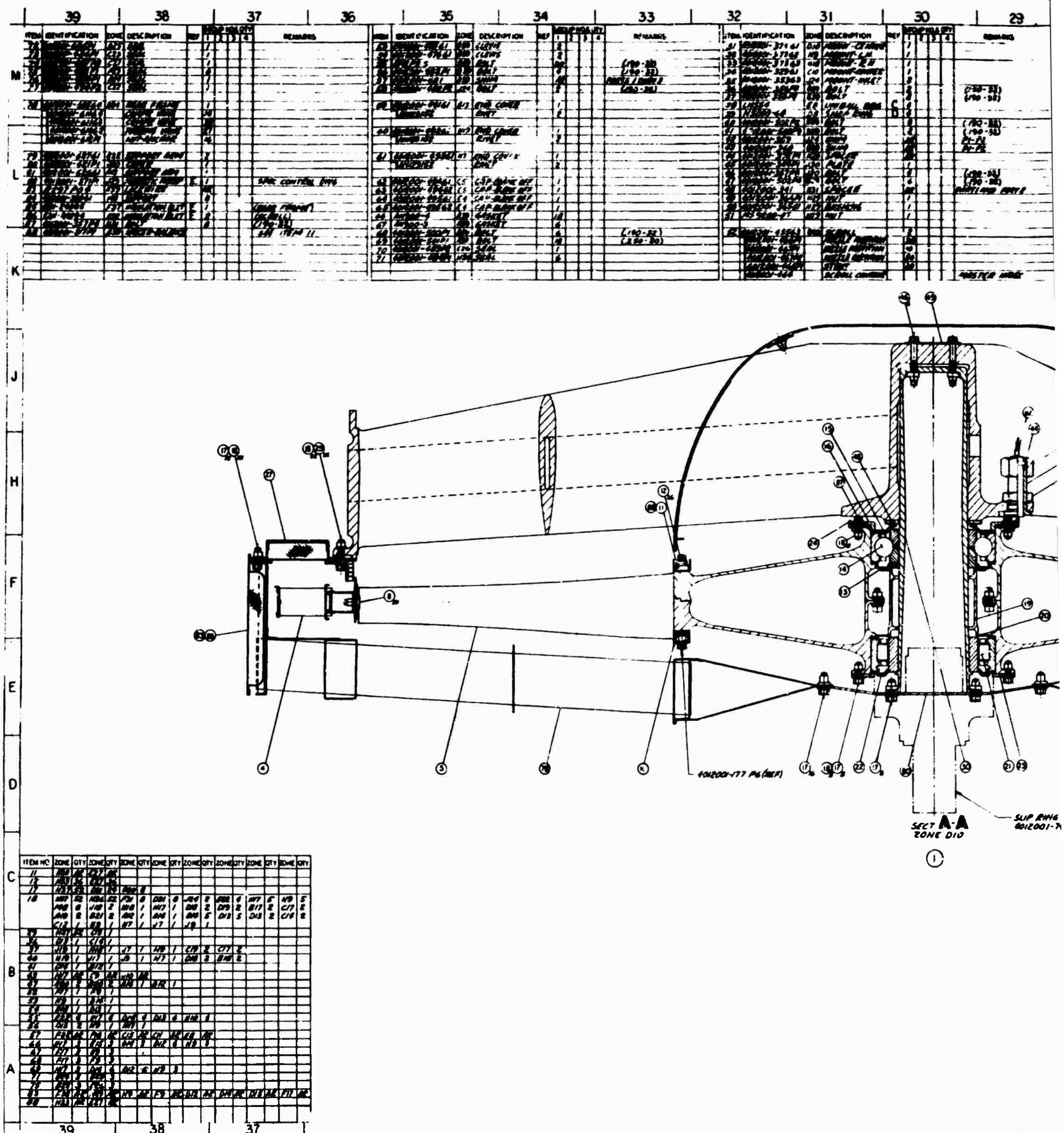
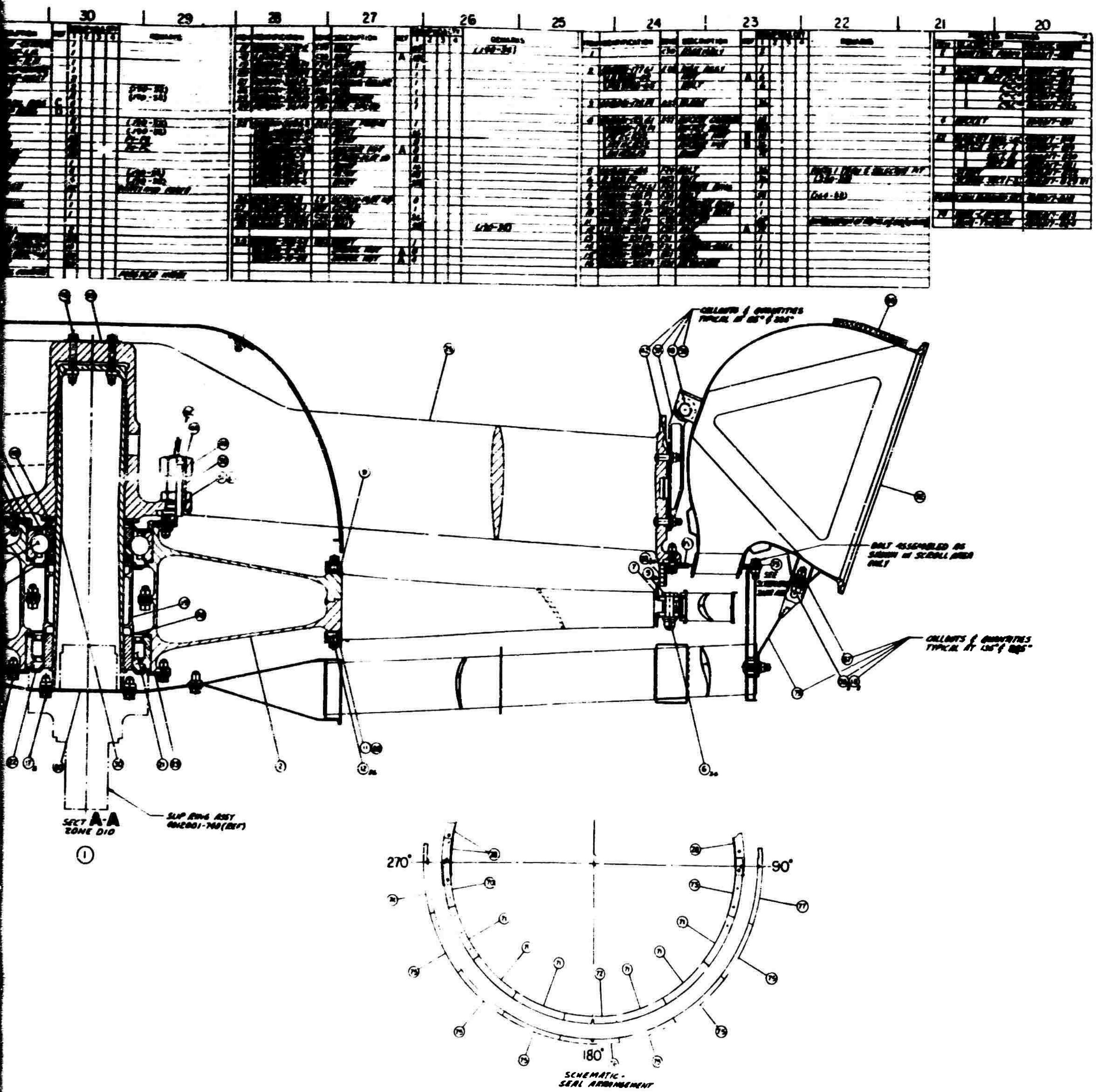


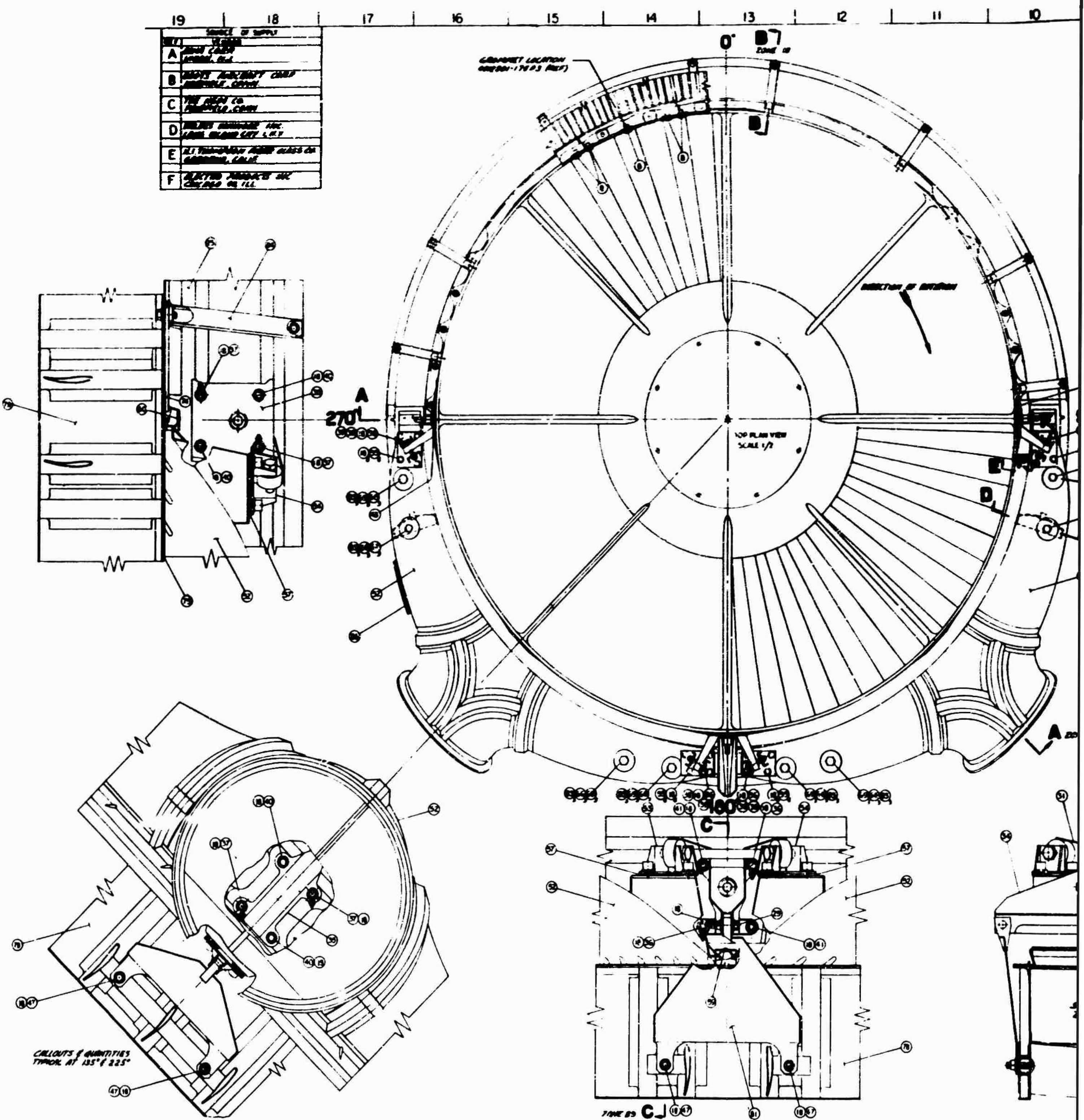
Figure I-5. Pitch Fan - Basic

Sheet 1 of 2



Pitch Fan - Basic Assembly X376

Sheet 1 of 2



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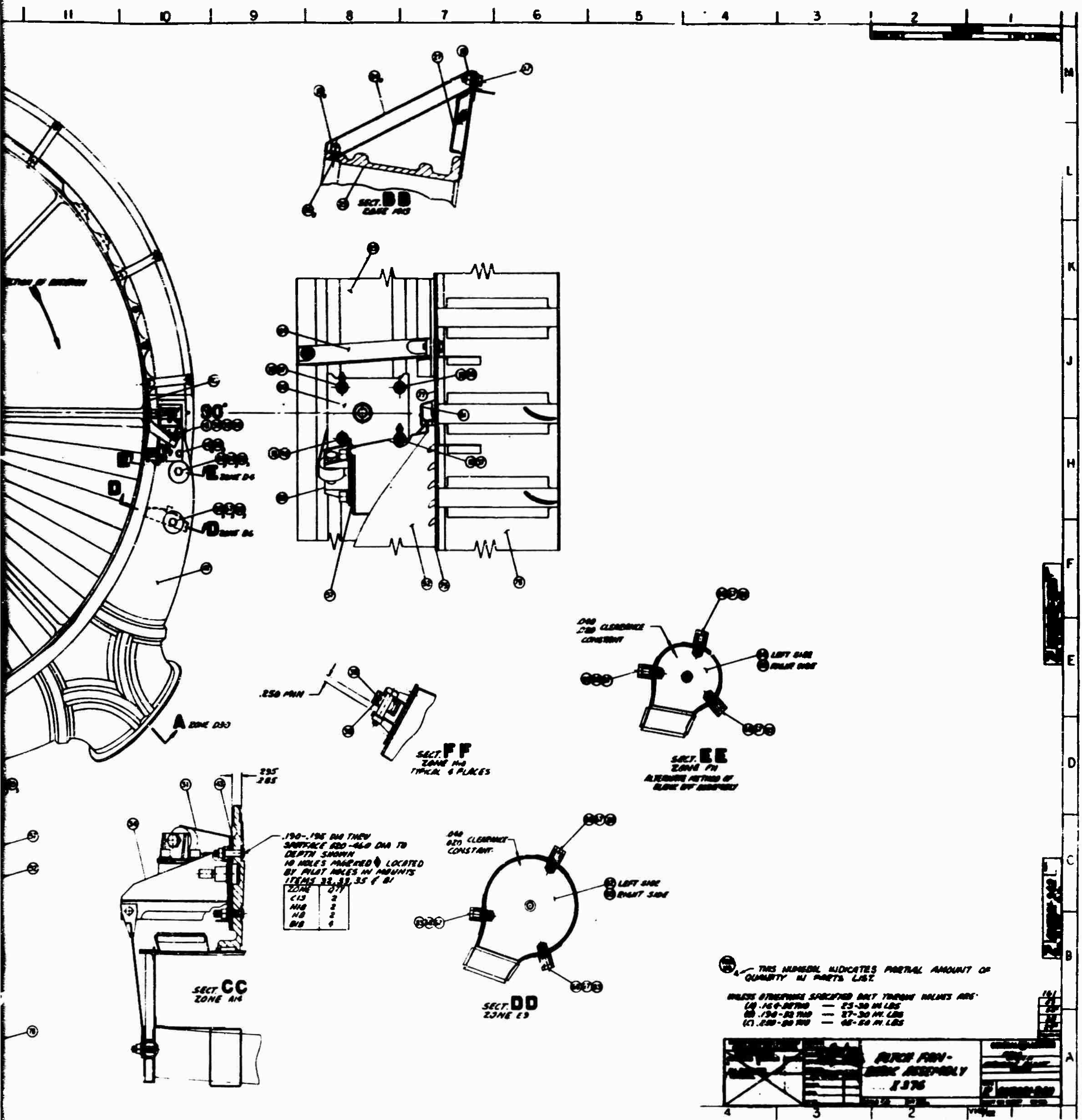

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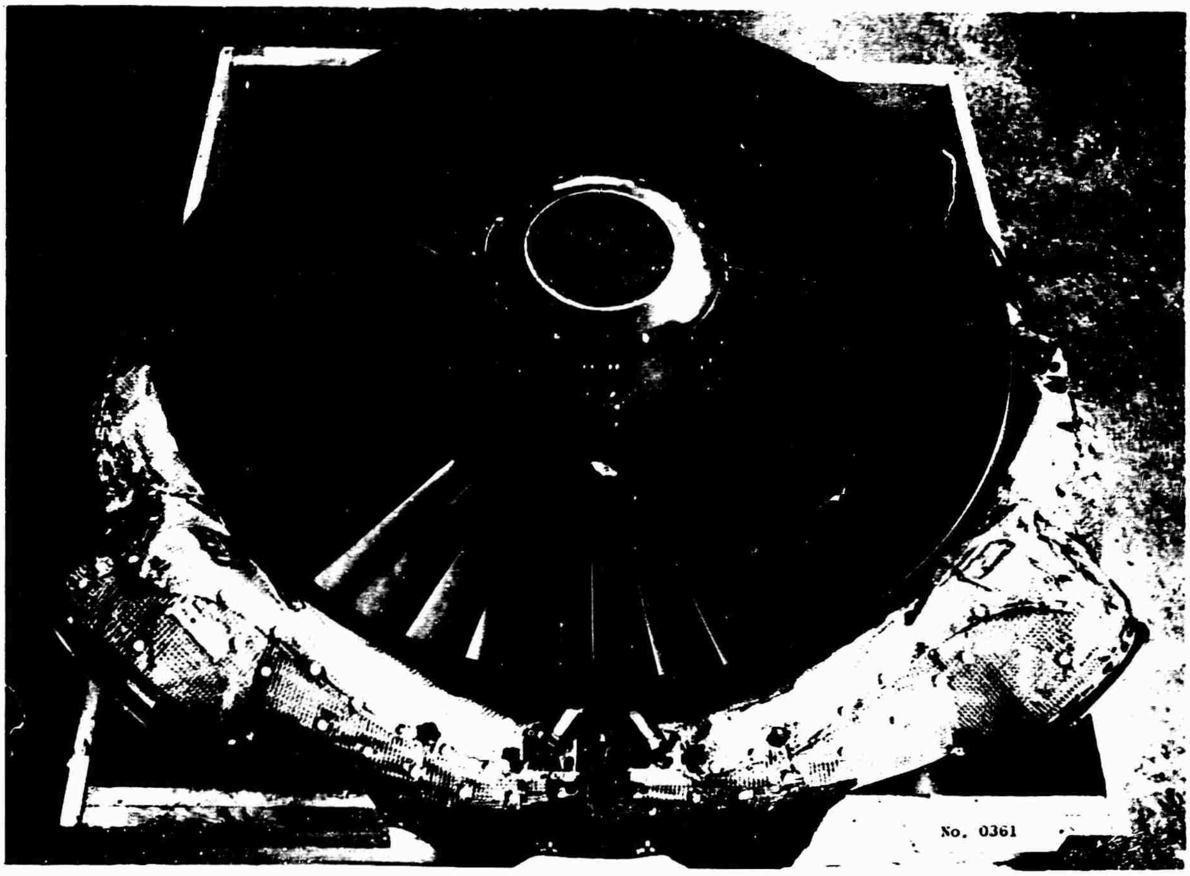


Figure I-6. Pitch Fan Assembly Before Test

2. PROPULSION SYSTEM INSTALLATION ARRANGEMENT

The X353-5B propulsion system was installed in General Electric's Evendale Test Facility arranged as it will be installed in the XV-5A research airplane. Figure I-7 is a view of the facility from above showing the test installation. Figures I-8A and I-8B show individual installations of the lift fan and pitch fan.

The system consisted of the following items:

Lift Fan	- X353-5B S/N 003L (B/U 2)
Pitch Fan	- X376 S/N 001 (B/U 2)
Diverter Valve Position #1	- X353-5B S/N 003L (B/U 2)
Diverter Valve Position #2	- X353-5B S/N 004R (B/U 2)
Cross Duct Position #1	- Ryan S/N 001
Cross Duct Position #2	- Ryan S/N 002
Pitch Fan Duct Position #1	- Ryan S/N 001
Pitch Fan Duct Position #2	- Ryan S/N 002
Engine #1	- J85-GE-5 (S/N 230730)
Engine #2	- J85-GE-5 (S/N 230729)

The lift fan was installed in a test type wing structure which has a NACA 65-210 series contour. The lift fan rotor centerline was 12 feet from the ground. Since the lift fan tested was a left hand fan, the exit louvers deflected the air forward instead of aft. The engine and fans were not enclosed as they will be in the airplane.

The pitch fan inlet provided by Ryan has the same contour as the airplane inlet (Figure I-9C). Some external stiffening was added to the inlet which penalized the pitch fan an undetermined amount (considered negligible). The stiffening along with internal ribs was required to further strengthen the inlet after it had lifted off the front frame during the early runs.

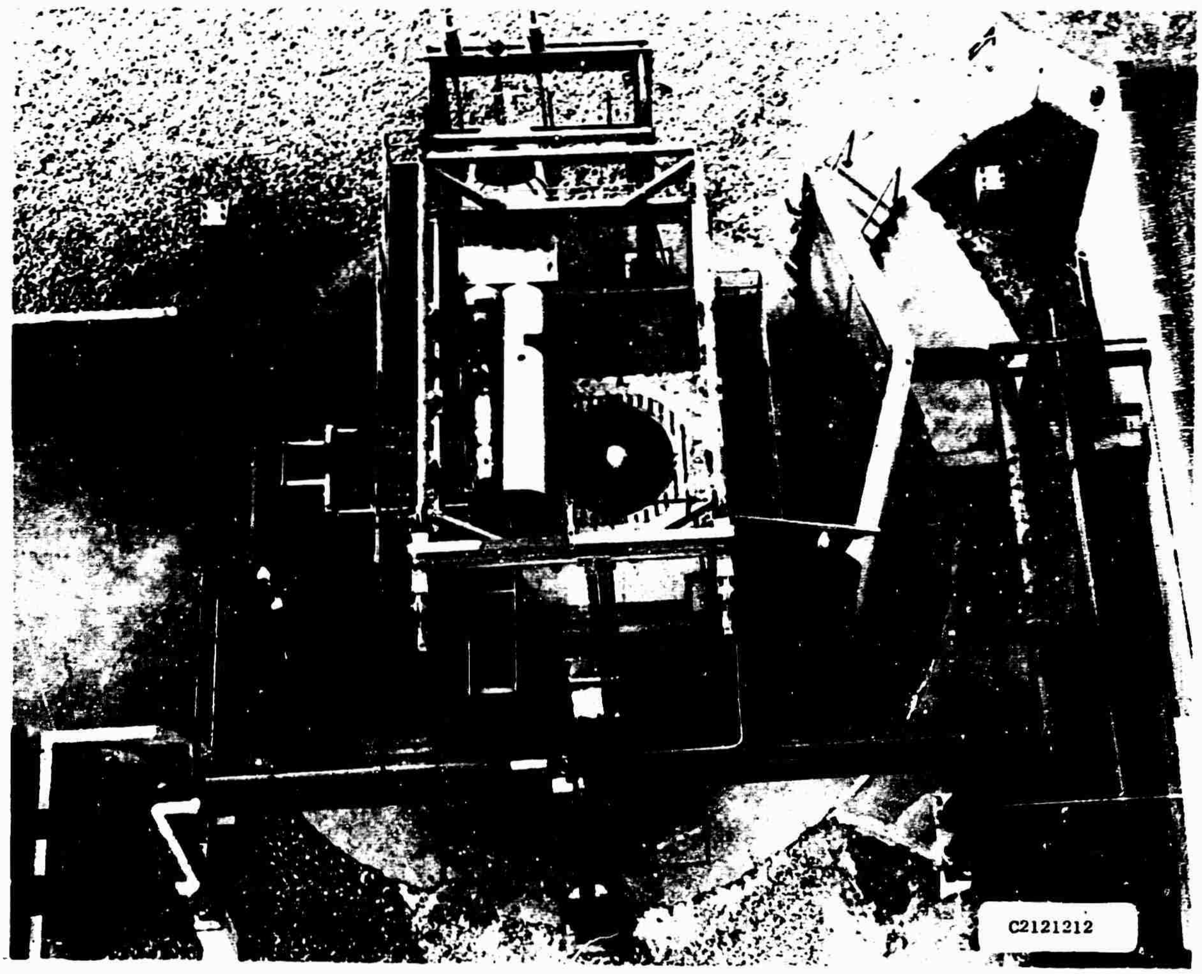


Figure I-7. FWT Installation (Aerial View)

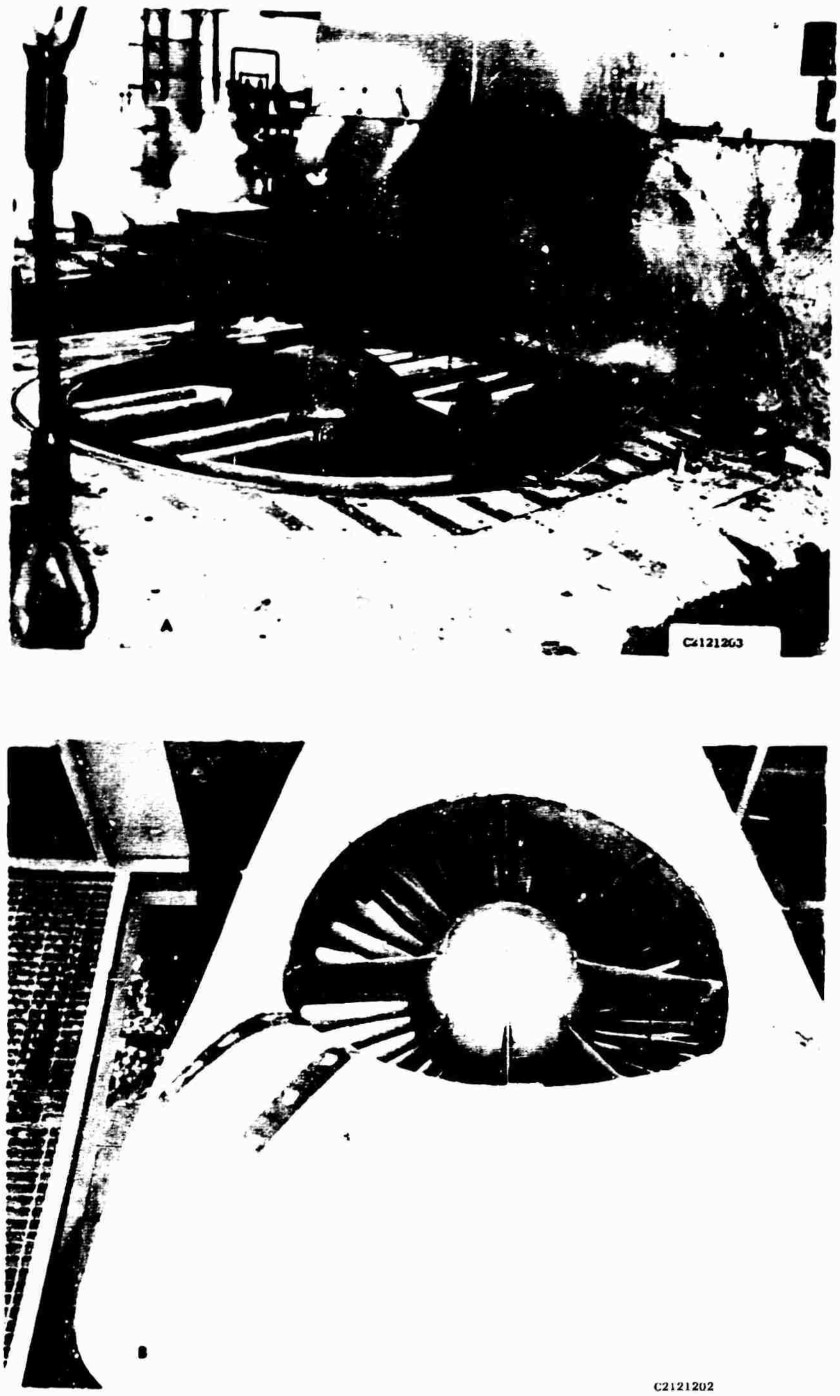


Figure I-8. A. Lift Fan Installation

B. Pitch Fan Installation

The engine inlets (Figure I-9A) are calibrated flow measuring sections and were not intended to simulate the XV-5A inlets. They have a standard bellmouth contour and incorporate a special bulletnose to allow for accurate inlet flow measurement.

Each fan was protected by an inlet screen (Figure I-9B typical). Fan inlet thermocouples were also attached to the screen to provide for measurement in a low velocity flow field. The screen losses reduced lift by approximately 0.4%. No correction is made to performance data for this loss.

Ducting interconnecting the lift fans and distributing bleed gas to the pitch fan is flight type XV-5A hardware supplied by Ryan (see Figures I-10A through I-12C). The cross-over ducts are shown in Figures 11 and 12A. Figure 11 shows the cross-over ducts during trial installation without insulation. A six inch long instrumented section was provided in each pitch fan duct to provide for bleed flow measurement. The orifices terminating the bleed ducts in Figure I-12C were used initially to enable testing the lift fan without the pitch fan installed in order to establish its individual performance level. The ducts were insulated with a 1/2" thickness of "Fibrefrax" covered by aluminum foil and held in place by wire mesh. Near the lift fan turbine stream, an additional covering of sheet stainless steel was finally added to avoid erosion (see Figure I-12A). Another view of the installation in Figure I-12B shows the "cruise" nozzles which were simple conical nozzles canted vertically 7° to turn the discharge air horizontal (engines installed at 5° angle to horizontal).* In this figure and Figures I-7 and I-9A can be seen an aluminum wall installed on the inboard side of the lift fan to simulate the XV-5A fuselage and to provide representative lift fan inlet flow conditions.

Non-flight type mounts were used but all frame loads and duct loads

*Overturning in test nozzle required because of short length.

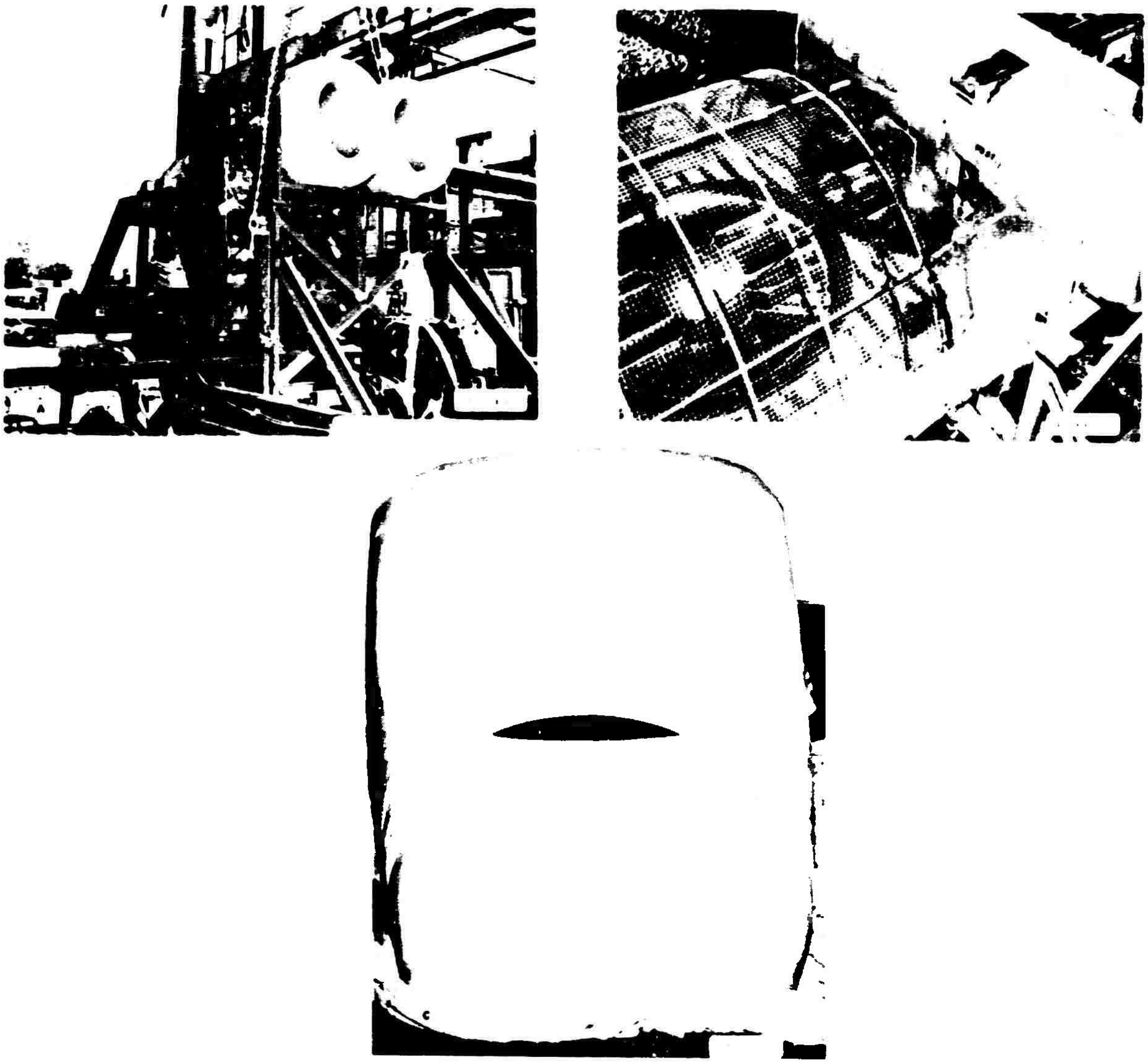
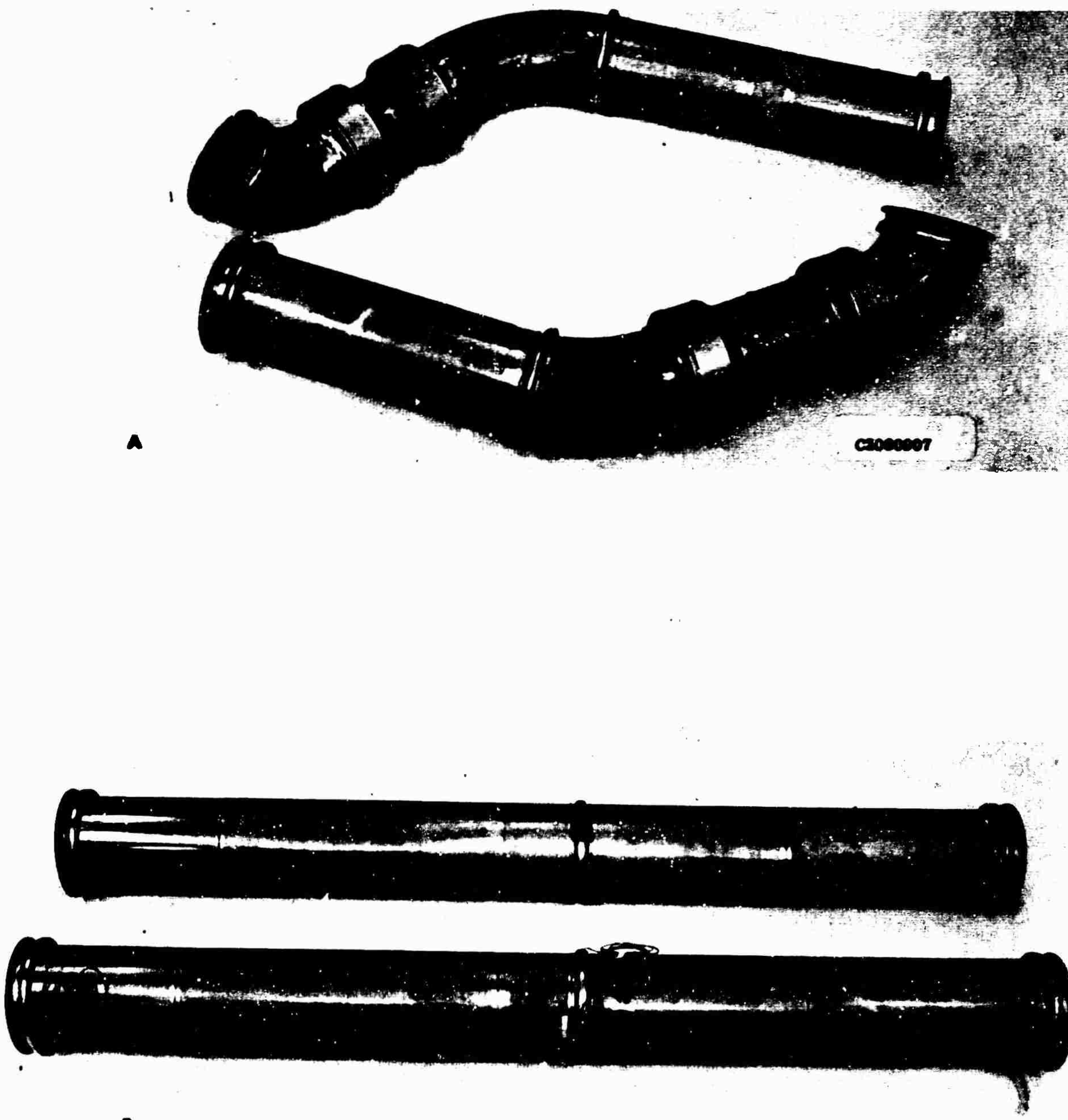


Figure I-9. A. Engine Test Inlets

B. Typical Fan Inlet Screen

C. Pitch Fan Test Inlet



A

B

Figure I-10. Pitch Fan Ducts (Ryan VX-5A)

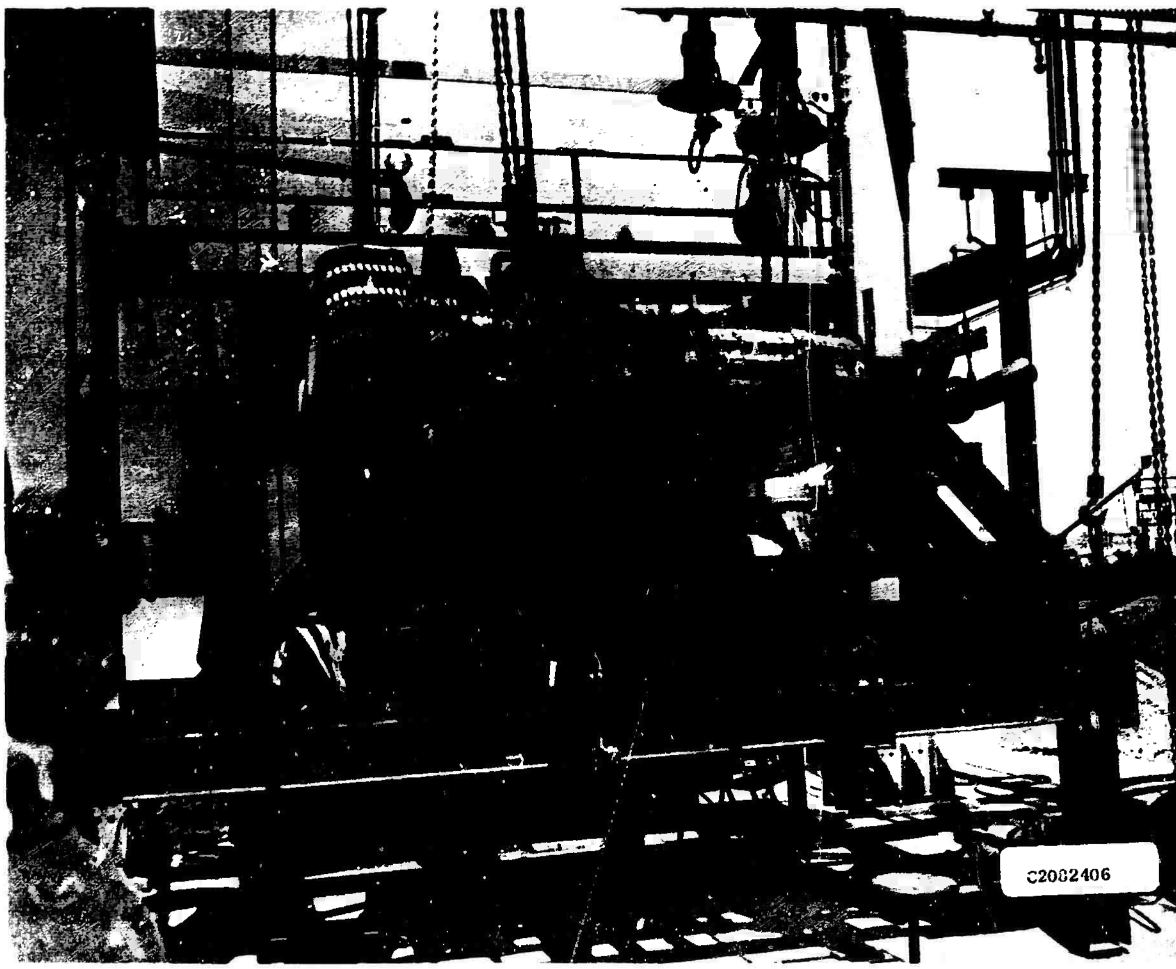


Figure I-11. Crossover Ducts Trail Assembly (Ryan XV-5A)

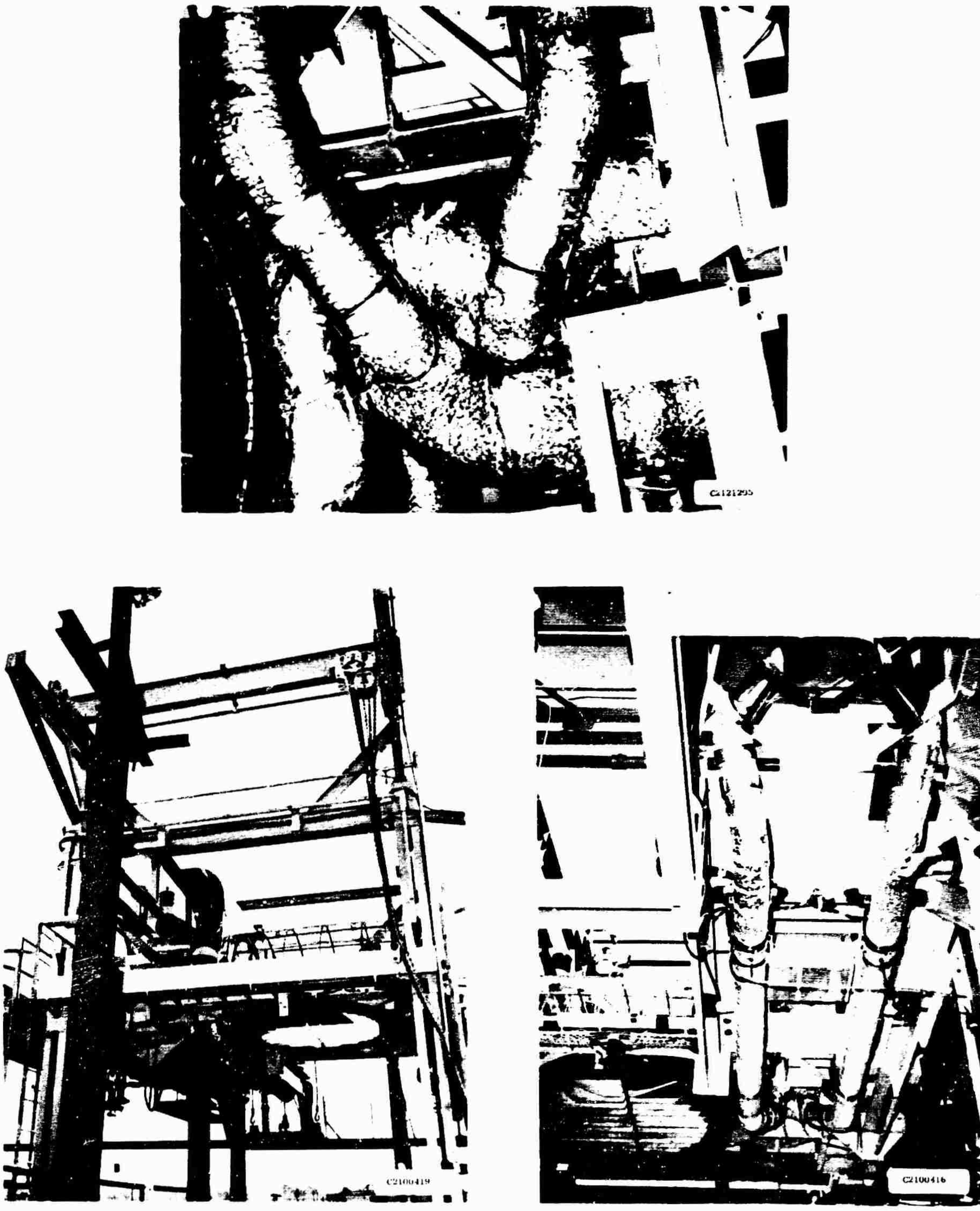


Figure I-12. A. Crossover Ducts From Below (Ryan XV-5A)

B. FWT Installation Showing Cruise Nozzles

C. Ducting Installation

were the same as will be encountered in the XV-5A airplane except, of course, maneuver loads, cross-flow loads, and airplane deflection loads. The basic facility design is for a right wing fan; the FWT fan was a left wing fan and the leading and trailing edge fan mounts were, therefore, switched to establish proper front frame loading from exit louver turning.

Non-flight type thrust reverser doors (Figures I-13B and I-13C) were used to spoil pitch fan thrust as required in the test. Their contour is closely similar to, but not precisely the same as the XV-5A door contours.

The engine flow which would normally go to a second wing fan was discharged overboard through ducting which was attached to the cross-over ducts (see Figure I-13A). This flow is controlled by trimmed conical nozzles terminating each duct and is measured by instrumentation installed in the ducts according to ASME standards. The thrust from this flow was taken out through a cable located between the ducts. This thrust and the cable restraint are perpendicular to the vertical and horizontal load cells thereby avoiding any effect on lift and thrust data,

3. PRE-TEST DEVIATIONS

The installation was intended to provide the basis for measuring uninstalled performance (neglects ground effect, inlet closure hardware, tailpipe performance effect). The interconnecting ducting performance is inseparable from the propulsion system performance and is included in the results as part of the fan losses. Table I lists all deviations which existed for the FWT.

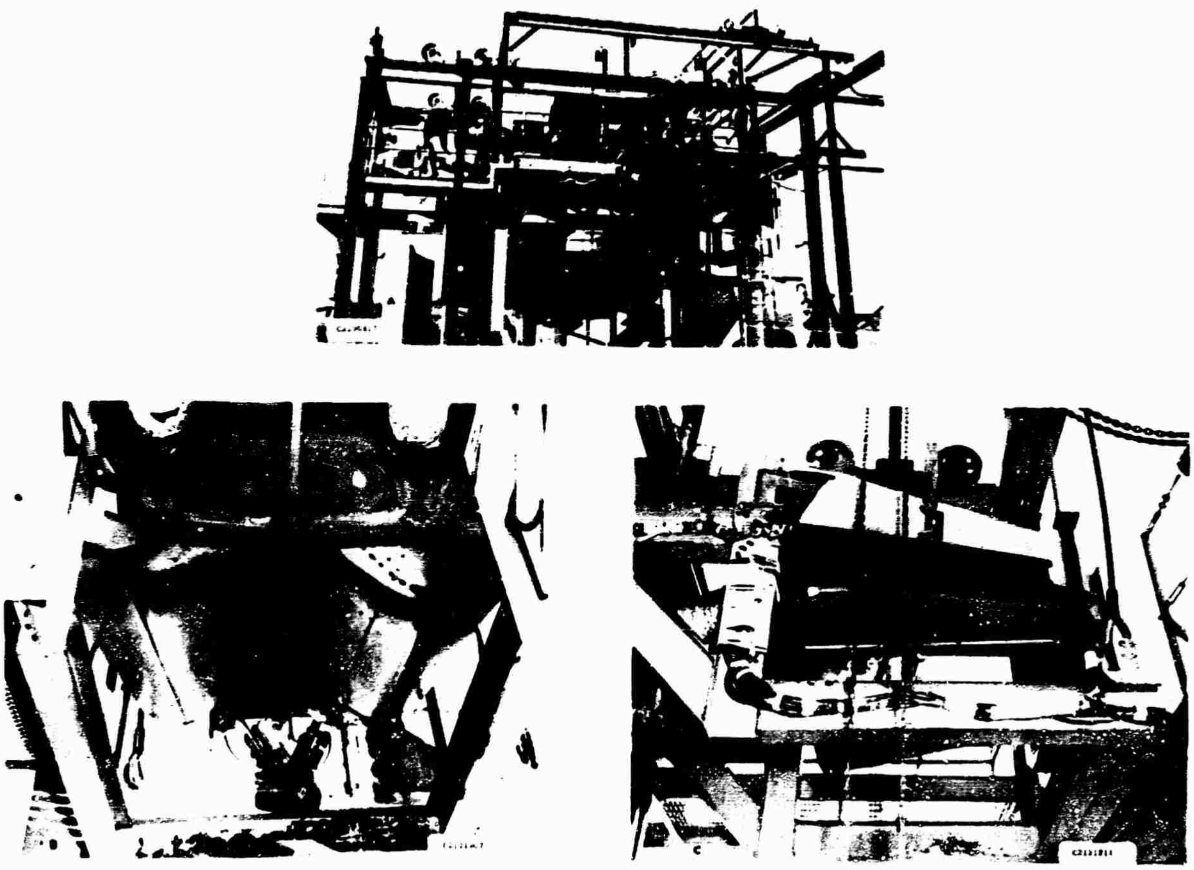


Figure I-13. A. Second Lift Fan Simulator Bleed System

B. Pitch Fan Test Thrust Reversers (Nominal Setting)

C. Pitch Fan Test Thrust Reversers - Side View

TABLE I. FLIGHTWORTHINESS TEST DEVIATIONS

Component	Test Deviation	Reason or Plan
A. Lift Fan	1. Simulated Ryan interface hardware	1. Not required in Flightworthiness test setup.
	a. Leading and trailing edge trunnions	a. Flight quality, General Electric design.
	b. Bellmouth to wing seal	b. Similar design.
	c. Exit louver actuators and support brackets	c. Electric screwjacks but loaded into lift fan rear frame as in XV-5A.
	d. Bulletnose cover	d. Test weight, General Electric design, no closures.
	2. No inlet closure hardware	2. Not required in Flightworthiness test setup.
	3. Fan inlet screen used	3 Reduce possibility of foreign object damage.
B. Pitch Fan	1. Test type thrust reverser	1. Electric screwjack actuation; instrumented for temperature, flight type doors will be checked out during Acceptance tests.
	2. Rear frame cover altered	2. Hole cut in cover for slipring.
	3. Test type inlet	3. Ryan provided, simple lap seal; no closure vanes.
	4. Fan inlet screen	4. Reduce possibility of foreign object damage.
	5. Test mounts	5. Flight quality, General Electric design.
C. Engines	1. Bellmouths, bulletnoses and seals	1. Ideal contour for flow measurement. Not intended for XV-5A simulation.
	2. Tailpipes	2. General Electric design for EGT calibration and A_8 adjustment; short for cantilever installation.
D. Diverter Valves	1. Actuators and linkage	1. Original design used. To be replaced by dual piston actuation in Acceptance test.
E. Bleed System	1. Simulates second fan	1. Used to measure flow split and adjust EGT.
	2. Mounting System	2. Ducts mounted to have thermal growth in same direction as fan. Mounts were insulated because they run cooler than 3 o'clock mounts on fan.
F. Cross-over Ducts	1. Fibrefrax and aluminum insulation	1. More practical for test than flight type insulation.
	2. Fuel drains	2. Added by General Electric XV-5A location but not flight type.
	3. Re-located point 10 mount	3. Required to avoid interference with bellows; approved by Ryan.
G. Pitch Fan Ducts	1. Six inch instrument spool piece	1 Inserted into ducting to measure flow, flow function and sound in each duct.
	2. Fuel drains	2. Added to each spool piece.
	3. Fibrefrax and aluminum insulation	3. More practical for test than flight type insulation.

Section C

M E T H O D   O F   T E S T

C. METHOD OF TEST

1. THRUST FRAME AND MEASUREMENT SYSTEM

The test stand used consists of three frame support structures which are cross-braced to each other (see Figure I-14). The propulsion system thrust frame is suspended from this structure by three vertical load cells which are used for lift measurement. Two horizontal load cells are attached to the trailing edge of the wing for thrust measurement.

The vertical load cells are Tate Emery Model EU20 hydraulic load cells. The accuracy of these cells was determined by applying vertical calibration loads at the lift fan center of lift and system center of lift. Both vertical and horizontal calibration loads were applied through a calibration ring (Figures I-15A & B) which in turn was calibrated using a dead weight testing machine. The lift accuracy is ± 1.71% for the lift fan and ± 1.94% for the pitch fan (Table II).

The horizontal load cells are Baldwin strain gage type U-1 load cells. Horizontal calibration loads were applied at both the wing leading and the trailing edges. The horizontal thrust accuracy is ± 2.65% (Table II).

To separate lift fan and pitch fan contributions to the measured lift, the pitch fan lift was obtained using the following formula (refer to the Appendix for derivation):

$$L_{PF} = \frac{L_{VN} - 0.01188\ L_T}{0.81690}$$

Where: L_{PF} = Pitch Fan Lift

L_{VN} = Vertical Nose Load Cell Lift

L_T = Total System Lift

TABLE II

LIFT AND THRUST ACCURACY

	System Lift	Lift Fan Lift	Pitch Fan Lift	Horizontal Thrust
Load Cell Calibration	±0.45%	N/A	N/A	±0.71%
Test Data Accuracy	±0.94%	±1.71%*	±1.94%*	±1.94%
Overall Accuracy	±1.39%	±1.71%	±1.94%	±2.65%

*95% Confidence limits, neglecting wind effect.

This formula was derived from load cell calibration data based on applied loads at a system center of lift corresponding to a 10 mph West wind. Thrust frame geometry is described in Figure I-14. Run 20 was conducted during 6 mph ENE winds; Run 37 occurred during 15 mph SW winds and yields more accurate pitch fan lift values (see Figure I-55). Analysis of wind influence on thrust measurement and fan performance is included in the Appendix.

2. TEST EQUIPMENT

Exit Louvers Actuators: Electric screwjacks were used to operate the exit louvers. Pushrods stop contact was purposely avoided because of the large forces which screwjacks can develop.

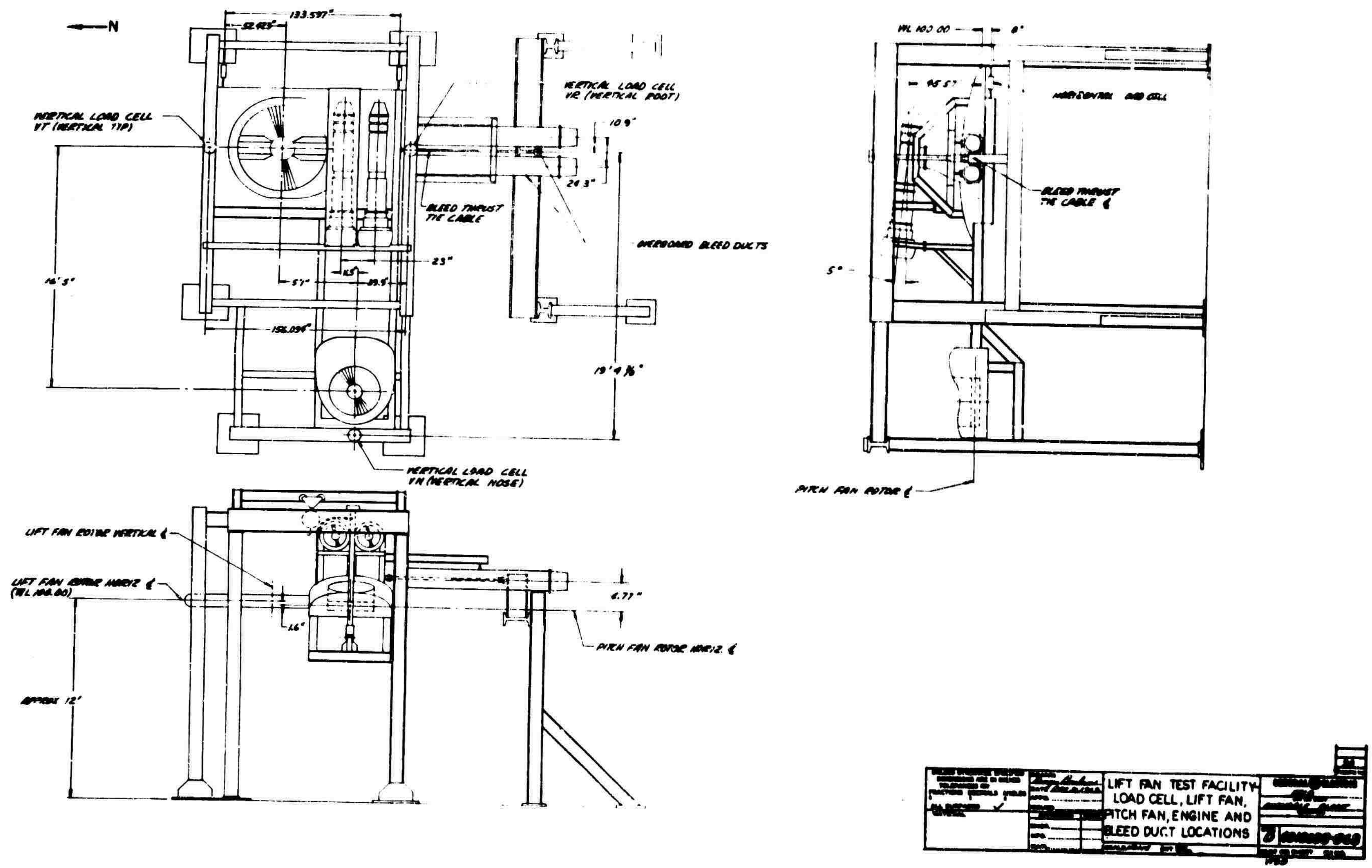


Figure I-14. Lift Fan Test Facility - Load Cell, Lift Fan, Pitch Fan, Engine And Bleed Duct Locations

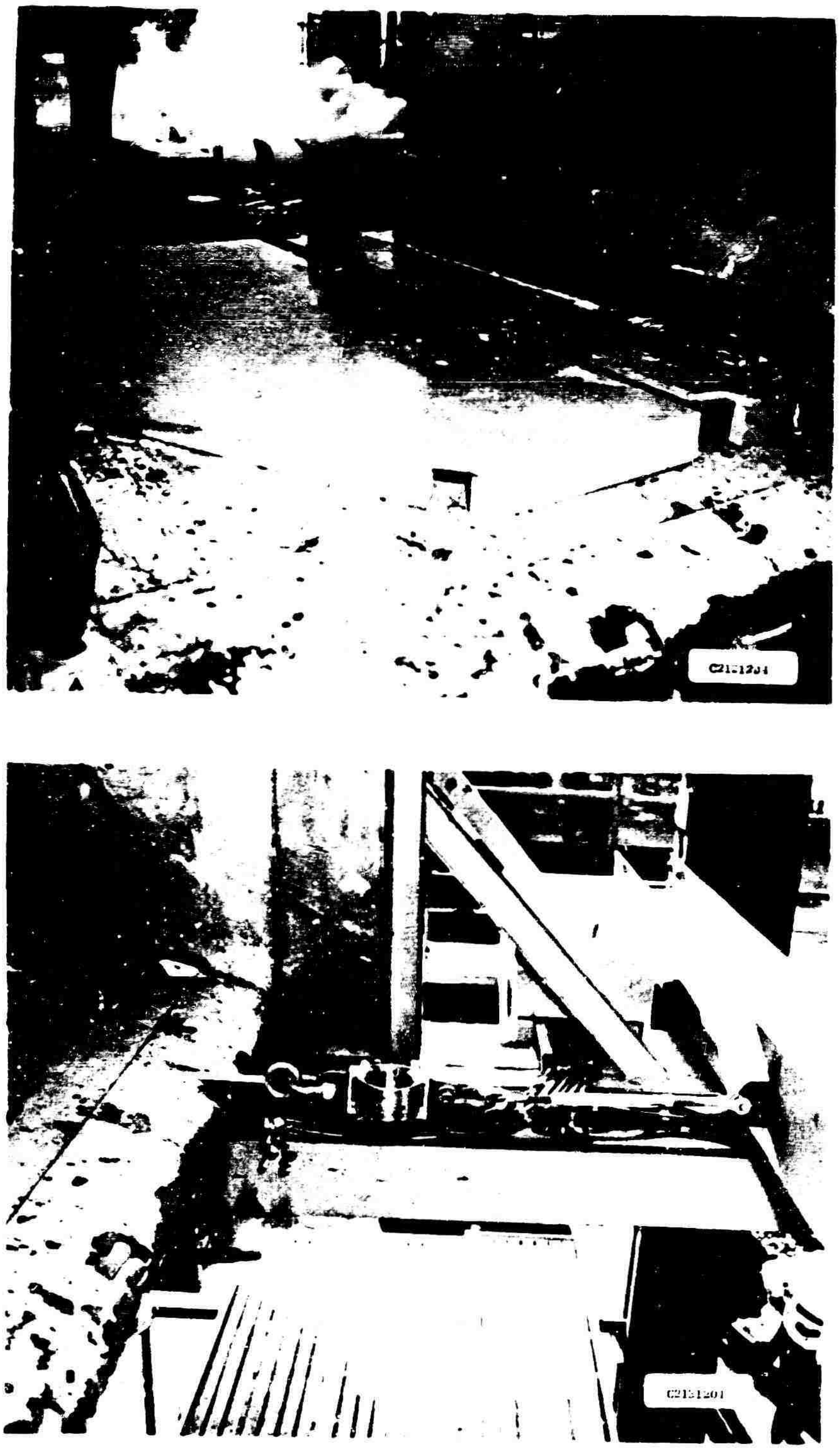


Figure I-15. A. Vertical Thrust Calibration Fixture

B. Horizontal Thrust Calibration Fixture

Thrust Reverser Doors: Thrust reverser doors provided were as nearly like the flight type doors as was economically practical. Drawings of these doors are available upon request. (4012028-714, 4012028-715, and 4012017-868). Bulkheads were made to support the doors and were also similar to the flight type bulkheads in contour (4012028-735 and 4012028-736).

Facility Wall: A 1/8" thick aluminum sheet was used to simulate the XV-5A fuselage wall. It was fitted to the inboard side of the lift fan extending straight up for the 40 inches and then leading into a 15 inch radius to the horizontal; the final section covered only the position number two engine.

Cooling Air: Cooling air was provided to the exit louver actuators and position transmitters. Cooling air was also required to purge the fiberglass pitch fan inlet because hot discharge air was being forced into the cavity of the inlet during reversed thrust test points. This occurred because there was no positive seal between the pitch fan rear frame and the fiberglass inlet closure.

"Cruise" Nozzles: The two "cruise" nozzles had provision for trimming the engine discharge area. Drawing 4012269-936 showing the detailed construction is available on request. The nozzles were interchangeable (via Marmon clamp) so that one, which contained 32 thermocouples used to calibrate the engine T_{t5} harness, could be tested with each engine.

3. INSTRUMENTATION

The total instrumentation provided for the test is listed in Table III. Operational and research type instrumentation is identified.

TABLE III. INSTRUMENTATION

Item	Location	Plane	Sensor	Readout	Quantity	Purpose
1	Engine inlet	2.0	Static pressure (wall)	100 in. H_2O mano	6[a]	Engine flow measurement.
2	Engine inlet	2.0	Total temperature (CA)	Digital mv recorder	3[a]	Engine flow measurement, correcting engine performance.
3	Engine turbine discharge	9.1	*Total temperature (CA)	Weston meter and Digital mv recorder	1[a]	Monitor engine performance and engine power.
4	Engine turbine discharge	9.1	Total pressure	60 in. Hg mano	21[a]	Engine power.
5	Engine turbine discharge	6.0	Total temperature (CA)	Digital mv recorder	33[c]	Calibrate station 5.1 EGT harness.
6	Fan rotor discharge	16.8	**Total pressure	100 in. H_2O mano	24[b]	Fan pressure rise.
7	Pitch fan scroll inlet	15.3	Total pressure	60 in. Hg mano	6[a]	Power and weight flow to the pitch fan
8	Pitch fan scroll inlet	15.3	Static pressure (wall)	100 in. H_2O mano ΔP with $P_{T15.3}$	3[a]	Weight flow to the pitch fan.
9	Overboard flow	5.3	Total temperature (CA)	Digital mv recorder	9[a]	Weight flow overboard.
10	Overboard flow	5.3	Static pressure (wall)	0-60 in. Hg mano	3[a]	Weight flow overboard.
11	Overboard flow	5.3	Total pressure	0-100 in. H_2O mano	13[a]	Weight flow overboard.
12	Pitch fan inlet	20.0	**Static pressure (wall)	100 in. H_2O mano	12[b]	Pitch fan flow.
13	Pitch fan rotor discharge	20.8	**Total pressure	100 in. H_2O mano	24[b]	Pitch fan pressure rise.
14	Slipring (fan)	-	Total temperature (CA)	Dial gage 0-300°F	1[b]	Bearing temperature.
15	Lift fan inlet temperature	10.0	Total temperature (CA)	Digital mv recorder	8	Correcting fan performance.
16	Pitch fan inlet temperature	20.0	Total temperature (CA)	Digital mv recorder	8	Correcting pitch fan performance.
17	Pitch fan duct and reverser door	-	**(CA) Thermocouple	Digital mv recorder	32[b]	Skin temperature measurement.
18	Pitch fan duct	-	**Sound probe	Tape recorder	1[b]	Sound pressure level.
19	J85 inlet	2.0	Boundary layer pressure	100 in. H_2O mano	10[b]	Flow calibration.
20			*Compressor discharge static Pressure	Kolsman gage 0-200 in. Hg	1[a]	Monitor engine performance.
21			*Lift fan bearing T.C. (CA)	0-400°F (CA) gage	2[b]	Fan bearing temperature.
22			*Pitch fan bearing T.C. (CA)	0-400°F (CA) gage	1[b]	Pitch fan bearing temperature.
23			*Flow potter	Berkley	1[a]	Fuel flow.
24			*Engine oil temperature (CA)	0-400°F (CA) gage	2 or 3[a]	Engine oil temperature.
25			*Fuel pressure transducer	0-600 psig gage	1[a]	Fuel control pressure.
26			*Oil pressure transducer	0-200 psig gage	1[a]	Oil pressure.
27			*Engine tach generator	0-18,000 rpm tach	1[a]	Engine speed.
28			*Fan speed pickup	Tach, Sanborne, and Berkley	1[b]	Fan speed
29			*Pitch fan speed pickup	Tach, Sanborne, and Berkley	1[b]	Pitch fan speed.
30			*Engine vibrations	0-10 mils with 70 cycle filter	4[a]	Engine vibes.
31			*Fan vibrations	0-20 mils with 10 cycle filter	2[b]	Fan vibes.
32			*Pitch fan vibrations	0-20 mils with 10 cycle filter	2[b]	Pitch fan vibes.
33			*Throttle position	Selsyn gage	1[a]	Throttle position.
34			*Diverter valve position micro switch	Light, on and off indicator	1[a]	Diverter valve position.
35			*Exit louver position	Selsyn gage -30° to +60°	2[b]	Exit louver position.
36			*Pitch fan thrust reverser	Selsyn gage 0° to 120°	2[b]	Thrust reverser position.
37	Pitch fan rotor		**Blade strain gage		6	Stress measurement.
38	Lift fan rear frame		**Stator strain gage		9	Stress measurement.
39	Lift fan rotor		**Blade strain gage		10	Stress measurement.
40	Lift fan inlet vane		**Strain gage		1	Stress measurement.
41	Lift fan rotor		**Rotating thermocouples		3	Torque band and shaft temperature.
42	Pitch fan rotor		**Rotating thermocouples		2	Torque band temperature.
43	Pitch fan front frame		**Frame thermocouples		4	Frame temperature measurement.

[a]Two sets required - one per engine. [b]One set only. [c]Used on each engine to calibrate the EGT harness.

*Operational instrumentation. **Research instrumentation

4. TEST PROCEDURE

A detailed test plan was prepared (included in Volume III) based on Specifications 114 and 115 which were complied with except that wind velocity usually exceeded the 5 mph level specified.

The order of the test was as follows:

Performance Calibration

Cycle #1 - Cyclic Endurance

Cycle #2 - Constant Power Endurance

Cycle #3 - Cyclic

Cycle #4 - Cyclic

Cycle #8 - Constant Power (Partial)*

Cycle #5 - Constant Power

Cycle #6 - Cyclic

Cycle #7 - Constant Power

Cycle #9 - Constant Power

Cycle #10 - Cyclic

Cycle #8 - Constant Power (Completed)

Rotor Penalty Test

Performance Recalibration

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*Delayed for potential exit louver penalty. Louvers later considered unsatisfactory so run on rest of hardware was completed at the end of the test.

D. CALIBRATIONS

1. INSTRUMENTATION SENSORS AND SYSTEM

Table IV lists all sensors and system calibration methods and test accuracies pertaining to the FWT. Diverter valve inlet pressure and temperature instrumentation are shown in Figures 16A and B. Lift fan and pitch fan sensors are shown in Figures 17A through G and 18A through F.

2. THRUST FRAME

Thrust frame accuracies were presented in the previous section. The load cell calibrations used are shown in Figures I-19, I-20, I-21, and I-22.

3. OVERSPEED LIMITER

A bench test of the overspeed limiter was made prior to flight-worthiness testing. The results are shown below:

	Warning Light On		Power Cut Back		Warning Light Off	
	RPM	%RPM	RPM	%RPM	RPM	%RPM
Pitch Fan Spec.	4074	100.00	4481	110.00	-	-
Pitch Fan Test	4073	99.98	4477	109.89	3936	96.6
Lift Fan Spec.	2640	100.00	2719	103.00	-	-
Lift Fan Test	2652	100.45	2730	103.42	2562	97.1

Since all warning and power cutback functions occurred with $\pm$ 0.5%

TABLE IV. INSTRUMENTATION ACCURACY AND CALIBRATION

Description	Scale	Units	Accuracy	Method of Calibration and Remarks
I. AIR AND GAS TEMPERATURE MEASUREMENT				Chromel-Alumel thermocouples were used throughout. System resistance for each thermocouple checked as less than 8 OHMS. Temperatures were recorded on digital millivolt recorder with a zero and full scale calibration signal being fed to recorder at all times.
J85 Inlet temperature	-10 to 140	°F (mv)	± 5°F	Impressed calibration voltage on system. Checked thermocouple vs. ambient temperature.
J85 Turbine discharge temperature	amb - 1800	°F (mv)	± 13°F	Aircraft type EGT meter - impressed calibration voltage; Digital mv recorder - calibration rakes installed aft of engine harness.
J85 Overboard bleed	amb - 1800	°F (mv)	± 13°F	Impressed calibration voltage on system.
Lift fan inlet temperature	-10 to 140	°F (mv)	± 8°F	Impressed calibration voltage on system. Checked thermocouple vs. ambient temperature.
Pitch fan inlet temperature	-10 to 140	°F (mv)	± 3°F	Impressed calibration voltage on system. Checked thermocouple vs. ambient temperature.
II. MECHANICAL TEMPERATURE MEASUREMENT				
Lift fan bearing temperature (3)	amb - 400	°F	± 6°F	Impressed calibration voltage on system.
Pitch fan bearing temperature	amb - 400	°F	± 8°F	Impressed calibration voltage on system.
Lift fan rotating temperatures (3)	amb - 1200	°F	± 15°F	Impressed calibration voltage on system. L&N recorder has one channel for continuous calibration signal.
Pitch fan rotating temperatures (3)	amb - 1200	°F	± 15°F	Impressed calibration voltage on system. L&N recorder has one channel for continuous calibration signal.
III. AIR AND GAS PRESSURE MEASUREMENT				All manometers checked for continuity. Specific gravity of manometer fluid checked.
J85 inlet boundary total pressure	0 - 100	inches H_2O	± .05 in. H_2O	
J85 inlet static pressure	0 - 100	inches H_2O	± .05 in. H_2O	
J85 Turbine discharge total pressure	0 - 60	inches Hg	± .05 in. Hg	
Pitch fan scroll inlet total pressure	0 - 60	inches Hg	± .05 in. Hg	
Pitch fan scroll inlet static pressure	0 - 100	inches H_2O	± .05 in. H_2O	
Overboard bleed total pressure	0 - 100	inches, Meriam Blue	± .05 in., Meriam Blue	
Overboard bleed static pressure	0 - 100	inches, Meriam Blue	± .05 in., Meriam Blue	
IV. J85 OPERATING PRESSURE MEASUREMENT				
Compressor discharge static pressure	0 - 200	inches Hg	± .5 in. Hg	Kollsman gage calibrated with lab pressure standard.
Fuel pressure	0 - 600	psig	± 10 psi	Gage calibrated with lab pressure standard.
Oil pressure	0 - 200	psig	± 5 psi	Gage calibrated with lab pressure standard.
V. FAN AND ENGINE SPEED MEASUREMENT				
J85 Speed	0 - 18,000	rpm	± 10 rpm	Berkley, Tachometer Indicator and Sanborne recorder calibrated with known frequency.
Lift fan speed	0 - 3,000	rpm	± 1 rpm	Berkley and Sanborne recorder calibrated with known frequency.
Pitch fan speed	0 - 3,000	rpm	± 1 rpm	Berkley and Sanborne recorder calibrated with known frequency
VI. VIBRATION MEASUREMENT				
J85 Vibrations (4 per engine)	0 - 10	mils	± 5% of Reading	Pickups and mounts calibrated on a shake table. Meters calibrated with known voltage. (70 cycle filter)
Lift fan vibrations (3)	0 - 20	mils	± 5% of Reading	Meters calibrated with known voltage (10 cycle filter).
Pitch fan vibrations (3)	0 - 20	mils	± 5% of Reading	Meters calibrated with known voltage (10 cycle filter).
VII. OTHER PARAMETERS MEASURED				
Mechanical stress				Scopes and recording tapes calibrated before and after each run. Reference channel recorded on tape continuously.
Fuel flow measurement	0 - 3,000	lbs/hr.	± 30 lbs/hr.	Flow meter calibrated on flow meter test stand.
Throttle position	-3 to 138	deg.	-	Calibrated with engine speed in engine checkout.
Diverter valve position	off or on	cruise or lift	-	Physical checkout.
Exit louver position	-10 to 90°	deg.	± 3°	Physical calibration with pendulum type protractor.
Thrust reverser position	0 to 120°	deg.	± 2°	Physical calibration with level type protractor.
J85 Engine oil temperature	amb - 400	°F	± 10°F	Impressed calibration voltage on system.

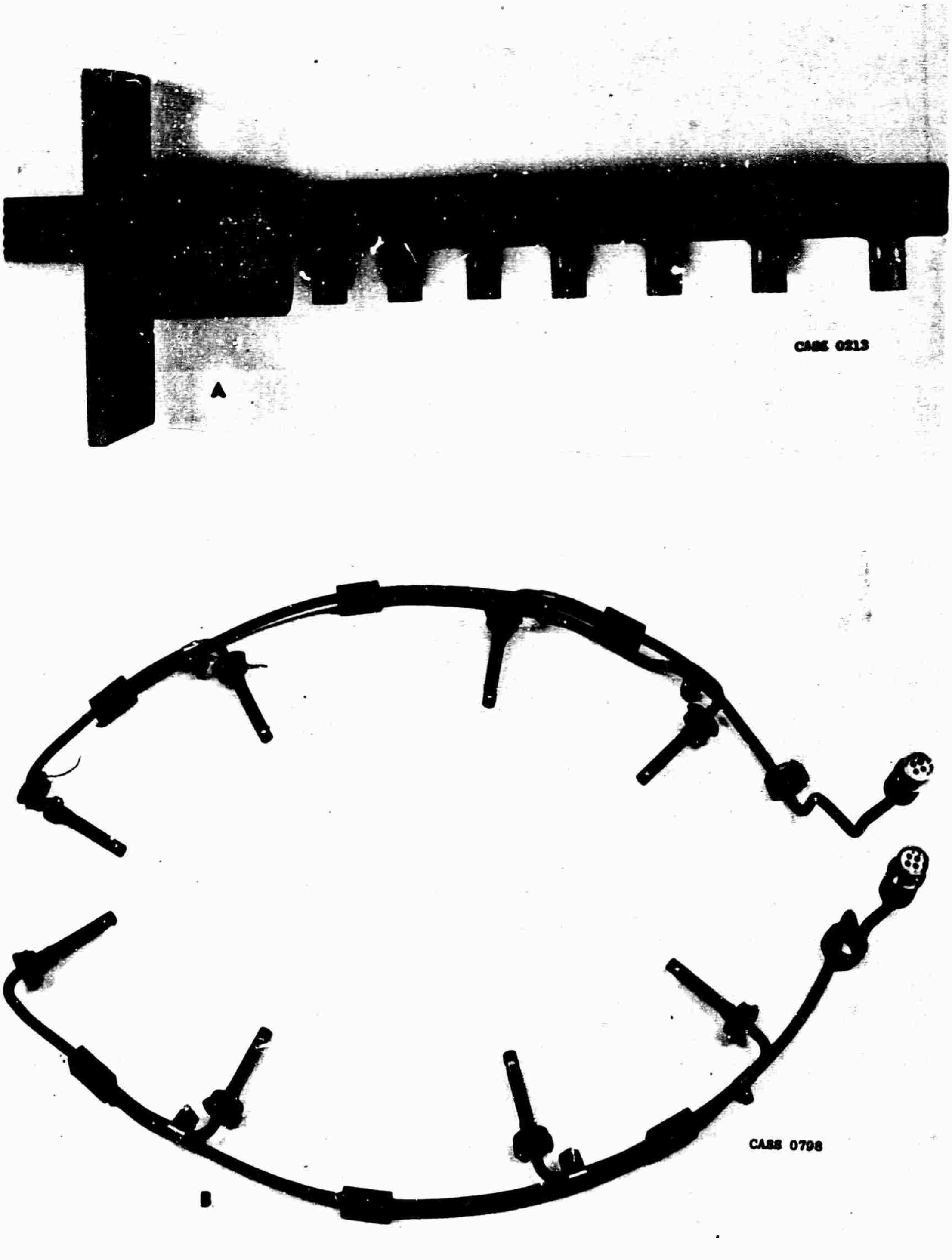


Figure I-16. A. Diverter Valve Inlet Total Pressure Rake

B. Diverter Valve Inlet Temperature Harness

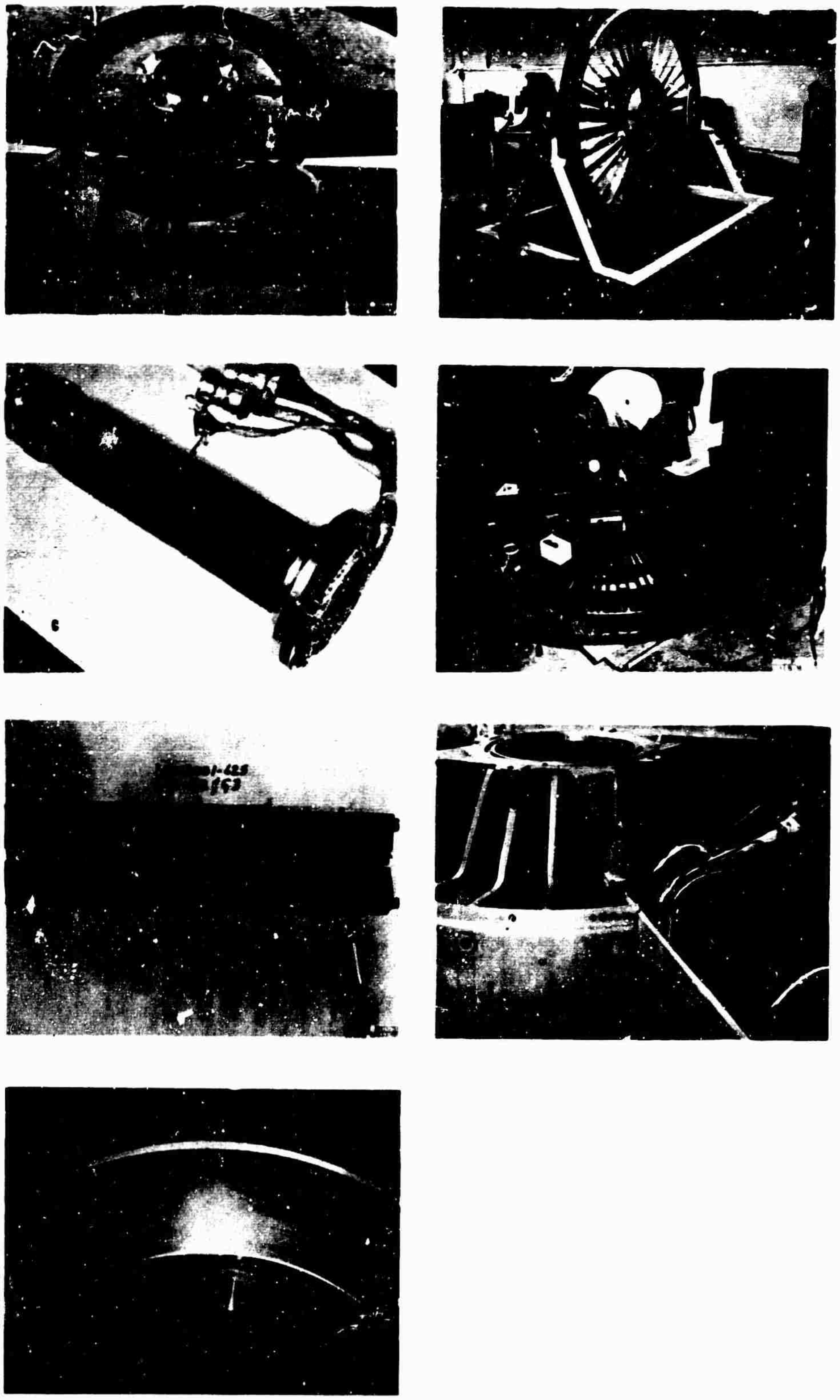


Figure I-17.
A. Lift Fan Bearing Thermocouple
B. Lift Fan Rotor Strain Gage Instrumentation
C. Lift Fan Slipring
D. Lift Fan Rear Frame Strain Gage Application
E. Lift Fan Rotor Discharge Pressure Rake
F. Lift Fan Vibe Sensor
G. Lift Fan Speed Sensor

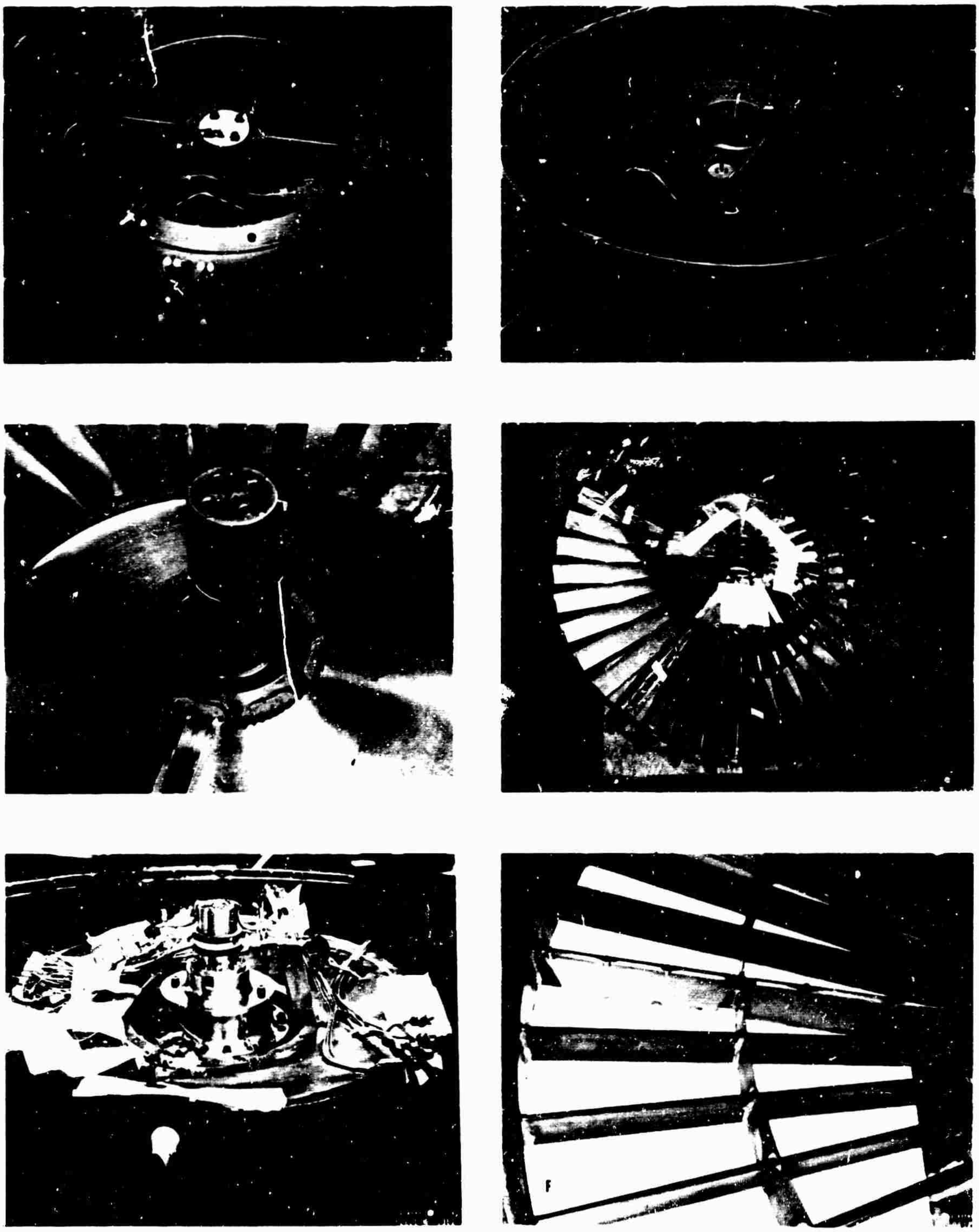


Figure I-18. A. Pitch Fan Vibe Sensor
B. Pitch Fan Speed Sensor
C. Pitch Fan Speed Gear And Bearing Thermocouple
D. Pitch Fan Rotor Strain Gage Installation
E. Pitch Fan Slipring Assembly
F. Pitch Fan Rotor Discharge Pressure Rakes

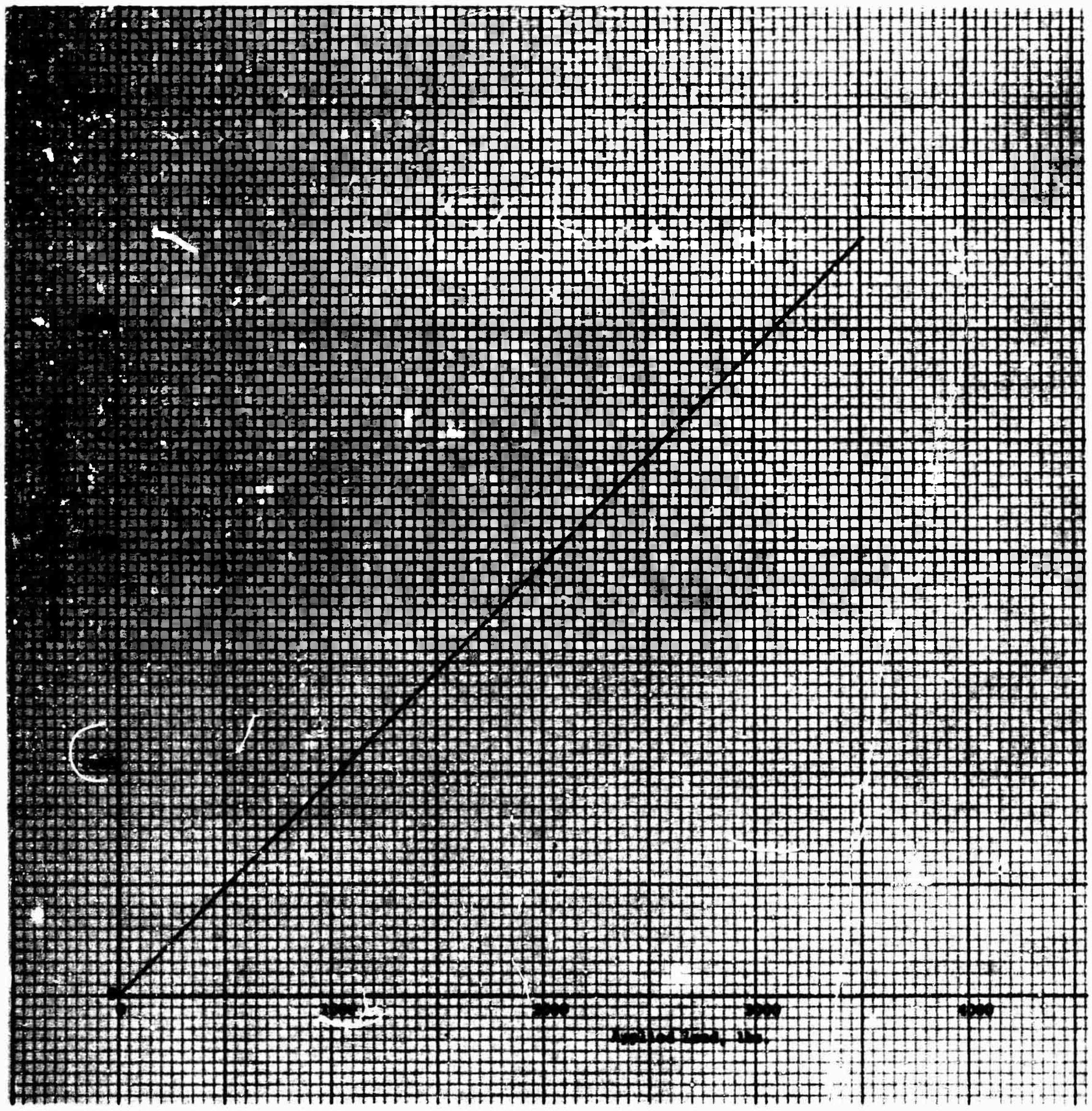


Figure I-19. Applied Load Vs Load Cell Indication (Total System Lift - 0 to 4000 Lbs.)

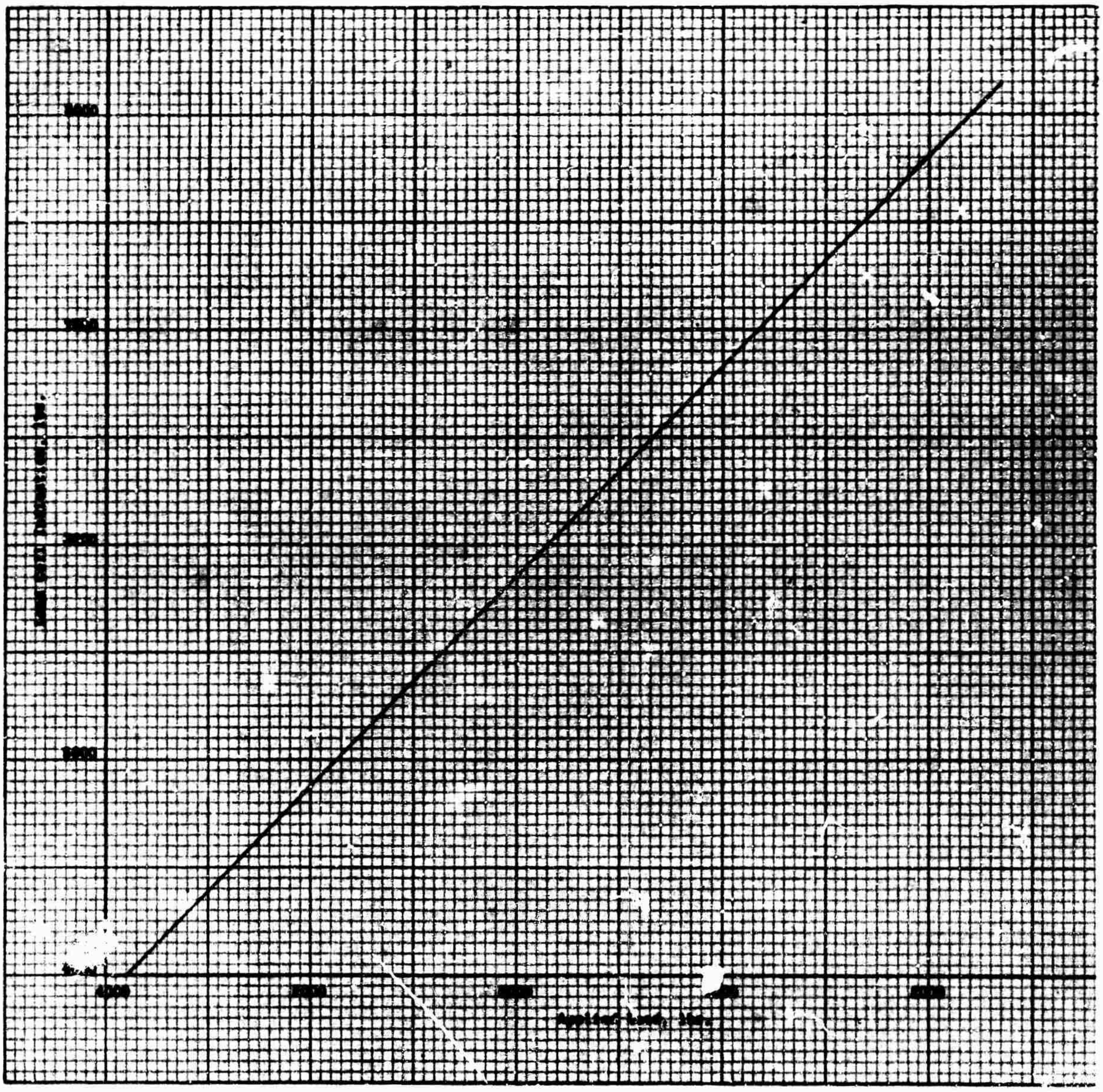


Figure I-20. Applied Load Vs Load Cell Indication (Total System Lift - 4000 to 8000 Lbs.)

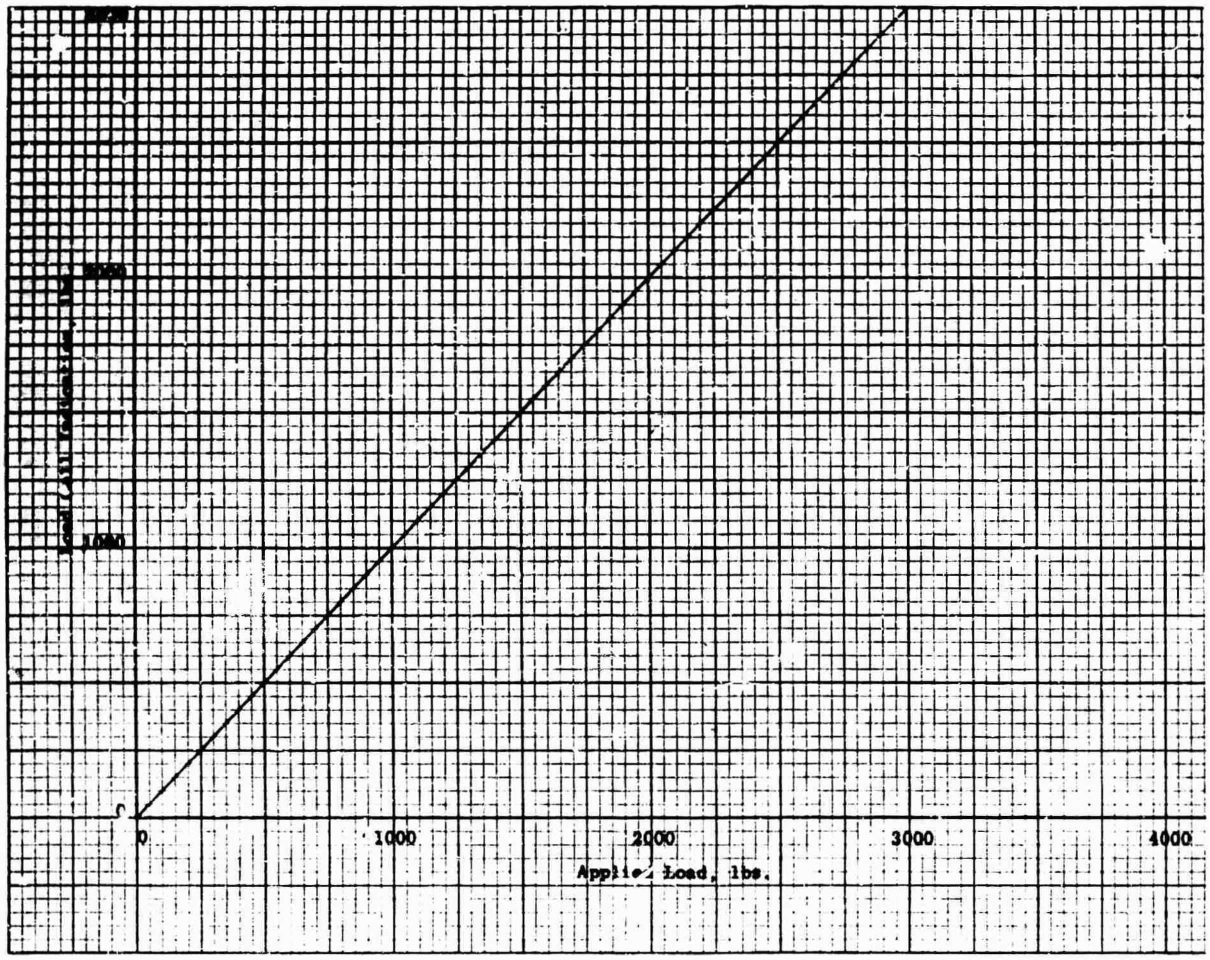


Figure I-21. Applied Load Vs Load Cell Indication (Horizontal Thrust - 0 to 3000 Lbs.)

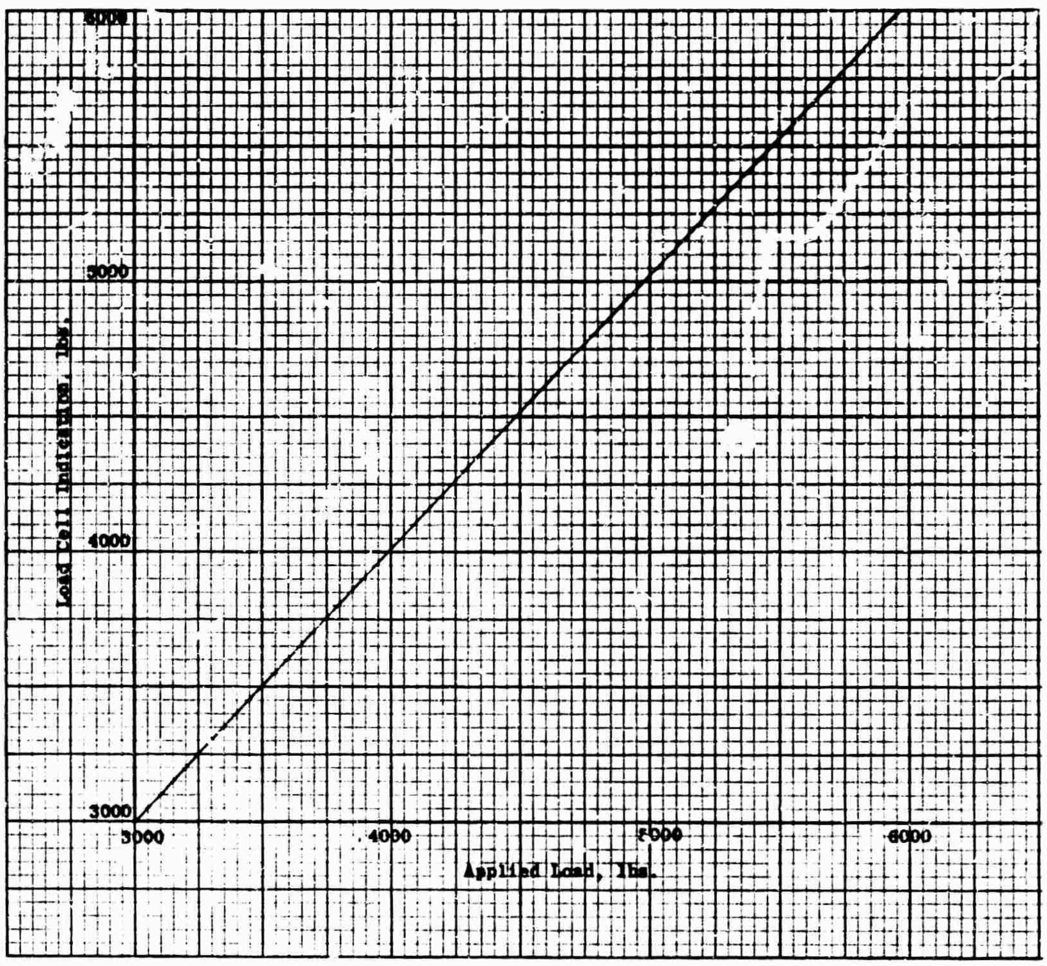


Figure I-22. Applied Load Vs Load Cell Indication (Horizontal Thrust - 3000 to 6000 Lbs.)

of specified values, no adjustments were made to the original setting within the electronics component.

The electronics component incorporates an offset function to permit a running demonstration of warning and power cut back functions without actually operating the fans overspeed. This offset function was used to demonstrate the overspeed limiter as required by Specification 114. A bench check of the offset function was also made as follows:

	Warning Light On		Power Cut Back		Warning Light Off	
	RPM	%RPM	RPM	%RPM	RPM	%RPM
Pitch Fan	3275	80.4	3591	88.1	3142	77.1
Lift Fan	2331	88.3	2398	90.0	2242	85.0

4. PERFORMANCE

System performance was calculated from Runs 19, 20 and 37 data. J85 bellmouth flow calibration and J85 EGT harness calibrations are shown in Figures I-23, I-24 and I-25.

5. AMBIENT CONDITIONS

The barometer used is a permanently installed instrument central for all FPLD testing. See Appendix for documentation of its calibration and accuracy. Ambient temperature was read from a thermocouple located at the North end of the test cell. It is mounted about 3 feet away from the building and about 12 feet above the ground and is shielded from direct sunlight.

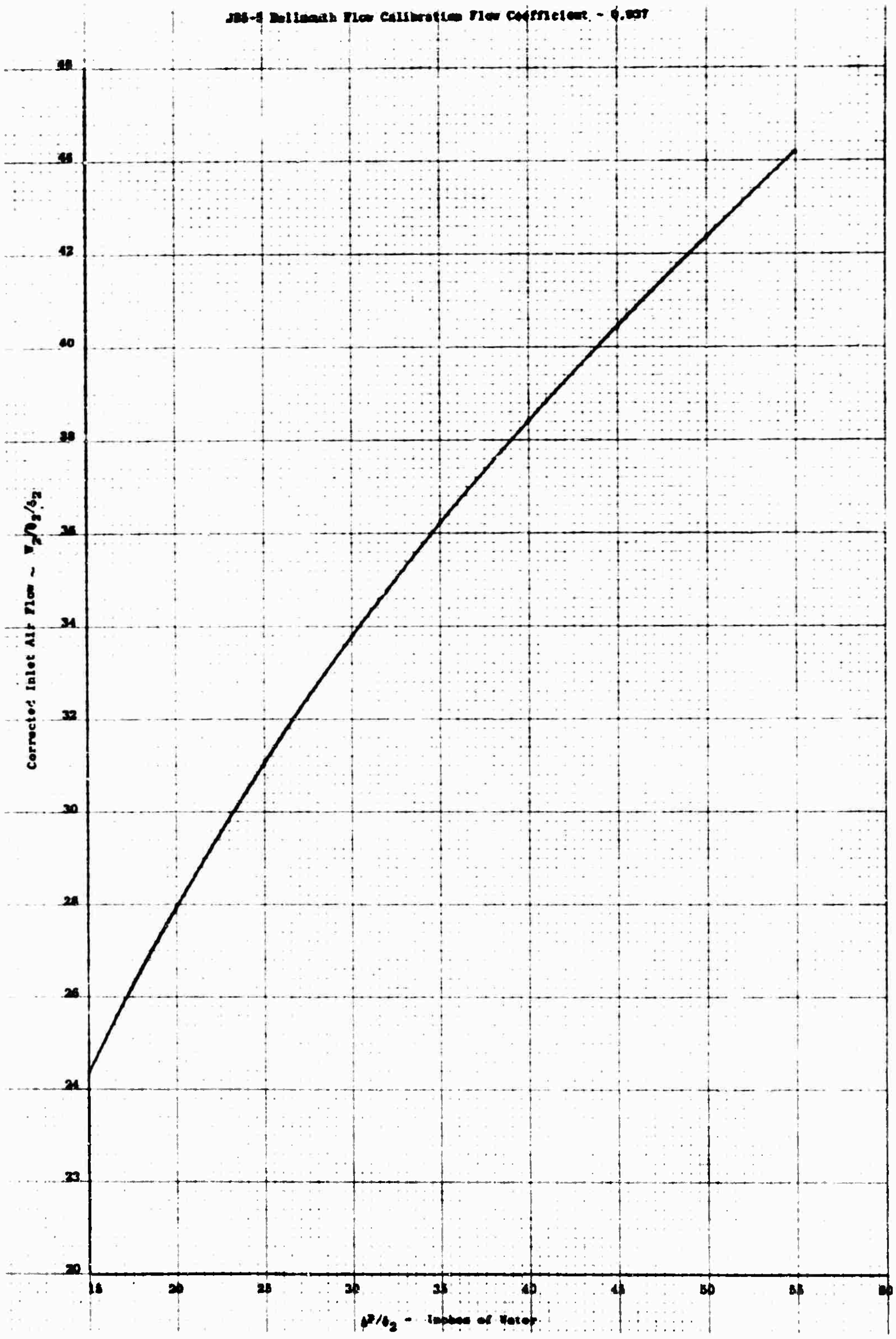


Figure I-23. J85-5 Inlet Weight Flow Versus Inlet Static Pressure

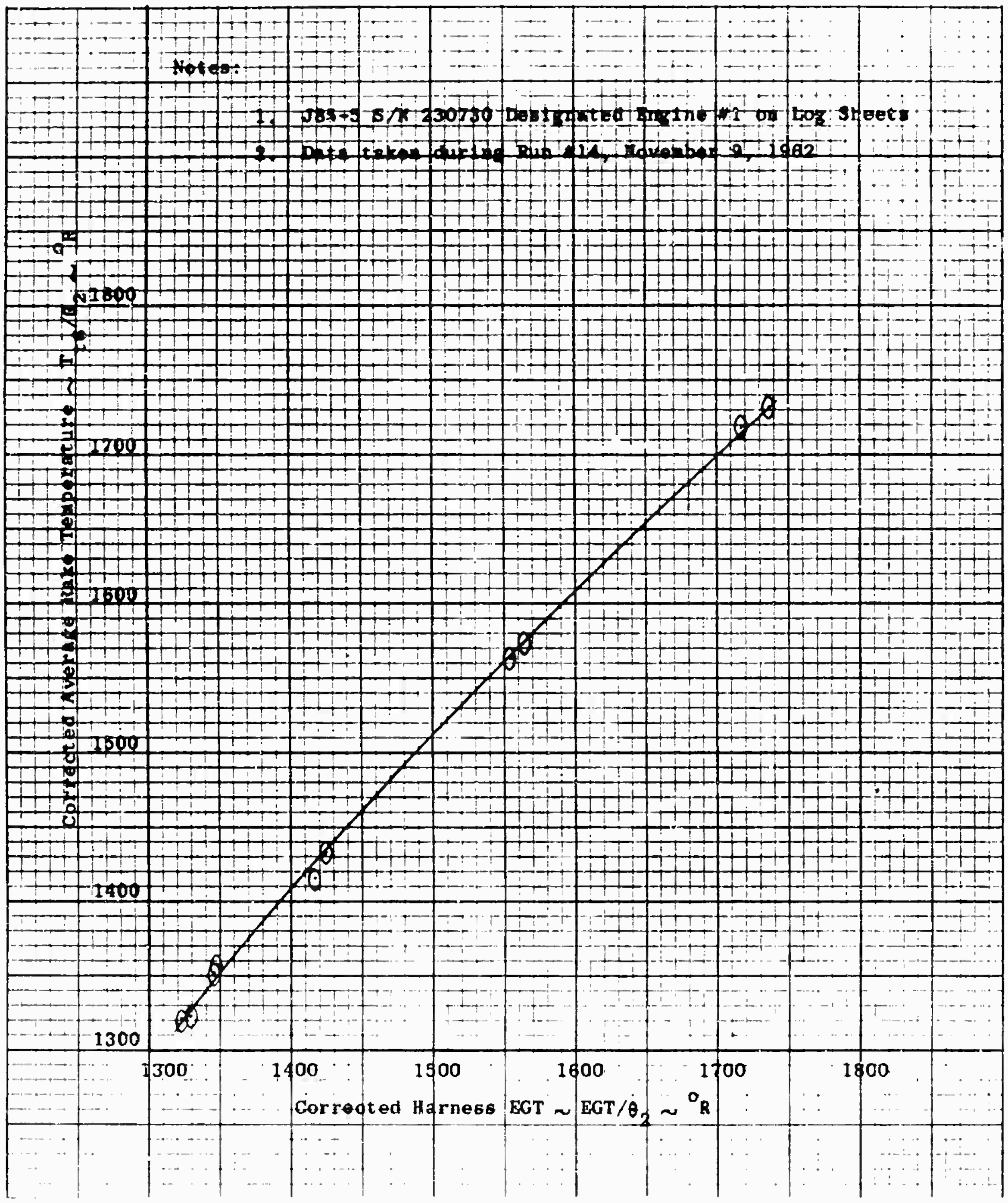


Figure I-24. J85-5 (230730) EGT Calibration

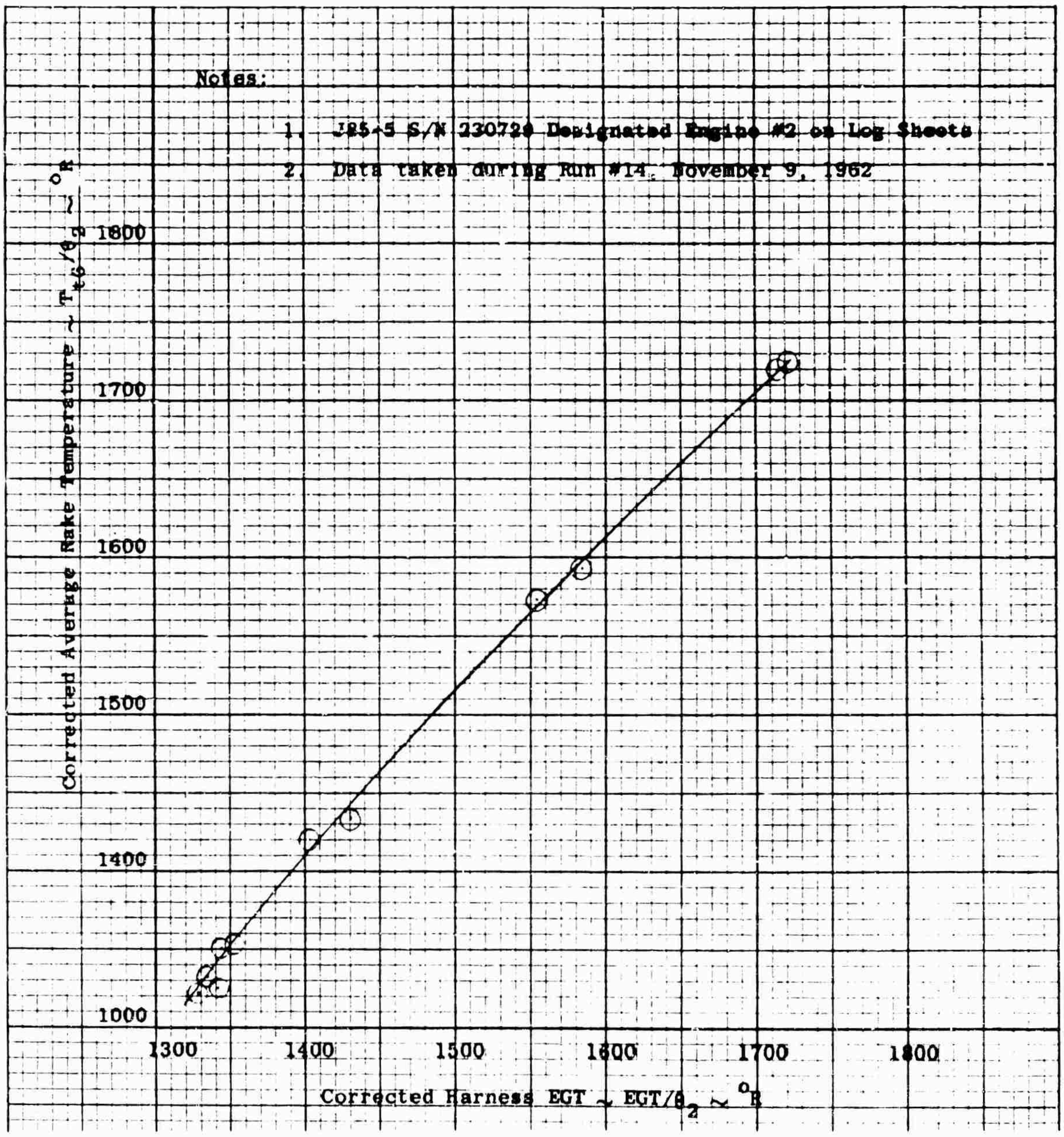


Figure I-25. J85-5 (230729) EGT Calibration

Section E

R E C O R D   O F   T E S T

E. RECORD OF TEST

1. TEST RUN CHRONOLOGY

Table V presents the test run chronology including operating times and significant events and observations.

2. STATISTICS OF TESTING

Table VI is a summary of operating statistics defining the general content of endurance testing accomplished.

TABLE V. FLIGHTWORTHINESS TEST CHRONOLOGY

Run No.	Date	Lift Fan (002) Time (hrs:mins.)	Lift Fan (002) Total Time (hrs:mins.)	Pitch Fan (001) Time (hrs:mins.)	Pitch Fan (001) Total Time (hrs:mins.)	(Diverter Valve (003) Time (hrs:mins.)	(Diverter Valve (003) Total Time (hrs:mins.)	Diverter Valve (004) Time (hrs:mins.)	Diverter Valve (004) Total Time (hrs:mins.)	Remarks
1-18	-	-	30:11	-	6:02	-	38:45	-	40:30	Preliminary operation.
19	11/21/62	0:30	0:38	0:38	0:38	1:40	1:40	1:48	1:48	Cruise performance calibration. Reached temperature limits on pitch fan front frame.
20	11/24/62	8:30	8:38	5:38	6:38	6:19	7:59	6:00	7:48	Lift fan and pitch fan performance calibration (including translated thrust reversers set at maximum. Insulation added between pitch fan scroll to front frame nozzle prior to run. Fiberglass inlet pulled up from pitch fan front frame. Lift fan circular inlet vane (inboard-forward) leading edge separated and cracked through spot weld (replaced prior to Run 21). Leading edge and spot weld cracks occurred in two inlet vanes (outboard-forward & inboard aft) - repaired prior to Run 21. Improperly assembled engine oil tank relief valve was reassembled after this run.
21	11/26/62	1:45	8:21	1:45	6:21	3:03	11:02	3:01	10:49	Pitch fan performance recalibration. Began cycle No. 1 (cyclic endurance) - interrupted after 1 hour. Pitch fan inlet pulled away. High pitch fan front frame temperature at max. reversed thrust. Exit louver #17 was cracked on pressure side and a spot weld had pulled loose (repaired prior to Run 22). Louver #23 removed by mistake. Replaced nut and bolt on left hand pitch fan mount after Run 21 (original nut and bolt were loose).
22	11/27/62	2:27	11:38	2:37	11:58	6:36	16:36	5:41	16:36	Cycle No. 1 cyclic endurance continued. Started cycle at 30 min. (30 min. to re-run) at 45 min. cycle time engine #1 flamed out - 14 min. interruption. At 2 hrs., 13 mins. cycle time, went off schedule 1 hr. for visitor demonstration. A buckle was noted at this time in the forward torque band. At 4 hrs., 22 mins. cycle time, went off schedule due to high pitch fan front frame temperature. During this interruption (10 hrs., 40 mins.) the area between pitch fan and fiberglass inlet was covered with sheet metal. Completed Cycle No. 1. The repair plug weld on louver #17 pulled out, (repaired prior to Run 23). Crack in spot weld on inboard-forward circular inlet vane (repaired prior to Run 23). Louver #18 and louver #13 cracks were found and repaired. Completed sealing between pitch fan and inlet after Run 22.
23	11/28/62	4:00	16:58	4:00	15:58	5:29	22:07	5:27	22:06	Cycle No. 2 (constant power endurance) begun. Shut down at 2 hrs., 20 mins. cycle time. Noted buckle in aft torque band. Cycle No. 2 completed. Torque bands were segmented after Run 23. Louver #16 cracked around repair weld. It was removed and repaired again. Cracks were found in all four circular inlet vanes and stop drilled prior to Run 24.
24	11/29/62	3:56	16:57	3:59	16:57	6:05	28:12	6:01	28:07	Cycle No. 3 (cyclic endurance) began and completed without interruption. Performance check of pitch fan made before starting Cycle No. 3. Found and stop drilled cracks in leading edge of circular vane (outboard-forward).
25	11/30/62	3:06	23:03	3:06	23:03	5:22	33:34	5:20	33:27	Cycle No. 4 (cyclic endurance) begun. Came off schedule at 2 hrs., 12 mins. to inspect hardware; noted break near aft torque band buckle - 45 min. interruption. Completed cycle No. 4. Stop drilled crack in outboard-aft circular vane after Run 25. Removed louvers #25 and 36 to repair end caps after Run 25. Removed flat door from diverter valve 003 to replace missing heat shield after Run 25. Adjusted scroll trim area and overboard bleed area to re-trim flow split and EGT.
26	12/1/62	1:26	24:26	1:26	24:26	1:57	35:31	1:54	35:21	Cycle No. 6 (constant power endurance) begun and interrupted after to repair louvers and vanes. Removed louver #22 and repaired four loose spot welds and a crack in leading edge. Removed louver #18 and repaired crack in spot weld on suction side. Removed two circular vanes (outboard-forward and outboard-aft) and welded cracks. Noted crack on other side of aft torque band buckle - removed piece of band at buckle.
27	12/2/62	4:00	28:26	4:00	28:29	4:14	36:45	4:11	38:32	Cycle No. 5 (constant power endurance) begun and completed without interruption except for cruise endurance which was done during Runs 33, 34 and 36. Exit louver #22 cracked at inboard leading edge and was replaced after Run 27. Louver #38 buckled and was replaced after Run 27. Louver #32 failed due to under cut weld - removed and repaired prior to Run 28. Louver #23 was removed to repair a pulled out spot weld. The louver area for louver #17 cracked and was replaced. The outboard-aft circular vane was cracked due to improper assembly. Cracks also occurred in outboard-forward and inboard-forward circular vanes. All cracks were stop drilled.
28	12/3/62	3:22	31:51	3:22	31:51	3:51	43:36	3:50	43:22	Cycle No. 6 (cyclic endurance) begun and completed without interruption except for cruise endurance which was done during Runs 33, 34 and 36.

TABLE V. (Continued)

39	12/3/62	3:48	34:39	2:46	34:29	2:01	46:37	3:00	44:22	Cycle No. 7 (constant power endurance) begun. Shut down after 2 hrs., 6 mins. cycle time because louver #22 had come off. Also replaced louvers 21 and 24 and repaired louvers #18 and 20 prior to completion of cycle No. 7. Removed and repair welded two circular inlet vanes at this time (outboard-forward and outboard-aft).
30	12/4/62	2:30	36:09	2:30	36:56	3:26	49:06	3:27	48:49	Cycle No. 7 completed.
31	12/5/62	3:02	40:01	2:02	40:01	3:41	53:47	2:41	53:30	Cycle No. 8 (constant power endurance) begun. Cycle was interrupted at 1 hr., 20 mins. to shut down for end of shift. Louvers #17, 18, 22, 20 and 26 were removed and repaired during this shutdown. Stop drilled cracks on two circular vanes (outboard-aft and inboard-forward). Noted pulled spot weld on outboard-aft circular vane - no repairs made. Completed cycle No. 6.
23	12/5/62	2:26	42:27	3:26	43:27	2:55	56:42	3:54	56:24	Cycle No. 9 (cyclic endurance) begun and completed without interruption except for cruise endurance. Completed 6 mins. of rotor penalty time (cyclic endurance). Noted minor denting of lift fan turbine buckets.
23 & 34	12/6/62	0:00	43:27	0:00	43:27	5:04	61:46	4:55	61:29	Cruise endurance make-up runs.
35	12/6/62	4:29	47:26	4:29	47:56	4:42	66:26	4:41	66:10	Cycle No. 10 (constant power endurance) begun and completed. Completed 25 mins. of rotor penalty time (cyclic and constant power endurance). Noted missing lift fan rotor carrier tab and extensive damage to lift fan turbine buckets. Noted break in forward torque band opposite point in aft band where buckle had broken out.
26	12/7/63	0:00	47:56	0:00	47:56	1:51	68:16	1:55	68:06	Completed cruise endurance. Completed flight-worthiness test endurance testing.
27	12/7/62	1:26	49:22	1:29	46:22	2:03	70:22	2:03	70:06	Performance recalibration run. Completed Flight-worthiness Test.

TABLE VI

X353-5B PROPULSION SYSTEM TEST STATISTICS

Item	Lift Fan	Pitch Fan	Diverter Valve 003	Diverter Valve 004
Preliminary Operation	29 hrs.	9 hrs.	39 hrs.	40 hrs.
Performance	9	9	12	12
Cyclic Endurance	18	18	29	29
Constant Power Endurance	22	22	24	24
Totals	78 hrs.	58 hrs.	104 hrs.	105 hrs.
Time at Max. Power, hrs.	22.5	22.5	34	34
Single Engine Operation, hrs.	2	2	-	-
Time at Critical Speed, hrs.	2.5	2.5	-	-
Throttle Bursts	82	82	142	142
Throttle Chops	76	76	132	132
Thrust/Lift Conversions	46	46	46	46
Lift/Thrust Conversions	46	46	46	46
Starts	-	-	38	37
Overspeed Checks	12		-	-
Maximum Test Speed	102%	108%	-	-

F. TEST DATA

The test hardware measured weight is presented in Table VII. Propulsion system total weight including a second lift fan is estimated in the table for reference.

Comparison with FRV Specifications 112 (Table VIII) and 113 (Paragraph 3.12) shows the following results:

	Specification Weight	Actual Weight
Lift Fan Group	838.6 lbs.	786.8 lbs.
Gas Generator - Diverter Valve Group	460.9 lbs.	462.7 lbs.
Pitch Fan Group	105.0 lbs.	112.5 lbs.
Miscellaneous Controls and Instrumentation Group:		
Lift Fan/Diverter Valve	13.0 lbs.	8.7 lbs.
Pitch Fan	4.0 lbs.	0.5 lbs.
Research	42.5 lbs.	27.7 lbs.

1. CONDITIONS OF TEST

Flow Split: To establish the gas power proportion delivered to each test component the fan scroll areas and the overboard bleed system areas were adjusted to (1) establish rated EGT and (2) to comply as closely as possible with Specifications 116 and 117 flow split requirements. The pitch fan scroll area can be adjusted at assembly only and is, therefore, fixed for a given installation. For the FWT the various area settings were as follows:

TABLE VII
ACTUAL WEIGHT BREAKDOWN

Group	Component	Sub Assembly	Total	Propulsion System Total
LIFT FAN				
	Rotor	276.72		
	Front Frame & Scroll	290.07		
	Rear Frame & Exit Louvers	219.97		
			786.76	1,573.52
PITCH FAN				
	Rotor & Shaft Assembly	41.28		
	Front Frame & Scroll	48.01		
	Rear Frame	23.22		
			112.51	112.51
DIVERTER VALVE				
	003		88.67	
	004		88.67	
				177.34
J85-5				
	230729		374.00	
	230730		374.00	
				748.00
INSTRUMENTATION				
	Operational:			
	Lift Fan	.90		1.80
	Pitch Fan	.50		.50
	Diverter Valve	.58		1.16
	Research:			
	Lift Fan	19.68		27.40*
	Pitch Fan	7.99		5.60*
	Overspeed Control	7.25		7.25
			36.90	
EXCEPTION:				
EXIT LOUVER POSITION TRANSMITTERS				

*Reduced requirements for flight test

Run #20

Pitch Fan	Design Lift Setting (≈ 81.5% Max. Total Area)
Lift Fan	#1 Engine: 5 of 8 Vanes Closed #2 Engine: 2 2/3 of 5 Vanes Closed (≈ 85% Max. Total Area)

Run #37

Pitch Fan	Design Lift Setting (≈ 81.5% Max. Total Area)
Lift Fan	#1 Engine: 3 of 8 Vanes Closed #2 Engine: 2 1/3 of 5 Vanes Closed (≈ 91.5% Max. Total Area)

Initially on Run #20 the measured EGT was slightly low; during the run (at Reading #559), the overboard bleed area was reduced to establish rated EGT. The difference in test conditions during Run #20 are presented in Table VIIIA and VIIIB. A further adjustment of the test conditions to more closely meet the specification standard was made for the recalibration Run #37 as indicated in Table VIIIC; both lift fan and bleed areas were readjusted.

Wind Condition: The prevailing wind at the test site is Westerly and is normally between 5 and 10 mph. The test specification condition of 5 mph or less could not be met at any time during the FWT. No correction is applied to the data for the variation in lift fan power absorption with wind which has been discussed in TCREC Technical Report 62-21*.

*General Electric Company, R62FPD306. This report is based on test results with the X353-5A lift fan. The same characteristic lift change with wind should not be applied to the X353-5B fan but the report is useful in presenting background for this phenomenon. The X376 power absorption when installed using the XV-5A inlet should be unaffected by wind based on similar X353-5A test results with the fan installed using a deep duct inlet.

TABLE VIIIA

GAS POWER DISTRIBUTION
RUN #20 READING NUMBERS 542 THROUGH 558

Parameter	Units	Engine #1	Engine #2
Reading		550	558
$N_{J85}/\sqrt{\theta_2}$	%	101.0	100.8
$W\sqrt{\theta_2}/\delta_2$	lb/sec.	43.20	43.78
W_2	lb/sec.	43.96	44.28
W_f	lb/hr.	2640	2685
$W_{5.1}$	lb/~~hr~~.sec.	44.69	45.03
$W_{5.1}$ - Leakage	lb/~~hr~~.sec.	44.33	44.67
$T_{5.1}$	°R	1674	1686
$(P_t/P_s)_{5.3}$		1.14	1.13
$W_{5.3}$	lb/sec.	20.18	19.70
$(P_t/P_s)_{15.3}$		1.027	1.026
$W_{15.3}$	lb/sec.	5.05	4.91
W_{LF}	lb/sec.	19.10	20.42
$W_{5.3}$	%	45.52	44.10
$W_{15.3}$	%	11.39	10.99
W_{LF}	%	43.09	44.91
A_{PF} (% of Max.)*	%	81.4	81.4
A_{LF} (% of Max.)*	%	88.6	88.6
$N_{LF}/\sqrt{\theta_{10}}$	%	71.1	72.3
L_{LF}/δ_2	lb.	3830	4022
$N_{PF}/\sqrt{\theta_{20}}$	%	80.3	79.5
L_{PF}/δ_2	lb.	1066	864

*Scroll area settings.

TABLE VIIIB

GAS POWER DISTRIBUTION
RUN #20 READING NUMBERS 559 THROUGH 644

Parameter	Units	Engine #1	Engine #2
Reading		566	566
$N_{J85}/\sqrt{\theta_2}$	%	99.6	99.76
$W\sqrt{\theta_2}/\delta_2$	lb/sec.	43.04	43.60
W_2	lb/sec.	43.11	43.64
W_f	lb/hr.	2680	2760
$W_{5.1}$	lb/~~hr.~~ sec.	43.85	44.41
$W_{5.1}$ - Leakage	lb/~~hr.~~ sec.	43.50	44.05
$T_{5.1}$	^oR	1708	1699
$(P_t/P_s)_{5.3}$		1.128	1.118
$W_{5.3}$	lb/sec.	19.60	19.25
$(P_t/P_s)_{15.3}$		1.029	1.028
$W_{15.3}$	lb/sec.	5.25	[illegible].02
W_{LF}	lb/sec.	18.65	19.78
$W_{5.3}$	%	45.06	43.70
$W_{15.3}$	%	12.07	11.40
W_{LF}	%	42.87	44.90
A_{PF} (% of Max.)*	%	81.4	
A_{LF} (% of Max.)*	%	88.6	
$N_{LF}/\sqrt{\theta_{10}}$	%	96.82	
L_{LF}/δ_2	lb.	6996	
$N_{PF}/\sqrt{\theta_{20}}$	%	104.17	
L_{PF}/δ_2	lb.	1723	

*Scroll area settings.

TABLE VIIIC

GAS POWER DISTRIBUTION
RUN #37 READING NUMBERS 1031 THROUGH 1051

Parameter	Units	Engine #1	Engine #2
Reading		1041	1041
$N_{J85}/\sqrt{\theta_2}$	%	99.0	99.4
$W\sqrt{\theta_2}/\delta_2$	lb/sec.	42.50	43.06
W_2	lb/sec.	41.11	41.89
W_f	lb/hr.	2485	2615
$W_{5.1}$	lb/hr.	41.80	42.62
$W_{5.1}$ - Leakage	lb/hr.	41.46	42.28
$T_{5.1}$	^oR	1686	1693
$(P_t/P_s)_{5.3}$		1.128	1.122
$W_{5.3}$	lb/sec.	18.30	18.48
$(P_t/P_s)_{15.3}$		1.028	1.029
$W_{15.3}$	lb/sec.	4.81	4.88
W_{LF}	lb/sec.	18.35	18.92
$W_{5.3}$	%	44.14	43.71
$W_{15.3}$	%	11.60	11.54
W_{LF}	%	44.26	44.75
A_{PF} (% of Max.)*	%	81.4	
A_{LF} (% of Max.)*	%	91.5	
$N_{LF}/\sqrt{\theta_{10}}$	%	95.87	
L_{LF}/δ_2	lb.	6677	
$N_{PF}/\sqrt{\theta_{20}}$	%	103.93	
L_{PF}/δ_2	lb.	1935	

*Scroll area settings.

Another effect of the wind on the data evaluation is treated in the Appendix. This has to do with determining the proper proportioning of total measured lift between the pitch fan and the lift fan and is not an additional influence on total lift or fan performance.

2. J85's VERSUS X353-5B SPECIFICATION ENGINE STANDARD

The station 5.1 flow function $\left(\frac{W\sqrt{T}}{P}\right)$ was calculated from measured parameters for each J85-GE-5 engine used in the FWT. Both engines when operated in the cruise mode at the design area for rated EGT developed the flow function corresponding to the specification standard.

For the lift mode the EGT condition was not precisely met which resulted in some small variation of engine flow function from standard for the performance checks. In Tables X and XI presented later, the maximum rating conditions have been corrected for any deviation in flow function from standard by interpolating Figure 31, FRV Specification 112. The maximum correction applied was minus 21 pounds.

3. COMPONENT PERFORMANCE RESULTS

Cruise Mode: Thrust, fuel flow, EGT and SFC for each engine/diverter valve combination are presented as a function of engine speed for the performance calibration and recalibration in Figure I-26 through I-33. Specification 112 performance is included for reference.

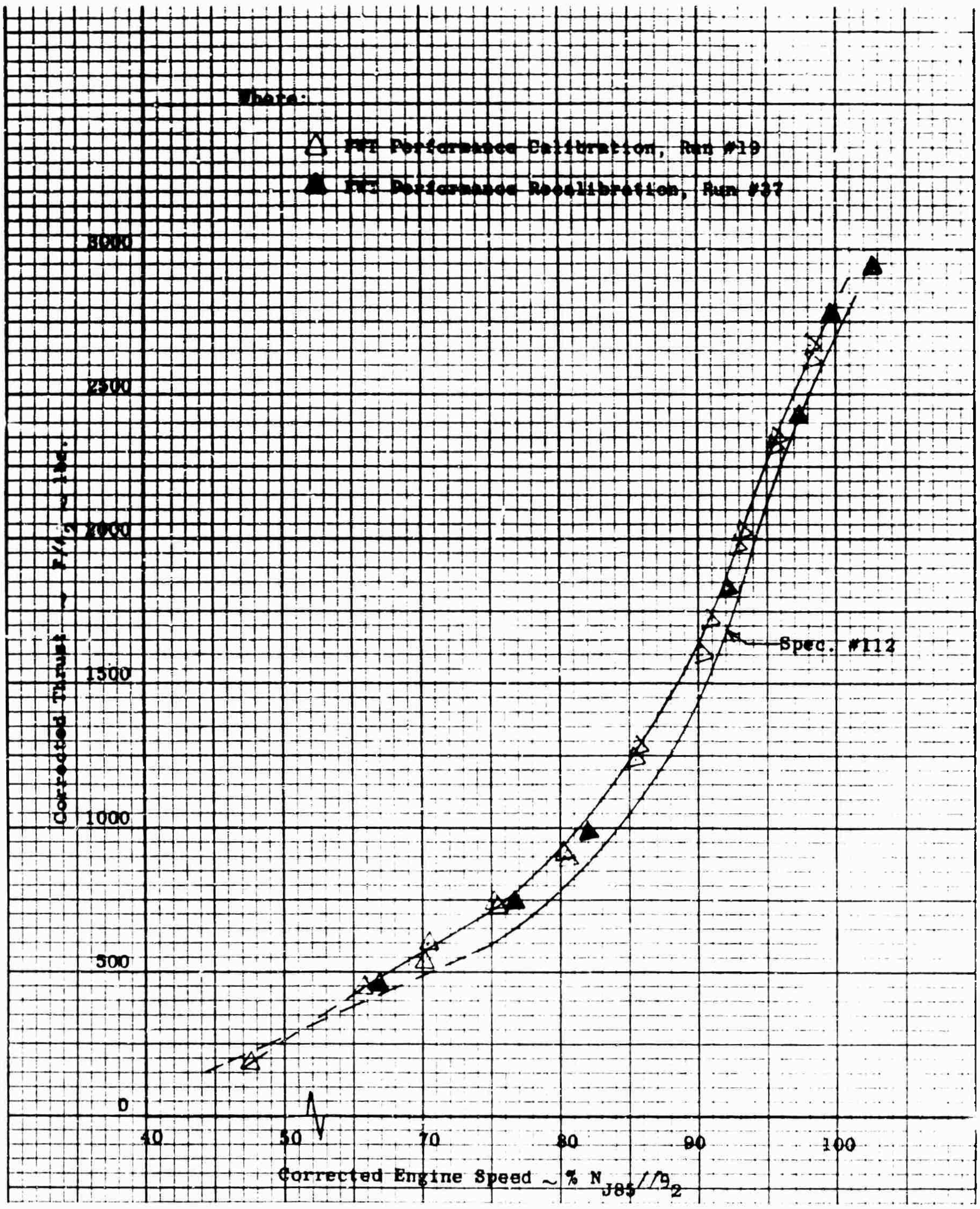


Figure I-26. Corrected Thrust Vs Corrected Speed, #1 J85 (Cruise Mode)

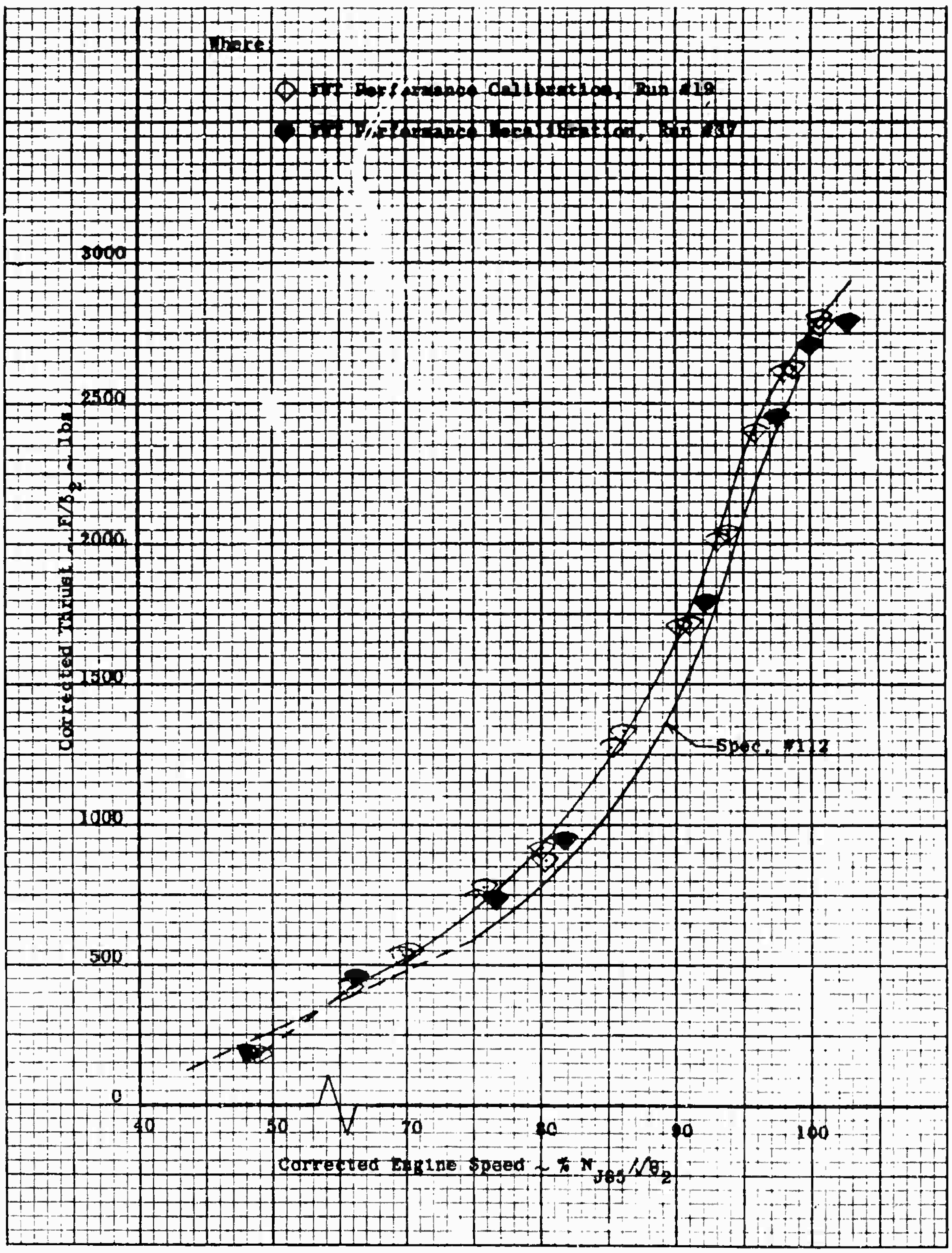


Figure I-27. Corrected Thrust Vs Corrected Speed, #2 J85
(Cruise Mode)

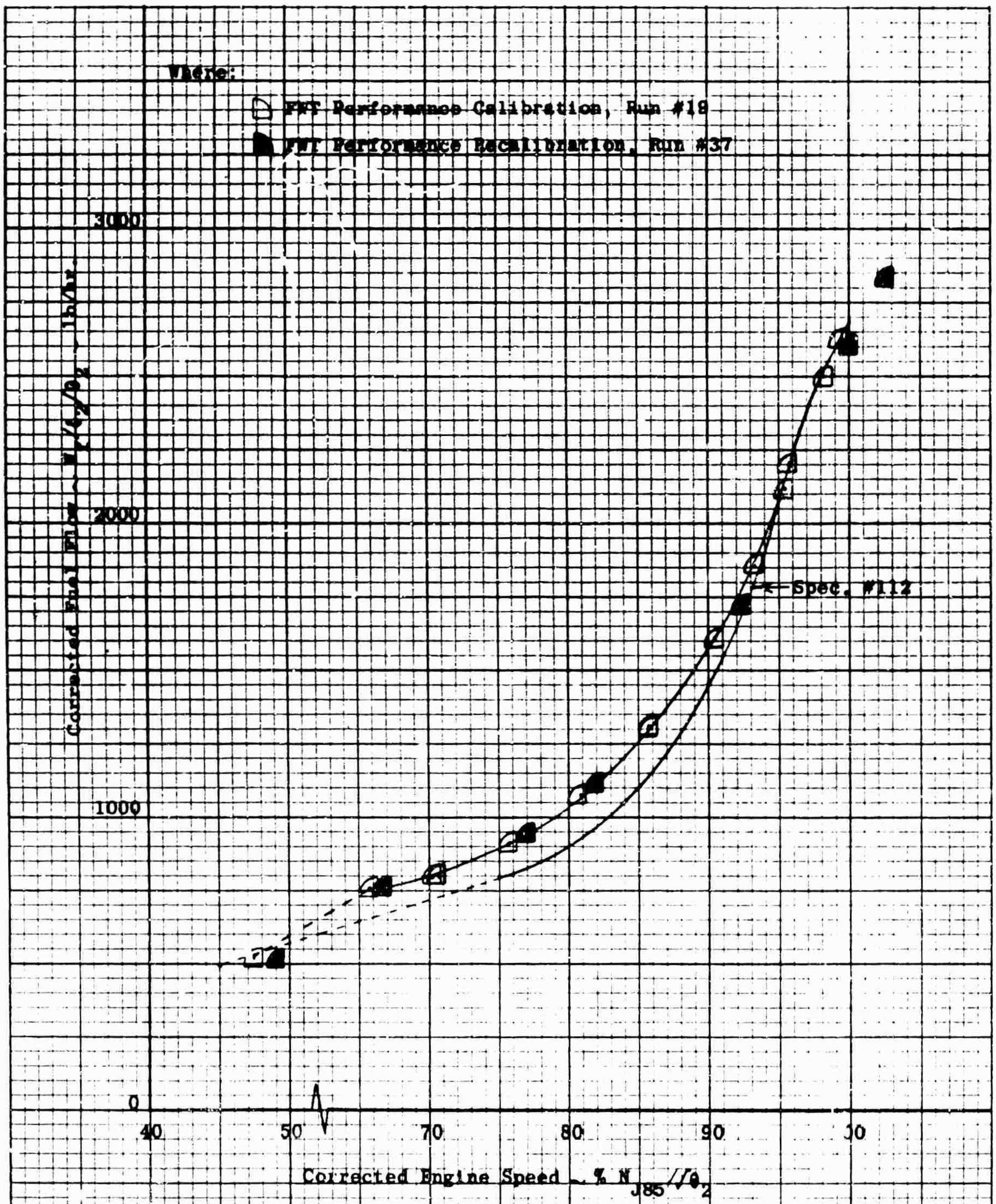


Figure I-28. Corrected Fuel Flow Vs Corrected Speed, #1 J85 (Cruise Mode)

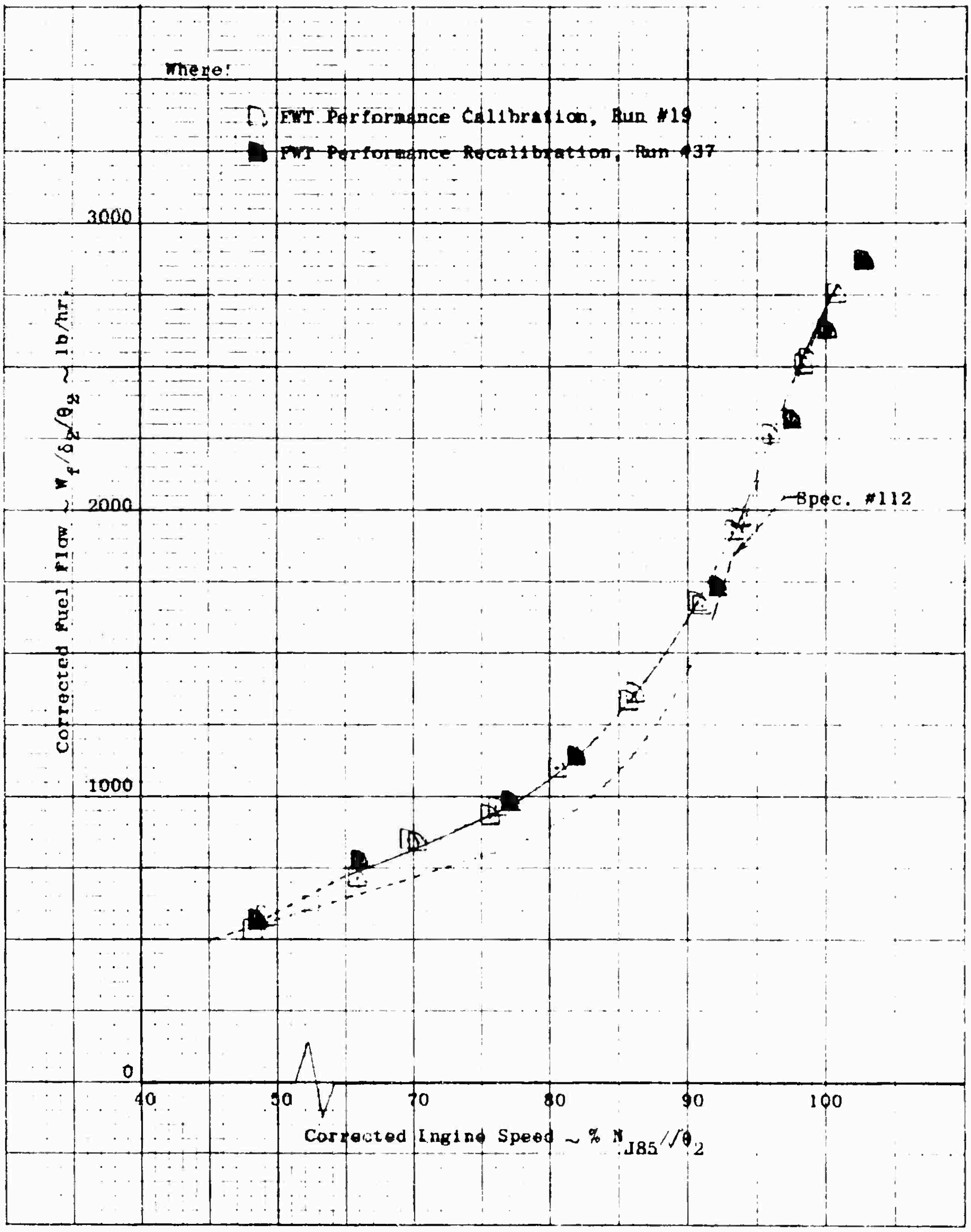


Figure I-29. Corrected Fuel Flow Vs Corrected Speed, #2 J85 (Cruise Mode)

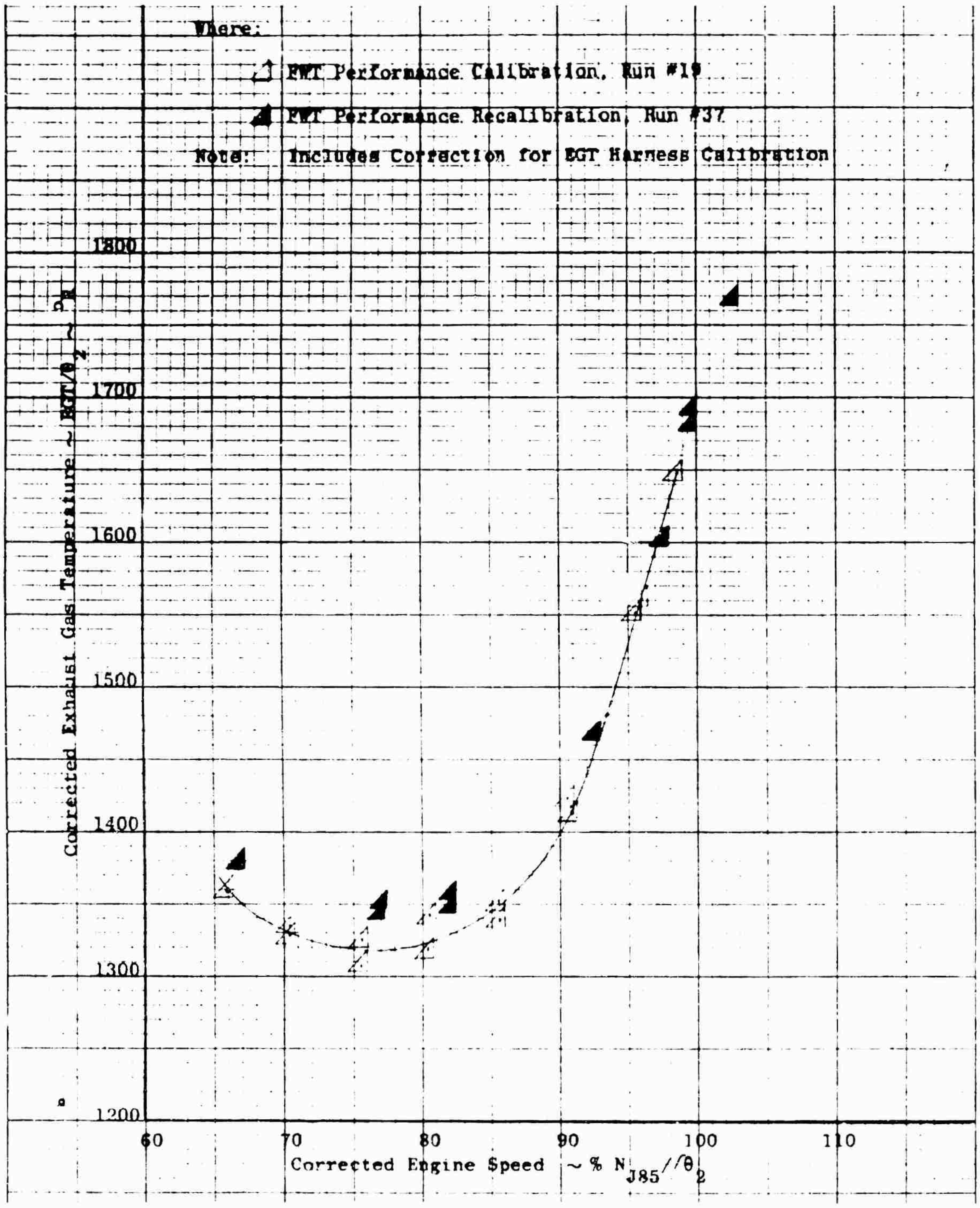


Figure I-30. Corrected EGT Vs Corrected Speed, #1 J85

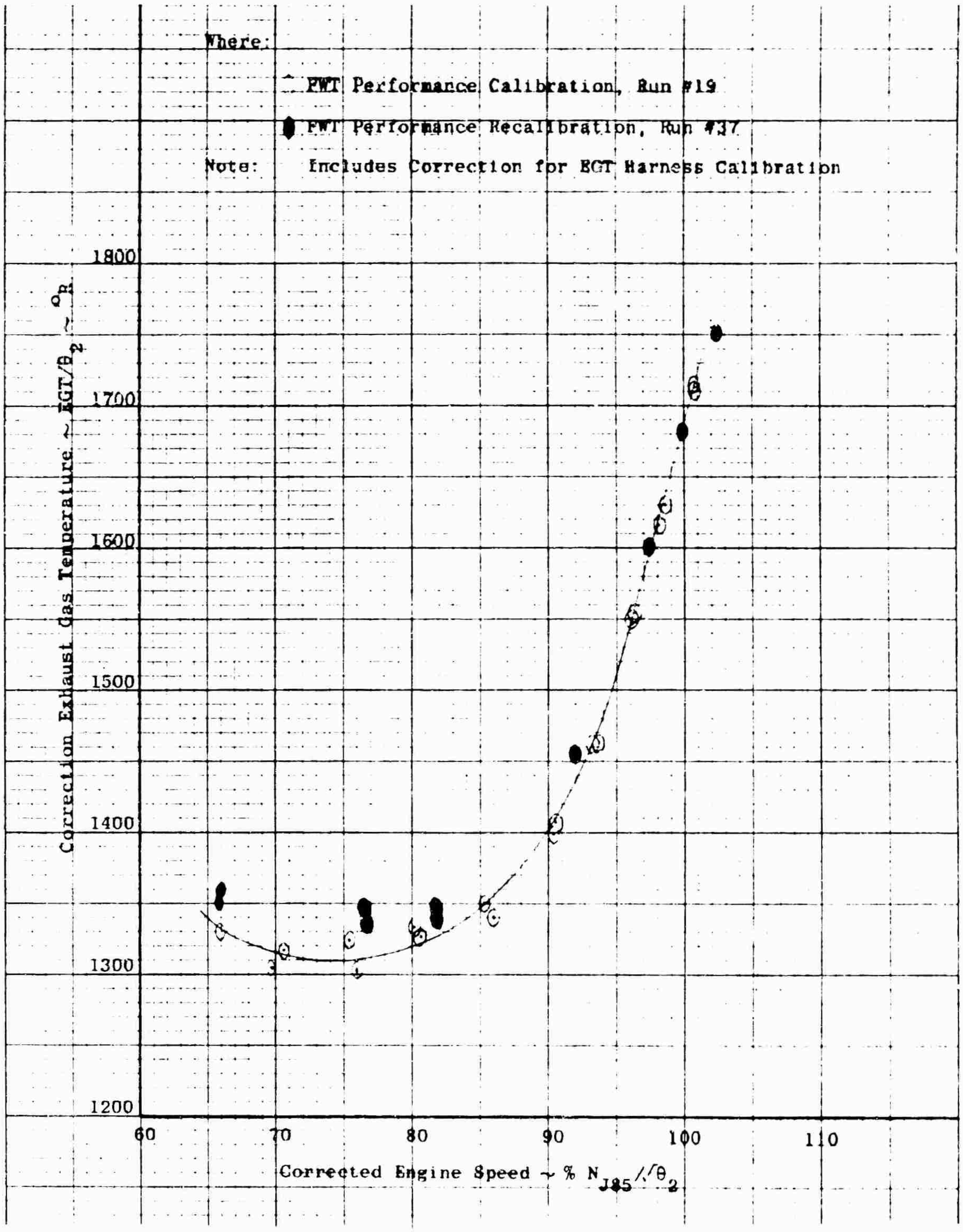


Figure I-31. Corrected EGT Vs Corrected Speec, #2 J85

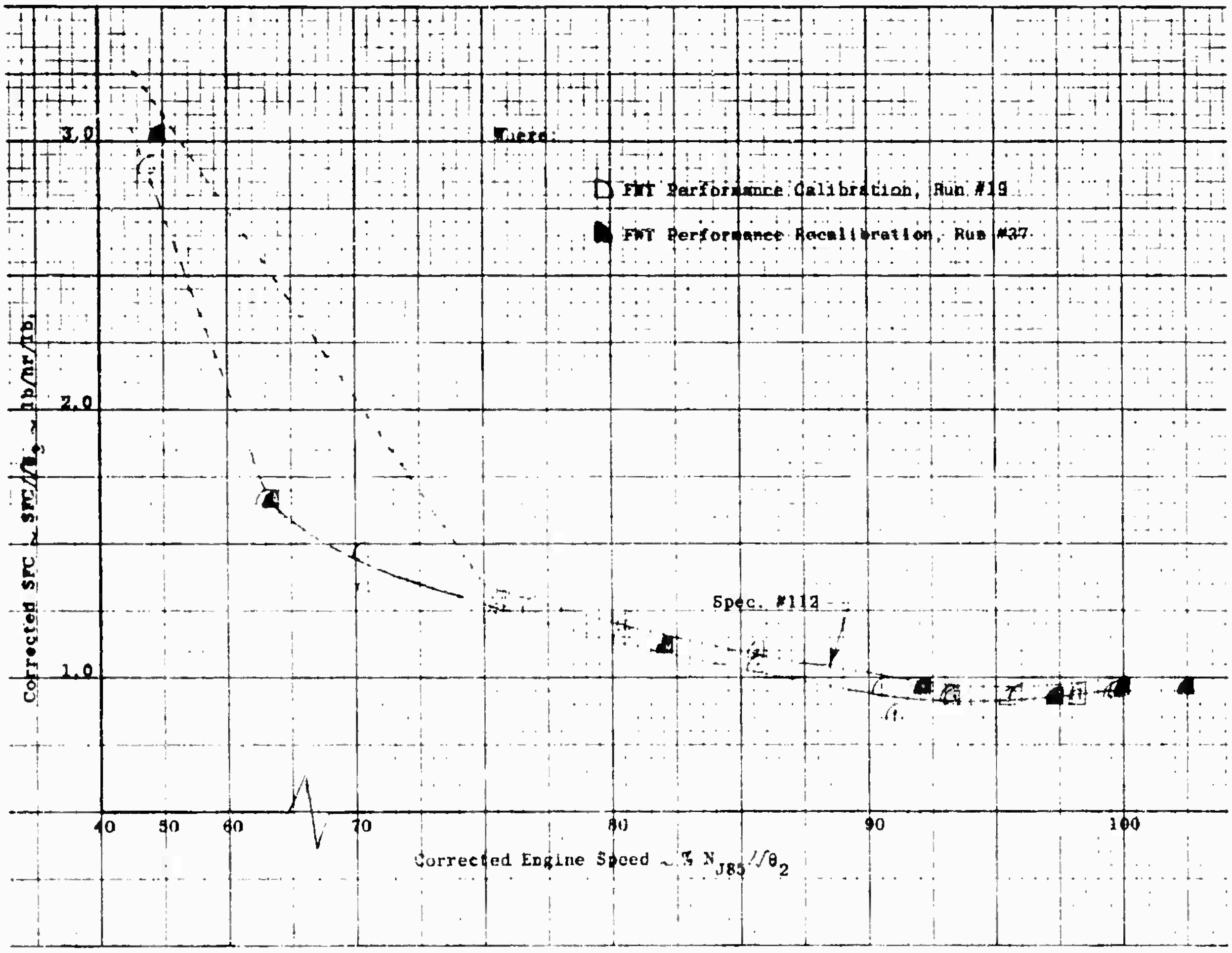


Figure I-32. Corrected SFC Vs Corrected Speed, #1 J85
(Cruise Mode)

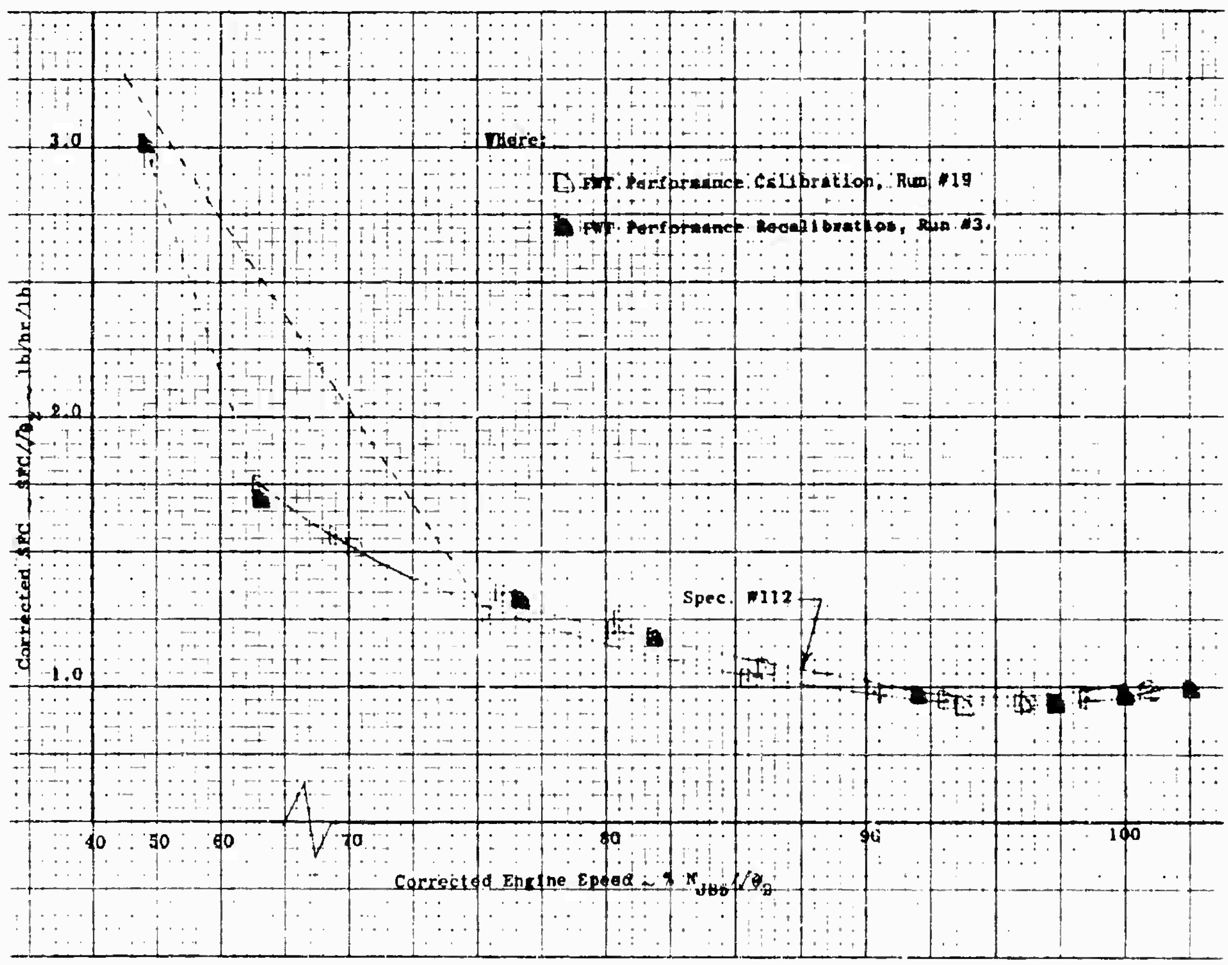


Figure I-33. Corrected SFC Vs Corrected Speed, #2 J85 (Cruise Mode)

These data are presented for an ARDC sea level standard day.

Ram drag correction was not applied to the cruise data. The difference between the Run #19 and Run #37 calibrations of ≈ 60 lbs. thrust is closely the value of a ram drag correction which could be estimated from the change in average wind conditions.

Lift Mode: Figures I-34 through I-35B present the measured results during the performance calibration (Run #20) with EGT, fuel flow, lift fan lift, horizontal thrust, pitch fan lift and fan speeds as a function of engine speed. Because of the specific pitch fan scroll area selected for the FWT, the bleed flow to the pitch fan was 11.5% compared to the required 10.6% at the pitch fan design lift setting as described in Specifications 112 and 113. Figure I-36A and B show the measured lift fan and pitch fan results of the FWT performance calibration (Run #20) corrected to the 10.6% pitch fan bleed condition. For the FWT performance recalibration (Run #37), measured performance is presented in Figures I-37 through I-39 and again are corrected to the 10.6% bleed level in Figures I-40 and I-41.

Additional data of interest to establish expected variations in the fan speeds is presented in Figures I-42 and I-43. The pitch fan bleed area will be reduced for the XV-5A installation to ≈ 76.8% of maximum to reduce the pitch fan speed ≈ 4% at the maximum power condition. The resulting bleed will be ≈ 10%.

Ram drag corrections for both the pitch fan and lift fan were applied in all cases to the lift fan horizontal thrust values based on average wind conditions. Engine ram drag was again neglected and is small compared with the fan ram drag.

Transients: The system transient characteristics were recorded versus time on oscillograph traces. Copies of representative

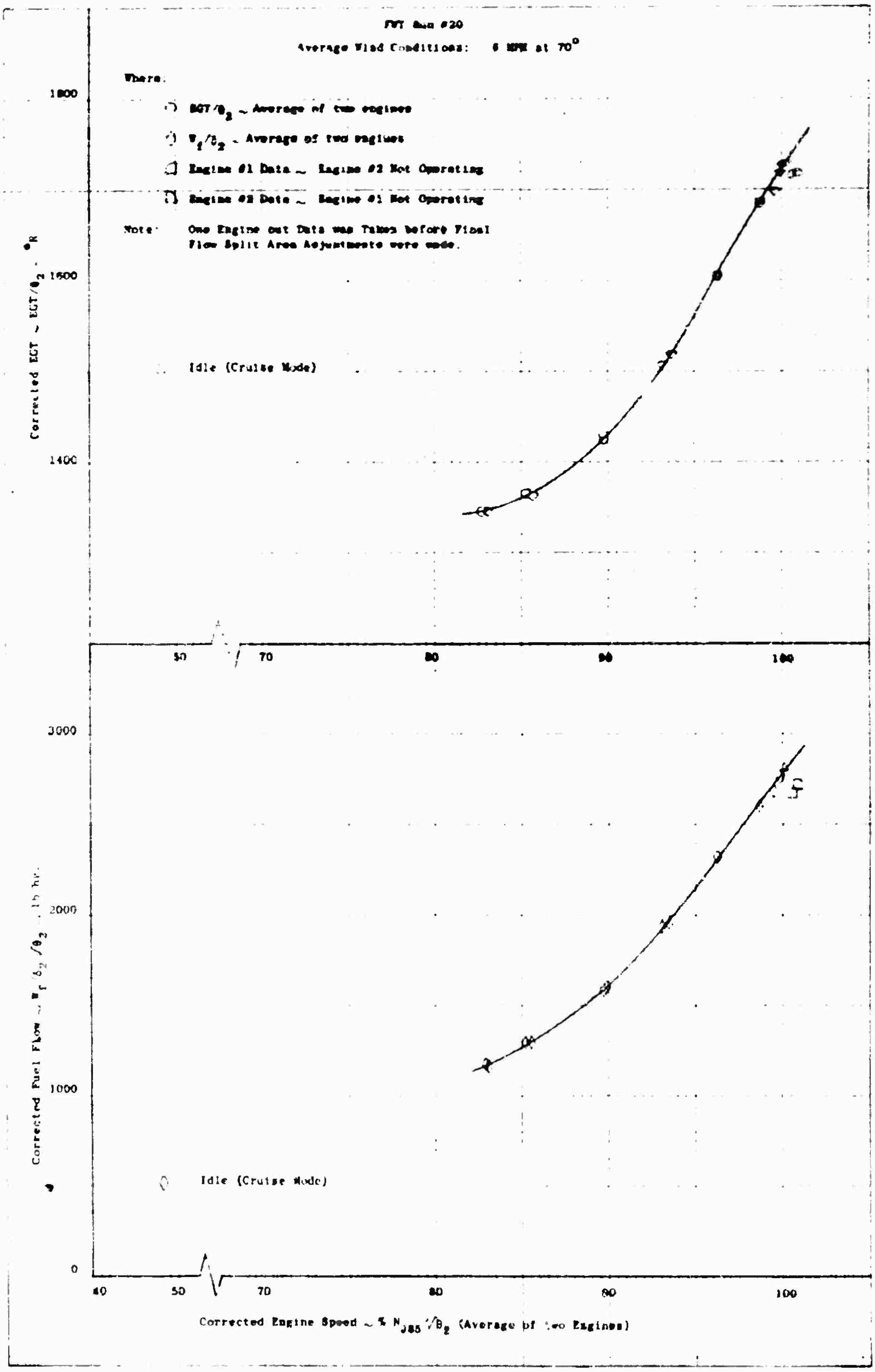


Figure I-34. Corrected EGT And Fuel Flow Vs Corrected Engine Speed (Lift Mode) FWT Performance Calibration, Run #20

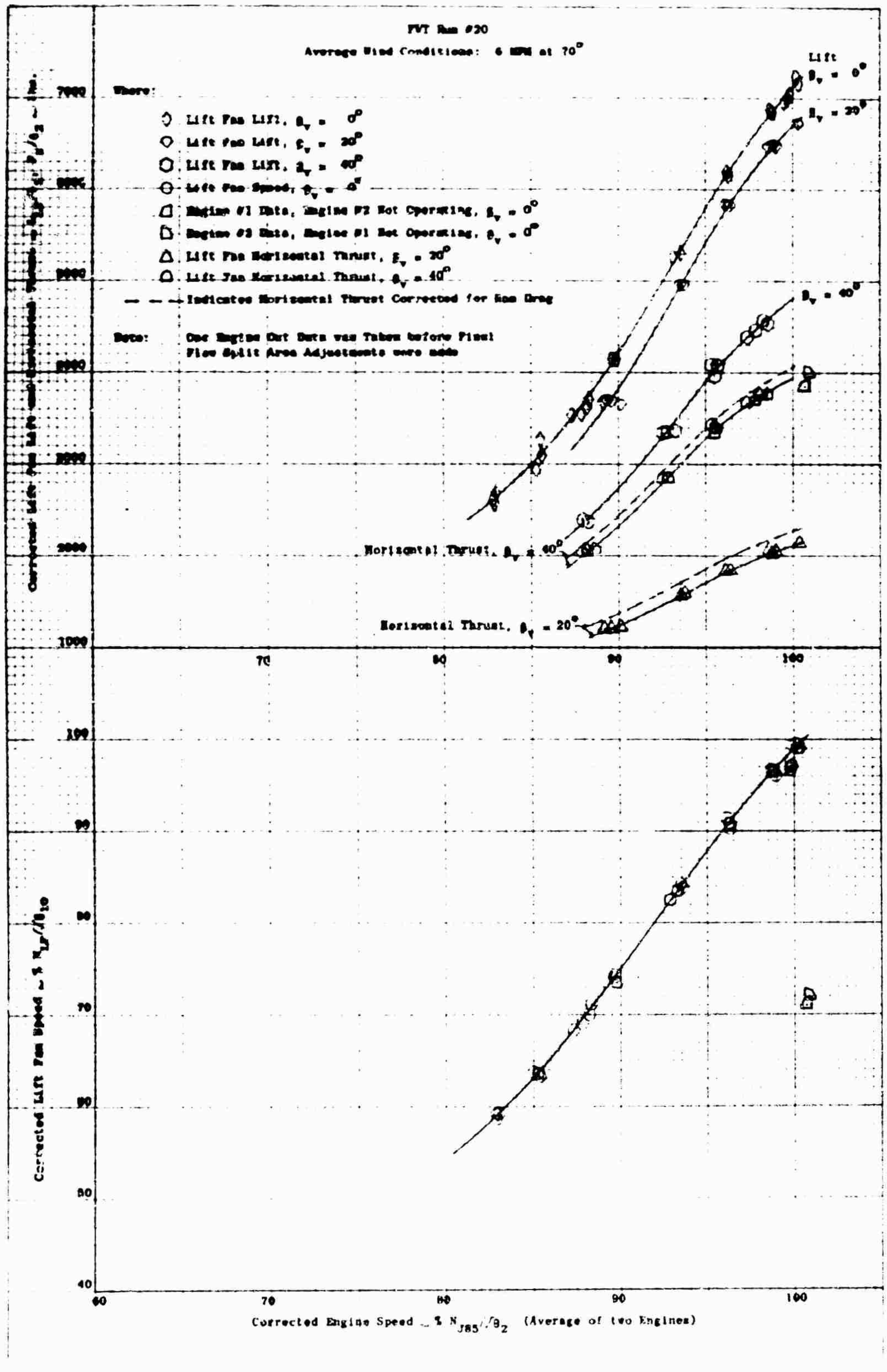


Figure I-35A. Corrected Lift Fan Lift, Horizontal Thrust And Speed Vs Corrected Engine Speed FWT Performance Calibration, Run #20

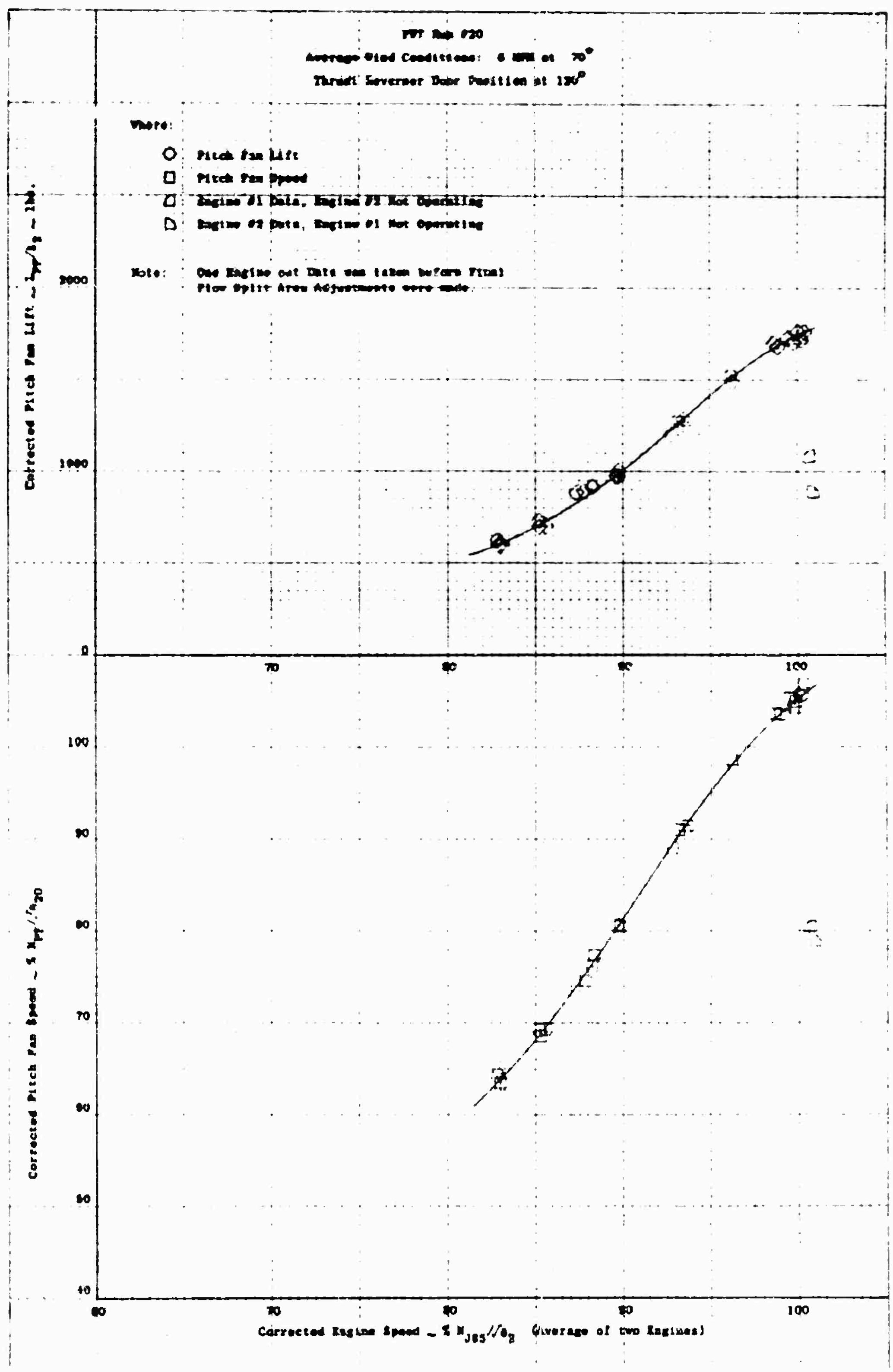


Figure I-35B. Corrected Pitch Fan Lift And Speed Vs Corrected Engine Speed FWT Performance Calibration, Run #20

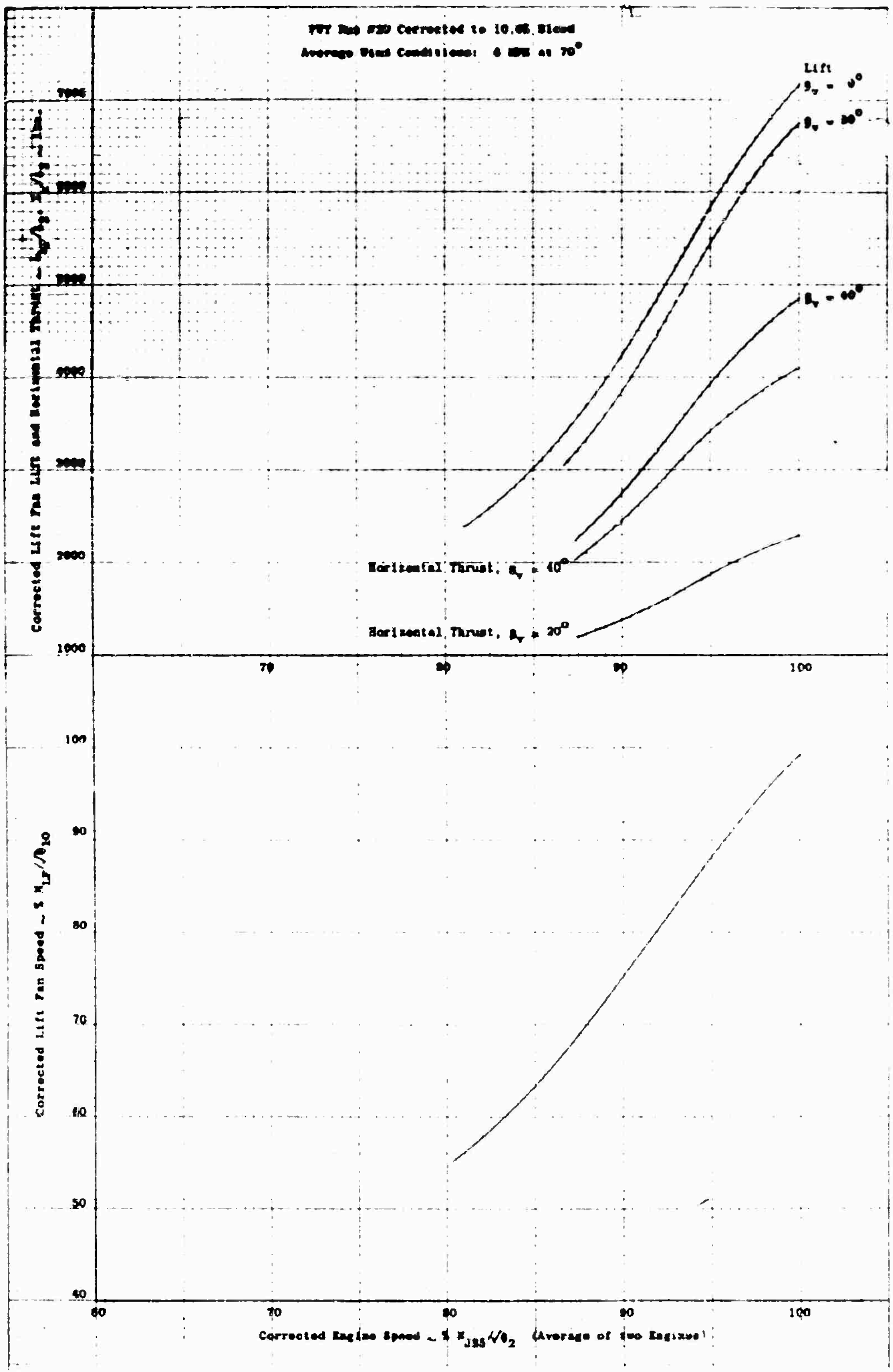


Figure I-36A Corrected Lift Fan Lift,,Horizontal Thrust and Speed Versus Corrected Engine Speed. FWT Performance Calibration, Run # 20, Corrected to 10.6% Bleed

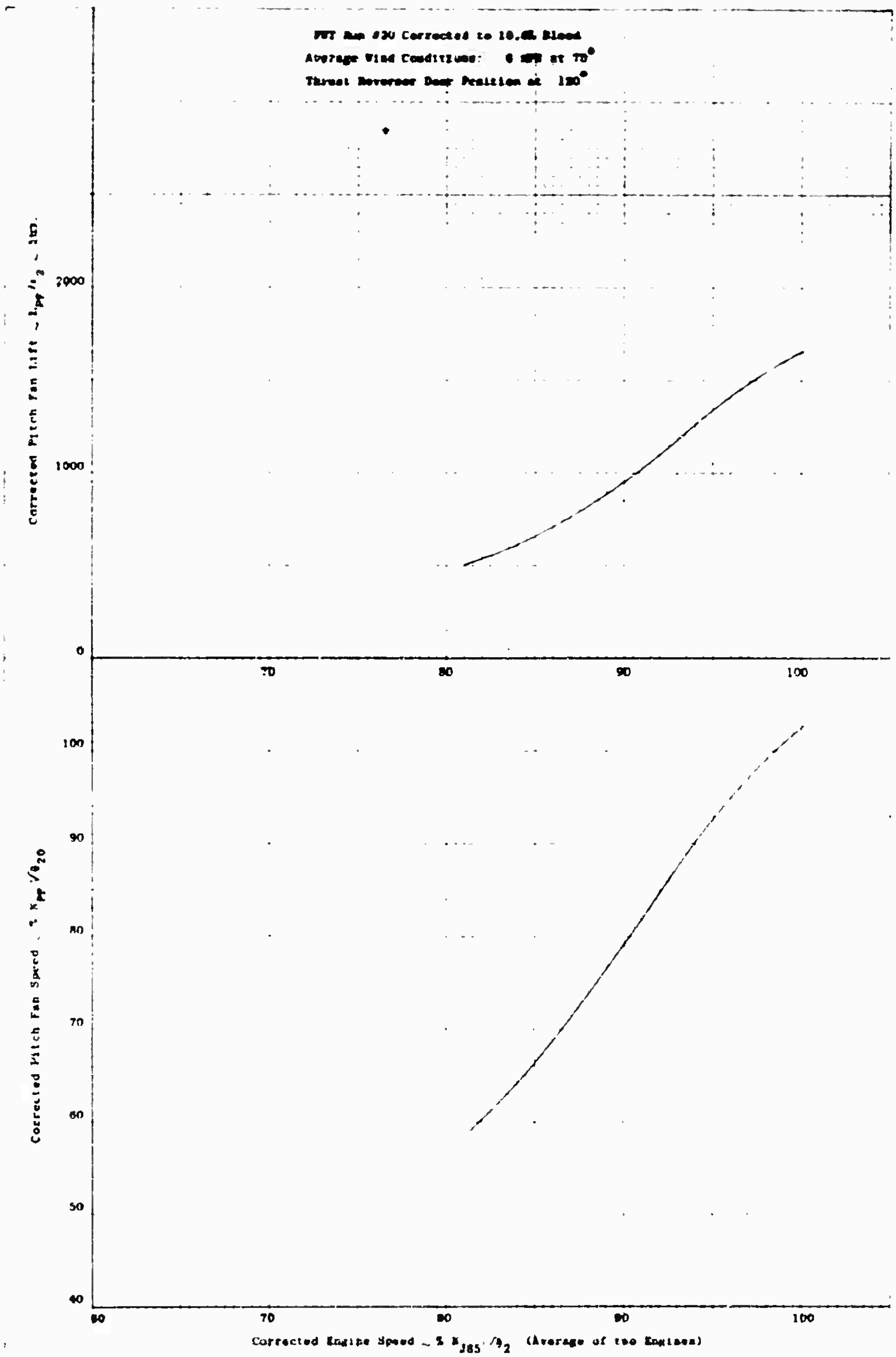


Figure I-36B Corrected Pitch Fan Lift and Speed Versus Corrected Engine Speed. FWT Performance Calibration, Run # 20, Corrected to 10.6% Bleed

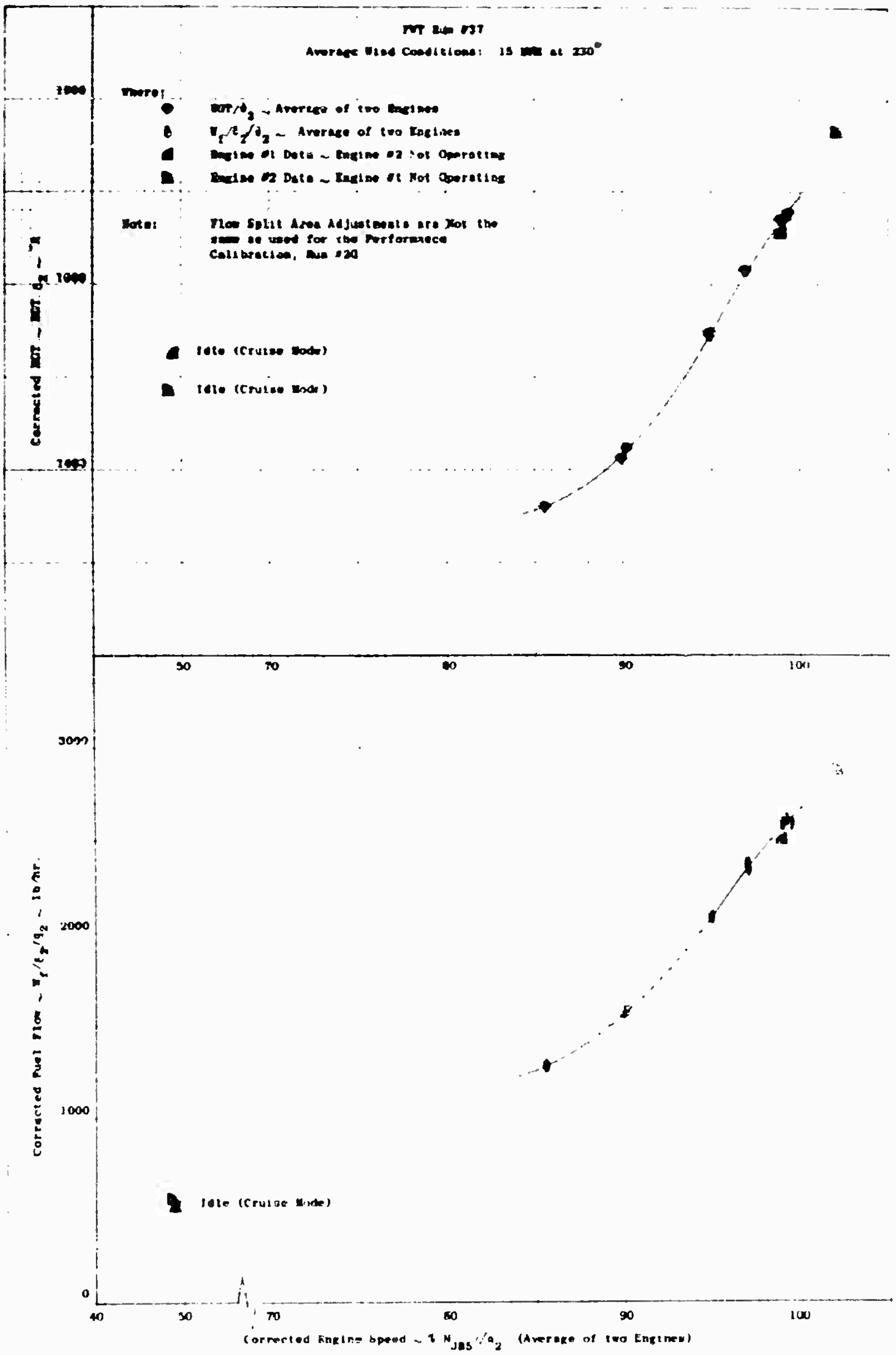


Figure I-37. Corrected EGT And Fuel Flow Vs Corrected Engine Speed (Lift Mode) FWT Performance Recalibration, Run #37

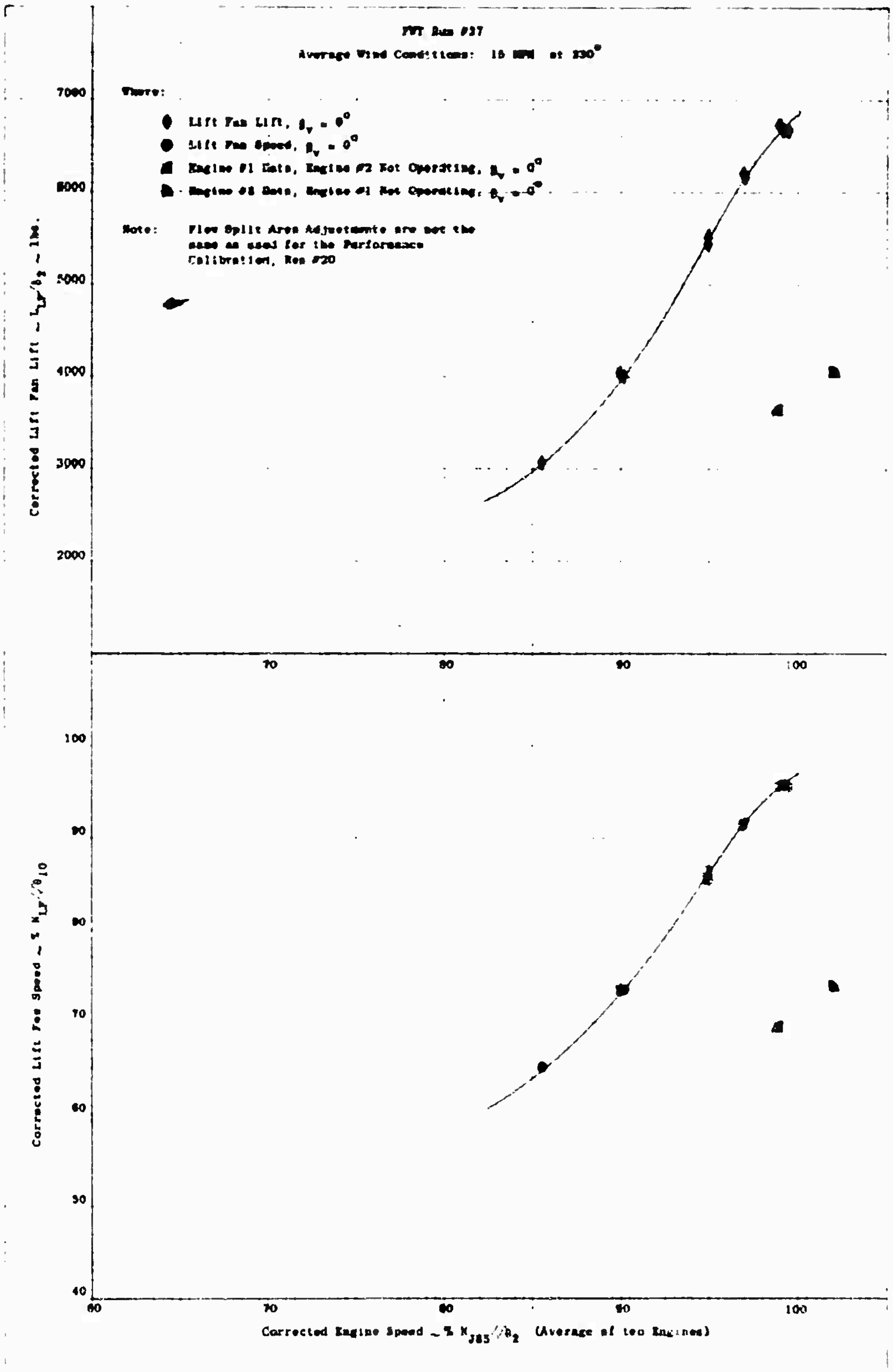


Figure I-38. Corrected Lift Fan Lift And Speed Vs Corrected Engine Speed. FWT Performance Recalibration, Run #37

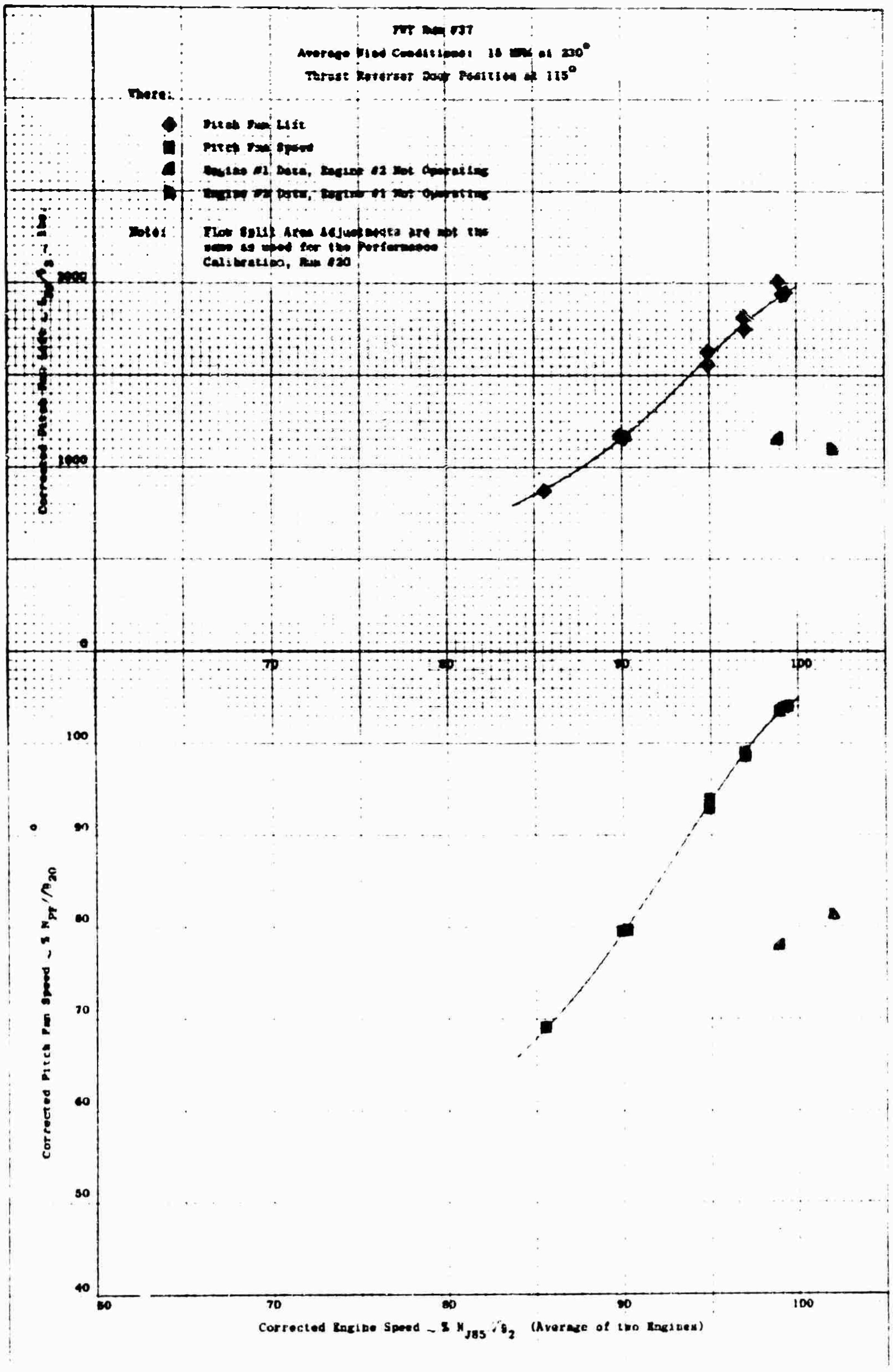


Figure I-39. Corrected Pitch Fan Lift And Speed Vs Corrected Engine Speed FWT Performance Recalibration, Run #37

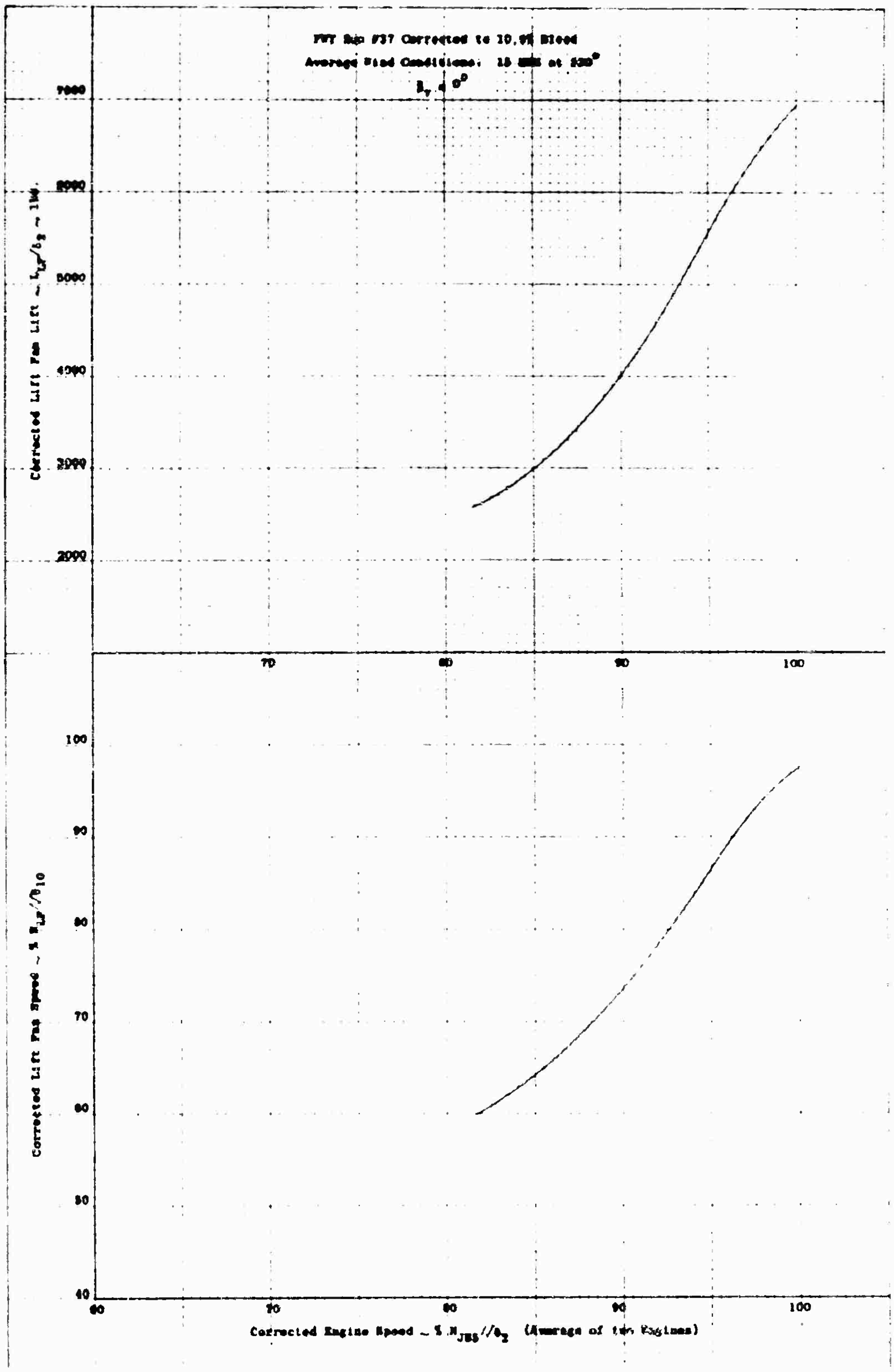


Figure I-40. Corrected Lift Fan Lift and Speed Vs Corrected Engine Speed. FWT Performance Recalibration, Run #37, Corrected to 10.6% Bleed

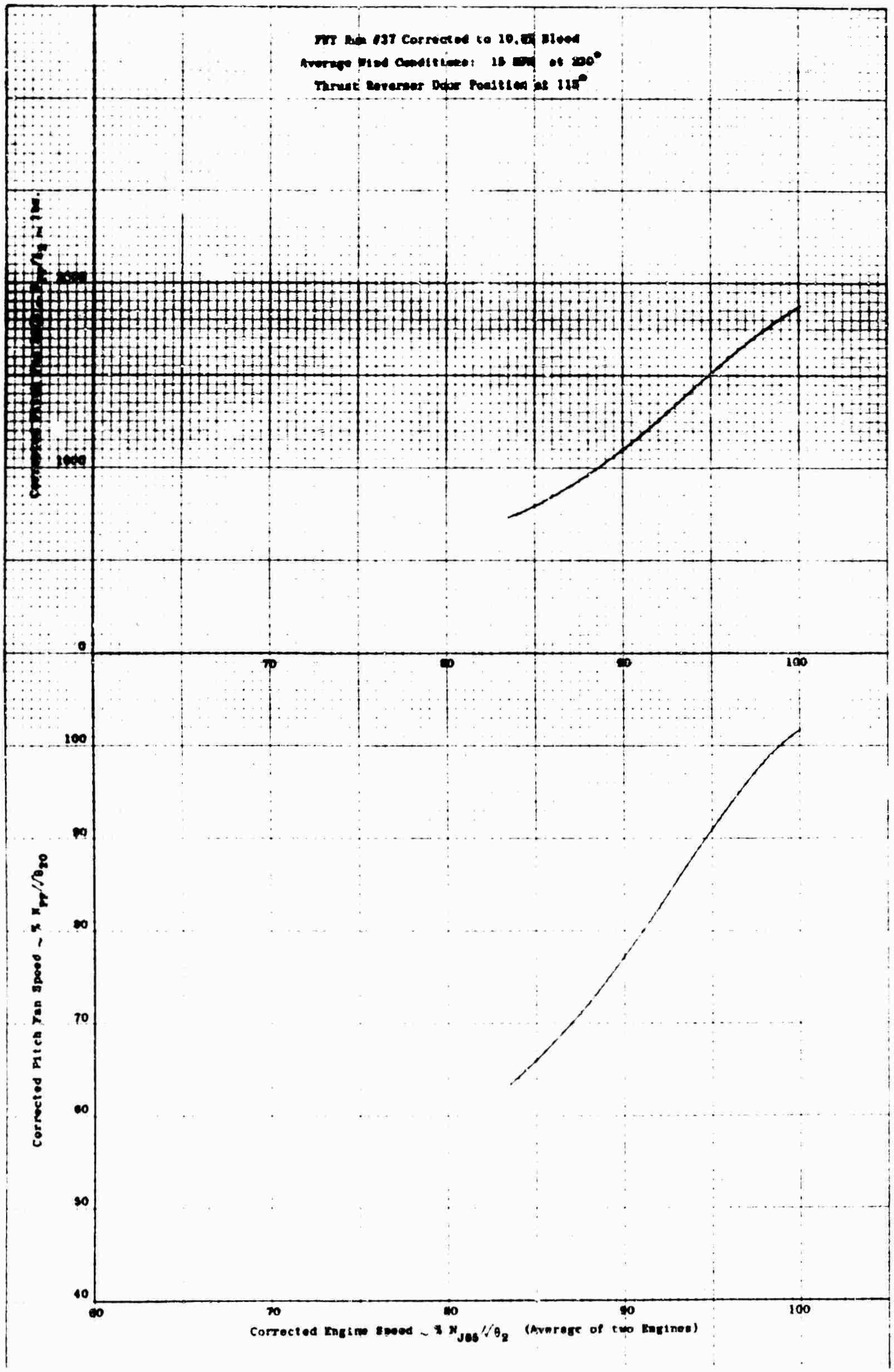


Figure I-41 Corrected Pitch Fan Lift and Speed Versus Corrected Engine Speed.FWT Performance Recalibration, Run # 37, Corrected to 10.6% Bleed

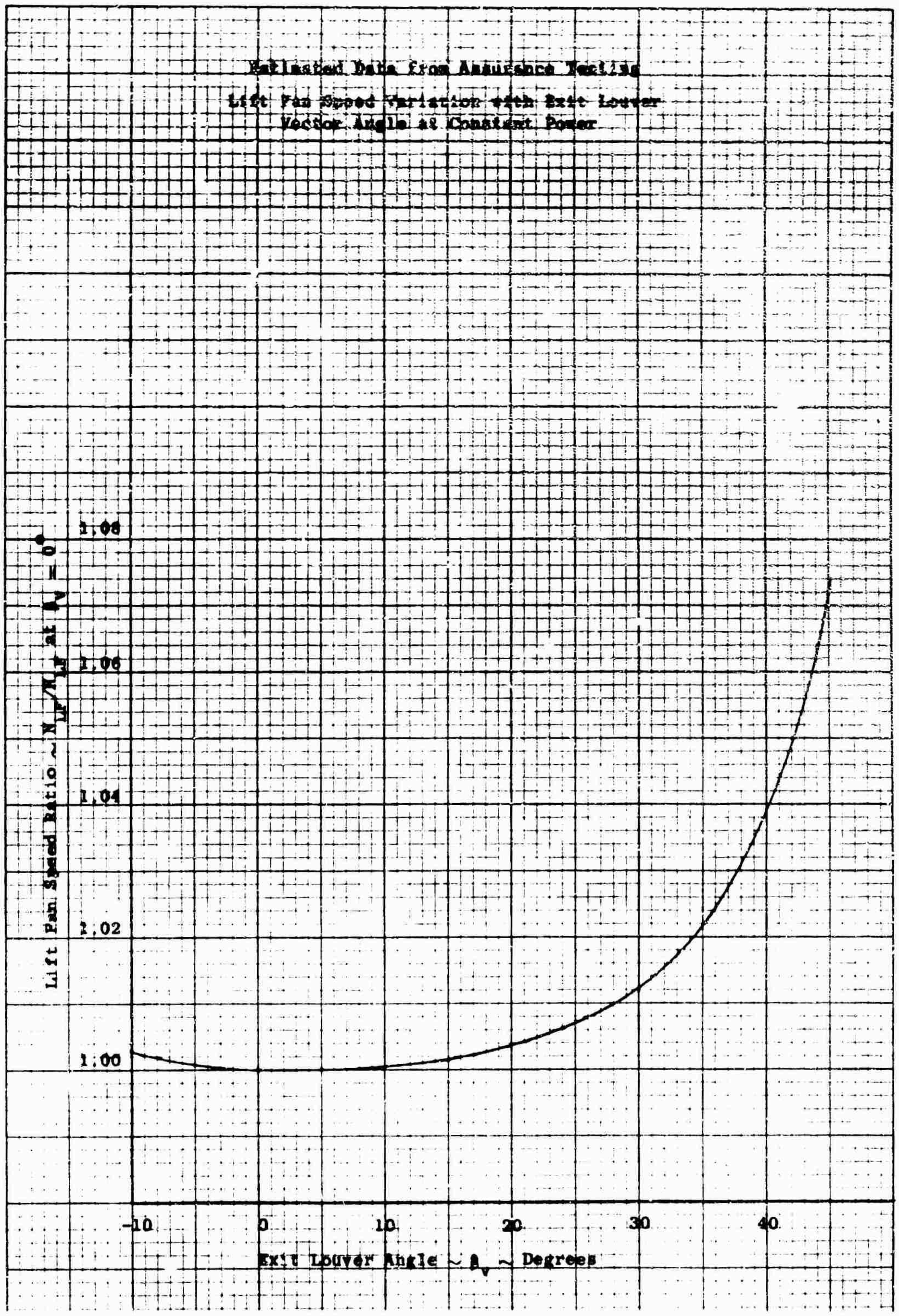


Figure I-42. Lift Fan Speed Ratio as a Function Indicated. Exit Louver Angle

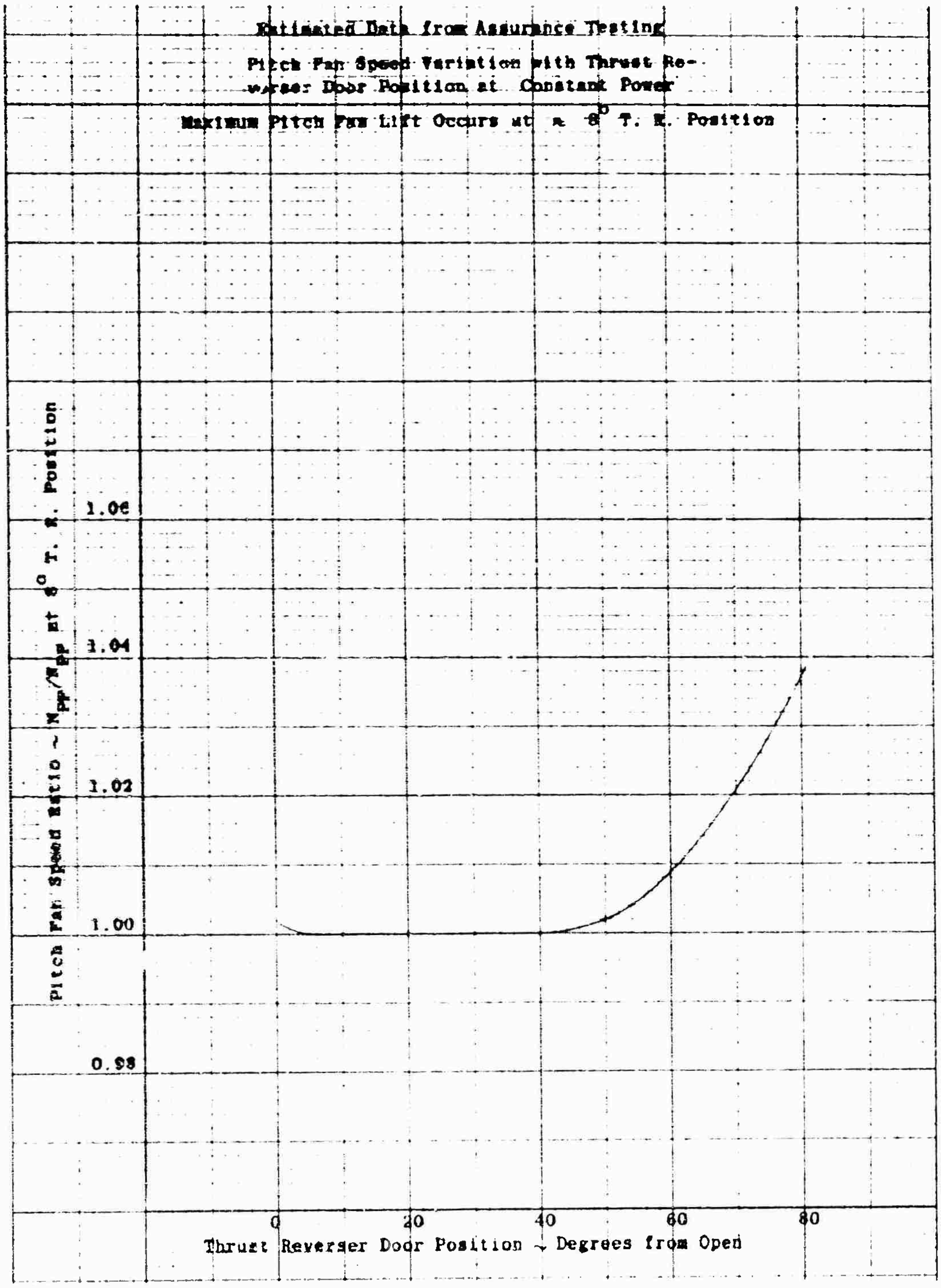


Figure I-43. Pitch Fan Speed Ratio as a Function of Thrust Reverser Door Position traces are presented in Figures I-44 through I-53. These traces were selected from the performance calibration (Run #20) and from FWT (Run #32) when more than 40 hours of FWT running time had been completed. Engine #2, J85-GE-5, S/N 230-729 had an unusually slow acceleration time compared to engine #1. This is reflected in the fan acceleration traces in Figures I-44 and I-46. The bottom two traces were alternately recording engine throttle position or diverter valve position depending on the type of transient being investigated. The pips at the bottom of the figure are one second interval indications.

4. PERFORMANCE COMPARISONS VERSUS X353-5B AND X376 SPECIFICATIONS

Comparative data are presented in Figures I-54 through I-65.

Figure I-54 shows the calibration and recalibration results for the lift fan with fan lift and speed presented as a function of engine speed.

Figure I-55 presents the same data for the pitch fan. Variation in wind condition between calibration and recalibration made a significant difference in the results. The recalibration is considered to be the more accurate because it was performed during wind conditions similar to those used in establishing the basis for calibration of the thrust frame. The effect of wind variation (discussed in the Appendix) would "correct" Run #20 data by increasing the pitch fan lift and by correspondingly decreasing lift fan lift. This effect of the wind is to redistribute the total lift on the three (3) vertical load cells because of a couple developed by the fan ram drag force and the horizontal thrust restraint. Figure I-56 presents the pitch fan speed as a function of ideal scroll inlet horsepower which should be independent of wind condition.

Figure I-57 presents both calibration and recalibration results of the pitch fan in terms of lift versus input horsepower and indicates the same wind effect noted in Figure I-55.

Figures I-58 through I-65 are plots of data taken from Figures I-44 through I-53 to compare fan response during throttle and diverter valve transients with specification values. In Figure I-58 additional data from the FWT assurance test are included to illustrate test performance with two engines having similar acceleration characteristics. The J engine response curve reflects the sluggish engine effect. The YJ engine performance indicates that two similar engines would provide a somewhat improved characteristic. To obtain the lift values the steady state relationship between fan speed and lift was used enabling a direct conversion from the recordings of the speed characteristics.

Step change response is compared in Figures I-60 and I-64. The test step changes were based on engine speed change of $\approx$ 5% which resulted in $\approx$ 10% lift increments for the fans.

Tables IX, X and XI provide direct comparison of performance at the Specification rating points. These data will be discussed in the analysis presented later in the report.

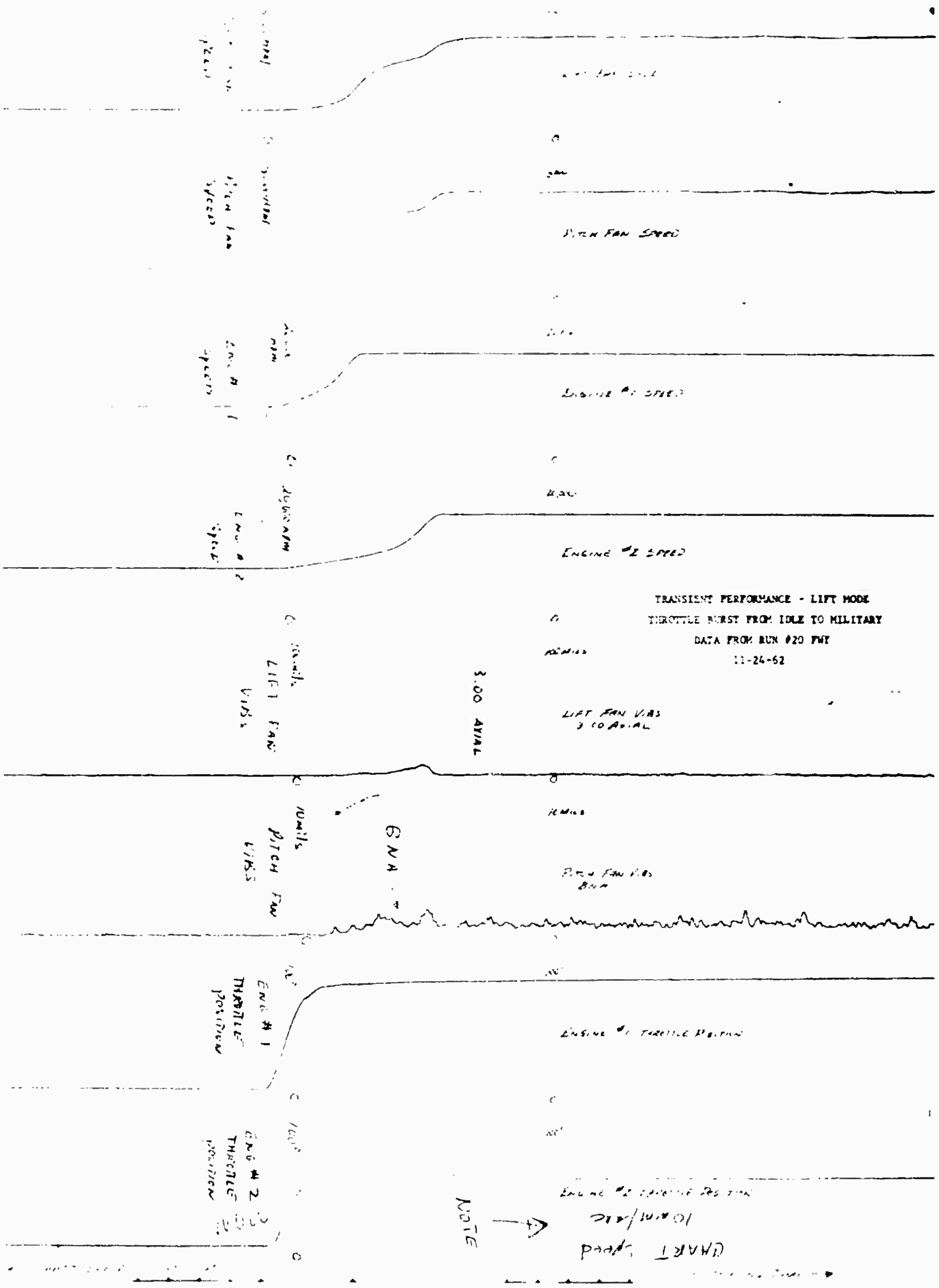


Figure I-44. Transient Performance - Lift Mode
Throttle Burst From Idle to Military

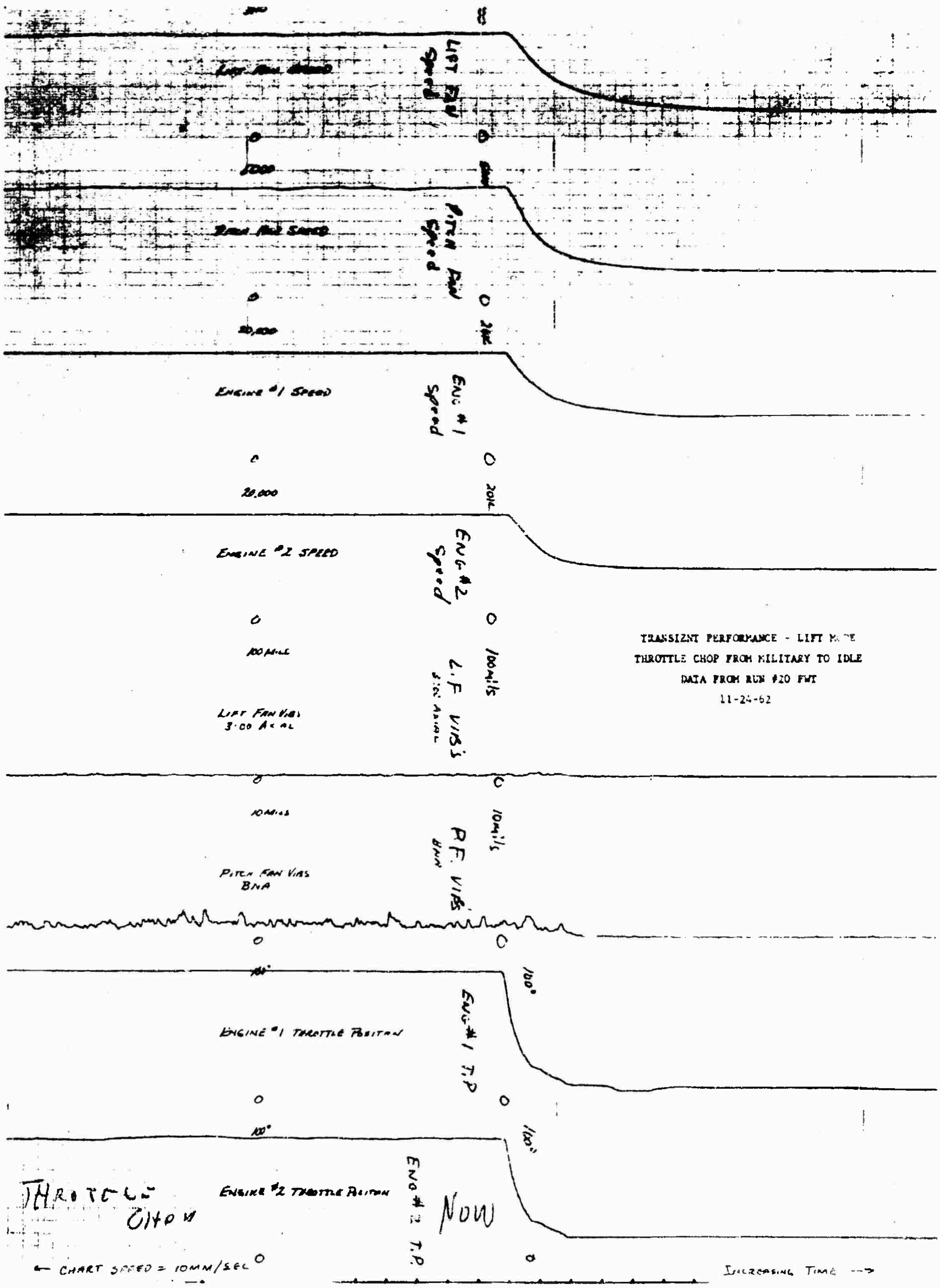


Figure I-45. Transient Performance - Lift Mode Throttle Chop From Military to Idle

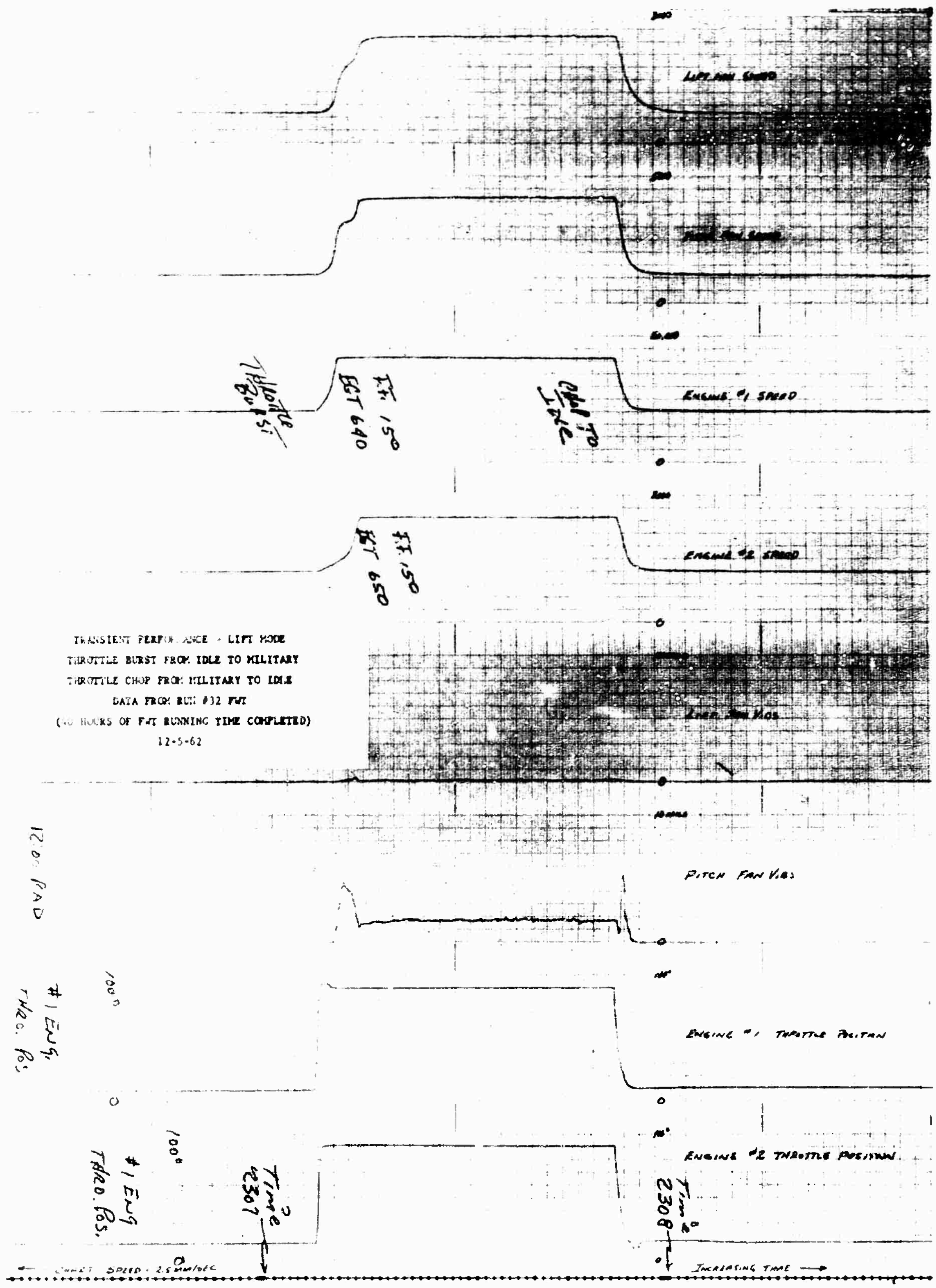


Figure I-46. Transient Performance - Lift Mode
Throttle Burst From Idle to Military
Throttle Chop From Military to Idle

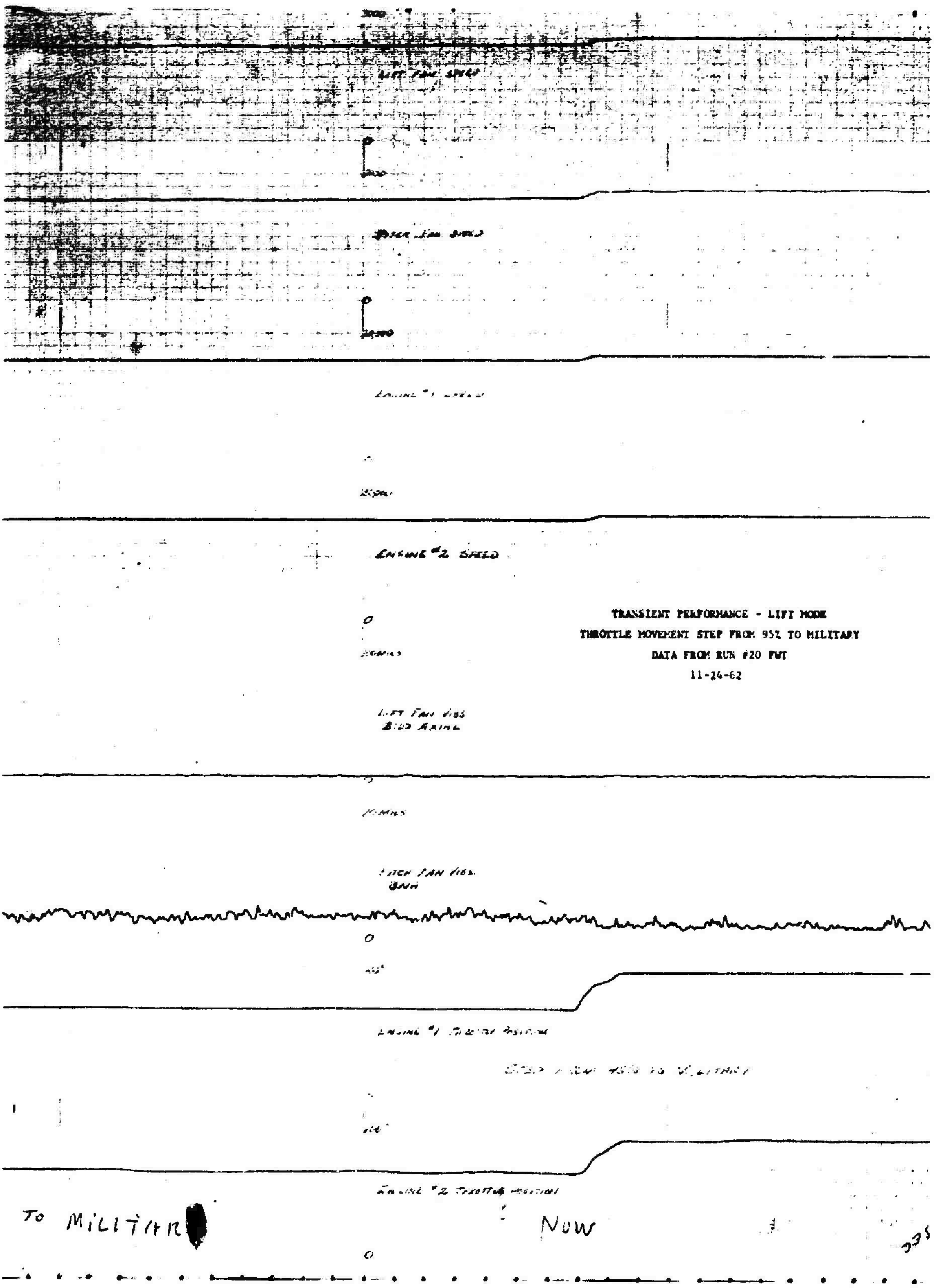


Figure I-47. Transient Performance - Lift Mode Throttle Movement Step From 95% to Military

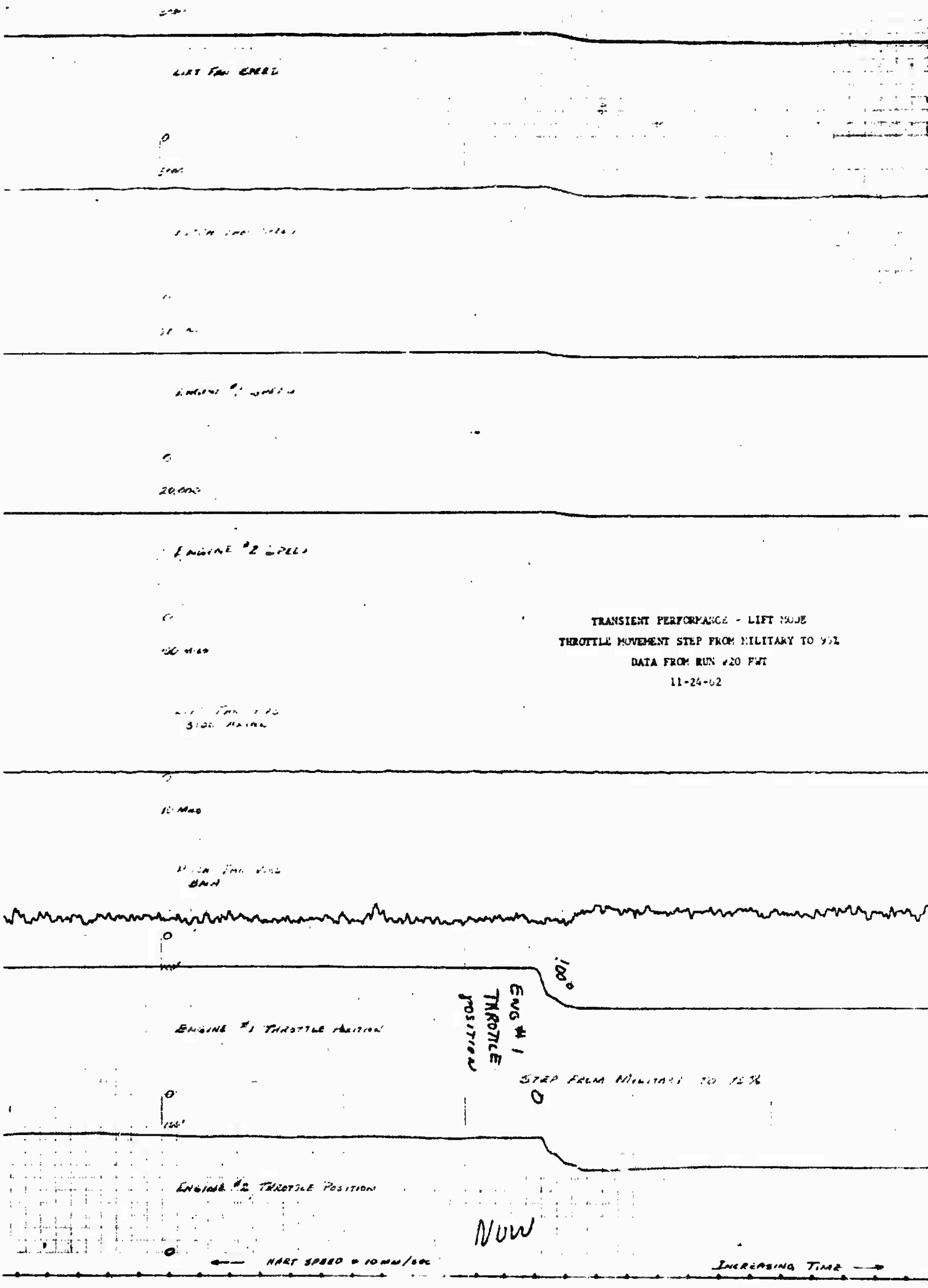


Figure I-48. Transient Performance - Lift Mode Throttle Movement Step From Military to 95%

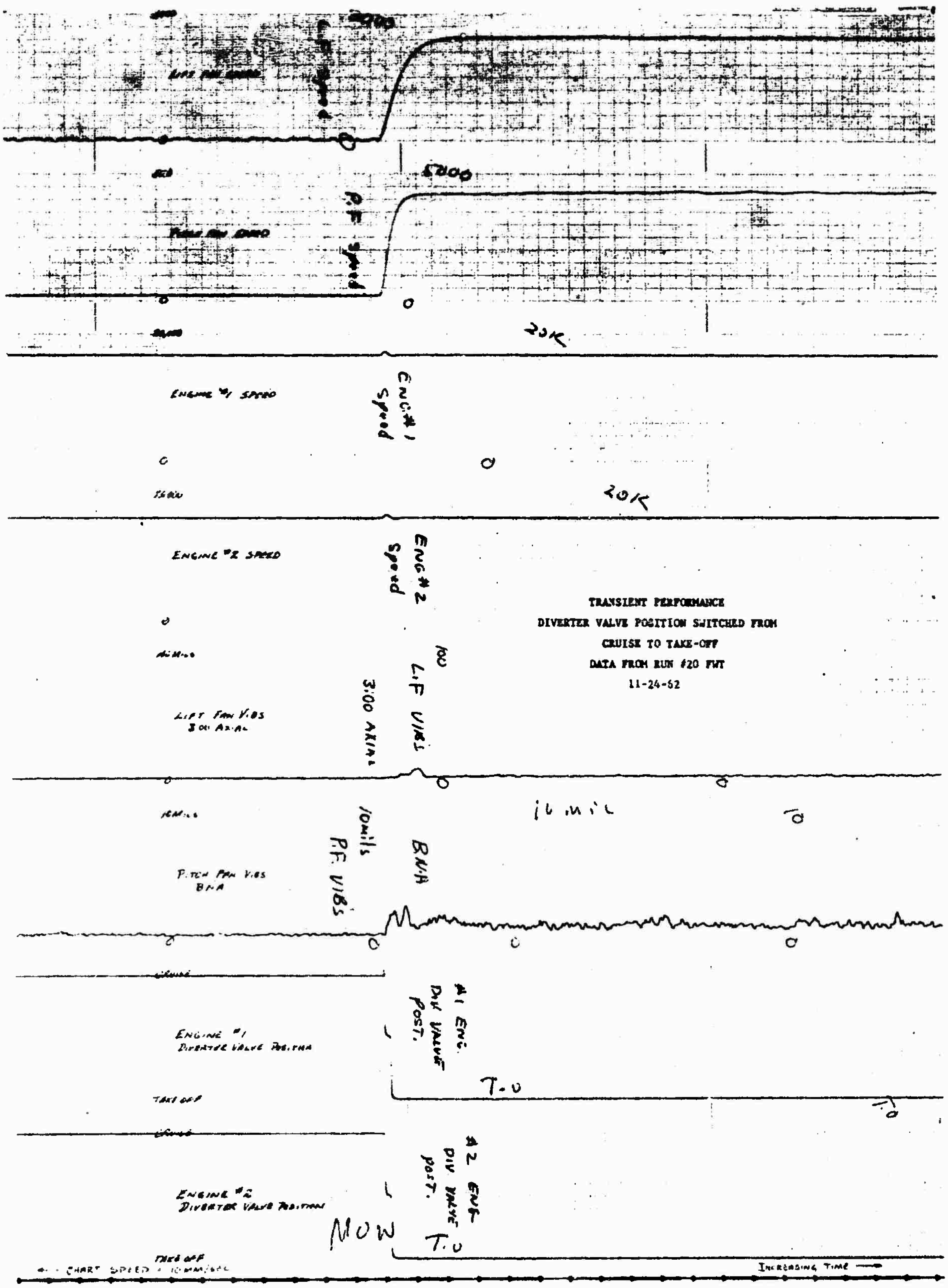


Figure I-49. Transient Performance
Diverter Valve Position
Switched From Cruise to Take-Off

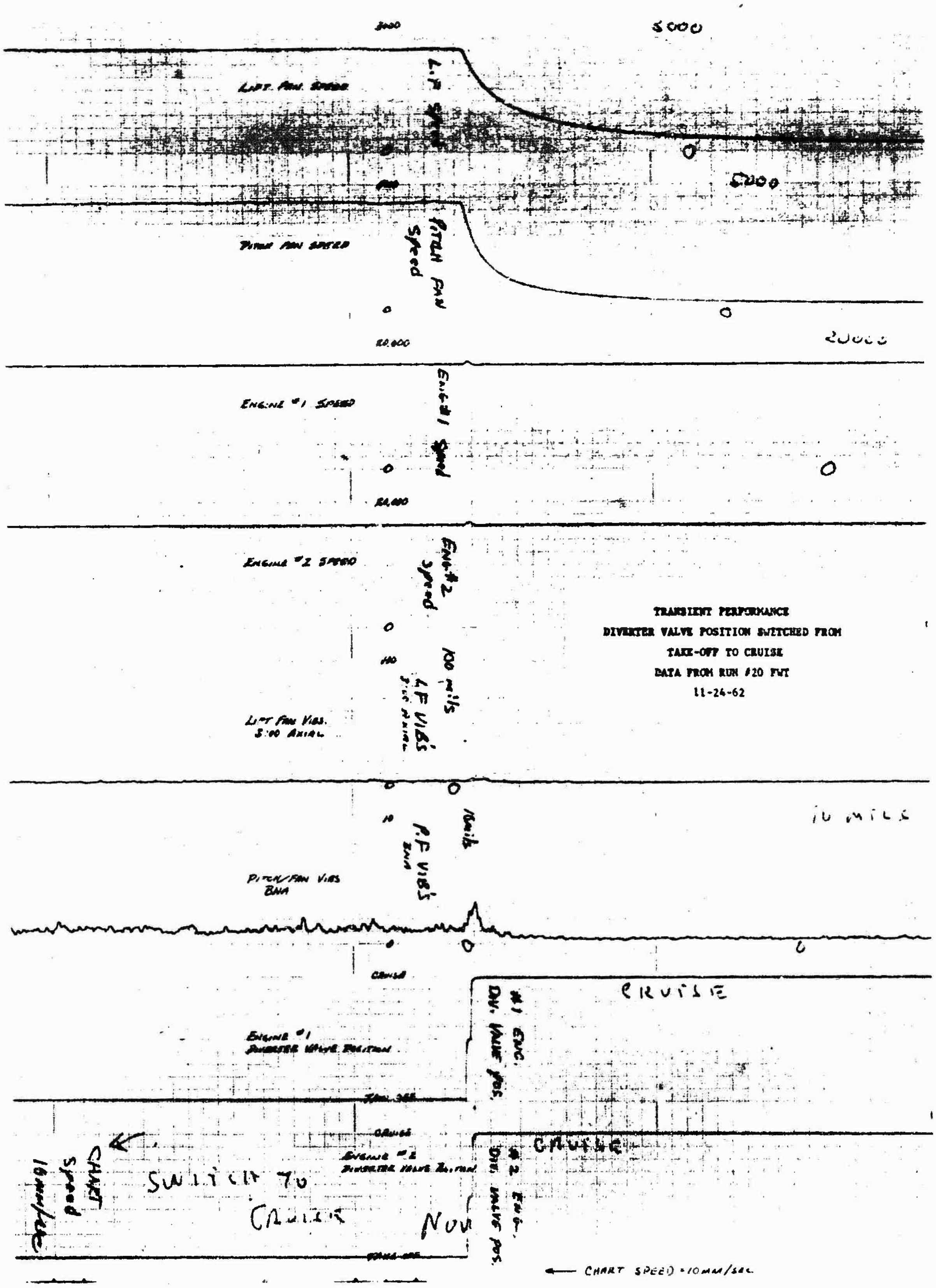


Figure I-50. Transient Performance
Diverter Valve Position
Switched From Take-Off to Cruise

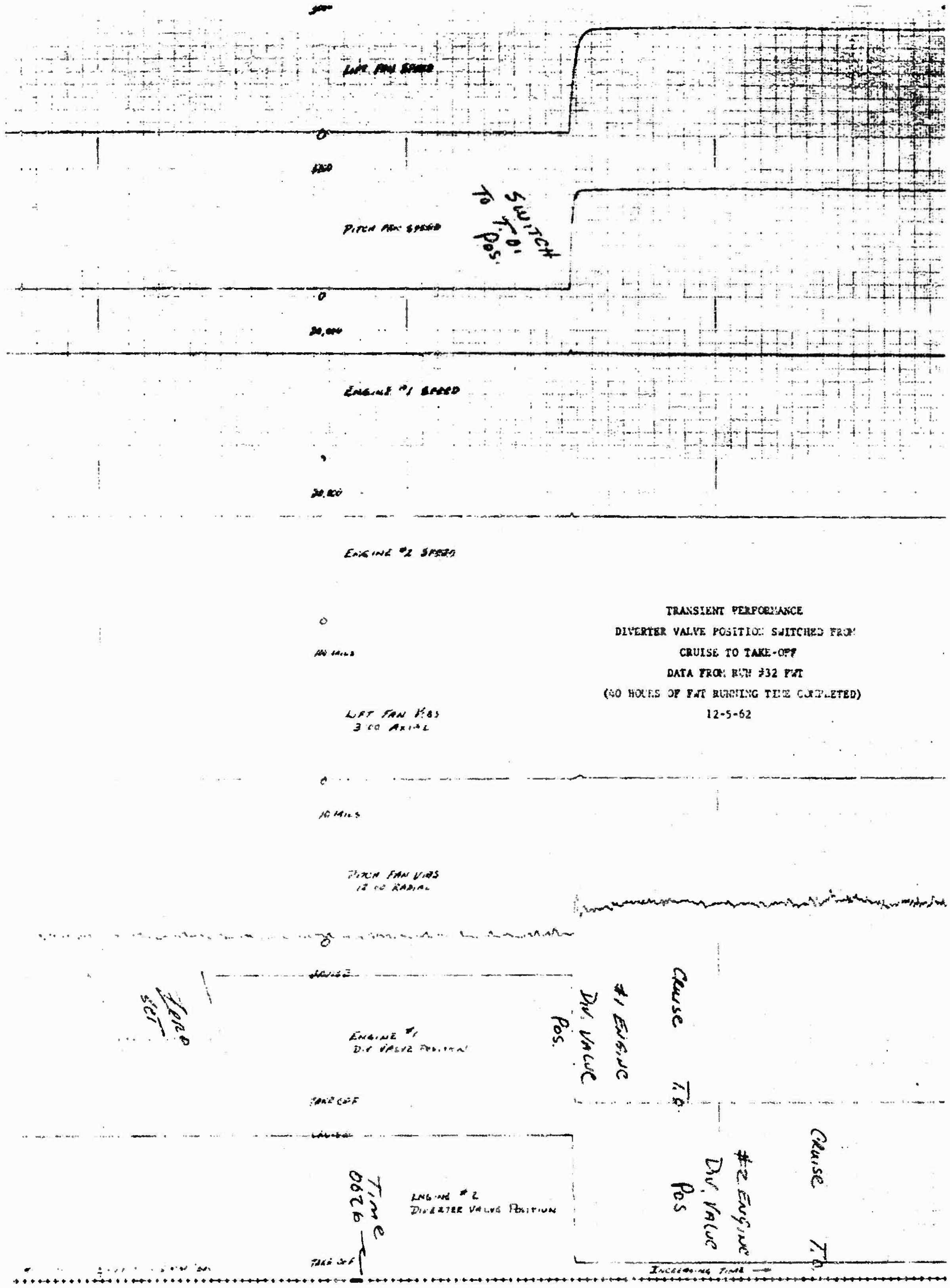


Figure I-51. Transient Performance Diverter Valve Position Switched From Cruise to Take-Off

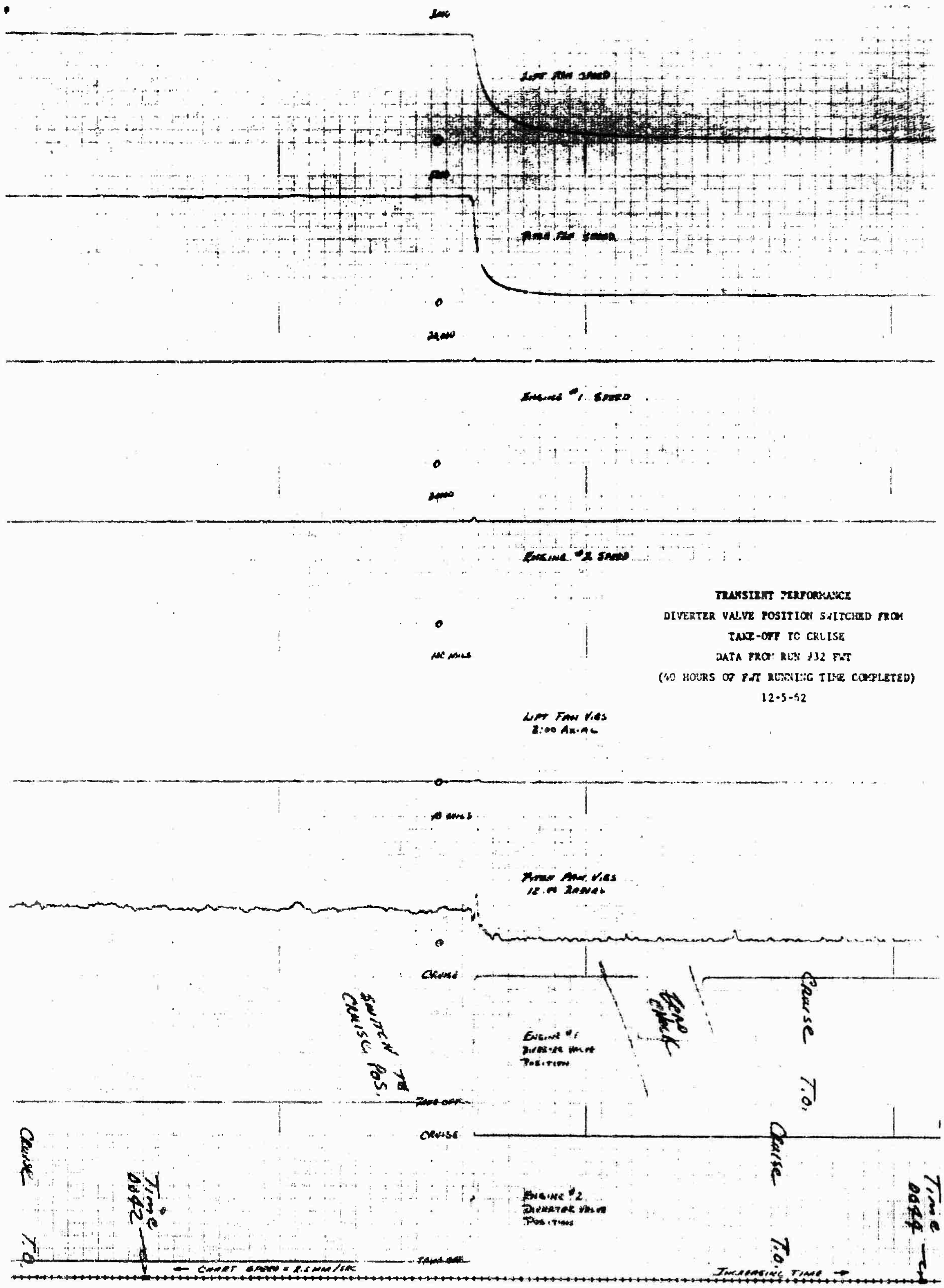


Figure I-52. Transient Performance
Diverter Valve Position
Switched From Take-Off to Cruise

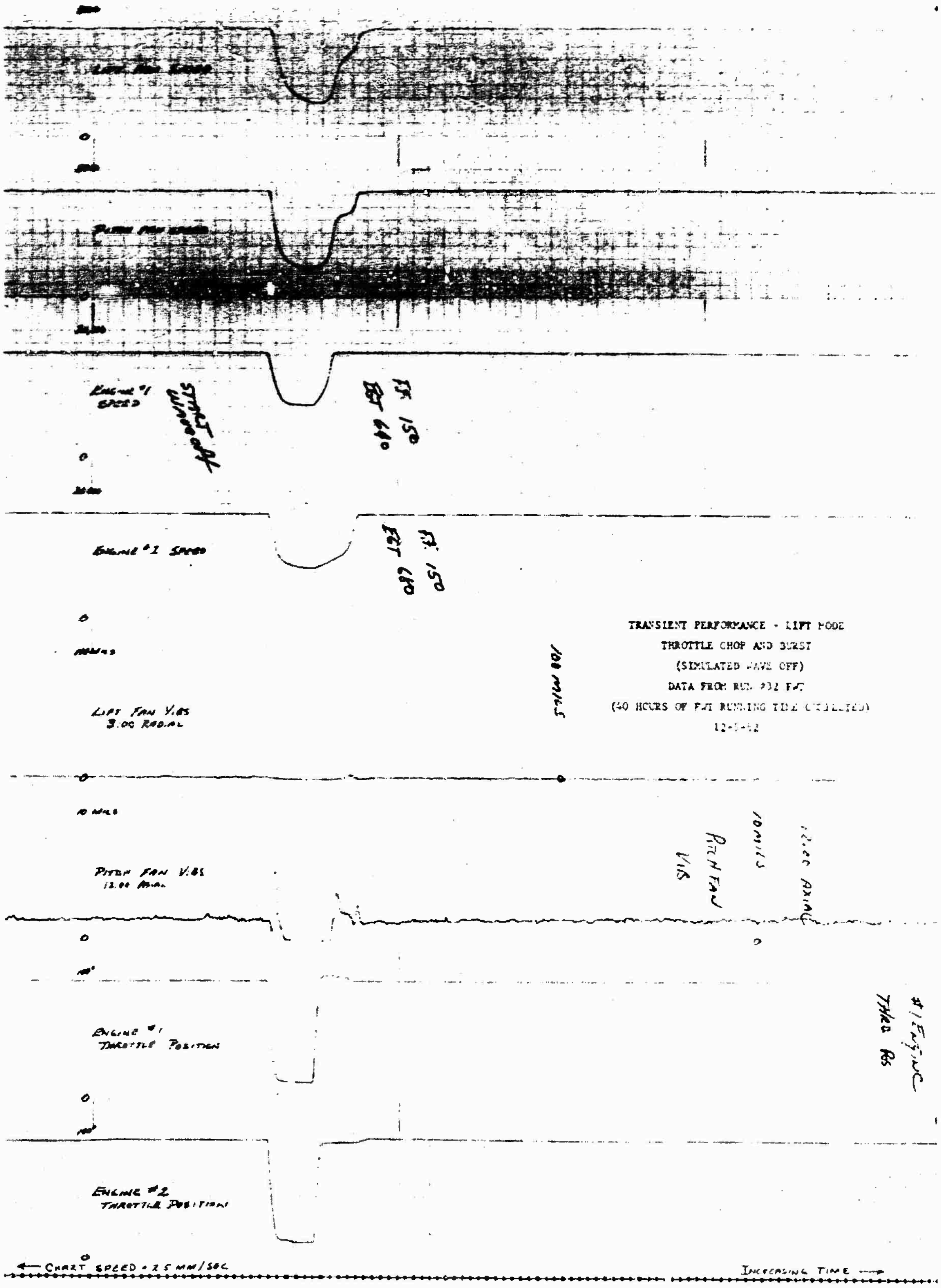


Figure I-53. Transient Performance - Lift Mode
Throttle Chop and Burst
(Simulated Wave Off)

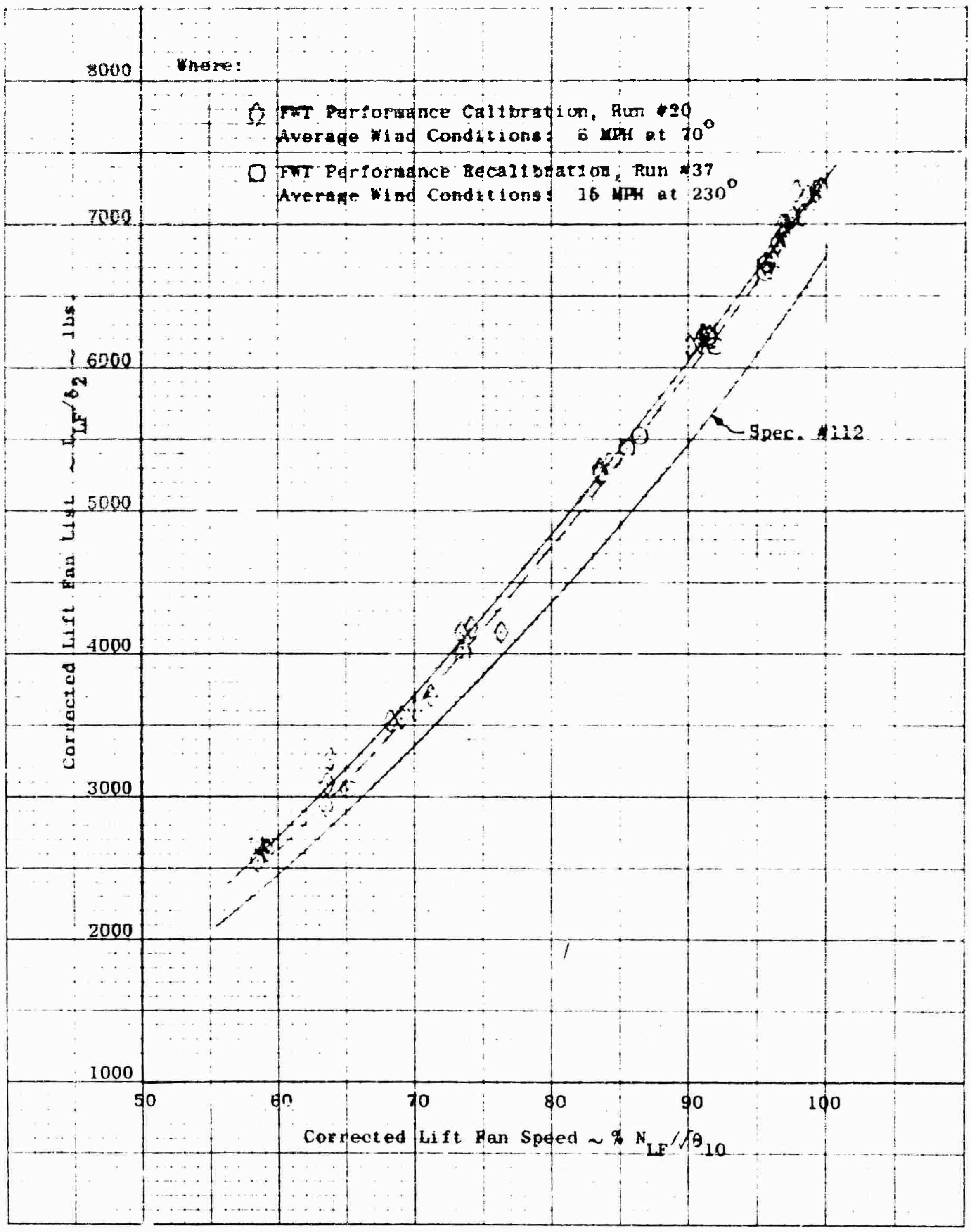


Figure I-54. Comparison of FWT Lift Fan Performance With Specification 112 ($\beta_V = 0^o$)

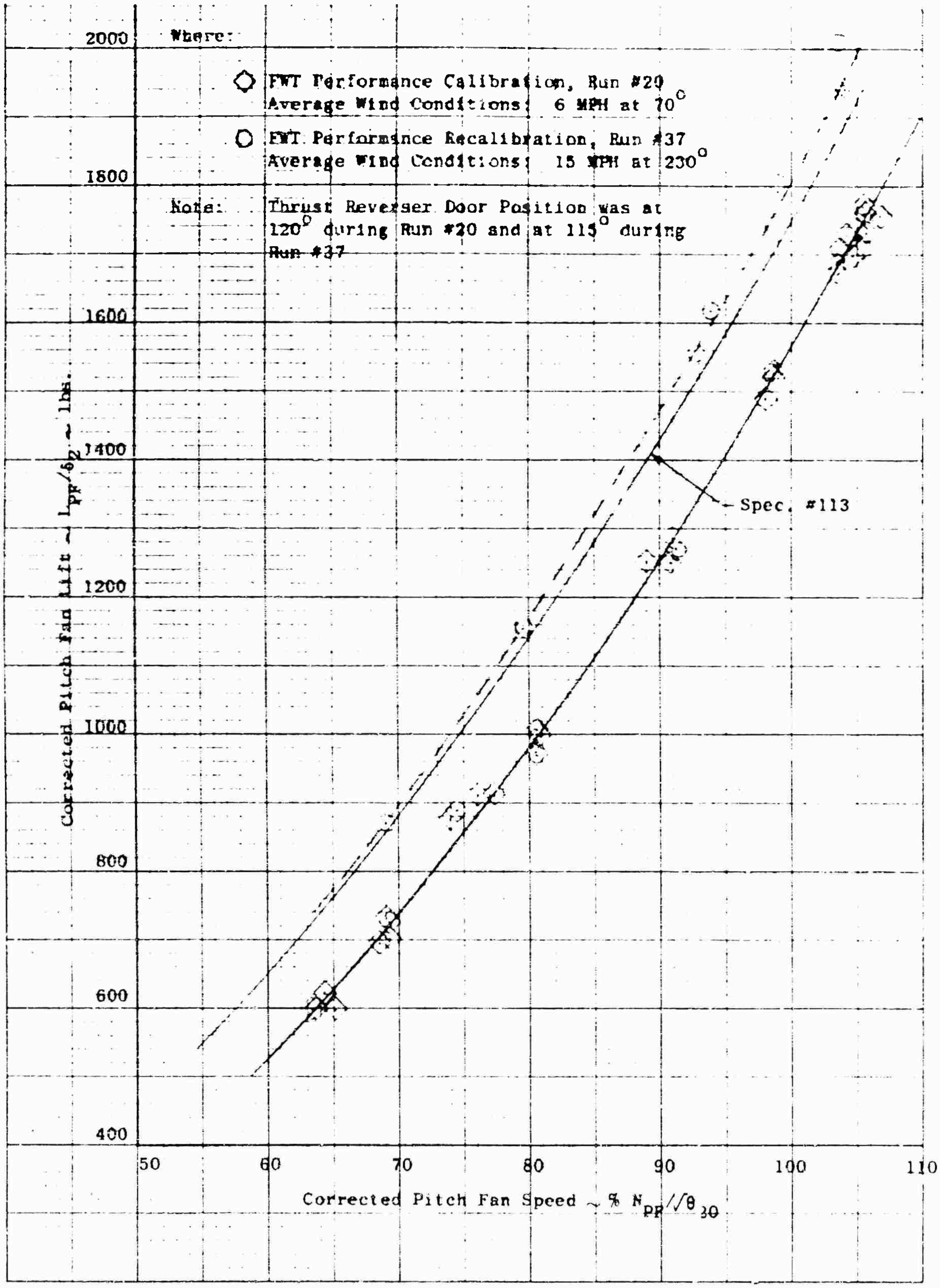


Figure I-55. Comparison of FWT Pitch Fan Performance With Specification N3

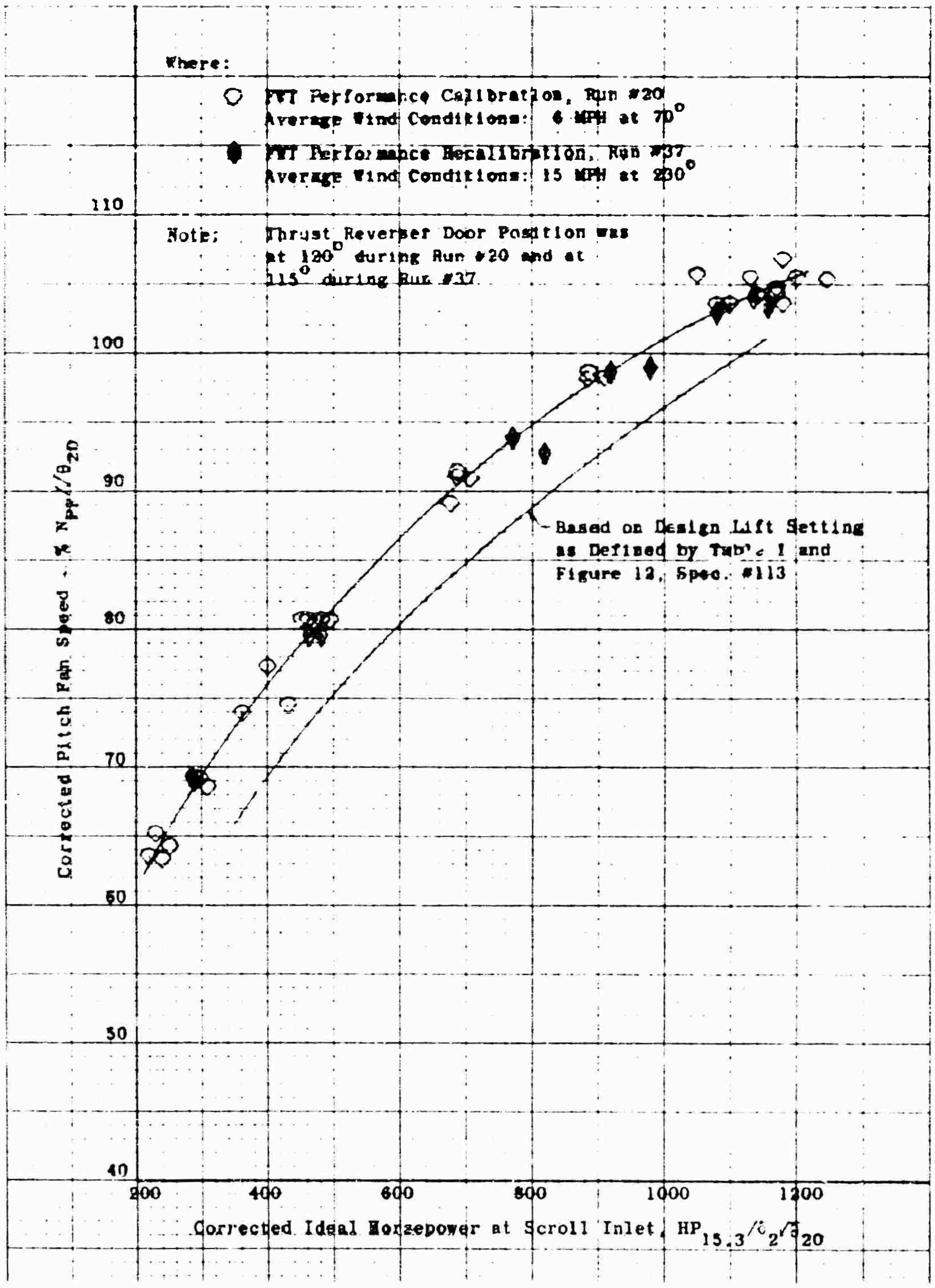


Figure I-56. Corrected Pitch Fan Speed Vs Scroll Inlet Ideal Horsepower

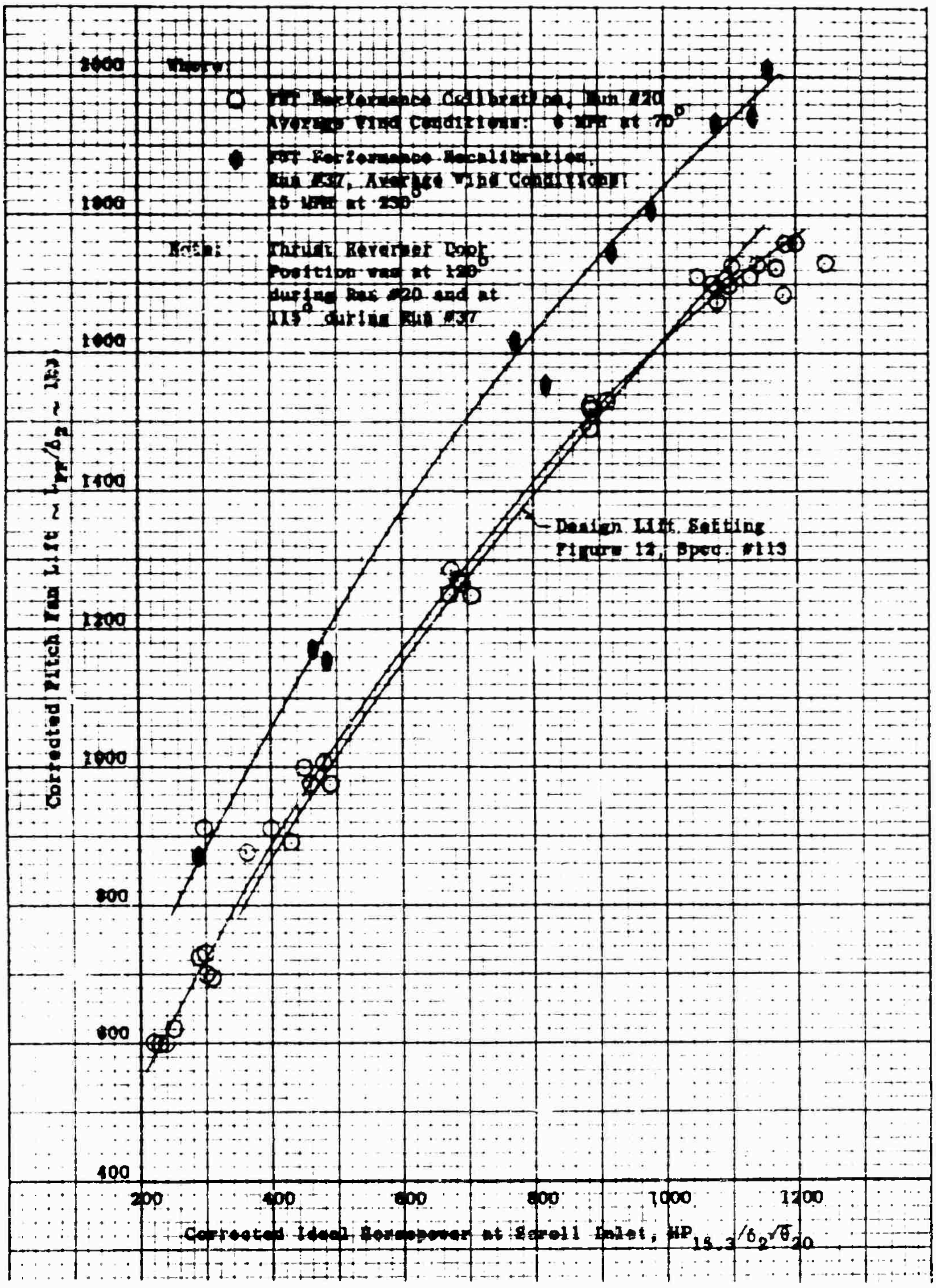


Figure I-57. Corrected Pitch Fan Lift Vs Scroll Inlet Ideal Horsepower

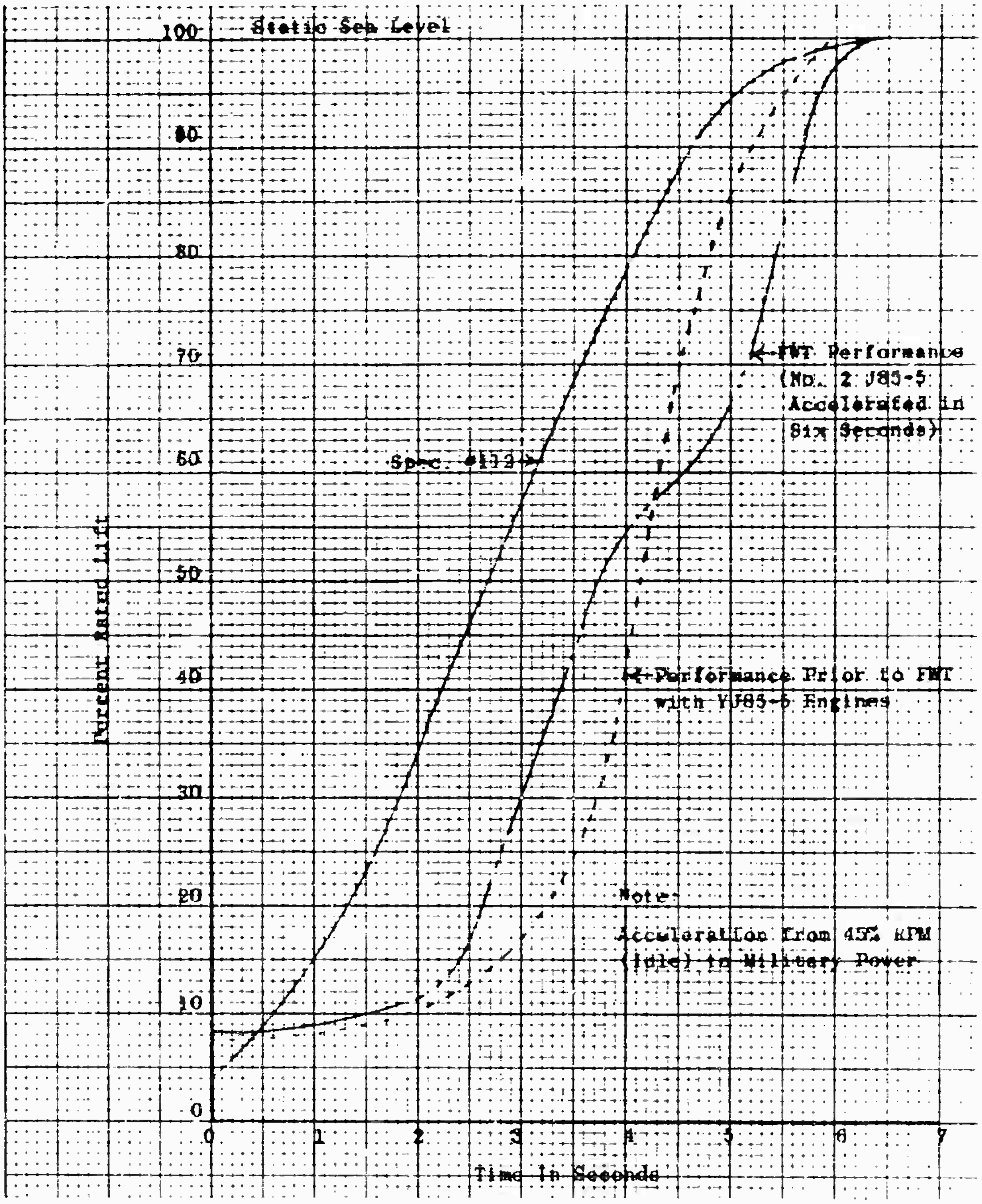


Figure I-58. Comparison of Lift Fan FWT Transient Performance With Specification 112 - Throttle Burst From Idle to Military

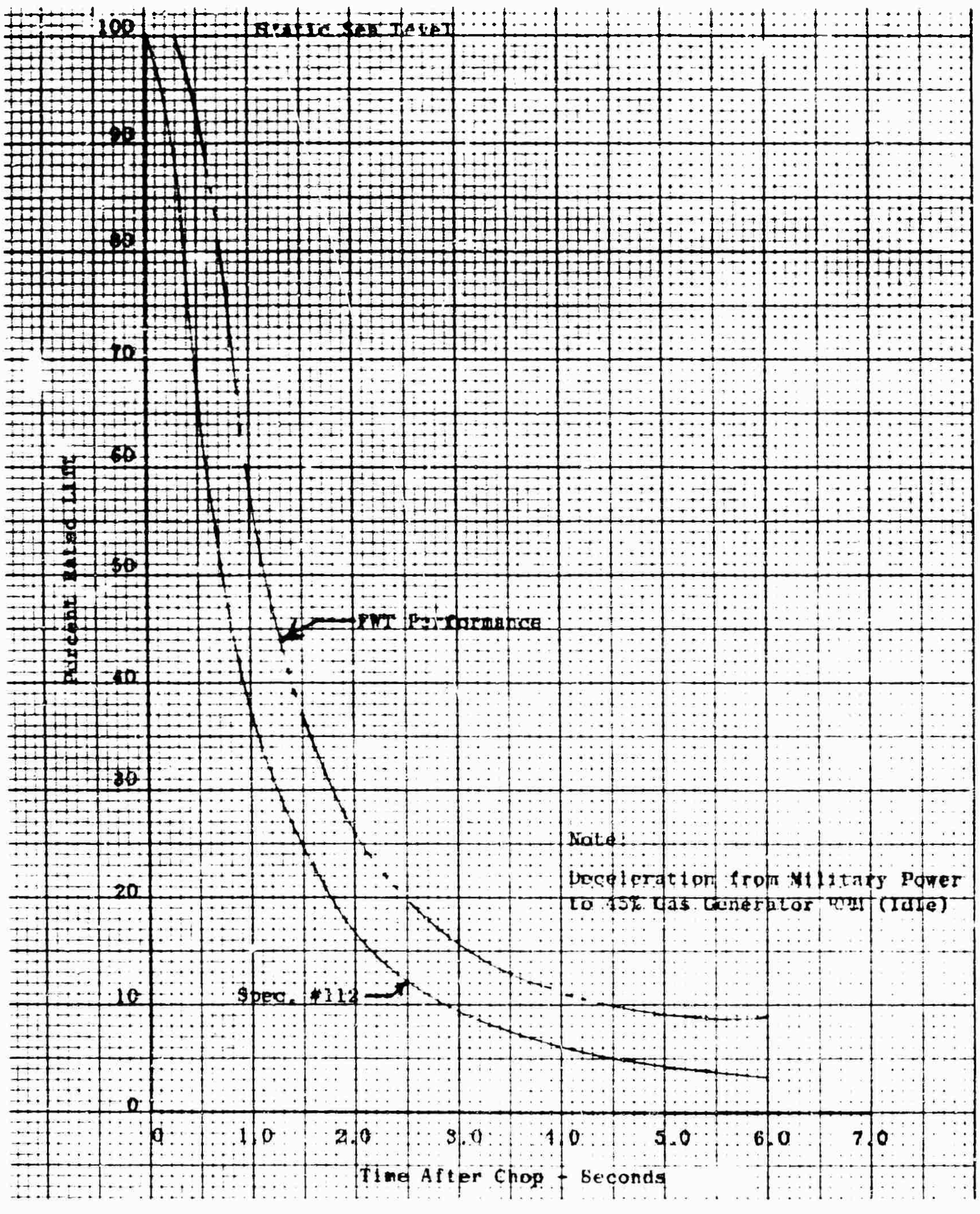


Figure I-59. Comparison Of Lift Fan FWT Transient Performance With Specification 112 - Throttle Chop From Military to Idle

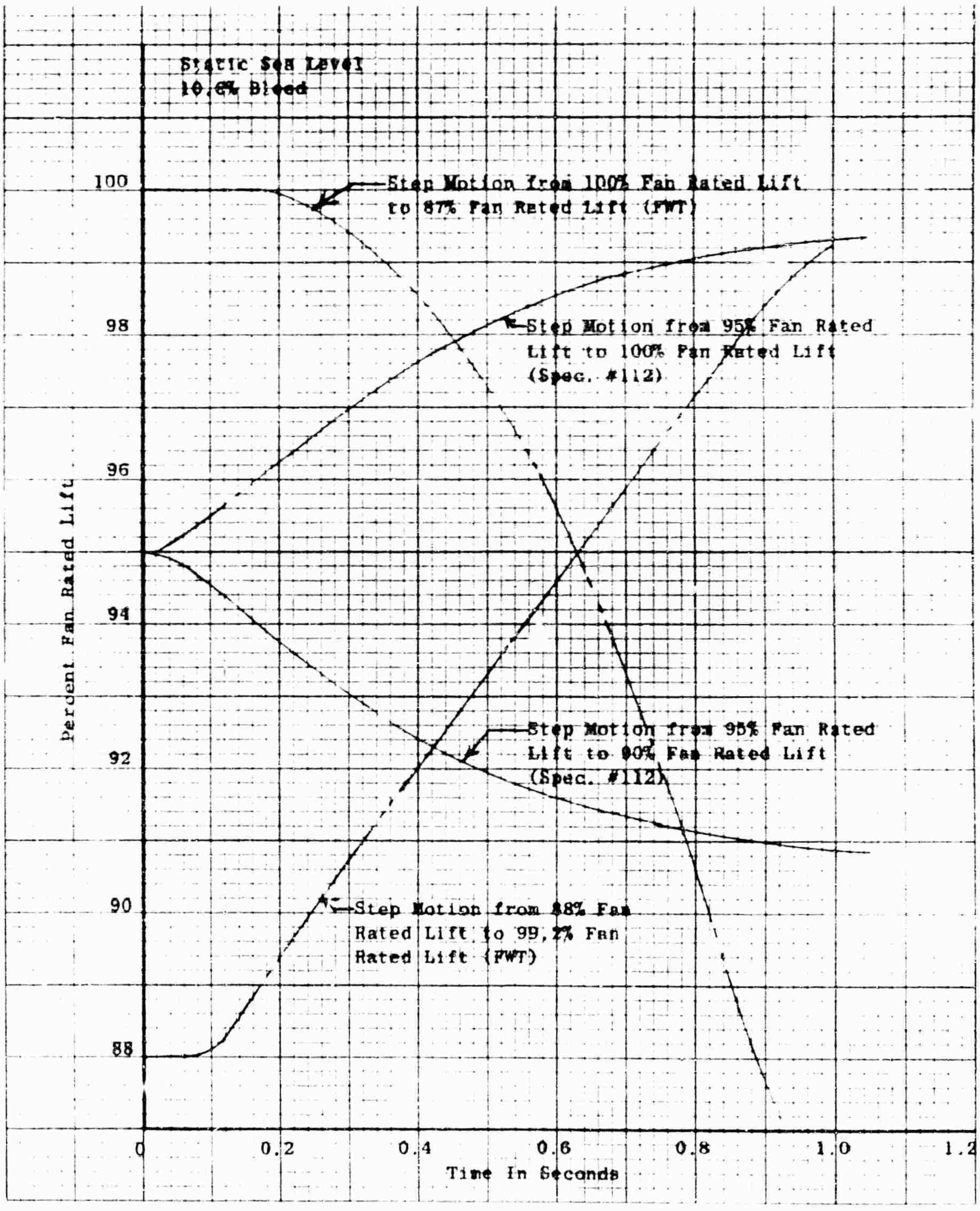


Figure I-60. Comparison of Lift Fan FWT Transient Performance With Specification 112 - Response to Step Motion of Turbojet Throttle

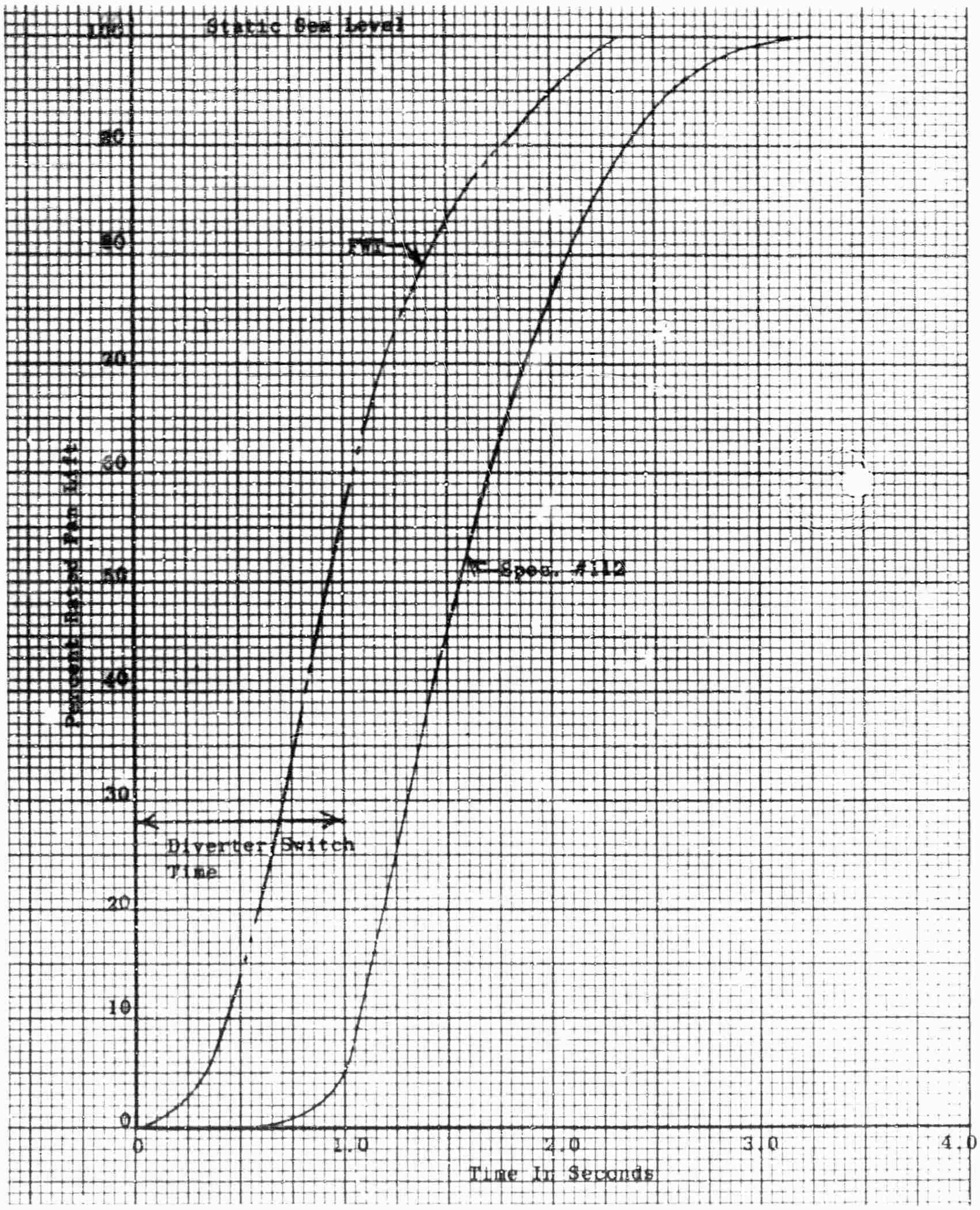


Figure I-61. Comparison of Lift Fan FWT Transient Performance With Specification 112 - Diverter Valve Switched From Cruise to Lift

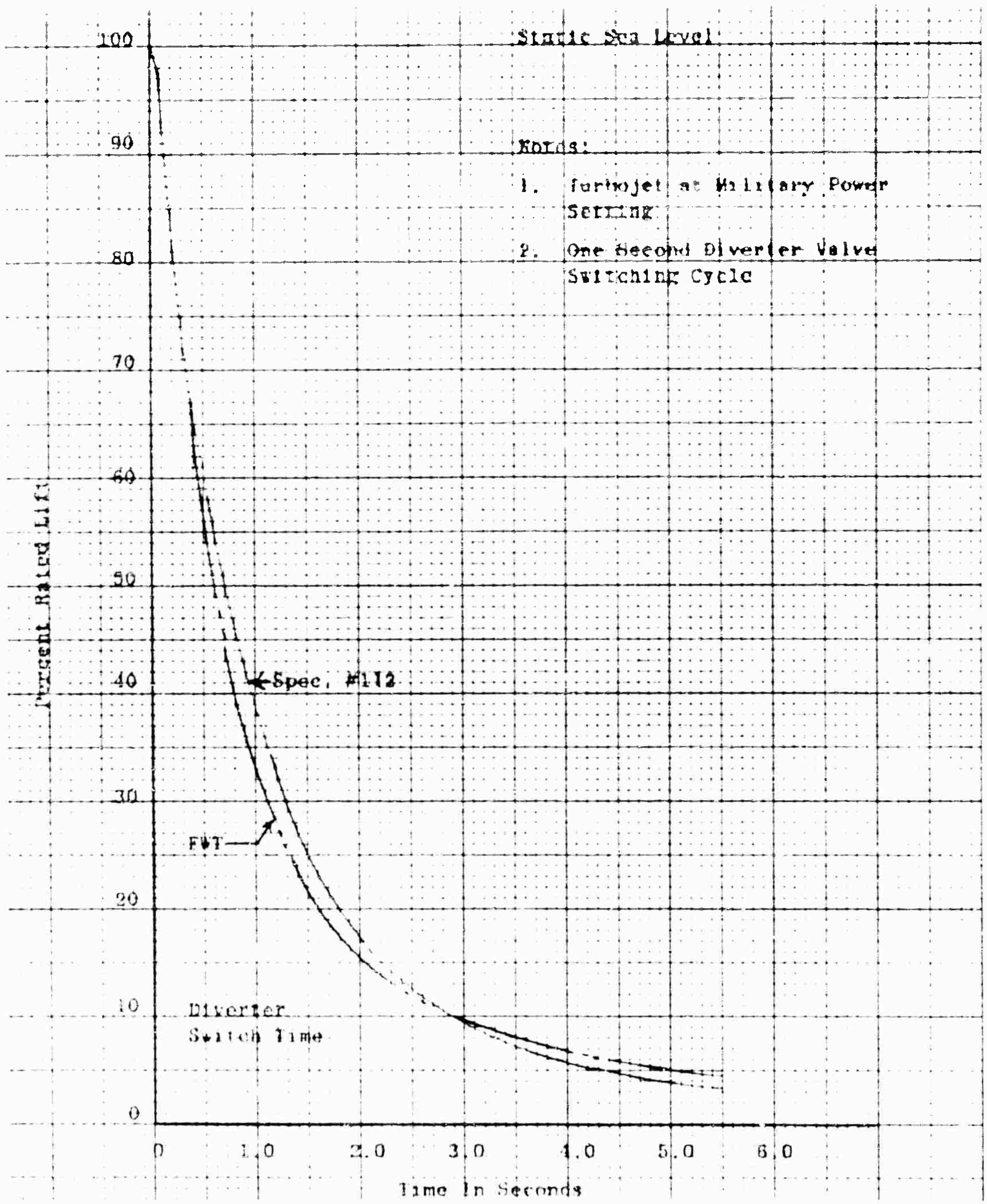


Figure I-62. Comparison of Lift Fan FWT Transient Performance With Specification 112 - Diverter Valve Switched From Lift to Cruise

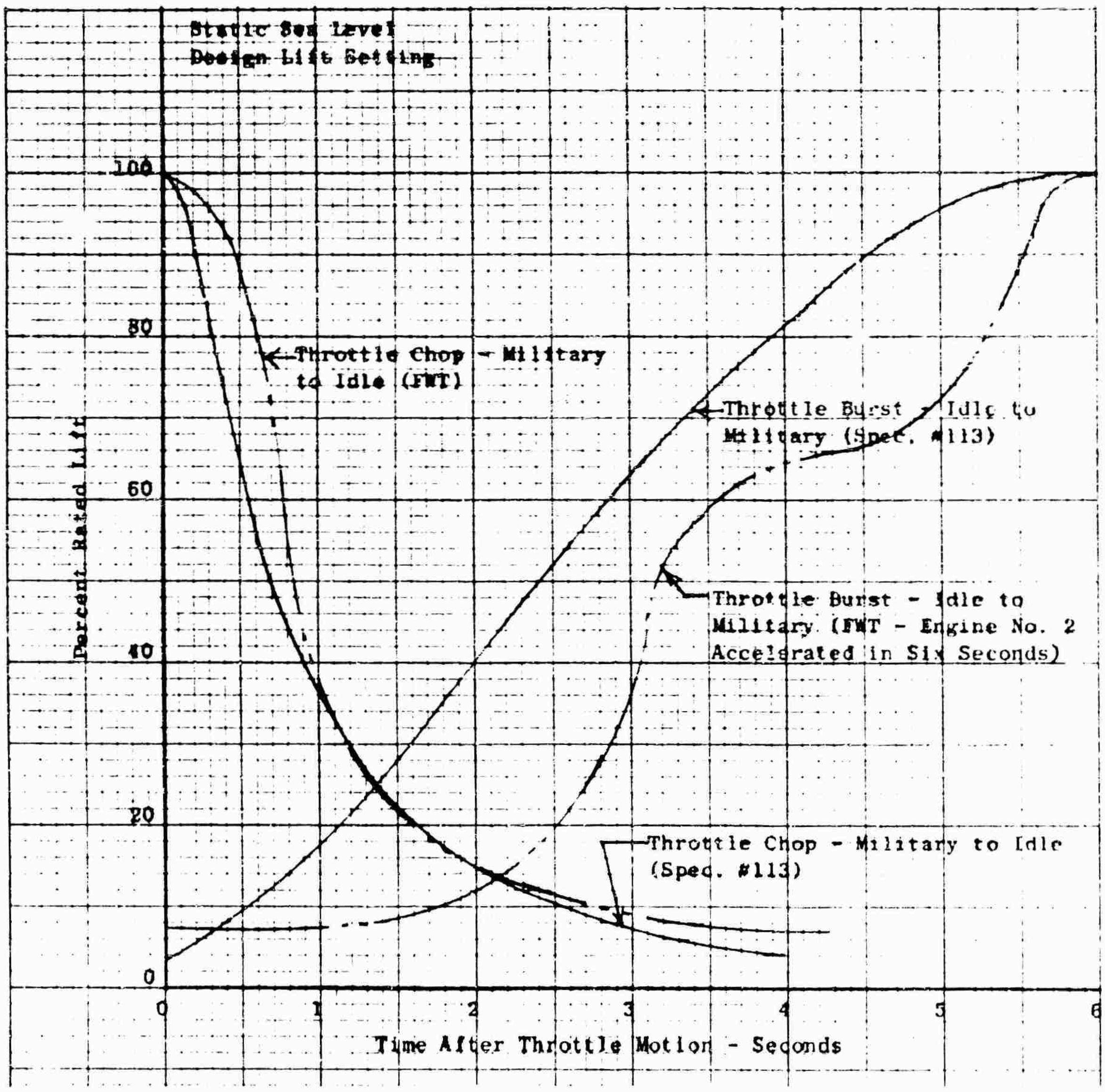


Figure I-63. Comparison of Pitch Fan FWT Transient Performance With Specification 113 - Throttle Burst From Idle to Military And Throttle Chop From Military to Idle

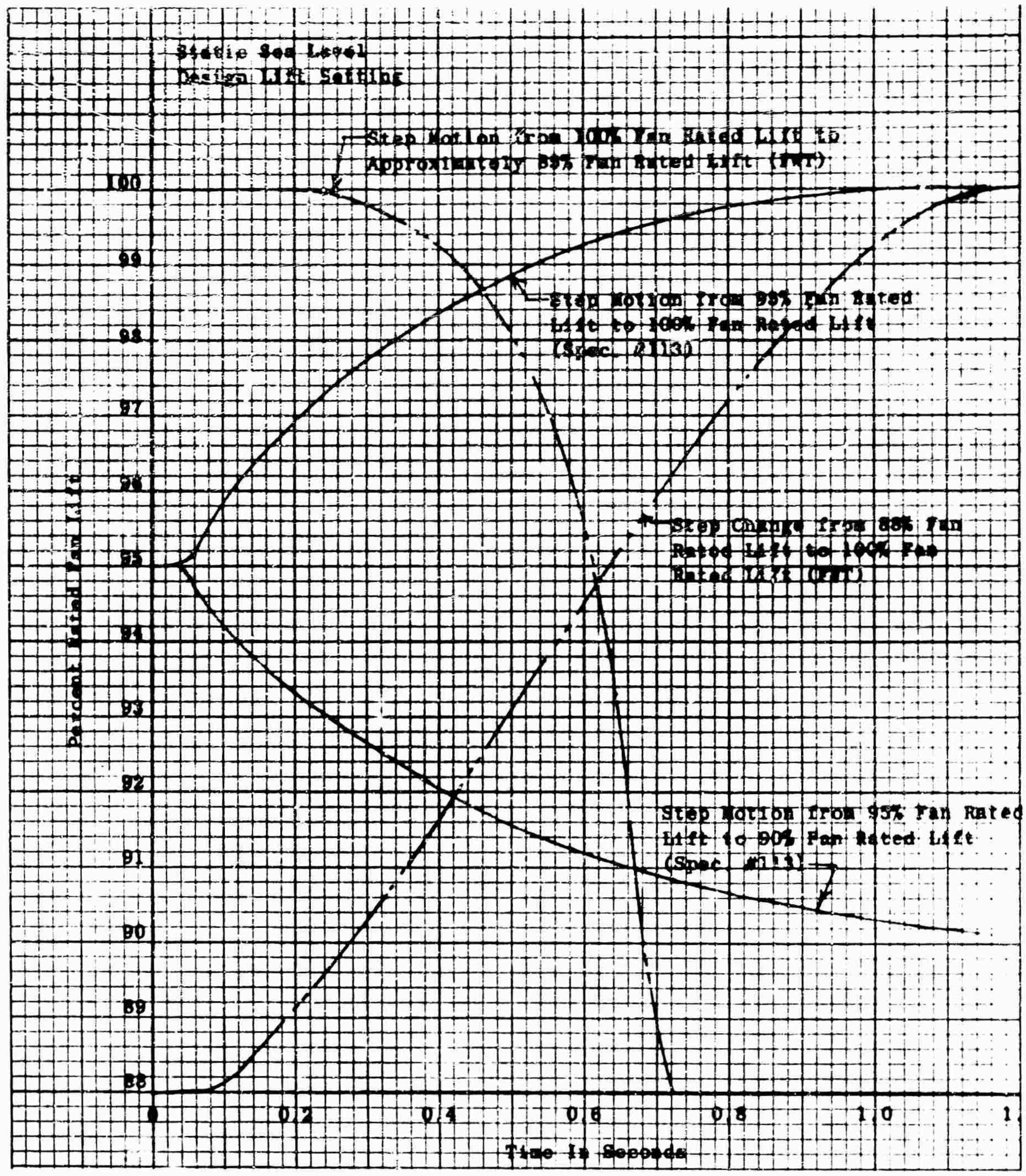


Figure I-64. Comparison of Pitch Fan FWT Transient Performance With Specification 113 - Response to Step Motion of Turbojet Throttle

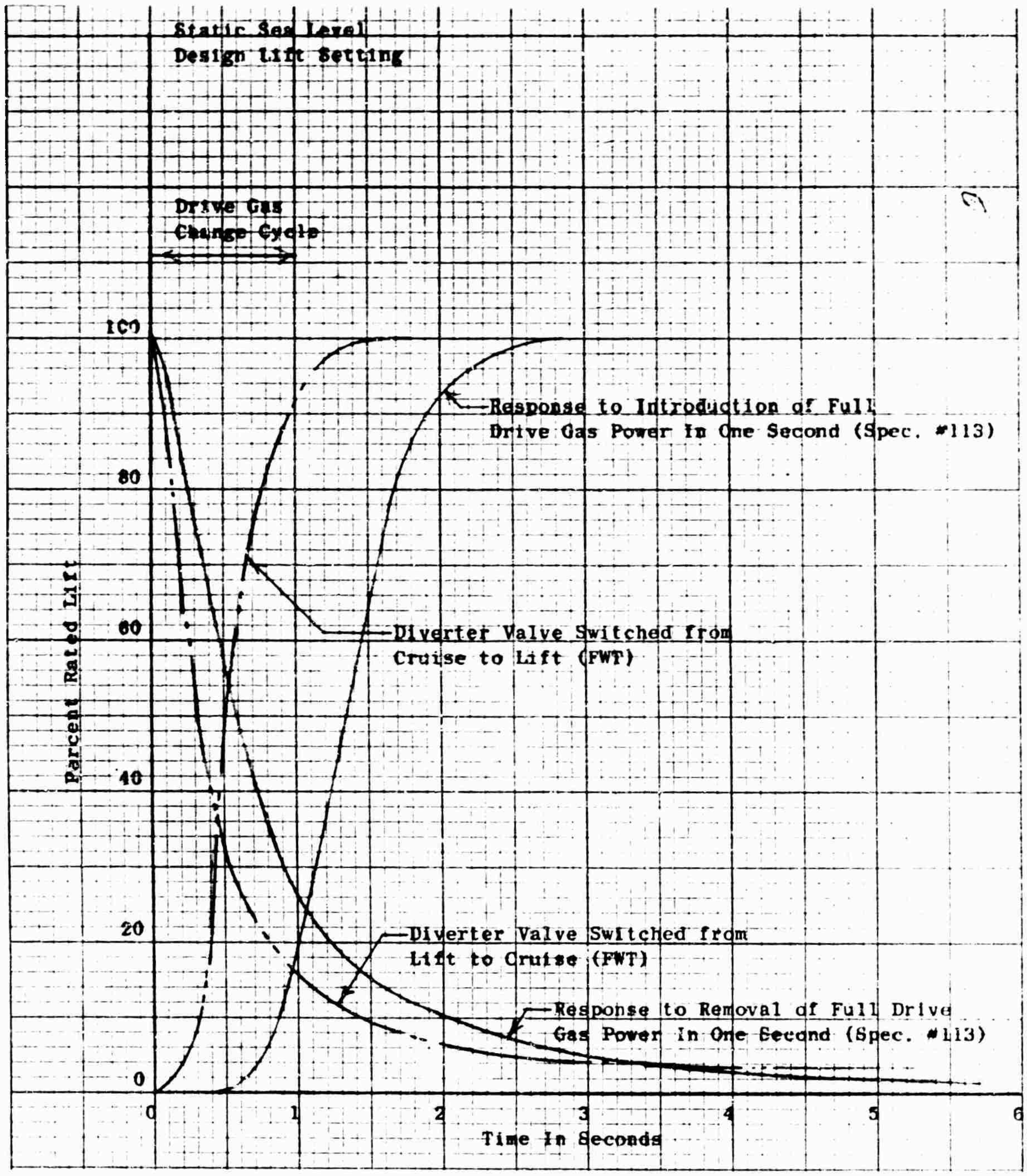


Figure I-65. Comparison of Pitch Fan FWT Transient Performance With Specification 113 - Diverter Valve Switched From Cruise to Lift and From Lift to Cruise

TABLE IX

CRUISE PERFORMANCE COMPARISON WITH SPECIFICATION 112
SEA LEVEL STATIC STANDARD DAY

Ratings	Military	95% RPM	90% RPM	75% RPM	Idle
Spec. Thrust, Pounds (Min.)	2658	2115	1401	591	153
Thrust (Calibration Run)	2770	2265	1460	525	180
Thrust (Recalibration Run)	2730	2185	1455	495	180
Spec. Turbojet Rotor RPM (Max.)	16,500	15,675	14,850	12,375	7425
Turbojet Rotor RPM (Calibration Run)	16,484	15,650	14,512	11,410	7920
Turbojet Rotor RPM (Recalibration Run)	16,500	15,675	14,743	11,253	8044
Spec. Fuel Flow, lb/hr. (Max.)	2679	2082	1451	789	499
Fuel Flow (Calibration Run)	2679	2082	1451	789	535
Fuel Flow (Recalibration Run)	2610	2000	1451	789	530
Spec. Measured Gas Temperature °F (Max.)	1236	-	-	-	-
Gas Temperature (Calibration Run)	1236	-	-	-	-
Gas Temperature (Recalibration Run)	1232	-	-	-	-
Spec. Turbojet Airflow, lb/sec. (±3%)	43.7	40.5	35.9	26.6	-

TABLE X

X353-5B SYSTEM PERFORMANCE COMPARISON WITH SPECIFICATION 112 AND 113 SEA LEVEL STATIC STANDARD DAY

Ratings (Turbojet Power Setting)	Military	Military Single Engine	95% RPM	90% RPM	85% RPM
Spec. Turbojet Rotor RPM (Max.)	16,500	16,500	15,875	14,850	14,025
Calibration	16,352	16,500	15,609	14,421	13,497
Recalibration	16,500	16,500	15,875	14,471	-
Spec. Fuel Flow, lb/hr. (Max.)	2,679	2,879	2,111	1,486	1,156
Calibration	2,675	2,679	2,110	1,420	1,130
Recalibration	2,675	2,679	2,090	1,400	-
Spec. Measured Gas Temperature, °F (Max.)	1,236	1,236	-	-	-
Calibration	1,236	1,236	-	-	-
Recalibration	1,236	1,236	-	-	-
Spec. Lift Fan Rotor RPM (Max.)	2,802	2,020	2,304	1,617	1,521
Calibration	2,574	1,878	2,304	1,817	1,521
Recalibration	2,574	1,880	2,289	1,817	-
Spec. Lift Fan Thrust, lbs. (Min.)	6,570	3,915	5,172	5 237	2,273
Calibration	6,970	3,876	5,710	3,550	2,490
Recalibration	6,940	3,808	5,570	3,470	-
Spec. Pitch Fan Rotor RPM (Max.)	3,903	2,891	3,460	2,717	2,274
Calibration	4,123	3,146	3,736	2,941	2,440
Recalibration	4,143	3,120	3,707	2,913	-
Spec. Pitch Fan Thrust, lbs. (Min.)	1,608	892	1,275	799	563
Calibration	1,610	920	1,310	790	530
Recalibration	1,870	1,039	1,510	940	-
		Vectored Louver Performance			
Spec. Horizontal Thrust ($\beta_v = 20^o$)	2,189	-	1,720	1,081	-
Calibration	2,230	-	1,830	1,190	-
Spec. Lift Thrust ($\beta_v = 20^o$)	6,013	-	4,726	2,970	-
Calibration	6,570	-	5,310	3,180	-
Spec. Horizontal Thrust ($\beta_v = 40^o$)	3,681	-	2,682	1,843	-
Calibration	4,000	-	3,360	2,030	-
Spec. Lift Thrust ($\beta_v = 40^o$)	4,387	-	3,434	2,197	-
Calibration	4,720	-	3,830	2,240	-

TABLE XI

X353-5B SYSTEM PERFORMANCE COMPARISON WITH SPECIFICATION 112 AND 113
2500 FT. ALTITUDE ANA 421 STANDARD HOT DAY

Ratings (Turbojet Power Setting)	Military	Military Single Engine*	95% RPM	90% RPM	85% RPM
Spec. Turbojet Rotor RPM (Max.)	18,500	16,500	15,675	14,850	14,025
Calibration	18,378	16,500	15,407	14,384	-
Recalibration	18,481	16,500	15,528	14,248	-
Spec. Fuel Flow, lb/hr. (Max.)	2,239	2,239	1,622	1,216	1,017
Calibration	2,185	2,239	1,567	1,178	-
Recalibration	2,204	2,239	1,577	1,159	-
Spec. Measured Gas Temperature, °F (Max.)	1,250	1,250	-	-	-
Calibration	1,250	1,250	-	-	-
Recalibration	1,250	1,250	-	-	-
Spec. Lift Fan Rotor RPM (Max.)	2,510	1,944	2,077	1,896	1,451
Calibration	2,481	1,813	2,077	1,696	-
Recalibration	2,490	1,814	2,077	1,896	-
Spec. Lift Fan Thrust, lbs. (Min.)	5,282	3,130	3,639	2,435	1,783
Calibration	5,702	3,112	4,009	2,667	-
Recalibration	5,828	3,057	3,954	2,575	-
Spec. Pitch Fan Rotor RPM (Max.)	3,771	2,783	3,103	2,523	2,164
Calibration	4,006	3,038	3,379	2,735	-
Recalibration	4,010	3,011	3,375	2,672	-
Spec. Pitch Fan Thrust, lbs. (Min.)	1,300	715	894	596	441
Calibration	1,306	739	901	584	-
Recalibration	1,508	834	1,094	871	-
Spec. Horizontal Thrust ($\beta_v = 20^{\circ}$)	1,758	-	1,209	815	-
Calibration	1,830	-	1,297	-	-
Spec. Lift Thrust ($\beta_v = 20^{\circ}$)	4,829	-	3,324	2,438	-
Calibration	5,334	-	3,642	-	-
Spec. Horizontal Thrust ($\beta_v = 40^{\circ}$)	2,946	-	2,046	1,397	-
Calibration	3,311	-	2,317	-	-
Spec. Lift Thrust ($\beta_v = 40^{\circ}$)	3,511	-	2,438	815	-
Calibration	3,853	-	2,593	-	-

*Military, single engine fan performance was scaled from the standard day values using the ideal fan laws and horsepower characteristics based on Specification 112 engine characteristics.

G. POST-TEST HARDWARE INSPECTIONS

1. INSPECTIONS PERFORMED

Tables XII, XIII and XIV present summaries of the various inspections performed on the hardware after complete assembly.

TABLE XII

DIVERTER VALVE PARTS INSPECTION

Part	Clean	Visual	Zyglo	Photo	Discrepancy
Valve Body	X	X			Yes
Aft Door	X	X			Yes
Forward Door	X	X			Yes
Linkage	X	X	X		No
Actuator	X	X			Yes*
Insulation	X	X			No
Expendables	X	X			No

* This actuator was not the flight type part.

TABLE XIII

LIFT FAN PARTS INSPECTION

Parts	Clean	Visual	Zyglo	Photo	Discrepancy
FRONT FRAME	X	X	X	X	Yes
Scroll Seals	X	X		X	Yes
Roller Bearing	X	X			No
Thrust Bearing	X	X			No
Grease Seals	X	X			No
Bearing Housing	X	X			No
Honeycomb Seals	X	X			No
Seals Supports	X	X			No
Insulation Blanket	X	X		X	Yes
Speed Pickup	X	X			No
SCROLL	X	X		X	Yes
Seals	X	X		X	Yes
Clevis	X	X			No
Pins	X	X			No
REAR FRAME	X	X	X	X	Yes
Honeycomb Seals	X	X		X	Yes
Insulation Blanket	X	X		X	Yes
Pushrods	X	X	X		No
Lever Arms	X	X	X		No
Louver Supports	X	X	X		No
Turbine Louvers	X	X	X		No
ROTOR	X	X		X	Yes
Disc & Shaft	X	X	X		No
Retainer Blade	X	X	X		No
Platforms	X	X	X	X	Yes
Blades	X	X	X*		No
Bucket - Carriers	X	X	X	X	Yes
Seals	X	X	X	X	Yes
Torque Bands	X	X	X	X	Yes
Pin Retainer	X	X	X	X	Yes
Covers	X	X		X	Yes
Expendables	X	X		X	No

*Magnaflux

Aluminum exit louvers and circular vane not included.

TABLE XIV

PITCH FAN PARTS INSPECTION

Part	Clean	Visual	Zyglo	Photo	Discrepancy
FRONT FRAME	X	X	X		No
Cover	X	X		X	Yes
Mounts	X	X	X		No
Roller Bearing	X	X		X	Yes
Thrust Bearing	X	X			No
Seals	X	X			Yes
Shaft	X	X			No
Mounts (Scroll)	X	X	X		No
Honeycomb Seals	X	X		X	No
Seals (Scroll)	X	X			No
Speed Pickup	X	X			No
SCROLLS	X	X			No
Insulation	X	X			No
Clevis	X	X	X		No
Pins	X	X	X		No
End Seals	X	X			No
REAR FRAME	X	X	X	X	Yes
Insulation	X	X			No
ROTOR	X	X		X	Yes
Disc	X	X	X		No
Blades	X	X	X		No
Bucket - Carrier	X	X	X	X	Yes
Torque Band	X	X	X		No
Retainer (Blade)	X	X	X		No
EXPENDABLES	X	X			No

2. NON-RE-USABLE PARTS

After inspection was completed several items of hardware were damaged or used beyond repair as listed in Tables XV, XVI and XVII.

TABLE XV

DIVERTER VALVE NON-RE-USABLE PARTS

Part No.	Name	Quantity	Expendable	Non-Expandable
4012153-386P1	Spring	1	X	
R108P20	Bolts	4	X	

TABLE XVI

LIFT FAN NON-RE-USABLE PARTS
ASSEMBLY DRAWING 4012001-941G1

Assembly-Item No.	Part No.	Name	Qty.	Ex-pend-able	Non-expend-able
4012001-941G1-47	4012001-368P1	Tab Washer	1	X	
4012001-190G1-6	4012001-159	Platform	3		X
4012001-190G1-7	4012001-168P1	Bolts	36	X	
4012001-190G1-8	4012001-145G2	Carrier	2		X
4012001-190G1-9	4012001-155G1	Seal	1		X
4012001-190G1-10	4012001-154G1	Torque Band	2		X
4012001-190G1-11	4012001-170P1	Bolt	108	X	
4012001-190G1-12	4012001-169P1	Tab	10	X	
4012001-190G1-13	4012001-167P1	Pin	36	X	
4012001-190G1-14	4012001-171P1	Pin	36	X	
4012001-190G1-15	4012001-166P1	Locking Strip	36	X	
4012001-190G1-16	4012001-156G2	Cover	2		X

All expendables other than those noted above; allow 10% normal replacement for a teardown and reassembly.

TABLE XVII

PITCH FAN NON-RE-USABLE PARTS
ASSEMBLY DRAWING 4012001-940G1

Item No.	Part. No.	Name	Qty.	Expendable	Non-expendable
22	4012001-335P1	Seal	1		X

All expendable hardware: Allow 10% normal replacement for a teardown and rebuild.

3. HARDWARE CONDITION AFTER TEST

Each item of hardware found to have any fault is described in Volume II including any damage not severe enough to prevent re-use. In addition metallographic examinations were performed on lift fan rotor parts as follows:

A. Three (3) failed carrier bolts (Part No. 4012001-170P1)
   1. Macro - 10X visual inspection (Figures I-67A through C).
   2. Macro - 7-30X visual inspection.
   3. Micro - 250X unetched section (Figure I-68).

B. Same as A-3 for three (3) unfailed carrier bolts (Figure I-69A and B).

C. Same as A-3 for three (3) unfailed platform bolts (Part No. 4012001-168P1).

D. Same as A-3 for three (3) AN-NAS-1003-1A bolts (Part No. 4012001-206); (Figure I-70)

E. 500X Unetched, tapered section (to reveal several planes), end view of torque band failure (test break No. 3); (Figures I-71A through F).

F. 500X Etched views of parts of the failure section in E. (Figures I-72A and B).

The 7-30X magnification examination of the bolts in the as fractured condition was used to determine the best area for microscopic examination, that is, where a cross-section might provide a maximum of information. The macroscopic examination also determined the basic pattern of failure which was typical of fatigue for a short distance and then a fracture pattern typical of a tensile failure. The fracture patterns do not indicate brittle behavior.

The microscopic examination of the bolts was performed on a plane taken through the longitudinal center axis of the threaded stem. The plane was located to pass through the fatigue failure side of the bolt. This examination shows the primary cause of failure to be excessive intergrannular attack (IGA) at the head to threaded stem radius. The IGA was measured at 0.001" to 0.0015" deep. The IGA promoted premature fatigue failure. The fatigue crack propagated to a point where the reduced area could no longer support the load and the rest of the fracture is typical of tensile failures.

The surface condition appearance in the radius under 250X magnification is normal and is not considered a notched condition. Note the secondary crack in Figure I-68.

Examination of unfailed carrier bolts and platform bolts all showed the same condition of IGA and surface oxidation. Examination of the AN bolts NAS-1003-1A indicated freedom from IGA as shown in Figure I-70.

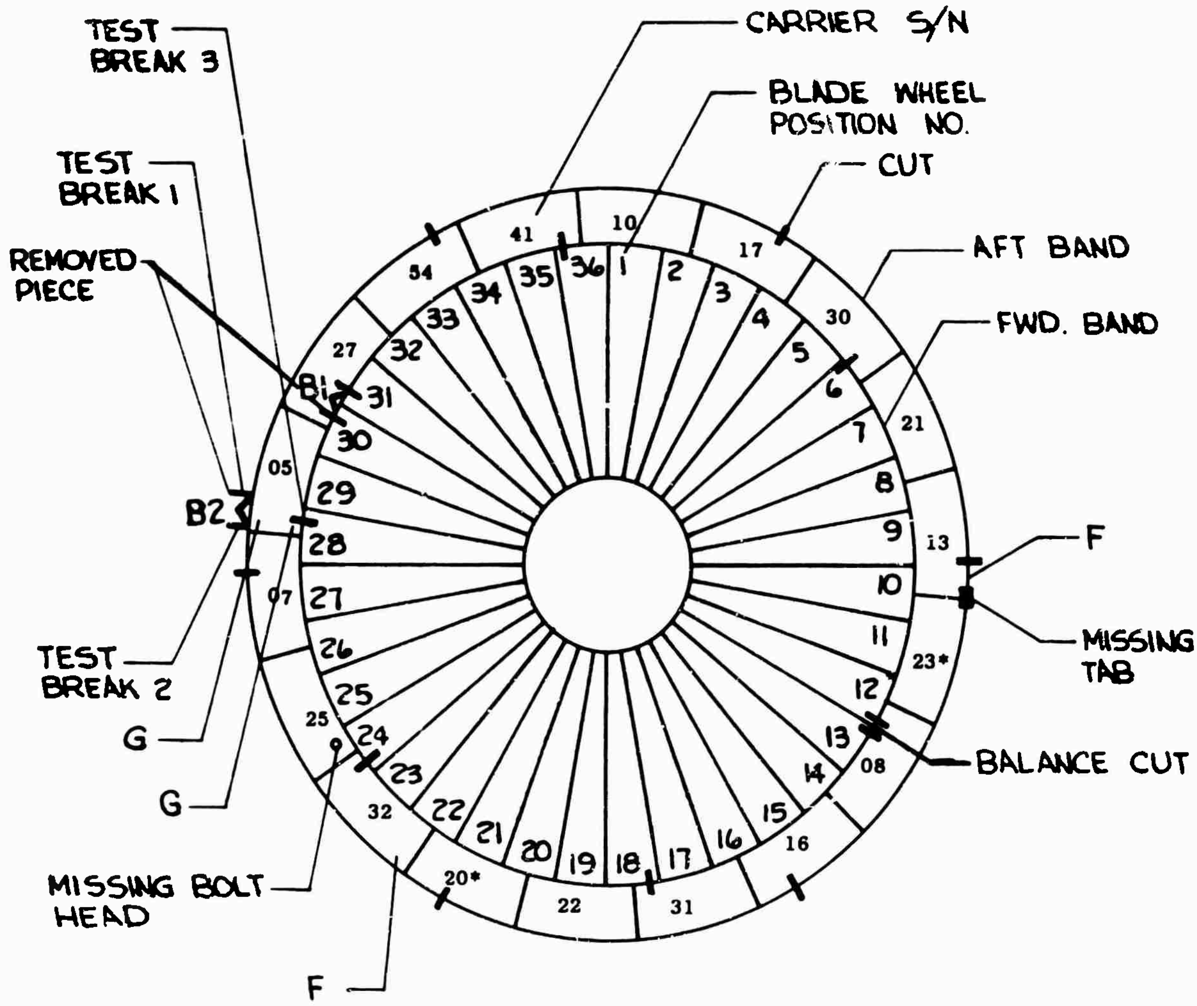
Microscopic examination of the forward torque band failure (test break No. 3, Figure I-66) revealed the presence of non-metallic inclusions at the crack interface. Further examination has shown these inclusions to be at the surface or slightly sub-surface (.001 to .002 inches).

Figures I-71 and I-72 are micro photographs at the crack interface and show sections along the band width. The high magnification (500X) results in approximately 1/4 of the band thickness being shown in the photograph. The small spherical particals dispersed through the cross section are carbides normal to the R41 alloy.

Figure I-72B shows the material cross-section after etchant has been added to bring out the grain boundaries. This figure is typical after a metal has been subjected to cold work (fretting). Note the deformation at the surface and the slip lines in the grains; measurement shows that this condition exists only within .001 and .002 inches of the surface of the material. The crack interface is trans-granular and typical of fatigue rather than tensile failure.

Non-metallic inclusions are known to be stress risers and contribute to a reduction in fatigue strength. Similarly fretting is known to play a strong role in the reduction of a material fatigue strength. Since some areas were observed to have more or as much fretting damage as the failure area and did not crack it is reasoned that the fretting combined with the non-metallic inclusions caused the failure in the band.

If the fretting exposes a non-metallic inclusion to the surface the combined effect is much more severe than the inclusion or fretting alone.



* CLASS IV (NON-REPAIRABLE)

B BUCKLE
F MAJOR FRETTING
G GALLING

Figure I-66. Lift Fan Rotor Configuration and Test Incident Schematic

Figure I-67 A. 10X Macroscopic Examination of Failed Bolt (Carrier S/N 25)

Figure I-67 B. 10X Macroscopic Examination of Failed Bolt (Carrier S/N 23)

Figure I-67 C. 10X Macroscopic Examination of Failed Bolt (Carrier S/N 13)

Figure I-68 250X Microscopic Examination of One Failed Bolt at the Head to Stem Radius. (Sectioned)

Figure I-69 A. 250X Microscopic Examination of One of the Unfailed Bolts at the Head to Stem Radius. (Sectioned)
B. Same - at other Side of Bolt

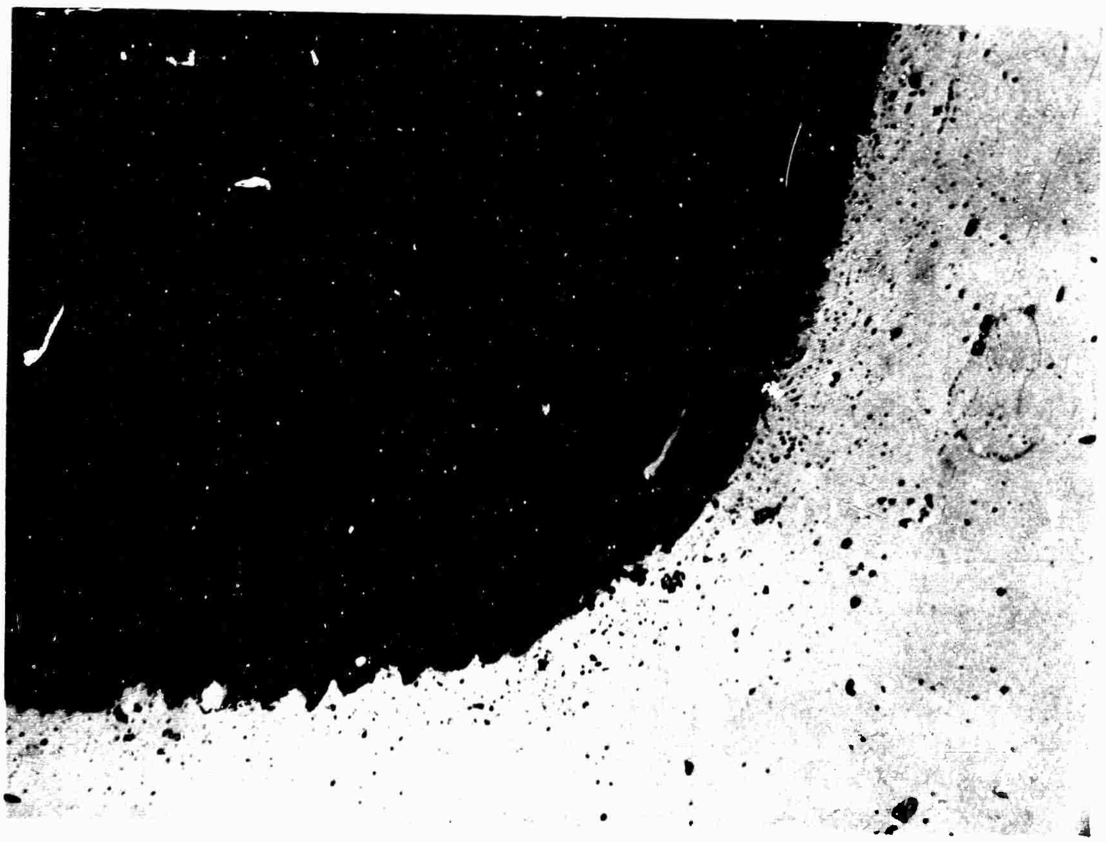


Figure I-70 250X Microscopic Examination of New AN Bolt at Head to Stem Radius

Figure I-71 A, B, C, D, E, and F. 500X Microscopic Examination of Torque Band Failure (Test Break No. 3) - Progressive Views Across the Failure

Figure I-71B

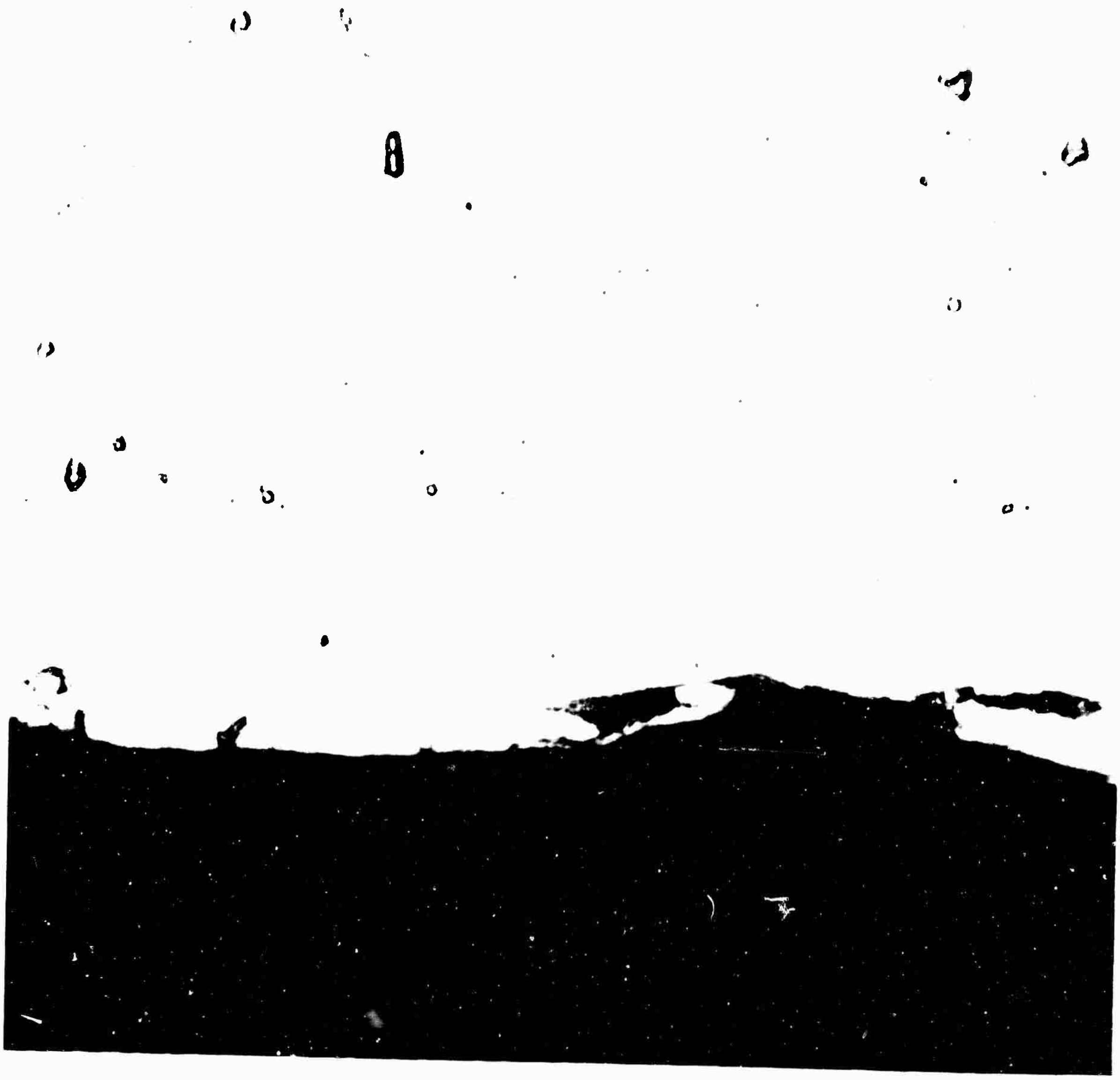


Figure I-71C

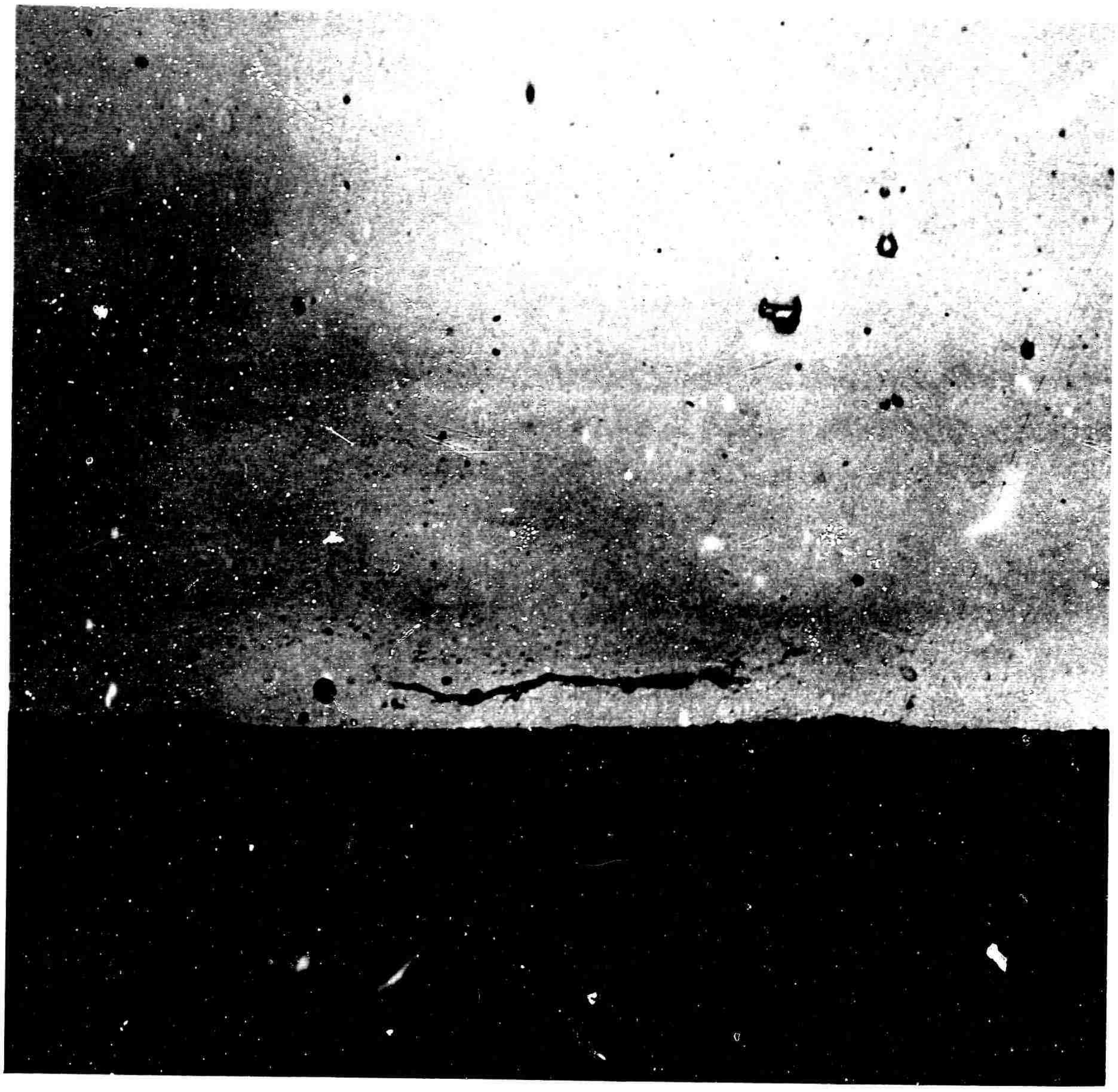


Figure I-71D

Figure I-71E

Figure I-71F

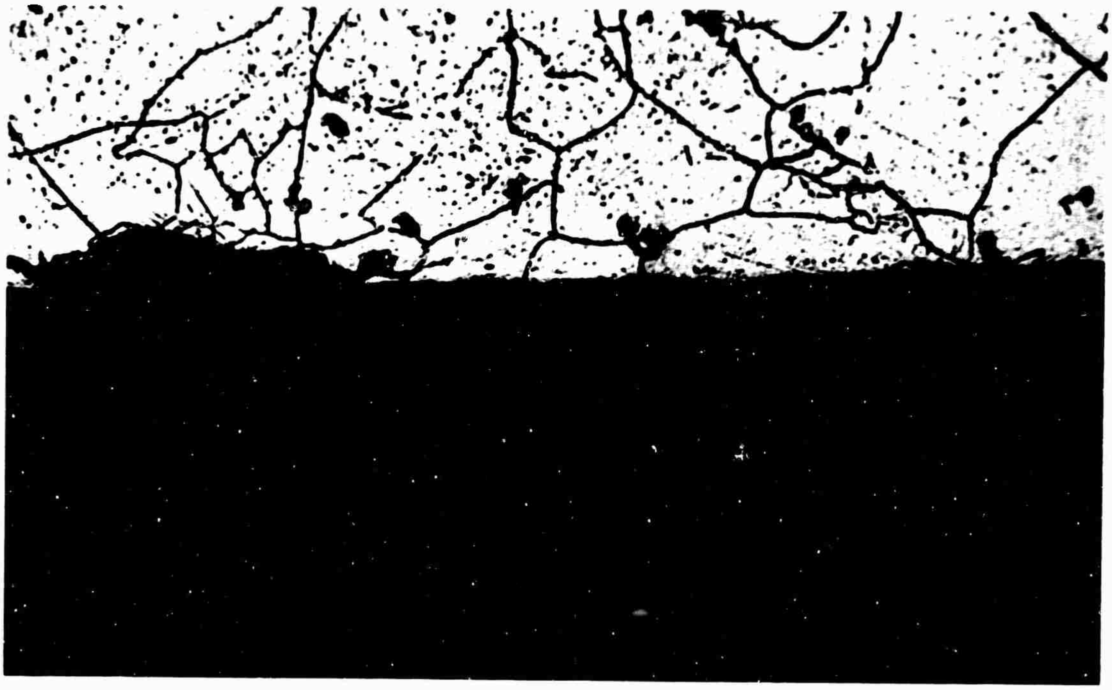


Figure I-72 A. Etched 500X Microscopic Examination of Grain Structure of Figure I-71A
B. Etched 500A Microscopic Examination of Grain Structure of Figure I-71D

H. ANALYSIS OF RESULTS

1. FAILURE ANALYSES

Diverter Valve: Failure of segments of the heat shield resulted from improper manufacturing assembly. Sufficient clearance for thermal growth was not provided according to design requirements where the shield is retained at the center of the door.

Lift Fan:

A. Torque Band - Buckles in the original design single piece bands occurred because of high compressive stresses generated by torque transmission loading and thermal strain combined with axial bending in the band at the rotor cosine 2θ resonance condition.

Test breaks No. 1 and No. 2 (refer to Figure I-66) were fatigue failures in the aft band at the buckle probably associated with thermal cycling of the part. In addition to incurring a thermal strain because of insufficient growth from the centrifugal field to compensate for the temperature change in the band, there is a delay after shutting down the fan during which time the band is at very high temperature.

Test break No. 3 (forward band) was a fatigue failure caused by non-metallic inclusions in the material and fretting damage to the band outside diameter. Micro-examination of the band up to 10 inches away from the failure has not shown inclusions as severe as that in the failure area (described in Section G) but inclusions at the surface or slightly sub-surface do exist in each of three sections studied. Fretting was not isolated to the failure area. Fretting which was felt to be as severe as that in the failure location did exist at several locations. Rather, the fretting pattern (except in locations where bolt heads failed) tended to be oriented with the torque band cuts and bolt torque levels in the proximity of the cuts.

The basic torque band design was to provide torque transmission from the center of a carrier to the center of the adjacent carrier by means of two bands (.045" x .400"). In addition, the ends of adjacent carriers are tied together by means of the torque band ear, carrier cover, and carrier tab to form an emergency transmission system in the event that a torque band failure did occur. Bolt torque requirements at the tab spanning adjacent carriers were established at different levels to allow for bolt thermal relaxation, insuring that the tab would be held to the carrier, but still not interferring with the carrier thermal expansion.

The advent of thermal buckles in the band enabled demonstrating the capability of the system to transmit torque at any joint with only one effective band. (As soon as a band buckles it loses its capacity to transmit the torque.) The decision to change the design to avoid buckles by cutting the band at several locations was based on successful operation of the fan for several hours with a buckle in the forward band. The cuts are spaced so that the opposite band is continuous across the joint. It is not known what the effectiveness of the emergency transmission system is in the cut band design but, even if totally ineffective for steady state operation, the entire torque would be transmitted through the continuous band opposite the cut. The detailed inspection following the FWT indicated several noteworthy items:

1. Fretting areas tended to be coincident with the torque band cuts.

2. Several areas containing cuts showed little fretting damage.

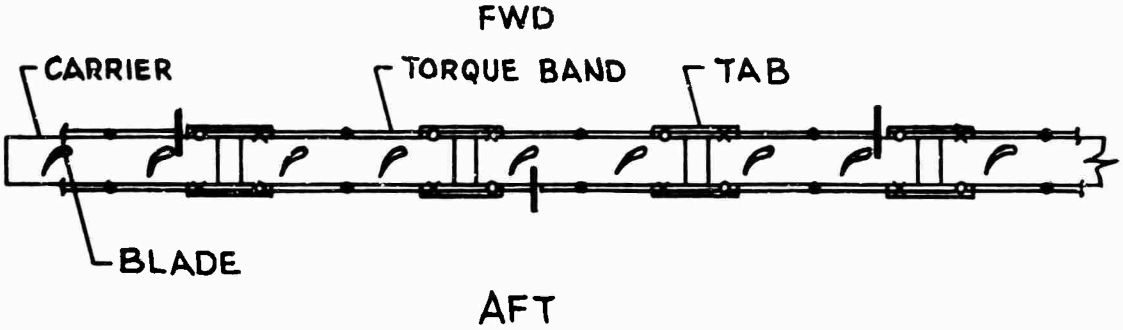
3. Carrier tabs were held in place on the high torque side of the joint of adjacent carriers and were sliding relative to the adjacent carrier.

4. Areas showing fretting at the cuts showed the low bolt torque side of the joint to be on the carrier where the torque band was cut. (For the FWT assembly no effort was made to set a torquing pattern except that at each joint the two bolts were torqued at the prescribed different values.)

5. Areas showing little or no fretting in the proximity of the cuts had the high bolt torque on the carrier where the band was cut.

Review of these findings indicates that if the high bolt torque level were deliberately placed on the carrier containing the cut, the torque would be transmitted from the center of one carrier to the end of the adjacent carrier through the friction in the joint, thereby eliminating the need for a torque band locally in this region. This would result in effective torque transmission without carrying the entire load through the emergency system and/or through the band on the side opposite the cut.

The schematic in Figure I-73 indicates the segmented band arrangement and the ideal torquing procedure to reduce fretting. Avoiding the combination of high loads in the opposite band from a cut joint and reducing fretting improves the fatigue life of the part.



Where:

- ● Indicates torque transmitting connection on carriers.
- O Oversize carrier holes; bolts torqued to 35 pound inches.
- X Oversize carrier holes; bolts torqued to 25 pound inches.
- | Cut to segment band.

FIGURE I-73 Lift Fan Optimum Carrier Bolt Torquing Procedure

When the aft band buckle finally cracked (test breaks No. 1 and No. 2) the presence of an intentional nearby cut (see Figure I-66) eliminated all possible means of transmitting the torque across the joint except through the forward band and the emergency torque system. This resulted in the forward band carrying more load, more strain and hence having more deflection. Any increase in amplitude in a metal to metal joint under high normal loads will result in increasing the potential of fretting damage in the joint.

The post-test inspection has shown that fretting will and can occur in the cut band configuration; it has also shown that this would not necessarily cause band failure. The effectiveness of proper bolt torque is apparent and the problem of "dirt" in the material was a contributor (as a stress riser) to the band failure when the band was subjected to the unusual loading at this particular joint.

B. Carrier Bolts - See Section G for metallographic examination results indicating primary cause of failure to be defective bolts.

C. Inlet Vanes and Exit Louvers - Tables XVIII and XIX list the maintenance incidents incurred with these parts during the FWT. The extent of repair required is not acceptable and these parts are not considered to have sufficient integrity. The nature of the failures has in most cases been directly traceable to improper manufacturing process control related to welding. The common types of faults identified during failure analyses were: 1) Filler and bulkhead welds dressed to insufficient section; 2) Undersized spot weld nuggets; 3) Cracked spot welds requiring plug repair; 4) Spot welds with no penetration; 5) Extensive oxidation preventing weld integrity. A judgment on design adequacy would be conclusive only if based on test experience using hardware initially without deficiencies.

The testing experience analyzed from Tables XVIII and XIX indicates the following general observations:

<u>Inlet Vanes</u>

1. All four quadrants required repair.

2. One quadrant required replacement.

3. The frequency of repair incidents was one every 3.42 hours.

TABLE XVIII

INLET VANE FWT MAINTENANCE DATA

Quadrant	Incident	Total Hours	FWT Hours	Cycles Completed between Repairs Part I	Cycles Completed between Repairs Part II	Remarks
SW	1	36	7			Replaced
	2	5	5	1		
	3	9	9		1	
	4	33	33	4	4	
NW	5	36	7			
	6	45	16	1	1	
	7	49	20	1		
	8	54	25	1	1	
	9	64	35	1	2	
SE	10	36	7			
	11	45	16	1	1	
	12	69	40	4	4	
NE	13	45	16	1	1	
	14	49	20	1		
	15	52	23	1		
	16	54	25		1	
	17	58	29		1	
	18	64	35	1	1	
	19	69	40	1	1	
TOTAL				19	19	

TABLE XIX

EXIT LOUVER FWT MAINTENANCE DATA

Louver Number	Incident	Total Hours	FWT Hours	Cycles Completed between Repairs Part I	Cycles Completed between Repairs Part II	Remarks
17	1	37	8			
	2	41	12	1		
	3	58	29	2	3	
	4	69	40	2	1	
18	5	41	12	1		
	6	45	16		1	
	7	54	25	2	1	
	8	64	35	1	1	
	9	69	40	1	1	
20	10	64	35	4	4	
21	11	64	35	4	4	Replaced
22	12	54	25	3	2	
	13	58	29		1	Replaced
	14	11	11	2	2	
23	15	58	29	3	3	
	16	61	32	1		Replaced
24	17	61	32	4	3	Replaced
25	18	52	23	3	1	
26	19	52	23	3	1	
28	20	69	40	5	3	
32	21	58	29	3	3	
38	22	58	29	3	3	
	23	69	40	2	2	
TOTAL				50	40	
Non-Operating Faults						
13		41	12			Handling Damage
23		37	8			Removed in Error

4. The average time between repairs for a given quadrant was 8.16 hours.

5. 47% of the repairs were temporary fixes not requiring part disassembly.

6. Two of the four vanes repaired performed satisfactorily for eight final endurance cycles.

7. There was no performance deficiency attributable to the vane faults or maintenance.

8. There was no fan or system damage attributable to the vane faults or maintenance.

Exit Louvers (Refer to Figure I-74)

1. All Inconel X louvers completed the FWT without test fault.

2. Ten of 22 aluminum louvers completed the FWT without test fault.

3. Over 80% of the repairs were required to louvers on the inactive arc half of the fan.

4. Four louvers required replacements.

5. The frequency of repair incidents was one every 4.17 hours.

6. The average time between repairs for a given louver was 17.57 hours.

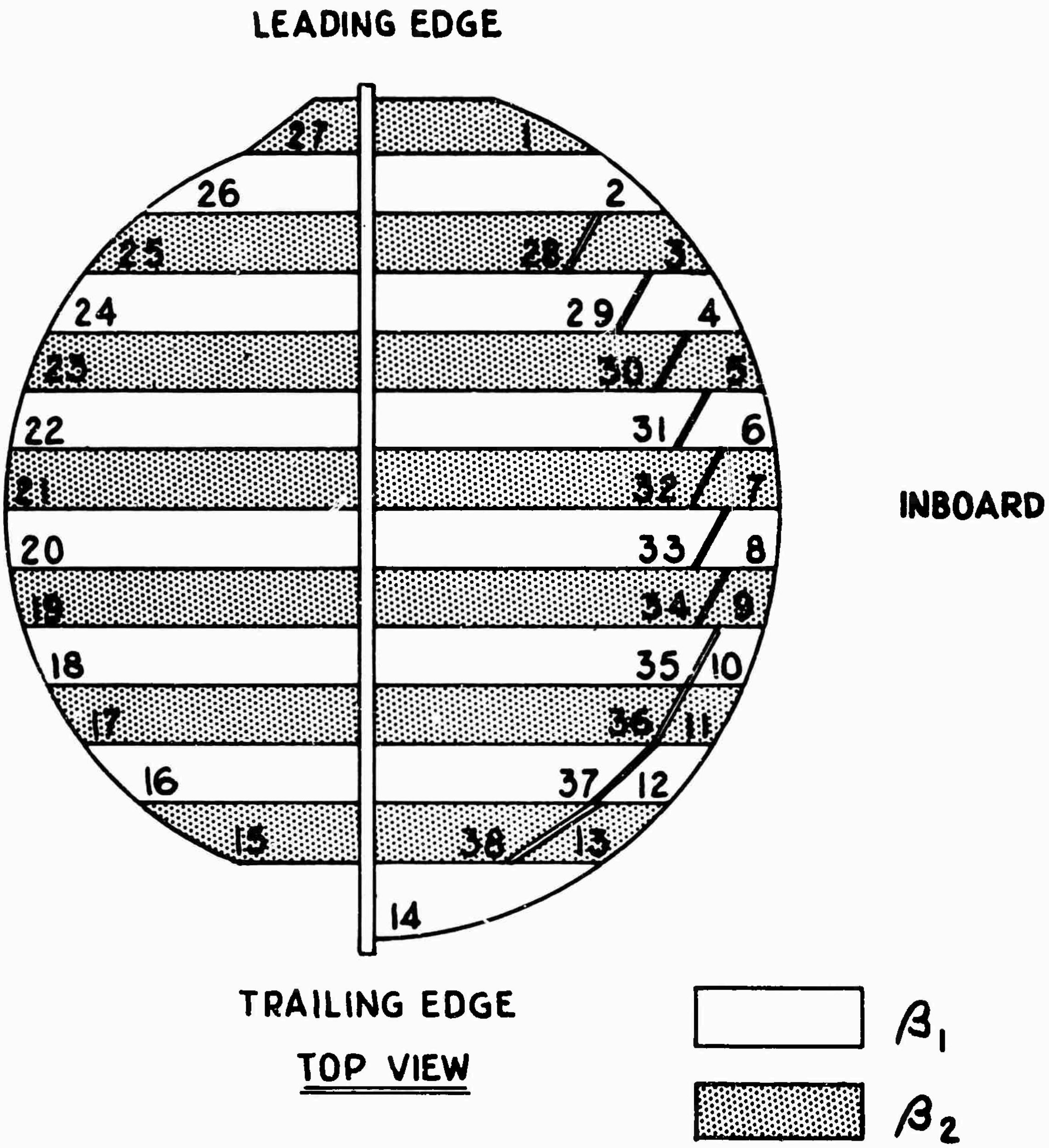


Figure I-74. Lift Fan Exit Louver Arrangement (Left Fan)

7. Accumulative operation before repair; (12 repaired louver population):

Number of Louvers	Consecutive Endurance Cycles
2	8
2	7
3	6
1	5
2	4
1	1

8. Repair integrity:

Repairs	Consecutive Endurance Cycles
1	5
1	4
2	3
2	2
4	1

9. Two of the 12 repaired louver population accounted for 39% of the repairs. Three others also required repair more than once.

10. Number 38 louver fault was the result of over-temperature by penetration of the turbine discharge gas into the fan stream.

There was no apparent type of operation that affected the incidence of inlet vane maintenance. The exit louver maintenance was also unrelated to the type of endurance cycle accomplished, however, each type cycle contains the same time requirement at maximum power with the louvers under heavy air loads (Part I: 60 minutes; Part II: 60 minutes); the high load configurations are also subject to separated flow conditions. It is not conclusive, but possible, that louvers on the active arc side of the fan were aided by their extensions into the turbine stream (damping?). Failures in the exit louvers were concentrated at the high load bearing end caps which were unable to transmit moment from high vectoring air loading without over-stressing the skins in any louver that had deficient weld in that area.

Design changes indicated in Figures I-75 and I-76 are planned for these parts to improve weld reliability.

D. Scroll - Buckling between hot gas inlets occurred during temperature transients. The skin in this section is shielded from the main gas stream except by partial venting. Skin temperature gradients were too high and additional stiffening in this region is required. A hat section support (as well as additional internal venting) is considered necessary as shown in Figure I-80.

Pitch Fan:

A. Front Frame - High indicated temperature levels encountered early in the FWT were corrected by incorporation of insulation pads between the frame and scroll center mounts described in Section B. It will be necessary to monitor frame temperatures during field and flight tests to establish installation and environment effects on the operating level.

B. Roller Bearing Inner Race - Score marks in the roller path were apparently caused by dirt in the bearing. The indication of local over-temperature on the edge of the race resulted from a tight grease seal rub.

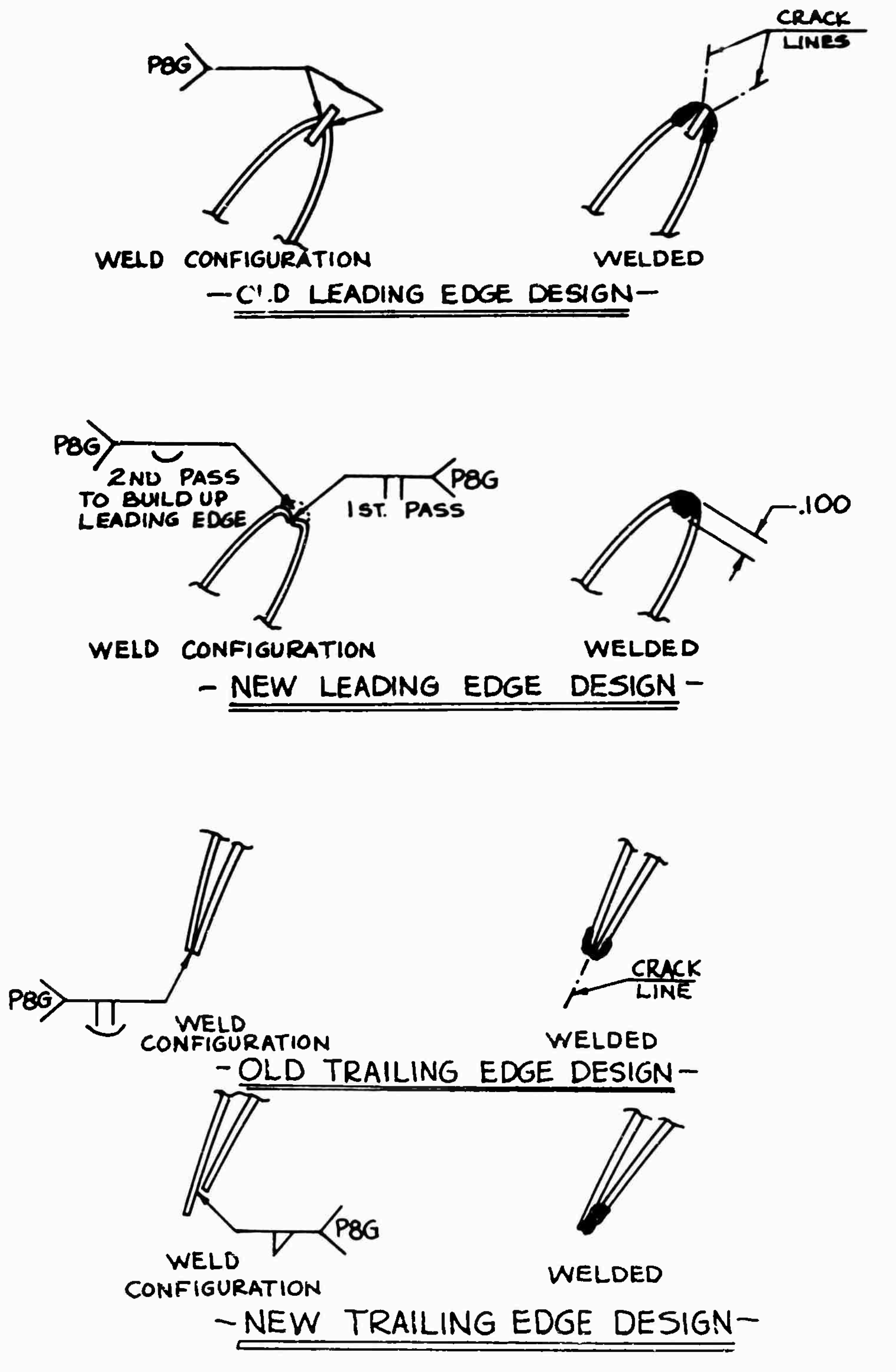


Figure I-75. Lift Fan Inlet Circular Vane Leading And Trailing Edge Weld Design Change

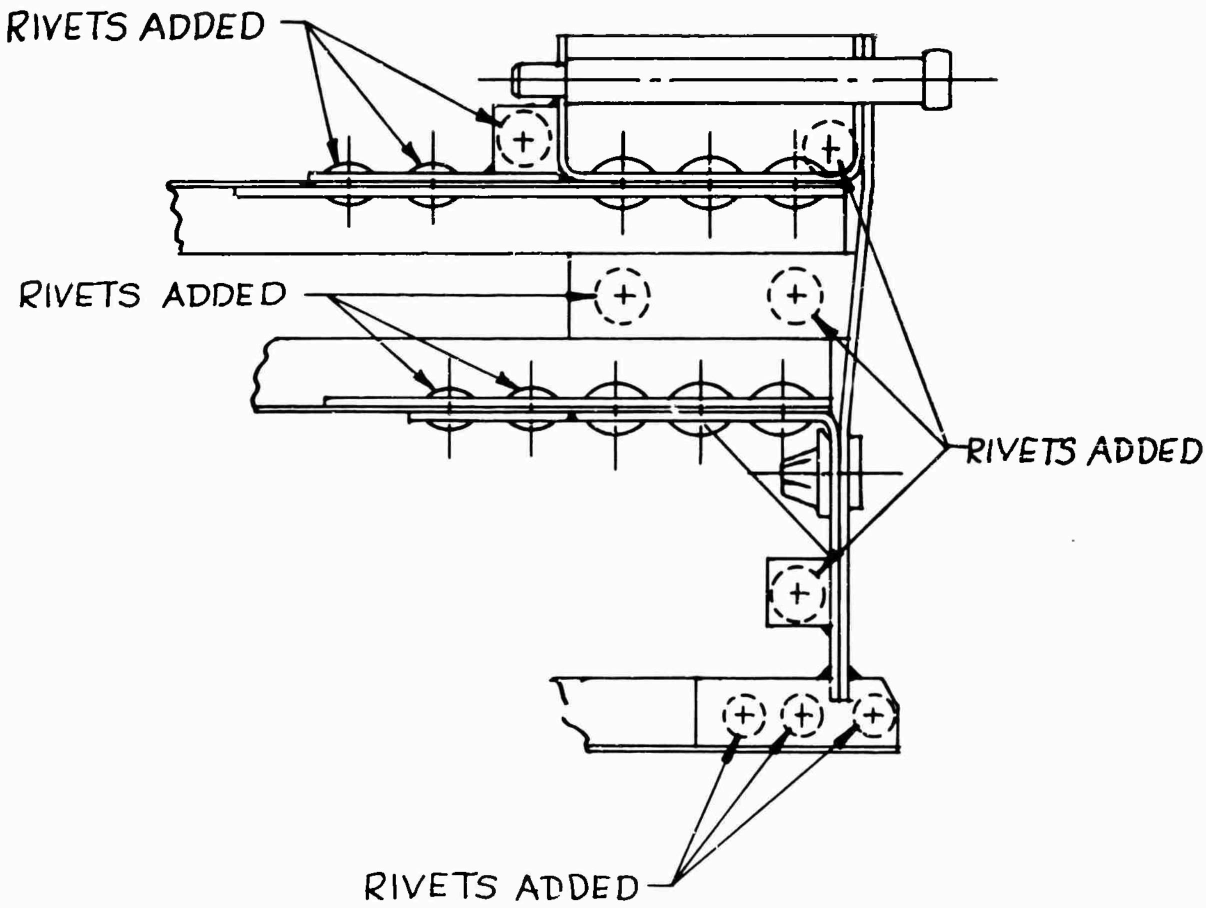


Figure I-76. Lift-Fan Exit Louver End Cap Design Change

2. PERFORMANCE ANALYSIS

Levels:

A. Cruise Mode - Table IX compares cruise mode performance with Table II from FRV Specification 112. The values presented in Table IX were taken from Figures I-26 through I-33 limited by the maximum allowable values of the rating conditions of Table II in Specification 112.

At military power the two J85/diverter valve combinations yielded an average of 4.2% higher thrust than specification level with both fuel flow and EGT at their maximum allowable values. It has previously been noted (Section F) that the engine flow functions measured at rated EGT are identical to the specification standard engine and this improved performance can, therefore, be attributed to lower diverter valve losses or leakage than estimated.

B. Lift Mode - Table X compares lift mode performance for both the lift fan and the pitch fan for an ARDC sea level standard day. Table XI presents the same results corrected to an ANA 421 standard hot day.

Table X results at military power show the lift fan to exceed Specification 112 by 6.1% in lift and the pitch fan to just meet Specification 113 minimum lift level with operation limited by maximum EGT and for the condition of 10.6% bleed gas powering the pitch fan. The pitch fan maximum allowable speed exceeded Specification 113 limit by 5.6% because of a low power absorption characteristic.

Generally, both lift fan and pitch fan performance met or exceeded specification levels at all part speed rating conditions. Single engine performance simulating either one engine out or sequential diverter valve operation for conversion showed the following thrust level relative to maximum power:

	FWT	Spec.
X353-5B	55.5% (3876)	57.1% (3915)
X376	59.6% (920)	55.4% (892)

The actual X353-5B single engine thrust was within 1% of the rating because of the generally higher level of performance obtained.

For a given fan speed the lift fan thrust was identical with either one or two engines providing input power. This suggests the single engine part speed deficiency to be traceable to fan turbine performance. Additional development effort will be required to determine the basis for this variation from estimated off-design performance.

C. Transients - In all cases transients resulted in terminal conditions being reached either sooner or very nearly in the same time as estimated in Specifications 112 and 113. The transient acceleration characteristic is quite different and indicates a slower initial response but a steeper slope so that the terminal condition is reached within the specification limit.

The step change test results are not directly comparable with the specification changes because the lift increment investigated was inadvertently twice the specification lift increment. It should be noted that the terminal conditions were, nevertheless, reached within specification limits.

Recalibration:

Performance recalibrations were made during Run #37. There was no significant deterioration in performance noted; variations indicated are within measurement accuracy. The comparative performance levels are included in Tables IX and X.

A summary of these data at military power show the change in performance at recalibration as follows:

	Δ Performance
Cruise Mode	- 1.5%
Lift Mode:	
Lift Fan	- 0.4%
Pitch Fan	+ 16.2%

Review of a few specific figures previously presented shows the calibration-recalibration characteristics clearly. Cruise thrust versus engine speed is compared for each J85-diverter valve combination in Figures I-26 and I-27. Lift fan lift versus lift fan speed is compared in Figure I-54.

Because of the significant influence of wind on the empirical relationship used to calculate pitch fan lift, the appropriate comparison for evaluating pitch fan performance deterioration is fan speed as a function of input power (Figure I-56). This indicates no change in pitch fan characteristic; the + 16.2% lift change at a given fan speed is all the result of the difference in wind conditions. An analysis of this difference in the "Appendix" indicates the recalibration to be a more accurate measure of the performance. Review of Table X gives the following recalibration performance relative to the specification levels:

Lift Fan Lift	+ 5.7%
Pitch Fan Lift	+ 16.2%

Single engine performance was correspondingly different:

	FWT	Spec.
X353-5B	54.8% (3808)	59.6% (3915)
X376	55.5% (1039)	55.4% (892)

3. FACTORS COMPROMISING SAFETY OF FLIGHT

The only parts tested considered to present a compromise to safety of flight are the lift fan exit louvers. Failure of the exit louvers during hovering or transition flight, as experienced in the FWT, could induce significant roll moment which could result in momentary uncontrolled flight.

All other items of hardware tested including the lift fan inlet vanes indicated sufficient reliability and integrity to permit experimental flight test using normal pre-flight and post-flight maintenance inspection. The inlet vane quality was extremely undesirable, however, and corrective measures are being incorporated.

I. RECOMMENDATIONS

1. GENERAL RECOMMENDATION

The General Electric Company recommends the U.S. Army (TRECOM) approves a flightworthiness rating for the X353-5B propulsion system based on the test reported herein and after satisfactory accomplishment of a 10-hour penalty run proposed for lift fan inlet vanes and exit louvers.

2. SPECIFIC RECOMMENDATIONS

A. All X353-5B propulsion system components be given a flightworthiness rating based on the performed test except: lift fan inlet vanes; lift fan exit louvers; and diverter valve actuation.

B. Lift fan inlet vanes and exit louvers be re-tested on a slave X353-5B lift fan which can also be an acceptance test vehicle in accordance with FRV Specification No. 116.

C. The inlet vanes be subjected to 10 hours of fan operation of which at least 90% is at maximum test engine power for a high fan flow condition.

D. The exit louvers be subjected to a re-run of the FWT schedule according to the FRV Specification No. 114 for high vector air load conditions as follows:

Part I

d.	Thrust vectoring and spoiling run	26 min.	
g.	Short maximum lift run	8	
h.	Maximum lift-maximum thrust run - TJ time reduced to minimum - L operation in lieu of TJ/L option	20	
i.	Idle thrust - idle lift-maximum lift run - TJ time reduced to minimum - Idle time two minutes only	6	
			60 min.

Part II

a.	Take-off simulation run - Maximum power, high vector only	30 min.	
b.	Conversion simulation run - Maximum power, L mode only	20	
c.	Landing simulation run - 2200 rpm high vector only	10	
			60 min.
		TOTAL	120 min.

Each part to be conducted five times (10 hours total) to provide the equivalent of a complete re-run of the FWT at these conditions.

E. Following the testing, the vanes and louvers be completely disassembled and inspected to provide the basis for rating approval by the contracting agency.

F. Flightworthiness rating be approved for the diverter valve actuator after satisfactory operation during the acceptance tests of diverter valves.

G. The segmented torque band configuration incorporated in the lift fan rotor during the FWT be retained as the approved rotor configuration (Reference Figure I-77) with copper-nickel-indium coating in radius between band and ear (0.002" average thickness) to retard fretting.

H. Lift fan carrier bolts (Part No. 4012001-170P1) be replaced by an AN bolt NAS-1003-1A (Part No. 4012001-206) having a shank grip length of 0.062" ± 0.015" and 0.005" increased shank radius. Shank O.D. is .1895"/.1870" versus original bolt thread O.D. of .190"/.1846" (Reference Figure I-78).

I. Lift fan platform bolts (Part No. 4012001-168P1) also be replaced by Part No. 4012001-206; platform relief cuts for clearance of tabs on the dovetail retainer ring be reworked to remove sharp corners by elongating the cut with a 0.060" drilled hole.

J. Platform and carrier bolt quality control be expanded to include:

1. 100% hardness inspection.
2. 100% dimensional inspection.
3. Sample lots metallographically examined.
4. Vendor microscopic analysis to define drawing notes which will be necessary to avoid repetition of bolt condition during any re-orders.

Figure I-77 Lift Fan Rotor Segmented Torque Band

Figure I-78. Original And New Design Carrier Bolts (Lift Fan)

K. The carrier bolt torquing procedure be modified to establish a pattern for improved torque transmission at carrier joints which include a torque band cut (Reference Figure I-73).

L. The lift fan rotor be sufficiently disassembled and inspected following the 10-hour penalty test to evaluate the condition of rotor hardware in the turbine/seal/torque band region.

M. The lift fan forward air seal (stationary) be modified to incorporate an opening in the inactive arc region to permit visual inspection of the forward side of the carriers, specifically the carrier bolts, without disassembly (Reference Figure I-79).

N. Non-destructive test techniques be employed to provide additional inspection for non-metallic inclusions in all lift fan torque band segments; all surface defects to be polished (≈ RMS 8 finish).

O. An external hat section be added to the lift fan scroll in the region between hot gas inlets to prevent buckling. (Reference Figure I-80). Seven (7) additional internal vent holes in this region be added to reduce skin temperature gradients.

P. The lift fan inlet vanes and exit louvers to be evaluated in the recommended penalty test incorporate manufacturing process changes to improve their quality and reliability including:

1. Development of improved aluminum cleaning processes for preparation for spot welding.

2. Establishing better process control to insure spot weld operation within desirable time limit after parts cleaning.

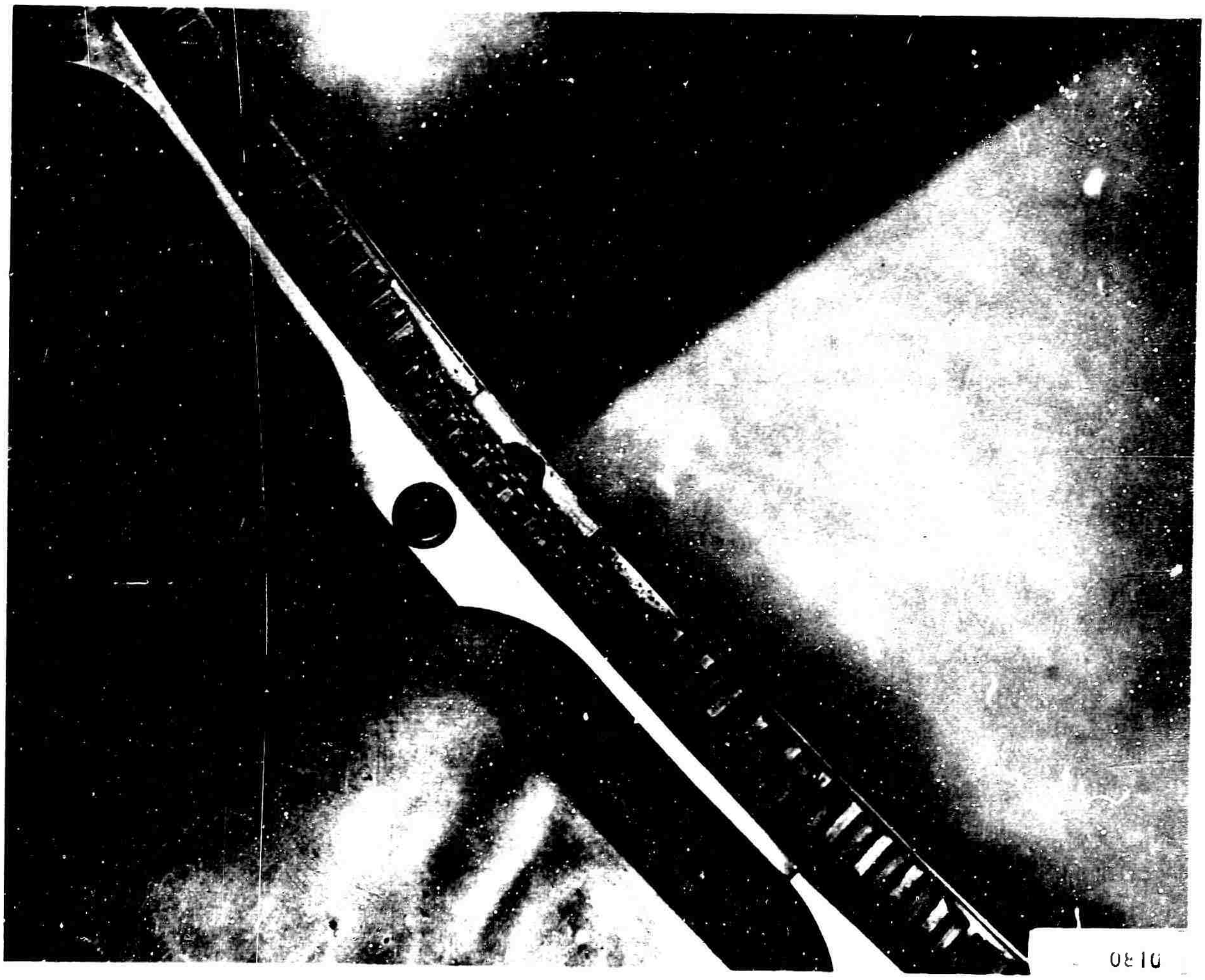


Figure I-79. Lift Fan Forward Air Seal Inspection Opening
(Lift Fan Forward Carrier Inspection)

Figure I-80. Hat Section Added To The Lift Fan Scroll

3. Improved control of spot welding current for weld uniformity; increased sampling inspection by destructive in-process checks.

4. Addition of protective atmosphere (argon) back-up for all fusion welds.

5. Modifications to the inlet vane skins to provide an improved welding configuration (Reference Figure I-74).

6. X-Ray inspection of welding for crack detection.

Q. The lift fan exit louver basic design be retained but rivets be added having sufficient strength to transmit loads into louver skins independent of weld integrity (Reference Figure I-76).

R. Exit louver #38 (Reference Figure I-75) be changed to all inconel X material to prevent buckling from turbine discharge gas penetration into the fan stream in this region.

S. Heat transfer between the pitch fan scrolls and front frame be reduced by:

1. Adding insulation pads to the scroll center mounts (Reference Figure I-81).

2. Improving scroll insulation in the center mount region (Reference Figure I-82).

3. Adding an insulation blanket to the front frame in the active arc region (Reference Figure I-83).

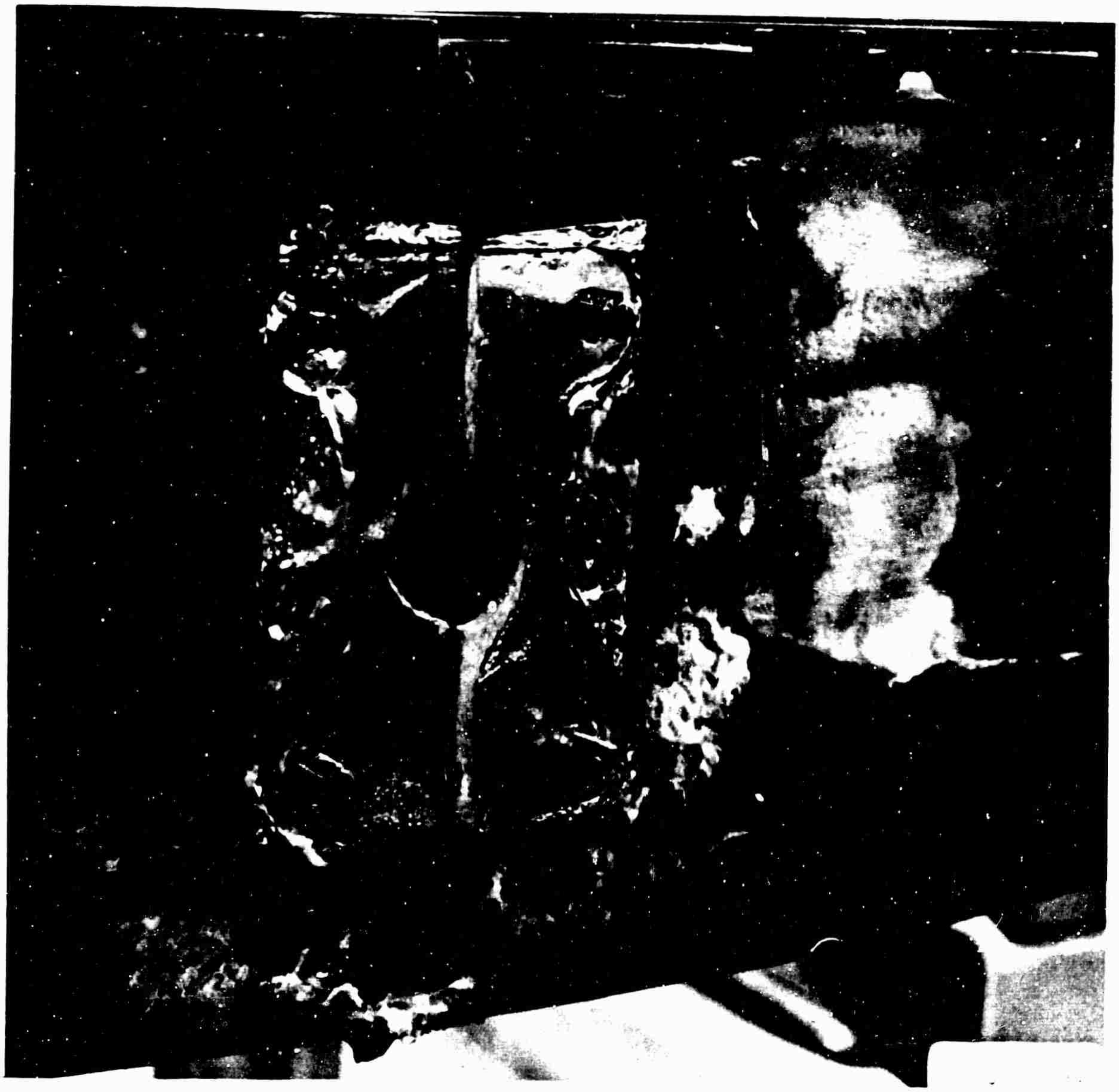


Figure I-81. Pitch Fan Scroll Mount Insulation

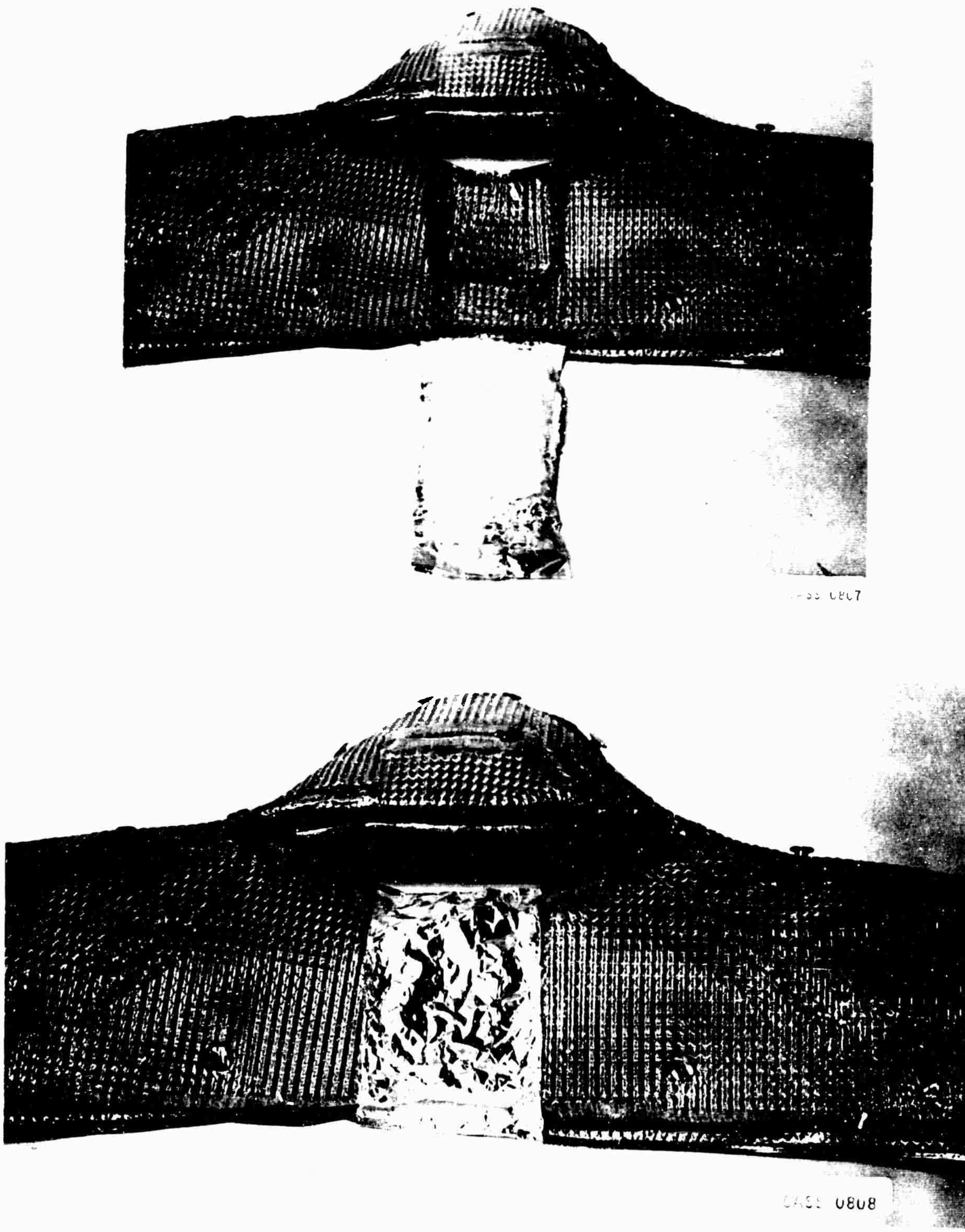


Figure I-82 Pitch Fan Scroll Insulation Modification

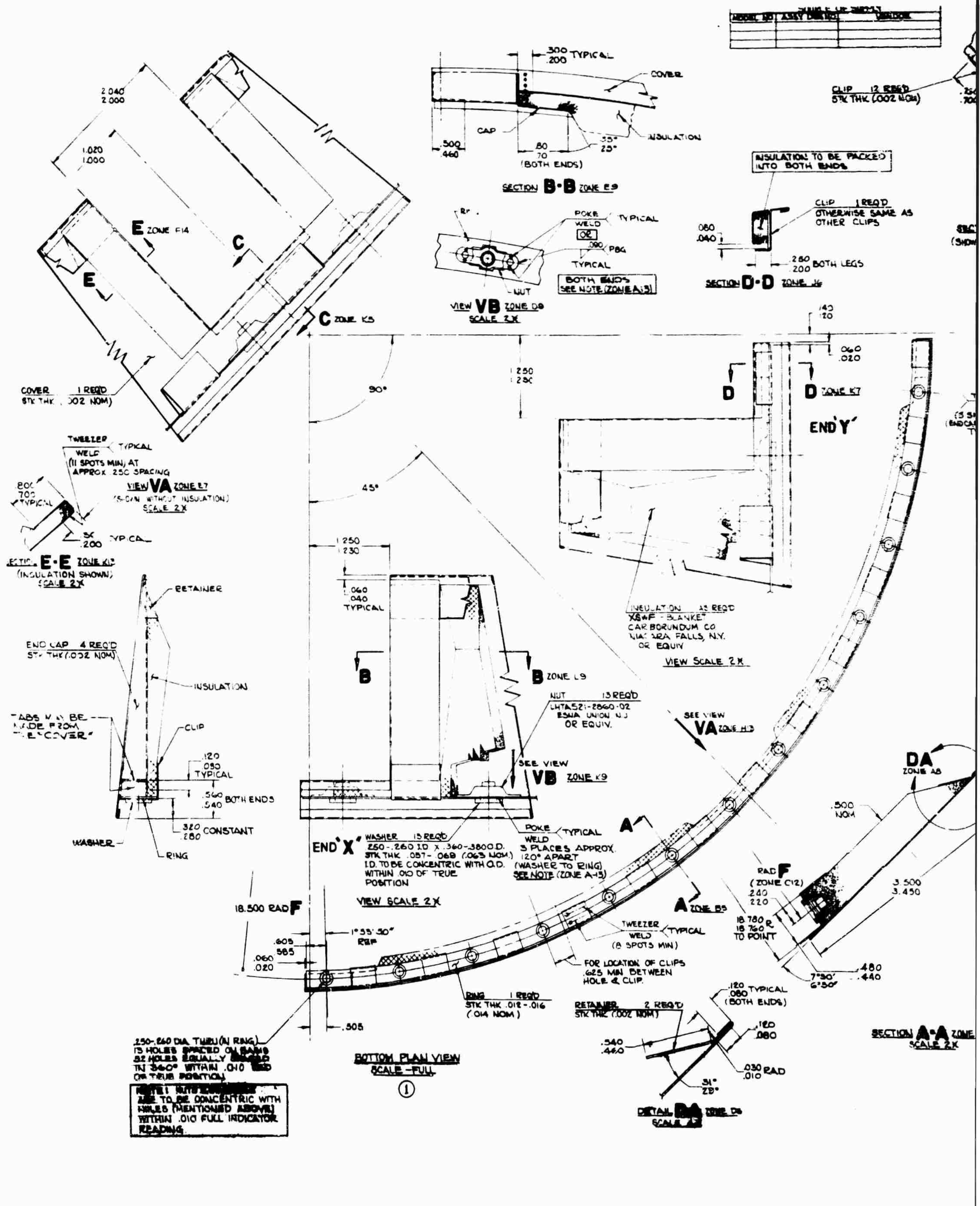
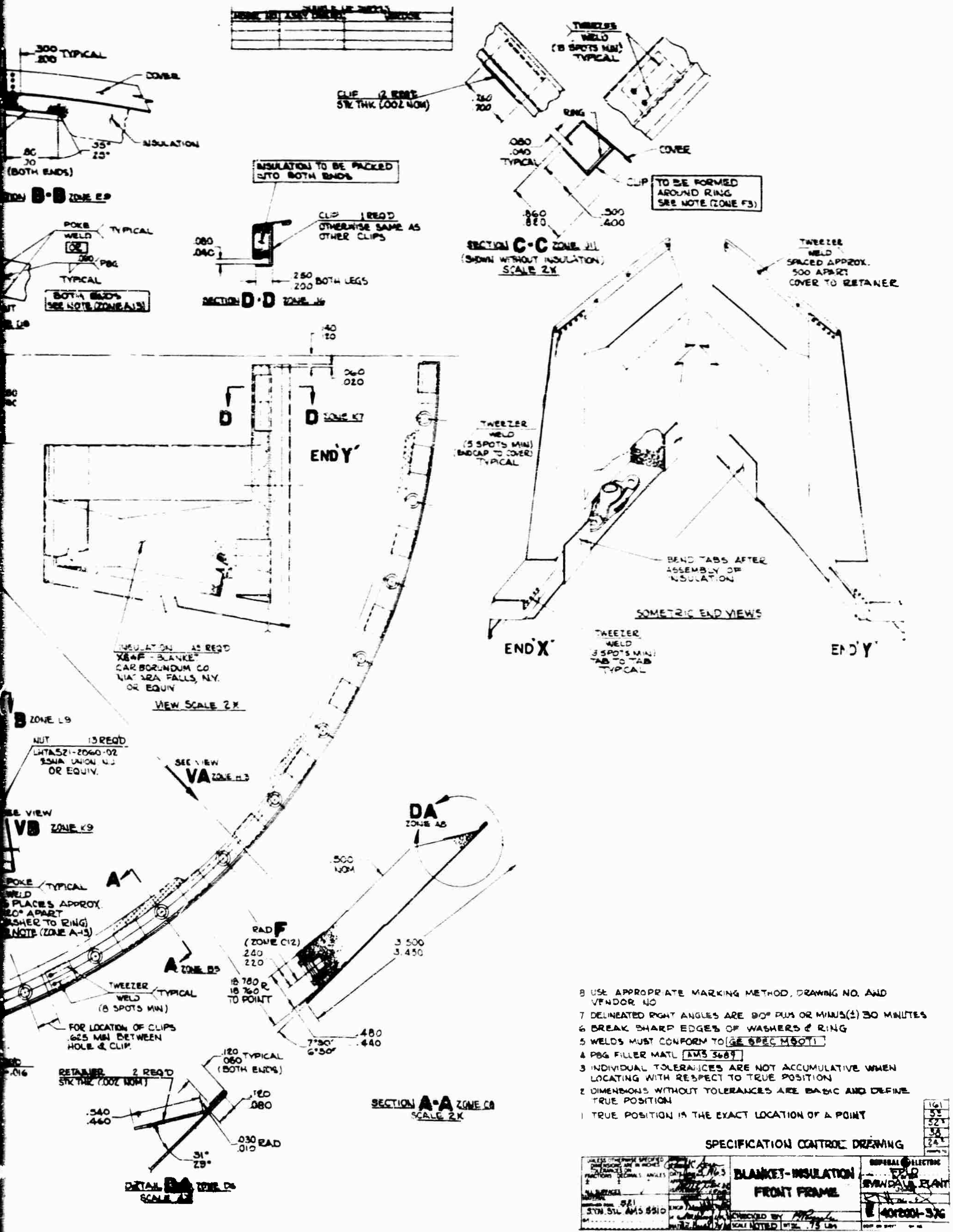


Figure I-85. Blanket Insulation Front Frame



re I-85. Blanket Insulation Front Frame

T. Pitch fan front frame thermocouples be provided to monitor frame temperature during field and flight test programs.

U. Pitch fan carrier bolts (Part No. 4012001-185P1) be metallographically examined on a sampling basis and 100% checked for grip length and hardness.

V. The flight type diverter valve actuators incorporate a stiffened section in the area of the pushrod which failed during the FWT.

W. Heat shield clearance be inspected prior to completing manufacture of diverter valve doors and held within drawing tolerance.

X. J85-GE-5 engines S/N 230-729 and -730 be processed through periodic inspection in preparation for flight test and to correct sluggish acceleration characteristic of engine -729.

3. SPECIFICATION CHANGES

A. X353-5B Propulsion System Specification No. 112 be modified as follows:

1. Reduce single engine performance by 3% lift at each rating condition in Tables I and III.

2. In Table XI reduce Lift Fan Group weight requirement from 849.6 lbs. to 846.0 lbs.* and increase Gas Generator Diverter Valve Group weight requirement from 462.9 lbs. to 464.0 lbs. (Table VIII to be adjusted accordingly.)

B. X376 Pitch Fan Specification No. 113 be modified as follows:

1. Increase pitch fan maximum speed by a range of 5% to

*The reduction in lift fan weight is recommended to compensate for recommended increases in diverter valve and pitch fan weights so that total XV-5A propulsion system weight remains unchanged.

6% between military and 85% power settings
Tables I and III.

2. Pitch fan weight requirement be increased to 114.0 lbs. It is now specified as 109.0 lbs. (Paragraph 3.12)

4. DISPOSITION OF HARDWARE

All hardware from the fans and diverter valves which underwent the flightworthiness rating test, except as listed in Tables XV, XVI and XVII, be reworked as necessary or replaced at the discretion of the General Electric Company and reassembled for use as FRV program spare assemblies.

5. TIME BETWEEN OVERHAUL

Time between overhaul be established at a minimum of 50 flight hours and a maximum of 100 flight hours for all components of the X353-5B propulsion system; extension of TBO beyond the minimum recommended time be subject to U.S. Army (TRECOM) approval.

Section J

A P P E N D I X

J. APPENDIX

FAN LIFT MEASUREMENT

Operation of two separate lift producers (X353-5B and X376 fans) simultaneously in the same thrust frame poses the problem of correctly separating the contribution of each to the total measured lift.

X353-5B performance can be obtained separately and subtraction of this from the total would yield X376 performance. This, however, involves subtraction of two large numbers to obtain the much smaller X376 lift value; any error in either large number (such as would be encountered with lift fan power absorption variations as a function of wind condition) would reflect as a much larger error in the pitch fan lift. The X376 fan could not be operated without the lift fan installed in the FWT test setup so it was necessary to develop an analytical method of calculating pitch fan lift from the system load cell readings.

DERIVATION OF PITCH FAN LIFT RELATIONSHIP

The pitch fan lift equation presented in Section C was derived as follows: The lift fan and pitch fan contributions to the vertical nose load cell (refer to Figure I-14) readings were determined from individual calibration loads applied at estimated fan centers of lift. Because of a prevailing West wind at the test site, the calibration load fo. the lift fan was shifted accordingly. The following empirical relationship was obtained that would be reasonably accurate for light prevailing wind conditions:

Where: L_{VN} is the vertical nose load cell reading

L_{PF} is the pitch fan lift

L_{LF} is the lift fan lift

L_T is the total system lift

$$\frac{L_{VN}}{L_{PF}} = 0.82878$$

and

$$\frac{L_{VN}}{L_{LF}} = 0.01188$$

$$L_{VN} = 0.82878\ L_{PF} + 0.01188\ L_{LF} \qquad (1)$$

also

$$L_T = L_{PF} + L_{LF} \qquad (2)$$

Rearranging and combining equations (1) and (2) gives:

$$L_{PF} = \frac{L_{VN} - 0.01188\ L_{LF}}{0.81690} \qquad (3)$$

WIND EFFECT ON THRUST MEASUREMENT

For a zero wind condition the fan center of lift is shifted toward the active arc of the turbine equivalent to ≈ 11% of the rotor radius. This does not affect the contribution of the lift fan to the vertical nose load cell reading but does affect that of the pitch fan because of the different fan/scroll orientations. The asymmetrical bellmouth used in the FWT installation (XV-5A aircraft nose) for the pitch fan has the effect of shifting the center of lift of the pitch fan in the opposite direction. An additional effect on both fan center of lifts is from wind; the ram drag force forms a couple with the thrust frame horizontal force restraint. The direction of the shift in center of lift is, therefore, a function of the wind direction, and the magnitude, a function of wind velocity. Engine ram drag has a simi'ar influence and adds to the "cocking" of the thrust frame.

A general expression is required to correlate all the test data regardless of wind conditions and this need is particularly apparent in the FWT data because of the very different wind conditions between calibration and recalibration runs (Run #20 and Run #37). Such an expression would take the form:

$$L_{PF} = \frac{L_{VN} - K_1 L_T}{K_2 - K_1} \qquad (4)$$

Where: K_1 is a constant and a function of lift fan center of lift.

K_2 is a constant and a function of pitch fan center of lift.

The values for K_1 listed below were obtained from FWT assurance runs at different wind conditions with lift fan S/N 003 operated alone (the pitch fan bleed was simulated but not contributing to lift). The influence of the J85 engines was incorporated in the K_1 values. The zero wind value of K_2 was obtained assuming the pitch fan center of lift at the rotor centerline (i.e., assumes bellmouth and turbine influences noted above cancel each other). An estimated ram moment was then used to adjust K_2 for wind.

Wind Velocity (mph)	Wind Direction	K_1	K_2
0	-	0	0.8288
5	West	-	0.8314
10	West	0.006	0.8341
5	East	-0.008	0.8262
10	East	-	0.8235

Using these values in equation (4) for Run #20 test points, a pitch fan lift of 1741 pounds is calculated (corrected to 100% speed) as opposed to 1567 pounds using equation (3). Recalibration data from Run #37 gives 1814 pounds lift using equation (4) as opposed to 1800 pounds using equation (3). The calibration loading that formed the basis for equation (3) was applied to the thrust frame representing a center of lift corresponding to a 10 mph prevailing West wind, the close agreement with equation (4) calculated lift for Run #37 (15 mph SW wind) is quite close. The agreement with "corrected" Run #20 results is within the test measurement accuracy. These results imply that the true pitch fan lift is between the "corrected" Run #20 data and Run #37 data. No attempt has been made, however, to "correct" the FWT data all of which was calculated based on equation (3). The very limited data which are available to estimate the K factors renders it inappropriate to attempt this. It is clear, nevertheless, that the ram drag effect is substantial and can reasonably account for differences in pitch fan lift such as calculated from Run #20 and Run #37 data where the wind varied both in direction and magnitude. This exercise demonstrates that, with additional data for various wind conditions, suitable constants can be determined to permit accurate pitch fan thrust calculation at any test condition. It is expected that the necessary data will be accumulated during acceptance testing planned for the FRV program.

It should be noted again that this effect of the wind does not alter the true total lift but is merely a redistribution on the load cells. Care must be exercised in estimating total XV-5A propulsion system lift because the portion allocated to the lift fan from such test data must be multiplied by two; and it should also be noted again that this wind effect is separate and distinct from the power absorption variation experienced with wing mounted fans in light winds as discussed in TCREC report 62-12.

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WALLACE & TIERNAN INC.
25 Main Street, Belleville 9, New Jersey

April 6, 1961

Customer General Electric Co., FPLD
Purchase Order #203-08963
Shipping Order #5821-14875A & B

We certify that the calibrations of the Wallace & Tiernan instruments Type FA-139, Serial Nos. FF02289 and FF02028 were performed against a liquid column referenced to our precision Standard Mercury Barometer and conform with the specifications of TP-17A-2 attached. The Wallace & Tiernan Standard Barometer is essentially a duplicate of, and is periodically checked against, the Standard Barometer located at the National Bureau of Standards.

The calibration accuracy of the instrument furnished on this order is, therefore, traceable to the National Bureau of Standards. The mercury column is based upon density of Hg at 0^{o} C and standard acceleration of gravity equal to 980.665 $CM/SEC.^2$ Calibration is done at ambient temperature of 25^{o} C.

Yours very truly,
WALLACE & TIERNAN INCORPORATED

A. Gaffney
Supt. of Production Test and
Production

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MEMO

SUBJECT: WALLACE & TIERNAN ANEROID BAROMETER BEING USED IN THE AIR SUPPLY CONTROL ROOM

April 5, 1961

This instrument is a gauge type barometer have a 14.5" scale with minimum graduations of 0.010" of mercury absolute. It has a sensitivity of one part in 4,000 and a accuracy of ± 0.3 millibars (.008" mercury absolute).

This instrument is calibrated to standard conditions.

a) inches of mercury absolute at 32°F
b) standard gravity - 980.665 cm/sec.^{2}

Local conditions are as follows:

a) Latitude - 39°14'50"
b) Longitude - 84°26'36"
c) Elevation - 565 feet
d) Gravity - 980.030 cm/sec.^{2} (POTSDAM)

M. Borgman
Instrument Lab.
FPLD, Bldg. 302, Ext. 819

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FUEL ANALYSIS REPORT

For: G. Wilson	Date: 11-21-62
Ext. 1828 Mail Drop: H-74	Engine Program: VTOL
Sample # 2	Engine #
Specification: JP-4 (MIL-J-5624E)	Sample Ident.: From 304 Fuel Field
Sample Dated: 11-20-62	
Sample Rec'd:	Charge #
Specific Gr. @ 60 °F .7592	Viscosity @ °F cs
Specific Gr. @ 0 °F .787	Viscosity @ °F cs
Specific Gr. @ 35 °F .771	Viscosity @ °F cs
Aniline Point: 133	Flash Point: °F
Aniline Gravity Product: 7299	Freezing Point: -86 °F
Net Heat: 18,748 BTU/lb.	Smoke Point: mm
Distillation:	Smoke Vol. Index:
Initial Boiling Point: 160 °F	Aromatics (by Volume): %
10% Evaporated @ 191 °F	Olefins, (by Volume): %
20% Evaporated @ 207 °F	Water Reaction:
50% Evaporated @ 295 °F	Solid Contaminants: mg/gal (0.80 micron filtration)
90% Evaporated @ 468 °F	Water Content @ 75°F ppm
End Point: 506 °F	Hydrogen/Carbon Ratio:
Residue: 0.9 %	Sulfur (by Weight): %
Loss: 1.1 %	Anti-Icing Additive: % (by Volume)
Thermal Stability @ °F	Other:
Pressure Drop: in/Hg	
Preheater Rating:	
Remarks:	

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Bldg. 200, Ext. 801