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TEST DATA REPORT, LOW SPEED WIND TUNNEL TESTS OF A FULL SCALE, FIXED GEOMETRY INLET, WITH ENGINE, AT HIGH ANGLES OF ATTACK

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REV SYM

ABSTRACT

A full scale inlet test was to be done in the NASA-ARC 40' X 80' WT to demonstrate satisfactory inlet performance at high angles of attack. The inlet was designed to match a Hamilton-Standard 55 inch, variable pitch fan, driven by a Lycoming T55-L-11A gas generator. The test was installed in the wind tunnel on two separate occasions but mechanical failures in the fan drive gear box early in each period terminated testing. A detailed description is included of the Model, installation, instrumentation and data reduction procedures. The final data acquired is contained as Volume II.

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TEST SUMMARY

Test Dates and Location

Testing was done in three parts. The initial checkout and static calibration tests were done at the Boeing Remote Engine Test Site, Tulalip, Washington during the period June 22 to July 10, 1976. The wind tunnel testing was done at the National Aeronautics and Space Administration's Ames Research Center (NASA-ARC), Moffett Field California, July 19 thru July 26, 1976 and September 27 thru October 7, 1976.

Authorization

The program, sponsored by NASA, was funded by contract NAS2-9215, "Large Scale Variable Pitch Lift/Cruise Fan Nacelle Test for the 40' X 80' Wind Tunnel". Internal funding within the Boeing Company occurred with IDWA #2B0009, W.O. 5-B6311-7550-192061 and #2B3173 W.O. # 5-73587-8050-192061. An add-on portion to the test, for which Boeing support was subcontracted to Hamilton Standard/NASALeRC was funded by Purchase Order E276925X4 "Reverse Thrust Wind Tunnel Tests", W.O. 5-B6661-8421-NASA01.

Faciltiy

The facility used for the static test and model checkout was the Tulalip Test Stand, T-1. The wind tunnel tests were done in the NASA-ARC 40 X 80 foot Wind Tunnel.

Purpose

The purpose of the test was to determine the range of nacelle tilt angles, freestream velocities, and engine airflow levels for which a fixed lip inlet can provide pressure recoveries and distortion levels that result in acceptable core engine/fan operating characteristics and fan blade stress levels.

Model

The test model was an asymmetric inlet, designed to match the airflow characteristics and geometry of a Hamilton Standard 55 inch variable pitch fan (QFT44-18) driven by a Lycoming T55-L-11A gas generator.

Recorded Parameters

The fan inlet, core engine inlet, core engine and fan nozzles were instrumented with sufficient pressures and temperatures to define pressure recoveries, distortions, static and total pressure profiles, and inlet/exit airflows. The model installation was mounted on balance for force measurement. Wind tunnel and engine operating parameters were measured to define the test conditions.

Tests

Tests were done at Tulalip to demonstrate the "model system readiness" for the wind tunnel test, confirm an airflow calibration and to determine the effect, if any, of a close proximity ground plane to the core/engine/fan exhaust nozzle exits.

Tests were then to be done in the wind tunnel at free stream velocities of 0 to 160 knots and inlet angles of attack 0 to 120°. During the first series of test runs in the wind tunnel the main power transfer gear in the fan gearbox (4.75:1 reduction) failed and temporarily ended the test. The model was repaired and reinstalled 2 months later. Again after 8 test runs the same gear failed in a slightly different location. The core engine oversped to a point where the 3rd stage turbine wheel shed its blades and burst. The complete core engine was demolished beyond repair. This ended the test.

Facility Occupancy

The model was installed at Tulalip for 19 days, during which 5.23 hrs of "engine-on time was logged. The first installation at NASA-ARC was for 8 days, 2.42 hrs "engine-on time and the second installation, 9 days, 4.33 hrs. "engine-on" time.

LIST OF FIGURES AND TABLES

J18-047

REFERENCES

1. D6-44058 "Test Planning and Coordination, Lift/Cruise Fan Inlet Test Program".

2. D180-20276-1 "Low Speed Tests of a Fixed Geometry Inlet for a Tilt Nacelle VSTOL Airplane," NASA CR-151922, January 1977.

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INTRODUCTION

During the first part of 1976, The Boeing Aerospace Company, Military Airplane Division was awarded, by NASA-ARC, an inlet design contract in support of a multi-mission VSTOL airplane. The performance of a Boeing fixed lip inlet would be demonstrated on a Hamilton-Standard Q-Fan (TM) demonstrator engine operating in a severe "angle-of-attack" environment provided by the NASA-ARC 40' X 80' WT. Boeing was the prime contractor responsible for the inlet and nacelle design, fabrication and assembly, installation, wind tunnel test and data analysis. The responsibility for supplying the core engine/fan system along with its operation during test was subcontracted to Hamilton-Standard (HS).

The main objective would be to demonstrate that a fixed lip inlet can provide adequate pressure recovery and distortion levels that result in acceptable core engine/fan stall margins and fan blade stress levels at combinations of large nacelle tilt angles, freestream velocities and engine airflow levels.

FACILITY

Testing was performed in the NASA-ARC 40 foot by 80 foot Wind Tunnel (40' X 80' WT). The Wind Tunnel has a closed 40 by 80 foot test section with semicircular sides of 20-foot radius, and a closed circuit air return passage. The general arrangement is shown in Figure 1. Air is driven in the wind tunnel by six 40 foot diameter fans which are powered by six, 6,000 horsepower electric motors. The tunnel operates with a stagnation pressure equal to atmospheric. The stagnation temperature varies from ambient upwards, due to the entrained products of combustion and the heat from the tunnel drive system.

Prior to installation of the test in the Wind Tunnel, the complete test system, engine through instrumentation through data reduction, was given an operational/functional checkout at the Boeing Tulalip Test Site, T-1.

INSTALLATION

The test model, installed in the wind tunnel, is shown in Figure 2. The main wind tunnel model support struts were removed and the semi-span turntable installed for mounting the nacelle. The nacelle was bolted atop a Boeing designed pylon-strut which in turn was bolted to the turntable. This entire assembly was mounted "on balance" for measuring the model forces. A large fairing was designed and built to fit around the strut and turntable and mounted "off balance" to provide shielding from the Wind Tunnel air forces. The centerline of the nacelle was 12'-7 1/8" above the Wind Tunnel floor and located on the vertical centerplane of symmetry in the Wind Tunnel.

The center of the installation, or center of rotation, was at tunnel station 261.5. A model alignment check was done after installation and the model was determined to be 0.6° nose down at 0° angle of attack. No correction was made for this slight deviation from the horizontal.

The rotation of the semi-span turntable is in the horizontal plane (normal inlet yaw) and since the inlet was asymmetric the inlet was installed on its side, i.e., the 90° position on the inlet lip was up in the wind tunnel. This exposed the windward designed side of the inlet to the tunnel flow at angles of attack. Figures 3, 4, and 5, show the nacelle at angles of attack of 0°, 60°, and 120° respectively.

The peripheral support equipment, other than the instrumentation systems, were mainly hydraulic and lubrication supply systems for the variable pitch fan. One large high pressure pump, reservoir and cooler were located on the first floor, with a gear box lubrication supply and scavenging pump (2) located on the second floor. The high pressure pump supplied fluid for the fan blade pitch change and control system and the engine power lever position in the system. The lube and scavenge pumps supplied and scavenged the fan gear box of lubrication oil.

The onboard fire system consisted of manifolded nozzles within the core engine cowling attached to two high pressure nitrogen bottles. In the event of an external engine fire the cavity inside the cowling would be filled with inert gas (N2). More detailed information regarding the installation support equipment may be found in the Plan of Test, reference 1.

The pretunnel installation system checkout was done at Tulalip, T-1. Here the nacelle assembly was bolted on a special shipping frame which in turn was welded to tie down plates beneath the test stand. Figure 6 shows the model installed at Tulalip.

MODEL

The test model, or nacelle, consisted of an inlet, a variable pitch fan, a gas turbine core engine, and the appropriate fairings, nozzles etc.

The inlet has a 57.826 inch highlight diameter, a 47.236"(1752.4 sq. in.) throat diameter and a 55 inch fan face diameter (1869.12 sq. in.). The inlet contours are asymmetric with the windward side (180°) having a higher contraction ratio than the leeward side (0°). The contraction ratio varies from 1.76 at 180° to 1.30 at 0°. At a given inlet station, both the internal and external contours are circular in cross section with offset centers. The inlet cowl was made of fiberglass.

The Hamilton-Standard Q-Fan(TM) demonstrator is a 55 inch, 13 bladed, variable pitch fan which utilizes a Lycoming T55-L-11A, 3750 hp gas turbine as the core engine. The fan has 17:1 bypass ratio and is driven through a 4.75:1 gear reduction to a maximum speed of 3365 rpm. The fan system used a 25.4 inch diameter "semi-elliptical" nose dome fairing. The fan exit nozzle was a simple, round, constant area, aluminum nozzle with an exit area of 1649 square inches. The core engine exit nozzle supplied with the engine, had an exit area of 394 square inches. A schematic of the inlet and nacelle showing the major components and station designations is shown in Figure 7.

INSTRUMENTATION

The test model instrumentation was divided into three groups: 1) Model performance, 2) Core engine/fan operation and health and 3) Wind Tunnel condition. A brief description of each group follows:

Model Performance

INLET: The inlet contained 45 cowl surface static pressure ports figure 8, and seven fan face total pressure rakes (70 total pressures, 7 statics and 3 flush mounted total pressure transducers,) figure 9. These rakes are also shown in the photograph, figure 10.

FAN DUCT: The fan duct had two rakes located just ahead of the fan nozzle exit, figure 11. The rakes each contained 10 total pressures, 3 total temperature probes, two Prandtl-type static probes and are shown in figure 12.

CORE ENGINE: The core engine compressor face was instrumented with 8 total pressure rakes (45 total pressures and 3 flush mounted transducers), figure 13, and 8 static pressure ports. One total pressure was also located at the core compressor inlet lip.

Engine performance was determined by measuring N1, N2, and power shaft torque. The engine nozzle contained two rakes, figure 14, with 5 total pressures and 5 total temperatures.

Core Engine/Fan Operation and Health

FAN: Fan operation and health was monitored by fan blade angle (FBA), fan RPM(N2/4.75) and 3 strain-gaged blades. In addition the gearbox lube oil pressure, temperature and flow were displayed on panel meters. Measurements were also displayed of the inlet, fan gear box and fan mount shroud, horizontal and vertical vibrations. Three of the 7 fan face total pressure rakes were strain gaged near the rake root to monitor stress levels during testing.

CORE ENGINE: The engine system contained all the normal monitor and control parameters, N1, N2, TT7, fuel and oil pressures and temperatures (various locations), three vibration pickups, and power lever angle and fuel supply. In addition six engine external structure and cowl cavity temperatures were displayed on panel meters.

Wind Tunnel

The Wind Tunnel instrumentation consisted of measuring the total and static pressure, and the total temperature. In addition the model lift, drag and side forces, pitch, yaw and rolling moments were measured by the facility balance system.

For the second phase, or reverse thrust testing the model was setup such that the following changes could be easily made within the existing instrumentation system:

1) Removal of the 7 fan face total pressure rakes (special plugs had been made for filling the holes in the duct).
2) Adding two aft (fan) facing total pressure rakes.
3) Addition of 1 fan shroud static PFC (Fig. 12) equi-distant from the fan blade centerline as cowl static PC42.
4) Addition of a pressure line to measure compressor discharge pressure.
5) Turning the two fan duct exit rakes to face aft.
6) The addition of 13 nozzle "exlet" static pressures to the data system.

The basic instrumentation/data recording system was a Boeing "Standard Digital Data System" (SDDS). The system contained signal conditioning equipment, monitoring equipment, scanivalves, analog to digital conversion etc. The system output data on punched paper tape for use with a PDP8/I computer. A detailed description of the exact equipment is contained in the Instrumentation Report, Appendix A. Detail scanning/instrumentation assignments are also included for reference. A photograph of the equipment along with the H-S furnished core engine/fan controls and monitors installed at NASA-ARC is shown in figure 15. H-S also furnished and operated the fan blade stress monitoring and recording equipment (Three of the 13 blades were gaged).

DATA REDUCTION

The data were reduced to semi-final form on-site during the test using a PDP8/I computer. The computer system (including line printer) was furnished and operated by Boeing with the data system. The data were reduced with data reduction program PN026-"Ames Q-FAN (TM) Nacelle Inlet Program". Final data tabulation or re-reduction was done at Boeing to convert the data into the metric system, SI units, and microfilm.

The equations used in the data calculations are described on the following pages referenced to the sample data page, figure 16. Total pressure data from the core engine compressor face probes were also used in calculating an engine manufacturers recommended distortion index. The "Allison Radial and Circumferential Distortion Index" data are contained as the page two output for each test point. This index, defined in the "Allison Gas Turbine Specification #844-B". is described in "Sub-routine EXTRA 6.01", Appendix B.

PN026 CALCULATIONS
(FORWARD FLOW - CAL026)

1. Tunnel static pressure based on AMES input data.

   PO = PTO - QPSF/144   (1a)

2. Inlet corrected airflow - table look-up. (Table 1)

   WK1 vs. PSTI
   where
   PSTI = ((PC(13) + PC(31) + PC(37) + PC(38))/4.0)/PTO

3. Inlet airflow.

   $$W1 = WK1 * \delta_T / \sqrt{\theta_T}$$

   where

   δ_T = TTO/518.67   (3a)

   θ_T = PTO/14.696

4. Fan face average total pressure recovery, area weighted.

   PTFA = PTFAV/PTO

   $$PTFAV = 1/1869.12 \sum_{n=1}^{10} PTFR_n \ (A_n) \quad (4a)$$

   $$PTFR = 1/7 \sum_{n=1}^{7} PTFX_n$$

   $PTFX_n$ = Individual fan face total pressures, number X (4b)

   A_n = Area weighting factor

n	A-in^2	PTF-X
1	93.462	1, 1[illegible], 21, 31, 41, 51, 61
2	93.462	2, 12, 22, 32, 42, 52, 62
3	280.362	3, 13, 23, 33, 43, 53, 63
4	280.362	4, 14, 24, 34, 44, 54, 64
5	280.362	5, 15, 25, 35, 45, 55, 65
6	280.362	6, 16, 26, 36, 46, 56, 66
7	280.362	7, 17, 27, 37, 47, 57, 67
8	93.462	8, 18, 28, 38, 48, 58, 68
9	93.462	9, 19, 29, 39, 49, 59, 69
10	93.462	10, 20, 30, 40, 50, 60, 70

5. Fan face total pressure distortion

$$DISF = (PTFX_{MAX} - PTFX_{MIN})/PTFAV$$

6. Fan duct airflow

$$WF = \sum_{n=1}^{20} \frac{A_i\ P_{TM_n}}{\sqrt{518.688}\ \sqrt{\theta_F}} \left\{ \frac{2g\ \gamma}{R(\gamma-1)} \left[\left(\frac{PM}{PTM_n}\right)^{\frac{2}{\gamma}} - \left(\frac{PM_n}{PTM_n}\right)^{\frac{\gamma+1}{\gamma}} \right] \right\}^{1/2}$$

$\gamma = 1.4015$

$g = 32.1741$ 16-ft/sec^2

$R = 53.35$ ft-1b/1b°R

PM = Fan duct nozzle static pressure* (6a)

for $1 \leq n \leq 10 = (PM2-PM1)\left(\frac{R_n - 18.61}{10.65}\right) + PM2 \quad R_n = \Big| \begin{matrix} 28.73 \\ \uparrow \\ 18.91 \end{matrix}$

for $11 \leq n \leq 20 = (PM4-PM3)\left(\frac{R_n - 18.61}{10.65}\right) + PM4$

$A_i = f(PTM_n)$

n	A_i - in^2
1,11	117.1
2,12	110.5
3,13	99.8
4,14	90.7
5,15	82.5
6,16	75.
7,17	66.4
8,18	63.5
9,19	58.5
10,20	60.2

R_n RADII Table

PROBE # (N)	RADIUS (R)
1,11	28.73
2,12	27.4
3,13	26.16
4,14	24.98
5,15	23.86
6,16	22.79
7.17	21.77
8,18	20.78
9,19	19.83
10,20	18.91

7. Fan duct corrected airflow

$$WKF = WF * \sqrt{\theta_F}/\delta_F$$

where

$$\theta_F = \left(\frac{1}{6} \sum_{n=1}^{6} TTM_n\right)/518.688 \quad (7a)$$

$$\delta_F = PTMAV/14.696$$

*For test runs 27-35 PM2 & 4 Probeswere damaged and PM = either PM1 or PM3 (no linear interpolation was done).

7. (Continued)

$$PTMAV = .992 \{\frac{1}{1649} \sum_{n=1}^{10} (\frac{PTM_n + PTM_{n+10}}{2}) * A_n\} \quad (7b)$$

PTM = Fan duct exit nozzle total pressures (7c)

A_n = two times the values shown in A_i table, for values $1 \leq n \leq 10$

8. Core engine compressor face airflow

$$WE = \sum_{n=1}^{8} WER_n$$

$$WER = \frac{16.96 * PTCAR_n}{\sqrt{TTC}} \left[\frac{2g\gamma}{R(\gamma-1)} \left(\left(\frac{PSC_x}{PTCAR_n}\right)^{\frac{2}{\gamma}} - \left(\frac{PSC_x}{PTCAR_n}\right)^{\frac{\gamma+1}{\gamma}} \right) \right]^{1/2}$$

PTCAR = The individual core engine rake average pressure.

TTC = Core engine compressor face total temperature

PSC_x = Core engine compressor face static pressure aligned with each core engine rake arm. (8a)

9. Core engine compressor face corrected airflow.

$$WKE = WE * \sqrt{\theta_E} / \delta_E$$

θ_E = TTC/518.688

TTC = Compressor face total temperature (9a)

δ_E = PTCAV/14.696

PTCAV = Area weighted average total pressure at the compressor face.

$$\sum_{n=1}^{48} \frac{PTC_n}{48}$$

PTC = Individual total pressures (48) at the core engine compressor face (9b)

10. Area weighted average total pressure recovery, core engine compressor face.

PTCA = PTCAV/PTO

11. Core engine compressor face total pressure distortion

DISC = (PTCMAX - PTCMIN)/PTCAV

12. Core engine horsepower

EP = 2π * ETM * CN2/330000

where ETM = Core engine torque (12a)

CN2 = Power turbine speed

13. Corrected core engine nozzle thrust - table look-up (Table 1)

CKFN vs. corrected engine horsepower (CP)

$$CP = EP/(\sqrt{\Theta_E} * \delta_E)$$

14. Core engine nozzle thrust.

$$FN = CKFN * \delta_E$$

15. Core engine nozzle exit velocity

$$VN = FN * g/WE + FF$$

where FF is a table look-up (Table 1)

FF vs. CKN1

CKN1 = Corrected compressor speed.

16. Average core nozzle total temperature.

$$TTNAV = 1/5 \sum_{n=1}^{5} TTN_n$$

17. Average core engine nozzle static pressure.

$$PNAV = 1/4 \sum_{n=1}^{4} PN_n$$

18. Average core engine nozzle total pressure.

$$PTNAV = 1/5 \sum_{n=1}^{5} PTN_n \qquad (18a)$$

19. Calculated inlet airflow.

$$W2 = \sum_{n=1}^{70} \frac{A*PTF_n}{\sqrt{TTO}} \left\{ \frac{2g\gamma}{R(\gamma-1)} \left[\left(\frac{PPA}{PTF}\right)_n - \left(\frac{PPA}{PTF}\right)_n^{\frac{\gamma+1}{\gamma}} \right] \right\}^{1/2}$$

$A = A_n/7$ (from the A_n table used in the calculation of PTFAV)

PPA = Interpolated average static pressure for each fan face total pressure probe.

$$\frac{(PCZ - PPY) * (RA - 13.797)}{13.703} + PPY \qquad RA \Big|_{13.237}^{27.228}$$

PC = Inlet cowl compressor face static pressure (19a)

PP = Inlet rake prandtl static pressure (19b)

19. (Continued)

n	z	y
$1 \leq n \leq 10$	39	1
$11 \leq n \leq 20$	40	2
$21 \leq n \leq 30$	41	3
$31 \leq n \leq 40$	42	4
$41 \leq n \leq 50$	43	5
$51 \leq n \leq 60$	44	6
$61 \leq n \leq 70$	45	7

20. Calculated inlet corrected airflow

$$WK2 = W2 * \sqrt{\theta_T} / \delta_T$$

21. Total fan face airflow.

$$W3 = WF + WE$$

22. Fan pressure ratio

$$FPR = PTMAV/PTFAV$$

23. Fan duct exit velocity

$$VM = \left[2gR \left(\frac{\gamma}{\gamma-1}\right) * TTMAV \left[1 - \left(\frac{PMAV}{PTMAV}\right)^{\frac{\gamma-1}{\gamma}} \right] \right]^{1/2}$$

TTMAV = Average fan duct nozzle total temperature

$$TTMAV = 518.688 * \theta_F$$

PMAV = Average fan duct nozzle static pressure.

$$1/4 \sum_{n=1}^{4} PM_n$$

24. Corrected compressor speed.

$$CKN1 = CN1/\sqrt{\theta_E}$$

25. Corrected power turbine speed.

$$CKN2 = CN2/\sqrt{\theta_E}$$

26. Fan inlet cowl surface mach numbers.

$$XMC_n = \left\{\frac{2}{\gamma-1}\left[\left(\frac{PTO}{PC_n}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]\right\}^{1/2} \qquad n = 1\text{-}45$$

27. Resultant of nacelle lift and drag forces. (ref. fig. 17)

$$FXZ = (FX^2 + FZ^2)^{1/2}$$

FX = Drag force

FZ = Lift force

28. Corrected inlet airflow per square foot.

WK1A = WK1/12.98

(REVERSE FLOW - CALTPS)

Calculations for the reverse testing mode are the same as the forward mode with the following exceptions.

2. WK1 is not computed.

3. W1 is not computed

4. PTFAR - Fan face total pressure average, area weighted (2 rakes)

PTFAR = PTFAVR/PTO

$$PTFAVR = \sum_{i=1}^{20} PTFR_i/_n ; \text{ if } PTFR_i \text{ is} > PTO + .1$$

n is the number of probes that satisfy the above requirement. ≤ 20

$PTFR_i$ are the individual fan face total pressures

if n=0 then, PTFAR & PTFAVR = 0.0

5. DISF - Fan face pressure distortion

$$DISF = (PTFR_{MAX} - PTFR_{MIN}) / PTFAVR$$

providing $PTFR_{MAX}$ AND $PTFR_{MIN}$ are > PTO + .1

13. CKFN - Corrected core engine nozzle thrust.

$$= \frac{FN}{\delta_E}$$

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14. FN = Core engine nozzle thrust

$$= \frac{VNI\ (WE+FF)}{g}$$

VNI = ideal velocity

WE = core engine mass flow

FF = fuel flow, table look-up f(CKN1)

g = gravitational constant 32.174

15. VNI = Ideal engine nozzle exit velocity

f(TTNAV, PO,PTNAV), subroutine SPEEDZ used.

$$VNI = \left\{ 2gR\left(\frac{\gamma}{\gamma-1}\right) (TTNAV) \left[1-\frac{PO}{PTNAV}^{\frac{\gamma-1}{\gamma}}\right] \right\}^{1/2}$$

19. W2 - not computed

20. WK2 - not computed

21. W3 - not computed

22. FPR - Fan stage pressure ratio

$$= \frac{PTFAVR}{PTMAV}$$

23. VMI - Ideal fan duct exit velocity

f(TTF, PO, PTFAVR), Subroutine SPEEDZ used

$$VMI = \left\{ 2gR\left(\frac{\gamma}{\gamma-1}\right) (TTF) \left[1-\frac{PO}{PTFAVR}^{\frac{\gamma-1}{\gamma}}\right] \right\}^{1/2}$$

$$\frac{2\pi(ETIN)(N2)(2547)}{(33000)(WF-WE)(.2395)(3600)} + TTMAV$$

ETIN = Engine torque (inch/lb)

26. XMC_i - Fan inlet cowl mach no. - not computed.

28. WK1A - not computed.

29. DISM - Fan duct nozzle distortion

$$= (PTM_{MAX} - PTM_{MIN})/PTMAV$$

PTM_{MAX} & PTM_{MIN} chosen from PTM_i where i = 1,10

30. FRAM - Ram drag

$$= \frac{WE(VFPS)}{g} \; [COS(ALPHA1)]$$

where WE = core engine mass flow

VFPS = tunnel velocity

g = gravitational constant 32.174

ALPHA1 = model angle of attack from tunnel paper tape recording

31. CT - Reverse thrust coefficient (Hamilton/Standard)

$$= \frac{RISE\pi}{2(RHO)(ND)^2}$$

where RISE - the time average value of the pressure rise behind the Q-FAN. PTFAVR-PTMAV

RHO = tunnel free stream density

N = N1 - propeller speed (RPS) (N1/60.)

D = propeller diameter (ft.) - (4.5833')

32. FNREV - Reverse thrust

$$= CT \; \left(\frac{WF*VMI}{g}\right)$$

g = 32.174 gravitational constant

VMI = ideal velocity (fan duct exit)

WF = mass flow (core engine compressor face)

CT = thrust coefficient.

The Wind Tunnel test conditions were recorded by the Wind Tunnel data system and output on punched paper tape. This tape was loaded into the PDP8/I along with the SDDS tape to produce a combined data output. Data values contained on the NASA tape were: Run, Condition, Angle of Attack, q, V_∞, TTO, PO, PTO Lift, Drag, Sideforce, Pitching Moment, Rolling Moment and Yawing Moment. Separate recordings of Tunnel total pressure and temperature (PTT, TTT) and static pressure (PST) were made by the SDDS as a backup to the Wind Tunnel supplied PTO, TTO, and PO. Figure 17 shows the model force component and sign convention used for this test.

The final data are contained on microfilm and have been included with this report as Volume II. Two sets of data (tabulated) are included; one in English units and the other in metric (SI) units. Included with the final data tabulations are total pressure contour plots for the fan face and core engine compressor face stations. Machine (SC4020) plots of the inlet cowl surface Mach number versus station plots are also included for each test point.

TEST PROCEDURE

Testing was done at NASA-ARC on first and second shifts. At the beginning of each day's testing and/or run-startup the data systems were all check calibrated and adjusted for the proper barometric readings. A wind-off zero was taken on the force measuring system. The following general sequence was then followed:

1) Start Wind Tunnel into the synchronizing mode.

2) Start fan gearbox scavenging pump

3) Start fan gearbox lubrication pump.

4) Start fan blade and PLA control hydraulic pressure pump

5) A final inspection of the facility and model test systems was completed.

6) The Wind Tunnel was then brought on-line

7) The engine was then started

8) The Wind Tunnel access door was closed

9) The engine was left at idle power until the Wind Tunnel speed was within approximately 20% of the end value. Then in parallel, the engine power setting (usually max. at the beginning of a run) and wind tunnel q were adjusted to the desired end value.

10) The test system was then allowed to stabilize for 15 seconds and data were recorded on both the SDDS and Wind tunnel data systems.

TEST PROCEDURE (Continued)

11) The engine power and/or fan blade angle were then reset to the next test condition. A detailed list of test conditions, sequence and the test points is contained in the "Detail Test Plan" appendix C.

12) After a sequence of test conditions were recorded the wind tunnel velocity and/or inlet angle of attack were reset to a new point. When the inlet angle of attack was reset the engine power was always set at some intermediate to high level such that there would be no chance of airflow separation (The inlet airflow separation was predicted to occur at low airflow settings) within the inlet.

A detailed record of the test conditions and notations are contained on the test run logs, Appendix D. Listed also are any leaking, disconnected, or plugged pressures, shorted thermocouples, etc.

TEST RESULTS

The test, as was previously stated, was terminated in the very early stages of running. Only seven of a desired thirty-six test conditions were recorded before the termination of testing. The following is a brief summary of the major events occurring during the three test periods.

The model was setup at Tulalip and after the normal amount of problems, "debugging" and adjustment, the first "engine-on" runs were attempted. Inspection of the engine and fan after the initial short check run revealed one fan blade in reverse pitch, completely out of synchronization. The fan assembly was disassembled and it was determined that a retaining collar (to the blade pitch actuator) had broken on that particular blade. The fan actuator assembly was then air freighted back to H-S at Windsor Locks, Conn. The actuator was repaired, inspected and the retaining collars replaced. It was determined that the cause of this failure was due to a previous rework of the actuator system for additional stroke (blade pitch). During this rework too much material had been machined from the end stop. The additional travel now allowed the "blade follower" to over center whereupon during actuator retraction it jammed and caused the collar to be broken. The fan was reassembled and checkout tests of the system resumed on a near normal basis. An airflow calibration run was made (runs 2-7) followed by the close proximity ground plane tests (runs 8-20). During the ground plane tests a large (10' X 20') deflector plate was mounted to the front of a forklift and positioned at distances of 7', 5', and 3' behind the core engine exhaust nozzle exit to evaluate back pressuring effects. After these tests were completed the model was sent to NASA-ARC.

The model was installed for the first time in the 40' X 80' WT in approximately 9 shifts. Testing began (run 21, 22) and continued through the static test conditions, 0° alpha (runs 22-25).

TEST RESULTS (Continued)

During the first "wind on" test series, 40 knots, 0° alpha, a large "pop" occurred within the nacelle followed by large quantities of discharged oil. The core engine oversped, the overspeed protection circuits activated, and the system shut down. Upon close inspection of the system it was determined that the fan would not rotate and disassembly of the fan system was undertaken in the Wind Tunnel. It was found that the main power transfer gear, the sun gear, in the fan gear box had failed and pieces had damaged and jambed the other gears. The engine/fan system was then removed from the Wind Tunnel for repair and returned to H-S.

The repairs took approximately 10 weeks with the model being returned to NASA-ARC in mid-September. The model was again installed in the 40' X 80' WT (6 shifts) and testing resumed with run 28. The static condition was repeated, (run 28) followed by 40 knots, 0°, 20°, 45°, and 60° alpha (runs 32 - 37). At the 75 knot, 75° alpha point the test engine again failed, first with emitted sparks, smoke, and oil followed by an explosion and disintegration of the aft portion of the engine. A small fire ensued but was quickly extinguished by the N2 system and hand held CO2 extinguishers. The immediate tunnel area and downstream in the diffuser to the trash screen were littered with bits and pieces of the engine turbine sections. Four holes were existant in the Wind Tunnel walls at various locations where the engine third stage turbine wheel, which had burst, had exited the tunnel circuit.

A formal accident review board was immediately convened by NASA to investigate and determine the cause of the accident, any negligence, and if applicable, recommend any future precautions or procedures. Several people, familiar with this type of engine, this type of failure were called in as consultants and investigators. At the time of this writing the accident board findings have not yet been released nor have any of the photographs of the damaged hardware.

A detailed analysis of the data acquired may be found in the Propulsion Staff document, reference 2. An analysis of the fan blade stresses, recorded during testing by H-S, is contained in Appendix E.

INLET CORRECTED AIRFLOW VS. CALIBRATION PRESSURE		ENGINE TORQUE VS. TORQUEMETER INDICATION		CORRECTED FUEL FLOW VS. CORR. ENGINE SPEED		CORRECTED CORE THRUST VS. CORR. POWER	
PAV	CDT	INDICATION % OF	ET	$N_1/\sqrt{\theta}$	$W_F/\delta\theta^{.712}$	EPK	FKN
		1300 lb-ft	inch-lb	% 18120 RPM	lb/hr	hp	lb
		100%	1550	55 %	340.	0	0
.55	.961	150	2350	60	390	200	30
.60	.937	200	3150	65	450	400	53
.65	.904	250	3900	70	520	600	73
.70	.860	300	4600	75	620.	800	91
.75	.806	350	5300	80	750	1000	108
.80	.739	400	5900	85	940	1200	123
.85	.654	450	6550	90	1220	1400	138
.90	.546	500	7150	95	1620	1600	152
.925	.478	550	7750	100	2120	1800	165
.950	.390	600	8350			2000	178
.975	.250	650	9000			2200	191
1.0	0	700	9650			2400	203
		750	10350			2600	215
		800	11150			2800	226
$WK1 = \frac{601.17\ CDT}{PTFA}$		850	12000			3000	238
		900	13000				
		950	14150				
		1000	15450				

L/CFA INLET TEST, DATA REDUCTION TABLES ~ TABLE 1

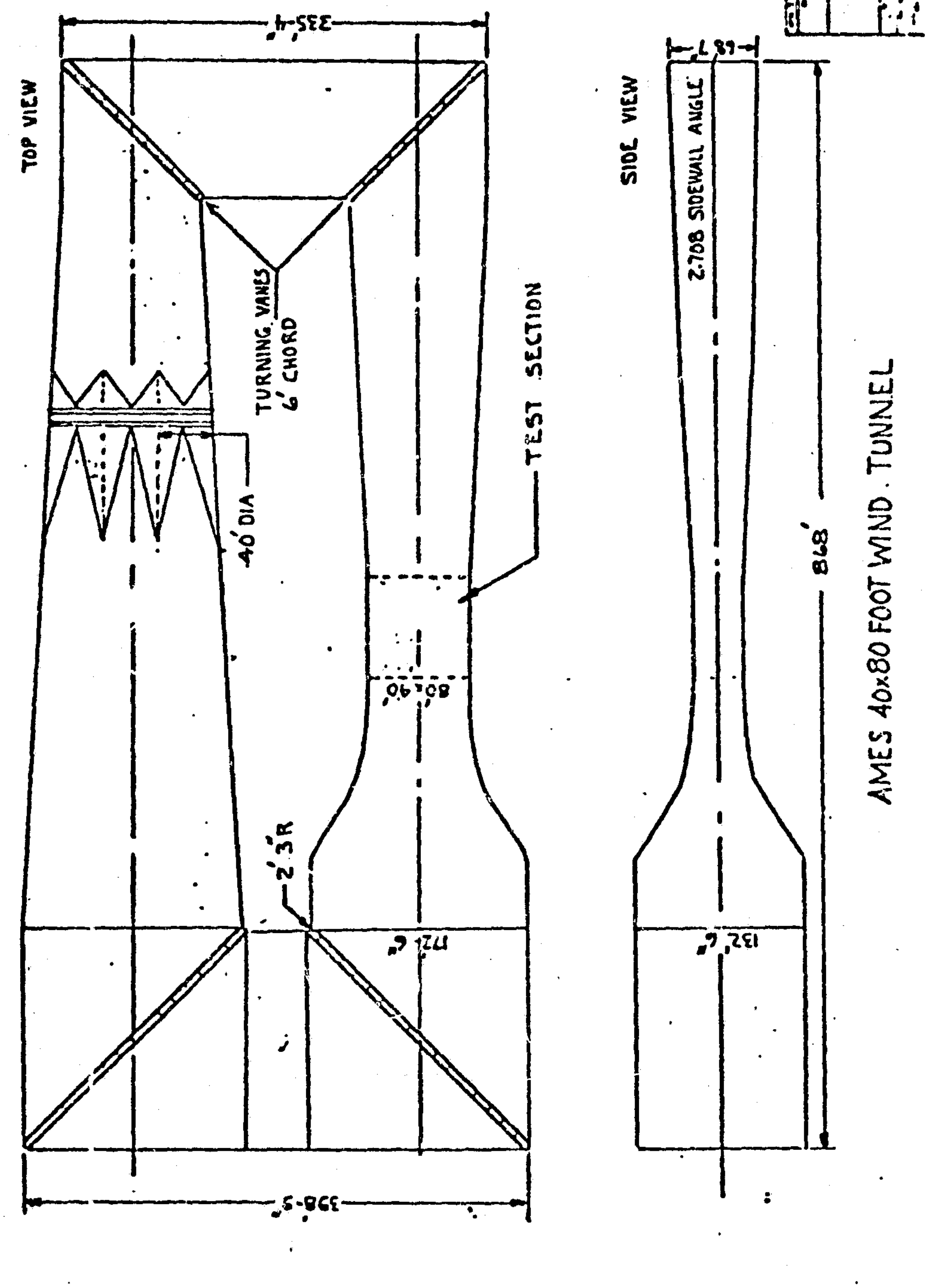

FIG 1

NASA-ARC 40'x80' WIND TUNNEL

T6-6094

			REVISED	DATE		
CALC					TEST MODEL INSTALLED	FIG 2
CHECK					IN THE 40'x80' WT	
APPD						T6-6094
APPD					THE BOEING COMPANY	PAGE 29

CALC			REVISED	DATE	AFT VIEW, 0° ANGLE OF ATTACK	FIG 3
CHECK						T6-6094
APPD					THE BOEING COMPANY	PAGE 30
APPD						

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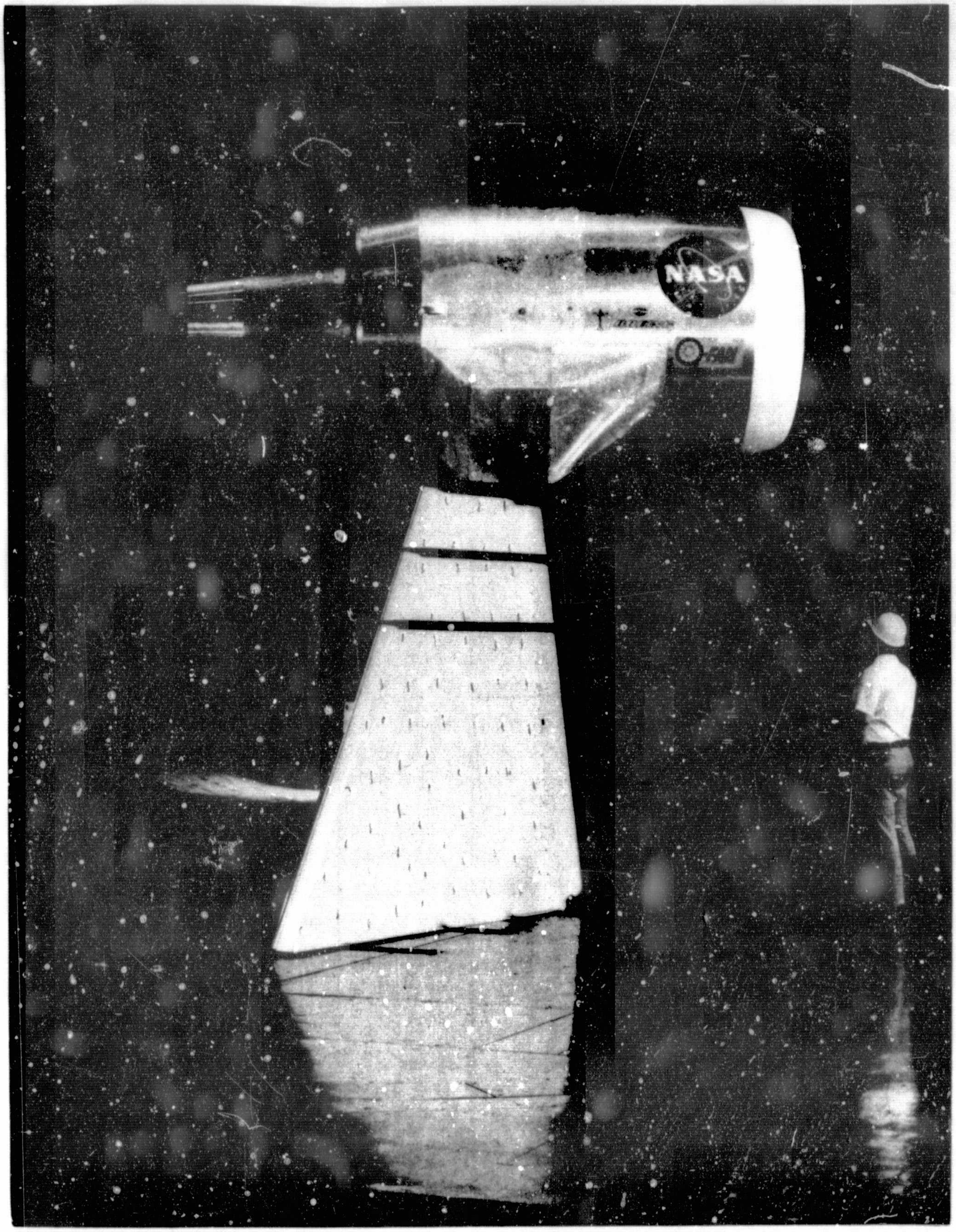

CALC			REVISED	DATE	60° ANGLE OF ATTACK	FIG 4
CHECK						T6-6094
APPD						
APPD					THE BOEING COMPANY	PAGE 31

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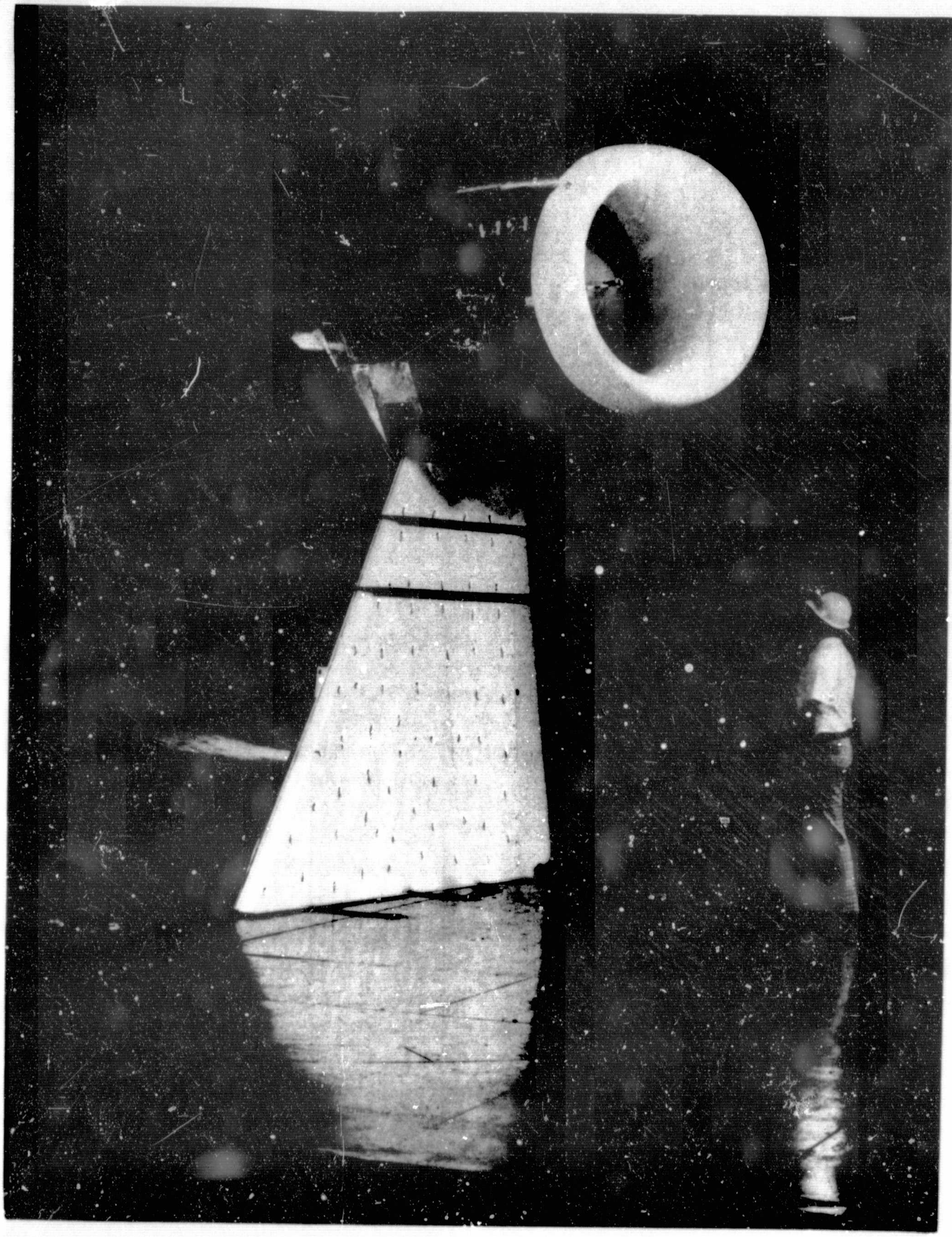
6-7000



CALC			REVISED	DATE	120° ANGLE OF ATTACK	FIG 5
CHECK						T6-6094
APPD					THE BOEING COMPANY	PAGE 32
APPD						

CALC			REVISED	DATE	MODEL ASSEMBLY AT T-1	FIG 6
CHECK						T6-6094
APPD						
APPD					THE BOEING COMPANY	PAGE 33

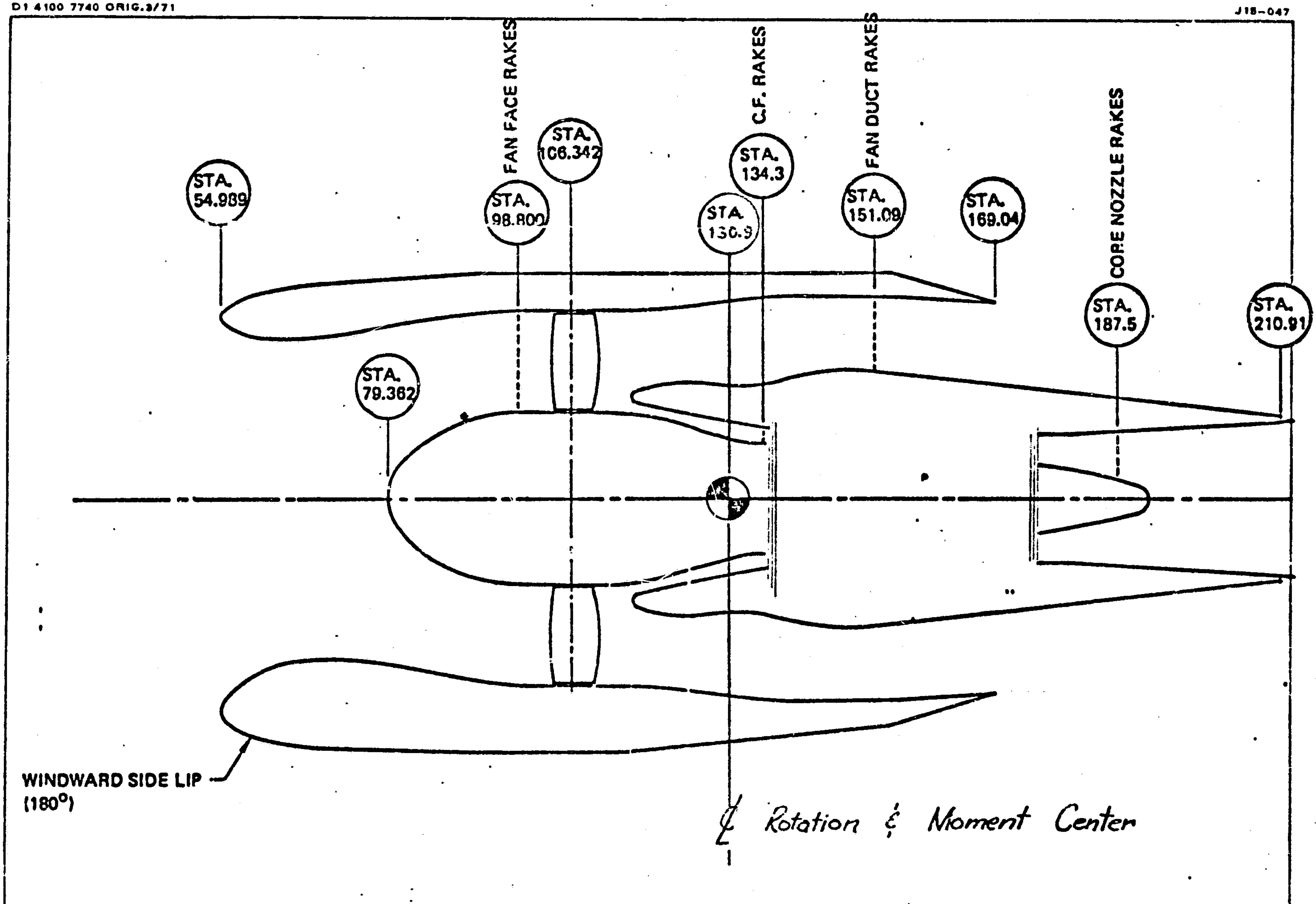


Figure 7, Model Schematic

REV SYM

INLET COWL INSTRUMENTATION ~ FIG 8

LEEWARD (0°) COWL STATIC PRESSURES

	PC No	STA	RAD	S_1	S_2	
EXTERNAL	1	58.405	29.288	4.477		
	2	56.271	28.324	2.131		
	3	55.366	27.599	.969		
	4	55.047	27.070	.348		
HI	5	54.989	26.721	0		
INTERNAL	6	55.007	26.510	.218		
	7	55.105	26.177	.565		
	8	55.289	25.847	.944		
	9	55.564	25.519	1.372		
	10	56.363	24.908	2.380		
	11	57.870	24.228	4.036		
	12	59.986	23.704	6.218		
	13	63.204	23.441	9.450	37.063	REF
	14	67.213	23.575		33.051	
	15	71.362	23.951		28.885	
	16	77.362	24.781		22.827	
	17	83.362	25.761		14.748	
	18	92.362	27.048		7.655	

WINDWARD (180°) COWL STATIC PRESSURES

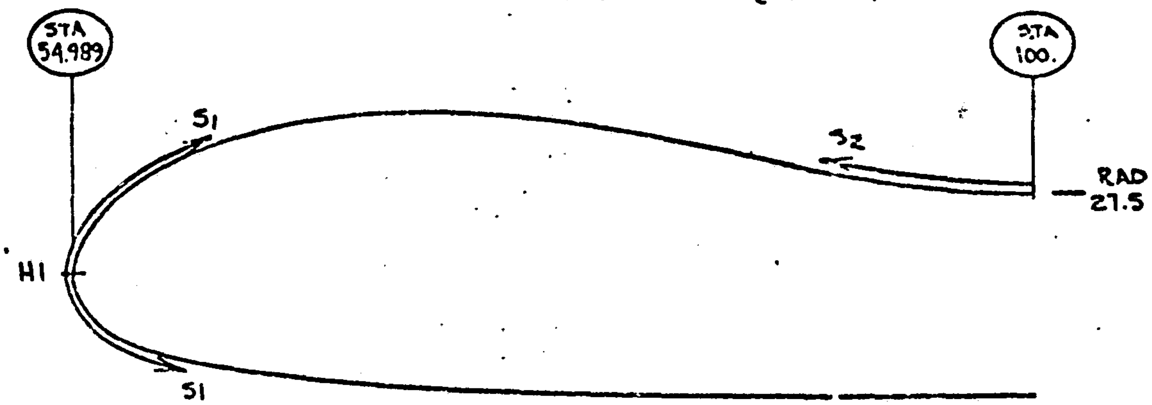
	PC NO.	STA	RAD	S_1	S_2	
EXTERNAL	19	58.405	34.656	5.314		
	20	56.271	33.623	2.933		
	21	55.366	32.586	1.549		
	22	55.047	31.699	.604		
HI	23	54.989	31.098	0		
INTERNAL	24	55.007	30.753	.345		
	25	55.105	30.246	.862		
	26	55.289	29.729	1.411		
	27	55.564	29.202	2.006		
	28	56.363	28.171	3.312		
	29	57.870	26.898	5.287		
	30	59.986	25.691	7.726		
	31	63.062	24.550	11.009		
	32	67.213	23.703	15.249		
	33	71.362	23.441	19.409	28.980	REF
	34	77.362	23.901		22.958	
	35	83.362	24.982		16.860	
	36	92.362	26.788		7.680	

SIDE COWL STATIC PRESSURES

PC NO.	STA	RAD	θ
37	68.690	23.617	90°
38	68.690	23.617	270°

S1 ~ SURFACE DISTANCE FROM HILITE (STA 54.989)

S2 ~ SURFACE DISTANCE FROM FAN FACE (STA 100)



FAN FACE COWL STATIC PRESSURES

PC NO	STA	RAD	S2	θ°
39	98.800	[1]	1.200	15.71
40	↓	↓	↓	67.14
41				118.57
42				170.00
43				221.43
44				272.86
45				324.29

[1] 27.5" NOMINAL

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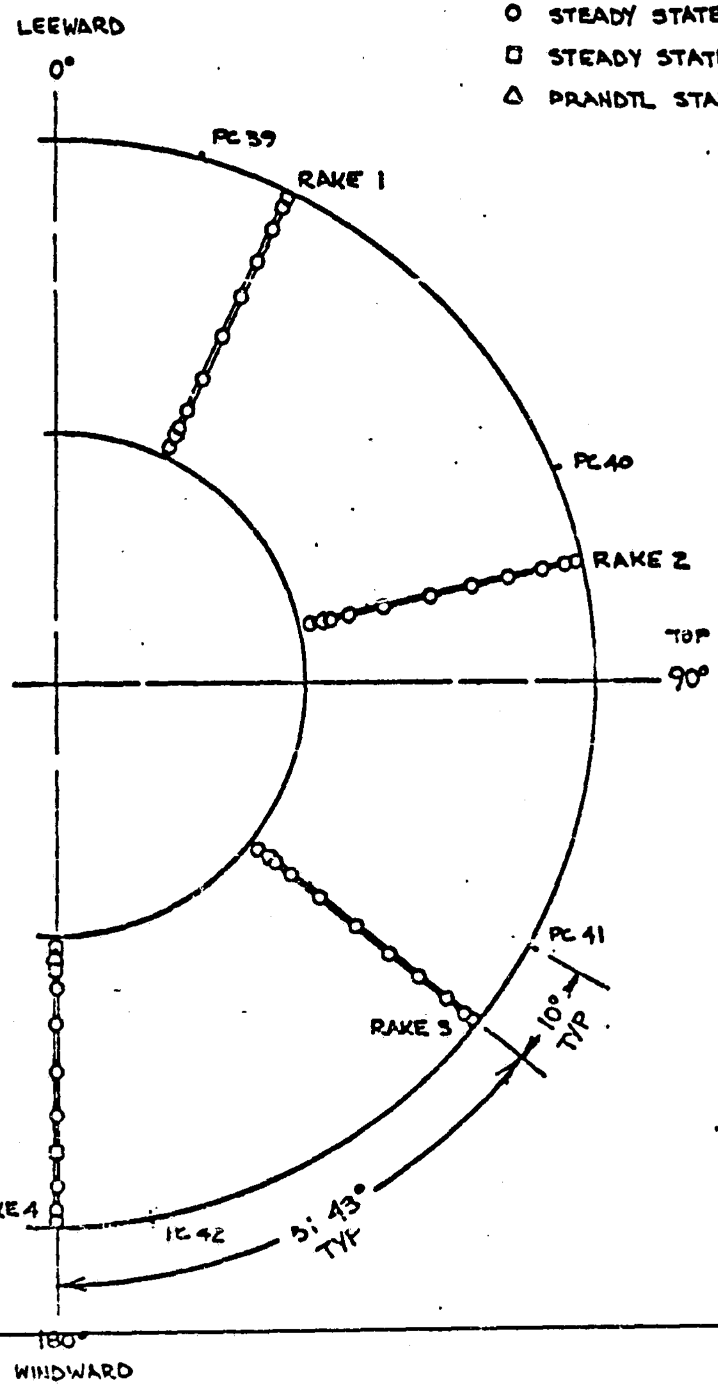
J18-047

REV SYM

O STEADY STATE TOTAL PRESSURE PROBE (PTFX)
□ STEADY STATE AND DYNAMIC TOTAL PROBES (SIDE BY SIDE) (PTFX, PDFX)
△ PRANDTL STATIC PROBE (PPX)

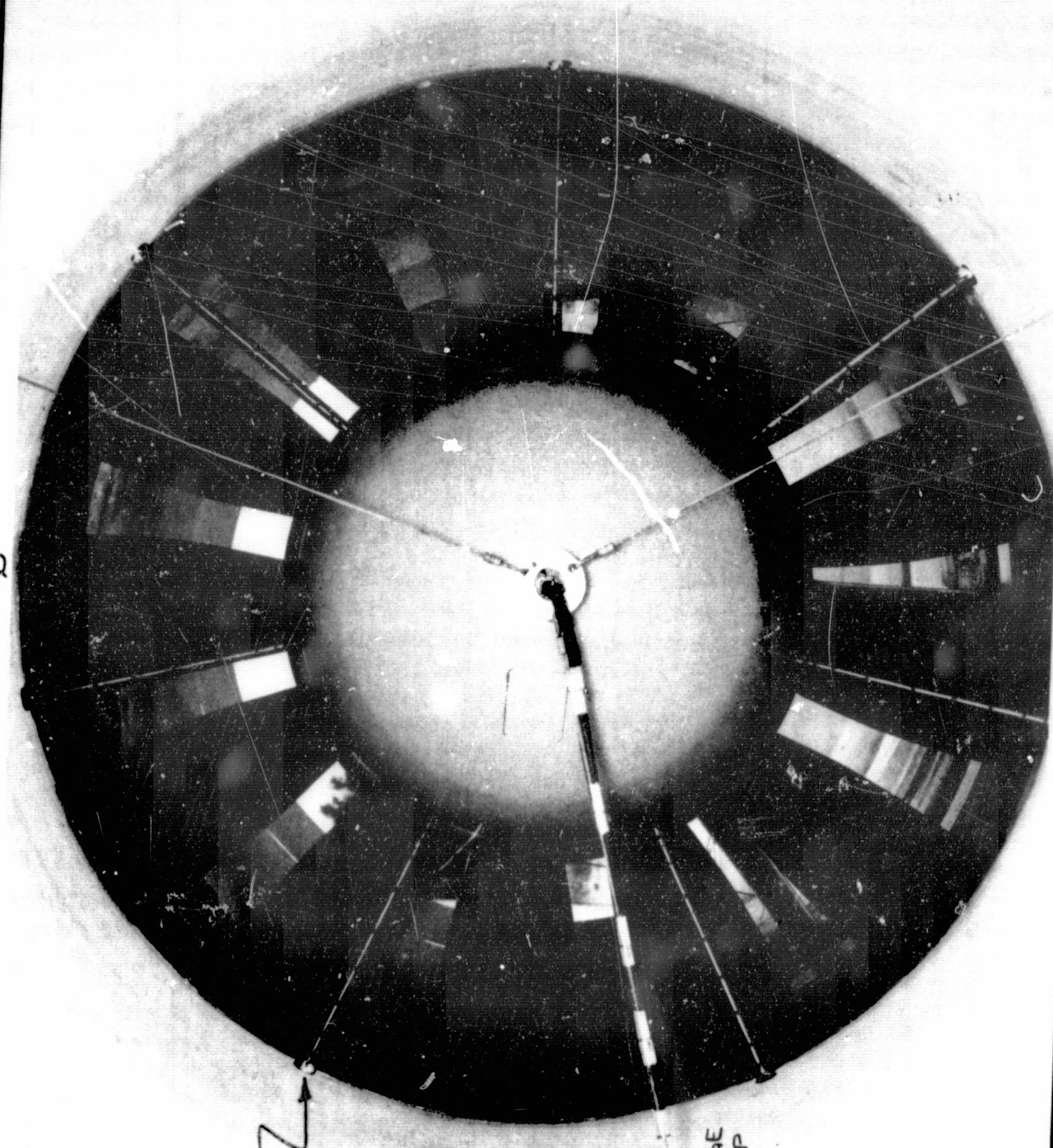
FAN FACE INSTRUMENTATION ~ FIG. 9



FAN FACE RAKE PROBE COORDINATES AND NUMBERING

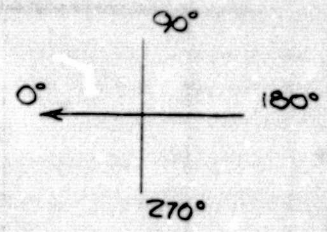
	RAKE 1	RAKE 2	RAKE 3	RAKE 4	RAKE 5	RAKE 6	RAKE 7	RING RADIUS	% AREA FOR RING
RING 1	PTF 1	PTF 11	PTF 21	PTF 31	PTF 41	PTF 51	PTF 61	27.228	5%
RING 2	2	12	22	32	42	52	62	26.676	5%
RING 3	3	13	23	33	43	53	63	25.537	15%
RING 4	4	14	24	34 ①	44	54	64	23.725	15%
RING 5	5	15	25	35	45	55	65	21.763	15%
RING 6	6	16	26	36	46	56	66	19.606	15%
RING 7	7	17	27	37	47	57	67	17.180	15%
RING 8	8	18	28	38	48	58	68	15.351	5%
RING 9	9	19	29	39 ②	49	59	69	14.350	5%
	PP1	PP2	PP3	PP4	PP5	PP6	PP7	13.797	—
RING 10	10	20	30	40 ③	50	60	70	13.237	5%
RAKE ANGLE	25.71°	77.14°	128.57°	180.00°	213.43°	282.86°	334.29°		

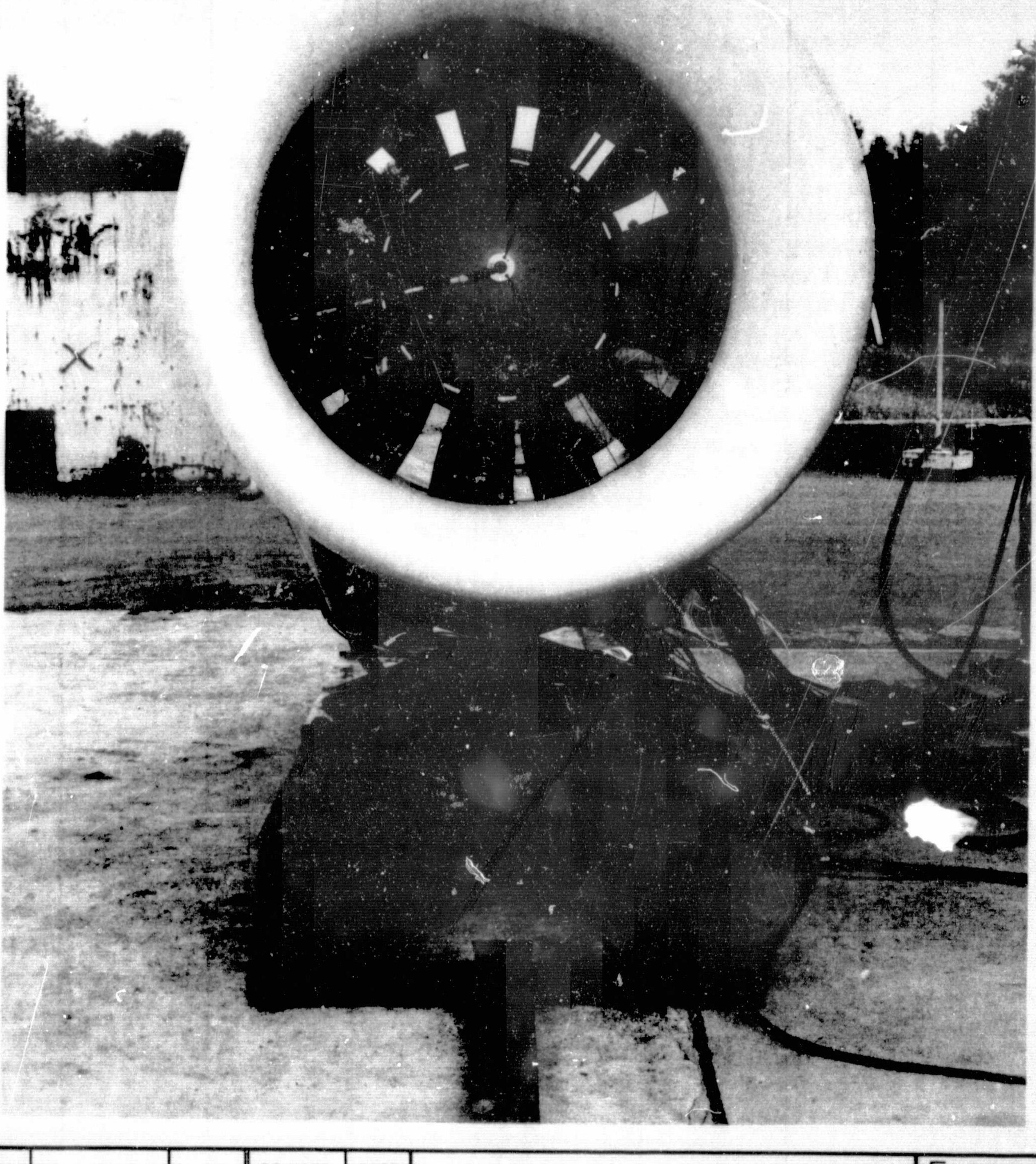
① PDF 1
② PDF 2
③ PDF 3
} DYNAMIC TOTAL PRESSURE PROBE MOUNTED SIDE BY SIDE WITH STEADY STATE PROBE



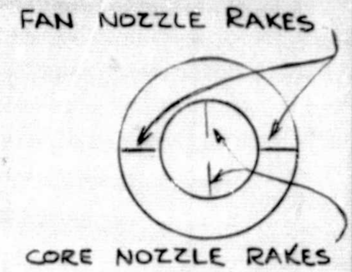
CONT NEXT PAGE

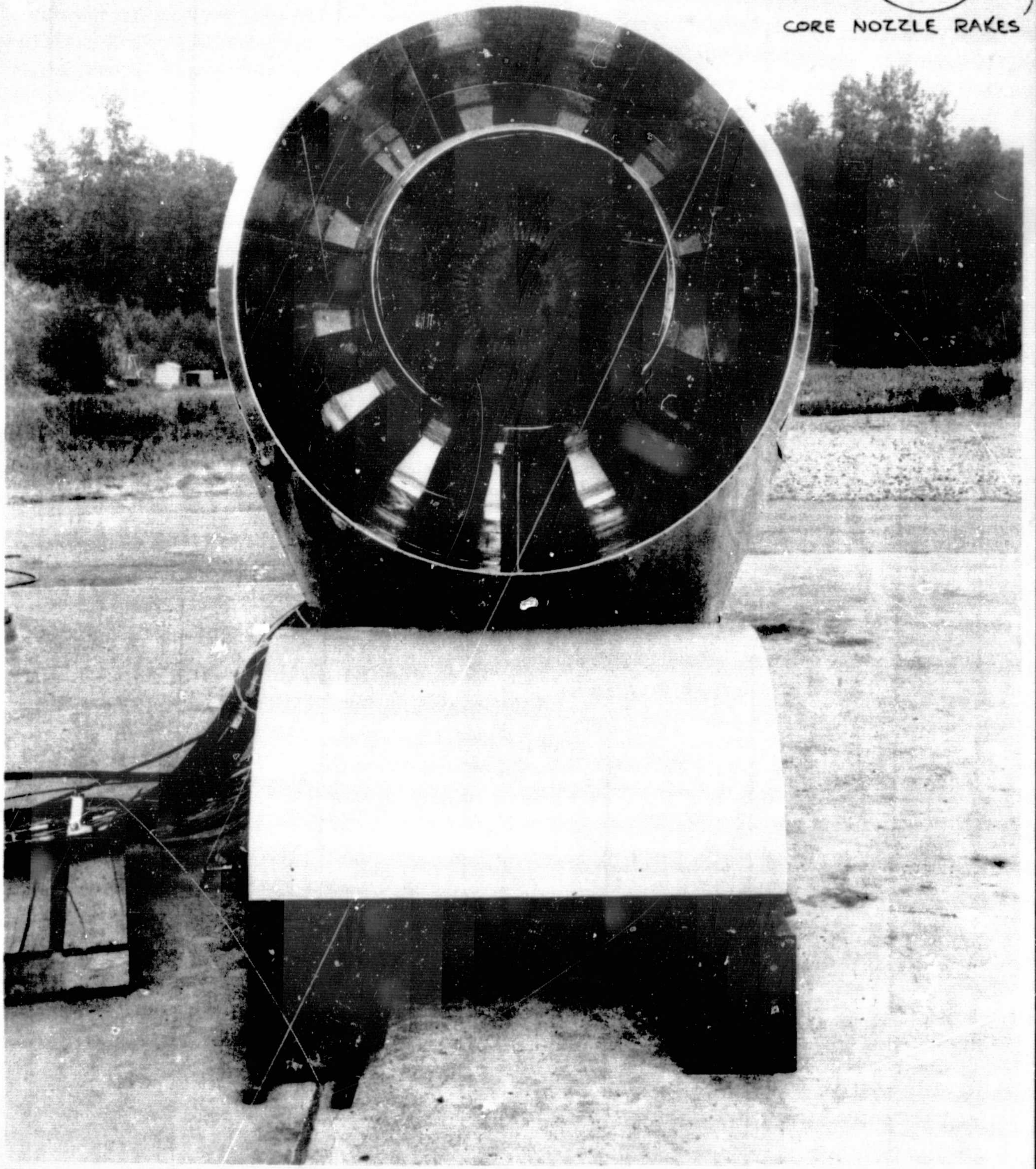
CALC			REVISED	DATE		
CHECK					FAN FACE ~ FRONT VIEW	FIG 10
APPD						T6-6091
APPD					THE BOEING COMPANY	PAGE 37





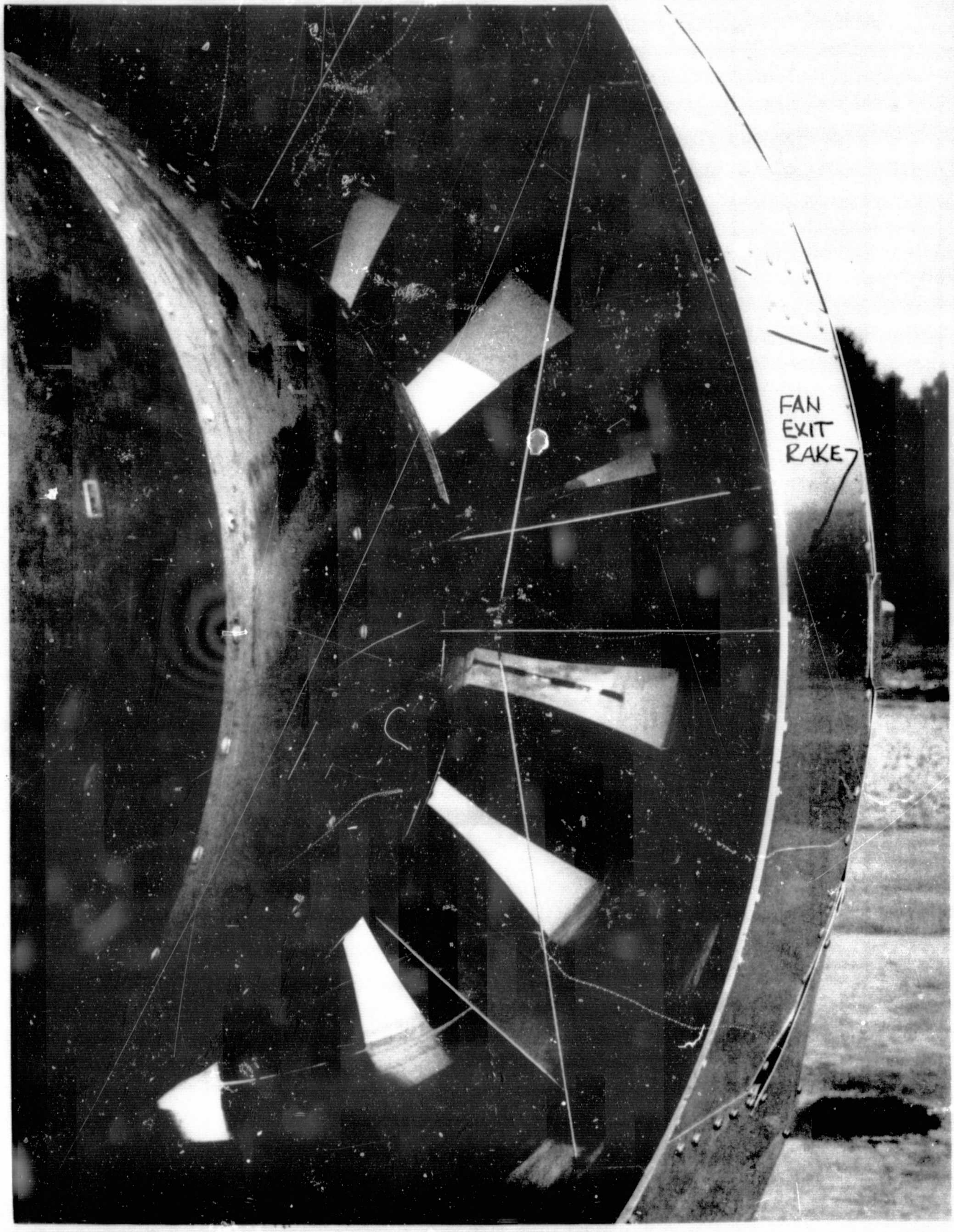
CALC			REVISED	DATE	FAN FACE ~ FRONT VIEW	FIG 10 CONT.
CHECK						T6-6094
APPD						
APPD					THE BOEING COMPANY	PAGE 38





CONT NEXT PAGE

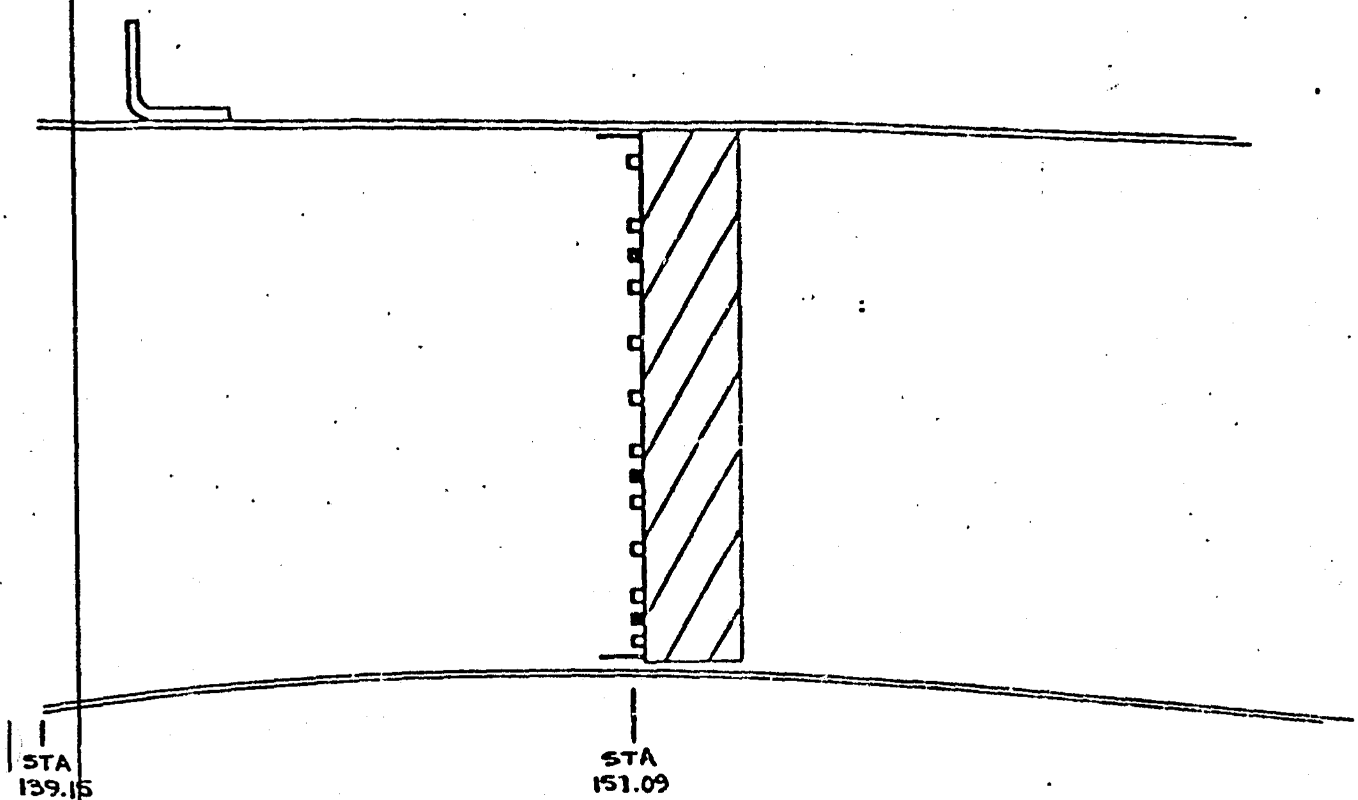
CALC			REVISED	DATE	AFT VIEW	FIG 11
CHECK					CORE ENGINE / FAN NOZZLES	T6-6094
APPD						
APPD					THE BOEING COMPANY	PAGE 39



CALC			REVISED	DATE	AFT VIEW	FIG 11 CONT.
CHECK						T6-6094
APPD						
APPD					THE BOEING COMPANY	PAGE 40

1. Cowl wall static pressure tap (PFD) @ STA 114.000, 180° (MATCHES PC42)

2. Existing H/S fan duct rakes @ STA 151.09, 0° & 180°



0° PROBES	180° PROBES	RADIUS STA 151.09	ΔA/AR
NOZZLE WALL	NOZZLE WALL	29.36	
PM1	PM3	29.26	
PTM1	PTM11	28.73	.142
PTM2	PTM12	27.40	.134
TTM1	TTM4	26.78	
PTM3	PTM13	26.16	.121
PTM4	PTM14	24.98	.110
PTM5	PTM15	23.86	.100
PTM6	PTM16	22.79	.091
TTM2	TTM5	22.28	
PTM7	PTM17	21.77	.083
PTM8	PTM18	20.78	.077
PTM9	PTM19	19.83	.071
TTM3	TTM6	19.37	
PTM10	PTM20	18.91	.073
PM2	PM4	18.61	
CORE CASE	CORE CASE	18.36	

ΔA: area assigned to total pressure probe
AR: flow area at rake face (STA 151.09)
= 1649 in²

FAN DUCT EXIT RAKES ~ FIG. 12

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VIEW LOOKING FROM FRONT TO REAR

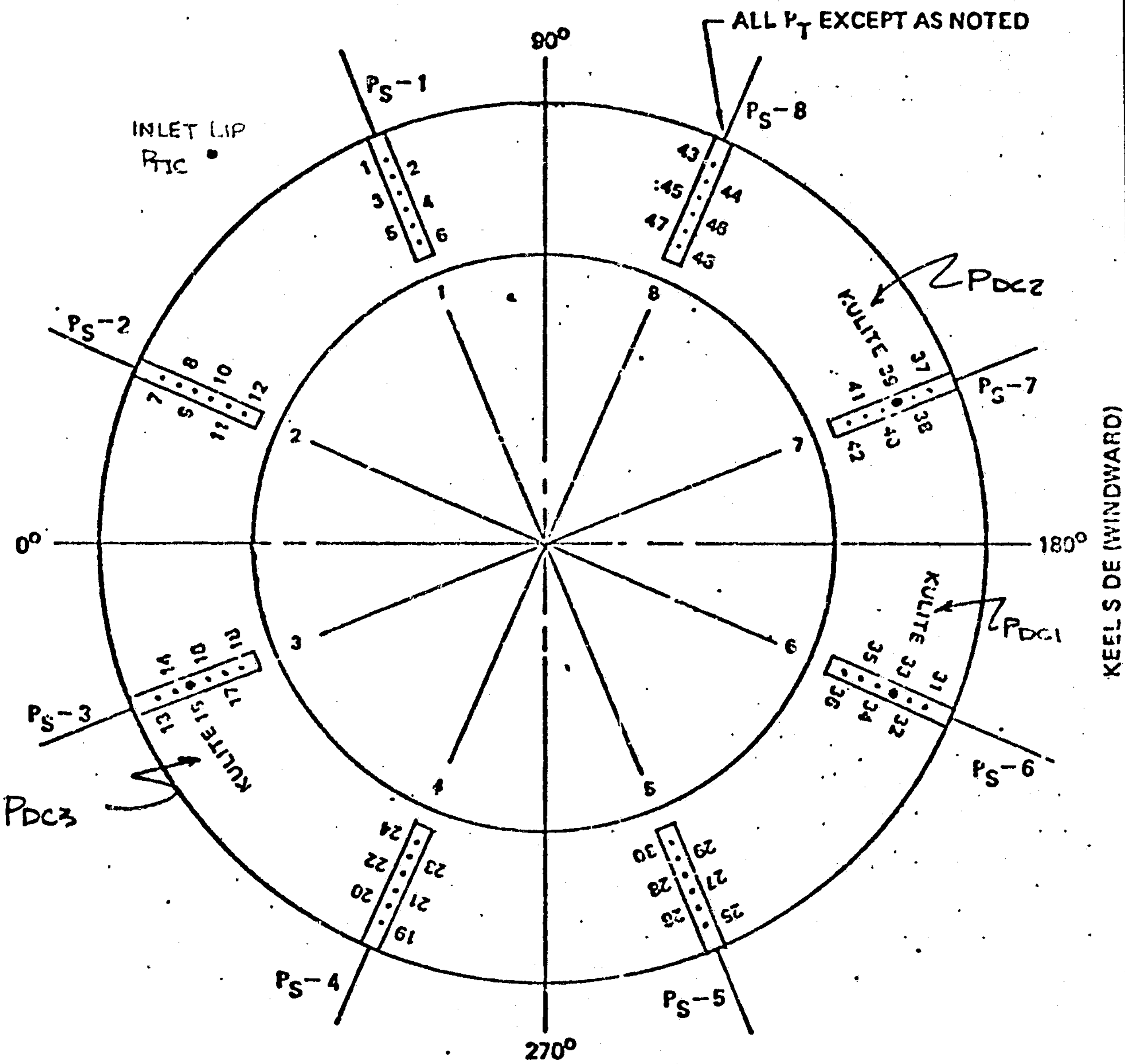
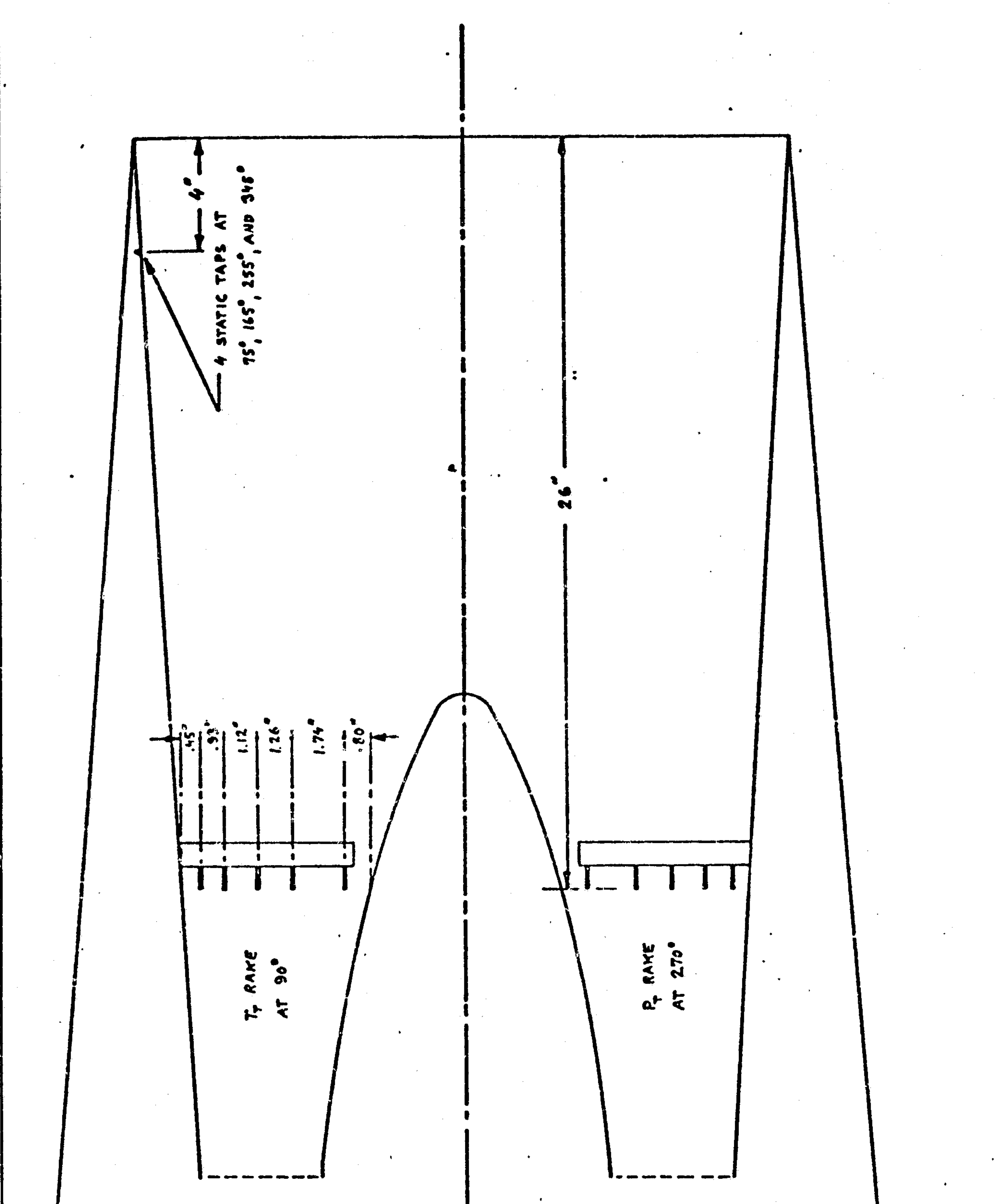
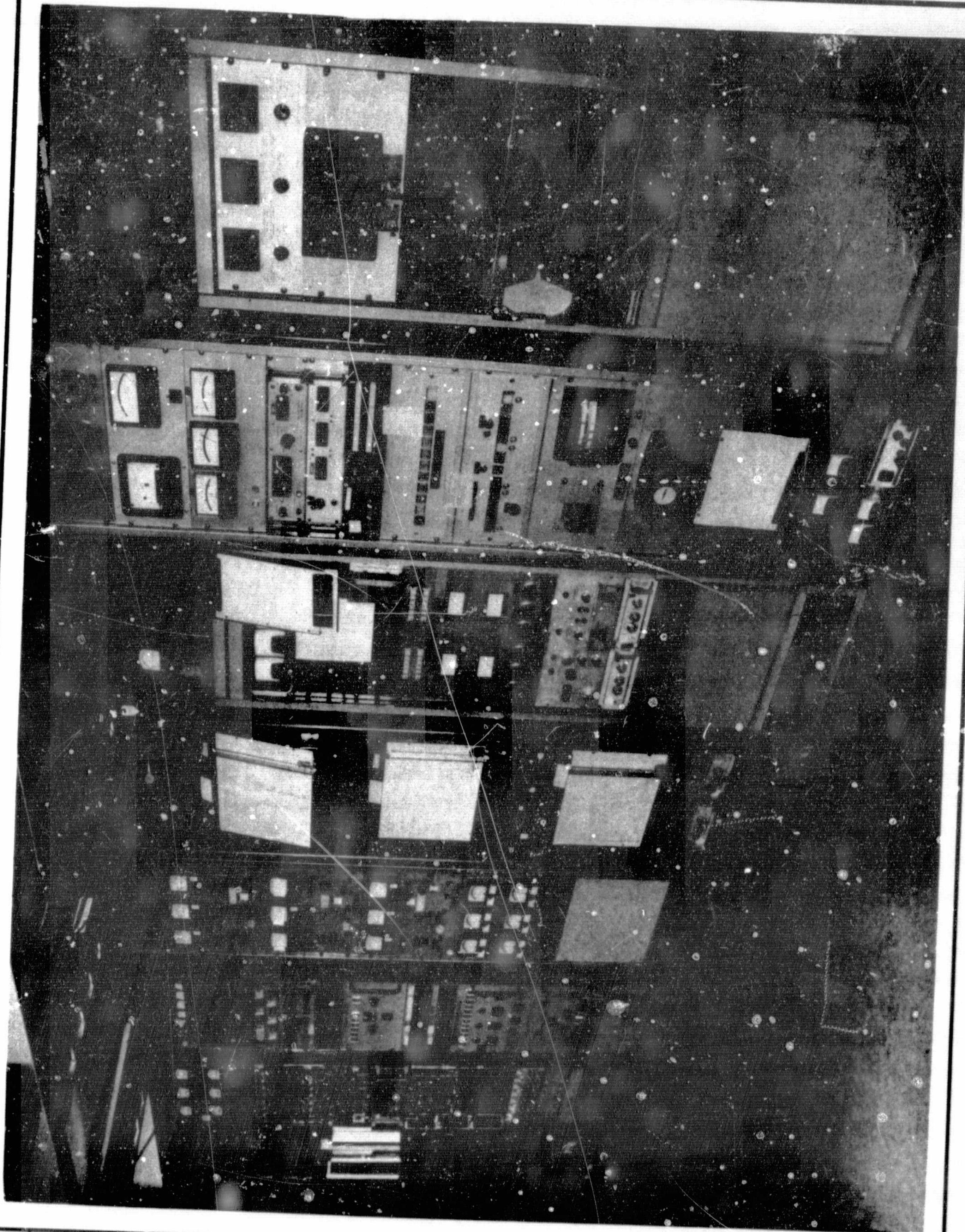


FIGURE 13

CORE ENGINE COMPRESSOR FACE INSTRUMENTATION



CORE ENGINE NOZZLE RAKES~ FIG 14



CALC			REVISED	DATE	INSTRUMENTATION SYSTEM DATA RECORDING, DISPLAY AND SYSTEM CONTROL & MONITORING	FIG 15
CHECK						T6-6094
APPD					THE BOEING COMPANY	PAGE 44
APPD						

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L/CFA Q-FAN INLET TEST
(ENGL

RUN	CORR	TEST NO.	VOO	ALPHA	1a QPSF	1a PTO
32.	2.	2532.	75.2	0.00	18.0	14.62

2 WK1	4 PTFA	5 DISF	FBA	7 WKF	PLA	9 WKE
387.8	0.9992	0.0333	51.4	335.0	73.6	23.9
3 W1	**20 WK2**	**4a PTFAV**	**22 FPR**	**6 WF**	**8 WE**	**24 KN1**
376.3	375.5	14.609	1.097	352.5	23.6	17106
21 W3	**19 W2**	**7b PTMAV**	**23 VM**		**9a TTC**	**25 KN2**
376.0	364.4	16.022	1157.		543.6	13698

STEADY STATE RAKE PRESSURES

FAN FACE

	RK25.7	RK77.1	RK126.	RK180	RK213	RK282	RK334	FAN RK1
19a	0.9112	0.9126	0.9152	0.9130	0.9156	0.9081	0.9101	6a 0.9
	0.9724	0.9713	0.9731	0.9682	0.9775	0.9719	0.9719	1.0
	1.0004	1.0009	1.0003	1.0008	1.0010	1.0006	1.0006	1.
	1.0009	1.0011	1.0006	1.0008	1.0010	1.0009	1.0007	1.
	1.0008	1.0012	1.0009	1.0008	1.0009	1.0009	1.0009	1.
	1.0008	1.0010	1.0007	1.0214	1.0010	1.0007	1.0009	7c 1.
	1.0008	1.0008	1.0010	1.0011	1.0010	1.0010	1.0009	1.
	1.0008	1.0009	1.0009	1.0012	1.0009	1.0008	1.0008	1.
	1.0008	1.0010	1.0010	1.0008	1.0008	1.0011	0.9994	1.
	1.0010	1.0009	1.0008	1.0008	1.0008	1.0009	0.9949	1.0
	0.9996	0.9996	1.0001	1.0001	0.9979	1.0001	0.9863	1.0
19b	0.9069	0.9084	0.9089	0.9085	0.9069	0.9073	0.9062	0.0

INLET COWL STATIC PRESSURES — 26 COWL SURFAC

1)	1.0006	0.9999	0.9842	0.9421	0.6997	0.0000	0.0141
6)	0.8723	0.8420	0.8364	0.8250	0.8349	0.4462	0.5019
11)	0.8276	0.8407	0.8540	0.8768	0.8845	0.5271	0.5041
16)	0.8932	0.9039	0.9143	0.9961	1.0001	0.4050	0.3827
21)	0.9994	0.9902	0.9794	0.9737	0.9636	0.0298	0.1185
26)	0.9540	0.9440	0.9173	0.9045	0.6956	0.2602	0.2860
31)	0.8675	0.9328	0.8449	0.8635	0.8853	0.4553	0.3169
36)	0.9159	0.8599	0.6568	0.9112	0.9126	0.3564	0.4690
41)	0.9152	0.9130	0.9156	0.9481	0.9101	0.3580	0.3629

CORE NOZZLE -TOTAL- PSIA 18a — -STATIC- PSIA 17

14.463 14.472 14.834 14.834 15.086 — 14.499 14.531 14.

27 FORCE BALANCE (REF FIGURE 17)

LBS				FT-LBS	
FX	FY	FZ	FXZ	QZ	Q
-3330.0	-69.0	-167.0	3334.2	-384.0	-9

FOLDOUT FRAME

N INLET TEST NASA-ARC 40X80-FOOT WIND TUNNEL
(ENGLISH UNITS)

GPSF	1a PTO	1 PO	TTO	CONF	DATE	PBAR
18.0	14.620	14.495	545.0	1.	100176.	14.622

SDDS MEASURED TUNNEL PARAMETERS (BACKUP)

PLA	9 WKE	10 PTCA	11 DISC	15 VN	PTT	PST	TTT
73.6	23.9	1.0161	0.0302	233.	14.641	14.509	543.6

WE	24 KN1	12 EP	14 FN	TT7	PTIC	28 WK1A
23.6	17106.	1965.	173.3	1784.5	1.0287	29.9

TTC	25 KN2	12a ET	13 FKN	18 PTNA
543.6	13698.	736.	171.4	14.738

	RK334	6a FAN NOZZLE RK1	FAN NOZZLE RK2	COMPRESSOR FACE RK1	RK2	RK3	RK4	RK5	RK6	RK7	RK8
1	0.9101	0.9997	1.0062	0.9465	0.9469	0.9472	0.9481	0.9487	0.9482	0.9489	0.9461 8a
9	0.9719	1.0880	1.0883	1.0036	1.0215	1.0057	1.0051	1.0090	1.0025	1.0071	0.9977
6	1.0706	1.1136	1.1126	1.0045	1.0186	1.0272	1.0266	1.0224	1.0252	1.0236	1.0219
9	1.0207	1.1215	1.1156	1.0221	1.0164	~~1.0268~~	1.0285	1.0241	~~1.0185~~	~~1.0166~~	1.0235 9b
9	1.0029	1.1212	1.1138	1.0267	1.0164	1.0268	1.0241	1.0186	1.0185	1.0188	1.0196
7	1.0029 7c	1.1170	1.1091	1.0217	1.0128	1.0179	1.0201	1.0127	1.0161	1.0138	1.0139
0	1.0009	1.1499	1.1000	1.0130	1.0115	1.0102	1.0122	1.0041	1.0078	1.0080	1.0056
8	1.0008	1.1073	1.0923								
1	0.9994	1.1034	1.0823								
9	0.9949	1.0934	1.0738								
1	0.9863	1.0694	1.0607								
3	0.9362	0.0000*	0.0000*								

Electrically Teed (3 PLS) - Kulite locations

7a TEMPERATURES FAN DUCT

RK1	RK2
560.7	558.8
558.3	555.9
556.0	552.6

DYNAMIC RMS

FAN	COMP
0.0220	0.0025
0.0084	******
0.0444	0.0002

26 COWL SURFACE MACH NUMBERS

0.0000	0.0141	0.1511	0.2931	0.3915
0.4462	0.5019	0.5082	0.5316	0.5143
0.5271	0.5041	0.4603	0.4375	1.0224
0.4050	0.3827	0.3600	0.0749	0.0000
0.0298	0.1185	0.1725	0.1956	0.2307
0.2602	0.2880	0.3533	0.3814	0.4001
0.4553	0.3169	0.4966	0.4628	0.4208
0.3564	0.4694	0.4715	0.3670	0.3639
0.3580	0.3629	0.3572	0.3737	0.3694

* PROBES/SENSOR INOPERABLE IGNORE DATA

STATIC- PSIA 17

.499 14.531 14.513 14.563

* -TEMP- DEG. R 16 *

1554.2 1554.0 535.0 1404.8 1414.1

Electrically Teed

FT-LBS

QZ	QY	QX
-384.0	-987.0	139.0

SAMPLE DATA SHEET - FIGURE 16

FOLDOUT FRAME 2

T6-6094

L/CFA Q-FAN INLET TEST NA
(ENGLIS

RUN NO.	COND NO.	TEST DATE	PAMB	PTTREF	CDA
32.	2.	100176.	14.6220	14.6290	18

ALLISON RADIAL RECOVERY INDEX

RECOVERY(100) 1.0161 RECOVERY(60) 1.0162 RECOVERY(40

ALLISON RADIAL DISTORTION INDEX

KR = 0.0005

ALLISON CIRCUMFERENTIAL RECOVERY INDEX

MINIMUM 120 DEGREE SECTOR = 1.0145 MIDPOINT= 150. D
MAXIMUM 240 DEGREE SECTOR = 1.0168

ALLISON CIRCUMFERENTIAL DISTORTION INDEX

KTHETA = 0.0023

ALLISON COMPOSITE DISTORTION INDEX

KCOMP = 0.0023

REP

FOLDOUT FRAME 1

INLET TEST NASA-ARC 40X80-FOOT WIND TUNNEL
(ENGLISH UNITS)

TREF	CDAY	CMONTH	CYEAR
.6290	18.	10.	76.

2 RECOVERY(40) 1.0157

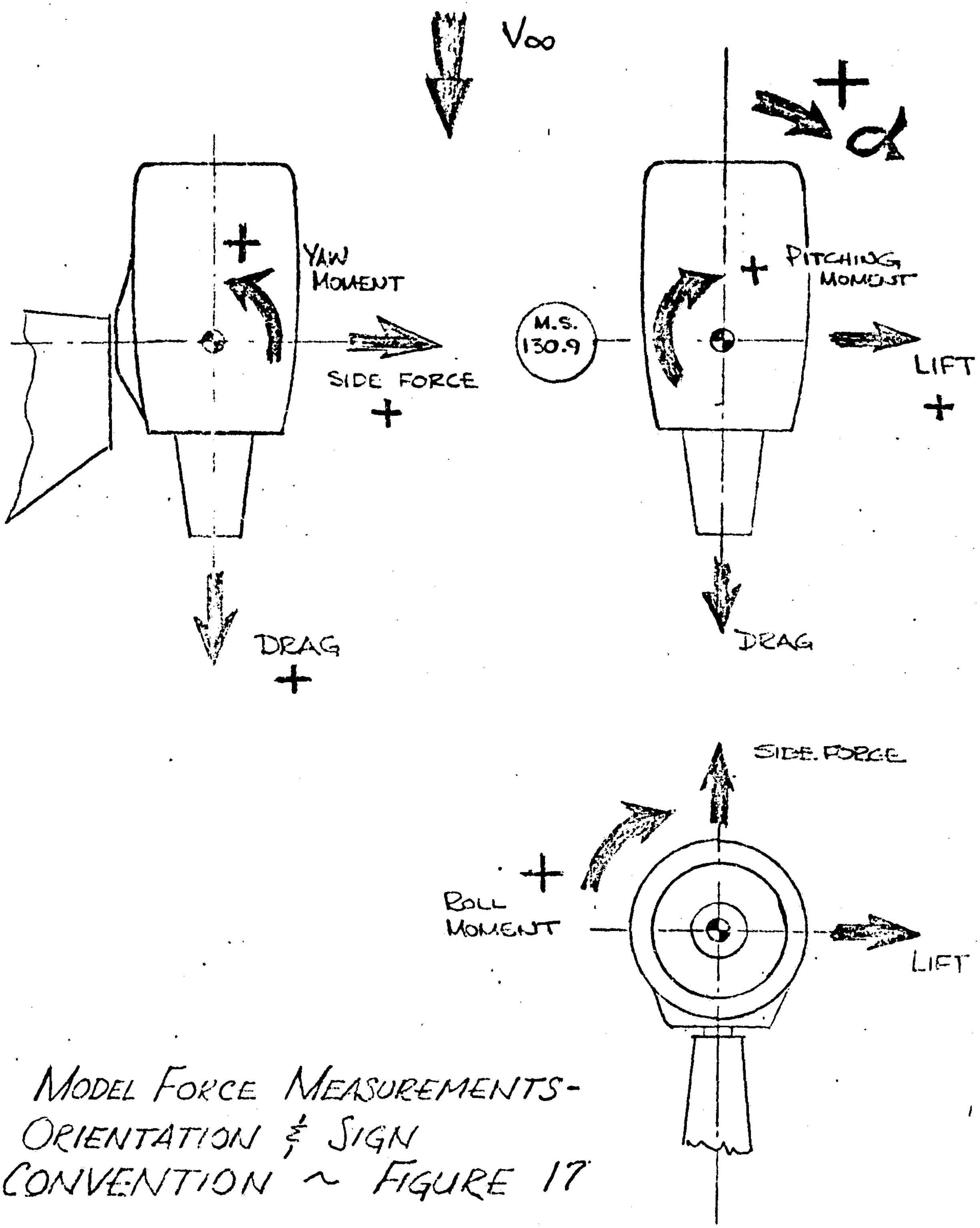
NT= 150. DEGREES

REF SUBROUTINE EXTRA 6.01
APPENDIX B

SAMPLE DATA SHEET ~ FIGURE 16
CONT.

FOLDOUT FRAME 2 76-6024

Pg 46



MODEL FORCE MEASUREMENTS - ORIENTATION & SIGN CONVENTION ~ FIGURE 17

J18-047

D1 4100 7740 ORIG.3/71

Appendix A

Instrumentation Report, Test 2532

October 19, 1976
B-8230-636

To: W. M. Shain

cc: J. Syberg

Subject: Instrumentation Report, Test 2532 - "Quiet Fan Engine Inlet Evaluation For Lift/Cruise For Airplane."

Reference: Your Test Instrumentation Request #1620 dated 3-26-76

For the record we attach simplified block diagrams and give below pertinent details of the instrumentation used in the subject test, which was performed at the NASA Ames 40' x 80' Wind Tunnel, Moffett Field, California.

A. SENSORS

Chnl.	Sym.	Variable	Description	S/N	Sensitivity
100*	S/V A	Scanivalve "A"	Statham PM131-25D	22188	1000 cts/psi
101*	S/V B	" "B"	"	35781	"
102*	S/V C	" "C"	"	50888	"
103*	S/V D	" "D"	"	57573	"
300**	S/V E	" "E"	"	57571	"
350***	S/V F	" "F"	Statham PM 856-25D	333	"
070	Ptt	Press, tunnel total	" PM6-1 D	6329	"
071	Pst	" " static	" PM6-2.5D	11239	"
072	Ttt	Temp, " total	Rosemount 104MA	A4664	1000 cts/°F
084	Pdc1	Press, dyn, core	Kulite XQL093-15	307	33,334 cts/psi
085	Pdc2	" " "	" "	310	"
087	Pdf1	" " fan	" 2766-5	28	"
088	Pdf2	" " "	" "	48	"
089	Pdf3	" " "	" "	30	"

*and every 4th channel thereafter ***and the following 10 channels
**and the following 47 channels

Hamilton-Standard provided the sensors for N1 rpm, N2 rpm, exhaust gas temp., torque, power lever angle, fan blade angle, and 12 other temperatures. NASA Ames provided the sensor for Alpha (Model angle of attack).

In addition we provided other sensors for displaying certain key parameters on x-y plotters. These were:

Parameter	Sensor	S/N	Remarks
Pc 13	CEC 4-326-15A	5470	Fed into a pressure averager and the numerator of an analog divider
Pc 33	"	5512	
Pc 37	"	5559	
Pc 38	"	9072	
Ptt (abs)	Statham PA 822-15A	4603	Denom. of Analog Divider
Inlet Profile	" PM 131-15D	8768	Sens.: - 1 psi per inch
Rake Posn.	Resistor Tree	None	Sens.: - 1 port per step

B. SIGNAL CONDITIONERS

1. Pressures: Twenty power & balance units, NLS model 1400 or Sigma Model SC-610, were used. Their excitation voltages were as follows:

Appendix A
TR-6094

S/V "A" - 4.678 VDC	Ptt - 0.410 VDC	Pfd3-13.103 VDC
" "B" - 5.770 "	Pst - 1.120	Pc13 - 1.468
" "C" - 5.172 "	Pdc1 - 5.968	Pc33 - 1.491
" "D" - 5.316 "	Pdc2 - 4.620	Pc37 - 1.500
" "E" - 5.306 "	Pdf1 - 10.163	Pc38 - 1.490
" "F" - 8.81C "	Pdf2 - 10.581	Ptt(abs) - 4.391

2. Dynamic Pressures: These were designated Pdc 1, Pdc 2, and Pdf1 thru Pdf3. After leaving the power & balance units mentioned above, their signals were passed thru DC-blocking capacitors then magnified 100 times by Preston Model 8300 amplifiers. These were then converted to RMS values by Boeing type 64-32684 RMS meters (which were set on the 300 MV range), then attenuated by a factor of ten before being recorded on the data system. These were also displayed on small monitor scopes (Calico Model 7000) and on pointer type indicators (Honeywell MM3, 0-1MA range).

3. Other Parameters

Variable	Signal Conditioner	Range	Remarks
N1 RPM	Vidar 326 F/V Converter	20KHZ	Used + 100 attenuator
N2 RPM	"	"	"
EGT & Ttn	Pace BRJ14-K Ref. Jct.		150° F Ref. Temp.
Ttm & Ttc	Pace BRJ14-E " "		"

In addition, the signals provided by Hamilton Standard were buffered by Preston 8300 amplifiers set at unity gain, then attenuated to fit the data system's 100 MV range.

C. DATA ACQUISITION SYSTEM

Boeing "Standard Digital Data System (SDDS)," Dwg. 64-31305. See attached block diagram.

D. DATA PROCESSING SYSTEM

Boeing "Tulalip Processing System", built around a Digital Equipment Corp. PDP-8/I computer. See attached block diagram.

The software was prepared by BCS' Anne Wangeman and John Benner. The digital programs were listed as "DEC 017", "SRV 017", and "PN 026". In addition two plotter programs were written: "SRV 027" for Inlet Pressure Mapping and "SRV 035" for Mach Plots.

E. MISCELLANEOUS:

1. Engine Controls: Although Hamilton Standard had primary responsibility for this, we helped extensively. Among our contributions were:

(a) Fabricating extension cables
(b) Wiring the motors for lubrication pumps and cooling fans; providing interconnecting control cables for same.
(c) Providing a 400 HZ power supply for, and system calibrating, the transmitter/indicator systems for fuel pressure, oil pressure and gear box oil pressure.

Appendix A
TS-6094
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(d) Providing starter system cables and solenoids.

2. X-Y Plots: Three HP 7001A plotters were provided and set up to measure:

    (a) Cowl Inlet Pressures (averaged) ; Ptt versus Pdfl (RMS)
    (b) Model Angle of Attack versus Pdfl (RMS)
    (c) Fan Face Inlet Pressure versus Port Position

3. Fan Inlet Pressure Rake Stresses: Four strain gage bridges, signal conditioners, monitor scopes and interconnecting cables were provided.

Prepared by RH Kriekenbeck
R.H. Kriekenbeck

Approved by L J Mertz 10/21/76
L.J. Mertz

RHK:sh

REQUESTING ORGANIZATION B-8425

INSTRUMENTATION SUPPORT ORGANIZATION B-8230

TEST INSTRUMENTATION REQUEST

VARIABLE TO BE MEASURED			RANGE		ACCURACY REQUIRED ± F.S.	FREQUENCY OF VARIABLE	SAMPLE RATE REQUIRED	NUMBER OF RECORDING CHANNELS							REMARKS
ITEM NO.	SYM	DESCRIPTION	MIN	MAX		CPS	SPS	OSCIL. SCOPE	STRIP CHART	MANUAL	DIGITAL DATA SYS	MAG TAPE	R_M	X/Y	
1		FAN FACE INST.													
	PTF	TOTAL PRESSURE	10	AMB	±.25						70			2	7 RAKES 10 PROBES PER
	PDF	DYN. TOTAL PRESS-RMS	✓	✓	±1		CONT	3			3			10	CONTINUOUS DISPLAY - KULITES
	PP	PRANDTL STATICS	10	✓	±.25						7			1	
2		INLET COWL INST.													
	PC	COWL STATICS	5	AMB	±.25						36			2	2 ROWS × 18
	PC	MISC. STATICS	✓	✓	✓						2				
	PC	FAN FACE WALL STATICS	10	✓	✓						8				
		ACCELEROMETER	-	10 [illegible]	1%					2					
3		FAN COWL INST.													2 RAKES
	PTM	TOTAL PRESS	10	17							20		2		FPR PTF/PTM
	PM	STATIC PRESS	8	AMB							4				
	TTM	TOTAL TEMP	AMB	140°							6				
4		CORE ENGINE INLET													
	PTC	INLET ENTRANCE TOTAL	12	17							1				(A)
	PIC	✓ ✓ STATIC	6	AMB							1				(A)
	PTC	COMP. FACE TOTALS	12	17							45				8 RAKES 6 PROBES PER
	PDC	DYN. TOTAL PRESS. RMS	✓	✓			CONT	3		-	3				KULITES FURN. BY HS

GENERAL INFORMATION

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PREPARED BY B. Shain 3-26-76
TEST ENGINEER

B D Metz
INSTRUMENTATION ENGINEER

APPROVED BY: J H Reinkenbeck
TEST LEAD ENGINEER 4-12-76

REVISED BY | DATE | REV LTR

TEST NO. 2532 TEST TITLE Q-FAN INLET TEST - FS

IDWA 2B0008
ERA NO. 2B3173 WORK ORDER 5-79970-8050-192061 EN / 5-73587-8052-[illegible]

TEST LOCATION NASA-ARC 40 × 80 WT

SCHEDULE START DATE JULY 19, 76 SCHEDULE COMP. DATE AUG 20 '76

#1620

PAGE 1 OF 3

REQUESTING ORGANIZATION B-8425

INSTRUMENTATION SUPPORT ORGANIZATION B-8230

TEST INSTRUMENTATION REQUEST

ITEM NO	SYM	DESCRIPTION (VARIABLE TO BE MEASURED)	RANGE MIN	RANGE MAX	ACCURACY REQUIRED % F.S.	FREQUENCY OF VARIABLE CPS	SAMPLE RATE REQUIRED SPS	OSCIL	STRIP CHART	MANUAL	DIGITAL AUTO SYS	MAG TAPE FM	D/M	X/Y	REMARKS
4	PFC	COMP FACE STATICS	10	AMB	±.25						6				
	TFC	COMP FACE TOTAL TEMP	AMB	148°	±1						1				(A)
5		CORE ENGINE NOZZLE													
	PTN	NOZZLE TOTAL PRESS	AMB	20	±.25						5				(A)
	PN	NOZZLE STATIC PRESS	10	AMB	±.25						3				(A)
	TTN	NOZZLE TOTAL TEMP	AMB	1000°	±1						5				(A)
6		ON-LINE DATA DISPLAY			±1%										
		3 X/Y PLOTTERS													
		α vs RMS													
		ΔP vs ½(PCN+PCM)/PTT													
		$P_{TFX_{10}}$ vs RADIUS													
7	PTT	PITOT/STATIC PROBE PSID	-.25	0	±.25						1				X-Y PLOTTER & P/R
	PST	PSID	-1.0	0	✓						1				REFERENCE
	TTT	TUNNEL TOTAL	AMB	120°F							1				
8	α	MODEL ANGLE OF ATTACK	0	120°	±.5°						1			1	SPLIT SIGNAL FROM WT SYS.

GENERAL INFORMATION

Appendix A
TO-1094

PREPARED BY B. Shain
TEST ENGINEER

INSTRUMENTATION ENGINEER

APPROVED BY: TEST LEAD ENGINEER
G H Kiakenbeck
INSTR. LEAD ENGINEER
4-12-76

REVISED BY	DATE	REV LTR

TEST NO 2532 TEST TITLE Q-FAN INLET TEST F.S.

EWA NO ______ WORK ORDER ______

TEST LOCATION ______

SCHEDULE START DATE ______ SCHEDULE COMP. DATE ______

#1620

PAGE 2 OF 3

B-8230-636

REQUESTING ORGANIZATION B-8425

INSTRUMENTATION SUPPORT ORGANIZATION B-8230

TEST INSTRUMENTATION REQUEST

ITEM NO	SYM	DESCRIPTION	RANGE MIN	RANGE MAX	ACCURACY REQUIRED % F.S.	FREQUENCY OF VARIABLE CPS	SAMPLE RATE REQUIRED SPS	OSCIL	STRIP CHART	MANUAL	DIGITAL DATA SYS	MAG TAPE FM	DVM		REMARKS
9		FAN/ENGINE OPERATION													
	T77	TURBINE TEMP	AMB	1000°	±1						1		1		
	N_2	TURBINE SPEED	0	16000							1		1		
	N_1	COMPRESSOR SPEED	0	6000							1		1		
	T	ENGINE TORQUE									1		1		
	FBA	FAN BLADE ANGLE	0	180°							1				
	PLA	POWER LEVER ANGLE	0	180°							1				
10		Thumbwheels.													
		CORR								3	digits				CONDITION No.
		TN.								4	″				40x80 I.D.
		TST								4	″				TEST No. = 2532
		RUN								2	″				RUN No.
		CONF								4	″				CONFIGURATION No
		Date								4	″				CALENDAR DATE
		PBAR								5	″				BAROMETRIC S/U REF

GENERAL INFORMATION

Appendix A
76-0024

PREPARED BY: B. Shein
TEST ENGINEER

INSTRUMENTATION ENGINEER

APPROVED BY: TEST LEAD ENGINEER
C.H. Kriekenbeck
INSTR. LEAD ENGINEER
4-12-76

REVISED BY | DATE | REV LTR

TEST NO 2532 TEST TITLE Q-FAN INLET TEST F.S

EWA NO ________ WORK ORDER ________

TEST LOCATION ________

SCHEDULE START DATE: ________ SCHEDULE COMP. DATE: ________

#1620

PAGE 3 OF 3

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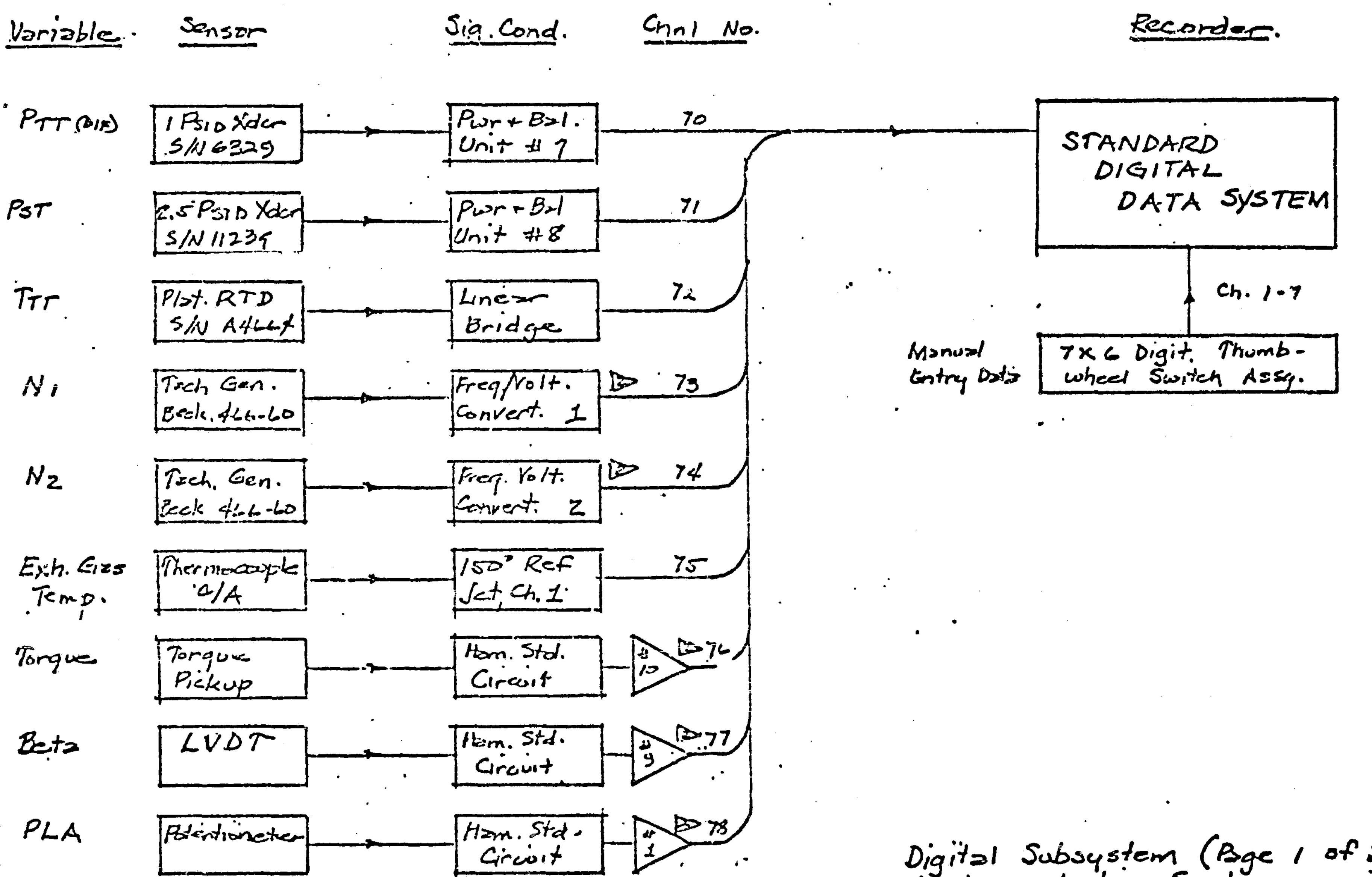

▷ Output attenuated by ÷100 Voltage Divider

Digital Subsystem (Page 1 of 2)
Instrumentation System
Lift/Cruise Fan Inlet Program
NASA-Ames Quiet Fan Engine
Test 2532

RHK 6-25-76
R-8230-636

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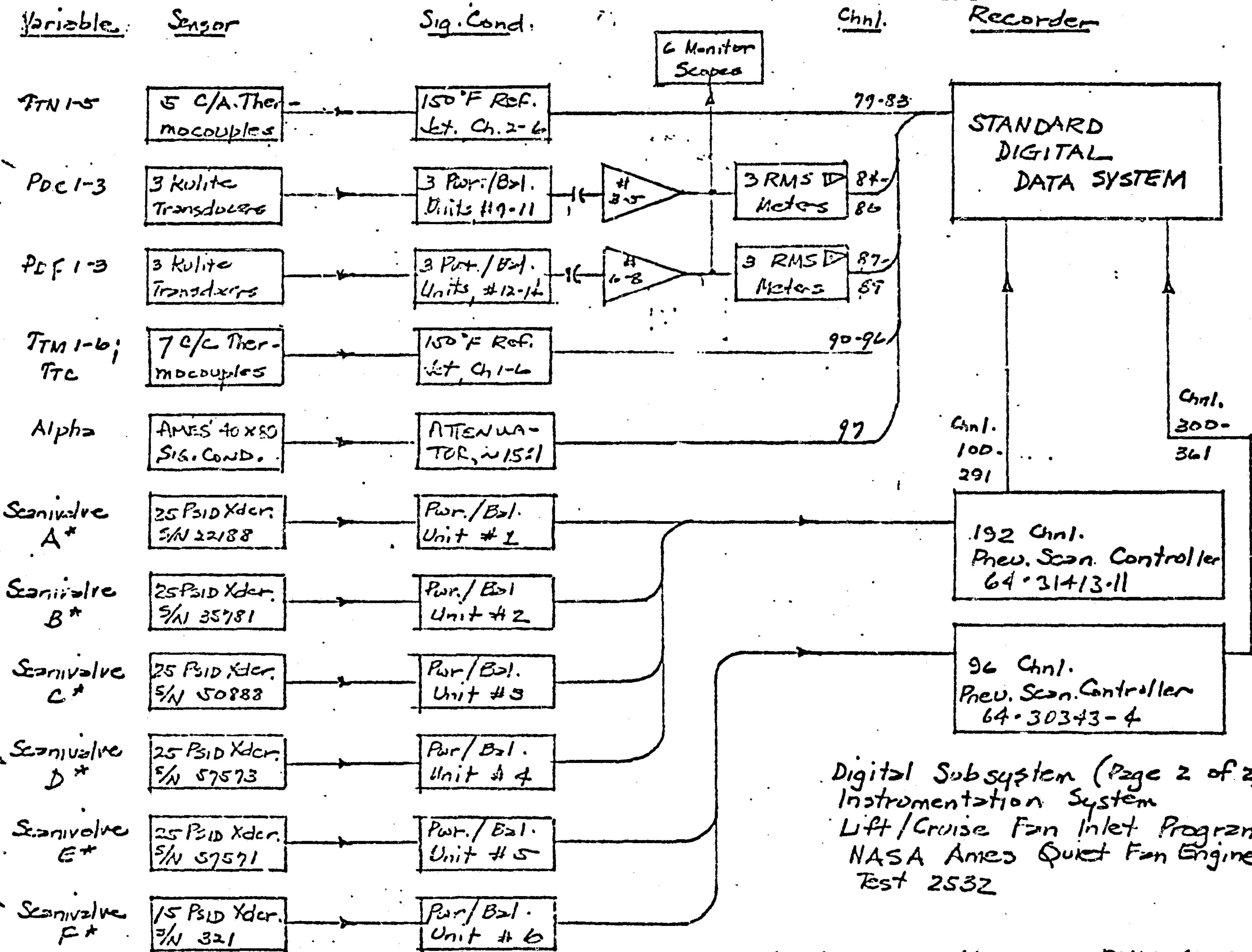

Digital Subsystem (Page 2 of 2)
Instrumentation System
Lift/Cruise Fan Inlet Program
NASA Ames Quiet Fan Engine
Test 2532

▷ output attenuated by ÷10 Volt. Divider

* See Scanivalve Assignment Sheet for the variables

RHK 6-25-76
B-823-636

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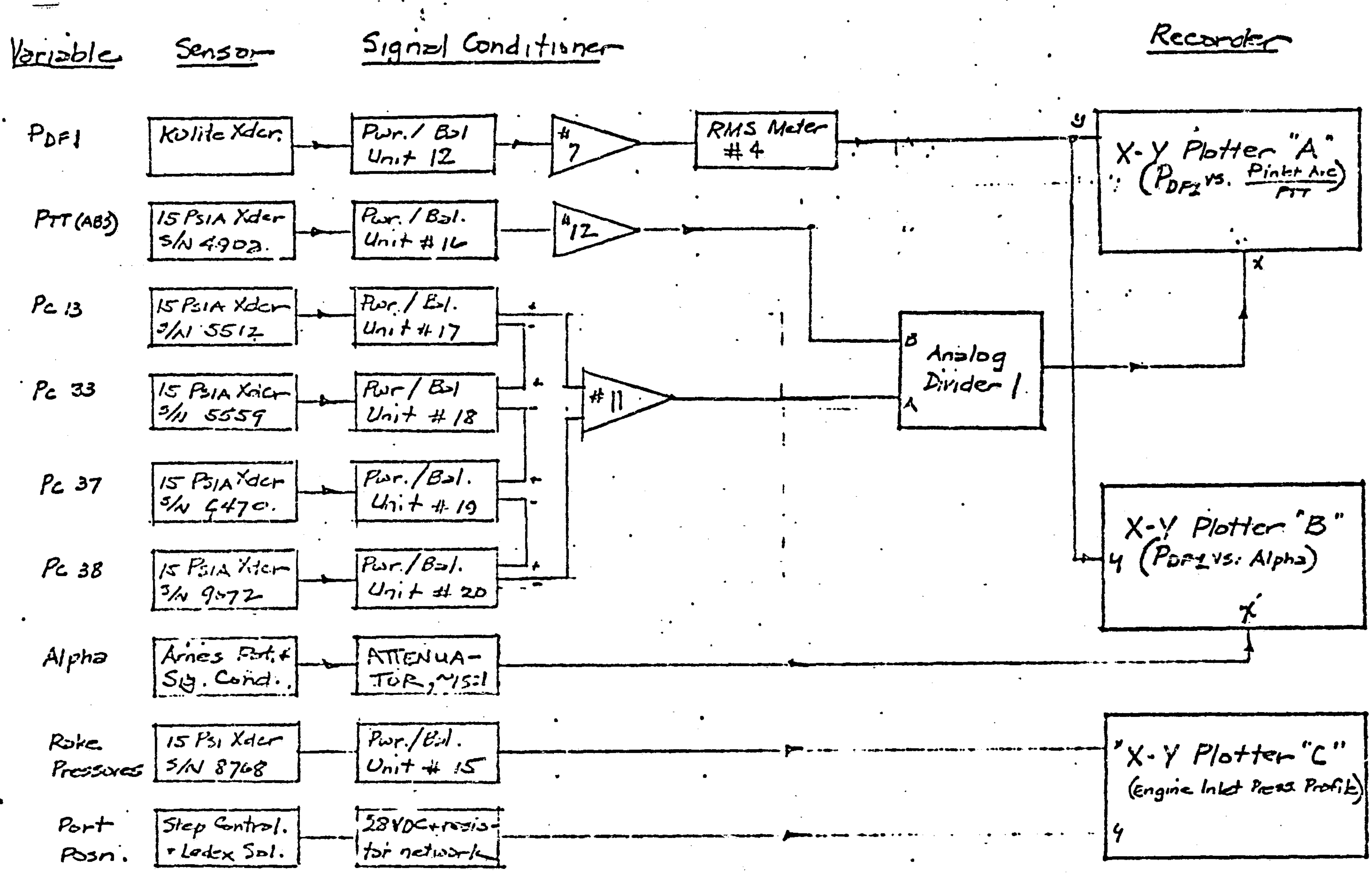

Analog Subsystem
Instrumentation System
Lift/Cruise Fan inlet Progr[am]
NASA Ames Q Fan Engine
Test 2532

B. 8230.636 RHK 6-25.

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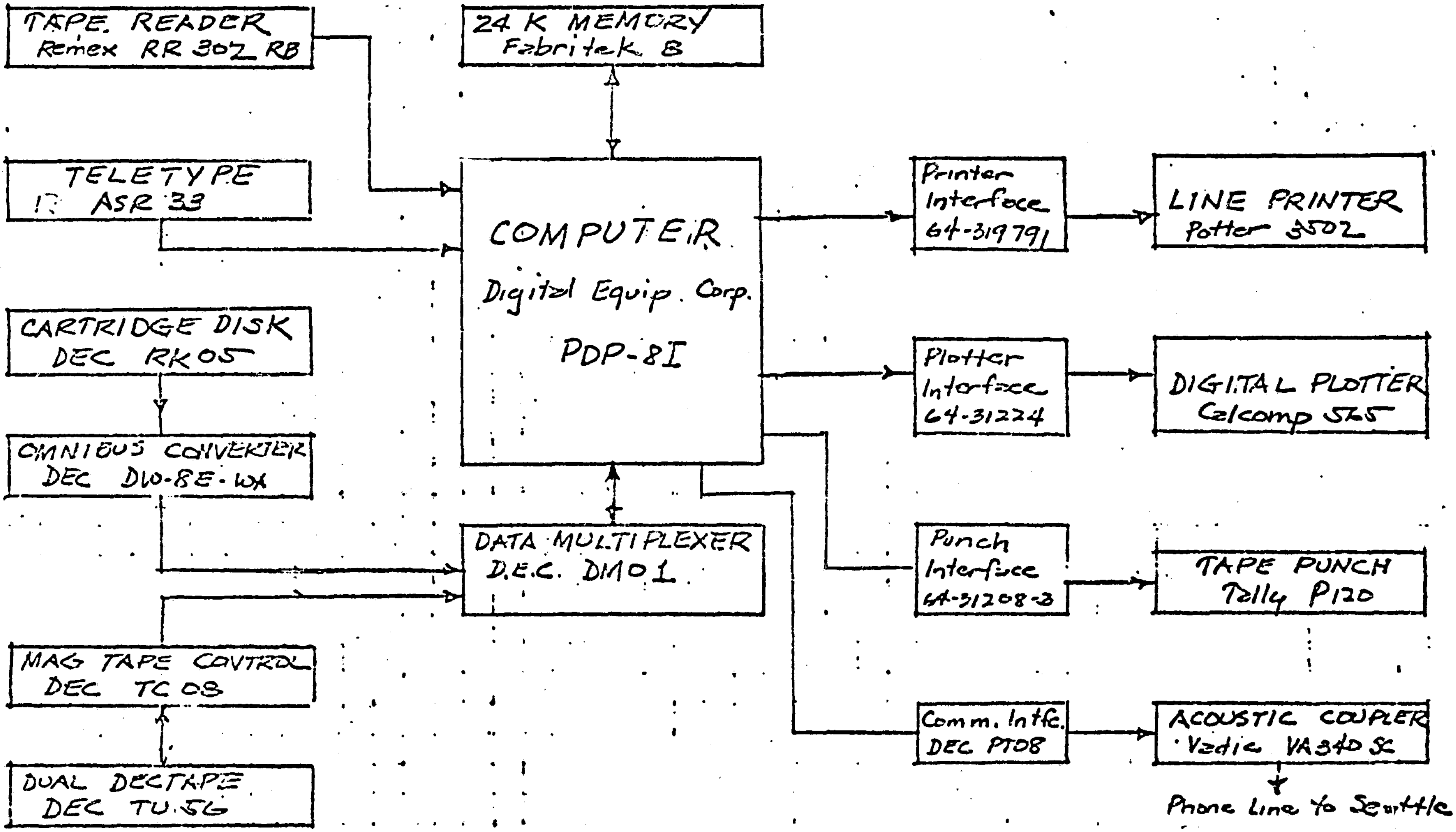

DATA PROCESSING SYSTEM
Test 2532-Q Fan Engine Inlet

RHK 10-18-76

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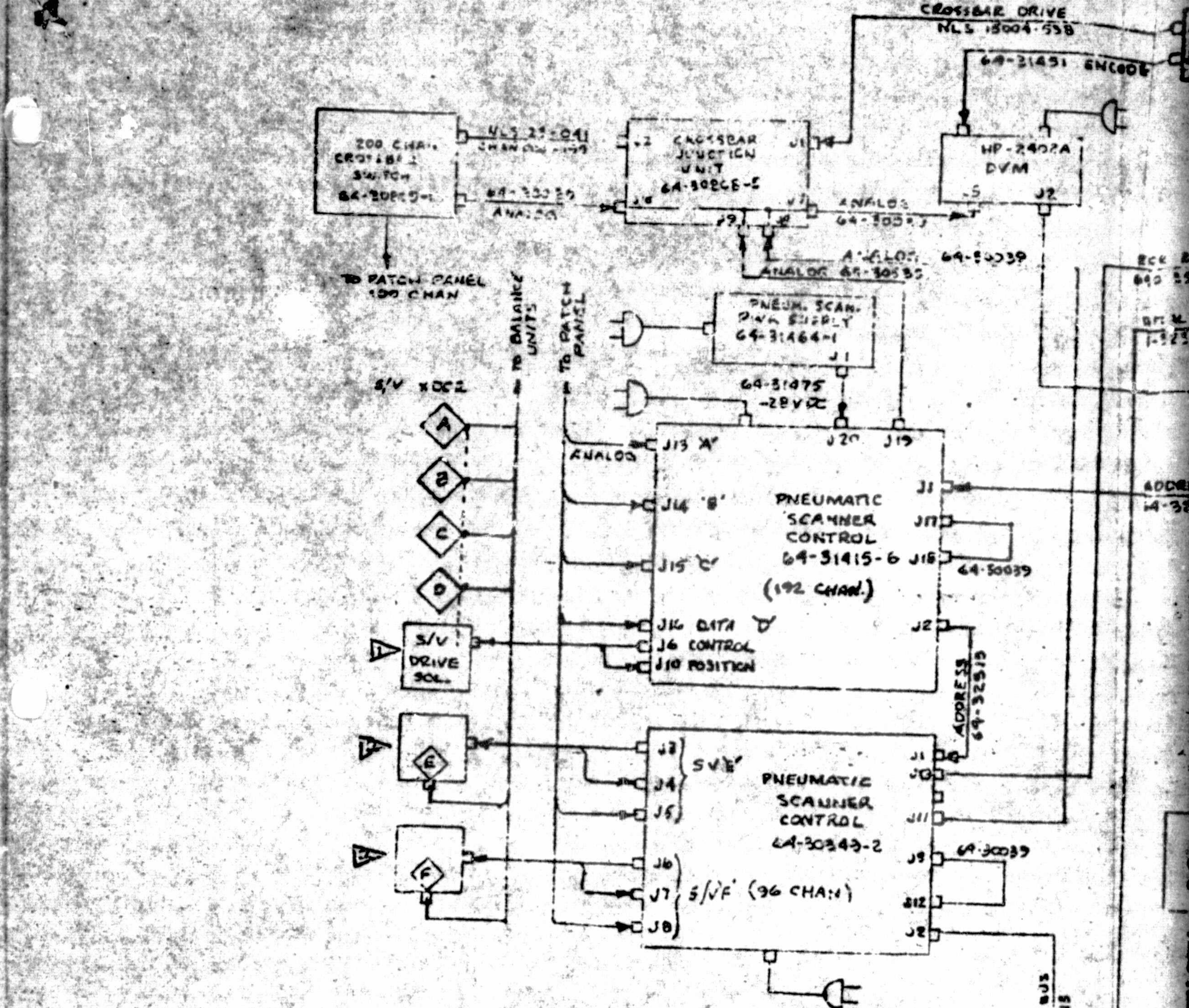
B-2230-636



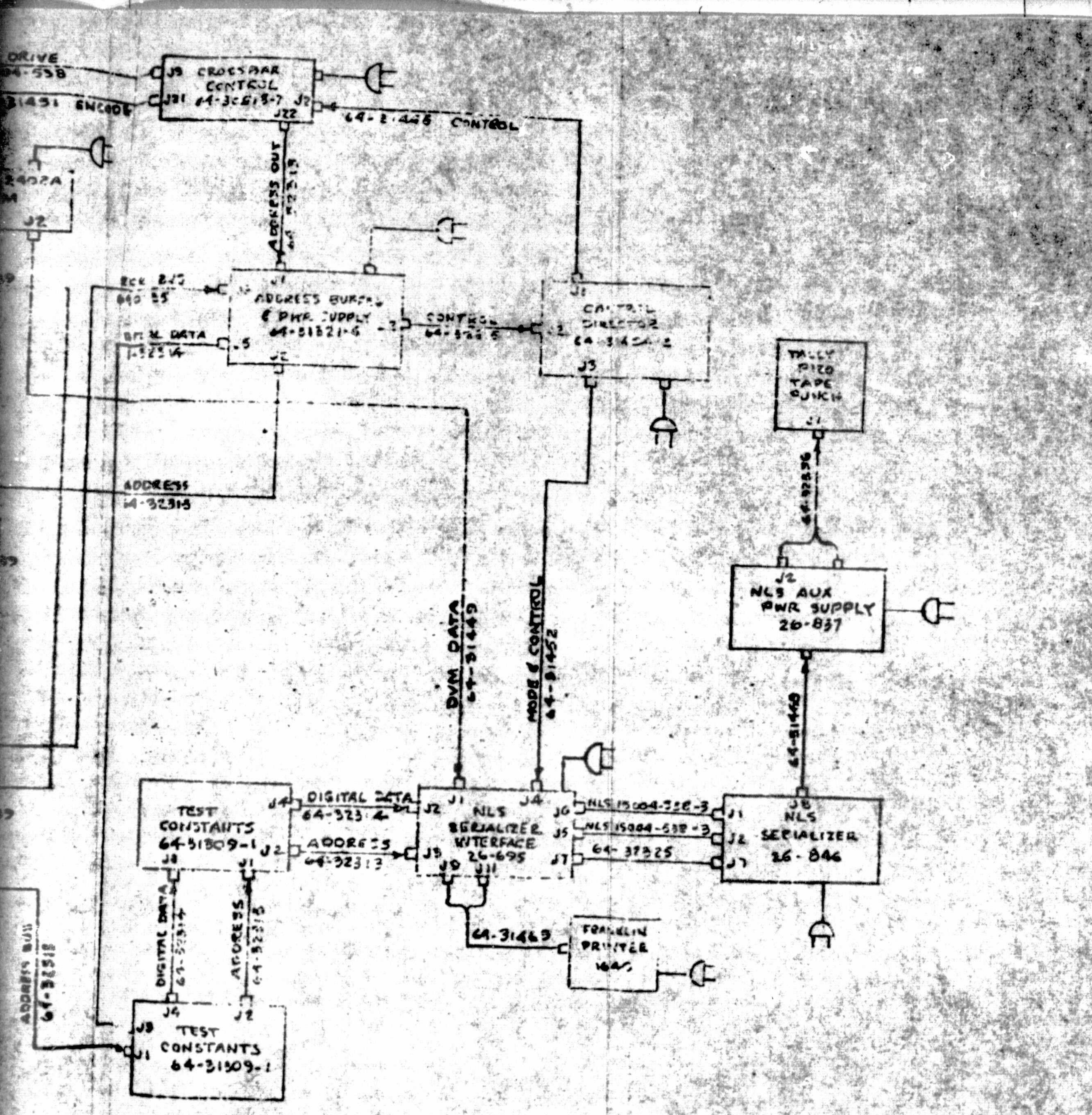
Scanivalve Type 48J

Scanivalve Type SKM 48 × 4

Configured especially for Test 2502, NASA Ames

W. H. Gamirer

8-25-76 FOLDOUT FRAME



STANDARD DIGITAL DATA SYSTEM
Boeing Dwg 64-31305

FOLDOUT FRAME 2

Appendix A
T6-6094

DATA SEQUENCE SHEET
TEST #2532

	SEQ.	CHANNEL NO.	SYM.	DESCRIPTION	SENSOR	SENSITIVITY	REMARKS
	1	01	Pbar	Manual Entry Data Thumbwheel Input Baro. Pressure	Thumbwheel Switch	5 digits	
	2	02		Date	"	6 "	
	3	03		Config. No.	"	3 "	
R	4	04		Run No. & Cond. No.	"	5 "	
	5	05		Test No.	"	4 "	
	6	06		Ames ID No.	"	4 "	
R	7	07		Alpha (Angle of Attack)	"	3 "	
	8	070	Ptt	Tunnel Tot. Press.	Statham PM6-1	1000 cts/psi	
	9	071	Pst	" Static Press.	Statham PM6-2.5	1000 cts/psi	
	10	072	Ttt	" Temp.	Rosemount 104MA	1000 cts/°F	
	11	073	N_1	LP Rotor Engine RPM	Beckman 460-60	1 ct/RPM	
	12	074	N_2	HP Rotor Engine RPM	Beckman 460-60	1 ct/RPM	

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Rev. 7-14-76 RHK

DATA SEQUENCE SHEET
TEST #2532

SEQ.	CHANNEL NO.	SYM.	DESCRIPTION	SENSOR	SENSITIVITY	REMARKS
13	075	Tt7	Engine Exh. Gas Temp.	Thermocpl. Type K	Table look-up.	
14	076	-	Torque	Ham. Std.	Ham. Std. will provide.	
15	077	Beta	Fan Blade Angle	Ham. Std.	Ham. Std. will provide.	
16	078	PLA	Power Lever Angle	Ham. Std.	Ham. Std. will provide.	
17	079	Ttn1	Exh. Noz. Temp.	Thermocpl. Type K	Table "K" look-up.	
18	080	Ttn2	Exh. Noz. Temp.	Thermocpl. Type K	Table "K" look-up.	
19	081	Ttn3	Exh. Noz. Temp.	Thermocpl. Type K.	Table "K" look-up.	
20	082	Ttn4	Exh. Noz. Temp.	Thermocpl. Type K	Table "K" look-up.	
21	083	Ttn5	Exh. Noz. Temp.	Thermocpl. Type K	Table "K" look-up.	
22	084	Pdc1	Core Dyn. Press.	Kulite	33,334 cts/PSI RMS	
23	085	Pdc2	Core Dyn. Press.	Kulite	33,334 cts/PSI RMS	
24	086	Pdc3	Core Dyn. Press.	Kulite	33,334 cts/PSI RMS	
						Page 2 of 4.

Rev. 7-14-76 RHK

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DATA SEQUENCE SHEET
TEST #2532

SEQ.	CHANNEL NO.	SYM.	DESCRIPTION	SENSOR	SENSITIVITY	REMARKS
25	087	Pdf1	Fan Dyn. Press.	Kulite	33,334 cts/PSI RMS	
26	088	Pdf2	Fan Dyn. Press.	Kulite	33,334 cts/PSI RMS	
27	089	Pdf3	Fan Dyn. Press.	Kulite	33,334 cts/PSI RMS	
28	090	Ttm1	Fan Cowl Temp.	Type T Thermocpl.	Table "T" look-up.	
29	091	Ttm2	Fan Cowl Temp.	Type T. Thermocpl.	Table "T"look-up.	
30	092	Ttm3	Fan Cowl Temp.	Type T Thermocpl.	Table "T" look-up.	
31	093	Ttm4	Fan Cowl Temp.	Type T Thermocpl.	Table "T" look-up.	
32	094	Ttm5	Fan Cowl Temp.	Type T Thermocpl.	Table "T" look-up.	
33	095	Ttm6	Fan Cowl Temp.	Type T Thermocpl.	Table "T" look-up.	
34	097	Alpha	Angle-of-Attack. (Ames will provide).		Ames will provide.	
35	096	Ttc	Compressor Face. Temp.	Type T Thermocpl.	Table "T" look-up.	
36	098		Spare			
						Page 3 of 4.

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Rev 7-14-76 RHK

DATA SEQUENCE SHEET

TEST #2532

SEQ.	CHANNEL NO.	SYM.	DESCRIPTION	SENSOR	SENSITIVITY	REMARKS
37	099		Spare			
38	100 [1]	S/V A	Scanivalve A	Statham PM131	1000 cts/PSI	
39	101 [1]	B	" B	"	" "	
40	102 [1]	C	" C	"	" "	
41	103 [1]	D	" D	"	" "	
43	300 [2]	E	" E	"	" "	
44	350 [3]	F	" F	"	" "	

[1] and every 4th channel thereafter; see Scanivalve Channel Assignment Sheet
[2] and the following 46 channels; see Scanivalve Channel Assignment Sheet
[3] and the following 11 channels.

Page 4 of 4.

Rev. 7-14-72 RHK

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PORT	SCANIVALVE "A" PARAMETER	ADDR	SCANIVALVE "B" PARAMETER	ADDR	SCANIVALVE "C" PARAMETER	ADDR	SCANIVALVE "D" PARAMETER	ADDR	
1	HOME REF	100	HOME REF	101	HOME REF	102	HOME REF	103	
2	DUMMY	104	DUMMY	105	DUMMY	106	DUMMY	107	
3	Ptc-1	108	Psc-1	109	Ptm-18	110	Pc-21	111	Ref. ports plumbed
4	Ptc-2	112	Psc-2	113	Ptm-19	114	DUMMY	115	to PamB outside
5	Ptc-3	116	Psc-3	117	Ptm-20	118	Pc-20	119	of W/t.
6	Ptc-4	120	Psc-4	121	DUMMY	122	Pc-19	123	Ptc 15, 33, & 39
7	Ptc-5	124	Psc-5	125	Pc-1	126	DUMMY	127	removed & replaced
8	Ptc-6	128	Psc-6	129	Pc-2	130	Pc-37	131	with Kulites.
9	Ptc-12	132	Psc-7	133	DUMMY	134	Pc-38	135	
10	Ptc-11	136	Psc-8	137	Pc-3	138	DUMMY	139	
11	Ptc-10	140	DUMMY	141	DUMMY	142	Pc-40	143	
12	Ptc-8	144	PTTC ~~Ptc-2~~	145	Pc-4	146	Pc-41	147	
13	Ptc-7	148	DUMMY	149	Pc-5	150	Pc-42	151	
14	Ptc-13	152	Ptn-1	153	Pc-6	154	Pc-43	155	
15	Ptc-14*	156	Ptn-2	157	Pc-7	158	Pc-44	159	
16	Ptc-16*	160	Ptn-4	161	Pc-8	162	Pc-45	163	
17	Ptc-17	164	Ptn-5	165	Pc-9	166	DUMMY	167	
18	Ptc-18	168	DUMMY	169	Pc-10	170	Ptf-70	171	
19	Ptc-24	172	Pn-1	173	Pc-11	174	Ptf-69	175	
20	Ptc-23	176	Pn-2	177	Pc-12	178	Ptf-68	179	
21	Ptc-22	180	Pn-3	181	DUMMY	182	Ptf-67	183	
22	Ptc-21	184	Pn-4	185	Pc-13	186	Ptf-66	187	
23	Ptc-20	188	DUMMY	189	Pc-14	190	Ptf-65	191	
24	Ptc-19	192	Ptm-1	193	Pc-15	194	Ptf-64	195	

ADDRESS/PORT NO.
SCANIVALVE INTERLACE MODE

Appendix A
T6-6094

Check: E J Stuver 6-15-76
E. J. Stuver Date

PORT	SCANIVALVE "A" PARAMETER	ADDR	SCANIVALVE "B" PARAMETER	ADDR	SCANIVALVE "C" PARAMETER	ADDR	SCANIVALVE "D" PARAMETER	ADDR	
25	Ptc-25	196	Ptm-2	197	DUMMY	198	Ptf-63	199	
26	Ptc-26	200	Ptm-3	201	Pc-16	202	Ptf-62	203	Ref. ports plumbed
27	Ptc-27	204	Ptm-4	205	Pc-17	206	Ptf-61	207	to Pamb outside
28	Ptc-28	208	Ptm-5	209	Pc-18	210	Ptf-51	211	of W/T.
29	Ptc-29	212	Ptm-6	213	Pc-39	214	Ptf-52	215	Ptc 15, 33, & 39
30	Ptc-30	216	Ptm-7	217	Pc-36	218	Ptf-53	219	removed & replaced
31	Ptc-36	220	Ptm-8	221	Pc-35	222	Ptf-54	223	with Kulites.
32	Ptc-35	224	Ptm-9	225	Pc-34	226	Ptf-55	227	
33	Ptc-34*	228	Ptm-10	229	DUMMY	230	Ptf-56	231	
34	Ptc-32*	232	DUMMY	233	Pc-33	234	Ptf-57	235	
35	Ptc-31	236	Pm-1	237	Pc-32	238	Ptf-58	239	
36	Ptc-37	240	Pm-2	241	Pc-31	242	Ptf-59	243	
37	Ptc-38*	244	Pm-3	245	Pc-30	246	Ptf-60	247	
38	Ptc-40*	248	Pm-4	259	Pc-29	250	DUMMY	251	
39	Ptc-41	252	DUMMY	253	Pc-28	254	Ptf-1	255	
40	Ptc-42	256	Ptm-11	257	Pc-27	258	Ptf-2	259	
41	Ptc-48	260	Ptm-12	261	Pc-26	262	Ptf-3	263	
42	Ptc-47	264	Ptm-13	265	Pc-25	266	Ptf-4	267	
43	Ptc-46	268	Ptm-14	269	Pc-24	270	Ptf-5	271	
44	Ptc-45	272	Ptm-15	273	Pc-23	274	Ptf-6	275	
45	Ptc-44	276	Ptm-16	277	Pc-22	278	Ptf-7	279	
46	Ptc-43	280	Ptm-17	281	DUMMY	282	Ptf-8	283	R
47	DUMMY	284	DUMMY	285	DUMMY	286	DUMMY	287	R
48	REF	288	REF	289	REF	290	REF	291	R

ADDRESS/PORT NO.
SCANIVALVE INTERLACE MODE

Appendix A
76-6094

Check: E J Stuver 6-15-76
E. J. Stuver Date

-2-of-3-

PORT	PARAMETER	ADDR	PORT	PARAMETER	ADDR	PORT	PARAMETER	ADDR
48	REF	300	24	** Ptf-40	324	48	REF	350
1	DUMMY	301	25	** Ptf-39	325	1	DUMMY	351
2	Ptf-9	302	26	** Ptf-38	326	2	PP-1	352
3	Ptf-10	303	27	** Ptf-37	327	3	PP-2	353
4	Ptf-20	304	28	** Ptf-36	328	4	PP-3	354
5	Ptf-19	305	29	** Ptf-35	329	5	PP-4	355
6	Ptf-18	306	30	** Ptf-34	330	6	PP-5	356
7	Ptf-17	307	31	** Ptf-33	331	7	PP-6	357
8	Ptf-16	308	32	** Ptf-32	332	8	PP-7	358
9	Ptf-15	309	33	** Ptf-31	333	9	Pdf	359
10	Ptf-14	310	34	Ptf-41	324	10	DUMMY	360
11	Ptf-13	311	35	Ptf-42	335	11	REF	361
12	Ptf-12	312	36	Ptf-43	336			
13	Ptf-11	313	37	Ptf-44	337			
14	Ptf-21	314	38	Ptf-45	338			
15	Ptf-22	315	39	Ptf-46	339			
16	Ptf-23	316	40	Ptf-47	340			
17	Ptf-24	317	41	Ptf-48	341			
18	Ptf-25	318	42	Ptf-49	342			
19	Ptf-26	319	43	Ptf-50	343			
20	Ptf-27	320	44	DUMMY	344			
21	Ptf-28	321	45	Pc-42	345			
22	Ptf-29	322	46	DUMMY	346			
23	Ptf-30	323	47	REF	347			

** Teed to pneumatic step sw.

ADDRESS/PORT NO.

SCANIVALVE INTERLACE MODE

Appendix A
76-6094

Check: E J Stuver 6-15-76
R. J. Stuver Date

TBC & QSEE INLETS - NASA-LeRC REV THRUST TEST

NOTE: CHANNELS 1-24 NO CHANGE

TABLE 3.3 (continued)

SDDS SEQUENCE SHEET

SEQ.	CHANNEL NO.	SYM.	DESCRIPTION	SENSOR	SENSITIVITY	REMARKS
25	087	~~Pde1~~		~~Kulite~~	~~1000 cts/PSI RMS~~	
26	088	~~Pde2~~		~~Kulite~~	~~1000 cts/PSI RMS~~	
27	089	~~Pde3~~		~~Kulite~~	~~1000 cts/PSI RMS~~	
28	090	Ttm1	Fan Cowl Temp.	Type T Thermocpl.	Table"T" look-up.	
29	091	Ttm2	Fan Cowl Temp.	Type T Thermocpl.	Table"T" look-up.	
30	092	Ttm3	Fan Cowl Temp.	Type T Thermocpl.	Table"T" look-up.	
31	093	Ttm4	Fan Cowl Temp.	Type T Thermocpl.	Table"T" look-up.	
32	094	Ttm5	Fan Cowl Temp.	Type T Thermocpl.	Table"T" look-up.	
33	095	Ttm6	Fan Cowl Temp.	Type T Thermocpl.	Table"T" look-up.	
34	097	Alpha	Angle-of-attack. (Ames will provide)		Ames will provide.	
35	096	Ttc	Compressor Inlet Temp.	Type T Thermocpl.		
36	098		Spare			

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72-0094

TBC & QSEE INLETS - NASA-LeRC REV. THRUST TEST

TABLE 3.3 (continued)
SDDS SEQUENCE SHEET

SEQ.	CHANNEL NO.	SYM.	DESCRIPTION	SENSOR	SENSITIVITY	REMARKS
37	099		Spare			
38	100 [1]	S/V A	Scanivalve A	PM131	25 psid	1000 cts/psi
39	101 [1]	B	" B	"	" "	"
40	102 [1]	C	" C	"	" "	"
41	103 [1]	D	" D	"	" "	"
43	300 [2]	E	" E	"	" "	"

[1] and every 4th channel thereafter; see Scanivalve Channel Assignment Sheet
[2] and the following 46 channels; see Scanivalve Channel Assignment Sheet
[3] and the following 11 channels.

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QSEE INLET

PORT	SCANIVALVE "A" PARAMETER	ADDR	SCANIVALVE "B" PARAMETER	ADDR	SCANIVALVE "C" PARAMETER	ADDR	SCANIVALVE "D" PARAMETER	ADDR	
1	HOME REF	100	HOME REF	101	HOME REF	102	HOME REF	103	
2	DUMMY	104	DUMMY	105	DUMMY	106	DUMMY	107	
3	Ptc-1	108	Psc-1	109	Ptm-18	110		111	Ref. ports plumbed
4	Ptc-2	112	Psc-2	113	Ptm-19	114	DUMMY	115	to PamR outside of
5	Ptc-3	116	Psc-3	117	Ptm-20	118		119	W/T.
6	Ptc-4	120	Psc-4	121	DUMMY	122		123	Ptc 15, 33, & 39
7	Ptc-5	124	Psc-5	125		126	DUMMY	127	removed & replaced
8	Ptc-6	128	Psc-6	129	- -	130		131	with Kulites.
9	Ptc-12	132	Psc-7	133	DUMMY	134		135	
10	Ptc-11	136	Psc-8	137		138	DUMMY	139	
11	Ptc-10	140	DUMMY	141	DUMMY	142	Pcr-1	143	
12	Ptc-8	144	PTIC ~~Ptc-2~~	145		146	DUMMY	147	
13	Ptc-7	148	DUMMY	149	Pcr-5	150	Pcr-2	151	
14	Ptc-13	152	Ptn-1	153	Pcr-6	154	DUMMY	155	
15	Ptc-14	156	Ptn-2	157	Pcr-7	158	Pcr-3	159	
16	Ptc-16	160	Ptn-4	161	Pcr-8	162	Pcr-4	163	
17	Ptc-17	164	Ptn-5	165	Pcr-9	166	DUMMY	167	
18	Ptc-18	168	DUMMY	169	Pcr-10	170	Ptfr-1	171	
19	Ptc-24	172	Pn-1	173	Pcr-11	174	Ptfr-2	175	
20	Ptc-23	176	Pn-2	177	Pcr-12	178	Ptfr-3	179	
21	Ptc-22	180	Pn-3	181	DUMMY	182	Ptfr-4	183	
22	Ptc-21	184	Pn-4	185	Pcr-13	186	Ptfr-5	187	
23	Ptc-20	188	DUMMY	189	Pcr-14	190	Ptfr-6	191	
24	Ptc-19	192	Ptm-1	193		194	Ptfr-7	195	

ADDRESS/PORT NO.
SCANIVALVE INTERLACE MODE

Appendix A
76-6094

QSEE 1/3

QSEE INLET

PORT	SCANIVALVE "A" PARAMETER	ADDR	SCANIVALVE "B" PARAMETER	ADDR	SCANIVALVE "C" R PARAMETER	ADDR	SCANIVALVE "D" R PARAMETER	ADDR	
25	Ptc-25	196	Ptm-2	197	DUMMY	198	Ptfr-8	199	
26	Ptc-26	200	Ptm-3	201	~~Pc-16~~	202	Ptfr-9	203	Ref. ports plumbed
27	Ptc-27	204	Ptm-4	205	~~Pc-17~~	206	Ptfr-10	207	to Pamb outside
28	Ptc-28	208	Ptm-5	209	~~Pc-18~~	210	Ptfr-20	211	of W.T.
29	Ptc-29	212	Ptm-6	213	~~Pc-39~~	214	Ptfr-19	215	Ptc 14, 33, & 39
30	Ptc-30	216	Ptm-7	217	~~Pc-36~~	218	Ptfr-18	219	removed & replaced
31	Ptc-36	220	Ptm-8	221	~~Pc-35~~	222	Ptfr-17	223	with Kulites.
32	Ptc-35	224	Ptm-9	225	~~Pc-34~~	226	Ptfr-16	227	
33	Ptc-34	228	Ptm-10	229	DUMMY	230	Ptfr-15	231	
34	Ptc-32	232	DUMMY	233	~~Pc-33~~	234	Ptfr-14	235	
35	Ptc-31	236	Pm-1	237	~~Pc-32~~	238	Ptfr-13	239	
36	Ptc-37	240	Pm-2	241	~~Pc-31~~	242	Ptfr-12	243	
37	Ptc-38	244	Pm-3	245	~~Pc-30~~	246	Ptfr-11	247	
38	Ptc-40	248	Pm-4	249	~~Pc-29~~	250	DUMMY	251	
39	Ptc-41	252	DUMMY	253	~~Pc-28~~	254	Psel-1	255	
40	Ptc-42	256	Ptm-11	257	~~Pc-27~~	258	Psel-2	259	
41	Ptc-48	260	Ptm-12	261	~~Pc-26~~	262	Psel-3	263	
42	Ptc-47	264	Ptm-13	265	~~Pc-25~~	266	Psel-4	267	
43	Ptc-46	268	Ptm-14	269	~~Pc-24~~	270	Psel-5	271	
44	Ptc-45	272	Ptm-15	273	~~Pc-23~~	274	Psel-6	275	
45	Ptc-44	276	Ptm-16	277	~~Pc-22~~	278	Psel-7	279	
46	Ptc-43	280	Ptm-17	281	DUMMY	282		283	
47	DUMMY	284	DUMMY	285	DUMMY	286	DUMMY	287	
48	REF	288	REF	289	REF	290	REF	291	

ADDRESS/PORT No.
SCANIVALVE INTERLACE MODE

Appendix A
76-6094

QSEE 2/3

QSEE INLET

	SCANIVALVE "E"		SCANIVALVE "B"		SCANIVALVE "C"		SCANIVALVE "D"		
PORT	PARAMETER	ADDR	PARAMETER	ADDR	PARAMETER	ADDR	PARAMETER	ADDR	
48	REF	300							
1	DUMMY	301							
2	Psel-8	302							
3	Psel-9	303							
4	DUMMY	304							
5	Psel-10	305							
6	Psel-11	306							
7	Psel-12	307							
8	Psel-13	308							
9	DUMMY	309							
10	Pdf DUMMY	310							
11		311							
12	REF	312							

R

ADDRESS/PORT NO.
SCANIVALVE INTERLACE MODE

Appendix A QSEE 3/3

TBC INLET

PORT	SCANIVALVE "A" PARAMETER	ADDR	SCANIVALVE "B" PARAMETER	ADDR	SCANIVALVE "C" PARAMETER	ADDR	SCANIVALVE "D" PARAMETER	ADDR	
1	HOME REF	100	HOME REF	101	HOME REF	102	HOME REF	103	
2	DUMMY	104	DUMMY	105	DUMMY	106	DUMMY	107	
3	Ptc-1	108	Psc-1	109	Ptm-18	110	Pc-21	111	Ref. ports plumbed
4	Ptc-2	112	Psc-2	113	Ptm-19	114	DUMMY	115	to PamB outside
5	Ptc-3	116	Psc-3	117	Ptm-20	118	Pc-20	119	of W/T.
6	Ptc-4	120	Psc-4	121	DUMMY	122	Pc-19	123	Ptc 15, 33, & 39
7	Ptc-5	124	Psc-5	125	Pc-1	126	DUMMY	127	removed & replaced
8	Ptc-6	128	Psc-6	129	Pc-2	130	Pc-37	131	with Kulites.
9	Ptc-12	132	Psc-7	133	DUMMY	134	Pc-38	135	
10	Ptc-11	136	Psc-8	137	Pc-3	138	DUMMY	139	
11	Ptc-10	140	DUMMY	141	DUMMY	142	Pc-40	143	
12	Ptc-8	144	PTIC ~~Ptc-2~~	145	Pc-4	146	Pc-41	147	
13	Ptc-7	148	DUMMY	149	Pc-5	150	Pc-42	151	
14	Ptc-13	152	Ptn-1	153	Pc-6	154	Pc-43	155	
15	Ptc-14	156	Ptn-2	157	Pc-7	158	Pc-44	159	
16	Ptc-16	160	Ptn-4	161	Pc-8	162	Pc-45	163	
17	Ptc-17	164	Ptn-5	165	Pc-9	166	DUMMY	167	
18	Ptc-18	168	DUMMY	169	Pc-10	170	Ptfr-1	171	R
19	Ptc-24	172	Pn-1	173	Pc-11	174	Ptfr-2	175	R
20	Ptc-23	176	Pn-2	177	Pc-12	178	Ptfr-3	179	R
21	Ptc-22	180	Pn-3	181	DUMMY	182	Ptfr-4	183	R
22	Ptc-21	184	Pn-4	185	Pc-13	186	Ptfr-5	187	R
23	Ptc-20	188	DUMMY	189	Pc-14	190	Ptfr-6	191	R
24	Ptc-19	192	Ptm-1	193	Pc-15	194	Ptfr-7	195	R

TBC 1/3

ADDRESS/PORT NO.
SCANIVALVE INTERLACE MODE

Appendix A
76-609

TBC INLET

	SCANIVALVE "A"		SCANIVALVE "B"		SCANIVALVE "C"		SCANIVALVE "D"		
PORT	PARAMETER	ADDR	PARAMETER	ADDR	PARAMETER	ADDR	PARAMETER	ADDR	
25	Ptc-25	196	Ptm-2	197	DUMMY	198	Ptfr-8	199	R
26	Ptc-26	200	Ptm-3	201	Pc-16	202	Ptfr-9	203	R Ref. ports plumbed
27	Ptc-27	204	Ptm-4	205	Pc-17	206	Ptfr-10	207	R to Pamb outside
28	Ptc-28	208	Ptm-5	209	Pc-18	210	Ptfr-20	211	R of W/T.
29	Ptc-29	212	Ptm-6	213	Pc-39	214	Ptfr-19	215	R Ptc 15, 33, & 39
30	Ptc-30	216	Ptm-7	217	Pc-36	218	Ptfr-18	219	R removed & replaced
31	Ptc-36	220	Ptm-8	221	Pc-35	222	Ptfr-17	223	R with Kulites.
32	Ptc-35	224	Ptm-9	225	Pc-34	226	Ptfr-16	227	R
33	Ptc-34	228	Ptm-10	229	DUMMY	230	Ptfr-15	231	R
34	Ptc-32	232	DUMMY	233	Pc-33	234	Ptfr-14	235	R
35	Ptc-31	236	Pm-1	237	Pc-32	238	Ptfr-13	239	R
36	Ptc-37	240	Pm-2	241	Pc-31	242	Ptfr-12	243	R
37	Ptc-38	244	Pm-3	245	Pc-30	246	Ptfr-11	247	R
38	Ptc-40	248	Pm-4	249	Pc-29	250	DUMMY	251	
39	Ptc-41	252	DUMMY	253	Pc-28	254	Psel-1	255	R
40	Ptc-42	256	Ptm-11	257	Pc-27	258	Psel-2	259	R
41	Ptc-48	260	Ptm-12	261	Pc-26	262	Psel-3	263	R
42	Ptc-47	264	Ptm-13	265	Pc-25	266	Psel-4	267	R
43	Ptc-46	268	Ptm-14	269	Pc-24	270	Psel-5	271	R
44	Ptc-45	272	Ptm-15	273	Pc-23	274	Psel-6	275	R
45	Ptc-44	276	Ptm-16	277	Pc-22	278	Psel-7	279	R
46	Ptc-43	280	Ptm-17	281	DUMMY	282		283	R
47	DUMMY	284	DUMMY	285	DUMMY	286	DUMMY	287	
48	REF	288	REF	289	REF	290	REF	291	

TBC 2/3

ADDRESS/PORT NO.
SCANIVALVE INTERLACE MODE

Appendix A
76-6094

TBC INLET

	SCANIVALVE "E"		~~SCANIVALVE "B"~~		~~SCANIVALVE "C"~~		~~SCANIVALVE "D"~~		
PORT	PARAMETER	ADDR	PARAMETER	ADDR	PARAMETER	ADDR	PARAMETER	ADDR	
48	REF	300							
1	DUMMY	301							
2	Psel-8	302							
3	Psel-9	303							
4	DUMMY	304							
5	Psel-10	305							
6	Psel-11	306							
7	Psel-12	307							
8	Psel-13	308							
9	DUMMY	309							
10	Pdf	310							
11	DUMMY	311							
12	REF	312							

R

ADDRESS/PORT NO.
SCANIVALVE INTERLACE MODE

TBC 3/3

Appendix A
T6-6094

Appendix B

Program Writeup Subroutine Extra 6.01

Allison Distortion Index

AP DOC
SUBROUTINE WRITEUP

22 November 1976

SUBJECT: Subroutine EXTRA6.01

AUTHOR: John L. Benner JLB

PURPOSE: EXTRA6.01 calculates the Allison Distortion Index for the NASA-AMES TEST 2532.

DISCUSSION: The Allison Distortion Index is calculated using the following procedure. First the rake average total pressure for each of the eight rake arms are calculated. Next the rake average pressures for 12 imaginary arms are calculated. These pressure have the following relationship to the actual recorded pressures.

Imaginary Rake No.	= 5/6 Actual Rake No.	+ 1/6 Actual Rake No.
1 (30 deg)	8	1
3 (90 deg)	7	6
4 (120 deg)	6	7
6 (180 deg)	5	4
7 (210 deg)	4	5
9 (270 deg)	3	2
10 (300 deg)	2	3
12 (360 deg)	1	8

Imaginary Rake No.	Average of Rake No. and	Actual Rake No.
2 (60 deg)	7	8
5 (150 deg)	5	6
8 (240 deg)	3	4
11 (330 deg)	1	2

From these rake average pressures, the twelve contiguous 120 degree sector average pressures are calculated. The minimum 120 degree sector is then located from this array.

The average compressor face total pressure (PTRRA) is calculated as the arithmetic average of the original 48 recorded pressures. Since ring number 3 lies close to the radius that separates the outer 40 and inner 60 percent of the total compressor face area the outer 40 percent average total pressure (PTRRPA) is calculated as the arithmetic average of rings 1-3 and inner 60 percent total pressure (PTRRFA) as the arithmetic average of rings 3-6. Radial total pressure distortion is then calculated as

$$KR = PTRRPA - PTRRFA/PTRRA$$

The circumferential total pressure distortion is calculated as

$$KTHETA = PTO_{240} - PTO_{120}/PTO_{360}$$

Appendix B
76-6094

DISCUSSION: (Continued)

The composite distortion index is calculated as

$$KCOMP = \sqrt{KR^2 + KTHETA^2}$$

USAGE: CALL EXTRA6(I4)

where I4 = Output Unit Code

COMMON/ALISON/ODAT3(8),ODAT3N(8),ODAT3U(8),ODAT3F(8),CDAY,
CMONTH,CYEAR

$OTDAT3_i$	=	Array for output of ALLISON variables.
$ODAT3N_i$	=	Array containing the names of the ALLISON variables.
$ODAT3U_i$	=	Array containing the units of the ALLISON variables.
$ODAT3F_i$	=	Array containing the formats of the ALLISON variables.
CDAY	=	Calculation day.
CMONTH	=	Calculation month.
CYEAR	=	Calculation year.

COMMON/CONS/

COMMON/PGNAMS/

COMMON/DATAIN/

COMMON/DATOUT/

COMMON/TITL/

See Program WRiteup of PN025 for the description of the above COMMON blocks.

SUBROUTINES USED: None

COMPUTER: PDP-8/I, PDP-8/E

LANGUAGE: FORTRAN IV

STORAGE: 3400_8

Appendix B
T6-6074

J15-047

Appendix C

Detail Test Plan

D1 4100 7740 ORIG.3/71

REV SYM

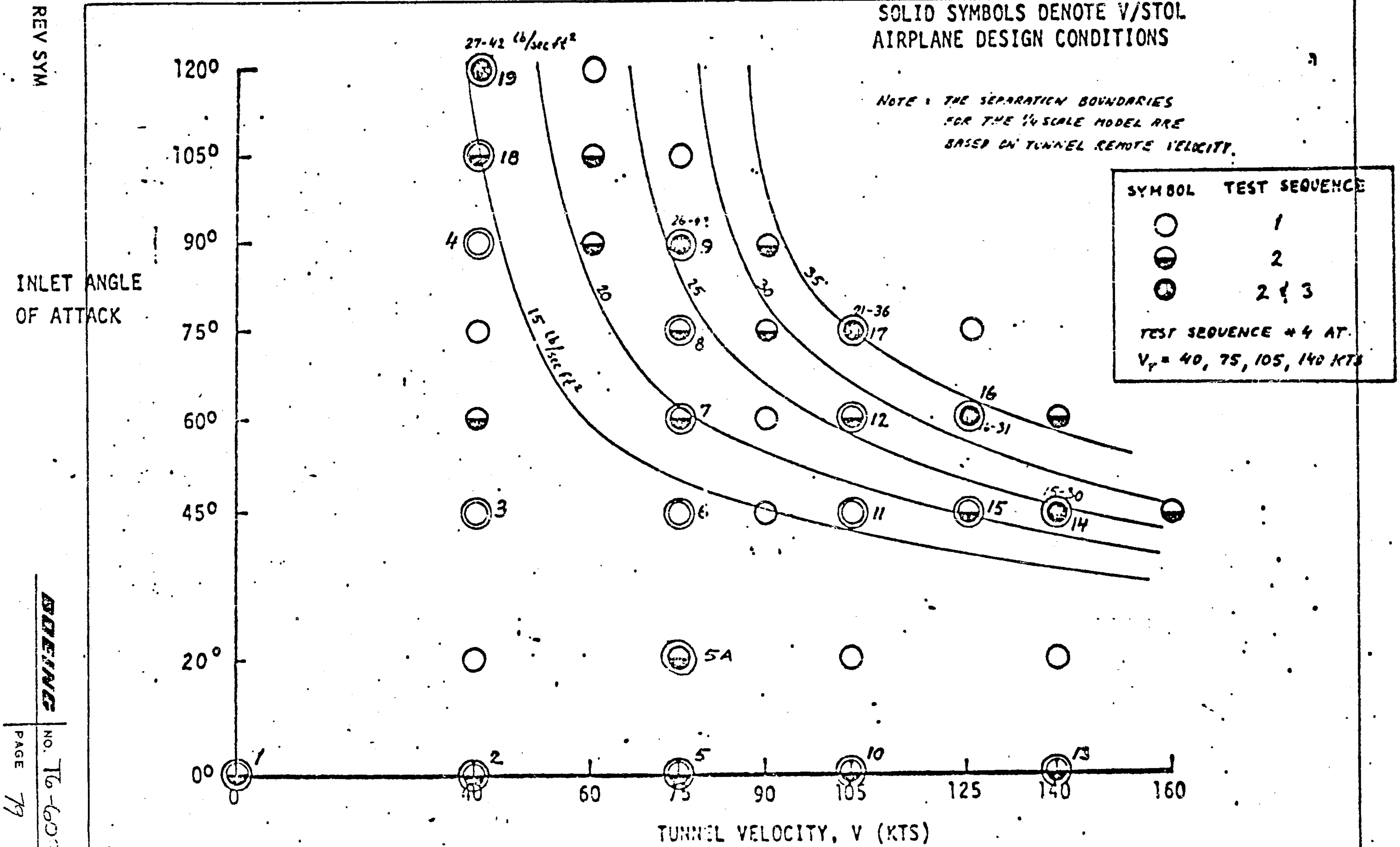


FIGURE 4.4, - WIND TUNNEL TEST MATRIX

J18-047

TEST SEQUENCE # 1

DATA POINT 1 : $\beta = 51.8°$, KN2 = 14200

Reduce KN2 to 10800 at constant β.

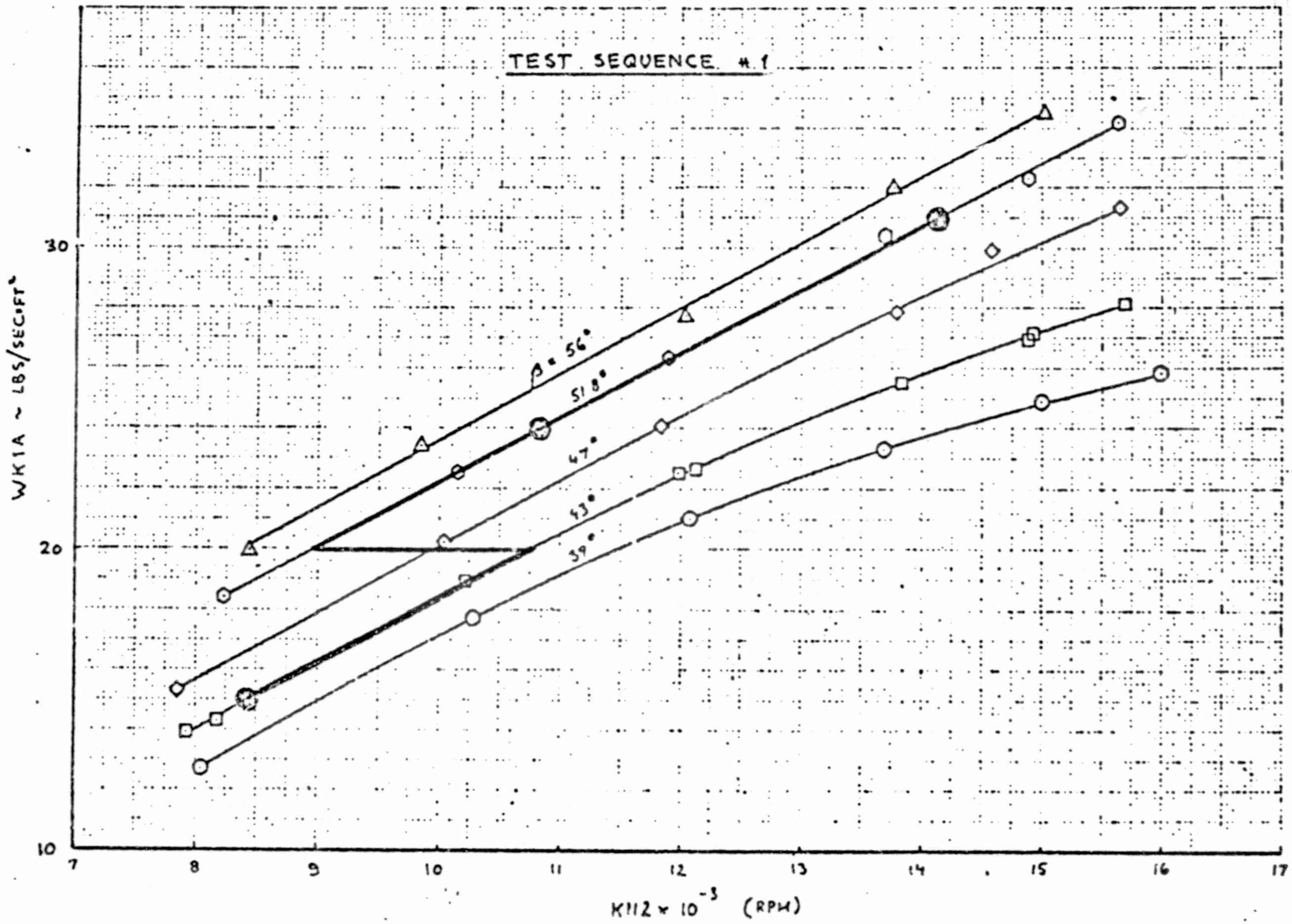
DATA POINT 2 : $\beta = 51.8°$, KN2 = 10800

Reduce KN2 to 9000 at constant β, change β to 43° at constant PLA, reduce KN2 to 8400 at constant β.

DATA POINT 3 : $\beta = 43°$, KN2 = 8400

END OF RUN

D1 4100 7740 ORIG.3/71



REV SYM

TEST SEQUENCE # 2

DATA POINT 1 : $\beta = 56°$, KN2 = 14750

Reduce KN2 to 13800 at constant β, change β to 51.8° at constant PLA, reduce KN2 to 14200 at constant β.

DATA POINT 2 : $\beta = 51.8°$, KN2 = 14200

Reduce KN2 to 12700 at constant β

DATA POINT 3 : $\beta = 51.8°$, KN2 = 12700

Reduce KN2 to 10800 at constant β

DATA POINT 4 : $\beta = 51.8°$, KN2 = 10800

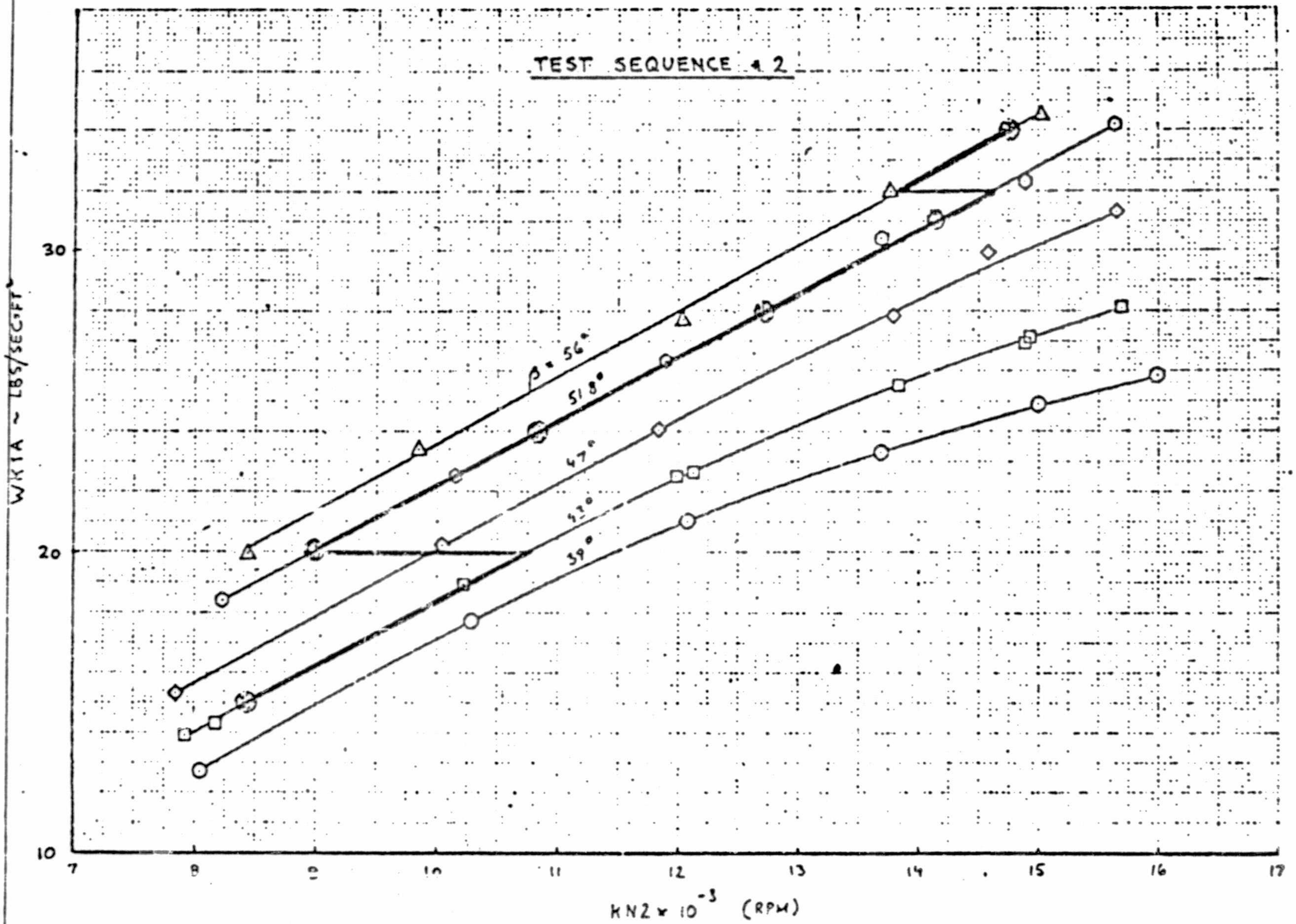
Reduce KN2 to 9000 at constant β

DATA POINT 5 : $\beta = 51.8°$, KN2 = 9000

Change β to 43° at constant PLA
Reduce KN2 to 8400 at constant β

DATA POINT 6 : $\beta = 43°$, KN2 = 8400

END OF RUN


TEST SEQUENCE # 2
WK1A ~ LBS/SEC-FT²
KN2 × 10⁻³ (RPM)
β = 56°
51.8°
47°
43°
39°
10
20
30
7
8
9
10
11
12
13
14
15
16
17

TEST SEQUENCE # 3

DATA POINT 1 : $\beta = 56°$, KN2 = 14750

Reduce KN2 to 12800 at constant β,
change β to 47° at constant PLA.

DATA POINT 2 : $\beta = 47°$, KN2 = 14750

Reduce KN2 to 12000 at constant β,
change β to 39° at constant PLA.

DATA POINT 3 : $\beta = 39°$, KN2 = 14750

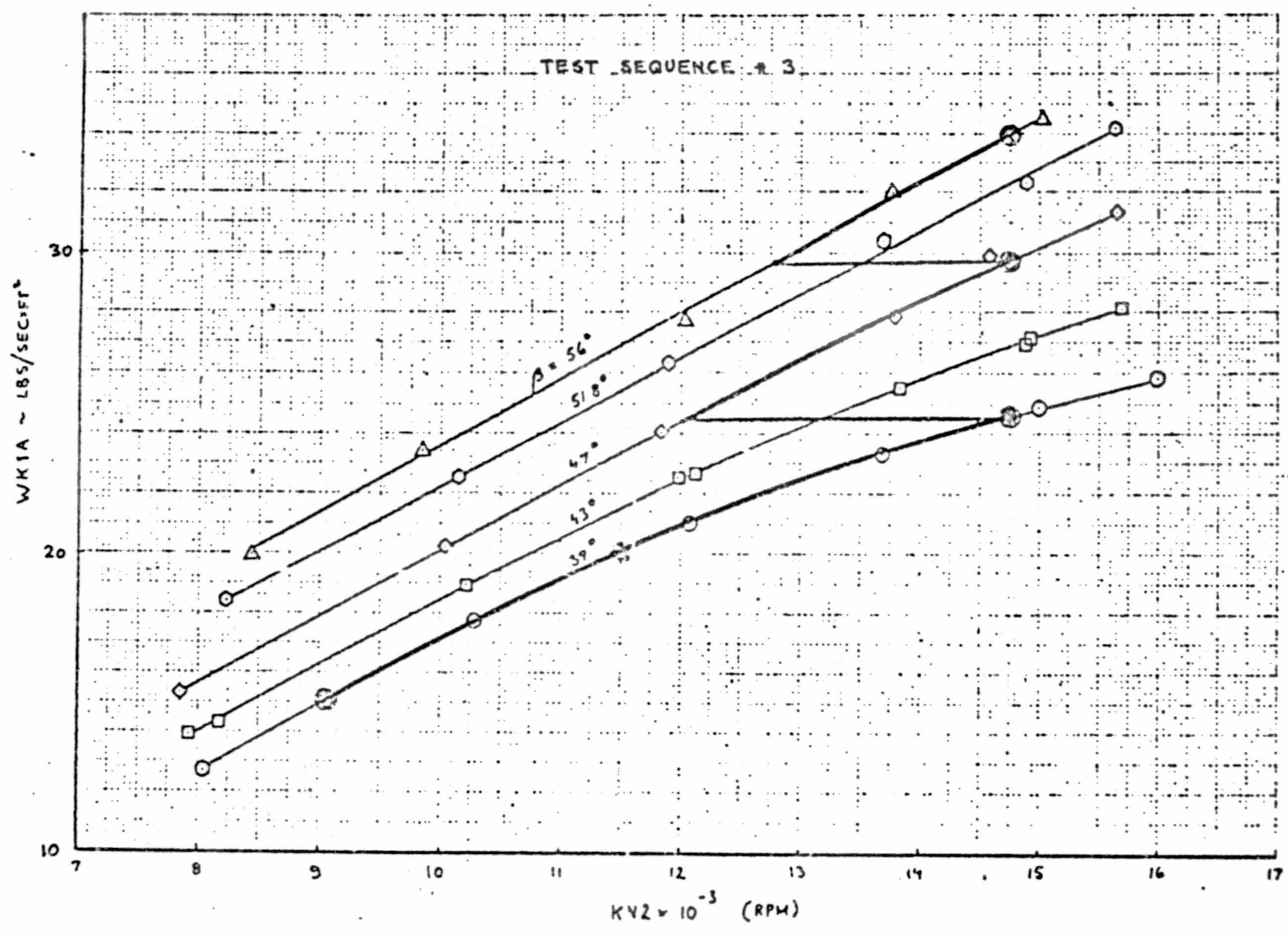
Reduce KN2 to 11500 at constant β.

DATA POINT 4 : $\beta = 39°$, KN2 = 11500

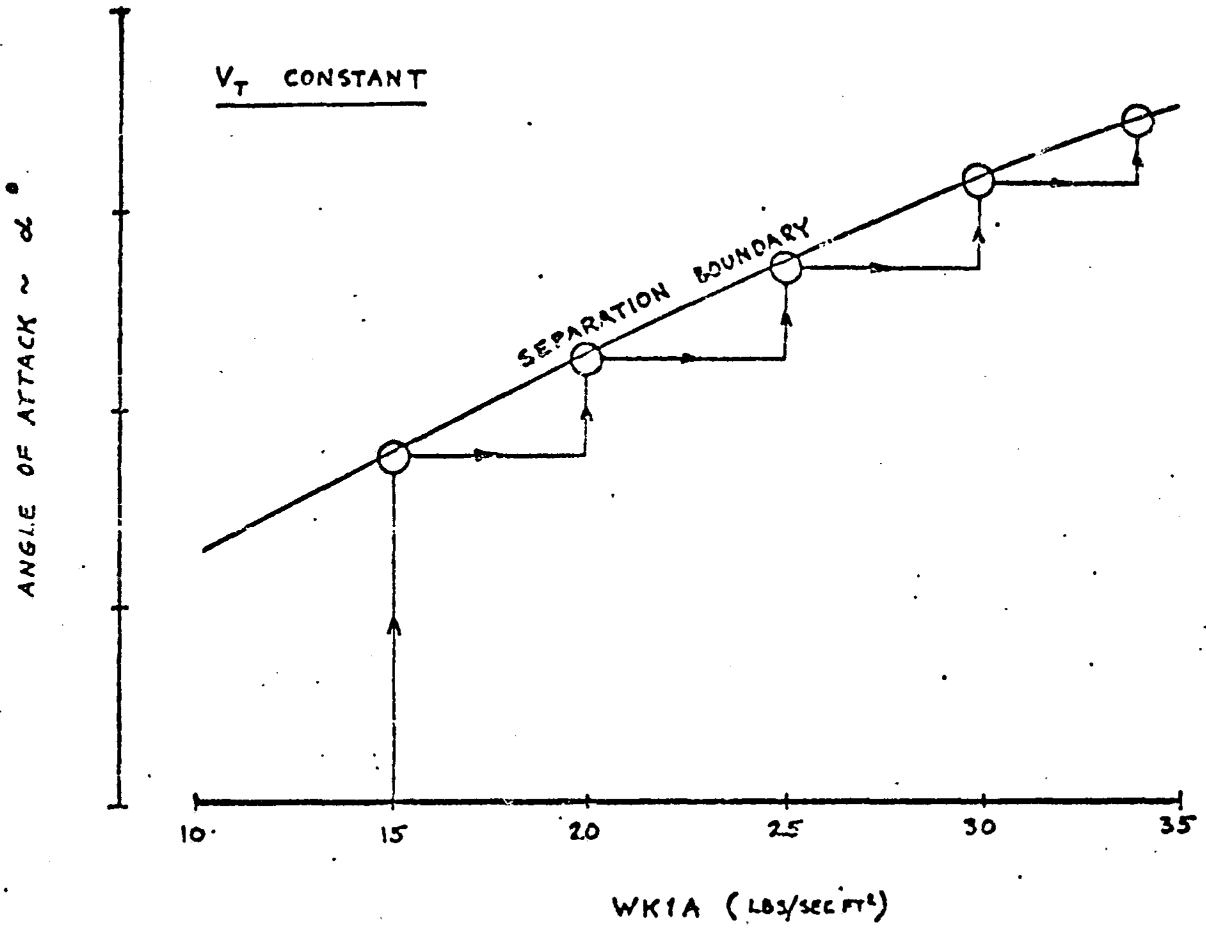
Reduce KN2 to 9000 at constant β.

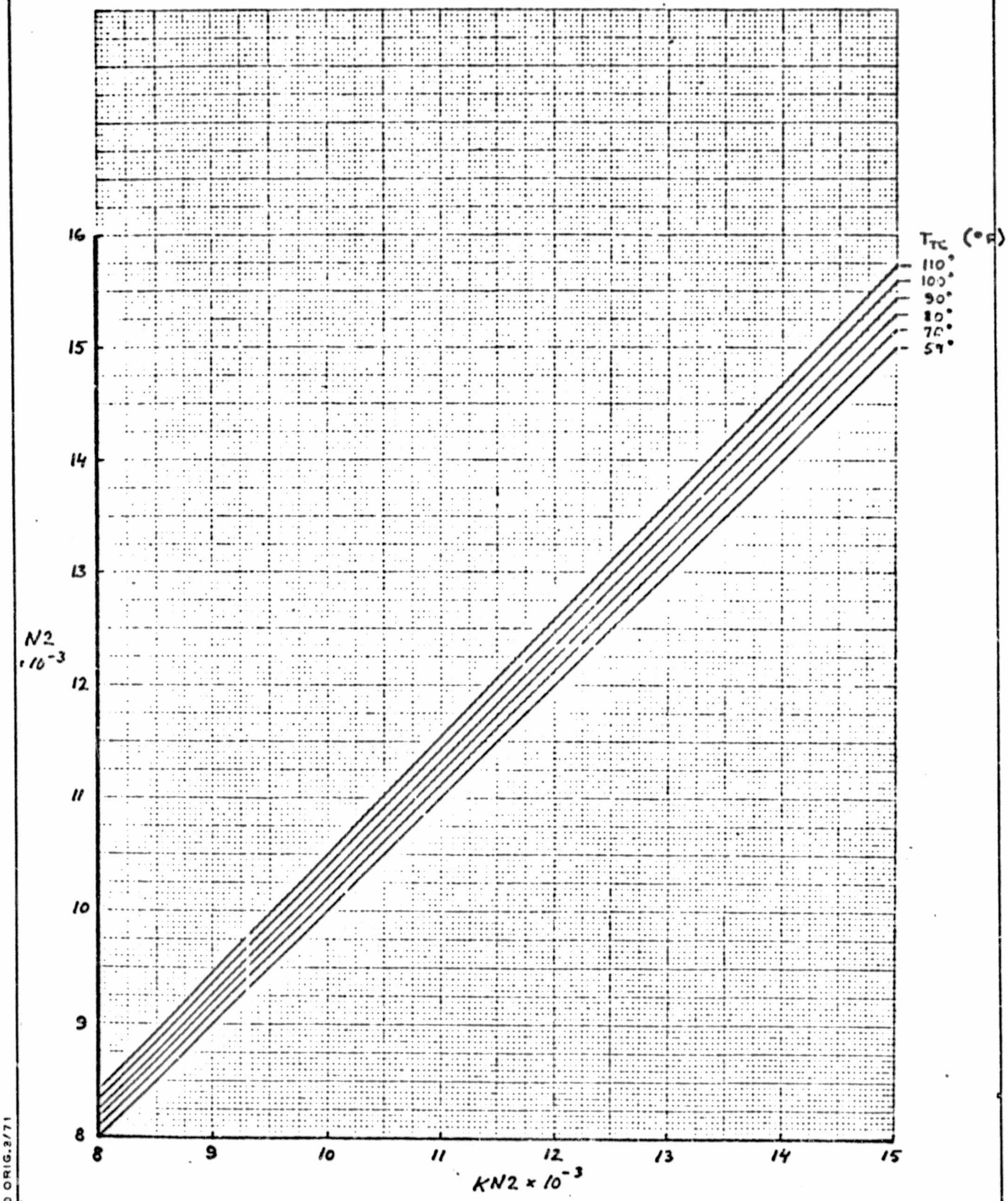
DATA POINT 5: $\beta = 39°$, KN2 = 9000

END OF RUN


TEST SEQUENCE # 3
WK1A ~ LBS/SEC·FT²
KY2 × 10^-3 (RPM)
β = 56°
51.8°
47°
43°
39°
10
20
30
7
8
9
10
11
12
13
14
15
16
17

TEST SEQUENCE # 4





D1 4100 7740 ORIG.2/71

J18-047

REV SYM

Appendix D

Test Logs

RUN NO.	CONFIGURATION TULALIP CHECKOUT PORTION	TYPE OF RUN	β DEG	N_2 RPM	α DEG	V_∞ KTS	V[illegible]	SEC PLA ?	FUSE LANDED ?	P_{AMB} PSIA	T_{AMB} °F	NOTES		PLA TE ?	RUN TIME BEGIN / END
1.1	'O'-FAN ON STATIC TIE-DOWN	[illegible]	3[illegible]°	[illegible]	0	0		No	No	14.650	64	1	3	7-8	10:20
1.2	" " " "	STATIC C/O	✓	7960	✓	✓	12.1	✓	✓	✓	64	✓		✓	10:32
2.1	" " " "	STATIC [illegible]	330°	8000	✓	✓		✓	✓	14.668	67.0	✓		✓	14:[illegible] / 14:5[illegible]
2.2	" " " "	STATIC [illegible]	✓	10000	✓	✓		✓	✓	14.670	67.8	2			15:12 / 15:15
2.2	" " (RERUN OF 2.2)	STATIC C/O	✓	10000	✓	✓		✓	✓	✓	67.9				15:20 / 15:25
2.3	" " 12000 N2	STATIC C/O	✓	12000	✓	✓		✓	✓	✓	✓				15:24 / 15:25
2.4	" " 14000 "	STATIC C/O	✓	14000	✓	✓		✓	✓	✓	67.3				1529 / 1531
2.5	" " 15000 "	STATIC C/O	✓	15000	✓	✓		✓	✓	✓	67.3				1533 / 1535
2.6	" " 16000 "	STATIC C/O		16000	✓	✓		✓	✓	✓	✓				1536 / 1539

1 TTN1 WAS N.G. FOR RUNS 1.1 & 1.2 - JUMPERED TO TTN-2 FOR RUN 2. ET(TORQUE) ~ 0

2 SDDS [illegible] 4 MAL-FUNCTIONED ON FIRST ATTEMPT. ALSO, NO OUTPUT FROM STRAIN-GAGE No 4

3 PLA DATA IS N.G. - AMPLIFIER GAIN SETTING ERROR CHANGED CAL. PLA WAS RE-CALIBRATED.

REC. | CHK | APPROVED | APPROVED | REVISED | DATE

D1-4103-1460 Org 3/71

TEST LOG 2532 TD

BOEING

NO. TG-6034

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D1-4103-1460 Org 3/71

RUN NO.	CONFIGURATION	TYPE OF RUN	β DEG	N_2 RPM	α DEG	V_{OS} KTS	W/A ?	GRD PLANE ?	FUSELAGE ?	P_{AMB} PSIA	T_{AMB} °F	NOTES △		DATE	RUN TIME BEGIN / END
3.1	'Q' - FAN ON STATIC TIE-DOWN $N_2 = 8000$	STATIC / C/C	43	8000	0	0		No	No	14.670	65-70	△1		7-8	15:58 / 16:03
3.2	✓ ✓ ✓ ✓ $N_2 = 10400$ ✓	STATIC / C/O	✓	10000	✓	✓		✓	✓	✓	66.4	✓		✓	16:05 / 1607
3.3	✓ ✓ ✓ ✓ $N_2 = 12,300$ ✓	STATIC / C/O	✓	12000	✓	✓		✓	✓	✓	66.3	✓		✓	16:08 / 16:10
3.4	✓ ✓ ✓ ✓ $N_2 = 14,090$ ✓	STATIC / C/O	✓	14000	✓	✓		✓	✓	14.671	66.4	✓		✓	16:11 / 16:13
3.5	✓ ✓ ✓ ✓ $N_2 = 15060$ ✓	STATIC / C/O	✓	15000	✓	✓		✓	✓	✓	✓	✓		✓	16:14 / 16:15
3.6	✓ ✓ ✓ ✓ $N_2 = 15830$ ✓	STATIC / C/O	✓	16000	✓	✓		✓	✓	✓	65.7	✓		✓	16:16 / 16:19

△1 ENGINE TORQUE VALUES (ET = FT-LBF) ARE IN ERROR FOR RUNS 1, 2 & 3 (LOWER THAN CORRECT)

REC. | CHK | APPROVED | APPROVED

REVISED | DATE

TEST LOG

BOEING

2532 TP

NO. TG-604

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RUN NO.	CONFIGURATION	TYPE OF RUN	β DEG	N_2 RPM	α DEG	V_∞ KTS	W√θ/δ [illegible]	GRD PLANE ?	FUSELAGE ?	P_{AMB} PSIA	T_{AMB} °F	NOTES		DATE '76	RUN TIME START / END
4.1	'Q'-FAN ON STATIC TIE-DOWN N_2=7910	C/O STATIC	47	8000	0	0		No	No	14.710	61.6	1		7-9-76	12:37 / 12:41
4.2	✓ ✓ ✓ N_2=10,030	C/O STATIC	✓	10000	✓	✓		✓	✓	✓	64.4			✓	16:04 / 16:08
4.3	✓ ✓ ✓ N_2=11,860 ✓	STATIC C/O	✓	12000	✓	✓		✓	✓	14.725	64.4				16:09 / 16:11
4.4	✓ ✓ ✓ N_2=13,960 ✓	STATIC C/O	✓	14000	✓	✓		✓	✓	✓	64.5				16:12 / 16:14
4.5	✓ ✓ ✓ N_2=14,950 ✓	STATIC C/O	✓	15000	✓	✓		✓	✓	✓	64.3				16:15 / 16:17
4.6	✓ ✓ ✓ N_2=15,900 ✓	STATIC C/O	✓	16000	✓	✓		✓	✓	✓	64.1				16:18 / 16:19

1 SHUT ENGINE DOWN AFTER COND. 4.1 TO REPAIR TT1 (ENG. EST.) Lead UNDER CORE COWLING. RESTARTED AT 16:04

APPROVED AD 5543-R2 | APPROVED | CHK | REC. | REVISED | DATE

TEST LOG

BOEING

NO. TG-6094

6-7000

RUN NO.	CONFIGURATION	TYPE OF RUN	β (DEG)	N_2 (RPM)	α (DEG)	V_∞ (KTS)	W√θ/δ (LBM/SEC/FT²)	GRD PLANE (?)	FUSELAGE (?)	P_{AMB} (PSIA)	T_{AMB} (°F)	NOTES			RUN TIME BEGIN / END
5.1	'Q'-FAN ON STATIC TIE-DOWN N_2 = 8160	STATIC / c/o	51.6	8000	0	0		NO	NO	14.725	61.9	⚠1		7/10	10:15 / 10:20
5.2	✓ ✓ ✓ ✓ N_2 = 10130 ✓	✓ / ✓	✓	10,000	✓	✓		✓	✓	14.720	✓			✓	10:21 / 10:22
5.3	✓ ✓ ✓ ✓ N_2 = 11,990 ✓	✓ / ✓	✓	12,000	✓	✓		✓	✓	✓	62.4			✓	10:23 / 10:25
5.4	✓ ✓ ✓ ✓ N_2 = 13,960 ✓	✓ / ✓	✓	13,000	✓	✓		✓	✓	✓	62.96			✓	10:26 / 10:28
5.5	✓ ✓ ✓ ✓ N_2 = 14,970 ✓	✓ / ✓	✓	15,000	✓	✓		✓	✓	✓	62.2			✓	10:29 / 10:31
5.6	✓ ✓ ✓ ✓ N_2 = 15920 ✓	✓ / ✓	✓	16,000	✓	✓		✓	✓	✓				✓	10:32 / 10:33

⚠1 PBAR SHOULD BE 14.720 PSIA

REC. | CHK | APPROVED | APPROVED | REVISED | DATE

AD 5543 R2

TEST LOG

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AD 5543-R2

APPROVED	APPROVED	CHK	REC.

RUN NO.	CONFIGURATION	TYPE OF RUN	β	N_2	α	V_∞	W_{KIA}	GRD PLANE	FUSE-LAGE	P_{AMB}	T_{AMB}	NOTES		DATE	RUN TIME BEGIN / END
			DEG	RPM	DEG	KTS	[illegible]	?	?	PSIA	°F	△			
6.1	$N_2 = 8440$ 'Q'-FAN ON STATIC TIE-DOWN	C/O STATIC	56.0	8000	0	0		No	No	14.715	62.7			7/10/72	10:37 / 10:40
6.2	$N_2 = 9940$ ✓ ✓ ✓ ✓	C/O STATIC	✓	10000	✓	✓		✓	✓	✓	✓			✓	10:41 / 10:43
6.3	$N_2 = 12000$ ✓ ✓ ✓ ✓	✓	✓	12000	✓	✓		✓	✓	✓	62.4			✓	10:44 / 10:45
6.4	✓ ✓ ✓ ✓	✓ ✓	✓	14000	✓	✓		✓	✓	✓	✓			✓	10:46 /
6.5	$N_2 = 15,060$ ✓ ✓ ✓ ✓	✓ ✓	✓	15000	✓	✓		✓	✓	✓	62.4			✓	/ 10:50
7.1	$N_2 = 8100$ ✓ ✓ ✓	✓ ✓	43	8000	✓	✓		✓	✓	✓	62.8			✓	1050 / 10:52
7.2	$N_2 = 12,150$ ✓ ✓ ✓ ✓	✓	✓	12000	✓	✓		✓	✓	✓	62.9			✓	10:53 / 10:54
7.3	$N_2 = 15,050$ ✓ ✓ ✓ ✓	✓ ✓	✓	15000	✓	✓		✓	✓	✓	63.4			✓	10:55 / 10:56
8.1	✓ GP @ 7'	STATIC	39	8000	✓	✓		YES	YES	14.710	64.5			✓	[illegible] /
8.2	✓ ✓	STAT	✓	12000	✓	✓		✓	✓	✓	✓			✓	1301 /

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TEST LOG

RUN NO.	CONFIGURATION	TYPE OF RUN	β DEG	N_2 RPM	α DEG	V_∞ KTS		GRD PLANE ?	FUSELAGE ?	P_{AMB} PSIA	T_{AMB} °F	NOTE		DATE	
8.3	Q-FAN T-1 GROUNDPLANE @ 7'	STATIC [illegible]	39	15000	0	0		YES	YES	14.710	64.7			7/10	1303
8.4	✓	✓	✓	16500	✓	✓		✓	✓	✓	✓			7/10	1305
9.1	✓	✓	51.8	8000	✓	✓		✓	✓	✓	✓			7/10	1310
9.2	✓	✓	51.9	12000	✓	✓		✓	✓	✓	66.2			✓	1313
9.3	✓	✓	✓	15000	✓	✓		✓	✓	✓	✓	1		✓	1315
10.1	✓	✓	✓	15K	✓	✓		✓	✓	14.705	✓	2		✓	1344
10.2	✓	✓	✓	MAX	✓	✓		✓	✓	✓	✓			✓	1348
11.1	✓	✓	56	15K	✓	✓		✓	✓	✓	✓			✓	1353
12.1	GP @ 5'	✓	39	8K	✓	✓		✓	✓	✓	68			✓	1410
12.2	✓	✓	✓	12K	✓	✓		✓	✓	14.700	✓			✓	1413

9.3 1 SCAN ABORTED. JITNEY STARTED MOVING BACK DATA N.G

CHIP DETECTOR GB ON OK W/O

2 1ST SCAN NG. REPEATED

BOEING

NO. T6-6094

RUN NO.	CONFIGURATION	TYPE OF RUN	β DEG	N_2 RPM	α DEG	V_∞ KTS		GRD PLANE ?	FUSELAGE ?	P_{AMB} PSIA	T_{AMB} °F	NOTE		DATE	TIME
12.3	O-FAN @ T-1 GROUNDPLANE @ 5'	STATIC	39	15K	0	0		YES	YES	14.700	67.6			7/10	1418
13.1	✓ ✓	✓	39	16K	✓	✓		✓	✓	✓	67.9			✓	1440
14.1	✓ ✓	✓	51.5	7K	✓	✓		✓	✓	✓	✓			✓	1445
14.2	✓ ✓	✓	✓	12K	✓	✓		✓	✓	✓	✓			✓	1447
14.3	✓ ✓	✓	✓	15K	✓	✓		✓	✓	✓	✓			✓	1449
15.1	✓ ✓	✓	✓	16K	✓	✓		✓	✓	✓	66			✓	1539
16.1	✓ ✓	✓	56	16K	✓	✓		✓	✓	✓	✓			✓	1543
17.1	✓ GROUNDPLANE @ 3'	✓	39	7K	✓	✓		✓	✓	✓	67.6	1		✓	1557
17.2	✓ ✓	✓	✓	12K	✓	✓		✓	✓	✓	✓	1 2		✓	1601
18.1	✓ ✓ REPEAT OF 17.2	✓	✓	12K	✓	✓		✓	✓	✓	67.7	1		✓	1648

1 SCANNER HANGING UP IN MID-SCAN REPEAT SCANS

2 β UNSTABLE

TEST LOG

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NO. TG-6074

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6-7000

RUN NO.	CONFIGURATION	TYPE OF RUN	β DEG	N_z RPM	α DEG	V_∞ KTS		GRD PLANE	FUSELAGE	P_{AMB}	T_{AMB} °F	NOTE		DATE	TIME
18.2	Q-FAN @ T-1 GP @ 3'	STATIC C/O	39	15K	0	0		YES	YES	14.750	67.7			7/10	1650
18.3	✓ ✓	✓	39	16K	✓	✓		✓	✓	✓	✓			✓	1653
19.1	✓ ✓ ✓	✓	51.8	8K	✓	✓		✓	✓	✓	✓			✓	1655
19.2	✓ ✓	✓	✓	12K	✓	✓		✓	✓	✓	✓			✓	1656
19.3	✓ ✓	✓	✓	15K	✓	✓		✓	✓	✓	✓			✓	1658
19.4	✓ ✓	✓	✓	16K	✓	✓		✓	✓	✓	✓			✓	1700
20.1	✓ ✓	✓	56	15K	✓	✓		✓	✓	✓	✓			✓	1703
20.2	✓ ✓	✓	✓	✓	✓	✓		✓	✓	✓	✓			✓	1704

20.2 REPEAT OF 20.1

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RUN NO.	CONFIGURATION	TYPE OF RUN	β DEG	N_2 SET RPM	α DEG	V_∞ KTS			P_{AMB} PSIA	T_{AMB} °F	N_1 TCL		DATE	TIME
21.1	'Q'-FAN @ NASA/AMES 40' X 80' IDLE DATA [illegible]	[illegible]	45°	[illegible]	-0-	-0-			14.734	77°	1		7/23	[illegible] / 16:28
22.1	✓ ✓ N_2 = 11,070 ?	STATIC	56°	11,070 MAX	✓	✓			14.735	82	2		✓	18:45 / 18:50
22.2	✓ ✓ N_2 = 14560	STATIC	51.8	MAX	✓	✓			✓	87	2		✓	19:00 / 19:05
23.1	✓ ✓ N_2 = 13,880	STATIC	56.0	MAX [illegible]	✓	✓			14.736	89				19:21 / 19:25
23.2	✓ ✓ ✓ N_2 = 14760	STATIC	51.8	MAX [illegible]	✓	✓			✓	90				19:27
23.3	✓ ✓ N_2 = 14180	STATIC	✓	14050	✓	✓			14.735	91				19:30
23.4	✓ ✓ N_2 = 12290	STATIC	✓	12610	✓	✓			✓	✓				19:32
23.5	✓ ✓ N_2 = 11,100	STATIC	✓	11,170	✓	✓			✓	92				19:33
23.6	✓ ✓ N_2 = 9920	STATIC	✓	9730	✓	✓			14.734					19:35
23.7	✓ ✓ N_2 = 9310	STATIC	45.8	9220	✓	✓								19:41

1 THERE WAS NO OUTPUT FOR TT7 DURING STARTUP.

2 TT7 READING IS LOWER THAN EXPECTED

TEST LOG

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RUN NO.	CONFIGURATION	TYPE OF RUN	β DEG	N_2 SET RPM	α DEG	V_∞ KTS				P_{AMB}	T_{AMB}	NOTE		DATE 1973	TIME
23.8	'Q' FAN @ NASA/AMES 40'X80' W/T N_2 = 8820	STATIC	45	8240	✓	✓				14.734	92	1		7-23	19:44
24.1	✓ ✓ N_2 = 15,350	STATIC	56	MAX 15550	O	O				14.750	73	2		✓	22:26
24.2	✓ ✓ N_2 = 15,490	STATIC	51.8	15290	✓	✓				✓	✓				22:28
24.3	✓ ✓ N_2 = 13670	STATIC	✓	13,800	✓	✓				✓	72				22:31
24.4	✓ ✓ N_2 = 12160	STATIC	✓	12380	✓	✓				✓	74				22:33
24.5	✓ ✓ N_2 = 10,950	STATIC	✓	10960	✓	✓				✓	✓				22:35
24.6	✓ ✓ N_2 = 9590	STATIC	✓	9550	✓	✓				✓	76				22:38
24.7	✓ ✓ N_2 = 9400	STATIC	45	9550	✓	✓				✓	✓	3			22:41
24.8	✓ ✓ N_2 = 8850	STATIC	✓	9550	✓	✓				✓	✓				22:4[illegible]
24.9	✓ ✓ N_2 = 8030	STATIC	45	8020	O	O				14.755	76				22:50

1 SHUTDOWN @ 19:47 2 START AT 22:25

3 Engine WAS UNSTABLE - REPEATED AT N_2 = 8890 AS COND. 24.8

REC. CHK APPROVED APPROVED REVISED DATE

TEST LOG

BOEING

NO. T6-6034

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BOEING

TEST LOG

RUN NO.	CONFIGURATION	TYPE OF RUN	β DEG	N_2 RPM	α DEG	V_∞ KTS				P_{AMB} PSIA	T_{AMB} °F	NOTE		DATE '76	TIME
25.1	'Q'-FAN @ NASA/AMES 40'X80' $N_2 = 15280$	TUNNEL ON	56	MAX 15280	0	40				14.762	76°	1		7/23	[illegible]
25.2	✓ ✓ $N_2 = 15030$	✓	51.8	15330	✓	✓				✓	79°	[illegible]			23:26 23:27
25.3	✓ ✓ $N_2 = 13860$	✓	✓	13800	✓	✓				✓	80°				23:30
25.4	✓ ✓ $N_2 = 12390$	✓	✓	12380	✓	✓				✓	✓	3			23:34
26.1	✓ ✓		5[illegible]	MAX 14,[illegible]		5.4 [illegible]				14.653	82			7/26	1500
			51.3	14,850								4			

1 START AT 23:14 FOR ENGINE [illegible] CREATED AS 25.2 AGAIN [illegible] TUNNEL [illegible] NOT RECORD DATA ON FIRST ATTEMPT AT 25.2.

3 SHUTDOWN AT 23:58 TO INVESTIGATE A OIL OR FUEL LEAK. (FUEL LEAK)

4 ENGINE FAN GEARBOX FAILURE OCCURRED BEFORE CONDITION 26.1 COULD BE RECORDED

REC. | CHK | APPROVED | APPROVED | REVISED | DATE

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APPROVED | APPROVED | CHK | REC. | REVISED | DATE

RUN NO.	CONFIGURATION	TYPE OF RUN	β DEG	N_2 RPM	α DEG	V_∞ KTS	$W_{K/A}$ LB/S			P_{AMB} PSIA	T_{AMB} °F	NOTES		DATE '76	RUN TIME
27.1	Q-FAN IN NASA/AMES 40'X 80' WIND TUNNEL	STATIC W/O	52	[illegible]	0	0	idle			14.6	67°	1 2		9/15	[illegible]
27.2	Engine C/O RUN	✓	52	[illegible]	0	0	[illegible]			14.6	67°	3		✓	[illegible]
27.3	✓	✓	52	[illegible]	0	0	IDLE			✓	67°			✓	[illegible]
28.1	STATIC	STATIC	52	[illegible]	0	2	[illegible]			29.78 14.625	70	4		✓	1350
28.2			51.8	[illegible]			[illegible]				80	5			[illegible]
28.3			✓	[illegible]			25				80	5			[illegible]
28.4			✓	[illegible]			[illegible]				82				1405
28.5			✓	[illegible]			[illegible]				82				[illegible]
28.6			53	[illegible]			15				✓				1412

2 TORQUE METER NOT READING
G/B VERT. VIB. METER NOT READING
1 CHIP 2 ACCY G/B & CHIP 3 2 SCAV LIGHTS CAME ON

3 CHIP 3 2 SCAV LIGHT WENT OFF

1 PM2 & PM4 WERE BROKEN OFF DURING THE ENGINE REPAIR HAD J. BONNER DELETE FROM PROGRAM (PM2 & PM4 ARE THE INNERMOST STATIC PROBES ON THE FAN DUCT EXIT RAKE

4 ENGINE CHIP DETECTOR LIGHTS (2) CAME ON

5 LOST H.S STRAIN GAGE SIGNALS

6 #3 KULITE WENT OUT. CONFIRMED LATER AS N.G. SHORTED OUT SOMEWHERE. (CORE OF PDC3)

TEST LOG

BOEING

NO. T6-6004

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REC. | CHK | APPROVED | APPROVED | REVISED | DATE

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TEST LOG

BOEING

RUN NO.	CONFIGURATION	TYPE OF RUN	β DEG	N_2 $\frac{KN2}{\sqrt{\theta_2}}$ RPM	α DEG	V_∞ KTS	W_{KIA} LB/S			P_{AMB} PSIA	T_{AMB} °F	NOTES		DATE '76	RUN TIME
29.1	Q-FAN IN NASA/AMES 40'X 80' WIND TUNNEL — AIR ON	#2	56	14750 / [illegible]	0	53 / 40	34			[illegible]	71			10/1	[illegible]
29.2			51.8	14200 / [illegible]			31			✓	73			✓	1404
29.3			✓	[illegible]			23			✓	76			✓	1408
29.4			✓	[illegible]			24			✓	78			✓	1410
29.5			✓	[illegible]			20			✓	79			✓	1412
29.6			43	[illegible]			[illegible]			✓	80			✓	1416
30.1		#1	51.5	[illegible]	45		31			✓	80			✓	1424
30.2			✓	[illegible]			24			✓	✓	1		✓	1426
30.3			43	[illegible]			15			✓	✓			✓	1430

1 CHIP 2 ON

NO. TG-6094

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BOEING
TEST LOG

RUN NO.	CONFIGURATION	TYPE OF RUN	β DEG	N_2 RPM	α DEG	V_∞ KTS	W_{K1A} LB/S			P_{AMB} PSIA	T_{AMB} °F	NOTES		DATE '76	RUN TIME
31.1	Q-FAN IN NASA/AMES 40'X 80' WIND TUNNEL	WIND ON	51.8	14,360	90°	40	31			14.122	76	1		10-1	17:52
31.2	✓ ✓	✓	✓	10,100	✓	38.5	24			✓	77			✓	17:57
31.3	✓ ✓	✓	43	7890	✓	39.0	15			✓	82			✓	18:03
32.1	✓ ✓	WIND ON	56	14,830	0°	74.5	34			✓	82			✓	18:12
32.2	✓ ✓	✓	51.8	13,960	✓	73.3	31			✓	86			✓	18:19
32.3	✓ ✓	✓	✓	12,700	✓	74.9	28			✓	86			✓	18:22
32.4	✓ ✓	✓	✓	10,350	✓	75	24			✓	85			✓	18:29
32.5	✓ ✓	✓	✓	7420	✓	75.5	20			14.638	85			✓	18:34
32.6		✓	43	6810	0	74.9	15			14.638	85			✓	18:38

1 ENG LIGHT AT 17:42

REC. | CHK | APPROVED | APPROVED | REVISED | DATE

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RUN NO.	CONFIGURATION	TYPE OF RUN	β DEG	N_2 RPM	α DEG	V_∞ KTS	$W_{K/A}$ LB/S			P_{AMB} PSIA	T_{AMB} °F	NOTES		DATE '76	RUN TIME
33.1	Q-FAN IN NASA/AMES 40'X 80' WIND TUNNEL V_{TL} = 75 KTS	WIND ON	56	14,920	20	75	34			14.640	85			10-1	18:43
33.2	✓ ✓ ✓	✓	51.8	14,100	✓	76.5	31			✓	86			✓	18:46
33.3	✓ ✓ ✓	✓	✓	12,600	✓	76.2	28			✓	87			✓	18:48
33.4	✓ ✓ ✓	✓	✓	10,180	✓	75.9	24			✓	✓			✓	18:52
33.5	✓ ✓ ✓	✓	✓	7450	✓	75.0	20			✓	✓			✓	18.55
33.6	✓ ✓ ✓	✓	43	7040	20	75.1	15			✓	87			✓	18:58
34.1	✓ ✓ ✓	✓	51.8	14,300	45	74.9	31			✓	✓			✓	19:04
34.2	✓ ✓ ✓	✓	✓	10,210	✓	74.9	24			✓	✓			✓	19:06
34.3	✓ ✓ ✓	WIND ON	43	6730	45	73.4	15			14.644	86			10-1	19:11

REC. | CHK | APPROVED | APPROVED | REVISED | DATE

TEST LOG

BOEING

NO. T6-6003-1

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RUN NO.	CONFIGURATION	TYPE OF RUN	β DEG	N_2 RPM	α DEG	V_∞ KTS	$W_{K/A}$ LB/S			P_{AMB} PSIA	T_{AMB} °F	NOTES		DATE '76	RUN TIME
35.1	Q-FAN IN NASA/AMES 40' X 80' WIND TUNNEL V_{TKL} = 75 KTS; φ = 60°	WIND ON	56	14,510	60°	74.9	34			14.644	85	1		10/1	19:17
36.1	✓ ✓ ✓	✓	56°	14,650	60°	74.5	34			14.679	70	2		10/1	23:34
36.2	✓ ✓ ✓	✓	51.8	14,110	✓	75.3	31			✓	72			✓	23:37
36.3	✓ ✓ ✓	✓	✓	12,640	✓	75.0	28			✓	73			✓	23:43
36.4	✓ ✓ ✓	✓	✓	10,580	✓	75.0	24			✓	74			✓	23:45
36.5	✓ ✓ ✓	✓	✓	9070	✓	74.3	20			✓	74			✓	23:53
36.6	✓ ✓ ✓	WIND ON	43	8340	60	74.1	15			14.6	75	3 2		10/1	23:55
37.1	✓ ✓ ✓	✓	43	9K	60	15 [illegible]	14			29.95 [illegible]	32	4		10/4	14:32
37.2			43	[illegible]											

1 CHIP LIGHT CAME ON AT 19:18. φ ROTATED TO 0° AND ENGINE COOLED & SHUTDOWN AT 19:25. CHIP LIGHT WAS FOR ACCESSORY GEARBOX (CHIP DETECTOR #2)

2 LIGHT AT 23:24 SHUT DOWN AT 00:01 3 ACC G/B CHIP LIGHT ON DURING RUNDOWN

4 INSTALLED TWO KULITE TRANSDUCERS IN CORE ENGINE CF PROBES. DISCONNECTED PTC 34 (TEED S/V LINE TO PTC 36 ADDR 220) LINE & INSTALLED NEW PDC 1 KULITE AT FITTING (SN 2590-4-310) APPROX 1 FT. OF 1/16 TUBE TO PROBE. INSTALLED PDC 2 IN PTC40 PROBE (TEED PTC40. S/V LINE TO PTC 37. ADDR 240) KULITE S/N 2590-4-307 BOTH KULITES ARE XQL-093-15D

REF. CHK. APPROVED APPROVED REVISED DATE

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RUN NO.	CONFIGURATION	TYPE OF RUN	β DEG	N_2 RPM	α DEG	V_∞ KTS	$W\sqrt{K}/A$ LB/S			P_{AMB} PSIA	T_{AMB} °F	NOTES		DATE '76	RUN TIME
	Q-FAN IN NASA/AMES 40'X 80' WIND TUNNEL														
38.1		#2	56	15100	75	75				14.7	85			10/4	1440
38.2			51.8	14100	✓	✓					87				1444

AFT END OF ENGINE DISINTERATED (BURST TURBINE DISC)

END OF TEST

TEST LOG

BOEING

Appendix D

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Appendix E

Lift Fan Technology Program

Blade Stress Report

Q-FAN DEMONSTRATOR

LIFT FAN TECHNOLOGY PROGRAM
BLADE STRESS REPORT

BLADE VIBRATORY STRESSES

FOR

Q-FAN DEMONSTRATOR

AT

BOEING TEST FACILITY (TULALIP)

AND

NASA AMES 40' x 80' WIND TUNNEL

Purchase Contract No. N-918745-9578
NASA Prime Contract 2-9215

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S. Parsons

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D. J. Nelson — Program Manager
D. J. Nelson

Prepared for: Boeing Aerospace Company, Seattle, Washington

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SUMMARY

The Hamilton Standard QFT-55 full scale Q-Fan Demonstrator propulsor was utilized by Boeing Aerospace Company to fabricate a large scale variable pitch Lift/Cruise fan nacelle. The unit was tested at Boeing's Tulalip, Washington static test facility and the NASA Ames 40' x 80' wind tunnel under a NASA Prime Contract NAS2-9215. The objectives of the tests were to determine the range of nacelle tilt angles, freestream velocities, and engine airflow levels for which a fixed lip inlet can provide pressure recoveries and distortion levels that result in acceptable engine core/fan operating characteristics and fan blade stress levels. This document presents the results of the blade stress data acquired during both phases of the testing.

INTRODUCTION

A comprehensive lift/cruise fan technology data base is required for the development of V/STOL airplanes for both civilian and military applications. Toward this objective, a Boeing designed engine nacelle, housing the existing Hamilton Standard 4.6 foot variable pitch fan driven by a Lycoming T55-L-11A turboshaft engine was tested in the NASA-ARC 40' x 80' wind tunnel.

TEST HARDWARE

The test hardware consisted of an asymmetric inlet, variable pitch Q-Fan and a T55-L-11A gas turbine. Appropriate cowling, fairings, and instrumentation were fabricated to complete the test item.

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TEST RESULTS

In connection with the Boeing-NASA V/STOL aircraft program, blade vibratory stresses were measured during the testing of the Hamilton Standard Q-Fan Demonstrator at Boeing's test facility (Tulalip) and in the NASA Ames 40' x 80' wind tunnel. This memorandum reports on the results of these measurements.

The rotating components of unit under test were identical to those described in Report NASA CR-121265 (HSER 6163) which covered the stresses measured at Hamilton Standard. Referring to Figure 6 (Page 239) of that report, stresses were measured using the strain gages located at 362 mm (14.25 in.) from the blade tip on Blades No. 1, 6 and 7 during this test program. Prior testing showed that the highest readings were at this location. The stresses were recorded on magnetic tape and played back onto Sanborn records. Also recorded and played back were torque, fan speed, and blade angle. The playback also included the 1F (once per fan revolution) component of the total vibratory stress for the strain gage on Blade No. 1. For the Ames tests, wind tunnel speed and fan angle of attack (actually yaw inflow angle) were noted on the log. The PLA (power lever angle) was also logged.

Three series of tests were conducted:

1. Static tests were conducted during the period from July 8-10, 1976, at Boeing's test facility. Testing included a simulated ground plane at nominal distances from one to two meters (3 to 7 feet) behind the fan/engine assembly.

2. Tests were conducted in the Ames tunnel during the period from July 23-26, 1976. Tunnel speeds were zero and 20 meters per second (40 knots). There was no inflow angle for these tests.

3. Additional tests were conducted in the Ames tunnel during the period from October 1-4, 1976. Tunnel speeds were 20 and 39 m/s (40 and 75 knots). Inflow angles for these tests were 0°, 45° and 90° at 20 m/s (40 knots) and 0°, 20°, 45°, 60° and 75° at 39 m/s (75 knots).

   Maximum fan speeds and blade angles were 3369 RPM and 56°.

For the first series of tests, without the simulated ground plane, the maximum measured total vibratory stress was ± 13.8 MN/m^2 (± 2000 psi) and the maximum measured 1F stress component was ± 1.9 MN/m^2 (± 270 psi). The maximum total stress condition was associated with operation near the 3F/1f critical speed, where the aerodynamic excitation component at three cycles per revolution is near the first flatwise natural bending frequency of the blades. A critical speed diagram is shown on Figure 5-39 of Report NASA CR-121265. With the simulated ground plane, the maximum measured total vibratory stress was ± 26.2 MN/m^2 (± 3800 psi) and the maximum measured 1F component was ± 3.2 MN/m^2 (± 460 psi).

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TEST RESULTS (continued)

For the second series of tests, the maximum measured total vibratory stress was ± 8.3 MN/m^2 (± 1200 psi) and again this was at operation near the 3F/1f critical speed. No 1F component was deduced for these tests.

For the third series of tests, the maximum measured total vibratory stress for steady state operating conditions was ± 18.6 MN/m^2 (± 2700 psi) and the maximum measured 1F stress component was ± 3.1 MN/m^2 (∓ 450 psi). The maximum stress conditions were at the maximum tested inflow angle and tunnel speed, 60° and 39 m/s (75 knots).

The maximum measured vibratory stresses are well within the continuous allowable level for these blades, which have solid dural spars. The Sanborn playbacks disclosed no new or unusual stress condition. The 3F/1f condition discussed above had been observed in previous testing.

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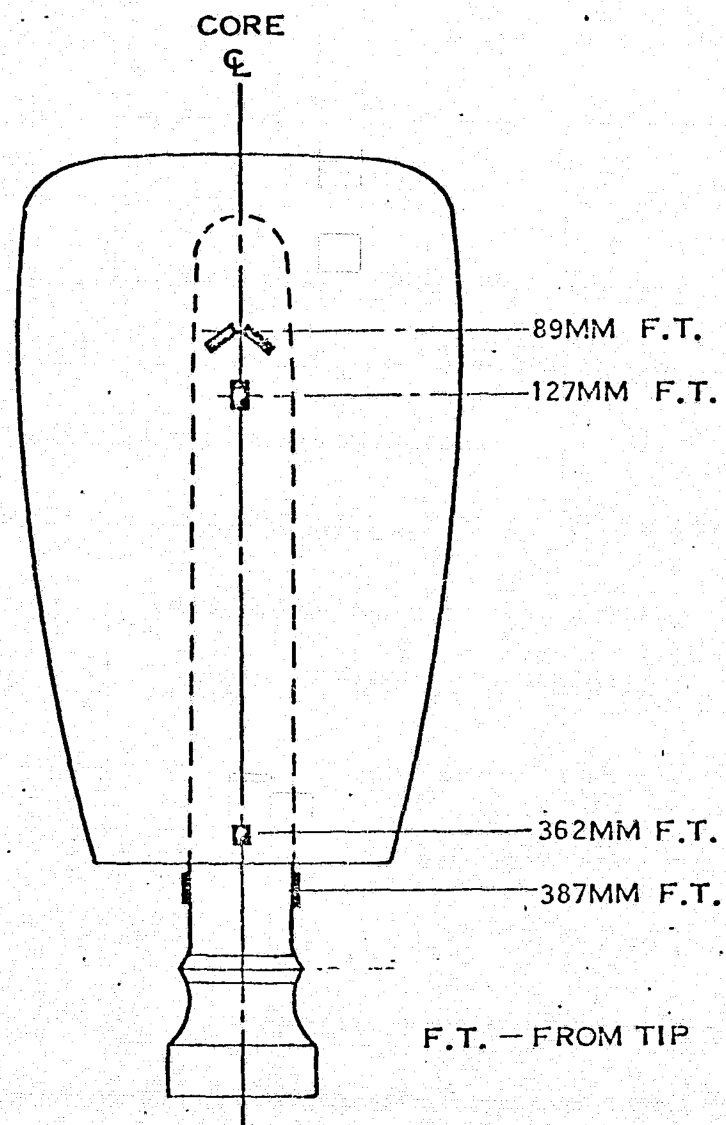

FIGURE 6

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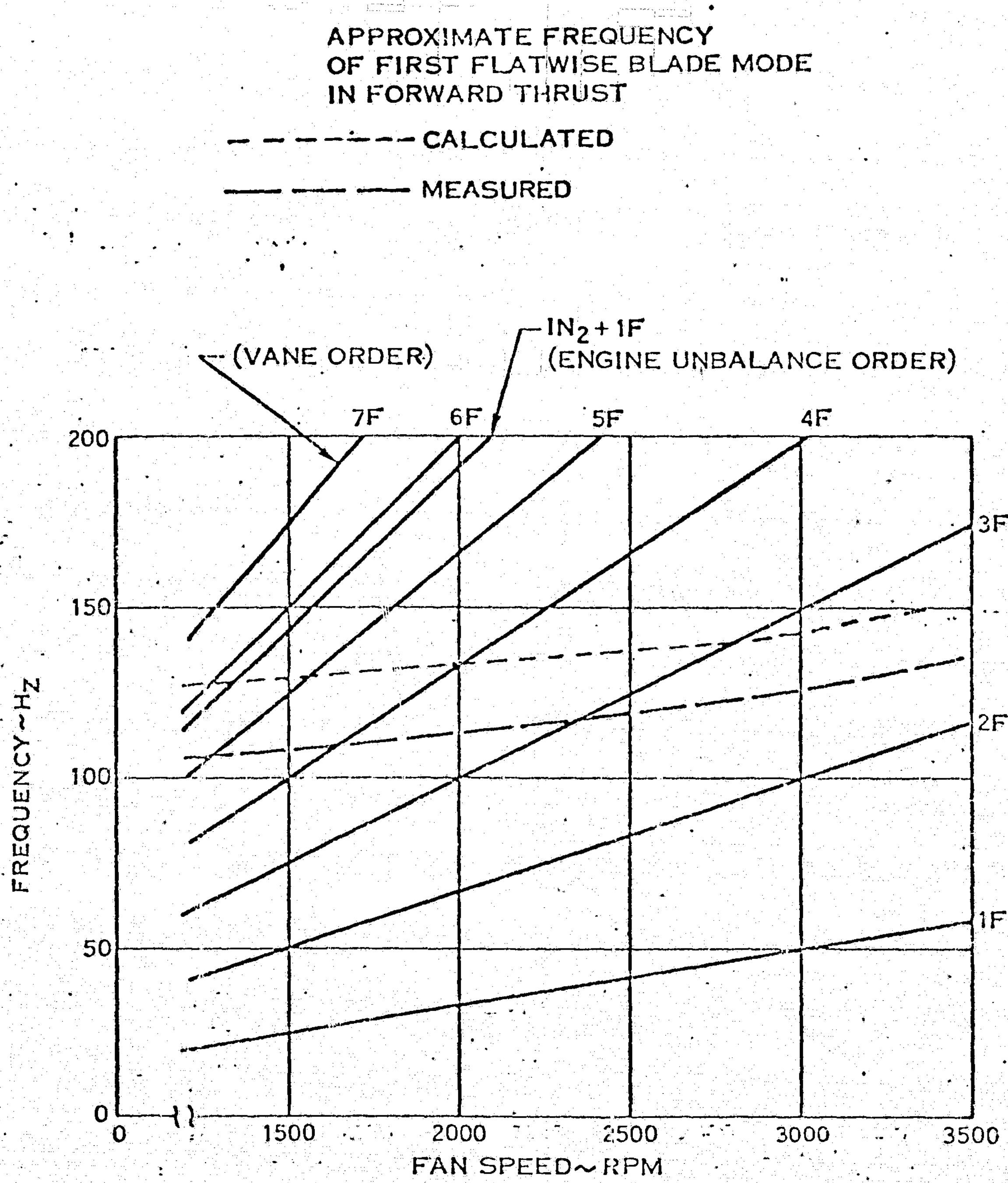

1.4 M DIAM. Q—FAN DEMONSTRATOR
CRITICAL SPEED DIAGRAM

FIGURE 5—39.

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Appendix F

Small Scale LCF Inlet, Fan Face Corrected Flow

Due to a malfunction in the flow metering system, the initially calculated inlet flow rates were in error for runs 4 through 33 in the small scale test. These flow rates were recalculated using the calibration curve developed from data obtained subsequent to repairs to the flow meter. The revised values of fan face corrected airflow per unit area are tabulated in this Appendix. Since the calibration curve is valid only when the inlet airflow is attached, the values shown for separated test points are approximate.

NOTE: AIRFLOWS IN PARENTHESES ARE APPROXIMATE VALUES FOR SEPARATED POINTS

RUN NO. /CONDITION NO.	A (ATTACHED) S (SEPARATED)	WCAZ (lb/sec ft²)
V_0 = 75 knots, α = 90°		
4/1	S	(19)
4/2	S	(21)
4/3		27.6
4/4	A	30.8
4/5	A	34.9
4/6	A	38.1
4/7	A	41.7
4/8	A	43.9
V_0 = 60 knots α = 90°		
5/1	S	(19)
5/2		23.6
5/3	A	26.3
5/4	A	29.7
5/5	A	35.5
5/6	A	38.0
5/7	A	41.8
5/8	A	43.9
V_0 = 90 knots α = 90°		
6/1	S	(21)
6/2	S	(23)
6/3	S	(25)
6/4		31.8
6/5	A	34.5
6/6	A	38.1
6/7	A	41.5
6/8	A	44.0

RUN NO. /CONDITION NO.	A (ATTACHED) S (SEPARATED)	WCAZ (lb/sec ft²)
V_0 = 40 knots α = 90°		
7/1	A	19.5
7/2	A	23.0
7/3	A	26.9
7/4	A	30.4
7/5	A	35.0
V_0 = 0 α = 90°		
8/1	A	30.0
8/2	A	35.1
8/3	A	38.4
8/4	A	42.1
8/5	A	44.3
8/6	A	18.5
V_0 = 125 knots α = 60°		
9/1	S	(19)
9/2	S	(21)
9/3	S	(25)
9/4	A	32.9
9/5	A	35.7
9/6	A	37.3
9/7	A	40.3
9/8	A	40.2
9/9	A	42.9
V_0 = 110 knots α = 60°		
10/1	S	(21)
10/2	S	(26)
10/3	A	34.1
10/4	A	40.4

RUN NO. /CONDITION NO.	A (ATTACHED) S (SEPARATED)	WCAZ (lb/sec ft²)
V_0 = 90 knots α = 60°		
11/1	S	(21)
11/2	A	27.3
11/3	A	34.0
11/4	A	40.1
V_0 = 70 knots α = 60°		
12/1	A	19.7
12/2	A	19.7
12/3	A	24.0
12/4	A	33.7
12/5	A	40.2
V_0 = 140 knots α = 60°		
13/1	S	(20)
13/2	S	(22)
13/3	S	(26)
13/4	S	(30)
13/5	A	38.1
13/6	S	(34)
13/7	A	39.8
13/8	A	42.8
V_0 = 115 knots α = 60°		
14/1	S	(23)
14/2	S	(24)
14/3	A	31.6
14/4	A	34.1

CALC			REVISED	DATE
CHK				
APR				
APR				

SMALL SCALE LCF INLET, BOEING 9-BY-9FT LSWT – FAN FACE CORRECTED FLOW PER UNIT AREA REVISED VALUES FOR TEST NO 2532

THE BOEING COMPANY

NOTE: AIRFLOWS IN PARENTHESES ARE APPROXIMATE VALUES FOR SEPARATED POINTS

RUN NO. /CONDITION NO.	A (ATTACHED) S (SEPARATED)	WCAZ (lb/sec ft²)
V_o = 120 knots $\alpha = 60°$		
15/1	S	(20)
15/2	S	(24)
15/3	A	32.7
15/4	A	35.2
V_o = 40 knots $\alpha = 60°$		
16/1	A	21.0
16/2	A	25.8
16/3	A	34.3
16/4	A	40.1
V_o = 85 knots $\alpha = 60°$		
17/1	S	(19)
17/2	A	22.8
17/3	A	25.6
17/4	A	28.4
17/5	A	33.6
V_o = 105 knots $\alpha = 75°$		
18/1	A	44.2
20/1	S	(24)
20/2	S	(24)
20/3	S	(27)
20/4	S	(31)
20/5	S	(31)
20/6		37.1
20/7	A	40.4
20/8	A	43.0
20/9		37.3
20/10	S	(33)
20/11	S	(34)

RUN NO. /CONDITION NO.	A (ATTACHED) S (SEPARATED)	WCAZ (lb/sec ft²)
V_o = 90 knots $\alpha = 75°$		
21/1	S	(21)
21/2	S	(22)
21/4	S	(25)
21/5	A	29.5
21/6	A	31.2
21/7	A	33.5
21/8	A	29.6
21/9	S	(26)
V_o = 0 $\alpha = 75°$		
22/3	A	24.4
22/4	A	35.0
22/5	A	41.0
V_o = 75 knots $\alpha = 75°$		
23/1	S	(20)
23/2		24.7
23/4	A	30.1
23/5	A	33.5
23/6	A	37.3
23/7	A	40.5
23/8	A	42.8
V_o = 40 knots $\alpha = 120°$		
24/1	A	21.4
24/2	A	23.6
24/3	A	28.0
24/4	A	31.0
24/5	A	33.7
24/6	A	37.7
24/7	A	40.7
24/9	A	43.2

RUN NO. /CONDITION NO.	A (ATTACHED) S (SEPARATED)	WCAZ (lb/sec ft²)
V_o = 75 knots $\alpha = 120°$		
25/1	S	(22)
25/2	S	(24)
25/3	S	(26)
25/4		28.6
25/5	A	30.5
25/6	A	33.0
25/7	A	37.1
25/8	A	40.3
V_o = 55 knots $\alpha = 120°$		
26/1	S	(20)
26/2	A	26.5
V_o = 140 knots $\alpha = 45°$		
27/1	S	(14)
27/2	S	(17)
27/3	A	25.9
27/4	A	28.6
27/5	A	34.4
27/6	A	36.9
27/7	A	40.1
27/8	A	43.6
V_o = 125 knots $\alpha = 45°$		
28/1	S	(18)
28/3	A	26.1
28/4	A	34.6

CALC		REVISED	DATE
CHK			
APR			
APR			

SMALL SCALE LCF INLET, BOEING 9-BY-9FT LSWT — FAN FACE CORRECTED FLOW PER UNIT AREA REVISED VALUES FOR TEST NO 2532

THE BOEING COMPANY

NOTE: AIRFLOWS IN PARENTHESES ARE APPROXIMATE VALUES FOR SEPARATED POINTS

RUN NO. /CONDITION NO.	A (ATTACHED) S (SEPARATED)	WCA2 (lb/sec ft²)	RUN NO. /CONDITION NO.	A (ATTACHED) S (SEPARATED)	WCA2 (lb/sec ft²)	RUN NO. /CONDITION NO.	A (ATTACHED) S (SEPARATED)	WCA2 (lb/sec ft²)
V_o = 90 knots α = 45°			V_o = 90 knots α = 45°					
29/1	A	18.9	33/1	S	(11)			
29/2	A	22.5	33/2	A	23.2			
29/3	A	25.0	33/3	A	28.5			
29/4	A	34.5	33/4	A	34.0			
			33/5	A	36.8			
V_o = 40 knots α = 45°			33/6	A	40.3			
30/1	A	19.2	33/7	A	43.0			
30/2	A	21.7						
30/3	A	24.5						
30/4	A	34.7						
V_o = 150 knots α = 45°								
31/3	S	(16)						
31/4	S	(19)						
31/5	S	(24)						
31/6	A	34.4						
V_o = 40 knots α = 45°								
32/1	A	12.3						
32/2	A	18.6						
32/3	A	24.3						
32/4	A	29.7						
32/5	A	35.2						
32/6	A	37.8						
32/7	A	41.0						
32/8	A	43.5						
32/9	A	12.2						

CALC			REVISED	DATE	SMALL SCALE LCF INLET, BOEING 9-BY-9FT LSWT — FAN FACE CORRECTED FLOW PER UNIT AREA REVISED VALUES FOR TEST NO 2532
CHK					
APR					THE BOEING COMPANY
APR					PAGE 116