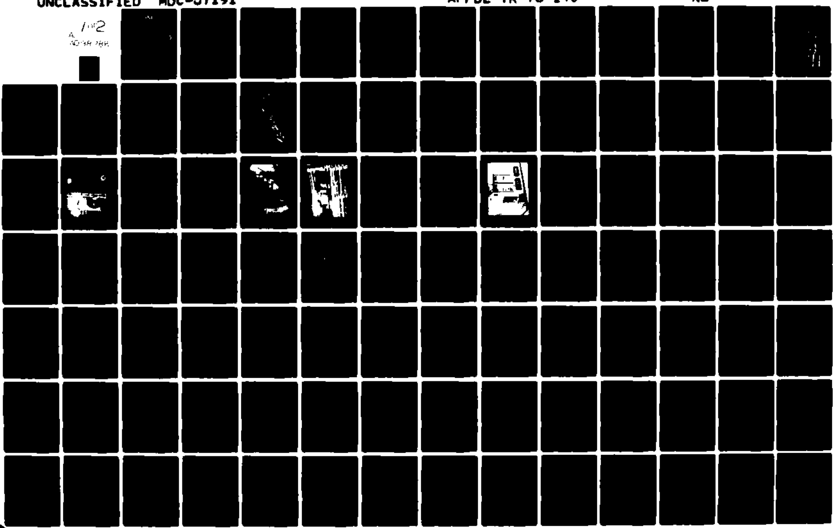
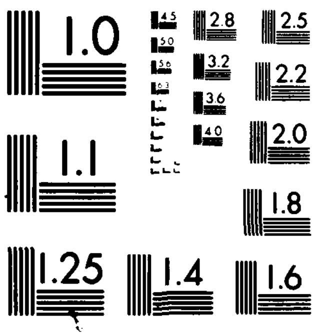
AD-A098 788   DOUGLAS AIRCRAFT CO LONG BEACH CA   F/G 20/1
YC-15 INTERIOR NOISE MEASUREMENTS. TECHNICAL DISCUSSION.(U)
MAR 81 J L WARNIX, D E HINES   F33657-72-C-0833
UNCLASSIFIED MDC-J7191   AFFDL-TR-76-140   NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AFFDL-TR-76-140 LEVEL II (2)

YC-15 INTERIOR NOISE MEASUREMENTS
Technical Discussion

McDonnell Douglas Corporation
Douglas Aircraft Company
Long Beach, California 90846

MARCH 1981

TECHNICAL REPORT AFFDL-TR-76-140
Final Report for Period 8 May 1975 — 8 December 1976

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Langley Research Center
Hampton, Virginia 23665

AIR FORCE FLIGHT DYNAMICS LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT PATTERSON AIR FORCE BASE, OHIO 45433

NOTICE

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture use, or sell any patented invention that may in any way be related thereto.

This report has been reviewed by the Office of Public Affairs (ASD/PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

Vincent R. Miller

VINCENT R. MILLER
Project Engineer
USAF

James A. Schoenster

JAMES A. SCHOENSTER
Technical Monitor
NASA/LaRC

Davey L. Smith

DAVEY L. SMITH, Chief
Structural Integrity Branch
Structures and Dynamics Division

FOR THE COMMANDER

Ralph L. Kuster

RALPH L. KUSTER, JR., Colonel, USAF
Chief, Structures and Dynamics Division

"If your address has changed, if you wish to be removed from our mailing list, or if the addressee is no longer employed by your organization please notify AFWAL/FIBED *W-PAFB, OH 45433 to help us maintain a current mailing list".*

Copies of this report should not be returned unless return is required by security considerations, contractual obligations, or notice on a specific document.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: (18) AFFDL/TR-76-140 (19)

2. GOVT ACCESSION NO.: AD-A098 788

3. RECIPIENT'S CATALOG NUMBER:

4. TITLE (and Subtitle): (6) YC-15 INTERIOR NOISE MEASUREMENTS . Technical Discussion .

5. TYPE OF REPORT & PERIOD COVERED: (9) Final Report, 8 May [redacted]75 - 8 Dec[redacted]76,

6. PERFORMING ORG. REPORT NUMBER: (14) MDC - J7191

7. AUTHOR(s): (10) James L./Warnix [redacted] Donald E./Hines

8. CONTRACT OR GRANT NUMBER(s): (15) F33657-72-C-0833 new Amendment No. P00032

9. PERFORMING ORGANIZATION NAME AND ADDRESS:
Douglas Aircraft Company
McDonnell Douglas Corporation
Long Beach, California 90846

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS:
Project Number: 1367 (17) 04
Task Number: 136704
Program Element : 62201F

11. CONTROLLING OFFICE NAME AND ADDRESS:
Air Force Flight Dynamics Laboratory
Aero-Acoustics Branch (FYA)
Wright-Patterson Air Force Base, Ohio 45433

12. REPORT DATE: (11) Mar[redacted]81

13. NUMBER OF PAGES: 115 (12) 124

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):

15. SECURITY CLASS. (of this report): UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

- o Acoustic loads
- o Airplane interior noise
- o Fuselage noise reduction
- o Boundary layer noise
- o Jet noise
- o Structural vibration
- o Powered lift noise
- o Noise prediction
- o Jet/Flap Interaction Noise

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Douglas Aircraft Company conducted tests to simultaneously measure exterior fuselage noise, structural vibration, and interior noise of a ~~USAF/McDonnell Douglas~~ YC-15 Advanced Medium-Range Short-Takeoff- and Landing Transport airplane that employs an under-the-wing, externally-blown-flap powered lift system. The data obtained are of high quality and constitute a comprehensive data base of static ground tests at various flap and engine settings and flight tests at typical STOL takeoff, taxi, cruise, and landing.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

FOREWORD

This report describes a joint program between the Air Force Flight Dynamics Laboratory and the NASA Langley Research Center to measure the fuselage exterior and interior acoustic environment and the structural vibrations of the fuselage shell of the USAF/McDonnell Douglas YC-15 (AMST) prototype during both ground and flight operations of aircraft No. 1, Serial No. 01875. The work was conducted from 8 May 1975 to 8 December 1976 and submitted in fulfillment of Data Item Number DI-S-3591/S-117-1 of Contract F33657-72-C-0833, Amendment/Modification No. P00032 and AF Project Number 1367, Task Number 136704. Flight instrumentation for the acquisition of the data presented herein was installed through AFFDL- and NASA-funded Amendment/Modification Numbers P00020, P00024, P00025, P00029, and P00032 to Air Force Contract No. F33657-72-C-0833.

The Air Force Project Engineers were D.L. Smith and later V.R. Miller. Mr. J. A. Schoenster, NASA Langley Research Center, was the NASA AMST Flight Experiments Technical Monitor and Mr. M. L. Lopez was the Douglas Program Manager. Principal Investigators and authors of this report were J. L. Warnix and D. E. Hines.

The draft report was submitted on 8 October 1976.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Cont'd)

LIST OF ILLUSTRATIONS (Cont'd)

LIST OF TABLES

1. INTRODUCTION

The purpose of this report is to describe the acoustic and vibration measurements conducted by Douglas Aircraft Company (DAC) during ground and flight operations of a YC-15 airplane; to assess the quality of the data obtained; and examine these data for trends indicative of jet exhaust noise, structure-borne engine vibration, and Under-the-Wing (UTW) Externally-Blown Flap (EBF) disturbances and their effects on cabin noise and fuselage skin response. The objective of the test program was to measure the fuselage exterior and interior acoustic environments and the structural vibrations of the fuselage shell during both ground and flight operations of the airplane. These data may ultimately be used in the development of technology required to predict and reduce interior noise for Short Takeoff and Landing (STOL) Externally Blown Flap (EBF) airplanes.

The acoustic and vibration measurements were acquired during two testing periods. In the first series of measurements (March, 1976) fuselage exterior and interior acoustic data and fuselage vibration data were recorded during ground and flight tests. In the second series of measurements additional fuselage exterior data were recorded during the "Engine Inlet Acoustics and EBF Aero-Acoustic Loads and Thermal Environment"(1) program tests in May, 1976. These data supplement the first series exterior acoustic data and demonstrate test repeatability.

This report consists of technical discussions. A description of the YC-15 airplane is contained in Section II. Descriptions of the data acquisition and data reduction systems are discussed in Sections III and IV. Sections V and VI describe the ground and flight tests that were conducted. Conclusions are given in Section VIII and Recommendations are presented in Section IX. An unpublished report (Reference 2) contains the tabulated acoustic and vibration data and pertinent airplane performance, engine parameter, and flap position time history data and is being held at AFFDL/FBE, Wright-Patterson Air Force Base.

2. AIRPLANE DESCRIPTION

The YC-15 (Figures 1 and 2) is a wide-bodied, high-wing, T-tailed military transport airplane. Four Pratt and Whitney JT8D-17 engines rated at 16,000 pounds (71,168 N) thrust at sea level under static conditions, are mounted in a forward position, and just under the wing. The unswept wing embodies supercritical aerofoil technology enabling the YC-15 to achieve modern jet transport speeds. The high-lift system of the YC-15 consists of a large chord, two-segment flap and full-span, leading-edge devices. The flaps are designed to penetrate the engine exhaust even at small deflection angles and to deflect the engine efflux downward at approximately the same angle as the flap deflection. This is accomplished by a double four-bar linkage which lowers the flap initially, and then progressively deflects and separates the two almost equal chord segments of the flap. The spoilers ahead of the flap are drooped as a function of flap motion to maintain an effective slot between the forward flap and the wing upper lip (spoiler trailing edge). The high lift system relies to a degree on the underlying principle of the jet flap; therefore, the required lift is achieved both from the deflected thrust and increased wing circulation.

A more detailed description of the YC-15 airplane can be found in the flight test plan(1). The YC-15 systems that directly pertain to this program are described below.

The engines are installed in nacelles (no acoustic treatment) that are supported by a wing pylon positioning the engine exhaust nozzles forward of and just below the wing leading edge. The general arrangement of the propulsion system is illustrated in Figure 3.

The external mixer nozzle arrangement promotes good mixing of fan and primary exhaust air with freestream air to produce rapid temperature and velocity reduction and to spread the exhaust wake over a large span of the flap.

Figure 1. YC-15

The centerlines of the inboard and outboard engines are at fuselage stations Z = 34.3, X = ± 206.0 and Z = 33.5, X = ± 331.0, respectively, and the jet exit planes are at Y = 693.5 and 706.0, respectively.

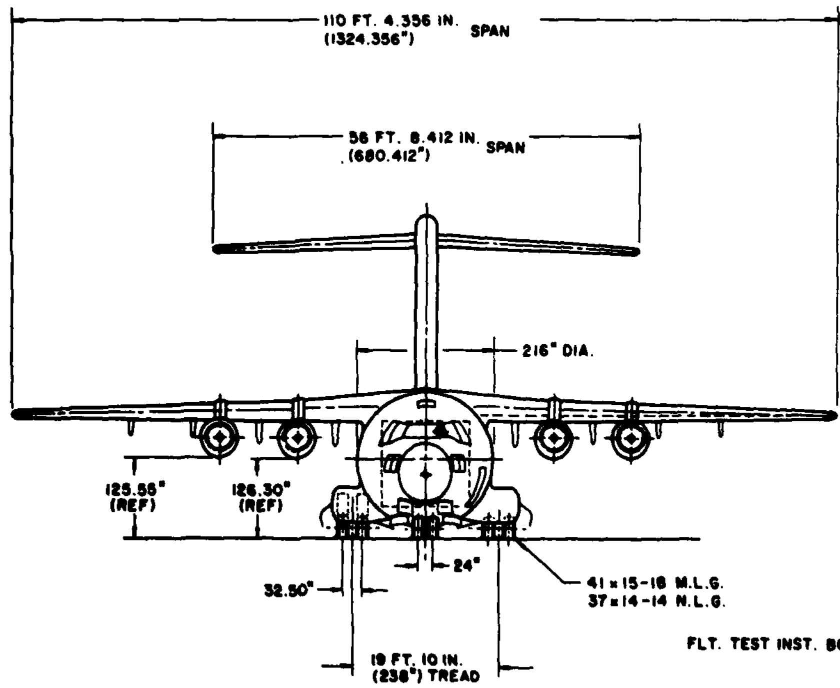
The flaps and linkage system are shown in Figure 4. The locations of the flaps, fairings, and engines with respect to the wing are shown in Figure 5. Figure 5 also shows the location of instrumentation associated with the "Engine Inlet Acoustics and EBF Aero-Acoustic Loads and Thermal Environment" program (see Reference 1).

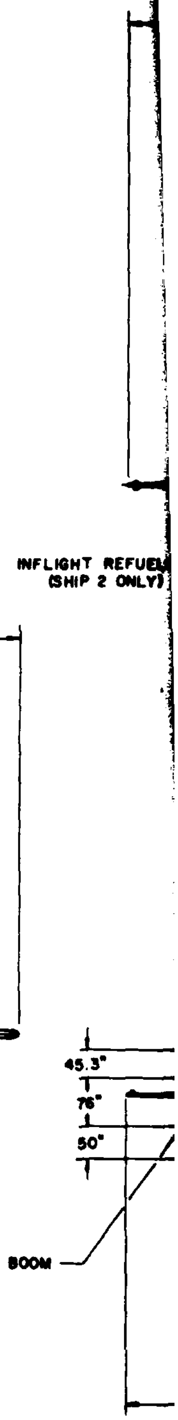
The fuselage is standard aircraft riveted rib stringer construction as shown in Figure 6. The airplane used in these tests did not contain interior acoustic insulation.

CHARACTERISTICS DATA

ITEM	WING (BASIC)	HORIZONTAL TAIL	VERTICAL TAIL
AREA SQ. FT.	1740	643	462
ASPECT RATIO	7.0	5.0	0.894
TAPER RATIO	0.3	0.45	1.0
SWEEP c/4	5° 53' 6"	4° 46' 12"	41°
ANHEDRAL	0°	3°	~
THICKNESS % CHORD	13.908% AVERAGE	11%	12%
INCIDENCE	.11 b/2 = 3.437° .323 b/2 = 4.147° .95 b/2 = 1.311°	+7° TO -12°	~
VOLUME RATIO	~	1.323	.1235

CARGO COMPARTMENT SIZE
544" LENGTH (EXCLUDES WALKWAY)
140" WIDTH
136" HEIGHT (MIN.)





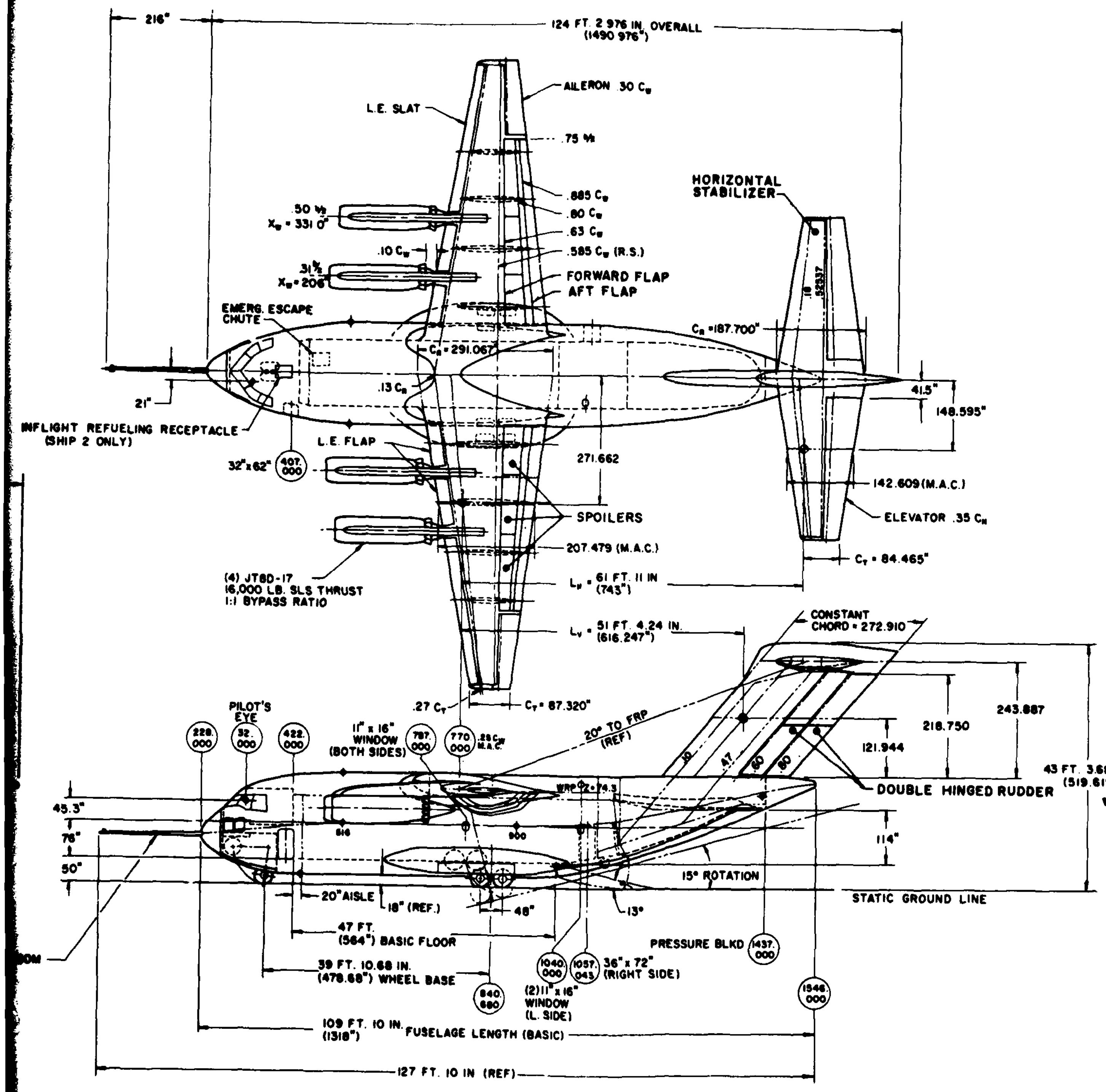


Figure 2. YC-15 General Arrangement

1 2

PRECEDING PAGE BLANK-NOT FILMED

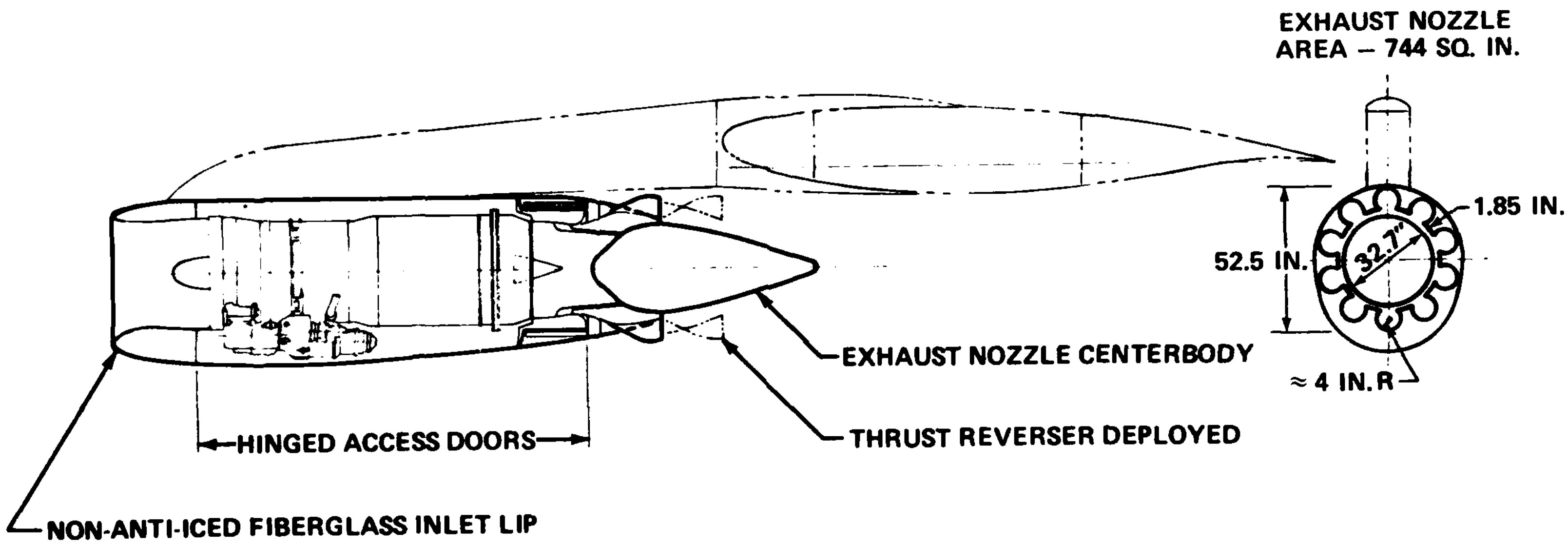


Figure 3. Propulsion System – General Arrangement

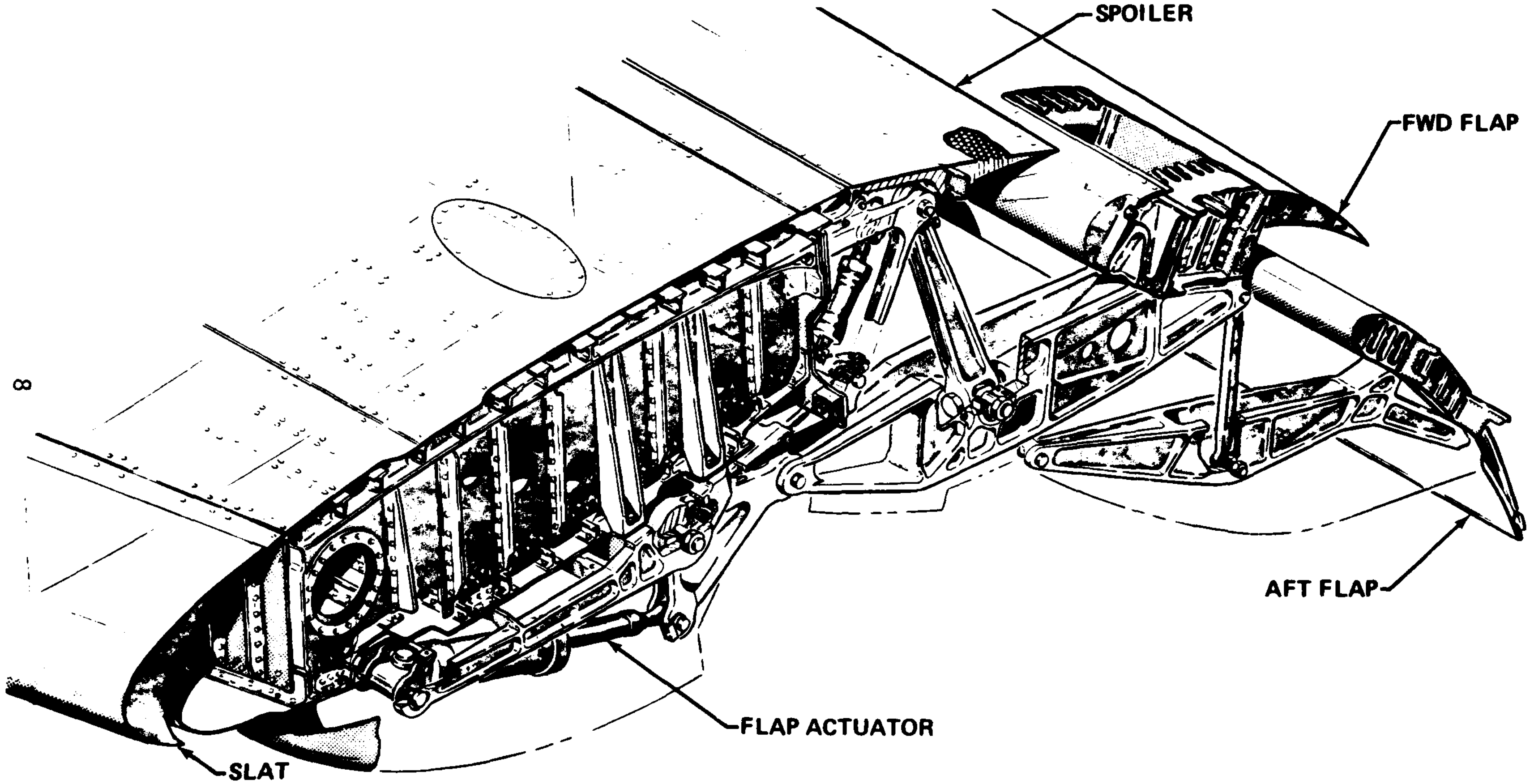
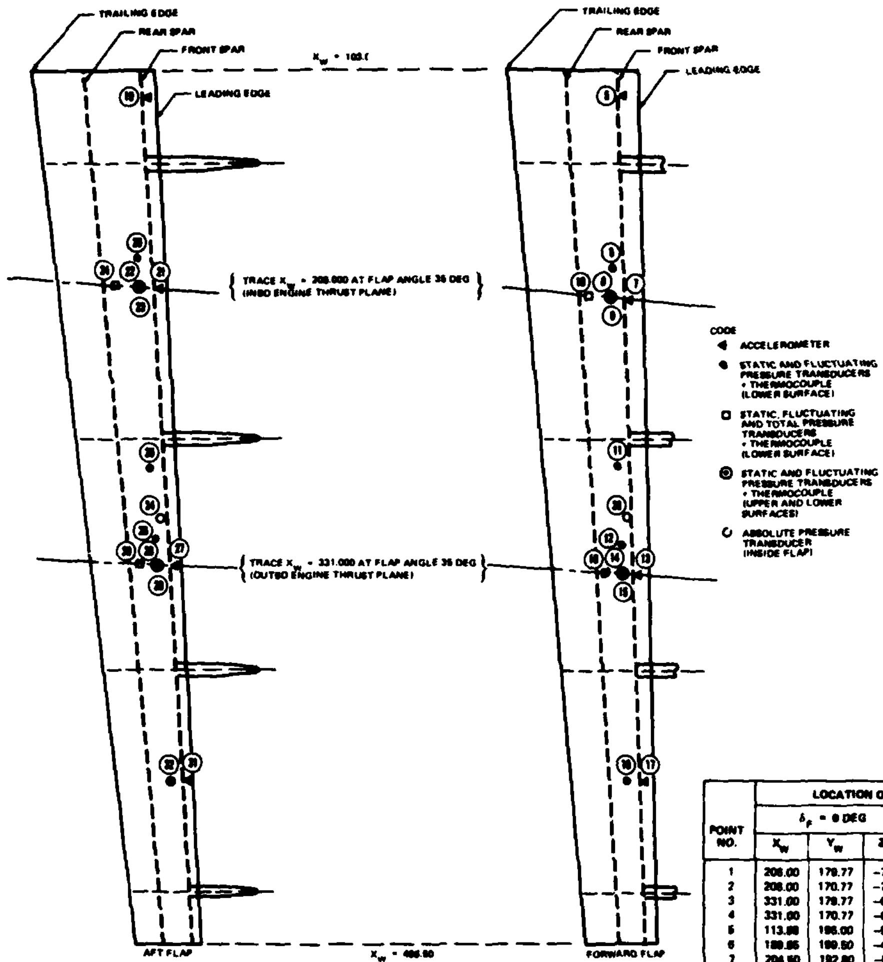
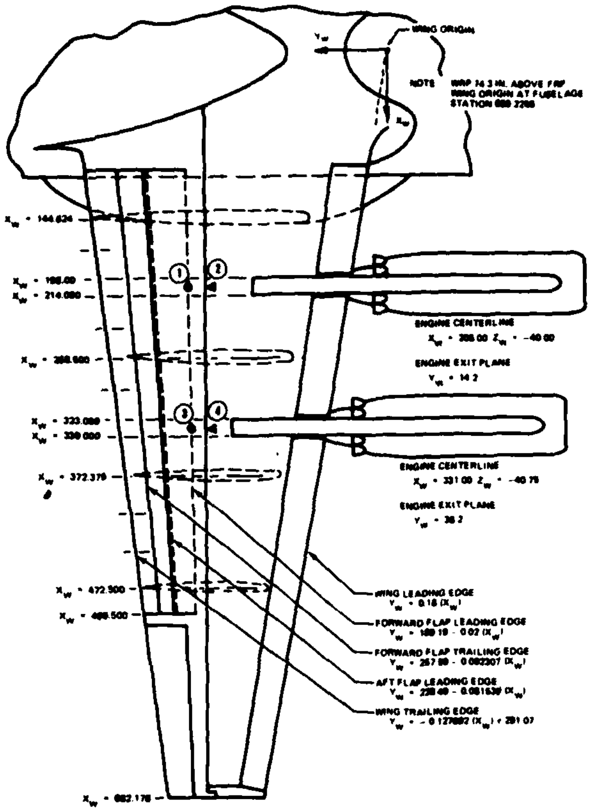


Figure 4. Wing/Flap Arrangement

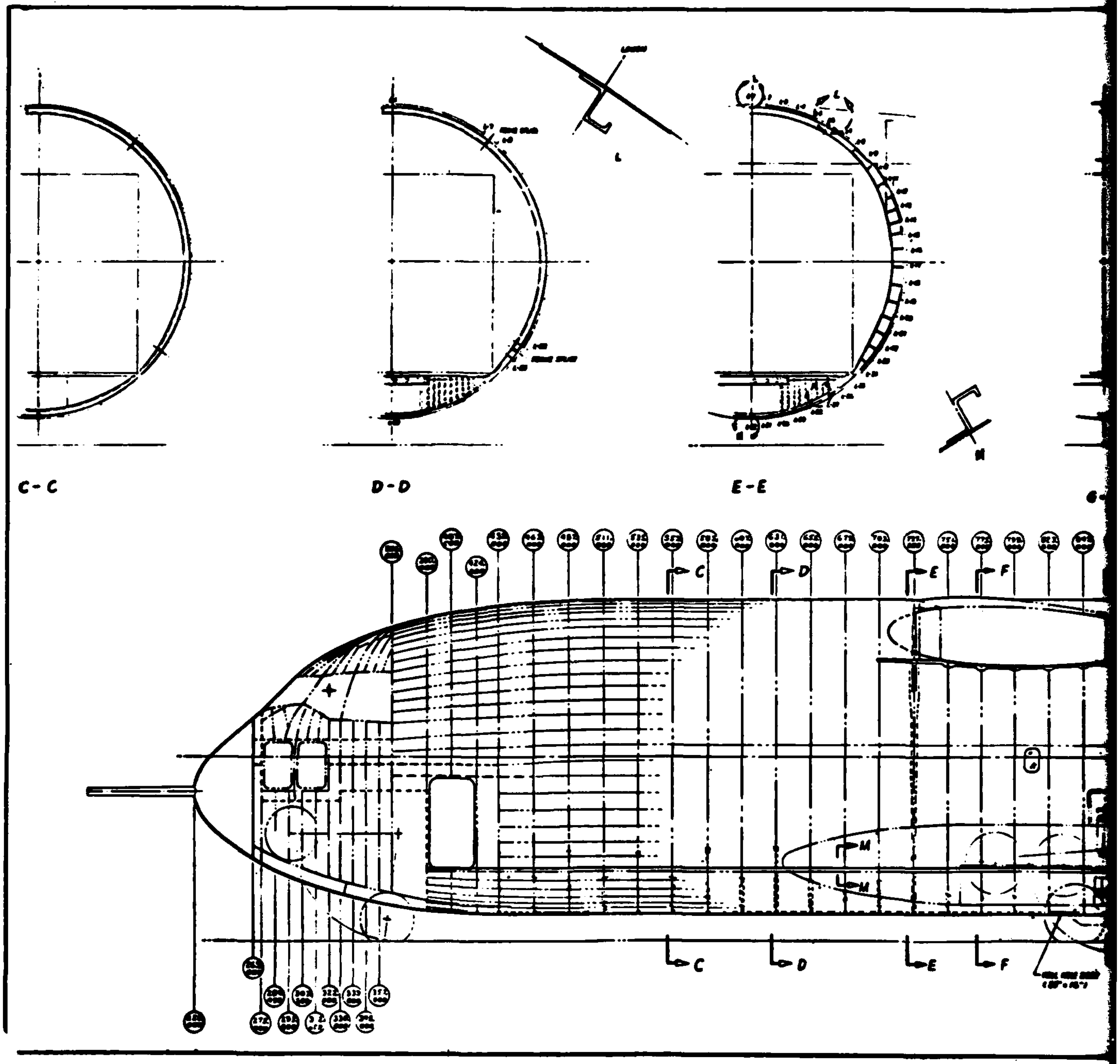


POINT NO.	LOCATION OF FLAP INSTRUMENTATION (DIMENSIONS						
	δ_F = 0 DEG			δ_F = 24 DEG			
	X_W	Y_W	Z_W	X_W	Y_W	Z_W	X_W
1	208.00	179.77	−7.20	208.00	179.77	−7.20	[illegible]
2	208.00	170.77	−7.80	208.00	170.77	−7.80	[illegible]
3	331.00	179.77	−6.05	331.00	179.77	−6.05	[illegible]
4	331.00	170.77	−6.85	331.00	170.77	−6.85	[illegible]
5	113.88	196.00	−6.80	116.27	216.36	−15.80	116.47
6	189.85	189.50	−4.42	191.31	218.10	−14.29	192.54
7	204.50	192.80	−5.30	206.78	211.02	−13.37	[illegible]
8	203.00	198.80	−4.42	204.44	217.08	−14.06	[illegible]
9	203.00	199.50	8.75	204.40	221.11	−1.46	[illegible]
10	202.80	209.92	−2.75	204.94	228.36	−15.27	[illegible]
11	202.65	198.75	−4.05	204.01	213.12	−12.81	[illegible]
12	313.66	195.22	−3.75	314.96	210.91	−11.90	[illegible]
13	327.90	189.88	−4.80	329.06	205.16	−11.38	330.87
14	327.46	194.70	−3.88	328.74	210.06	−11.73	[illegible]
15	327.00	194.65	7.30	328.31	212.82	−1.10	[illegible]
16	327.40	201.90	−2.46	328.80	217.34	−12.37	[illegible]
17	422.90	185.75	−4.10	423.82	198.81	−9.42	424.82
18	422.87	192.10	−3.18	424.08	206.10	−10.15	[illegible]
19	113.88	228.75	−1.98	117.92	264.18	−30.00	121.38
20	189.86	221.32	−0.43	193.78	264.20	−26.41	[illegible]
21	201.10	219.00	−1.25	204.90	251.22	−26.14	207.91
22	201.90	228.10	−0.30	205.74	260.93	−27.86	[illegible]
23	201.90	226.66	6.00	206.75	261.38	−21.03	[illegible]
24	201.20	238.16	0.86	206.91	269.42	−31.38	[illegible]
25	202.30	220.42	0.22	206.09	240.36	−23.75	[illegible]
26	313.66	212.22	0.18	317.02	240.27	−30.21	319.73
27	325.70	212.80	−0.82	329.07	238.72	−21.08	331.73
28	325.75	219.68	0.18	329.45	246.90	−23.16	332.27
29	325.70	218.98	5.67	329.42	247.73	−17.80	332.49
30	325.25	228.65	0.68	329.38	254.81	−28.35	332.37
31	422.25	205.80	−0.66	425.18	228.73	−17.44	427.87
32	422.90	213.80	0.16	425.82	236.53	−20.06	428.34
33	305.00	190.80	0.00	308.10	207.04	−7.06	307.27
34	305.00	205.00	2.80	308.07	234.83	−15.68	319.72



FLAP INSTRUMENTATION (DIMENSIONS – INCHES)							PARAMETER NUMBER 26XX					
	δ_F = 24 DEG			δ_F = 46 DEG			FLUCTUATING PRESSURE TRANSDUCER	STATIC PRESSURE TRANSDUCER	TOTAL PRESSURE TRANSDUCER	ACCELEROMETER	ABSOLUTE PRESSURE (INSIDE FLAP)	THERMOCOUPLE
[illegible]	X_W	Y_W	Z_W	X_W	Y_W	Z_W						
[illegible]	208.00	179.77	−7.20	208.00	179.77	−7.20	01	02				03
[illegible]	208.00	170.77	−7.80	208.00	170.77	−7.80				04		
[illegible]	331.00	179.77	−8.05	331.00	179.77	−8.05	05	06				07
[illegible]	331.00	170.77	−8.65	331.00	170.77	−8.65				08		
[illegible]	115.27	216.35	−15.08	116.47	227.61	−21.04				09		
[illegible]	101.31	218.10	−14.29	102.84	228.03	−21.17	10	11				12
[illegible]	205.78	211.02	−13.37	208.80	221.14	−18.64				13		
[illegible]	204.44	217.08	−14.08	205.65	228.85	−20.78	14	15				16
[illegible]	204.40	221.11	−1.46	205.90	233.98	−9.67	17	18				19
[illegible]	204.54	228.26	−16.27	206.83	237.33	−24.82	20	21	22			23
[illegible]	204.01	213.12	−12.81	208.15	221.79	−18.90	24	25				26
[illegible]	314.98	210.91	−11.90	316.08	219.20	−17.81	27	28				29
[illegible]	328.05	205.16	−11.39	330.07	213.90	−16.82				30		
[illegible]	328.74	210.08	−11.73	329.83	218.24	−17.41	31	32				33
[illegible]	328.31	212.82	−1.10	329.98	223.08	−7.86	34	35				36
[illegible]	328.88	217.34	−12.37	330.08	226.10	−19.92	37	38	39			40
[illegible]	423.82	198.81	−9.42	424.82	208.12	−12.83				41		
[illegible]	424.08	205.19	−10.15	425.08	212.09	−15.18	42	43				44
[illegible]	117.92	264.19	−30.00	121.28	277.08	−53.80				45		
[illegible]	193.78	264.20	−25.41	196.80	266.76	−48.84	46	47				48
[illegible]	204.90	261.22	−25.14	207.91	263.70	−46.27				49		
[illegible]	205.74	260.93	−27.88	208.94	270.71	−51.08	50	51				52
[illegible]	205.75	261.28	−21.03	209.15	274.53	−46.25	53	54				55
[illegible]	288.01	269.42	−31.28	289.33	278.22	−57.80	56	57	58			59
[illegible]	288.09	240.20	−23.76	288.01	280.43	−44.03	60	61				62
[illegible]	317.02	240.27	−20.21	319.73	251.30	−37.67	63	64				65
[illegible]	329.07	230.72	−21.00	331.73	260.06	−38.32				66		
[illegible]	328.46	246.80	−23.16	332.27	266.52	−42.86	67	68				69
[illegible]	329.42	247.73	−17.09	332.40	258.71	−38.26	70	71				72
[illegible]	329.38	264.91	−26.36	332.37	262.11	−48.90	73	74	75			76
[illegible]	426.18	228.73	−17.44	427.52	237.09	−31.83				77		
[illegible]	426.62	238.53	−20.06	426.34	243.92	−37.17	78	79				80
[illegible]	308.18	207.04	−7.08	307.27	216.07	−12.01					85	
[illegible]	308.07	234.83	−15.88	310.72	248.29	−31.36					86	

Figure 5. Location of Flap Instrumentation



C - C
D - D
E - E
C
D
E
F
M

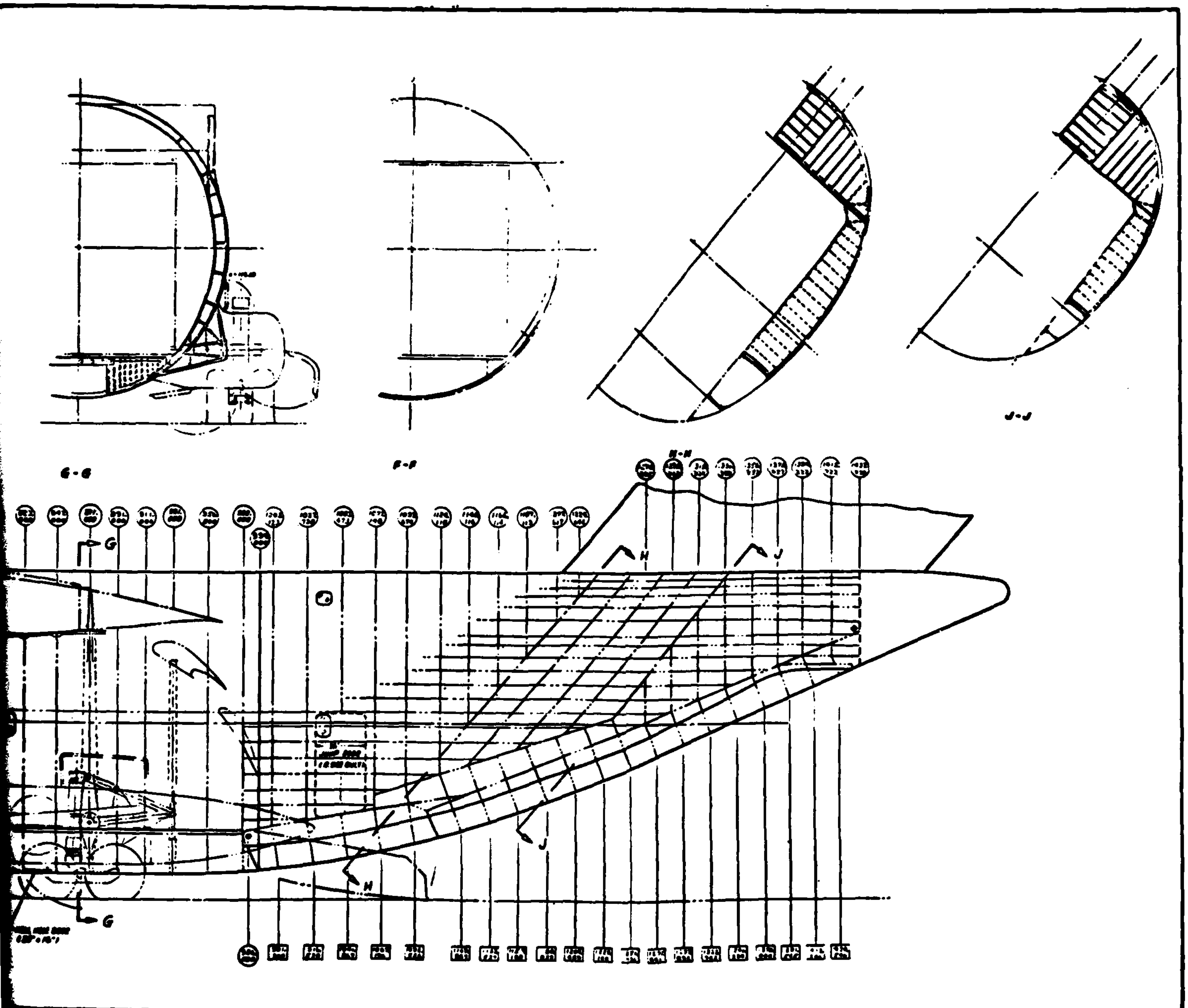


Figure 6. YC-15 Fuselage Structure

3. DATA ACQUISITION SYSTEM

The data acquisition systems for the interior acoustic tests and the flap loads and inlet acoustic tests are diagrammed in Figures 7 and 8, respectively. Note, however, that only the flush-mounted exterior microphones (transducers 1-9) were used in the "Engine Inlet Acoustics and EBF Aero-Acoustic Loads and Thermal Environment" program tests (see Reference 1).

Three basic transducer types were used to measure exterior acoustic loads, local fuselage vibrations, and interior noise levels. These transducers, their associated signal conditioning equipment, and the recording/monitoring equipment are described below.

3.1 Exterior (Flush-Mounted) Microphone System. Endevco Corporation Model 2150 M4A high intensity piezoelectric microphones and Endevco Model 2760A charge amplifiers were used for the acquisition of the exterior acoustic loads data. The microphones and charge amplifiers exhibit a frequency response that is flat within ± 5 percent and less than ± 35 degrees phase shift from 2 Hz to 20 KHz.

3.2 Fuselage Vibration System. Local fuselage vibration was measured with Bolt, Beranek, and Newman Inc. (BBN) Model 501 piezoelectric accelerometers with internal preamplifier and mating power supply (Model P-10) and the Intech Inc. Model 2583 voltage amplifier. Each accelerometer and signal conditioner has a frequency response that is flat within ± 5 percent over a frequency range of 8 Hz to 20 KHz.

3.3 Interior Microphone System. The equipment for the measurement of interior noise consisted of the following Bruel and Kjaer (B&K) equipment: Type 4134 one-half inch diameter condenser microphone cartridge, type 2615 microphone preamplifier, and type 226-16 power supply and signal conditioner. This system provides a frequency response that is flat within ± 1 dB over a range of 20 Hz to 20 KHz.

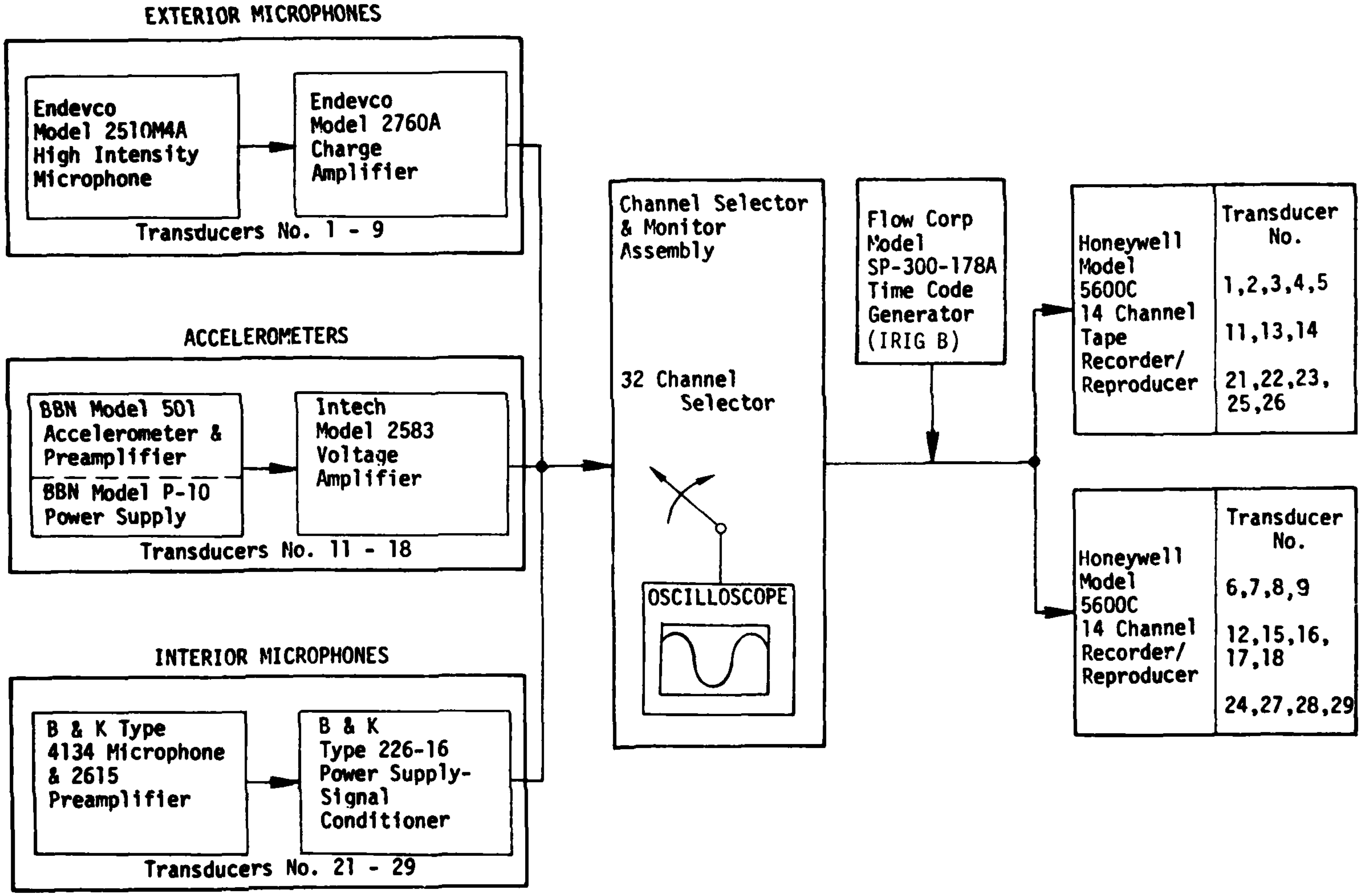


Figure 7. YC-15 Data Acquisition System Block Diagram

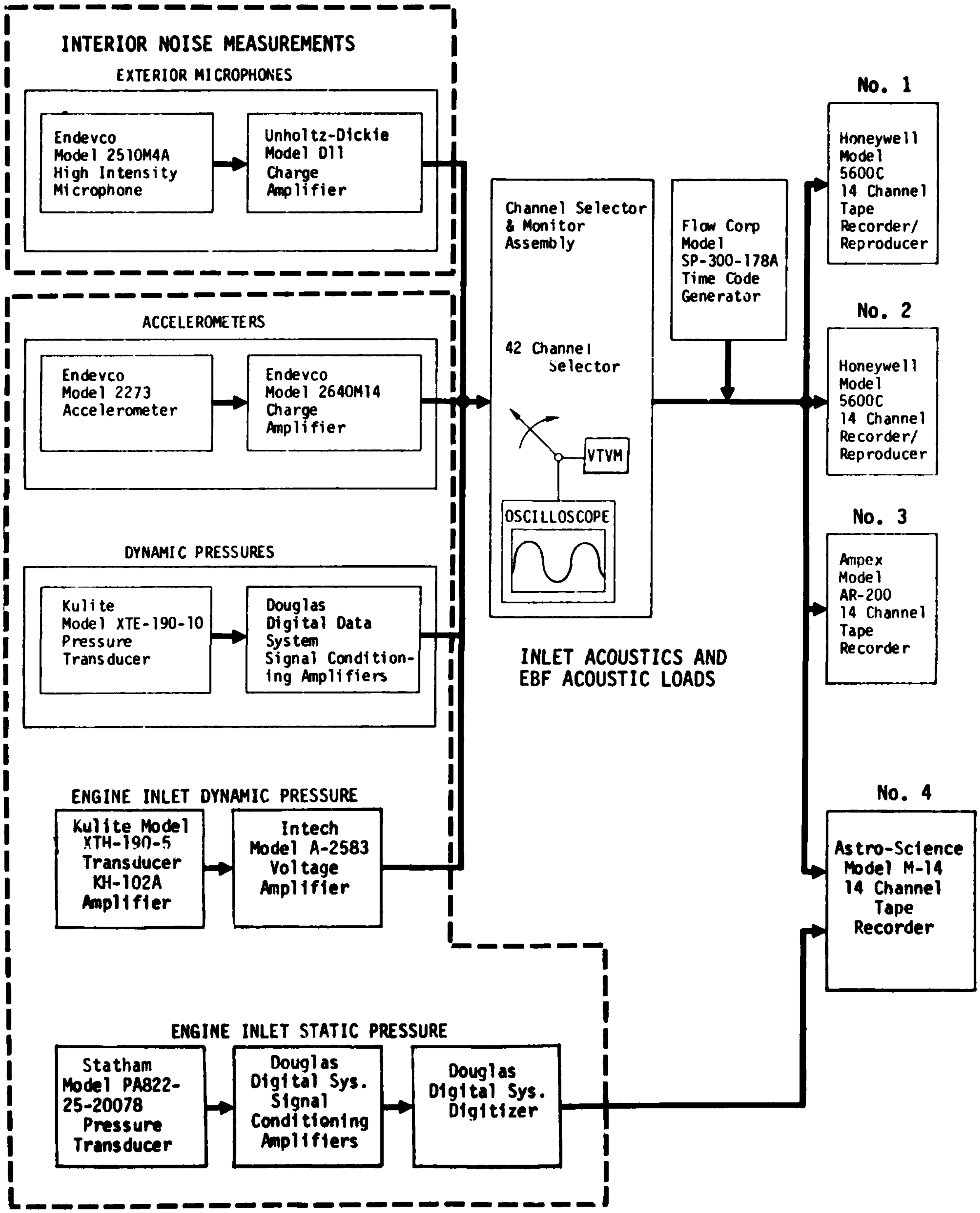


Figure 8. Fuselage Exterior and Flap Loads and Engine Inlet Data Acquisition System Block Diagram

3.4 Transducer Installation. The mounting system for the flush-mounted exterior microphones is shown in Figure 9. Photographs of a typical mounting provision are shown in Figures 10 and 11. The mounting provisions were constructed so that the diaphragm of each exterior microphone was flush with the exterior skin of the aircraft. The gap between the microphone and the fuselage skin was sealed with a sealant to provide both pressure seal and isolation from the aircraft sidewall.

The accelerometers were either bonded directly to the aircraft structure or screwed into mountings that were bonded to the structure with dental cement.

The interior microphones were either clamped to the aircraft structure or mounted on tethered tripod stands.

3.5 Transducer Location. The transducer locations are shown in Figure 12 (except for microphone 9, the forward exterior flush-mounted microphone location) and listed in Table 1. Figure 13 is a photograph of the YC-15 aft interior showing the deep frames at stations 1077 and 1145. In order to locate the accelerometers in the proximity of the flush-mounted microphones and also reduce the effects of the microphone mounts, the accelerometers were mounted one panel below the microphones where possible. Since this procedure would place accelerometers 15 and 17 on a doubled skin area, the transducers were moved up to the panel containing the flush mounted microphones as shown in Figure 14. The rationale used in selecting transducer locations is given in Table 2.

3.6 Instrumentation Signal Monitoring System. A data channel selector and oscilloscope was mounted in an instrumentation rack to allow a visual display of data channel signals as a rapid means of checking data signals.

3.7 Data Recording System. The data recording system consisted of two Honeywell Model 5600C instrumentation recorders for the acoustic tests and two Honeywell Model 5600C, one Ampex Model AR-200, and one Astro-Science

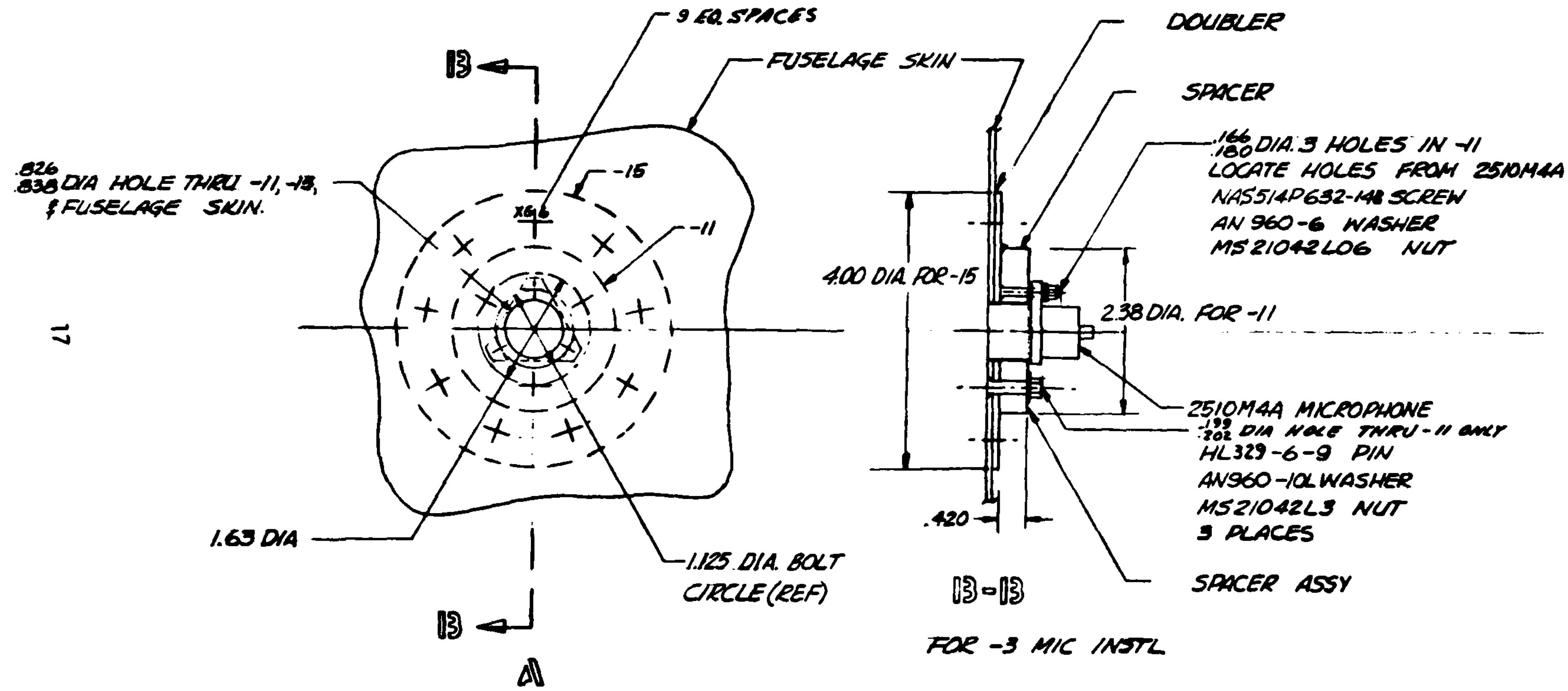


Figure 9. YC-15 Flush-Mounted Microphone Mounting System

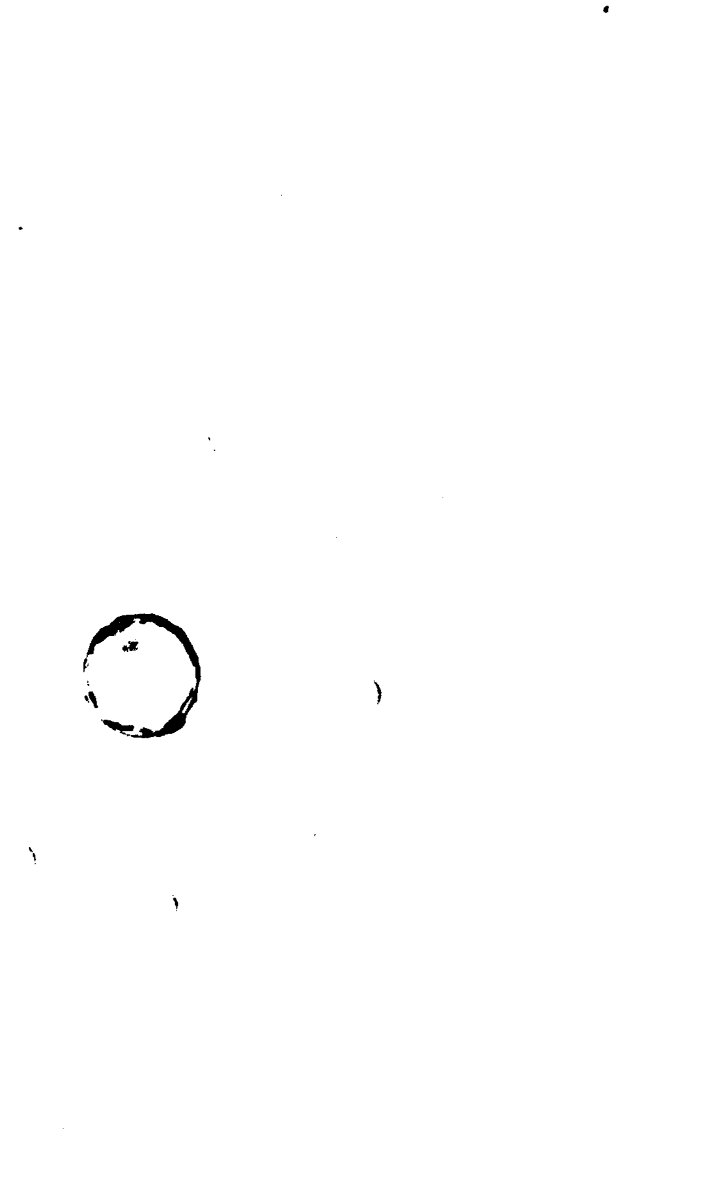


Figure 10. YC-15 Flush-Mounted Microphone — Exterior Photograph

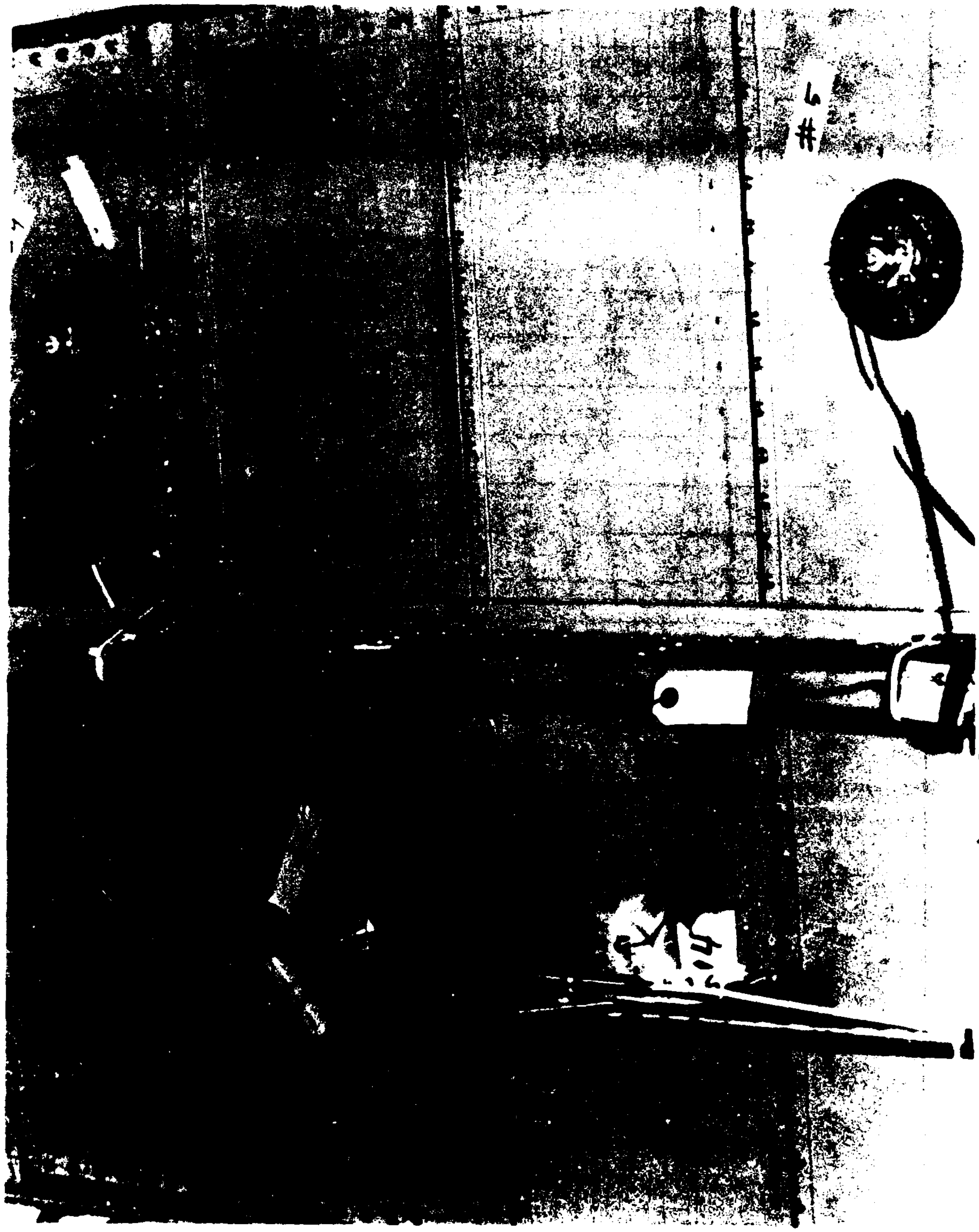
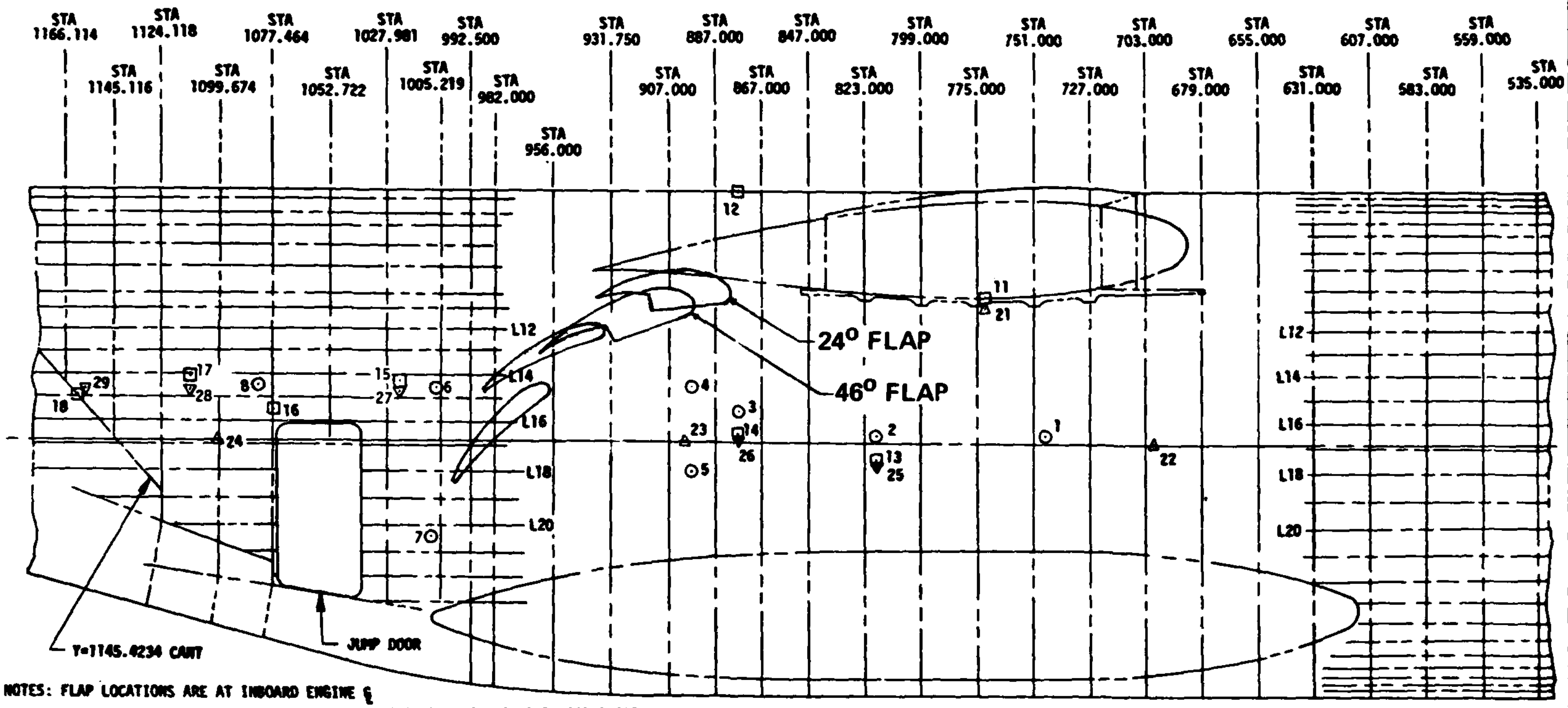


Figure 14. YC-15 Flush-Mounted Microphones — Interior Photograph



NOTES: FLAP LOCATIONS ARE AT INBOARD ENGINE ℄

⊙ INDICATES TRANSDUCERS NO. 1 - 9, EXTERIOR FLUSH MOUNTED MICROPHONES

⊡ INDICATES TRANSDUCERS NO. 11 - 18, ACCELEROMETERS

△ INDICATES TRANSDUCERS NO. 21 - 24, INTERIOR MICROPHONES, ℄

▽ INDICATES TRANSDUCERS NO. 25 - 29, INTERIOR MICROPHONES, SIDEWALL

EXTERIOR FLUSH MOUNTED TRANSDUCER NO. 9 (⊙) IS LOCATED AT FUSELAGE STATION Y=415.500 AND 4.5 INCHES ABOVE L13.

Figure 12. YC-15 Transducer Locations

TABLE 1

YC-15 TRANSDUCER LOCATIONS

TRANSDUCER NUMBER	TRANSDUCER TYPE	X*	Y*	Z*
1	Exterior Flush-Mounted Microphones	-108	745	3
2		-108	818	3
3		-107	877	13
4		-105	897	24
5		-108	897	-7
6		-105	1009	24
7		- 99	1014	-41
8		-103	1094	25
9		- 85	415	43
11	Accelerometers	- 45	773	55
12		- 45	877	97
13		-108	818	-7
14		-108	877	3
15		-106	1020	24
16		- 94	1077	13
17		-104	1104	14
18		- 86	1160	20
21	Interior Centerline Microphones	- 45	769	53
22		0	700	0
23		0	900	0
24		0	1100	0
25	Interior Sidewall Microphones	-104	818	-7
26		-104	877	3
27		-102	1020	24
28		-100	1104	14
20		- 86	1145	18

* Airplane coordinates
Note: All dimensions inches

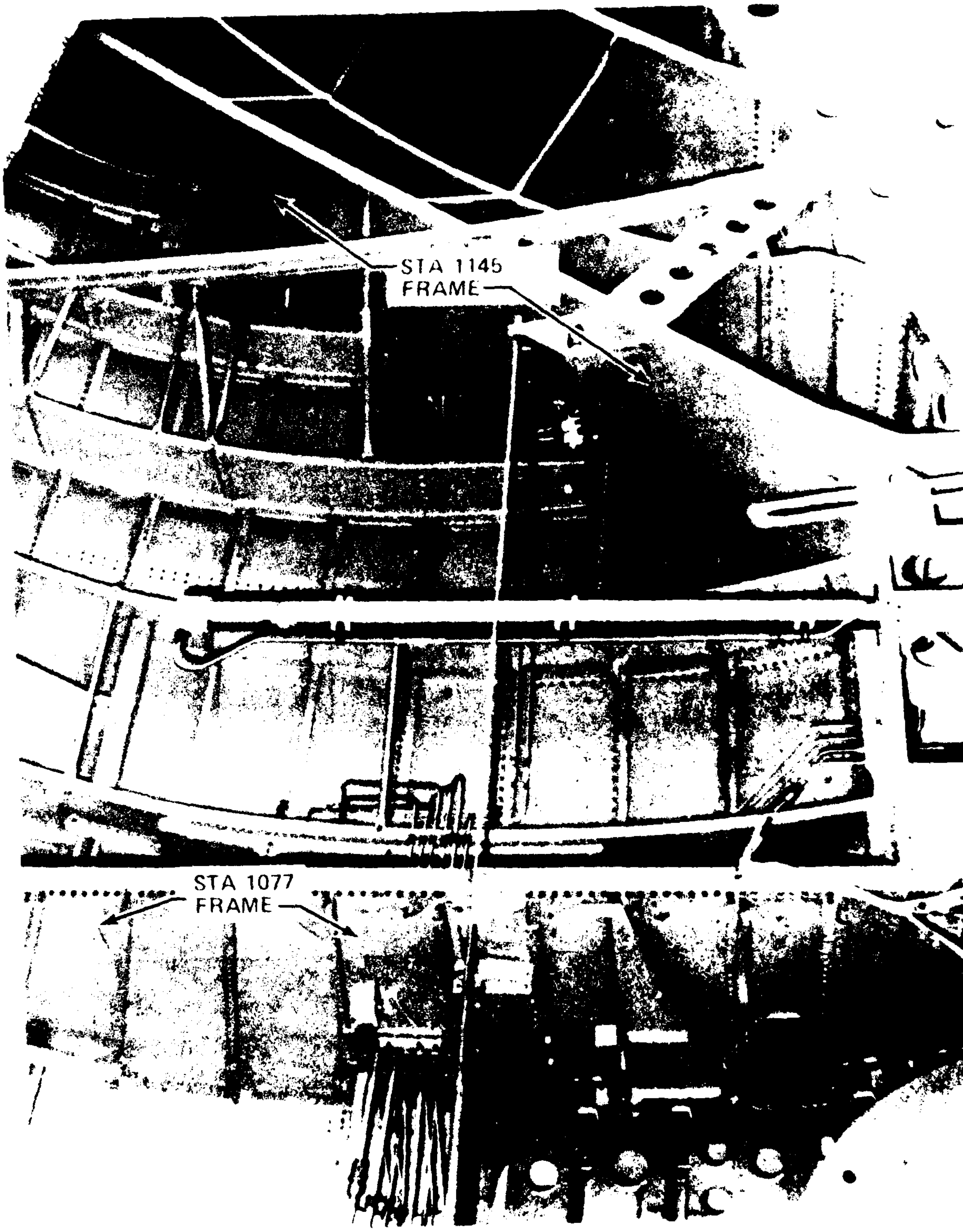


Figure 13. YC-15 Aft Interior

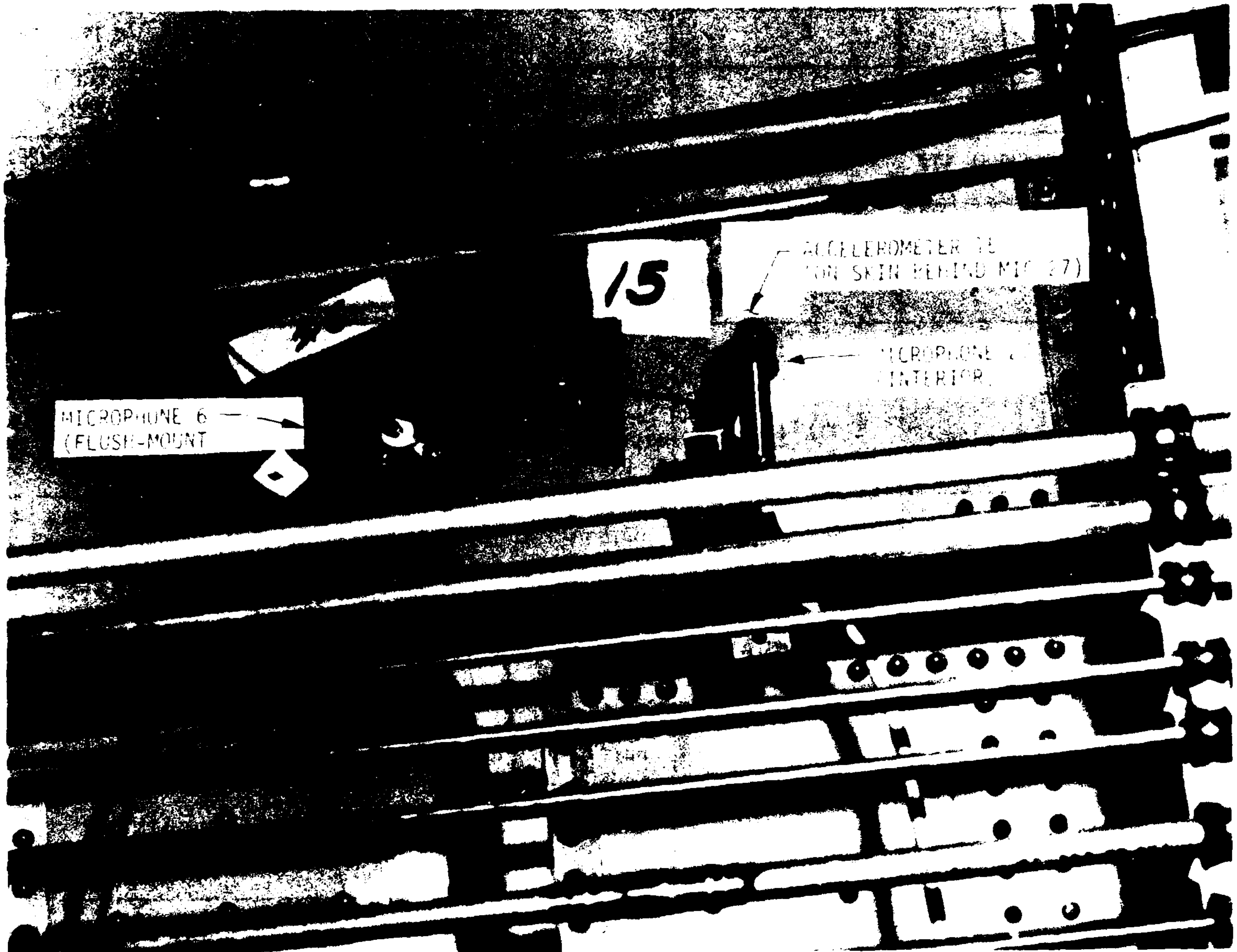


Figure 14. Location of Accelerometer No. 15

TABLE 2 - YC-15 TRANSDUCER LOCATION CRITERIA

PLACEMENT CRITERIA	TRANSDUCER NUMBER		
	FLUSH MOUNTED MICROPHONES	ACCELEROMETERS	INTERIOR MICROPHONES
In expected high environmental areas established using far field directivity patterns for leading and trailing edges and are in the high energy levels measured by NASA	3,4 & 5	14	26
In expected high environmental areas for the 46 degree flap setting located using far field acoustic radiation patterns. In addition, this region may be subject to scrubbing at lower flap settings	7	14	27
In expected secondary jet impingement and/or scrubbing for the 46 degree flap setting	6		
To define the gradient of environments which will aid in the subsequent prediction of interior noise and location of relatively high environmental areas	1,2,3,4 5,7,8 & 9	13,14,15 & 17	25,26,27 & 28
To define the contribution of vibratory energy originating in the high lift system to interior noise		11 & 12	21
To define the contribution of deep frames to interior noise		16 & 18	28 & 29
To determine the integrated effect of noise source			22,23 & 24
To define intensities of interior noise sources during STOL operations	ALL TRANSDUCERS		
To define the boundary layer and free jet environments during cruise conditions	ALL TRANSDUCERS		
Specified by "Engine Inlet Acoustic Program"	9		

Model M-14 recorder for the flap loads and inlet acoustic tests[1]. The tape recorders have a frequency response that is flat within ± 1 dB over a range of 0 - 10 KHz at 30 in/sec tape speed using an FM recording mode.

The tape channel allocations for the interior acoustics tests were selected to facilitate cross-correlation of the data. The transducers were grouped and assigned to the tape recorders as shown below in Table 3.

TABLE 3 - TAPE RECORDER CHANNEL ALLOCATION

Transducer Type	Recorder #1 Group Number					Recorder #2 Group Number					
	1	2	3	4	5	6	7	8	9	10	11
Exterior Microphones	3,4,5	2	1			7	6	8			9
Accelerometer	14	13			11		15	16,17	18	12	
Interior Microphones	23,26	25		22	21		27	24,28	29		

During the flap loads and inlet acoustics tests, the data from microphones 2, 5, and 6 were recorded on the same tape recorder (#1) as the inboard flap data to permit mathematical correlation of flap loads and fuselage sidewall loads. Data from microphone 9 were recorded on the same tape recorder as the inlet data. The tape recorder allocations are shown below in Table 4.

TABLE 4 - TAPE RECORDER ASSIGNMENTS

No.	Tape Recorder	Transducers
1	Honeywell Model 5600C - #1	2, 5, 6
2	Honeywell Model 5600C - #2	
3	Ampex Model AR-200	4, 7, 8
4	Astro-Science Model M-14	9, 3, 1

Data monitoring and recording equipment were installed on an aircraft pallet as shown in Figure 15.

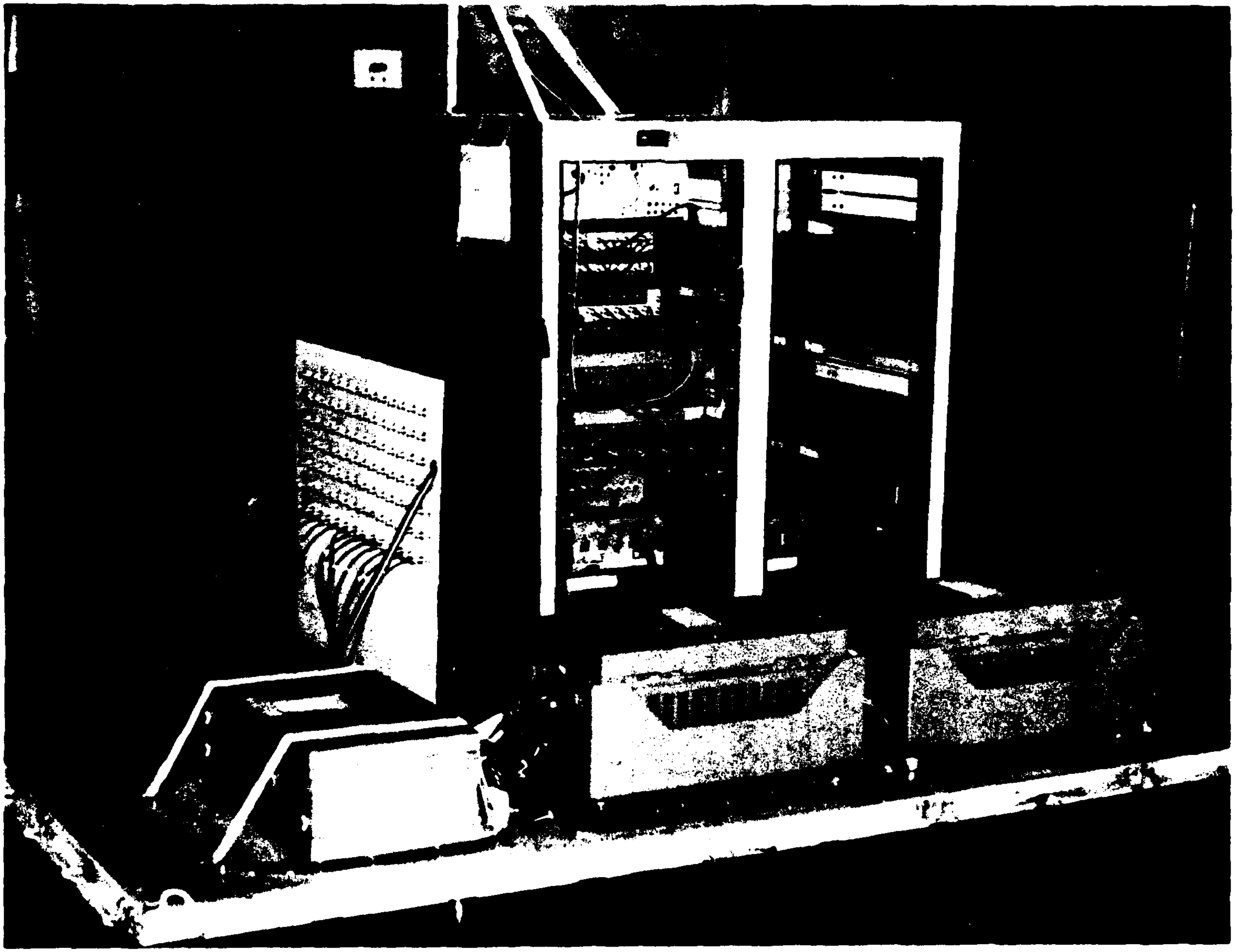


Figure 15. Pallet Installation

3.8 Calibration Procedures. Calibration signals of known voltages and frequencies were recorded on the acoustic and vibration analog data channels to provide reference signals for data reduction purposes. Data channels that were common to a particular tape recorder had 1 KHz and 10 KHz reference signals applied simultaneously to all channels to provide a channel phase reference to account for tape recorder and tape reproducer head stack alignment.

All data channels were calibrated with pink noise (constant energy per octave bandwidth) to provide a reference signal for the determination of data channel frequency response characteristics. These data were used to perform frequency response corrections during data processing.

Individual vibration channels were calibrated at 100 Hz with specific reference voltages that were equivalent to the output signal of each accelerometer when subjected to a known vibration provided by an electromechanical shaker. The acoustic data channels were calibrated with a B&K Type 4220 pistonphone providing a 124 dB re 20 μPa at 250 Hz.

These data were used to determine acoustic and vibration test signal amplitudes during data processing. Thirty seconds of ambient and/or system noise were recorded on magnetic tape prior to starting the engines and after the day's tests. These measurements determine the background level of the data acquisition system for each channel and were used to adjust test signals that were within 10 dB of background levels.

3.9 System Accuracy. The estimated error of the data acquisition system after correcting for frequency is the root-mean-square value of the individual instrument errors of the applicable system components. Table 5 presents the instrument errors of the applicable system components with and without data correction factors and the estimated system errors after correction for the interior noise, exterior noise, and fuselage vibration data acquisition systems.

TABLE 5 - ESTIMATED DATA ACQUISITION SYSTEM ERROR

Acquisition System Type	Component	Manufacturer/Model	Instrument Error	Approx Instr Error W/Correction [2]
Interior Noise	1/2 in. Condenser Microphone with Microphone Preamplifier	Bruel & Kjaer/4131 with B&K/226-16	± 1.5 dB	± 0.2 dB
	Signal Conditioner	B&K/226-16	± 0.5 dB	± 0.3 dB
	Tape Recorder	Honeywell/5600C	± 1.0 dB	± 0.3 dB
	Pistonphone	B&K/4220	± 0.2 dB	± 0.1 dB
	Precision Noise Generator	Hewlett-Packard/8057A	± 0.5 dB	± 0.2 dB
		ESTIMATED UNCORRECTABLE SYSTEM ERROR[1]		± 0.5 dB
Exterior Noise	Piezoelectric Microphone	ENDEVCO/2150M4A	± 1.5 dB	± 0.5 dB
	Charge Amplifier	ENDEVCO/2760A and Unholtz-Dickie/D11	± 0.4 dB	± 0.2 dB
	Tape Recorder	Honeywell/5600C	± 1.0 dB	± 0.3 dB
	Pistonphone	B&K/4220	± 0.2 dB	± 0.1 dB
	Precision Noise Generator	Hewlett-Packard/8057A	± 0.5 dB	± 0.2 dB
		ESTIMATED UNCORRECTABLE SYSTEM ERROR[1]		± 0.7 dB
Fuselage Vib.	Piezoelectric Accelerometer with Preamplifier-Pwr Supply	Bolt Beranek & Newman/501 Bolt Beranek & Newman/P-10	± 1.2 dB	± 0.5 dB
	Voltage Amplifier	INTECH/2583	± 0.4 dB	± 0.2 dB
	Tape Recorder	Honeywell/5600C	± 1.0 dB	± 0.3 dB
	Audio Oscillator	Hewlett-Packard/202B	± 0.4 dB	± 0.4 dB
	Vacuum Tube Voltmeter	Hewlett-Packard/400H	± 0.2 dB	± 0.2 dB
	Precision Noise Generator	Hewlett-Packard/8057A	± 0.5 dB	± 0.2 dB
		ESTIMATED UNCORRECTABLE SYSTEM ERROR[1]		± 0.8 dB

NOTES: (1) Estimated system error is the root mean square of the applicable individual instrument errors.
(2) Estimated errors with frequency response corrections applied.

4. DATA REDUCTION

Data processing was limited to that required to verify the quality of the data and to provide overall pressure and acceleration levels. Most of the transducer signals have been reduced to one-third octave-band levels.

4.1 Data Processing. Data processing was performed in the Douglas Acoustics and Vibration Data Center. Data from the first series of tests were digitized and recorded on magnetic tape with the Controlled Integrating Spectrum Analyzer (CISA) of the Acoustics and Vibration Data Center.

The basic data were then processed and printed with the Flight and Laboratory Development Sigma 7 Computer Program G4SE. Averaging time for data processing was 10 seconds for most cases. All acoustic data were corrected for system frequency response and pressure response characteristics, and all vibration data were corrected for system frequency response.

The data from the second series of measurements were reduced by passing the recorded signals through a General Radio Model 1952 Universal Filter with a bandpass of 40-11,200 Hz and a Bruel & Kjaer Type 2107 Frequency Analyzer using the linear weighting network. These data were then recorded as time history charts on a Bruel and Kjaer Type 2305 Level Recorder containing a logarithmic potentiometer. The filter bandpass was selected to match that used in the first series of measurements. No frequency response corrections were made in processing the second series data to determine overall levels since the corrections have a negligible effect on overall levels.

4.2 Data Format. The Program G4SE output is a tabular listing of one-third octave-band, octave-band, A-weighted, and overall levels. Acoustic and vibration overall levels are presented in Section VII. One-third octave band data and A-weighted levels for most of the test conditions are contained in Reference 2 - an unpublished Douglas Aircraft Company report.

5. GROUND AND FLIGHT TESTS

5.1 Test Configurations and Conditions. Acoustic and vibration measurements were obtained during two testing periods. The first series of tests were conducted in March, 1976, and consisted of simultaneously measuring the exterior fuselage noise levels, fuselage vibration, and interior noise levels. The ground and flight tests that were conducted in the first and second series measurements are shown in Tables 6 and 7 respectively. The second series of tests consisted of supplemental measurements made of the exterior fuselage noise levels in May, 1976 concurrently with "YC-15 EBF Aero-Acoustic Loads and Thermal Environment" tests. The second series of tests were similar to the first series of tests.

Test No. G-1 was planned to provide a better understanding of the effects of flap and power settings on engine-and flap-generated noise. Tests G-2 and G-3 yield information regarding the contributory effects of the inboard and outboard engines to exterior fuselage and interior noise. The taxi test, G-4, provides information on forward speed effects.

Tests F-1 and F-3 provide takeoff and landing data and F-3 data (after liftoff), in comparison with G-4, permits evaluation of ground reflection effects. Tests F-2 and F-4, in conjunction with F-1 and F-3, provide additional data on the relative contributions of the inboard and outboard engines. Test F-5 provides data on the turbulent boundary layer and forward speed effects during cruise at 18,000 feet. Test F-6 provides data with high thrust and extended flaps used in a "go-around approach". Test F-7 provides data during cruise at 30,000 feet. In an attempt to isolate the acoustic effects of on-board equipment, data were obtained during a sequence of securing the air-conditioning, the avionics cooling fans, and the fuel boost pumps. Test F-8 provides cruise data at 250 KEAS and 30,000 feet with all engines at idle to provide data on the effects of jet/engine noise and boundary layer noise on interior noise.

TABLE 6 - YC-15 GROUND TESTS

TEST NUMBER	FIRST SERIES MEASUREMENTS		SECOND SERIES MEASUREMENTS	
	FLAP ANGLE	ENGINES @ EPR	FLAP ANGLE	ENGINES @ EPR
G-1.1	1°	1,2,3,4 @ 1.05	0°	1,2,3,4 @ 1.05
G-1.2	1°	1,2,3,4 @ 1.59	0°	3,4 @ 1.55
G-1.3	1°	1,2,3,4 @ 1.89	0°	3,4 @ 1.85
G-1.4	1°	1,2,3,4 @ 2.21	0°	3,4 @ 2.21
G-1.5	23°	1,2,3,4 @ 1.06	21°	1,2,3,4 @ 1.05
G-1.6	23°	1,2,3,4 @ 1.59	21°	3,4 @ 1.55
G-1.7	23°	1,2,3,4 @ 1.90	21°	3,4 @ 1.85
G-1.8	23°	1,2,3,4 @ 2.21	21°	3,4 @ 2.21
G-1.9	46°	1,2,3,4 @ 1.06	47°	1,2,3,4 @ 1.05
G-1.10	47°	1,2,3,4 @ 1.39	45°	3,4 @ 1.55
G-2.2	1°	1,4 @ 1.57	0°	1,4 @ 1.55
G-2.3	1°	1,4 @ 1.89	0°	1,4 @ 1.85
G-2.4	1°	1,4 @ 2.20	0°	1,4 @ 2.21
G-2.6	23°	1,4 @ 1.59	22°	1,4 @ 1.55
G-2.7	23°	1,4 @ 1.88	22°	1,4 @ 1.85
G-2.8	22°	1,4 @ 2.19	22°	1,4 @ 2.21
G-2.10	47°	1,4 @ 1.58	46°	1,4 @ 1.55
			0°	2,3 @ 1.55
			0°	2,3 @ 1.85
			0°	2,3 @ 2.21
			22°	2,3 @ 1.55
G-3.1	23°	2,3 @ 1.90		
G-3.2	24°	2,3 @ 2.20		
G-3.4	1°	2,3 @ 2.19		
G-4	48°	1,2,3,4 @ 2.20		

TABLE 7 - YC-15 FLIGHT TESTS

TEST NUMBER	FIRST SERIES MEASUREMENTS				SECOND SERIES MEASUREMENTS			
	ALTITUDE FT (m)	SPEED KEAS (m/sec)	ENGINES @ EPR	FLAP ANGLE	ALTITUDE FT (m)	SPEED KEAS (m/sec)	ENGINES @ EPR	FLAP ANGLE
F-1	Field,2000 (610)	0	1,2,3,4 @ 2.20	23°	Field,2000 (610)	0	1,2,3,4 @ 2.21	24°
F-2	Field,2000 (610)	0	1,2,4 @ 2.20	24°	Field,2000 (610)	0	1,2,4 @ 2.21	24°
F-3	Approach,2300 (701)	85 (44)	1,2,3,4 @ 1.60	48°	Approach,2300 (701)	85 (44)	1,2,3,4 @ 1.40	48°
F-4	Approach,2700 (823)	85 (44)	1,2,4 @ 2.10	41°	Approach,2700 (823)	85 (44)	1,2,4 @ 1.70	46°
F-5.1	18,022 (5493)	195 (101)	1,2,3,4 @ 1.42	1°	18,072 (5508)	192 (99)	1,2,3,4 @ 1.42	0°
F-5.2	17,897 (5455)	239 (123)	1,2,3,4 @ 1.53	1°	18,065 (5506)	245 (126)	1,2,3,4 @ 1.60	0°
F-5.3	17,908 (5458)	280 (144)	1,2,3,4 @ 1.66	2°	17,998 (5486)	287 (148)	1,2,3,4 @ 1.68	0°
F-5.4	17,883 (5451)	311 (171)	1,2,3,4 @ 1.89	1°	18,035 (5497)	326 (168)	1,2,3,4 @ 1.90	0°
F-6	Go-Around Approach,2500 (762)	100 (51)	1,2,3,4 @ 1.40	48°	Go-Around Approach,2500 (762)	100 (51)	1,2,3,4 @ 2.10	24°
F-7.1	29,813 (9087)	248 (128)	1,2,3,4 @ 2.01	3°	29,779 (9077)	238 (123)	1,2,3,4 @ 2.01	0°
F-7.2	29,813 (9087)	248 (128)	1,2,3,4 @ 2.01	3°				
F-7.3	29,813 (9087)	248 (128)	1,2,3,4 @ 2.01	3°				
F-7.4	29,813 (9087)	248 (128)	1,2,3,4 @ 2.01	3°				
F-8	29,813 (9087)	248 (128)	1,2,3,4 @ flight idle	3°				

5.2 Test Procedures. Procedures for the ground and flight tests were delineated on individual flight cards defining techniques, conditions, configuration, description, and sequence of the events. The conditions, descriptions, and configurations are consistent with those presented in Tables 6 and 7. The general test procedures are outlined below.

End-to-end calibration of the data acquisition system was performed during preflight check out, and dynamic calibrations were performed before and after each test sequence.

During ground tests the tape recorder input for each channel was monitored with an oscilloscope during idle and maximum power setting to confirm proper system operation and to establish proper gain settings. The channels were also monitored during the tests.

During the flight test the tape recorders were remotely operated, making channel monitoring impractical. Proper operation was confirmed prior to takeoff, and gain settings were preset based on ground test results.

During each test the tape recorder was turned on when proper conditions were reached and allowed to run until sufficient data were recorded.

The channel assignments, calibration levels, gain setting, test conditions, and time of day were recorded in the tape log.

6. GROUND TEST RESULTS

This section is divided into three areas: Exterior Fuselage Noise Levels, Structural Vibration Levels, and Interior Noise Levels.

6.1 Exterior Fuselage Noise Levels. The overall sound pressure levels (OASPLs) measured on the external fuselage during the first and second series of ground tests are presented in Tables 8 and 9. The quality of some data was not acceptable and has been deleted from the tables. The reasons for these deletions are given in the tables as footnotes.

Data quality can be investigated by comparing results to existing analytical or experimental data, determining statistical properties when sufficient data is available or determining if consistent and reasonable relationships exist in the data. The latter approach was selected because useful relationships may be determined, comparable analytical or experimental data were not available, and the amount of data was limited. However, it should be emphasized that indicated relationships are based on a limited amount of data gathered on a specific and complicated configuration.

The OASPL, as a function of thrust, F/δ, for a single engine and flap setting are presented in Figures 16 through 23 for microphones 1, 2, and 4 through 9 for $F/\delta > 5000$ pounds (22,500 N). $F/\delta \propto M^2$ is a good approximation for exhaust nozzle Mach numbers up to 1 (Equation 11 of Appendix) and $F/\delta \propto (\text{velocity of expanded jet})^{1.7}$ is a good approximation for the JT8D-17 engine with an external mixer at sea level and for $F/\delta \gtrsim 7{,}000$ pounds (31,000 N). Engine data are presented in the Appendix. Thrust values were obtained from Figure 24 using the Engine Pressure Ratios (EPRs) presented in Tables 8 and 9.

The 38 log (F/δ) line presented in Figures 16 to 23 was obtained from the first series of tests by normalizing all of the 0° and 24° flap data to the sound pressure level measured for the 9,000 pound thrust case for each microphone and flap setting and plotting these values on one curve as indicated in Figure 25. The upper and lower bounds to the data for microphones 1-8 and above 9,000 pounds are the 45 log F/δ and 30 log F/δ lines; the best visual fit being about 38 log F/δ.

TABLE 8 - YC-15 EXTERIOR NOISE MEASUREMENTS - FIRST SERIES GROUND TESTS - OVERALL SOUND PRESSURE LEVELS, dB re 20 μPa

TEST NO.	FLAP ANGLE	ENGINE NO. @ EPR[e]	THRUST[a] LBS (N)	FLUSH-MOUNTED EXTERIOR MICROPHONES MIC 1	MIC 2	MIC 3	MIC 4	MIC 5	MIC 6	MIC 7	MIC 8	MIC 9
G.1-1	1°	1,2,3,4 @ 1.05	1,000 (4400)	128	(b)	(c)	123	121	116	118	118	121
G-1.2	1°	1,2,3,4 @ 1.59	9,100 (40,500)	142	140		138	137	135	135	134	131
G-1.3	1°	1,2,3,4 @ 1.89	12,600 (56,000)	146	146		143	143	141	142	140	133
G-1.4	1°	1,2,3,4 @ 2.21	16,200 (72,100)	150	151		148	147	146	146	146	133
G-1.5	23°	1,2,3,4 @ 1.06	1,000 (4400)	128	125		124	122	117	118	116	122
G-1.6	23°	1,2,3,4 @ 1.59	9,100 (40,500)	142	142		140	140	135	137	134	131
G-1.7	23°	1,2,3,4 @ 1.90	12,800 (56,900)	148	148		146	146	141	142	140	133
G-1.8	23°	1,2,3,4 @ 2.21	16,400 (73,000)	151	152		150	149	146	147	144	135
G-1.9	46°	1,2,3,4 @ 1.06	1,000 (4400)	128	124		122	123	114	118	116	122
G-1.10	47°	1,2,3,4 @ 1.39	6,400 (28,500)	139	(b)		133	137	132	134	132	131
G-2.2	1°	1,4 @ 1.57	8,900 (39,600)	(d)	134		133	134	131	132	130	127
G-2.3	1°	1,4 @ 1.89	12,600 (56,000)	137	138		138	138	137	137	136	128
G-2.4	1°	1,4 @ 2.20	16,000 (71,200)	141	142		142	142	141	142	140	129
G-2.6	23°	1,4 @ 1.59	9,100 (40,500)	135	135		135	135	131	132	130	128
G-2.7	23°	1,4 @ 1.88	12,500 (55,600)	139	139		140	140	137	138	136	128
G-2.8	22°	1,4 @ 2.19	15,900 (70,700)	142	143		144	144	141	143	140	130
G-2.10	47°	1,4 @ 1.58	9,000 (40,000)	134	134		133	135	128	130	130	127
G-3.1	23°	2,3 @ 1.90	12,800 (56,900)	(d)	146		144	143	138	139	134	132
G-3.2	24°	2,3 @ 2.20	16,000 (71,200)	150	151		149	148	144	145	142	133
G-3.4	1°	2,3 @ 2.19	15,900 (70,700)	150	(d)		147	146	144	143	142	131
G-4	48°	1,2,3,4 @ 2.20		149	148	148	143	148	144	145	145	136
	INSTRUMENTATION SYSTEM BACKGROUND LEVELS (POST FLIGHT)			108	107	107	106	107	105	105	113	109

NOTES:
(a) Installed thrust values are for each engine mentioned.
(b) Signal varies in amplitude (low frequency oscillation).
(c) Signal conditioning malfunction
(d) Intermittent signal
(e) Unmentioned engines were operated at idle; EPR is average for engines mentioned.

TABLE 9 - YC-15 EXTERIOR NOISE MEASUREMENTS - SECOND SERIES GROUND TESTS - OVERALL SOUND PRESSURE LEVELS, dB re 20 μPa

TEST NO.	FLAP ANGLE	ENGINE NO. @ EPR[d]	THRUST[a] LBS (N)	FLUSH-MOUNTED EXTERIOR MICROPHONES MIC 1	MIC 2	MIC 3	MIC 4	MIC 5	MIC 6	MIC 7	MIC 8	MIC 9
G-1.1	0°	1,2,3,4 @ 1.05	1,000 (4400)	126	125	121	(c)	121	119	119	116	124
G-1.2	0°	3,4 @ 1.55	8,500 (38,300)	143	142	138	135	138	136	136	134	132
G-1.3	0°	3,4 @ 1.85	12,200 (54,300)	147	147	143	(c)	143	141	141	140	131
G-1.4	0°	3,4 @ 2.21	16,100 (71,600)	151	152	148		148	147	146	145	134
G-1.5	21°	1,2,3,4 @ 1.05	1,000 (4400)	127	125	122		123	118	120	(c)	125
G-1.6	21°	3,4 @ 1.55	8,600 (38,300)	143	143	140		140	136	137	134	133
G-1.7	21°	3,4 @ 1.85	12,200 (54,300)	147	148	145		145	142	142	140	133
G-1.8	21°	3,4 @ 2.21	16,100 (71,600)	151	153	150		150	147	147	144	135
G-1.9	47°	1,2,3,4 @ 1.05	1,000 (4400)	127	125	123	123	123	116	119	115	122
G-1.10	45°	3,4 @ 1.55	8,600 (38,300)	144	143	140	(c)	140	136	137	(c)	134
G-2.2	0°	1,4 @ 1.55	8,600 (38,300)	135	136	134		134	131	133	129	131
G-2.3	0°	1,4 @ 1.85	12,200 (54,300)	139	144	138		143	142	138	135	128
G-2.4	0°	1,4 @ 2.21	16,100 (71,600)	142	144	142	139	144	141	143	140	130
G-2.6	22°	1,4 @ 1.55	8,600 (38,300)	135	137	135	134	136	131	132	130	128
G-2.7	22°	1,4 @ 1.85	12,200 (54,300)	139	140	139	(c)	140	136	140	138	129
G-2.8	22°	1,4 @ 2.21	16,100 (71,600)	144	145	144	144	145	142	144	140	131
G-2.10	46°	1,4 @ 1.55	8,600 (38,300)	136	137	135	135	136	129	132	129	128
	0°	2,3 @ 1.55	8,600 (38,300)	142	141	137	(c)	136	133	133	130	131
	0°	2,3 @ 1.85	12,200 (54,300)	147	146	142	(c)	142	139	139	137	131
	0°	2,3 @ 2.21	16,100 (71,600)	151	151	147	145	147	144	144	142	132
	22°	2,3 @ 1.55	8,600 (38,300)	143	142	139	135	139	134	135	132	134
G-3.1	22°	2,3 @ 1.85	12,200 (54,300)	146	147	144	143	144	140	140	138	131
G-3.2	22°	2,3 @ 2.21	16,100 (71,600)	150	152	149	149	149	145	145	142	133
	47°	2,3 @ 1.55	8,600 (38,300)	143	142	139	140	141	137	137	135	132
G-4	46°	1,2,3,4 @ 1.60	9,200 (40,900)	144	143	142	142	142	137	138	136	134
INSTRUMENTATION SYSTEM BACKGROUND NOISE				105	111	108	108	113	111	113	108	115

*NOTES: (a) Unmentioned engines were operated at idle. - EPR is average of the mentioned engines.
(b) Installed single engine thrust for each engine mentioned.
(c) Intermittent data.
(d) Unmentioned engines were operated at idle; EPR is average for engines mentioned.

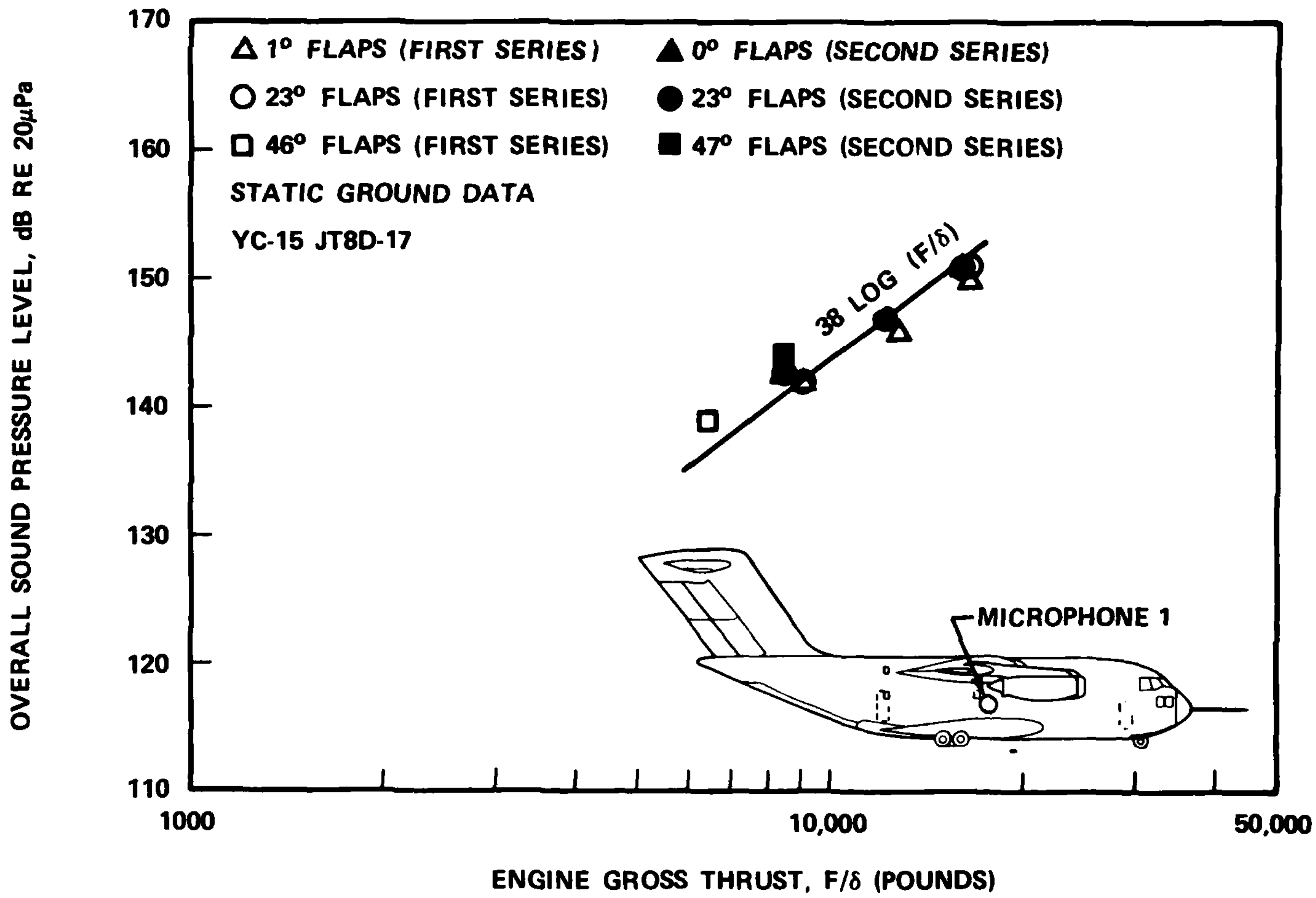


Figure 16. External Fuselage Noise Levels — All Engines Operating — Microphone 1

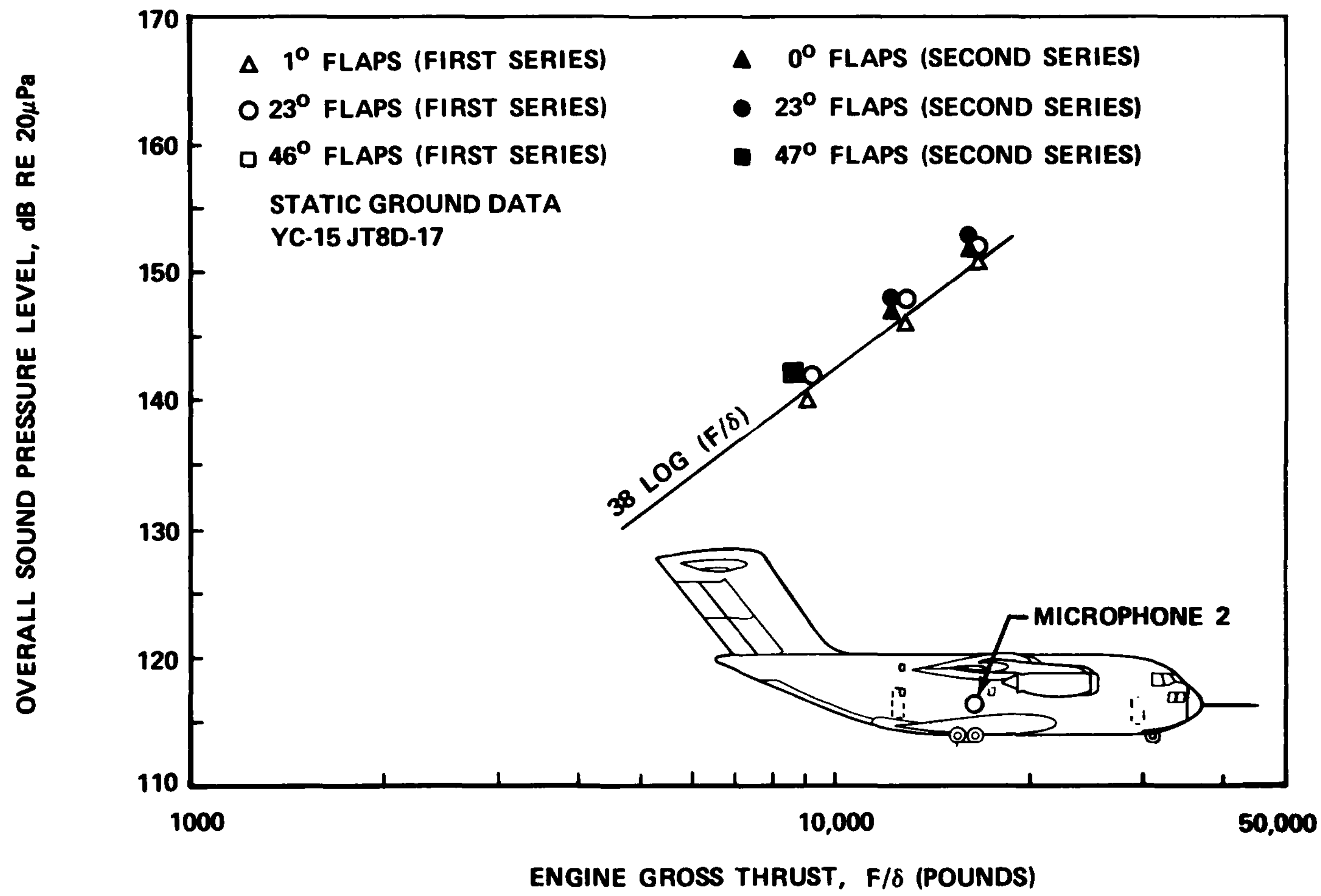


Figure 17. External Fuselage Noise Levels – All Engines Operating – Microphone 2

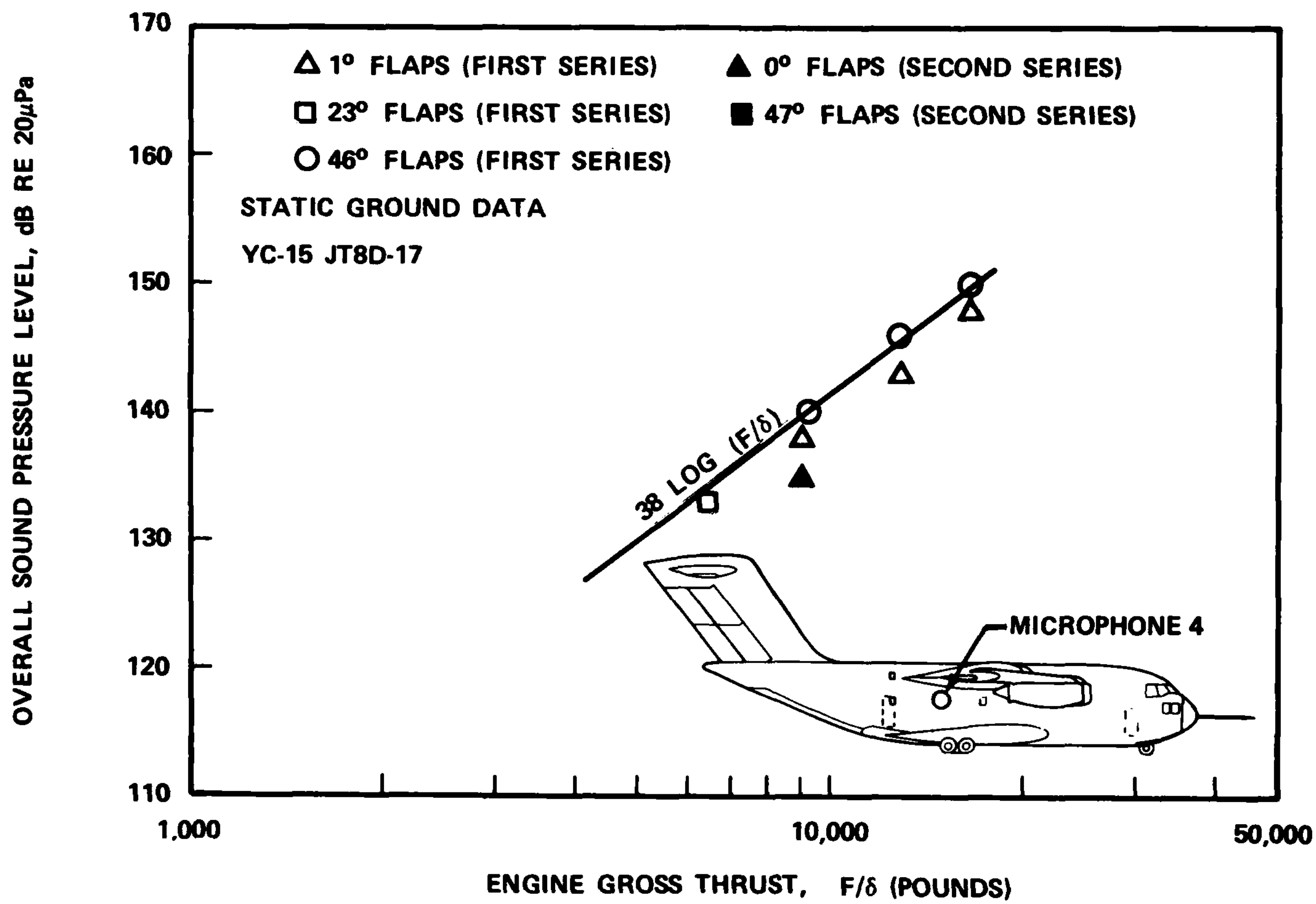


Figure 18. External Fuselage Noise Levels — All Engines Operating — Microphone 4

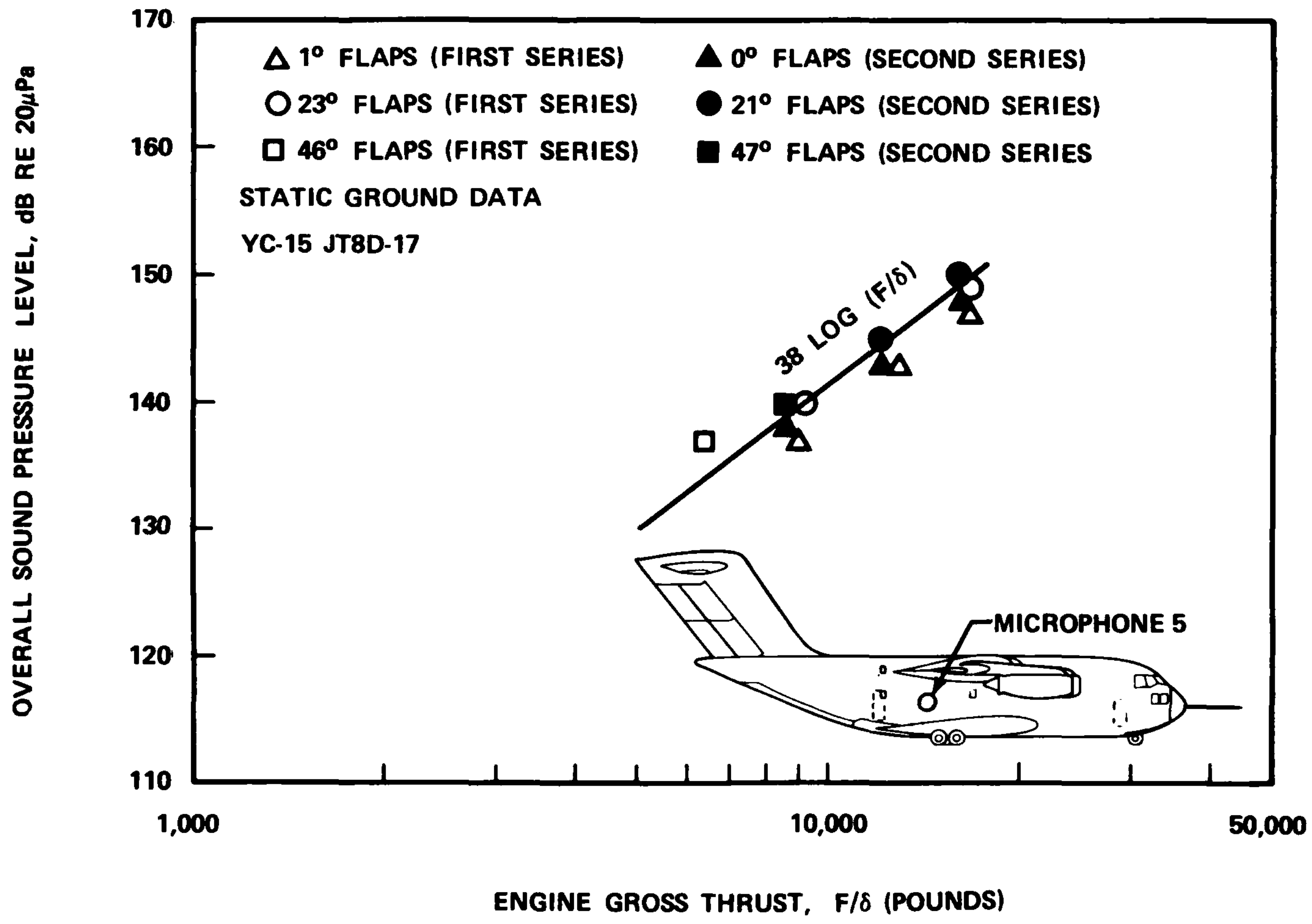


Figure 19. External Fuselage Noise Levels – All Engines Operating – Microphone 5

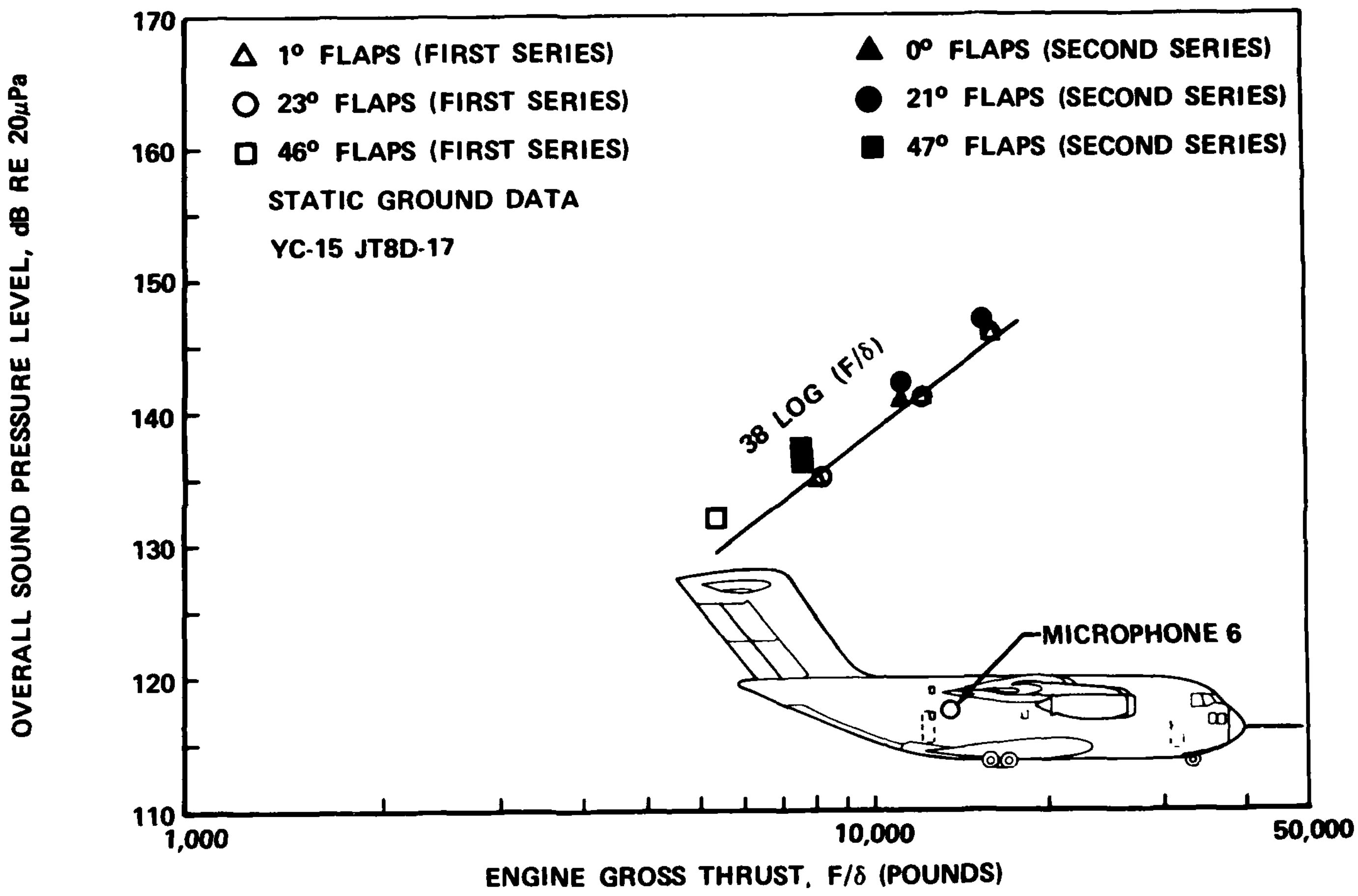


Figure 20. External Fuselage Noise Levels – All Engines Operating – Microphone 6

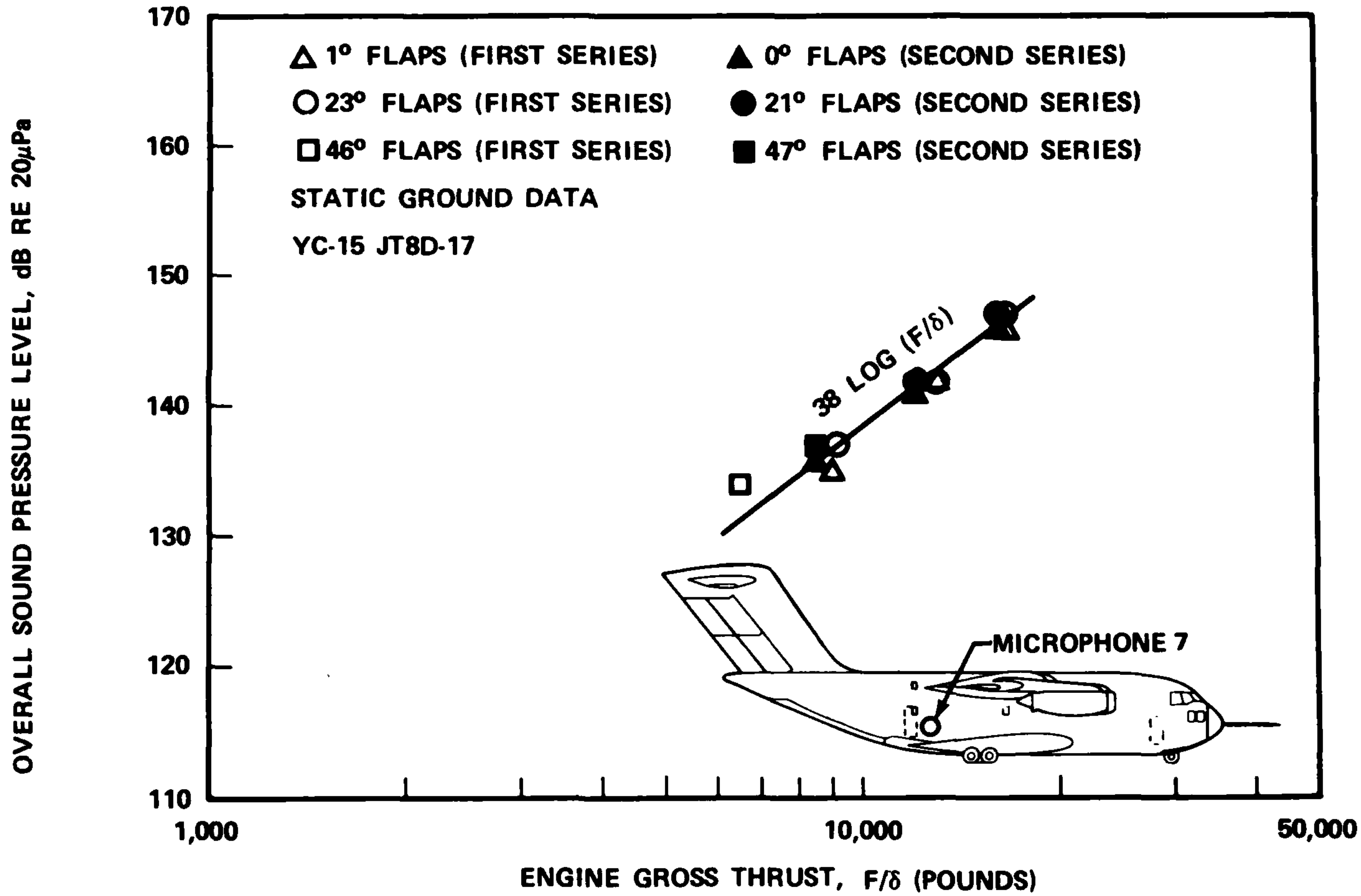


Figure 21. External Fuselage Noise Levels – All Engines Operating – Microphone 7

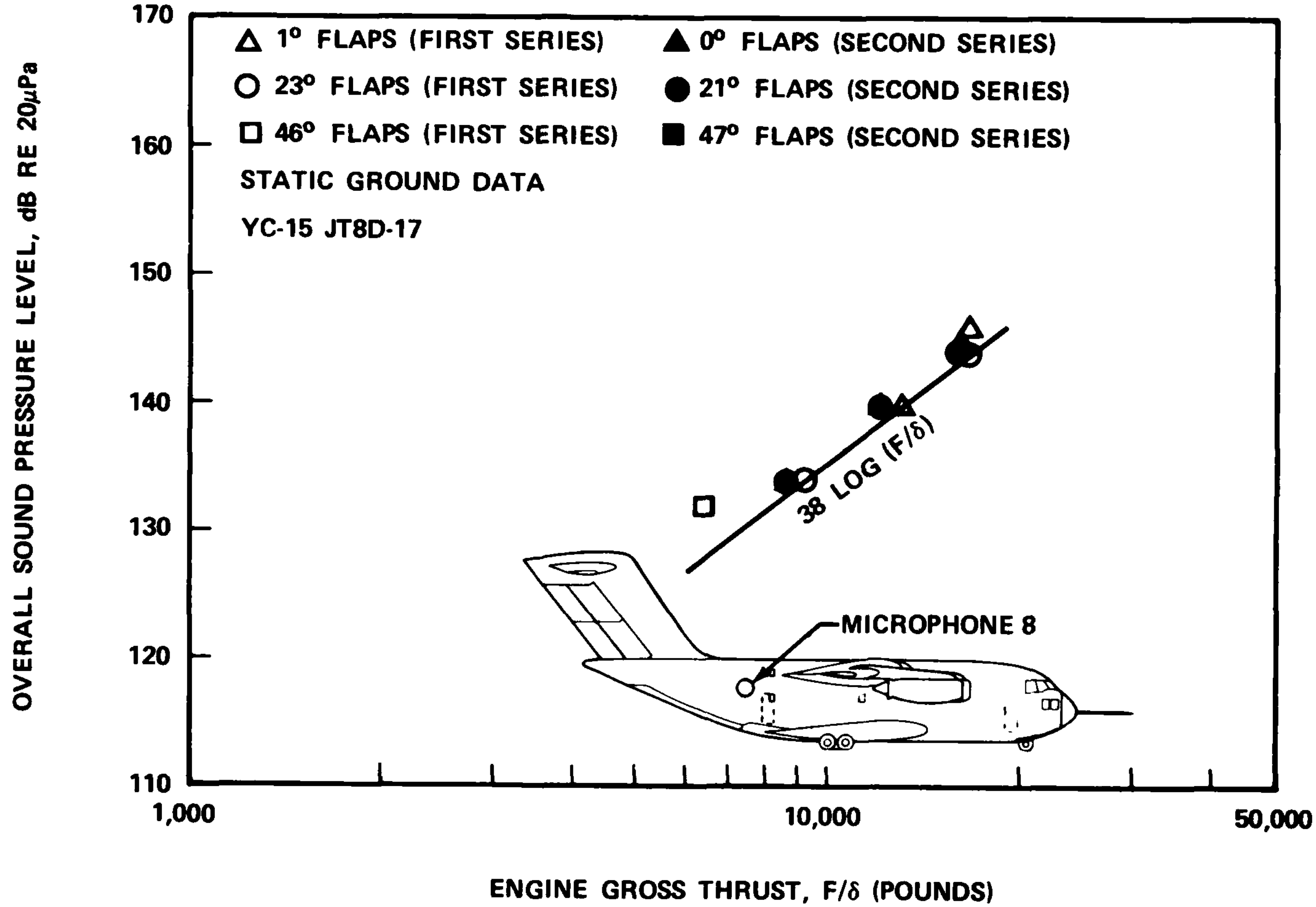


Figure 22. Exterior Fuselage Noise Levels – All Engines Operating – Microphone 8

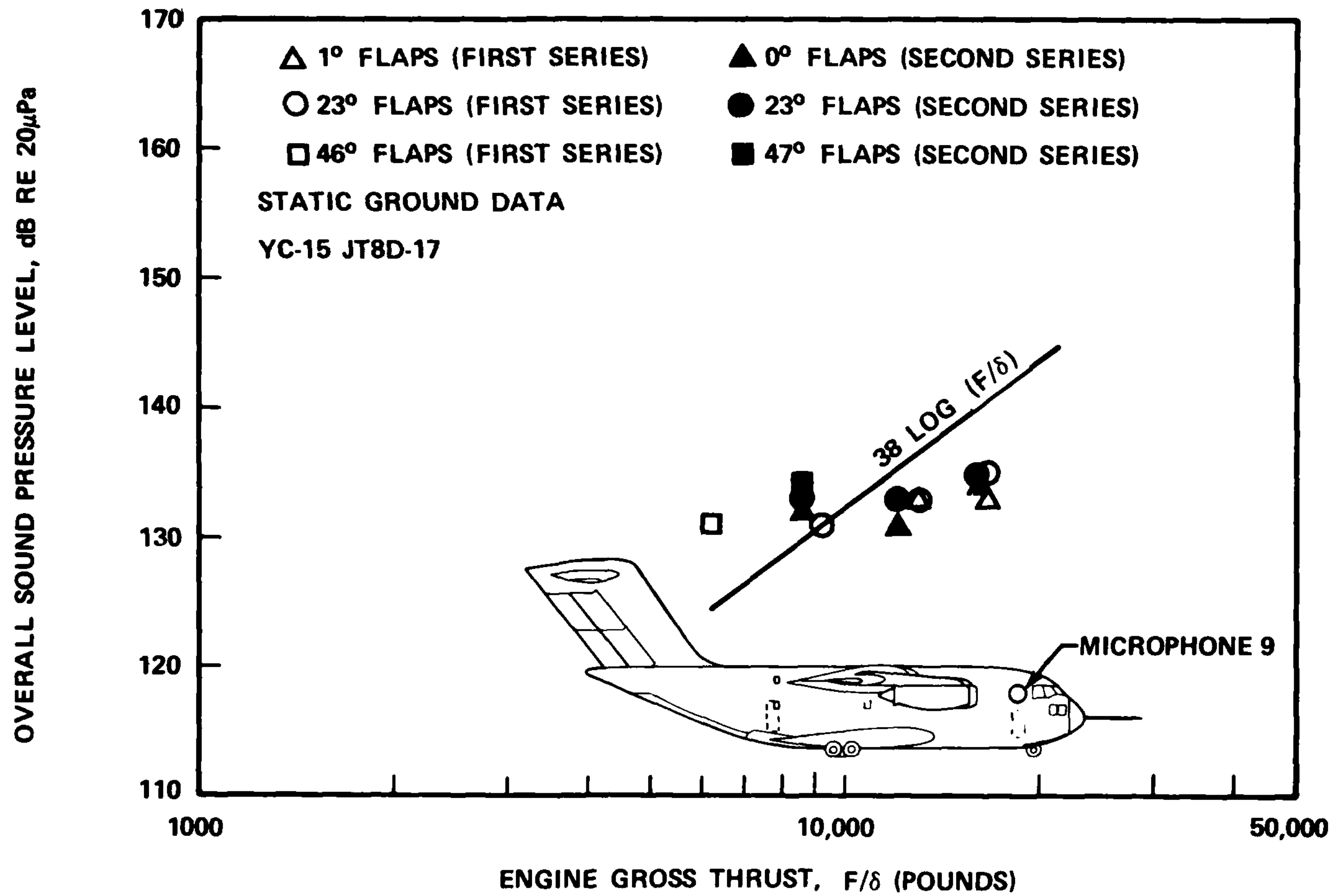


Figure 23. Exterior Fuselage Noise Levels – All Engines Operating – Microphone 9

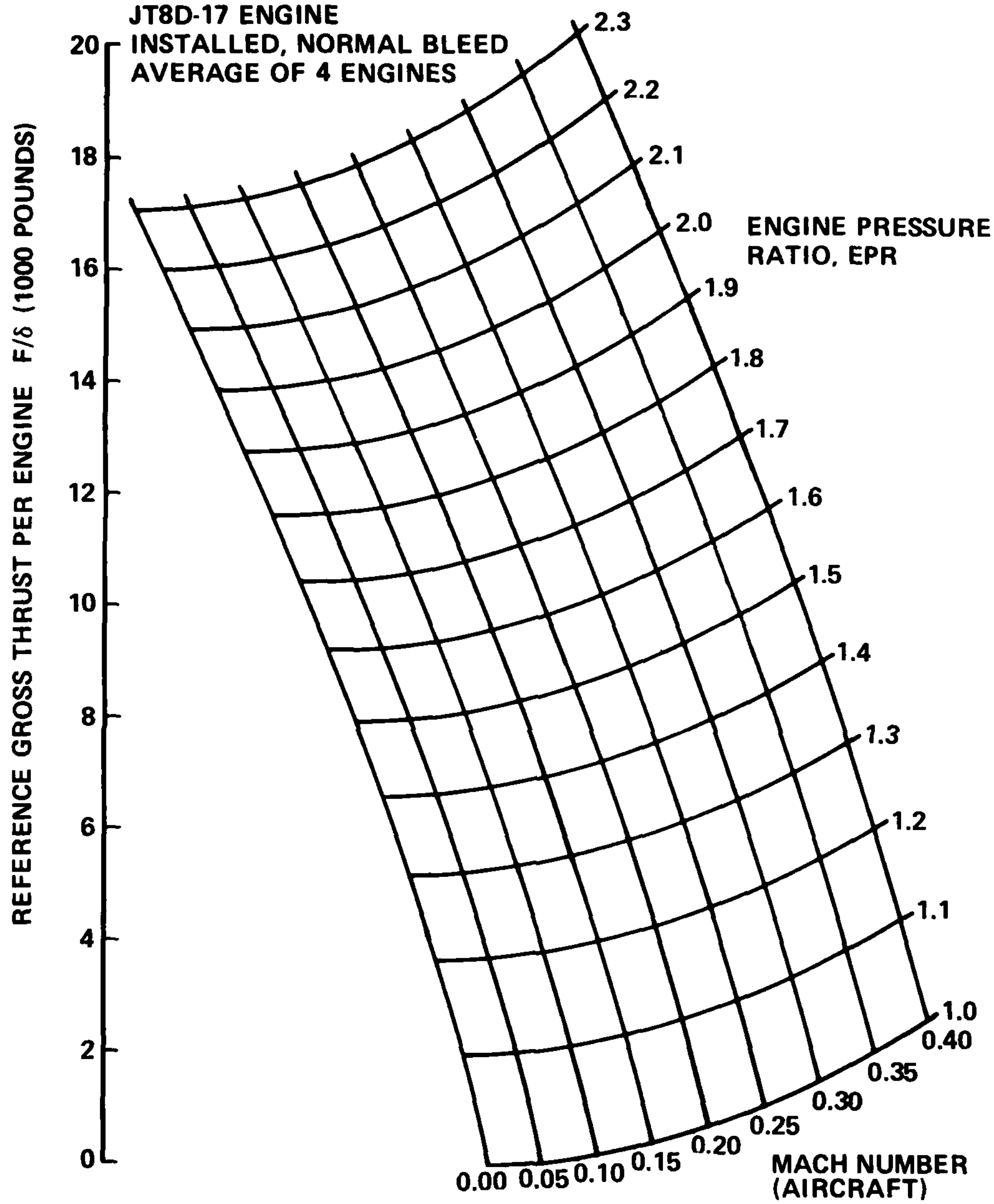


Figure 24. YC-15 Generalized Gross Thrust

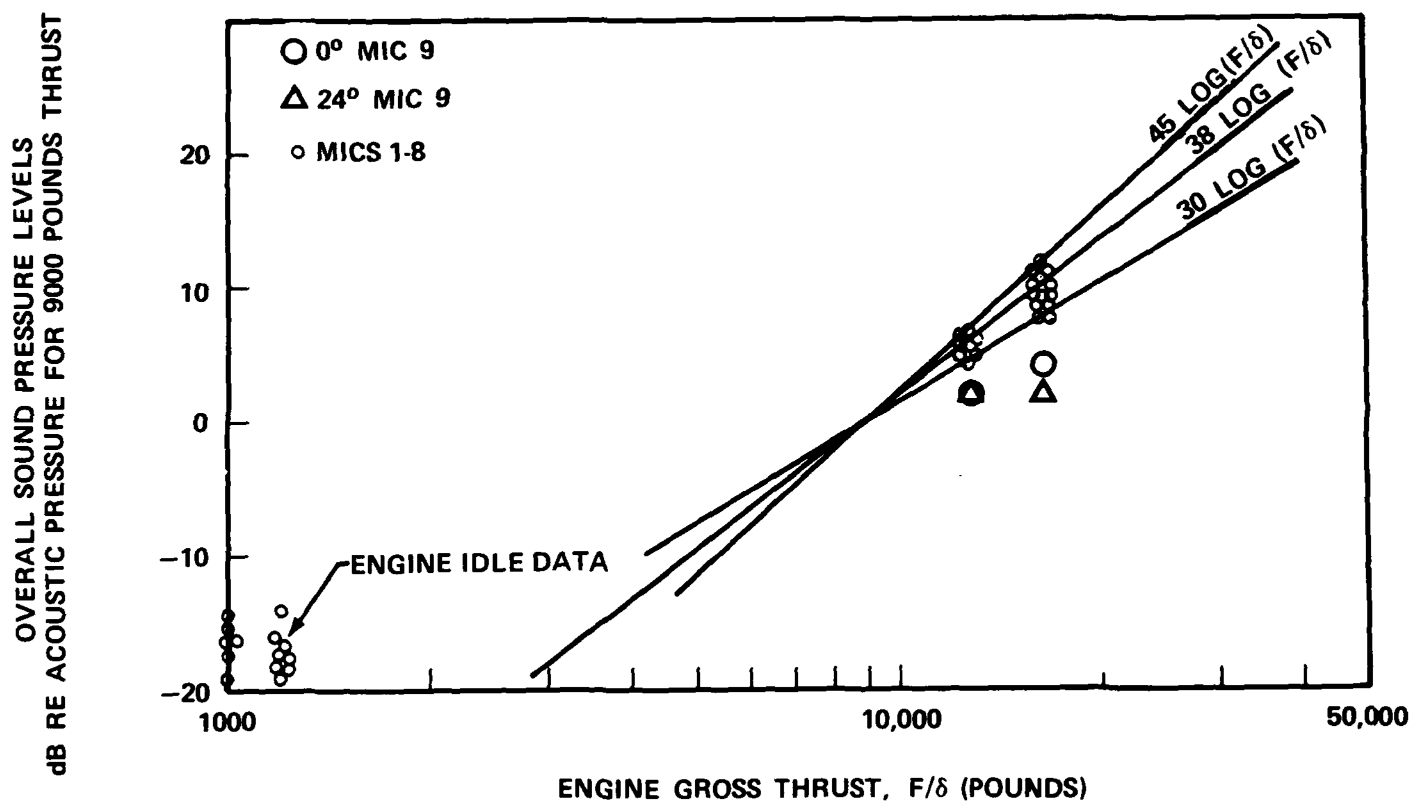


Figure 25. Normalized Overall Sound Pressure Level Versus Thrust

The observations to be made from Figures 16-23 are:

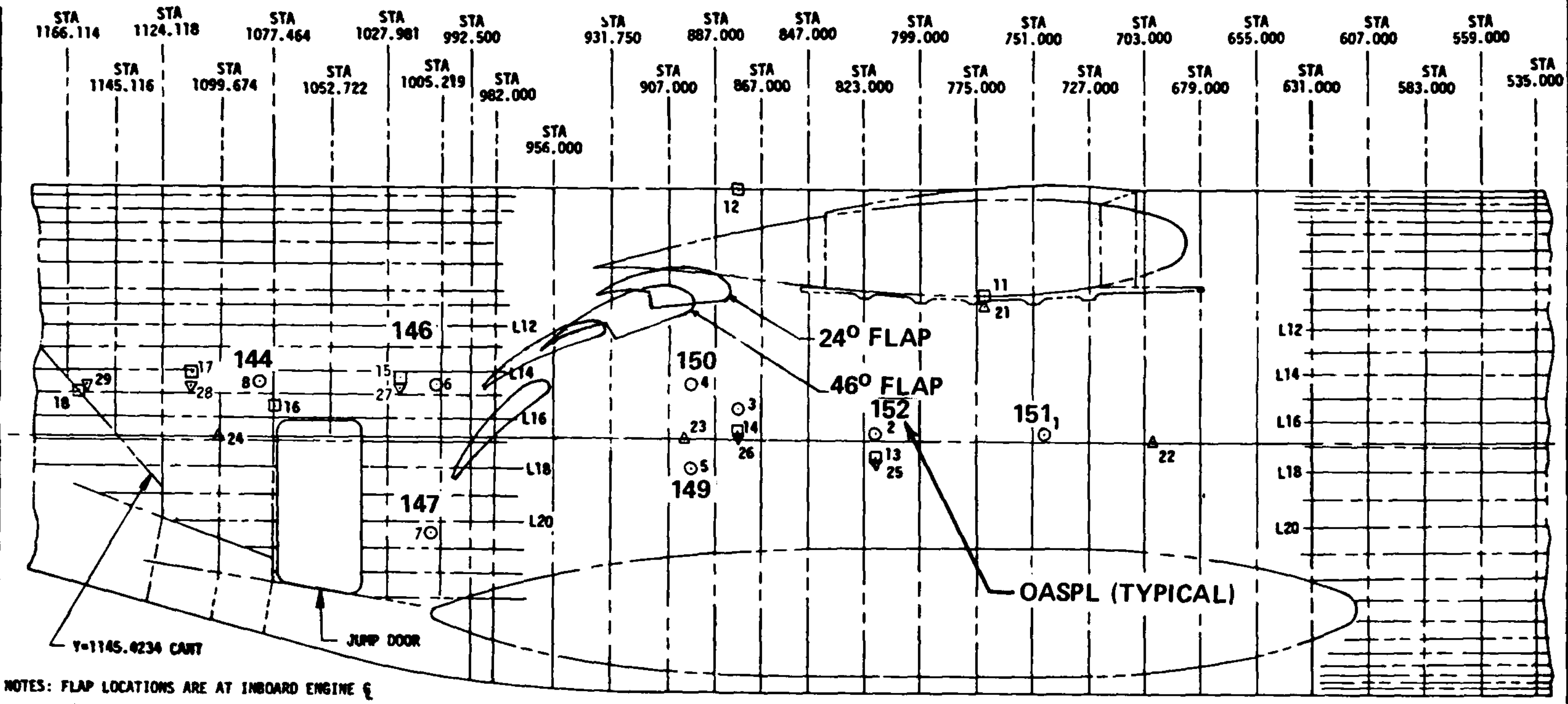
(1) The data for each microphone and each flap setting appear to be consistent with the exception of microphone 4 (second series) at 0° flaps and 8,600 pounds (38,200 N). The consistency between both sets of tests demonstrates the repeatability of the obtained data.

(2) The measured data for each flap setting and microphone follow the 38 log F/δ line fairly well except at engine idle (1,000 pounds or 4,500 N) and for microphone 9. Slopes could have been identified for each location and flap setting; however, this would not add to data quality evaluation or the observation that OASPL = K + N Log F/δ for the higher thrust values. The idle values should be controlled by engine turbomachinery rather than aerodynamic sources and are not expected to follow the same trend. The sound pressure level of microphone 9 is probably controlled by inlet noise, and, again, the same trend would not be expected.

(3) The effect of flap settings on the overall levels are small.

The OASPLs as a function of fuselage location measured during the first series of tests are shown in Figures 26 and 27 for 16,000 pounds (73,000 N) thrust with 24° flaps, and 6400 pounds (28,000 N) thrust with 46° flaps, respectively. The 24° flaps data indicate that the OASPL is fairly uniform between the exhaust nozzle and the flaps and less behind the flaps. The 46° flap data indicate the same basic trend except for microphone 4. The lower noise levels at the microphone 4 position may have resulted from shielding by the large fairing (see Figures 1-5) that covers the inboard flap retraction mechanism.

Plots of OASPL from the first series of tests versus thrust for a 24° flap angle with outboard (engines 1 and 4) and inboard (engines 2 and 3) engines operating separately and in combination are presented in Figures 28 through 35. The sum of the mean-squared pressures measured with the engines operating separately agrees well with the values measured with the engines operating together. This indicates that the acoustic sources for one engine



NOTES: FLAP LOCATIONS ARE AT INBOARD ENGINE ℄

⊙ INDICATES TRANSDUCERS NO. 1 - 9, EXTERIOR FLUSH MOUNTED MICROPHONES

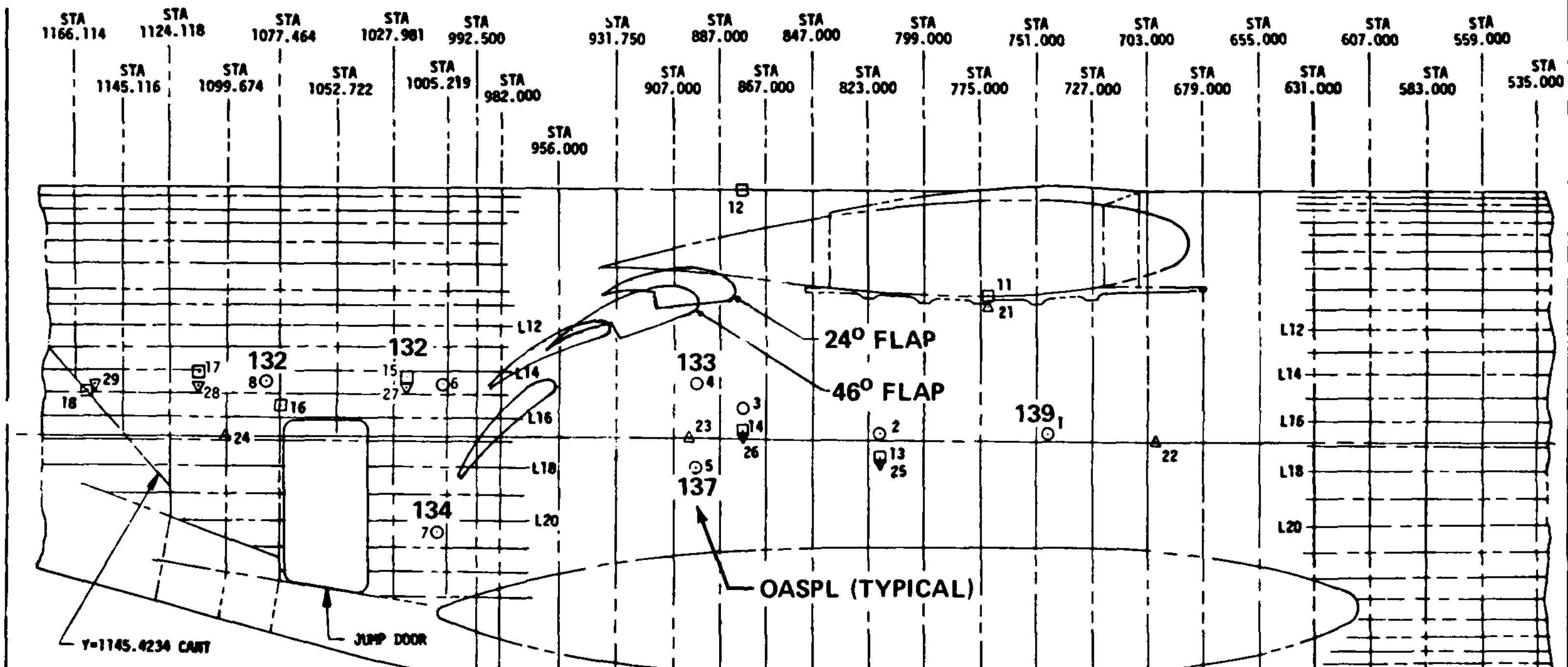
⊡ INDICATES TRANSDUCERS NO. 11 - 18, ACCELEROMETERS

△ INDICATES TRANSDUCERS NO. 21 - 24, INTERIOR MICROPHONES, ℄

▽ INDICATES TRANSDUCERS NO. 25 - 29, INTERIOR MICROPHONES, SIDEWALL

EXTERIOR FLUSH MOUNTED TRANSDUCER NO. 9 (⊙) IS LOCATED AT FUSELAGE STATION Y=415.500 AND 4.5 INCHES ABOVE L13.

Figure 26. Exterior Fuselage Noise Levels – 24-Deg Flaps – 16,400 Pounds Thrust



NOTES: FLAP LOCATIONS ARE AT INBOARD ENGINE ℄

⊙ INDICATES TRANSDUCERS NO. 1 - 9, EXTERIOR FLUSH MOUNTED MICROPHONES

⊡ INDICATES TRANSDUCERS NO. 11 - 18, ACCELEROMETERS

△ INDICATES TRANSDUCERS NO. 21 - 24, INTERIOR MICROPHONES, ℄

▽ INDICATES TRANSDUCERS NO. 25 - 29, INTERIOR MICROPHONES, SIDEWALL

EXTERIOR FLUSH MOUNTED TRANSDUCER NO. 9 (⊙) IS LOCATED AT FUSELAGE STATION Y=415.500 AND 4.5 INCHES ABOVE L13.

Figure 27. Exterior Fuselage Noise Levels – 46-Deg Flaps – 6,400 Pounds Thrust

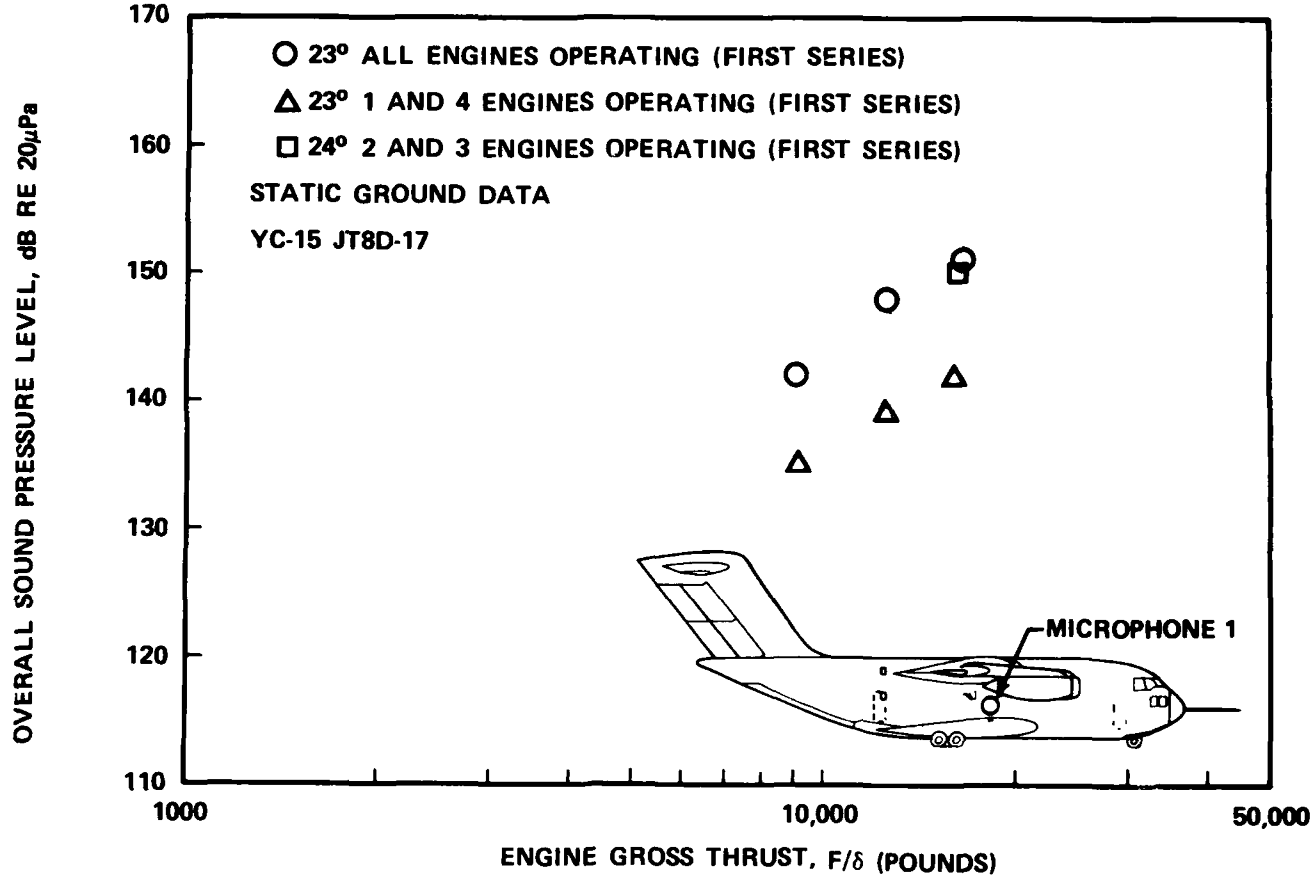


Figure 28. Exterior Fuselage Noise Levels – Two Versus Four Engines – Microphone 1

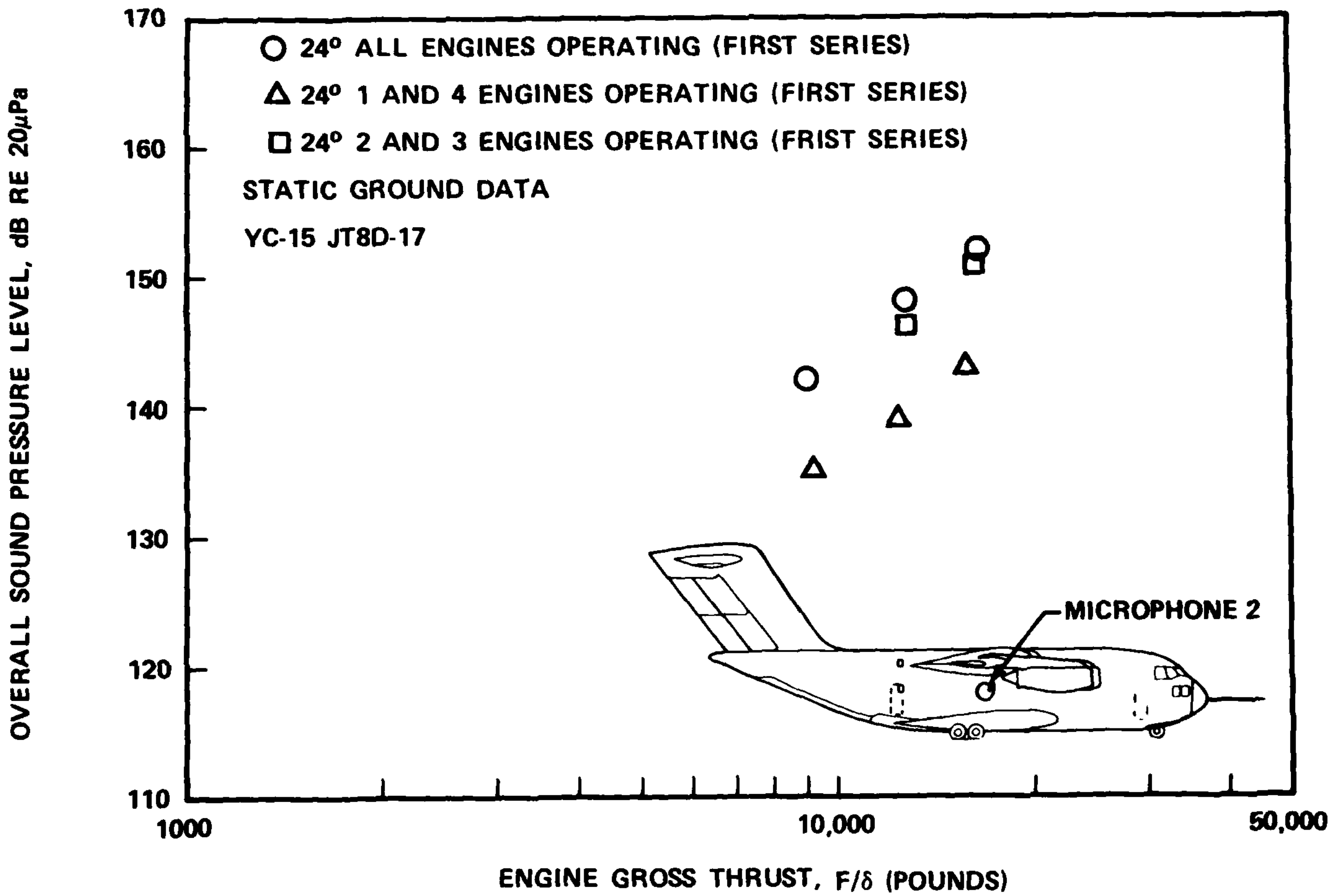


Figure 29. Exterior Fuselage Noise Levels – Two Versus Four Engines – Microphone 2

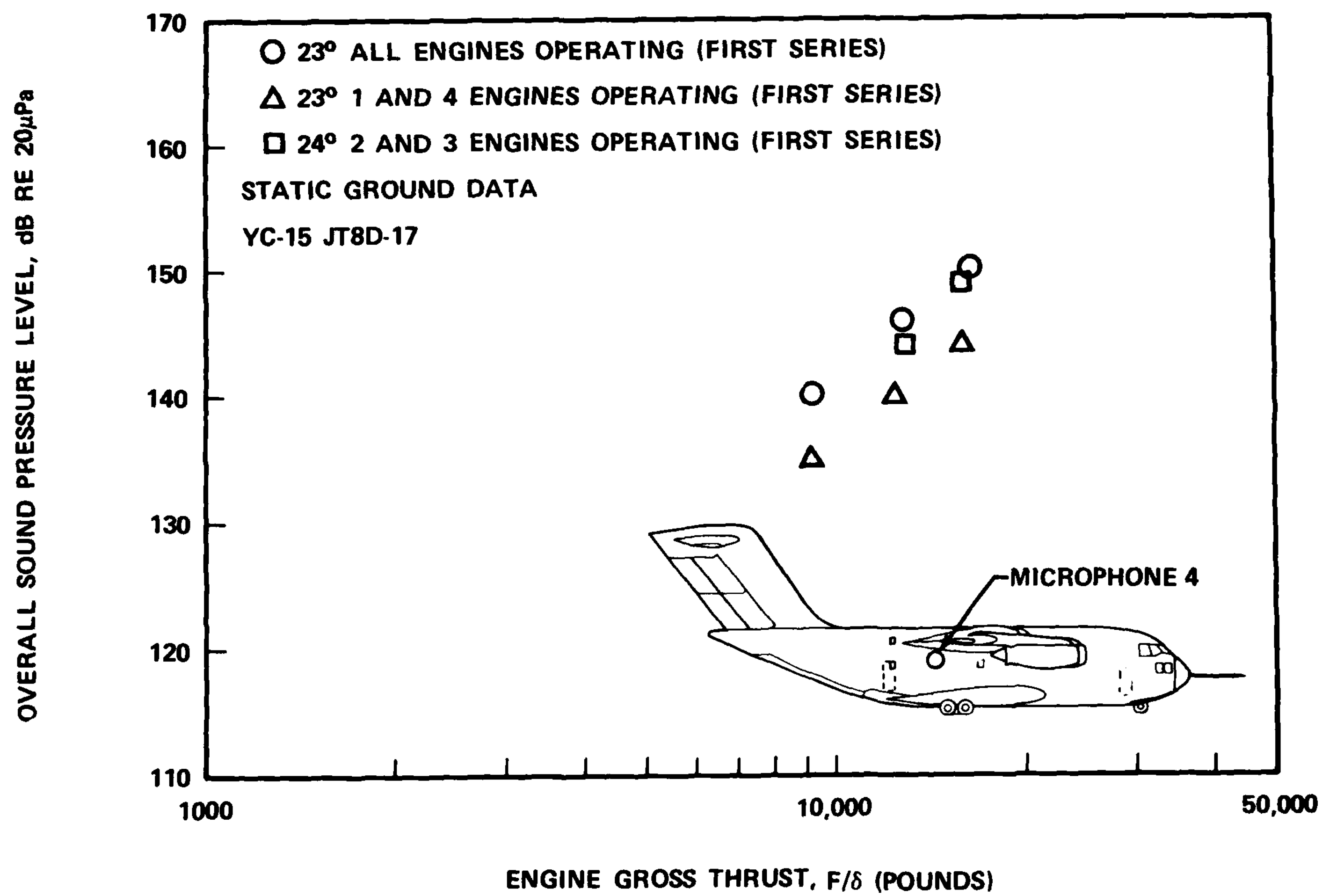


Figure 30. Exterior Fuselage Noise Levels – Two Versus Four Engines – Microphone 4

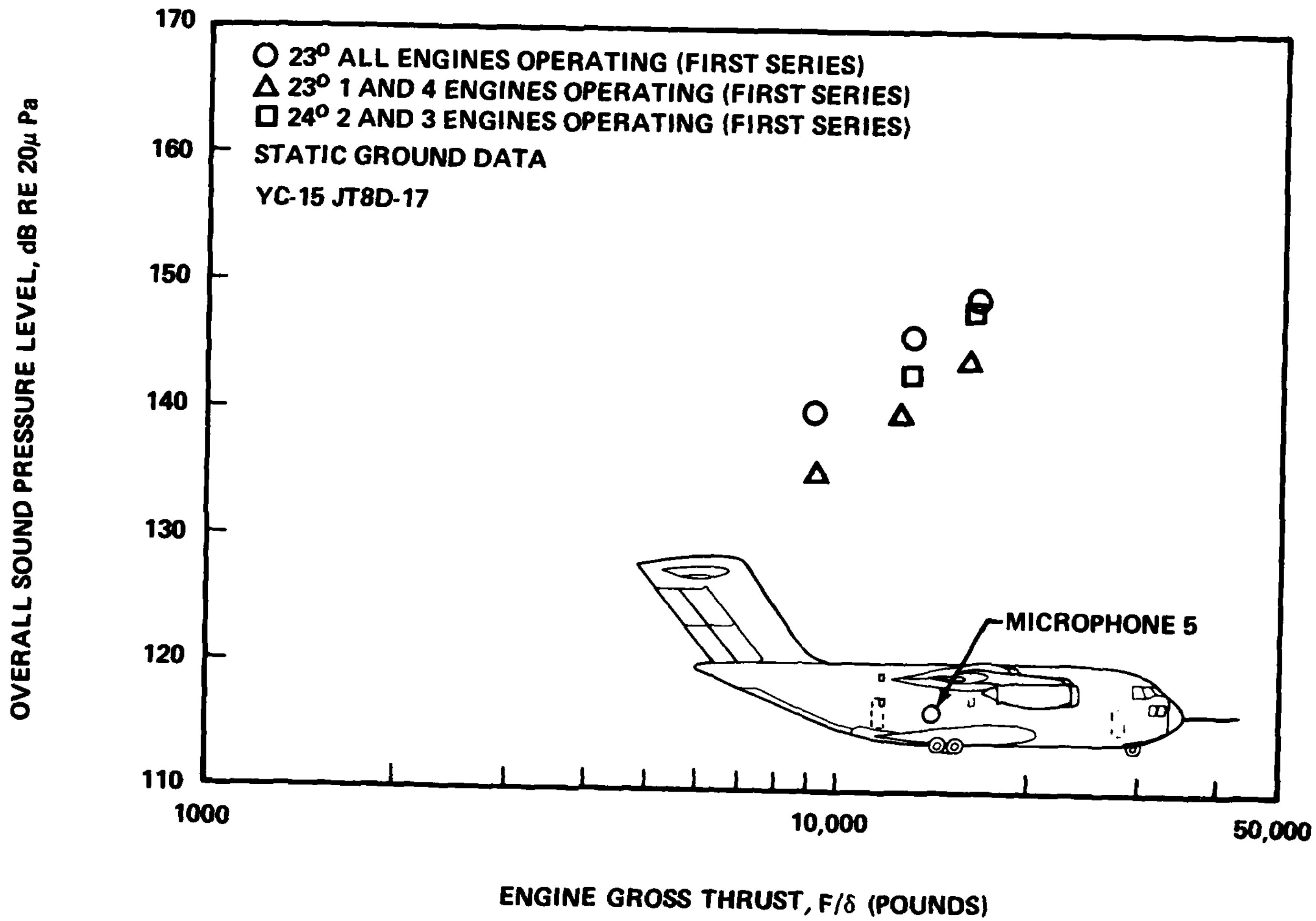


Figure 31. Exterior Fuselage Noise Levels – Two Versus Four Engines – Microphone 5

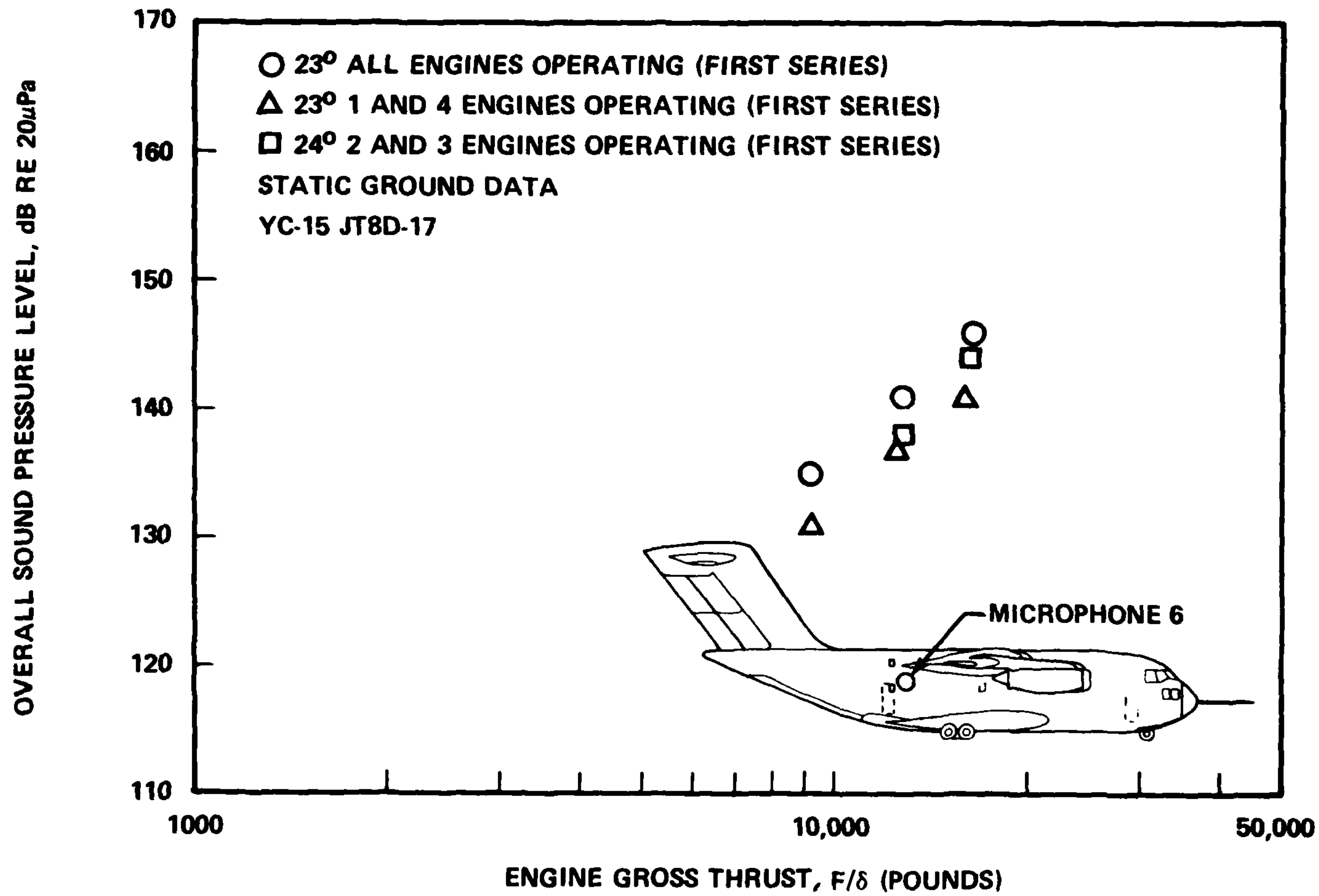


Figure 32. Exterior Fuselage Noise Levels – Two Versus Four Engines – Microphone 6

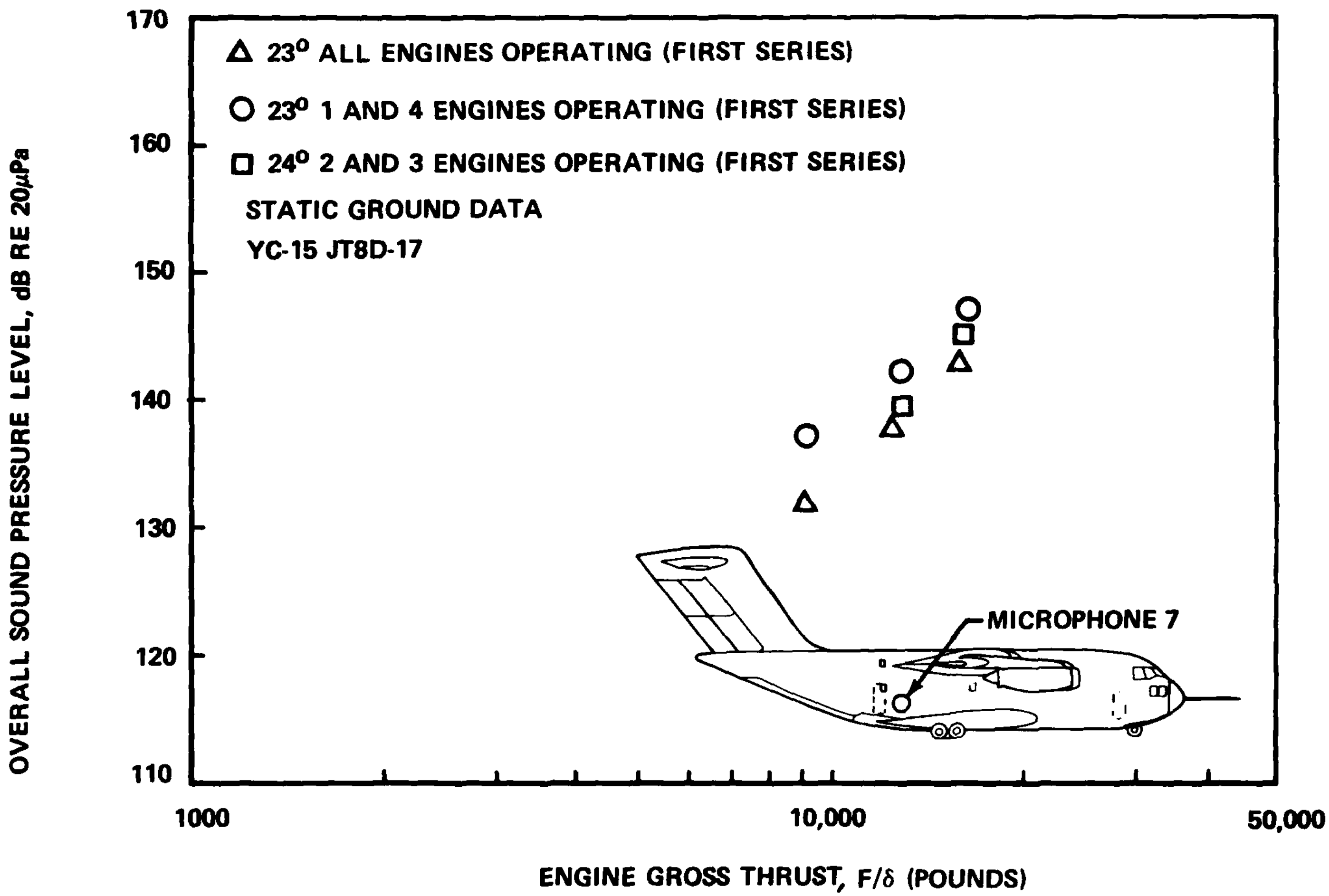


Figure 33. Exterior Fuselage Noise Levels – Two Versus Four Engines – Microphone 7

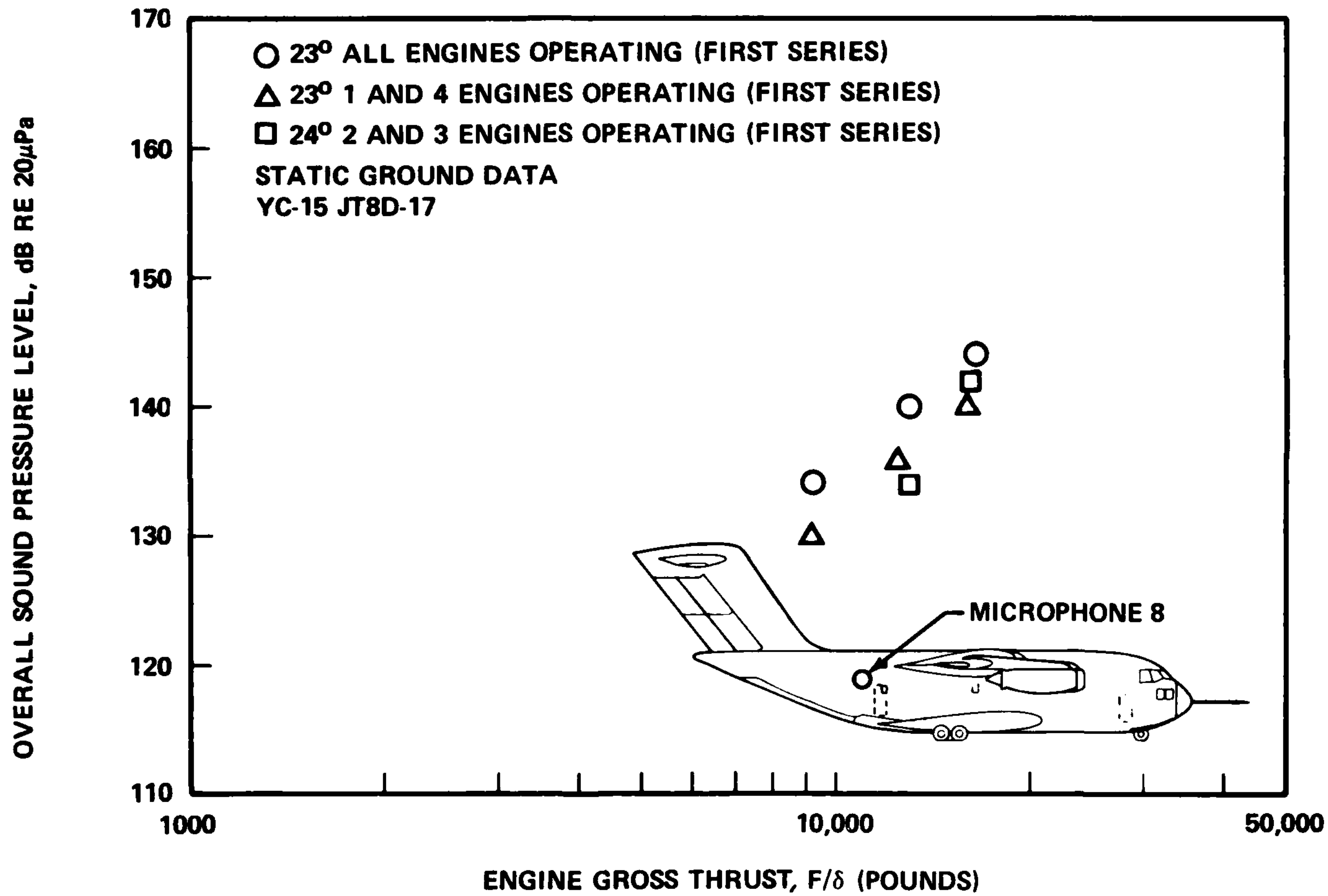


Figure 34. Exterior Fuselage Noise Levels — Two Versus Four Engines — Microphone 8

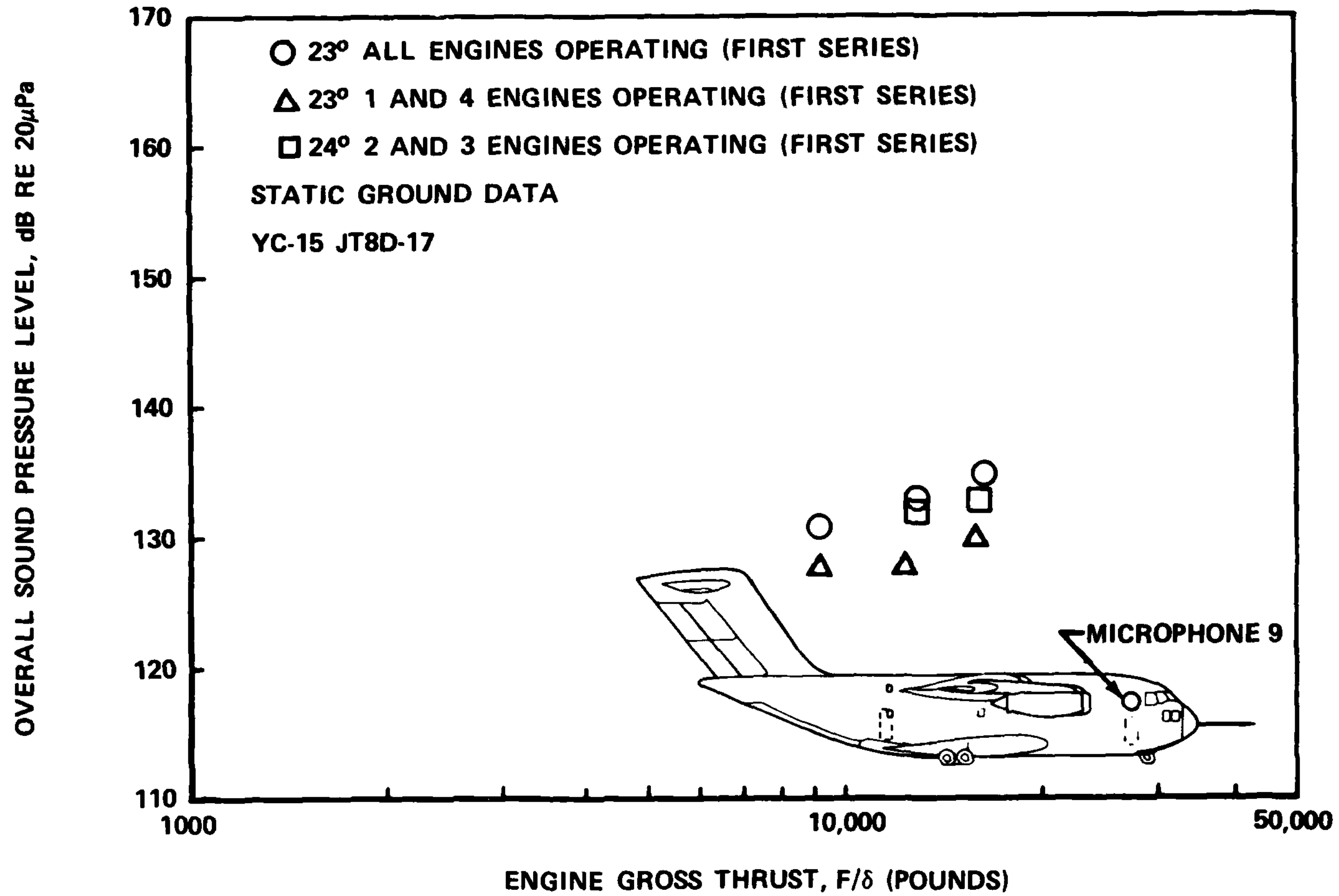


Figure 35. Exterior Fuselage Noise Levels – Two Versus Four Engines – Microphone 9

are not altered by the operation of an adjacent engine. The overall sound pressure levels for the fuselage sidewall under the wing are influenced strongly by the inboard engines; however, at the aft microphone locations, the exterior fuselage noise levels are determined by the outboard engines as well. The relative values of the OASPL, referred to levels measured with only the outboard engines at takeoff power generated by the inboard engines are shown in Figure 36 for takeoff power.

Octave-band sound pressure levels for various flap settings and microphone locations are shown in Figures 37 through 43 for 9,000 pounds (40,500 N) thrust. The 1° and 23° flap cases were plotted directly from first series tests, G-1.2 and G-1.6. The 46° flap data were corrected using the 38 log F/δ expression previously obtained.

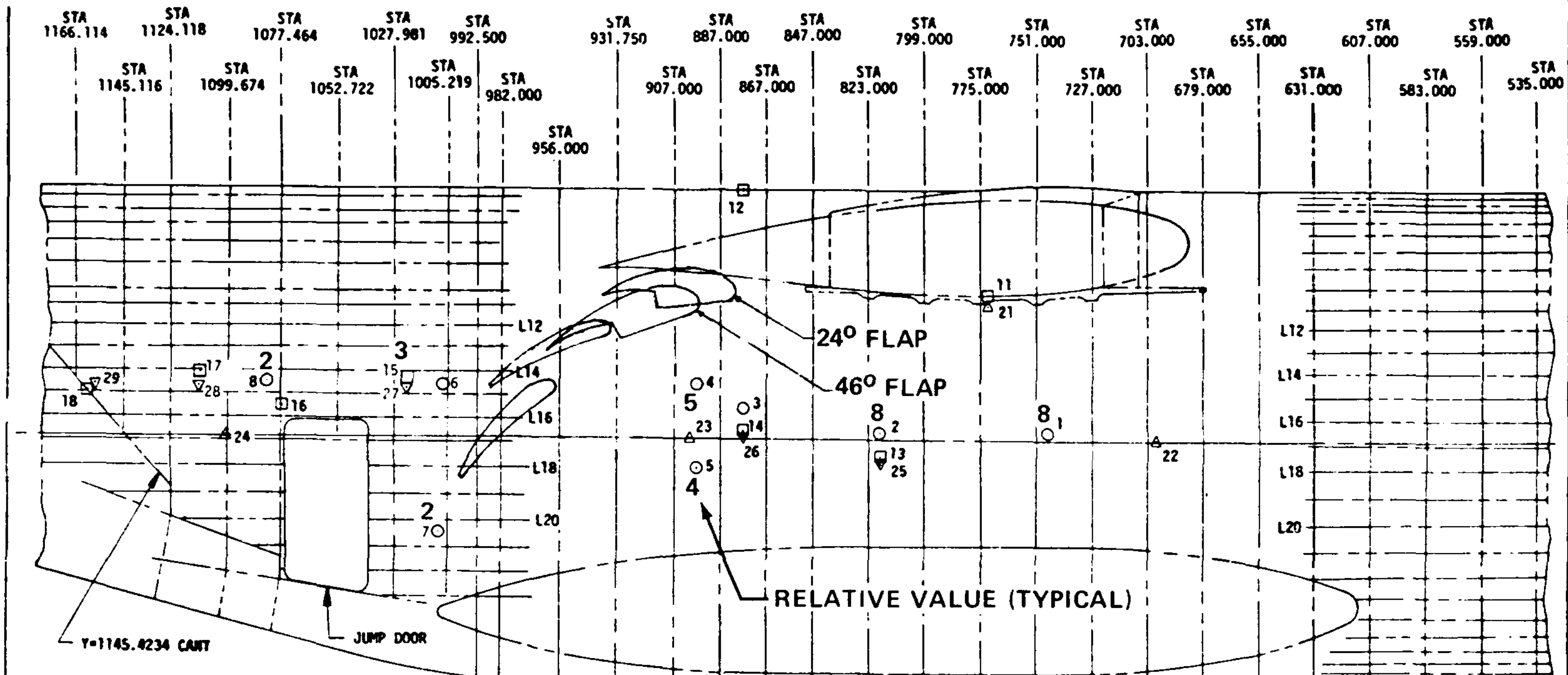
Figures 37 through 43 indicate that:

(1) Increasing the flap angle increases the noise levels below 500 Hz. Microphone 4 (Figure 39) does not strictly follow this generalization, possibly due to the shielding effect of the fairing.

(2) The high frequency environment is not largely affected by changes in flap setting except for microphone 6 (Figure 41), where changes in the jet scrubbing on the fuselage may offer a possible explanation.

(3) The peak frequency shifts to lower values for aft microphone locations. This frequency shift is illustrated by comparing octave-band sound pressure levels from microphones 1 and 8 as shown in Figure 44. The levels are nearly identical at 63 Hz and 125 Hz and are separated by about 15 dB at 8,000 Hz. The overall values differ by about 7 dB.

6.2 Structural Vibration Levels. The overall vibration levels, measured in the first series of tests, are presented in Table 10. Some general observations that can be made at this time are (1) the responses from accelerometers 12 through 16 show essentially the same dependence on thrust



NOTES: FLAP LOCATIONS ARE AT INBOARD ENGINE ℄

○ INDICATES TRANSDUCERS NO. 1 - 9, EXTERIOR FLUSH MOUNTED MICROPHONES

□ INDICATES TRANSDUCERS NO. 11 - 18, ACCELEROMETERS

△ INDICATES TRANSDUCERS NO. 21 - 24, INTERIOR MICROPHONES, ℄

▽ INDICATES TRANSDUCERS NO. 25 - 29, INTERIOR MICROPHONES, SIDEWALL

EXTERIOR FLUSH MOUNTED TRANSDUCER NO. 9 (⊙) IS LOCATED AT FUSELAGE STATION Y=415.500 AND 4.5 INCHES ABOVE L13.

Figure 36. Relative Sound Pressure Levels – Engines 2 and 3 Minus Engines 1 and 4 – Full Power – 24-Deg Flaps

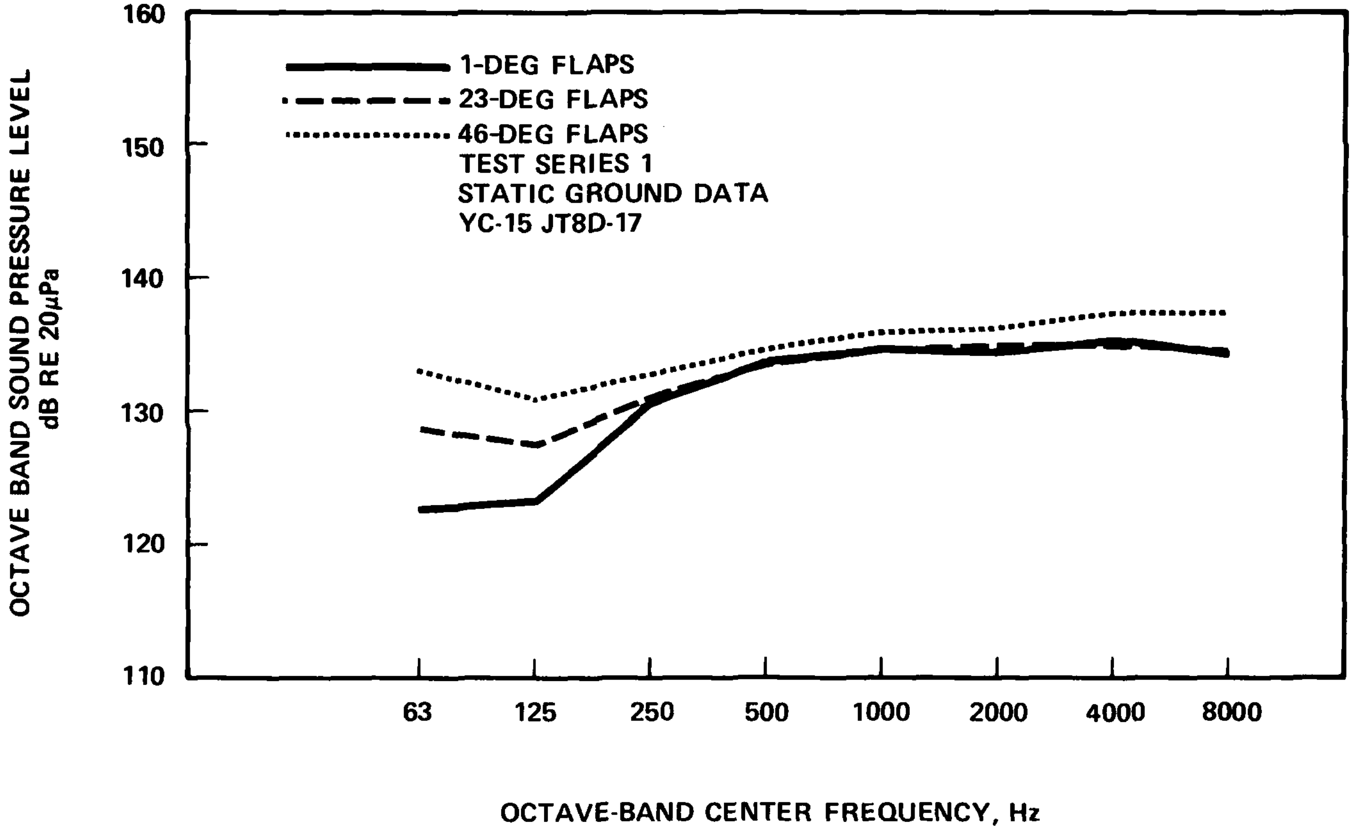


Figure 37. Exterior Fuselage Noise Levels – All Engines Operating – Corrected to 9000 Pounds Thrust – Microphone 1

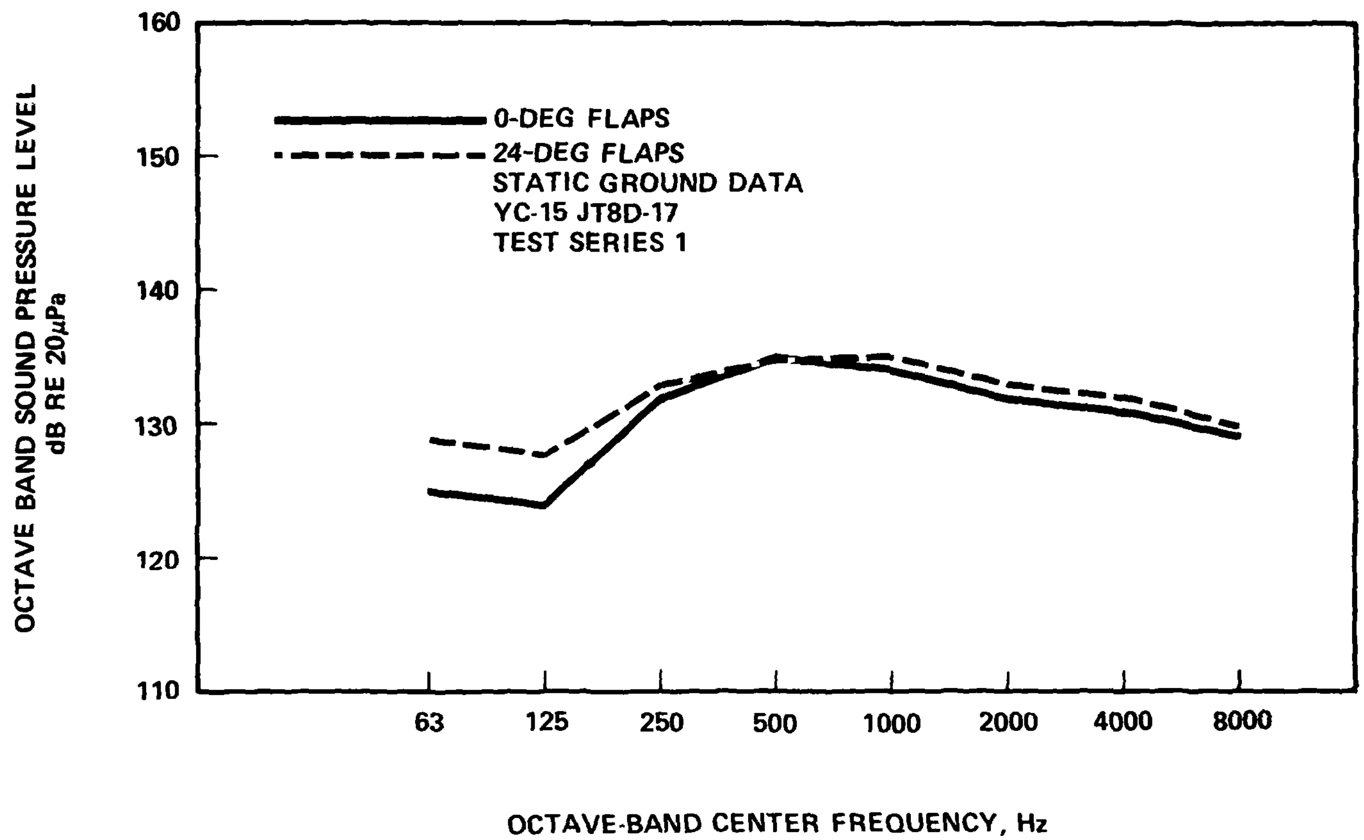


Figure 38. Exterior Fuselage Noise Levels – All Engines Operating – Corrected to 9000 Pounds Thrust – *Microphone 2*

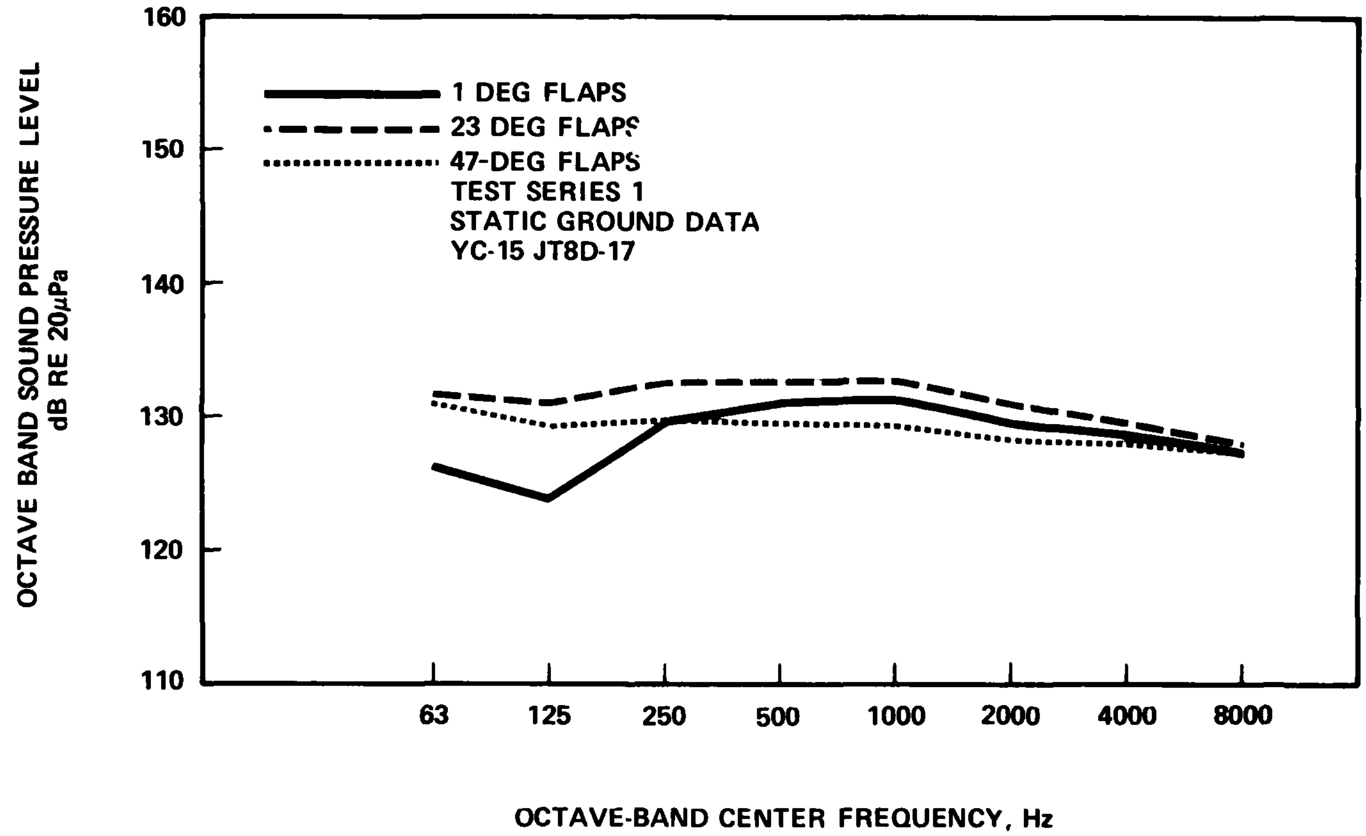


Figure 39. Exterior Fuselage Noise Levels – All Engines Operating – Corrected to 9000 Pounds Thrust – Microphone 4

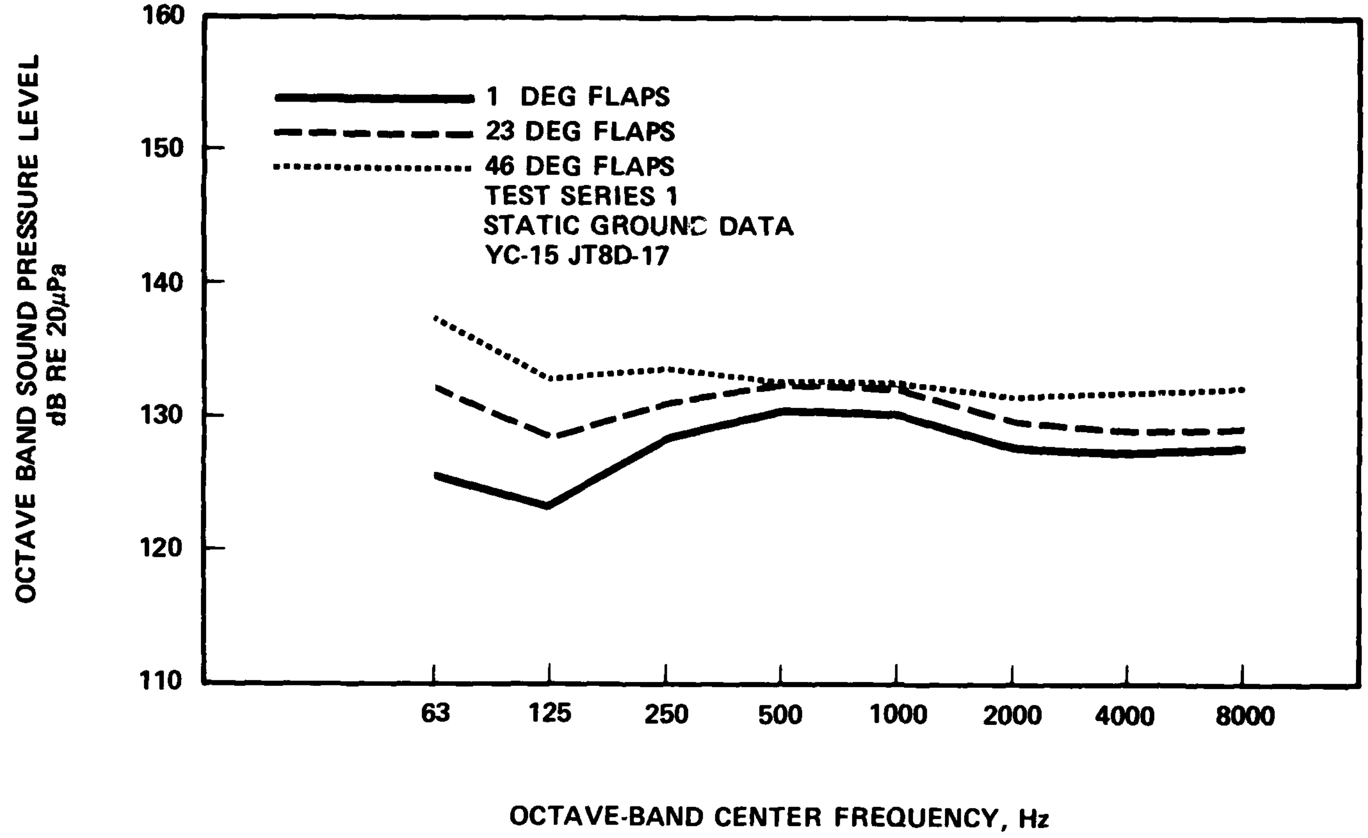


Figure 40. Exterior Fuselage Noise Levels – All Engines Operating – Corrected to 9000 Pounds Thrust – Microphone 5

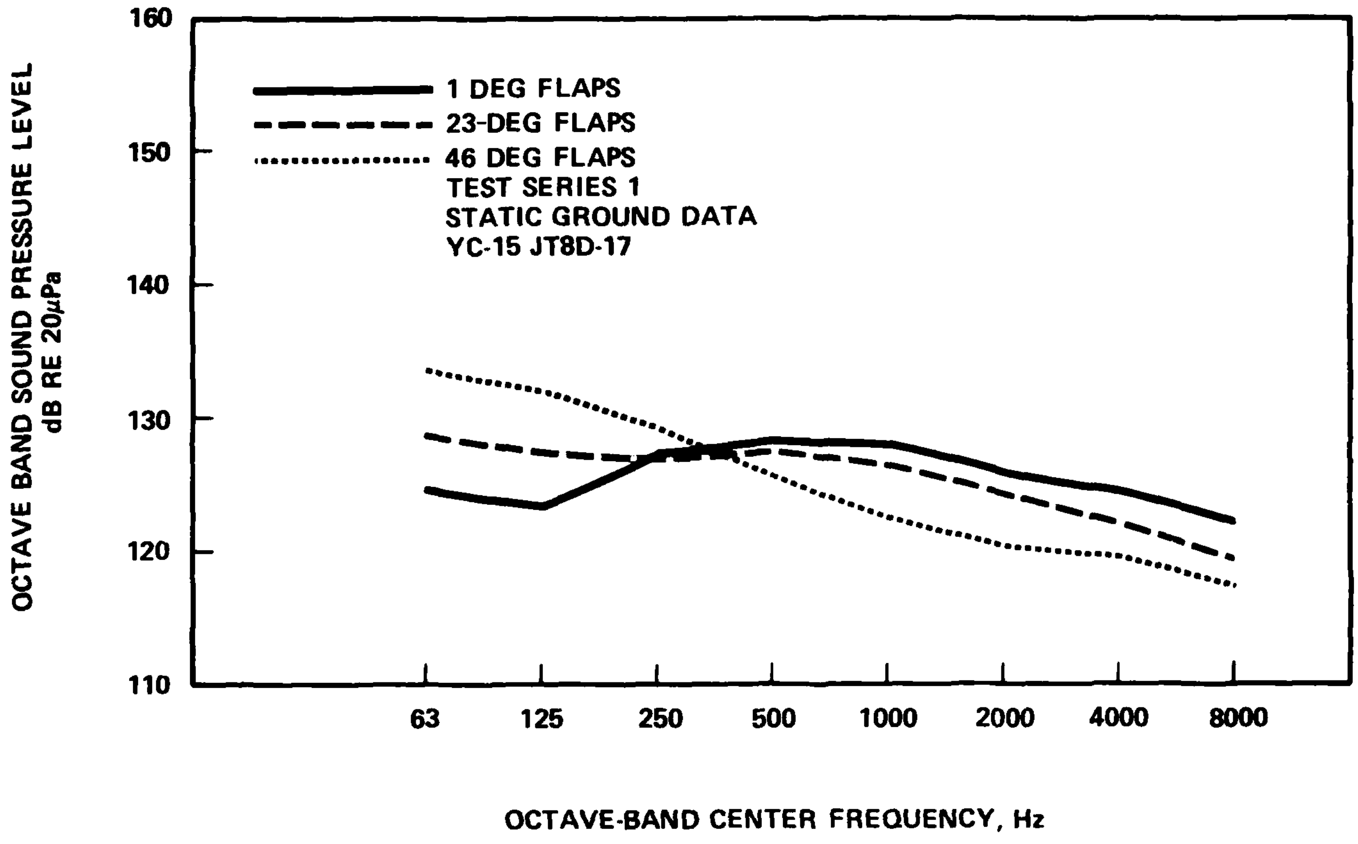


Figure 41. Exterior Fuselage Noise Levels — All Engines Operating — Corrected to 9000 Pounds Thrust — Microphone 6

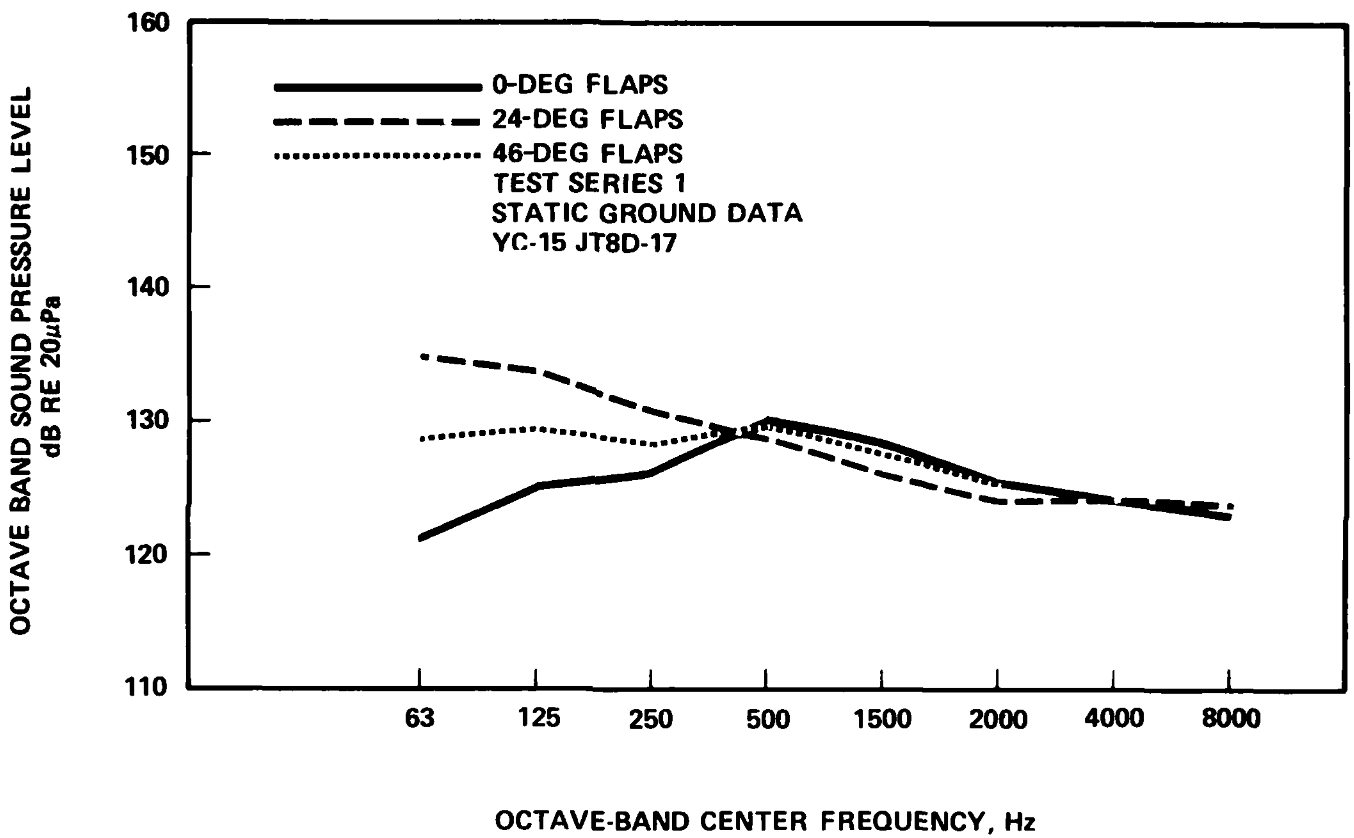


Figure 42. Exterior Fuselage Noise Levels – All Engines Operating – Corrected to 9000 Pounds Thrust – Microphone 7

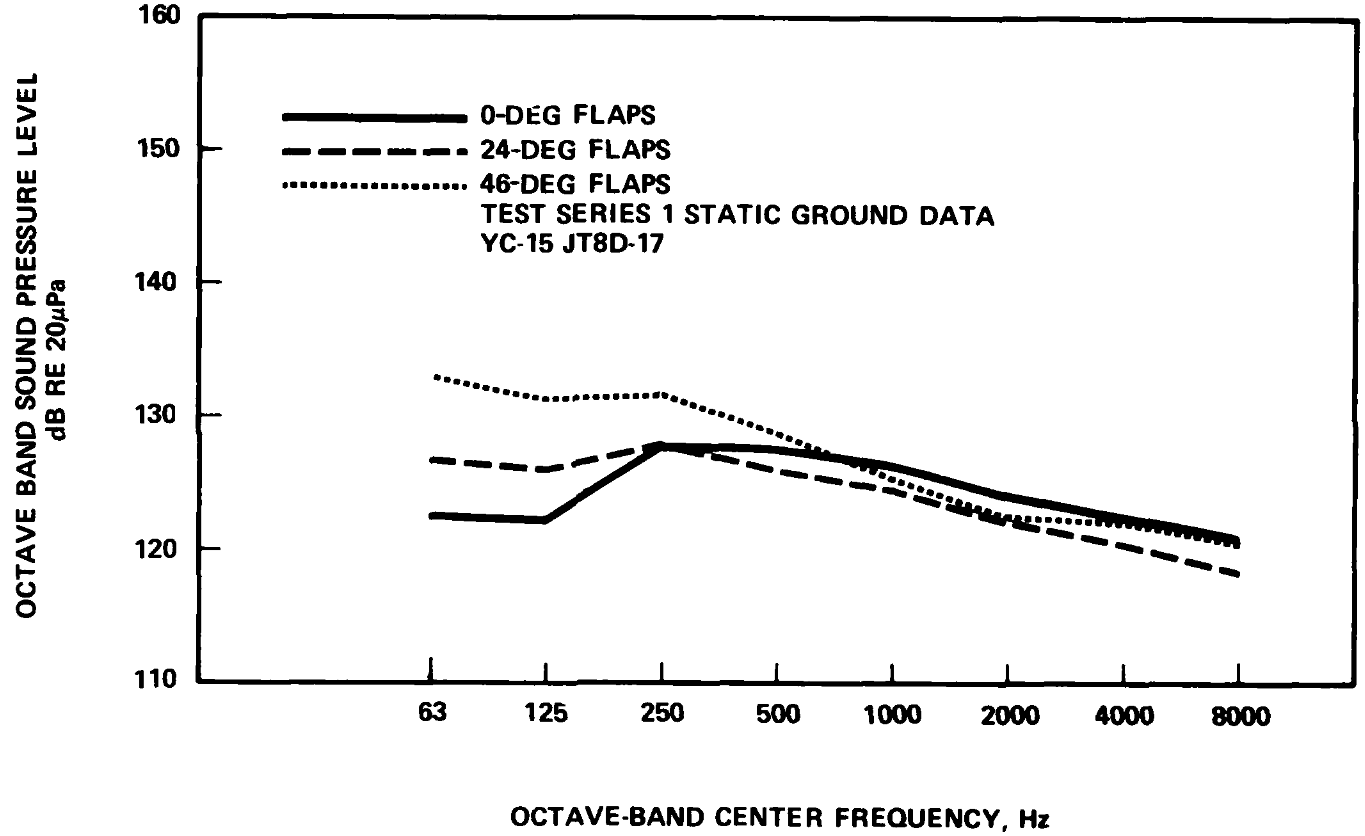


Figure 43. Exterior Fuselage Noise Levels – All Engines Operating – Corrected to 9000 Pounds Thrust – Microphone 8

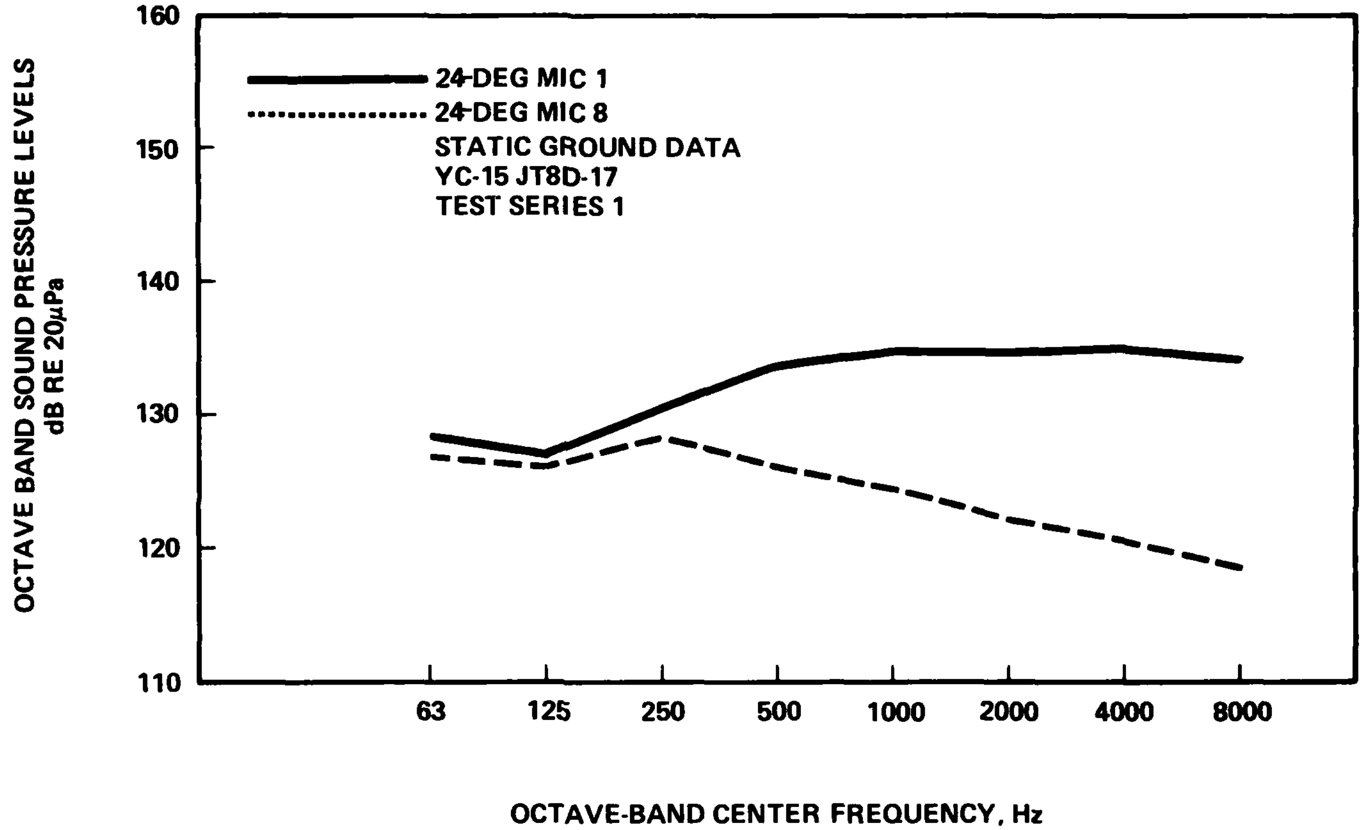


Figure 44. Spectral Comparison — 24-Deg Flaps — All Engines Operating — 16,400 Pounds Thrust — Microphones 1 and 8

TABLE 10 - YC-15 FUSELAGE VIBRATION MEASUREMENTS -
GROUND TESTS - OVERALL VIBRATION LEVELS

TEST NO.	FLAP ANGLE	ENGINE NO.[c] @ EPR	THRUST[d] LBS (N)	ACC 11	ACC 12	ACC 13	ACC 14	ACC 15	ACC 16	ACC 17	ACC 18
				ACCELEROMETER - dB re 10^{-5} m/sec^2							
G-1.1	1°	1,2,3,4 @ 1.05	1,000 (4400)	128	123	130	125	125	116	(b)	110
G-1.2	1°	1,2,3,4 @ 1.59	9,100 (40,500)	130	137	144	140	143	133		(b)
G-1.3	1°	1,2,3,4 @ 1.89	12,600 (56,000)	132	142	148	146	149	139		
G-1.4	1°	1,2,3,4 @ 2.21	16,200 (72,000)	134	146	154	150	154	144		
G-1.5	23°	1,2,3,4 @ 1.06	1,000 (4400)	126	123	131	127	126	115	114	110
G-1.6	23°	1,2,3,4 @ 1.59	9,100 (40,500)	129	141	146	142	140	133	(b)	(b)
G-1.7	23°	1,2,3,4 @ 1.90	12,800 (56,900)	132	145	151	147	146	138		
G-1.8	23°	1,2,3,4 @ 2.21	16,400 (72,900)	135	148	155	152	151	143		
G-1.9	46°	1,2,3,4 @ 1.06	1,000 (4400)	125	123	131	127	122	115	115	109
G-1.10	47°	1,2,3,4 @ 1.39	6,400 (28,500)	126	135	117	138	136	129	(b)	(b)
G-2.2	1°	1,4 @ 1.57	8,900 (39,600)	(a)	(a)	(a)	136	139	129		
G-2.3	1°	1,4 @ 1.89	12,600 (56,000)	129	136	142	141	144	134		
G-2.4	1°	1,4 @ 2.20	16,000 (71,200)	131	140	146	145	149	139		
G-2.6	23°	1,4 @ 1.59	9,100 (40,500)	129	135	140	137	138	129		
G-2.7	23°	1,4 @ 1.88	12,500 (55,600)	130	139	144	142	144	134		
G-2.8	22°	1,4 @ 2.19	15,900 (70,700)	131	143	147	146	148	139		
G-2.10	47°	1,4 @ 1.58	9,000 (40,000)	128	134	116	137	135	128		
G-3.1	23°	2,3 @ 1.90	12,800 (56,900)	131	140	(a)	146	140	132		
G-3.2	24°	2,3 @ 2.20	16,000 (71,200)	134	148	155	151	149	140		
G-3.4	1°	2,3 @ 2.19	15,900 (70,700)	133	144	154	121	151	140		134
G-4	48°	1,2,3,4 @ 2.20		134	147	154	150	149	143		137
INSTRUMENTATION SYSTEM BACKGROUND LEVELS (POST FLIGHT)				107	111	114	115	113	105	111	(b)

NOTES: (a) Signal varies in amplitude (low frequency oscillation).
(b) Signal conditioning malfunction.
(c) Unmentioned engines were operated at idle; EPR is average for engines mounted.
(d) Installed thrust values are for each engine mentioned.

except for three values, accelerometer 13, conditions G1.10 and G2.10 and accelerometer 14, condition G3.4; (2) the inboard engines appear to control the vibration responses at accelerometer 12 through 16 locations; and (3) the vibration measured on the wing box (accelerometer 11) is less sensitive to thrust level than the other measurements.

The overall vibration levels for accelerometers 12 and 14 are presented in Figures 45 and 46 for 0°, 24° and 46° flap settings. The 38 log F/δ slope fits the data as well as it does for the flush-mounted microphones. Figure 47 shows the vibration of the wing box location.

Figure 48 shows the variation of vibration level with accelerometer location. The trends are similar to those shown in Figures 26 and 27 for the exterior acoustic environment.

The octave-band levels for accelerometers 11, 12, and 14 for 16,400 pounds (73,800 N) thrust and 24° flaps are shown in Figure 49. The two things of primary interest are that the wing box response (accelerometer 11) is well below the fuselage response and the vibration level at the top and side of the fuselage (accelerometers 12 and 14) are nearly the same below 1000 Hz. The difference is even less at the 9200 pound (41,000 N) thrust setting as is shown in Figure 50. This indicates that the wing box is probably not a significant radiator of acoustic energy and that there is a high degree of circumferential mobility of vibratory energy. This mobility should be considered in prediction and control of interior noise.

6.3 Interior Noise Levels. The overall interior acoustic levels, measured with first series of tests, are presented in Table 11. General observations that can be made by examining the table are:

(1) The overall sound pressure level at centerline microphone locations 22, 23, and 24 are nearly the same indicating the interior is highly reverberant.

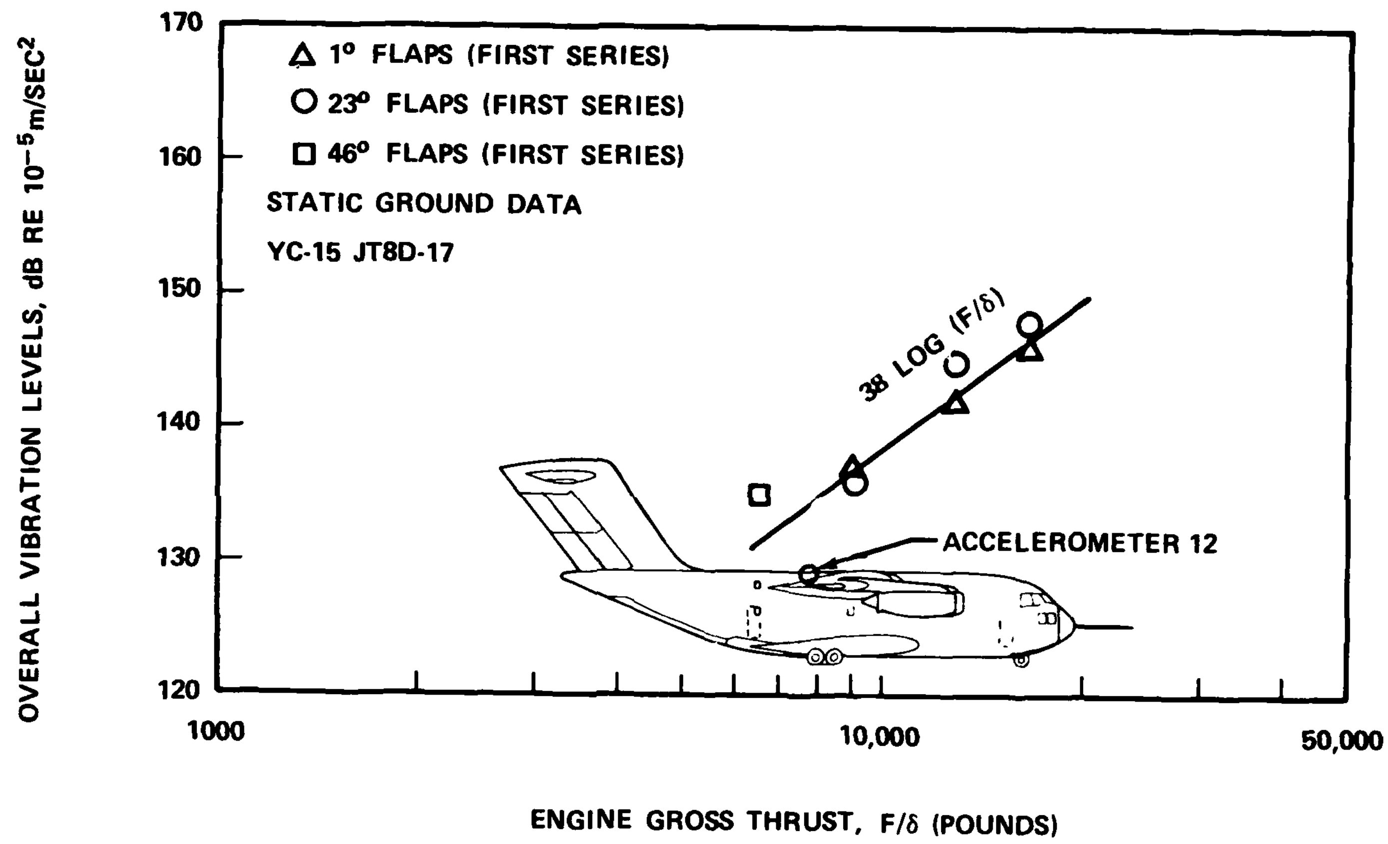


Figure 45. Overall Vibration Levels – All Engines Operating – Accelerometer 12

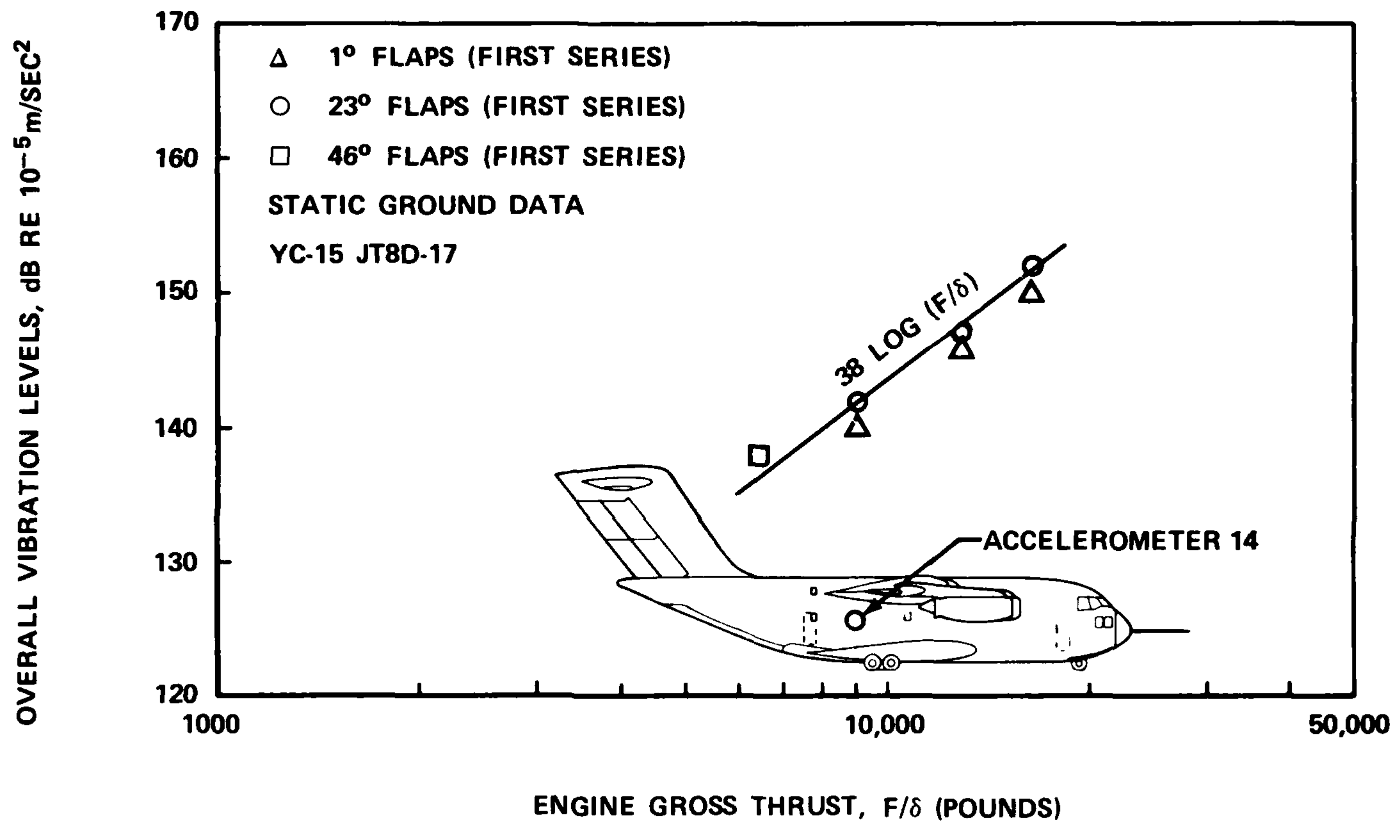


Figure 46. Overall Vibration Levels – All Engines Operating – Accelerometer 14

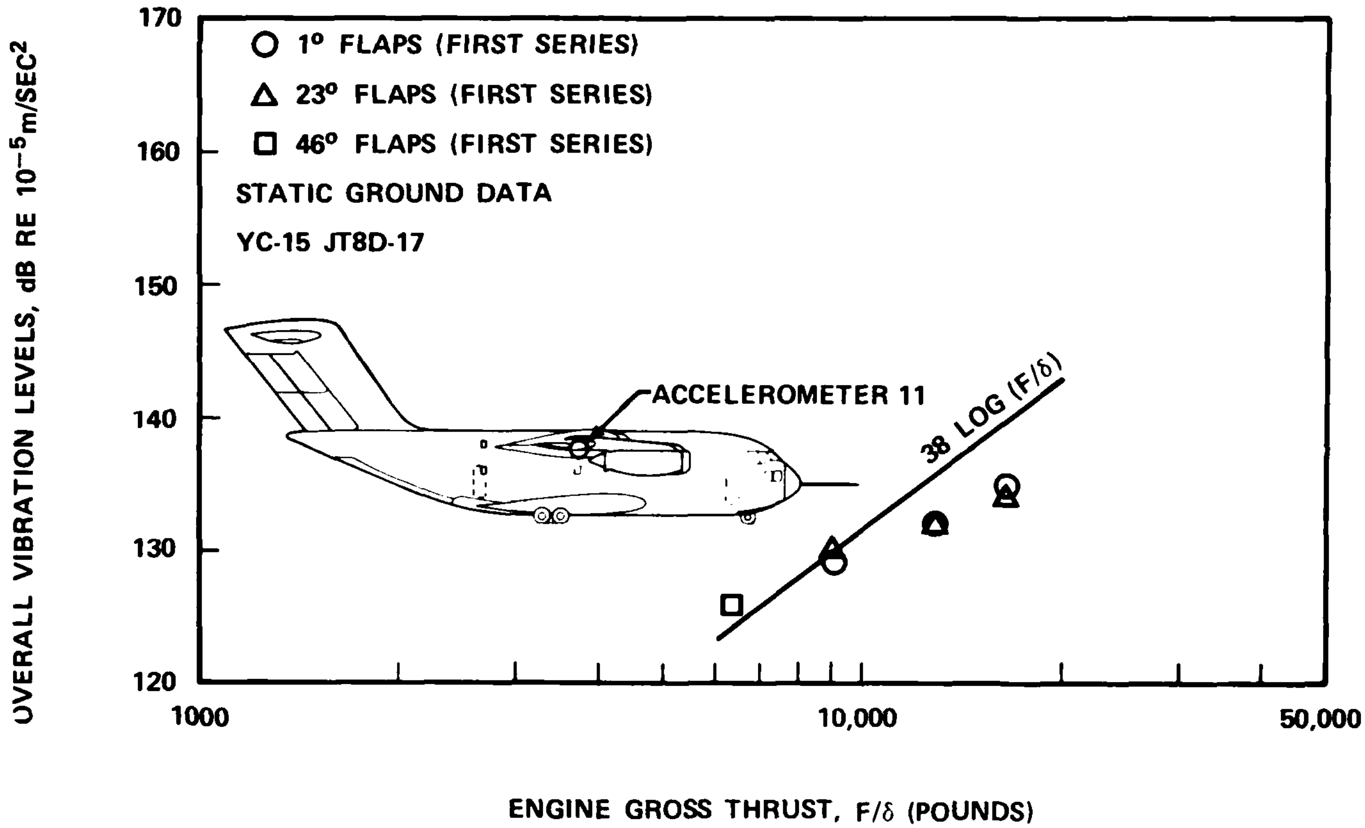
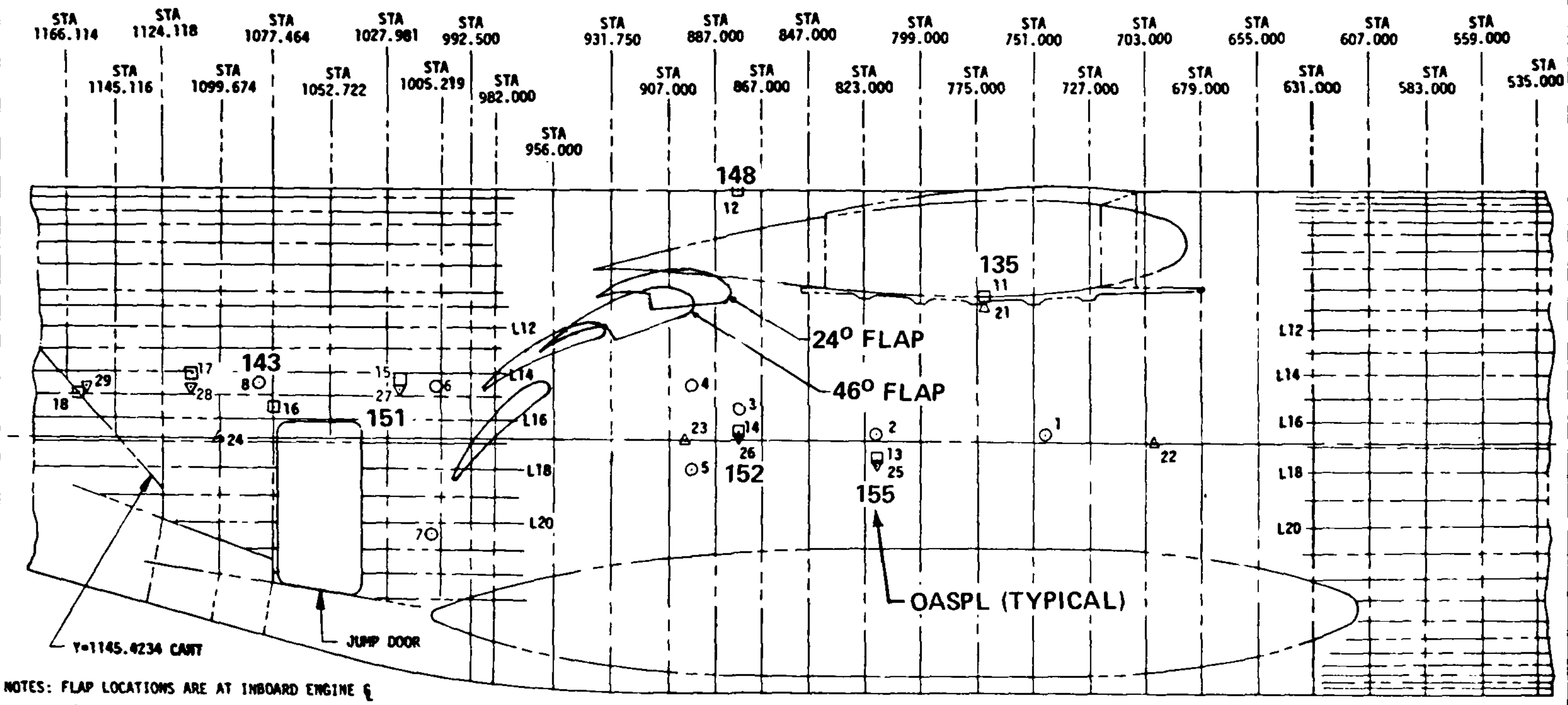


Figure 47. Overall Vibration Levels – All Engines Operating – Accelerometer 11



NOTES: FLAP LOCATIONS ARE AT INBOARD ENGINE ℄
○ INDICATES TRANSDUCERS NO. 1 - 9, EXTERIOR FLUSH MOUNTED MICROPHONES
□ INDICATES TRANSDUCERS NO. 11 - 18, ACCELEROMETERS
△ INDICATES TRANSDUCERS NO. 21 - 24, INTERIOR MICROPHONES, ℄
▽ INDICATES TRANSDUCERS NO. 25 - 29, INTERIOR MICROPHONES, SIDEWALL
EXTERIOR FLUSH MOUNTED TRANSDUCER NO. 9 (⊙) IS LOCATED AT
FUSELAGE STATION Y=415.500 AND 4.5 INCHES ABOVE L13.

Figure 48. Overall Vibration Levels – 24-Deg Flaps – 16,400 Pounds Thrust

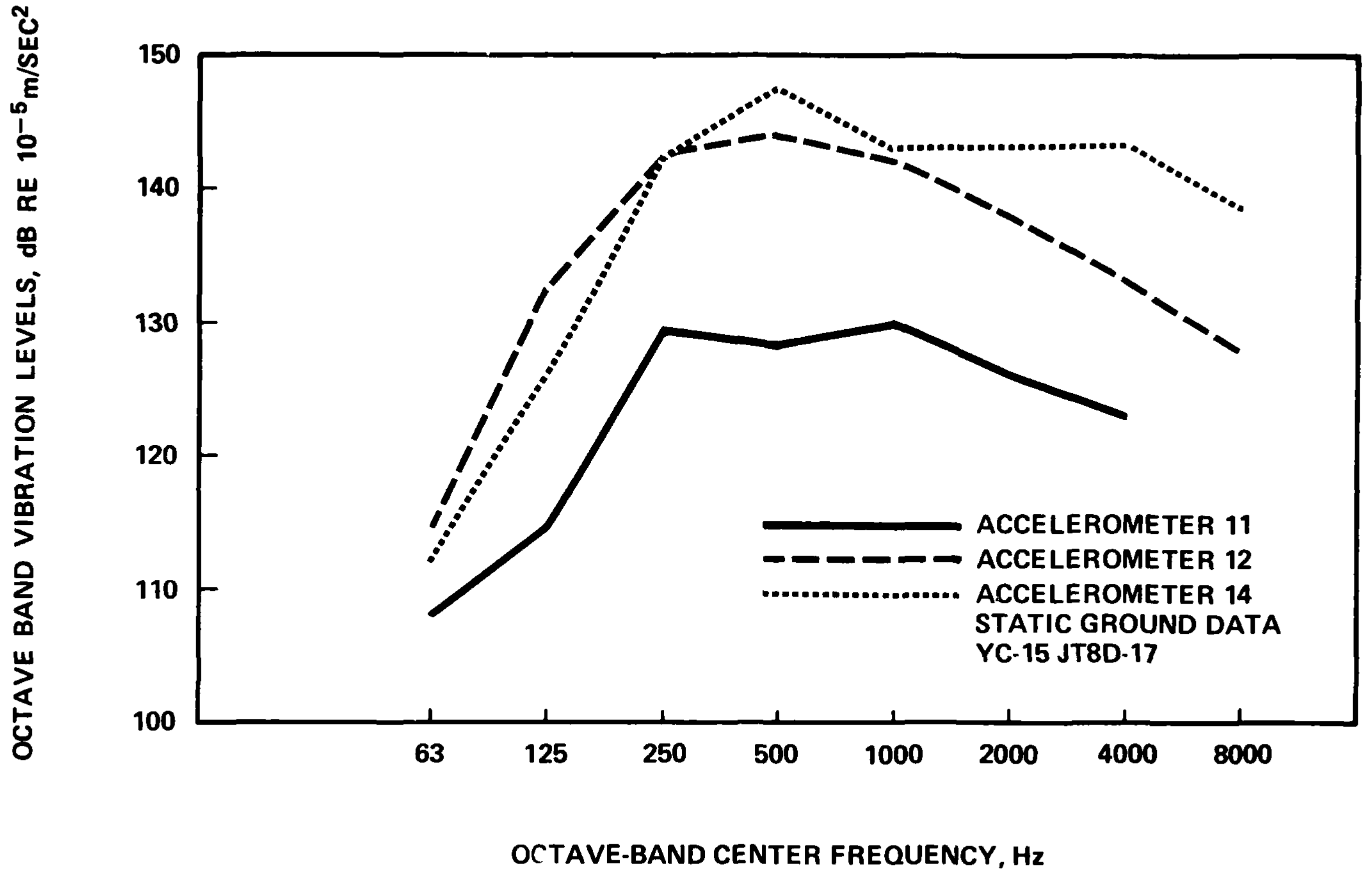


Figure 49. Octave Band Vibration Levels – 24-Deg Flaps – All Engines Operating – 16,400 Pounds Thrust

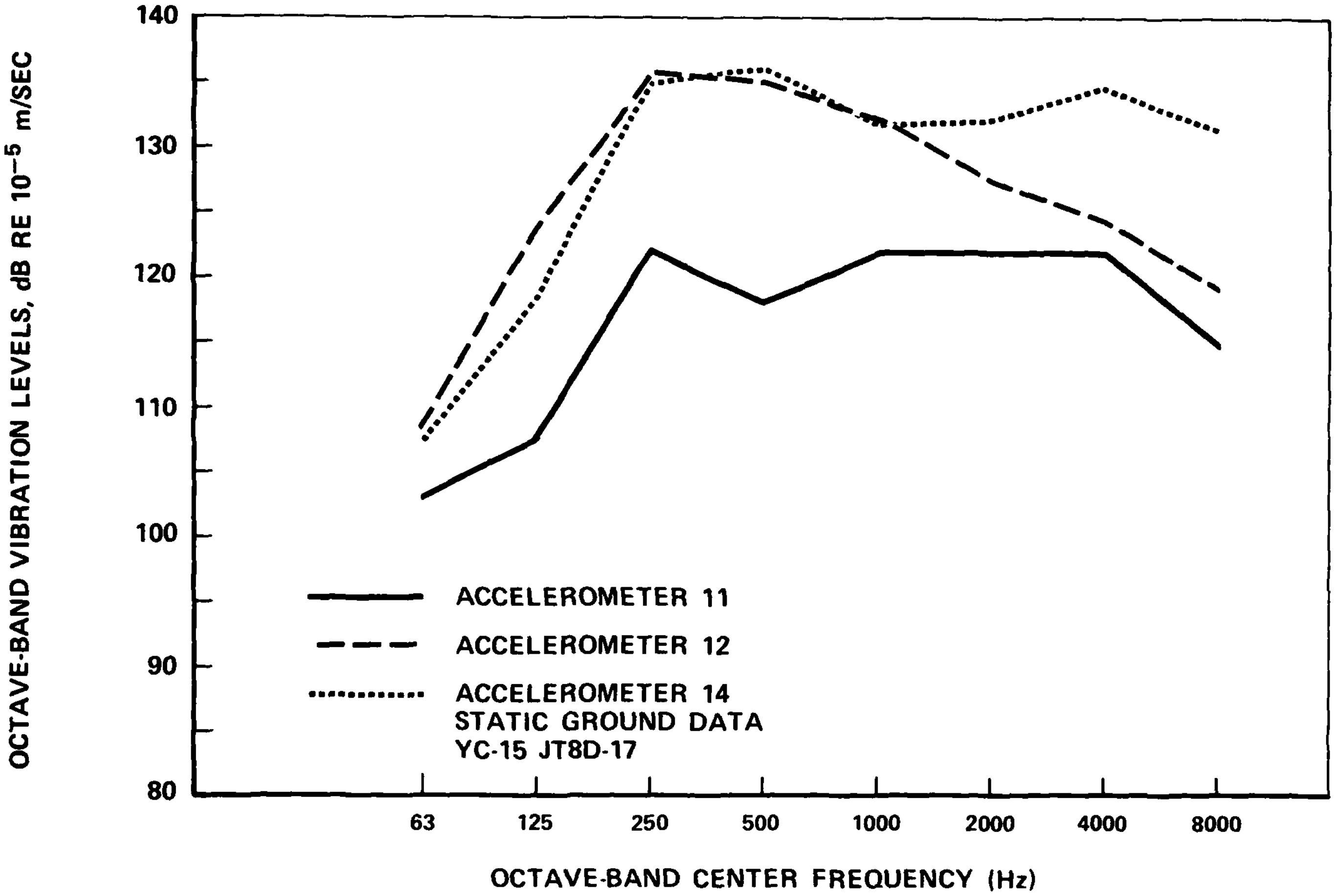


Figure 50. Octave-Band Vibration Levels – 23-Deg Flaps – All Engines Operating at 9200 Pounds Thrust

TABLE 11 - YC-15 INTERIOR NOISE MEASUREMENTS - GROUND TESTS - OVERALL SOUND PRESSURE LEVELS, dB re 20 μPa

TEST NO.	FLAP ANGLE	ENGINE NO.[b] @ EPR	THRUST[c] LBS (N)	INTERIOR MICROPHONES (21-24 C.L., 25-29 SIDEWALL) MIC 21	MIC 22	MIC 23	MIC 24	MIC 25	MIC 26	MIC 27	MIC 28	MIC 29
G-1.1	1°	1,2,3,4 @ 1.05	1,000 (4400)	104	99	100	98	105	104	104	105	101
G-1.2	1°	1,2,3,4 @ 1.59	9,100 (40,500)	119	116	117	116	121	121	122	122	119
G-1.3	1°	1,2,3,4 @ 1.89	12,600 (56,000)	124	121	122	121	126	126	127	128	124
G-1.4	1°	1,2,3,4 @ 2.21	16,200 (72,000)	128	124	126	125	130	130	131	132	129
G-1.5	23°	1,2,3,4 @ 1.05	1,000 (4400)	103	99	101	99	104	104	104	103	110
G-1.6	23°	1,2,3,4 @ 1.59	9,100 (40,500)	121	117	119	117	123	123	124	123	121
G-1.7	23°	1,2,3,4 @ 1.90	12,800 (56,900)	125	122	124	122	128	129	128	128	126
G-1.8	23°	1,2,3,4 @ 2.21	16,400 (72,900)	129	126	127	126	131	131	132	132	130
G-1.9	46°	1,2,3,4 @ 1.06	1,000 (4400)	104	99	100	99	105	104	103	103	(a)
G-1.10	47°	1,2,3,4 @ 1.39	6,400 (28,500)	118	114	115	114	119	120	121	121	118
G-2.2	1°	1,4 @ 1.57	8,900 (39,600)	118	111	112	112	115	116	118	118	115
G-2.3	1°	1,4 @ 1.89	12,600 (56,000)	118	116	117	117	120	121	123	123	120
G-2.4	1°	1,4 @ 2.20	16,000 (71,200)	122	120	121	121	123	124	127	127	124
G-2.6	23°	1,4 @ 1.59	9,100 (40,200)	116	112	114	113	117	118	119	119	117
G-2.7	23°	1,4 @ 1.88	12,500 (55,600)	120	117	118	118	121	122	124	124	122
G-2.8	22°	1,4 @ 2.19	15,900 (70,700)	124	121	122	122	125	126	128	128	126
G-2.10	47°	1,4 @ 1.58	9,000 (40,000)	116	113	114	113	118	119	119	119	117
G-3.1	23°	2,3 @ 1.90	12,800 (56,900)	124	121	122	117	126	127	124	123	121
G-3.2	24°	2,3 @ 2.20	16,000 (17,200)	127	125	126	125	130	130	131	130	128
G-3.4	1°	2,3 @ 2.19	15,900 (70,700)	124	120	121	120	127	127	127	127	124
G-4	48°	1,2,3,4 @ 2.20		124	126	127	125	131	131	132	132	130
INSTRUMENTATION SYSTEM BACKGROUND LEVELS (POST FLIGHT)				82	81	82	79	82	81	89	91	88

NOTES: (a) Signal varies in amplitude (low frequency oscillation).
(b) Unmentioned engines were operated at idle; EPR is average for engines mounted.
(c) Installed thrust values are for each engine mentioned.

(2) The inboard engines control the interior noise environment.

(3) Sidewall microphones 25 through 28 measured noise levels that were several decibels above the centerline values, indicating that energy is being transmitted through the walls.

(4) Microphone 29 does not indicate that the aft deep frame is a major acoustic energy radiator.

(5) The measurements from microphones 24, 27, and 28 for condition G-3.1 and microphone 29 for G-1.6 are not consistent with the rest of the data.

The overall sound pressure levels measured by microphone 23 as a function of thrust and flap angle are presented in Figure 51. The variation of noise level versus thrust is similar to that observed for the exterior acoustic and sidewall vibration data.

Figure 52 presents the octave-band sound pressure levels recorded at microphone position 23 for 0°, 24°, and 46° flaps and corrected to 9,000 pound (40,000 N) as were the exterior noise levels thrust. The effect of the flap setting is evident below 500 Hz.

Octave band noise levels for an exterior position (microphone 2) and the corresponding interior centerline noise levels (microphone 23) are presented in Figure 53 and the resulting "noise reduction" shown in Figure 54 was about as expected. Here noise reduction is defined as the arithmetic difference in SPL as measured by an exterior and an interior microphone.

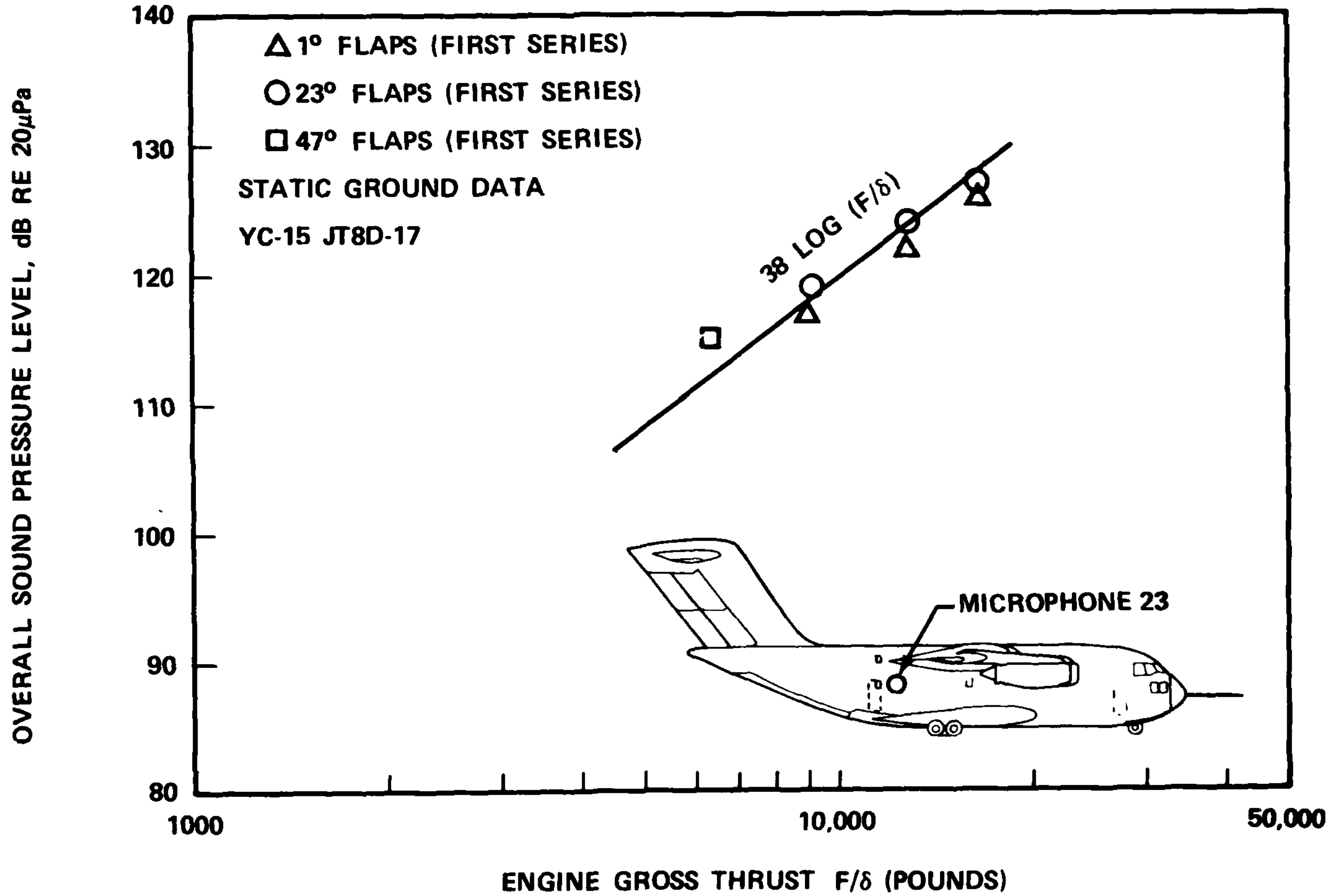


Figure 51. Interior Noise Levels – All Engines Operating – Microphone 23

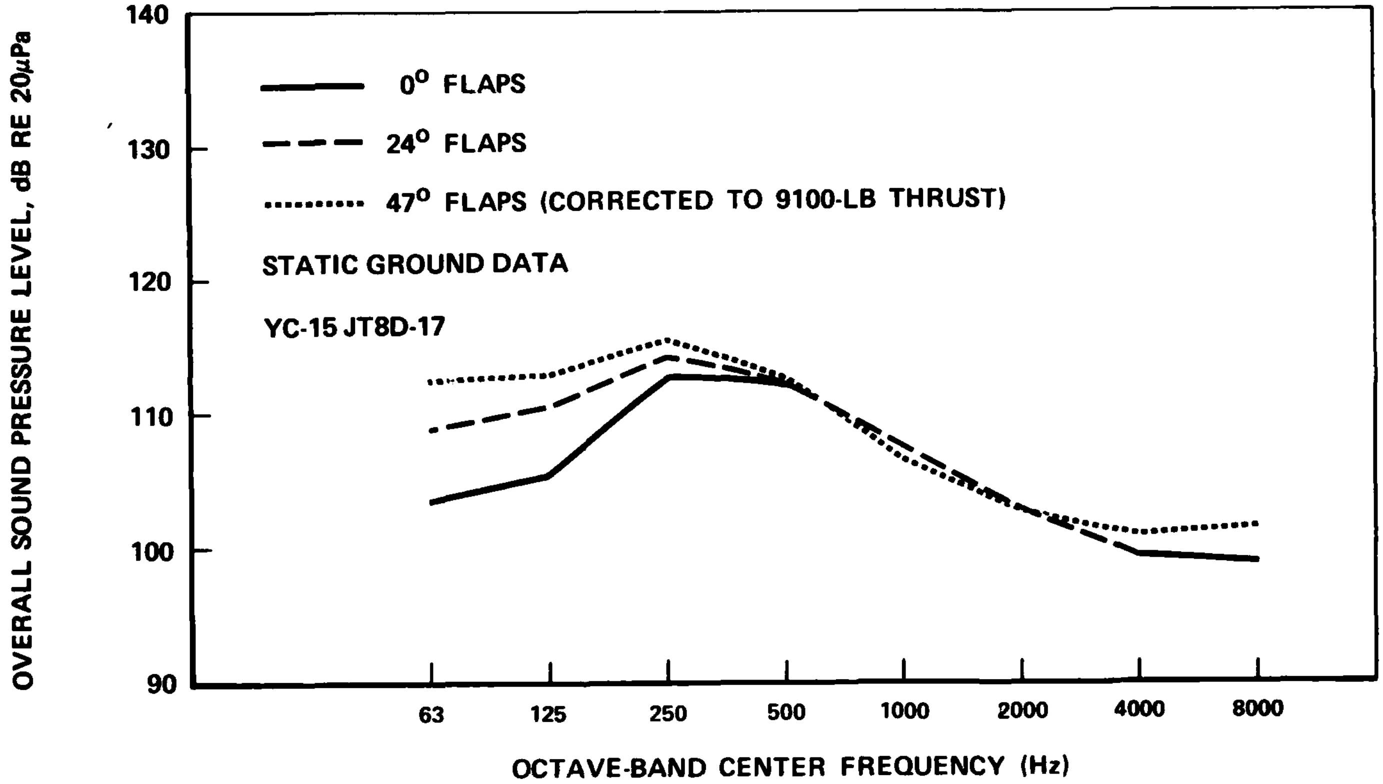


Figure 52. Interior Noise Frequency Distribution – Static Ground Data – Corrected to 9000 Pounds Thrust – All Engines Operating – Microphone 23

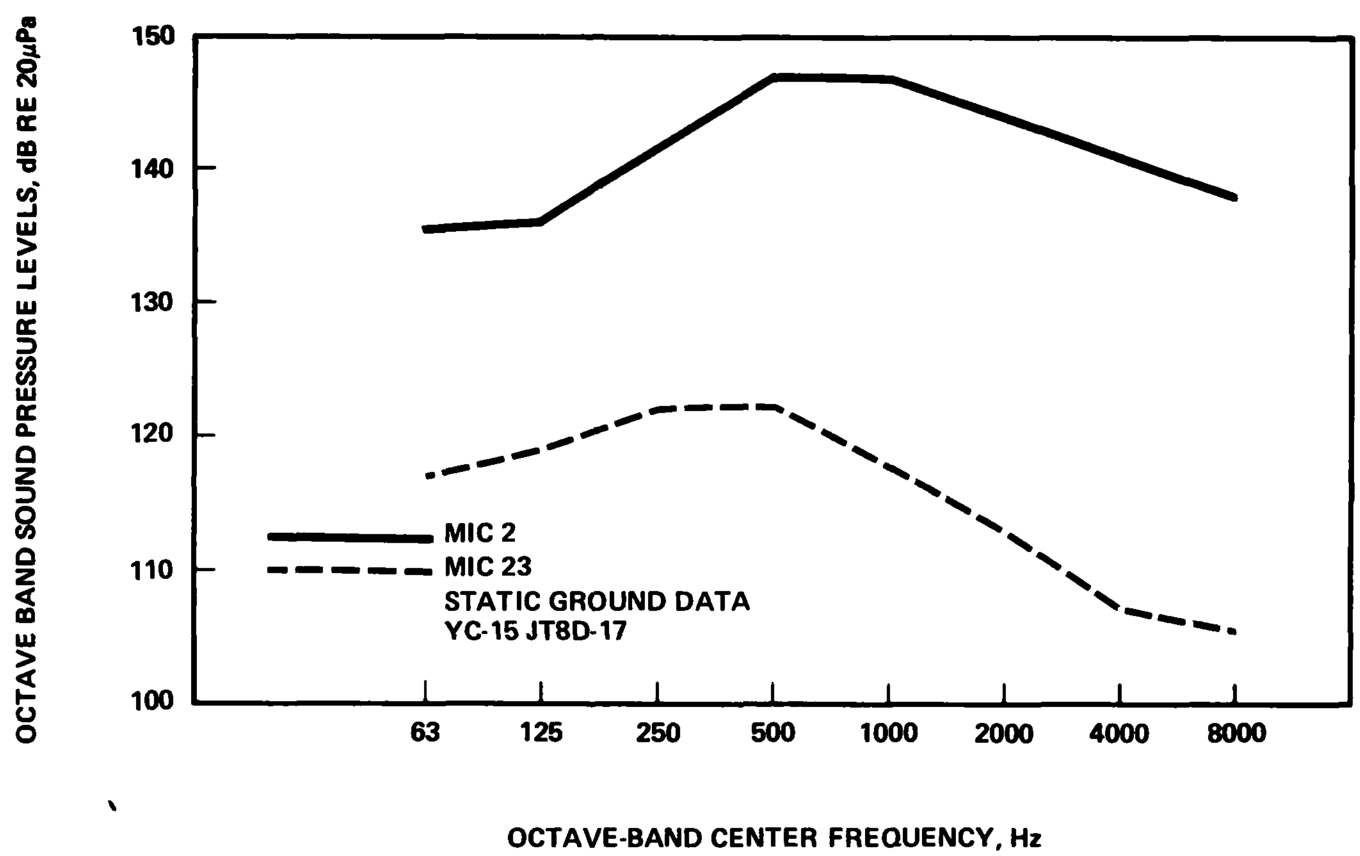


Figure 53. Exterior and Interior Centerline Acoustic Levels – 24-Deg Flaps – 16,400 Pounds Thrust – All Engines Operating

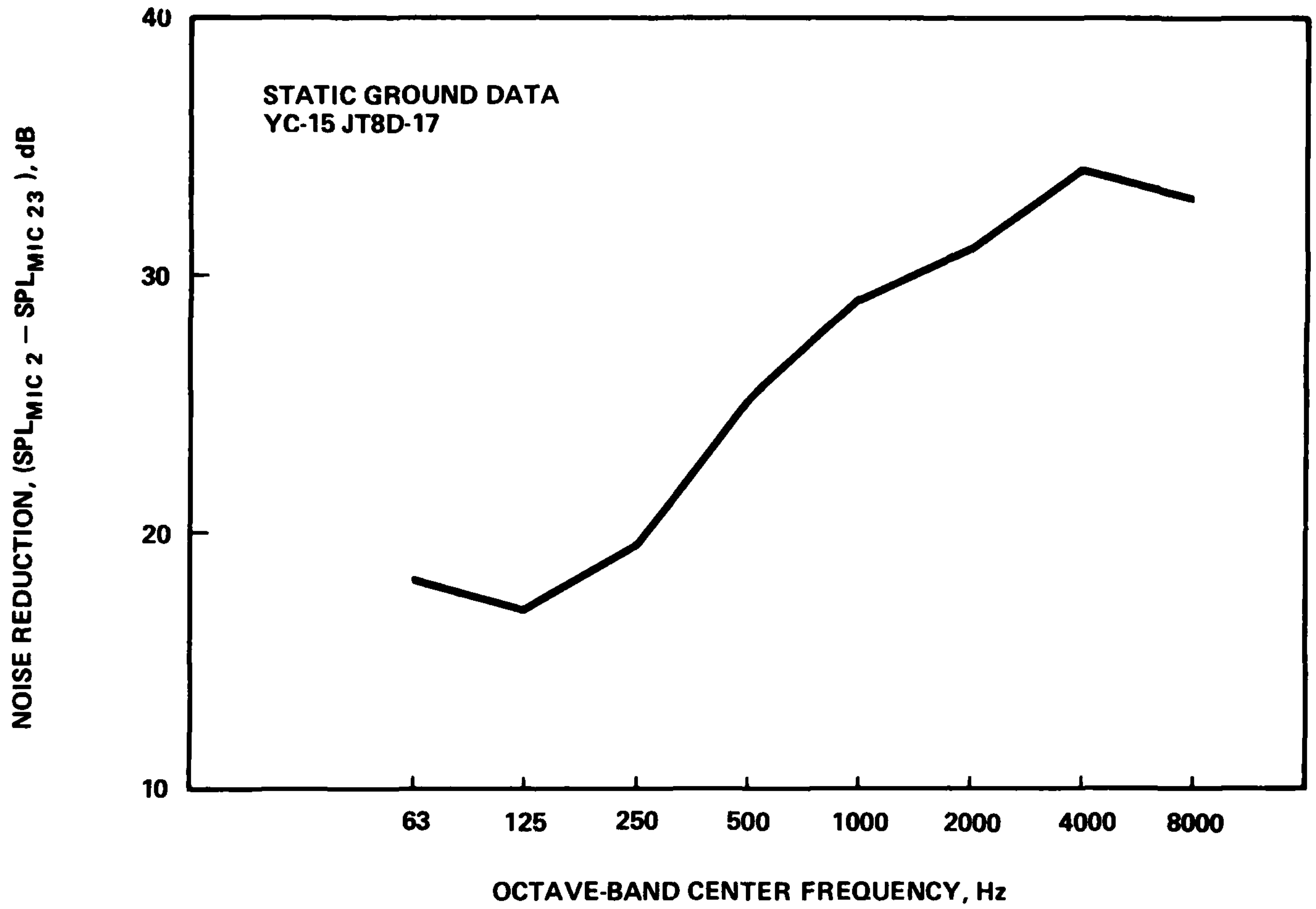


Figure 54. Noise Reduction – 24-Deg Flaps – 16,400 Pounds Thrust – All Engines Operating

7. FLIGHT TEST RESULTS

7.1 External Fuselage Noise Levels. Tables 12 and 13 present overall values of the external fuselage noise levels that were obtained in the first and second series of measurements, respectively. The tables indicate that the noise levels are highest at positions nearest the exhaust nozzle of the inboard engine and decrease gradually with distance aft of the engines. Microphone 9, located forward of the engines, almost always exhibited the lowest values. Microphone 2 is typically representative of maximum values regardless of flight condition.

Data repeatability between the first and second series of measurements is good considering that only the steady-state tests of similar flight conditions could be used in comparison. The only flight tests that are suitable to determine data consistency are tests F-1 (takeoff at brake release), F-5.1 - F-5.4, and F-7.1 (cruise conditions). Table 14 gives the differences in measured OASPL between tests for each microphone for these flight conditions. As indicated in the table the deviations are quite small in most cases.

Figure 55 provides a one-third octave-band presentation of the fuselage noise levels measured at the microphone 2 position for three representative STOL flight conditions: takeoff, STOL landing approach, and a typical cruise at 18,000 feet (4,486 m). For frequencies less than about 500 Hz the differences in magnitudes among the curves is less than 10 dB. The STOL landing condition exhibit higher values of low frequency noise in relation to the rest of its spectrum than is seen in the other two cases. This is probably due to the low frequency radiated noise generated by the blown flaps. An example of this low frequency flap-radiated noise is presented in Figure 56.

Figure 57 is a one-third octave-band presentation of the measured fuselage noise levels at the microphone 9 position. At 250 KEAS (129 m/sec) and 30,000 feet (9,144 m) altitude, only 1 to 2 dB differences are seen between

TABLE 12 - YC-15 EXTERIOR NOISE MEASUREMENTS - FIRST SERIES FLIGHT TESTS - OVERALL SOUND PRESSURE LEVELS, dB re 20, μPa

TEST NO.	ALTITUDE FT (m)	SPEED KEAS (m/sec)	FLAP ANGLE	ENGINE NO.[c] @ EPR	FLUSH-MOUNTED EXTERIOR MICROPHONES MIC 1	MIC 2	MIC 3	MIC 4	MIC 5	MIC 6	MIC 7	MIC 8	MIC 9
F-1	Field	0	23°	1,2,3,4 @ 2.20	(a)	151	149	149	149	146	146	143	134
F-2	Field	0	24°	1,2,4 @ 2.20	(a)	140	(b)	139	141	135	140	135	127
F-3	Approach	85 (44)	48°	1,2,3,4 @ 1.60	142	142	(b)	140	141	139	134	138	132
F-4	Approach	85 (44)	41°	1,2,4 @ 2.10	137	138	136	138	139	138	135	135	128
F-5.1	18,022 (5493)	195 (101)	1°	1,2,3,4 @ 1.42	134	133	131	130	131	127	128	125	129
F-5.2	17,897 (5455)	239 (123)	1°	1,2,3,4 @ 1.53	136	136	134	133	133	131	131	129	129
F-5.3	17,908 (5458)	280 (144)	2°	1,2,3,4 @ 1.66	138	139	137	136	136	133	134	132	130
F-5.4	17,883 (5451)	331 (171)	1°	1,2,3,4 @ 1.89	144	144	144	142	143	140	139	137	133
F-6	Go Around Approach	100 (51)	48°	1,2,3,4 @ 1.40	(a)	137	(b)	135	136	136	128	132	130
F-7.1	29,813 (9087)	248 (128)	3°	1,2,3,4 @ 2.01	(a)	140		138	138	133	134	131	128
F-7.2	29,813 (9087)	248 (128)	3°	1,2,3,4 @ 2.01	141	140		138	139	134	134	131	128
F-7.3	29,813 (9087)	248 (128)	3°	1,2,3,4 @ 2.01	140	140		138	138	133	134	131	128
F-7.4	29,813 (9087)	248 (128)	3°	1,2,3,4 @ 2.01	140	140		138	138	133	134	131	128
F-8	29,813 (9087)	248 (128)	3°	1,2,3,4 @ flight idle	129	132		129	128	129	129	128	127
INSTRUMENTATION SYSTEM BACKGROUND LEVELS (POST FLIGHT)					108	107	107	106	107	105	105	113	109

NOTES: (a) Signal varies in amplitude (low frequency oscillation).
(b) Signal conditioning malfunction.
(c) Unmentioned engines were operated at idle; EPR is average for engines mounted.

TABLE 13 - YC-15 EXTERIOR NOISE MEASUREMENTS - SECOND SERIES FLIGHT TESTS - OVERALL SOUND PRESSURE LEVELS, dB re 20 μPa

TEST NO.	ALTITUDE FT (m)	SPEED KEAS (m/sec)	FLAP ANGLE	ENGINE No.[a] @ EPR	FLUSH-MOUNTED EXTERIOR MICROPHONES MIC 1	MIC 2	MIC 3	MIC 4	MIC 5	MIC 6	MIC 7	MIC 8	MIC 9
F-1	Field	0	24°	1,2,3,4 @ 2.21	151	152	149	(b)	150	147	147	144	142
F-2	Field	0	24°	1,2,4 @ 2.21	142	144	142	↓	143	140	143	140	132
F-3	Approach	85 (44)	48°	1,2,3,4 @ 1.40	140	138	136	↓	137	136	129	(b)	131
F-4	Approach	85 (44)	46°	1,2,4 @ 1.70	126	145	125	↓	144	135	121	120	125
F-5.1	18,072 (5508)	192 (99)	0°	1,2,3,4 @ 1.42	136	135	132	↓	132	132	128	126	130
F-5.2	18,065 (5506)	245 (126)	0°	1,2,3,4 @ 1.60	135	138	130	↓	135	132	131	130	131
F-5.3	17,998 (5486)	287 (148)	0°	1,2,3,4 @ 1.68	140	140	138	138	138	135	134	133	131
F-5.4	18,035 (5497)	326 (168)	0°	1,2,3,4 @ 1.90	144	145	144	143	144	140	139	136	133
F-6	Go Around Approach	100 (52)	24°	1,2,3,4 @ 2.10	149	150	147	(b)	147	143	143	140	134
F-7.1	29,779 (9077)	238 (123)	0°	1,2,3,4 @ 2.01	140	140	138	(b)	139	134	134	131	129
INSTRUMENTATION SYSTEM BACKGROUND NOISE (PRE FLIGHT)					105	111	108	108	113	111	113	108	115

NOTES: (a) Unmentioned engines were operated at idle; EPR is average for engines mentioned.
(b) Intermittent data.

TABLE 14 - FLIGHT TEST DATA REPEATABILITY - EXTERIOR (FLUSH-MOUNTED) MICROPHONES

	ΔOASPL,* dB								
TEST NO.	MIC 1	MIC 2	MIC 3	MIC 4	MIC 5	MIC 6	MIC 7	MIC 8	MIC 9
F-1	--	+1	0	--	+1	+1	+1	+1	+8
F-5.1	+2	+2	+1	--	+1	+5	0	+1	+1
F-5.2	-1	+2	-4	--	+2	+1	0	+1	+2
F-5.3	+2	+1	+1	+2	+2	+2	0	+1	+1
F-5.4	0	+1	-1	+1	+1	0	0	-1	0
F-7.1	--	0	--	--	+1	+1	0	0	+1

*ΔOASPL = OASPL (second series test) - OASPL (first series test)

-- Lack of data

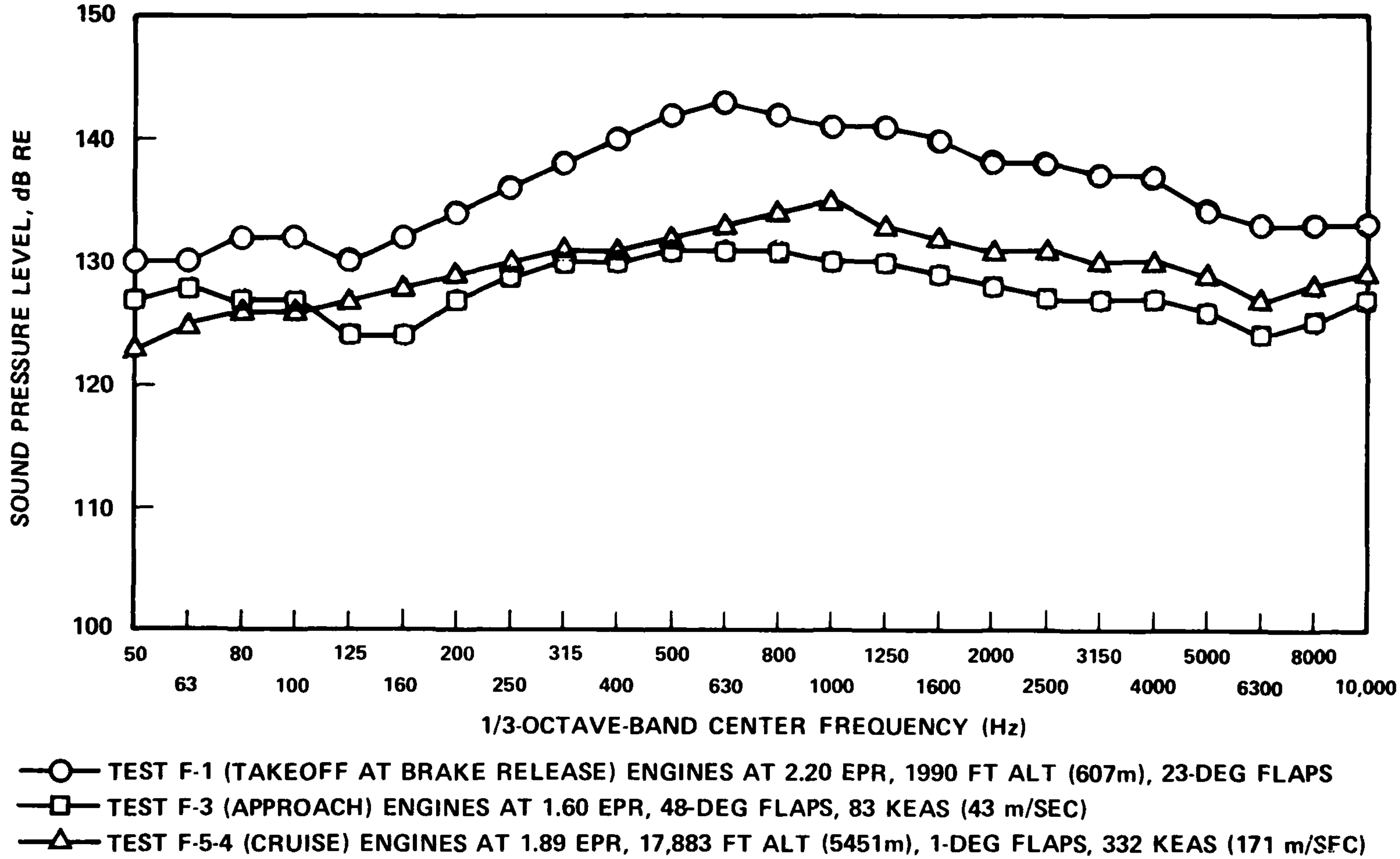


Figure 55. Exterior Fuselage Noise Level Measured at Microphone No. 2 Location

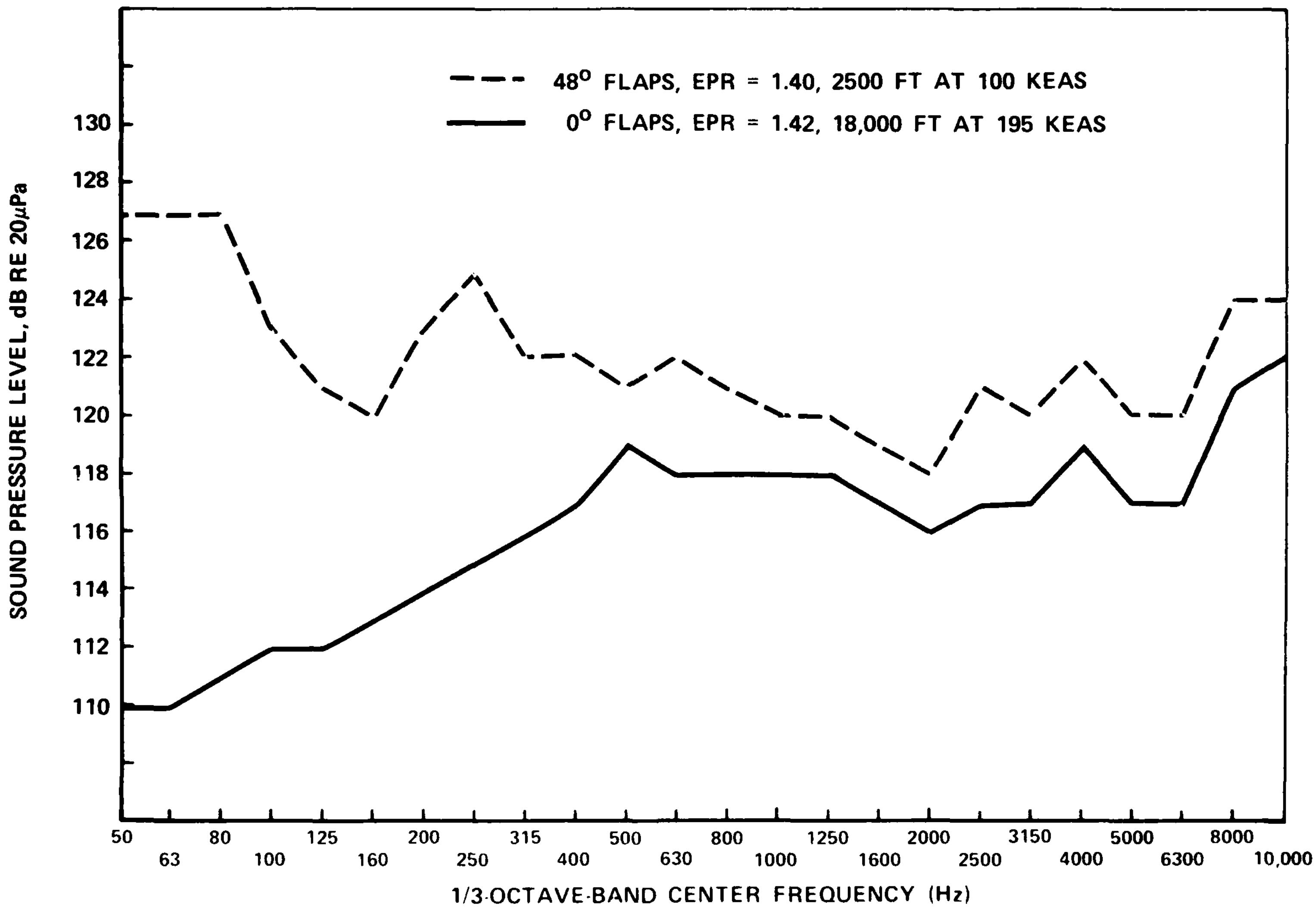
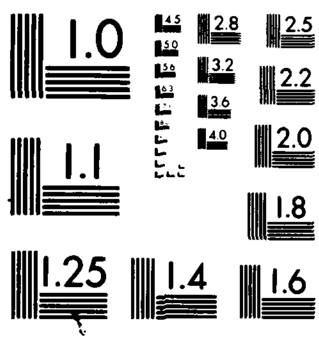


Figure 56. Exterior Fuselage Noise Levels Measured at Microphone 5 Location

AD-A098 788 DOUGLAS AIRCRAFT CO LONG BEACH CA F/G 20/1
YC-15 INTERIOR NOISE MEASUREMENTS. TECHNICAL DISCUSSION.(U)
MAR 81 J L WARNIX, D E HINES F33657-72-C-0833
UNCLASSIFIED MDC-J7191 AFFDL-TR-76-140 NL

2 of 2
AD A098788

END
DATE FILMED
8-81
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

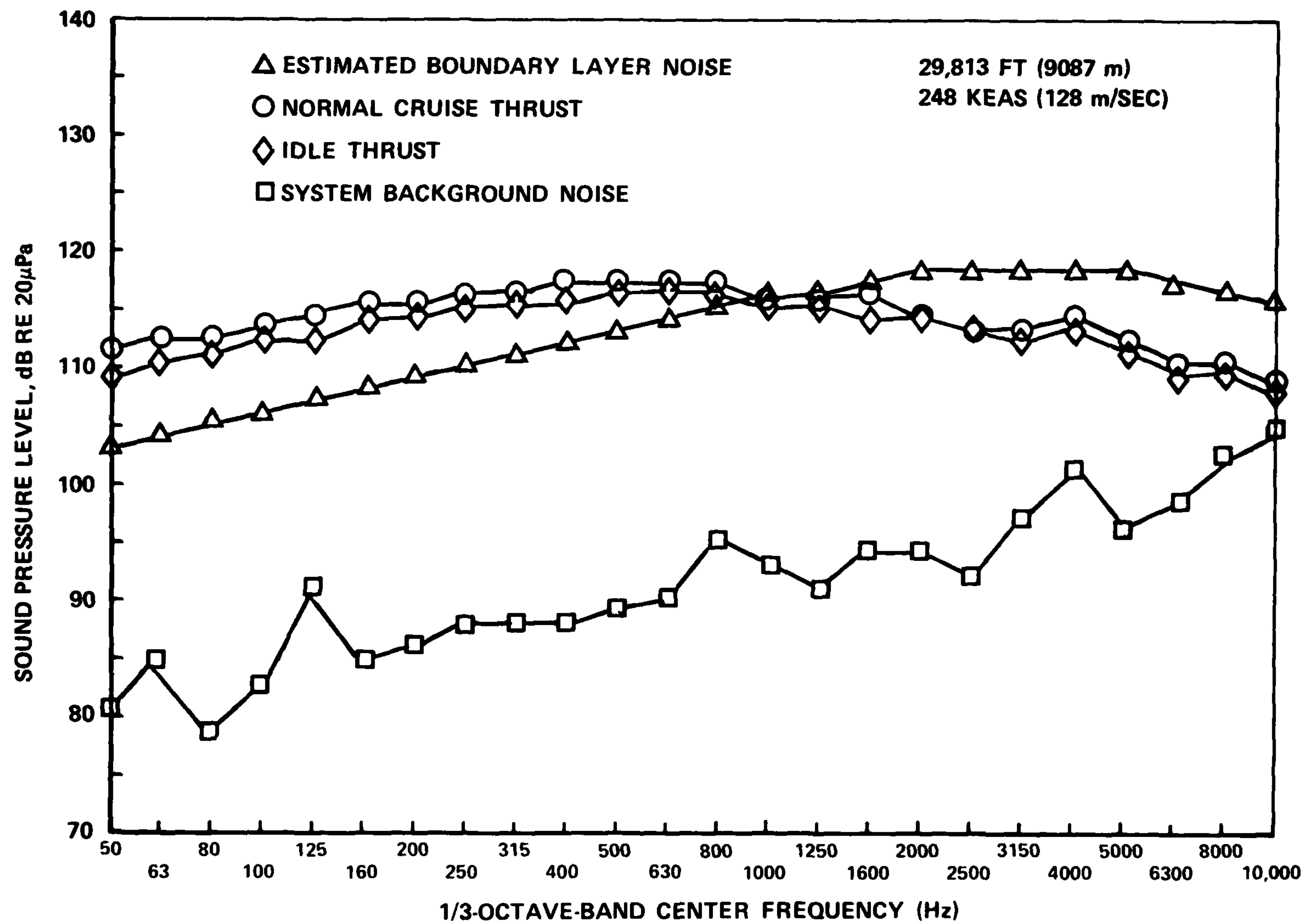


Figure 57. Exterior Fuselage Noise Levels Measured at Microphone 9 Location

the cruise thrust and engine idle thrust settings, indicating that the measurement is largely controlled by the turbulent boundary layer. A comparison of measured values to predicted boundary layer noise according to Cockburn and Jolly[3] indicate that the overall level is about the same; however, the measured value exhibits more energy in lower frequency bands than predicted. This apparent discrepancy is perhaps partially explained by the fact that microphone 9 is located on an expanding (or conical) section of fuselage whereas the prediction routine is for locations on a constant section cylindrical shell.

Figure 58 presents one-third octave-band noise levels measured at a position on constant section sidewall (microphone 4). The predicted boundary layer levels agree very well with levels measured at engine idle except for the higher frequencies where the engines may dominate even at an engine idle setting. At normal cruise engine thrust the engines dominate in all frequency bands. It should also be noted that Figures 57 and 58 show that typically the signal at all frequencies is sufficiently higher than the system background noise to insure quality data.

While data from some of the flush-mounted microphones agree very well with predicted boundary layer values, other positions disagree somewhat. For example, at the microphone 2 location the one-third octave-band measured levels, shown in Figure 59, disagree appreciably with predicted levels for the lower frequency bands, indicating a significant amount of additional low frequency energy is incident on this portion of the fuselage. Above 1000 Hz the trend is the same.

7.2 Structural Vibration Levels. Vibration levels that were measured simultaneously with interior and exterior noise levels at the locations shown on Figure 12 are given in Table 15. Table 15 indicates that the vibration levels of the fuselage structure during takeoff are highest in the vicinity of the flaps and during landing are highest under the wing. At cruise, the acceleration levels increase with an increase in airspeed in much the same manner as was observed for the exterior noise levels.

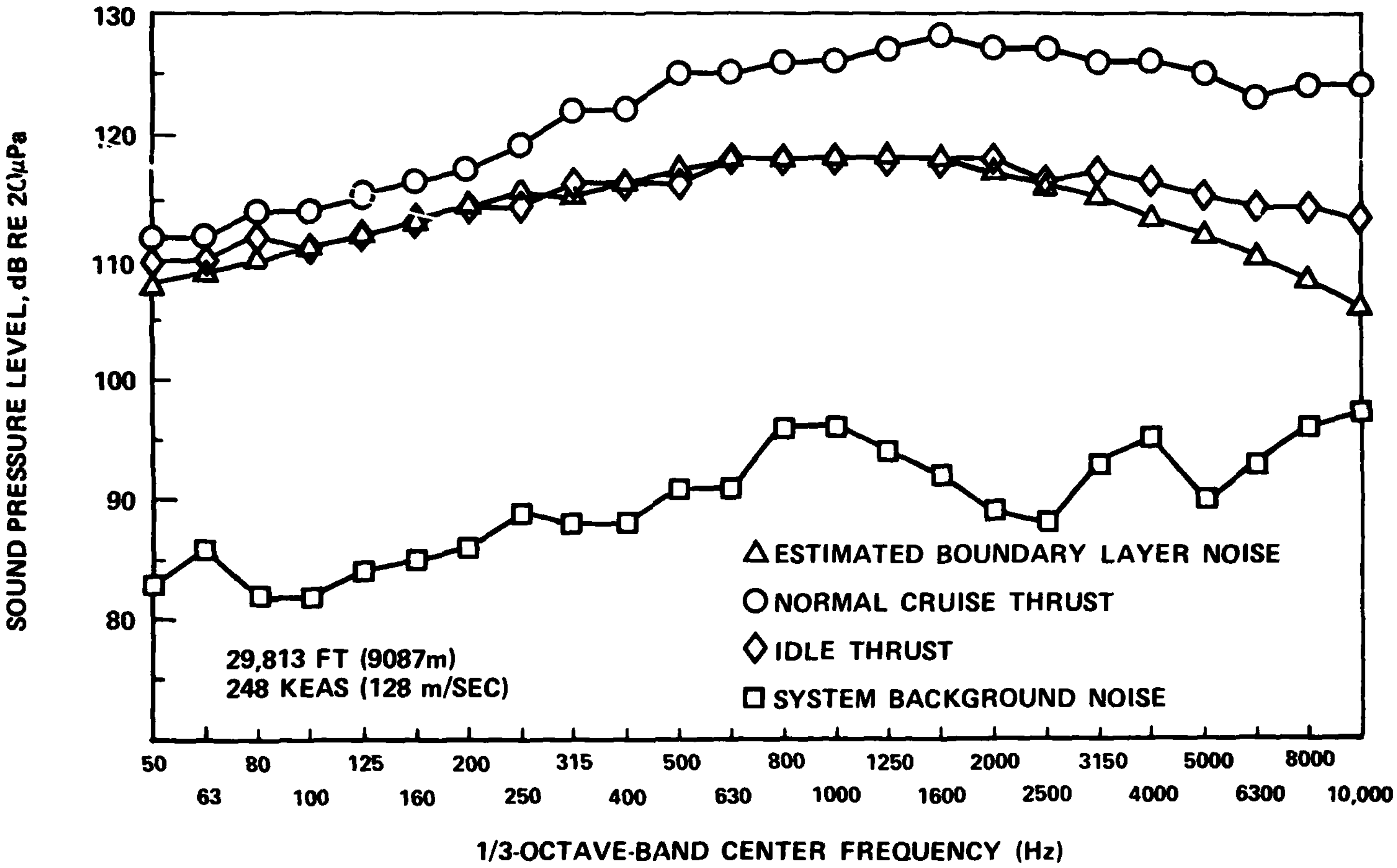


Figure 58. Exterior Fuselage Noise Levels Measured at Microphone 4 Location

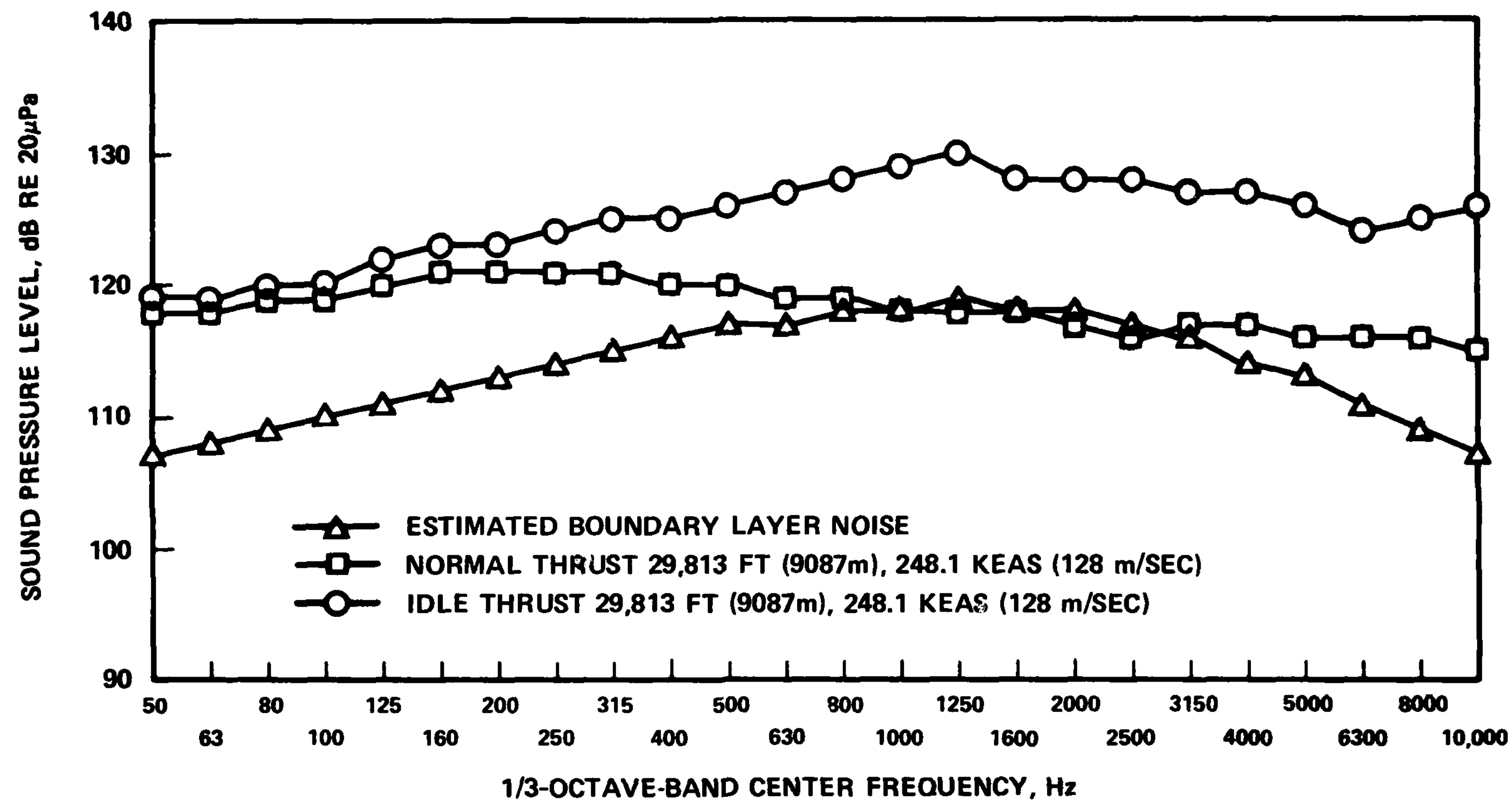


Figure 59. Exterior Fuselage Noise Levels Measured at Microphone No. 2 Location

TABLE 15 - YC-15 FUSELAGE VIBRATION MEASUREMENTS - FLIGHT TESTS - OVERALL VIBRATION LEVELS, dB re $10^{-5} m/sec^2$

TEST NO.	ALTITUDE FT (m)	SPEED KEAS (m/sec)	FLAP ANGLE	ENGINE No.[c] @ EPR	ACCELEROMETER ACC 11	ACC 12	ACC 13	ACC 14	ACC 15	ACC 16	ACC 17	ACC 18
F-1	Field	0	23°	1,2,3,4 @ 2.20	134	148	121	151	150	142	(b)	(b)
F-2	Field	0	24°	1,2,4 @ 2.20	132	141	(a)	143	(a)	136		
F-3	Approach	85 (44)	48°	1,2,3,4 @ 1.60	131	139	146	142	141	134		
F-4	Approach	85 (44)	41°	1,2,4 @ 2.10	131	138	142	141	140	135		
F-5.1	18,022 (5493)	195 (101)	1°	1,2,3,4 @ 2.20	126	128	137	133	132	122		
F-5.2	17,897 (5455)	239 (123)	1°	1,2,3,4 @ 1.53	126	130	116	135	134	125	116	
F-5.3	17,908 (5458)	280 (144)	2°	1,2,3,4 @ 1.66	126	133	140	138	137	129	117	
F-5.4	17,883 (5451)	331 (171)	1°	1,2,3,4 @ 1.89	128	138	146	146	145	135	135	
F-6	Go around Approach	100 (52)	48°	1,2,3,4 @ 1.40	129	133	141	137	134	127	(b)	
F-7.1	29,813 (9087)	248 (128)	3°	1,2,3,4 @ 2.01	125	134	143	141	139	130	124	
F-7.2	29,813 (9087)	248 (128)	3°	1,2,3,4 @ 2.01	125	134	143	142	140	130	(b)	
F-7.3	29,813 (9087)	248 (128)	3°	1,2,3,4 @ 2.01	124	134	143	141	139	130	119	
F-7.4	29,813 (9087)	248 (128)	3°	1,2,3,4 @ 2.01	125	134	143	141	139	130	119	
F-8	29,813 (9087)	248 (128)	3°	1,2,3,4 @ Idle	120	130	113	128	131	125	115	
INSTRUMENTATION SYSTEM BACKGROUND LEVELS					107	111	114	115	113	105	111	

NOTES: (a) Signal varies in amplitude (low frequency oscillation).
(b) Signal conditioning malfunction.
(c) Unmentioned engines are operated at idle; EPR is average for engines mentioned.

7.3 Interior Noise Levels. Table 16 presents the interior noise levels measured during the flight tests. Figures 60, 61, and 62 present sidewall and centerline OASPL as a function of fuselage location that were measured inside the YC-15 during takeoff, cruise, and landing approach. The OASPLs are fairly uniform throughout the interior. For example, if OASPLs measured at the sidewall locations for tests F-1, F-3, and F-5.4 are plotted as a function of fuselage station Y, as in Figure 63, this uniformity can be seen. For each flight condition, the data have been normalized to the maximum level measured along the sidewall. Test F-1 (takeoff at brake release) provides data at high EPR, moderate flap angle, and zero forward speed; test F-3 (STOL landing approach) provides data at moderate EPR, high flap angle, and 85 KEAS; and test F-5.4 (cruise) provides data at high EPR, 0° flap angle, 350 KEAS and the highest boundary layer noise provided in the test ensemble. Going aft, the OASPLs measured at the sidewall locations increase slightly from fuselage stations Y = 800 to Y = 1000, then exhibit a slight decrease. The variation in OASPL along the sidewall from Y = 800 to Y = 1150 is 3 dB or less regardless of flight conditions. The centerline microphones exhibit a 3 dB decrease from Y = 800 to Y = 1100. At Y = 700, approximately the fuselage reference plane containing the inboard engine exhaust nozzles, the data indicate that the noise is less than the more aft locations, indicating that lower levels probably exist forward of about Y = 700.

The F-7 tests were included to determine if noise from some of the onboard aircraft equipment could be isolated. However, in view of the consistency of measured data among these tests, seen both in Table 14 and in the one-third octave band levels, it has been concluded that the bare aircraft sidewall does not provide sufficient noise reduction to measure the effects of noise generated by onboard equipment.

Table 17 lists one-third octave-band noise reduction values that were measured during takeoff, cruise, and landing approach conditions. A noteworthy observation is that the values of noise reduction for the takeoff and landing approach conditions are almost identical in every one-third octave-band; however, they differ significantly from the noise reduction measured at a cruise condition. The difference in noise reduction between

TABLE 16 - YC-15 INTERIOR NOISE MEASUREMENTS - FLIGHT TESTS - OVERALL SOUND PRESSURE LEVELS, dB re 20 μPa

TEST NO.	ALTITUDE FT (m)	SPEED KEAS (m/sec)	FLAP ANGLE	ENGINE No.[b] @ EPR	INTERIOR MICROPHONES (21-24 CENTERLINE, 25-29 SIDELINE) MIC 21	MIC 22	MIC 23	MIC 24	MIC 25	MIC 26	MIC 27	MIC 28	MIC 29
F-1	Field	0	23°	1,2,3,4 @ 2.20	128	125	127	125	130	131	131	131	129
F-2	Field	0	24°	1,2,4 @ 2.20	124	122	123	121	(a)	127	128	128	126
F-3	Approach	85 (44)	48°	1,2,3,4 @ 1.60	122	118	119	118	124	125	125	125	124
F-4	Approach	85 (44)	41°	1,2,4 @ 2.10	123	120	122	120	125	126	128	128	126
F-5.1	18,022 (5493)	195 (101)	1°	1,2,3,4 @ 2.20	109	106	107	105	112	110	112	111	107
F-5.2	17,897 (5455)	235 (123)	1°	1,2,3,4 @ 1.53	111	109	110	108	113	113	113	113	110
F-5.3	17,908 (5458)	280 (144)	2°	1,2,3,4 @ 1.66	114	112	113	112	115	115	117	117	114
F-5.4	17,883 (5451)	331 (171)	1°	1,2,3,4 @ 1.89	119	117	119	117	121	121	122	122	119
F-6	Go Around Approach	100 (51)	48°	1,2,3,4 @ 1.40	118	113	115	113	119	119	120	121	119
F-7.1	29,813 (9087)	248 (128)	3°	1,2,3,4 @ 2.01	115	113	114	112	117	117	117	116	114
F-7.2	29,813 (9087)	248 (128)	3°	1,2,3,4 @ 2.01	115	114	114	112	117	117	117	117	114
F-7.3	29,813 (9087)	248 (128)	3°	1,2,3,4 @ 2.01	115	113	114	112	117	117	117	116	114
F-7.4	29,813 (9087)	248 (128)	3°	1,2,3,4 @ 2.01	115	113	114	112	117	117	117	116	114
F-8	29,813 (9087)	248 (128)	3°	1,2,3,4 @ 2.01	107	105	106	106	108	108	111	111	108
INSTRUMENTATION SYSTEM BACKGROUND LEVELS (POST FLIGHT)					82	81	82	79	82	81	89	91	88

NOTES: (a) Signal varies in amplitude (low frequency oscillation).
(b) Unmentioned engines were operated at idle; EPR is average for engines mentioned.

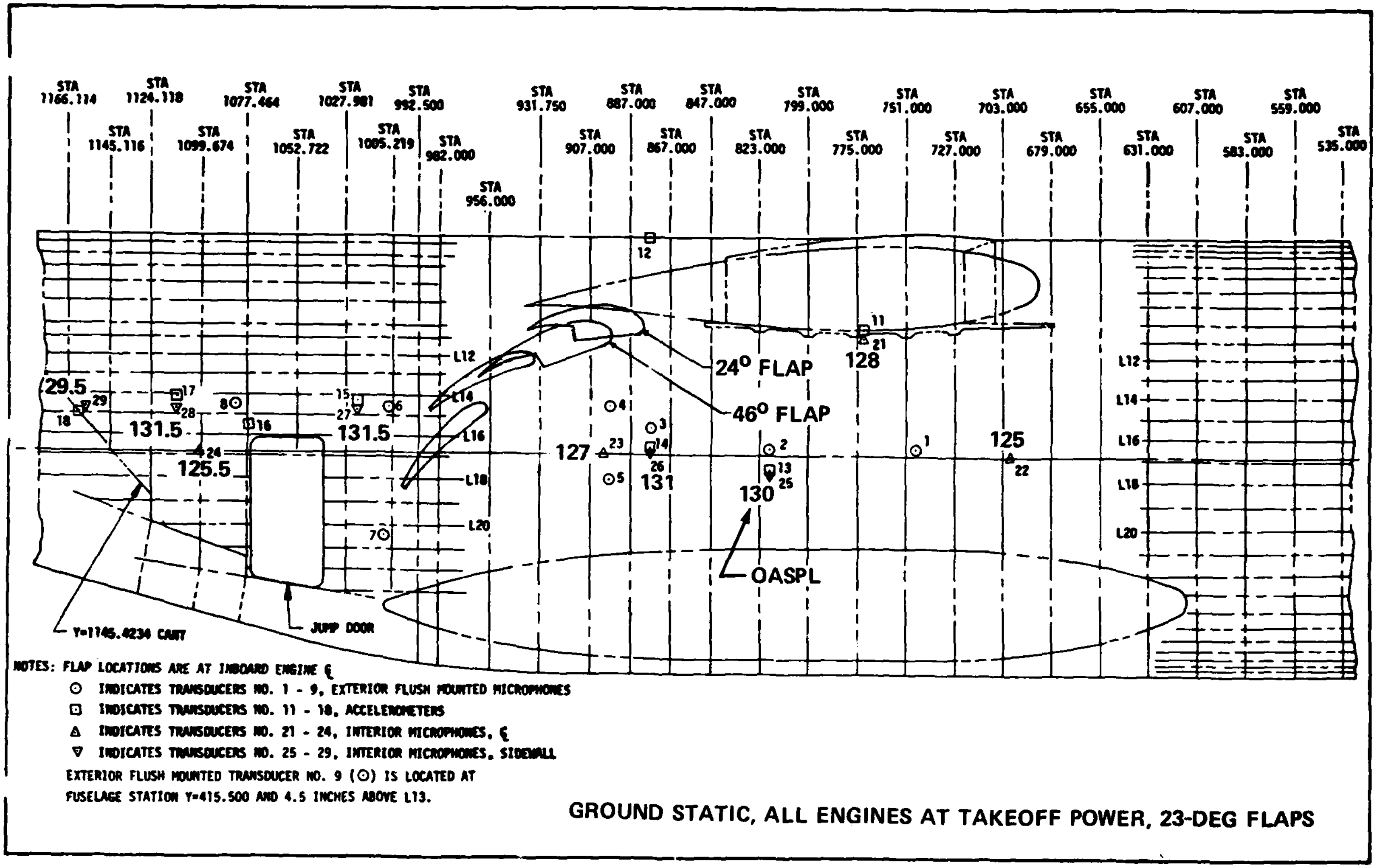
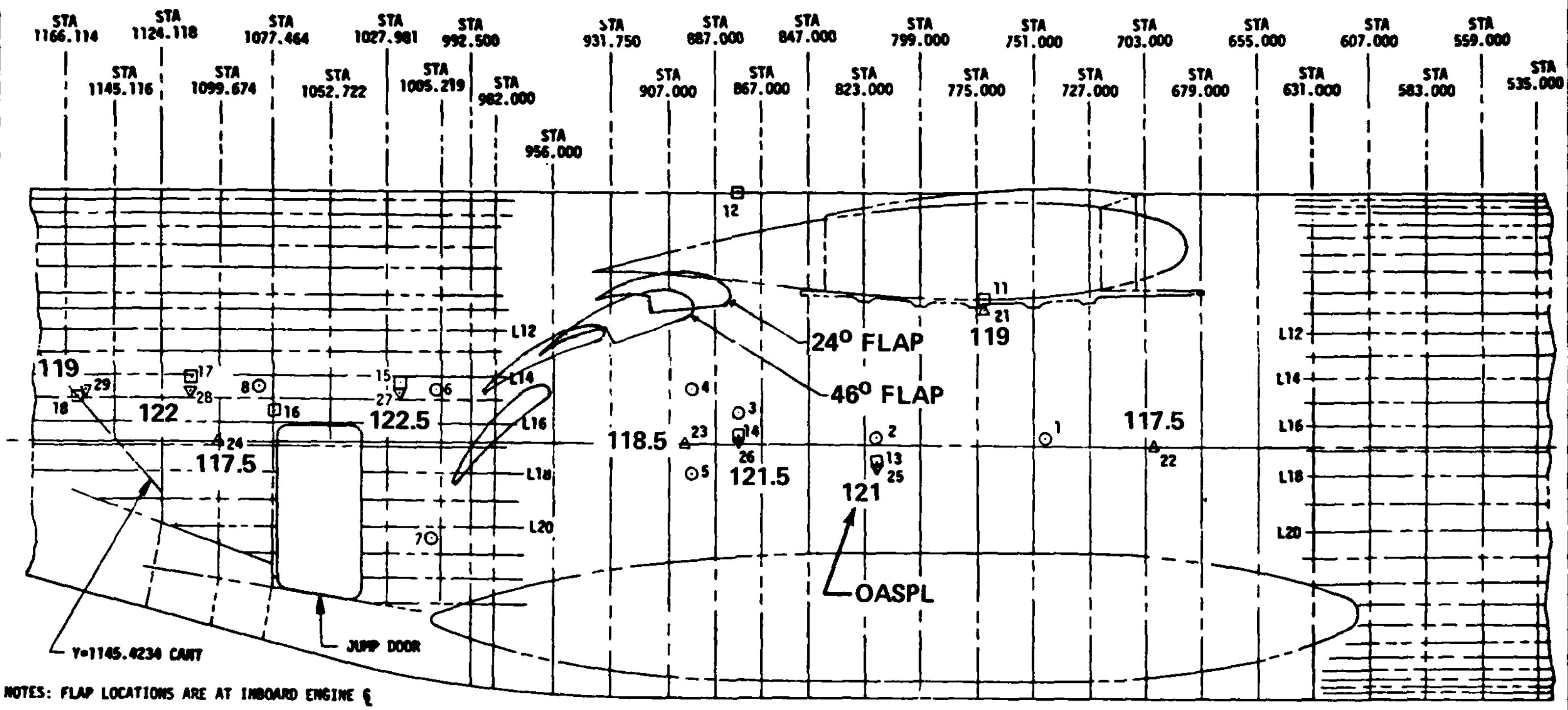


Figure 60. YC-15 Interior Noise During Takeoff



NOTES: FLAP LOCATIONS ARE AT INBOARD ENGINE ℄

○ INDICATES TRANSDUCERS NO. 1 - 9, EXTERIOR FLUSH MOUNTED MICROPHONES

⊡ INDICATES TRANSDUCERS NO. 11 - 18, ACCELEROMETERS

△ INDICATES TRANSDUCERS NO. 21 - 24, INTERIOR MICROPHONES, ℄

▽ INDICATES TRANSDUCERS NO. 25 - 29, INTERIOR MICROPHONES, SIDEWALL

EXTERIOR FLUSH MOUNTED TRANSDUCER NO. 9 (⊙) IS LOCATED AT FUSELAGE STATION Y=415.500 AND 4.5 INCHES ABOVE L13.

18,000 FT (5486m), 340 KEA (185m/SEC), 1-DEG FLAPS

Figure 61. YC-15 Interior Noise During Cruise

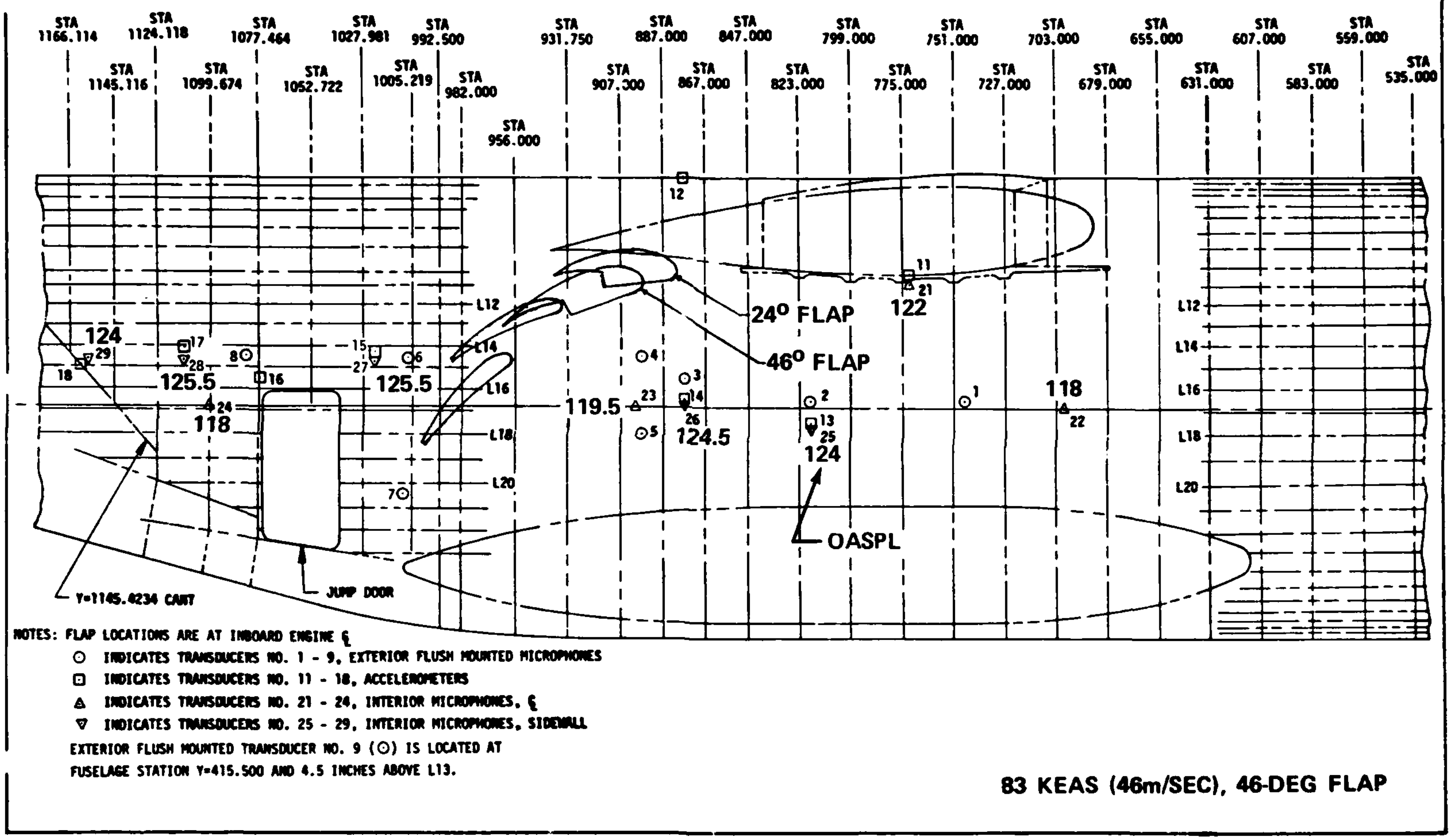


Figure 62. YC-15 Interior Noise During STOL Landing Approach

SIDEWALL MICROPHONE NUMBER	TAKEOFF (F-1) ABSOLUTE VALUE (dB Re 20 $\mu N/M^2$)	TAKEOFF (F-1) NORMALIZED VALUE (dB Re MAX)	CRUISE (F-5, 4) ABSOLUTE VALUE (dB Re 20 $\mu N/M^2$)	CRUISE (F-5, 4) NORMALIZED VALUE (dB Re MAX)	APPROACH (F-3) ABSOLUTE VALUE (dB Re 20 $\mu N/M^2$)	APPROACH (F-3) NORMALIZED VALUE (dB Re MAX)
25	130	–1	121	–1	124	–1
26	131	0	121	–1	125	0
27	131	0	122	0	125	0
28	131	0	122	0	125	0
29	129	–2	119	–3	124	–1

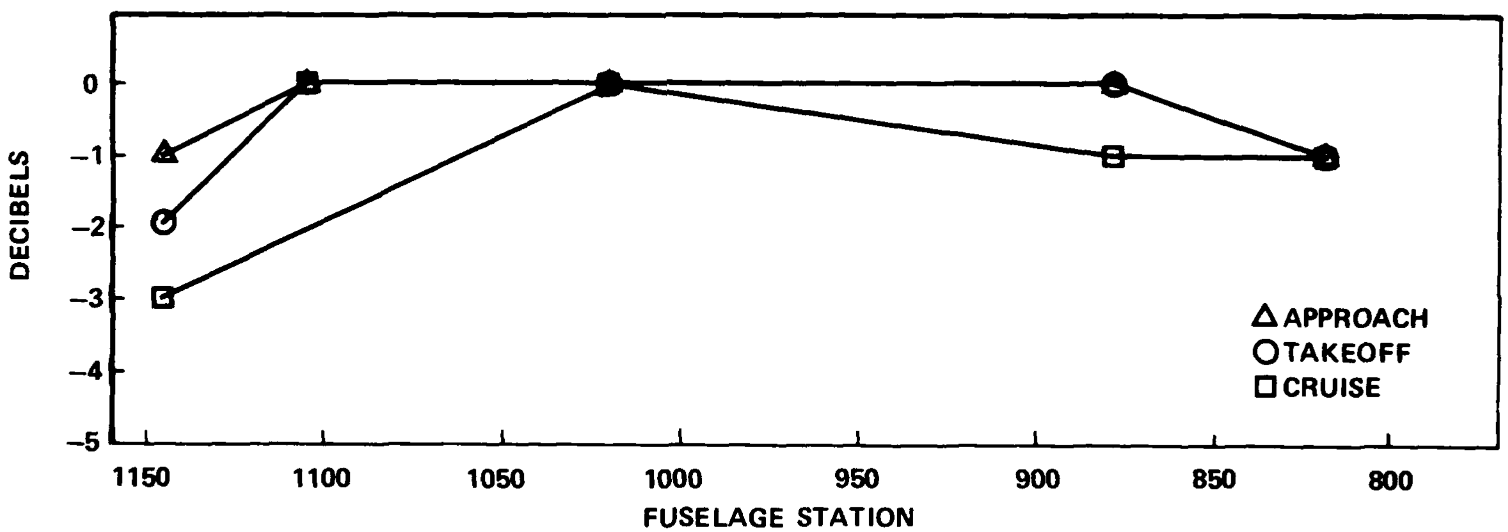


FIGURE 63. SIDEWALL OASPL VERSUS FUSELAGE STATION

TABLE 17 - MEASURED NOISE REDUCTION

ONE-THIRD OCTAVE FREQUENCY BAND (Hz)	TAKEOFF			APPROACH			CRUISE		
	MIC 2	- MIC 25	= NR	MIC 2	- MIC 25	= NR	MIC 2	- MIC 25	= NR
50	130	112	18	127	108	19	123	94	29
63	130	114	16	128	111	17	125	99	26
80	132	116	16	127	112	15	126	99	27
100	132	120	12	127	117	10	126	100	26
125	130	117	13	124	112	12	127	101	26
160	132	119	13	124	113	11	128	103	25
200	134	121	13	127	115	12	129	105	24
250	136	120	16	129	113	16	130	108	22
315	138	122	16	130	114	16	131	110	21
400	140	123	17	130	114	16	131	113	18
500	142	122	20	131	113	18	132	114	18
630	143	120	23	131	109	22	133	113	20
800	142	116	26	131	104	27	134	109	25
1000	141	112	29	130	102	28	135	107	28
1250	141	112	29	130	102	28	133	108	25
1600	140	112	28	129	102	27	132	107	25
2000	138	110	28	128	100	28	131	105	26
2500	138	108	30	127	98	29	131	103	28
3150	137	107	30	127	99	28	130	103	27
4000	137	106	31	127	98	29	130	101	29
5000	134	107	27	126	99	27	129	101	28
6300	133	107	26	124	99	25	127	99	28
8000	133	105	28	125	98	27	128	97	31
10000	133	101	32	126	95	31	129	95	34

cruise conditions and takeoff and approach conditions probably stem from differences in the forcing functions and merit further investigation.

Figure 64 is a one-third octave-band presentation of simultaneously measured external fuselage noise levels and aircraft centerline noise levels for normal cruise engine thrust and engine idle at 30,000 feet (9,144 m) altitude and 250 KEAS (129 m/sec). The predicted boundary layer noise for the microphone 5 location is shown in comparison with measured noise levels at engine idle. Figure 64 also indicates that the decrease in interior noise due to reducing engine thrust is very nearly the same as the reduction in the external noise levels, leading to the conclusion that engine-generated noise controls the interior acoustic environment aft of the engine exit at cruise. The differences between the exterior curves and the interior curves are the measured noise reduction for the two engine thrust cases. This measured in-flight noise reduction is shown in Figure 65. Figure 65 indicates that at engine idle (when the external fuselage loads are largely determined by the turbulent boundary layer) the noise reduction is higher than when the engine noise dominates the noise levels. This effect is seen below about 800 Hz, a range where the boundary layer noise should exceed engine generated noise when the engines are at idle. Above about 800 Hz the noise reduction measured at engine idle is less than that measured at the higher engine thrust. This may be due to the contamination of the interior noise resulting from external energy penetrating the sidewall by noise generated by onboard aircraft equipment.

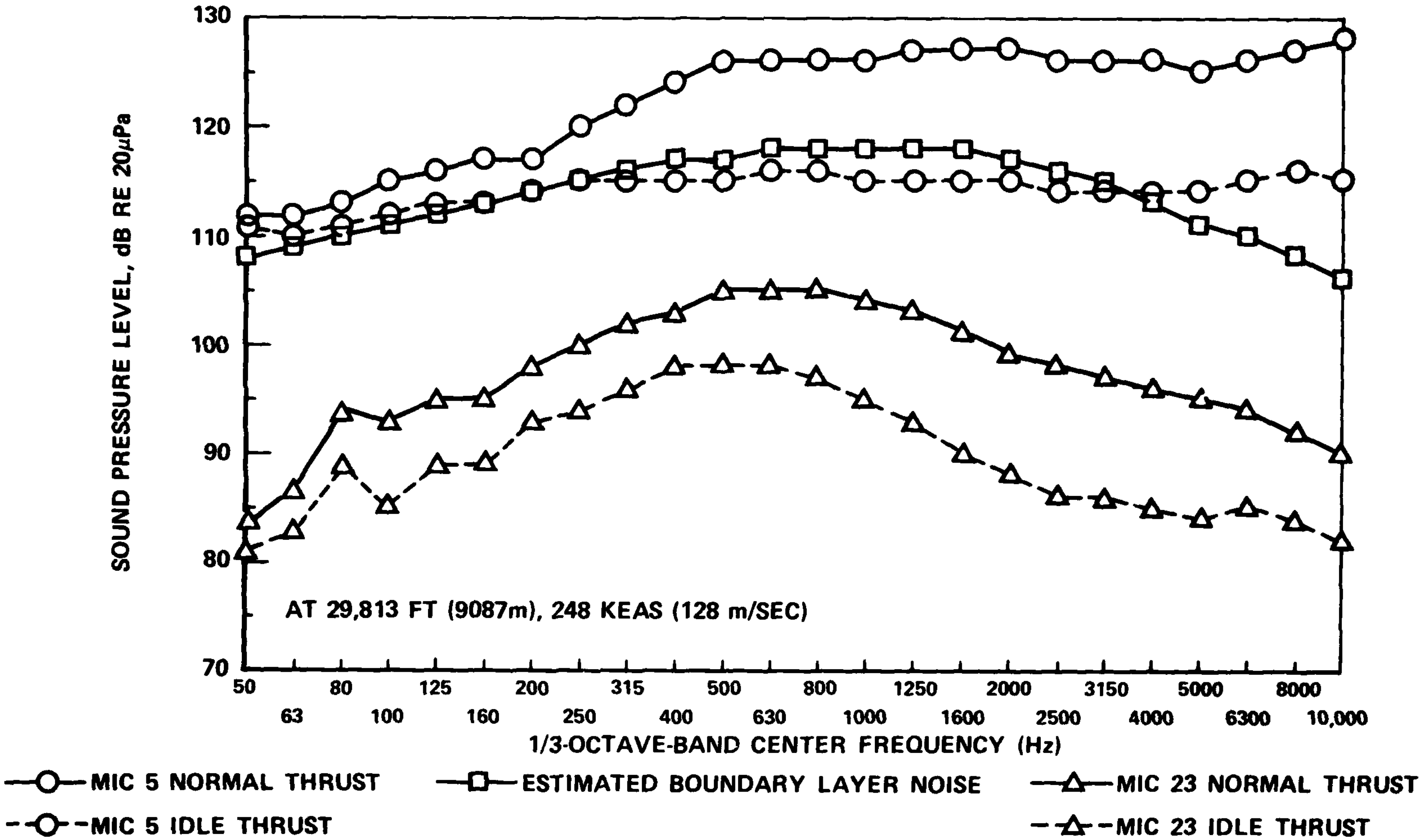


Figure 64. Simultaneously Measured Interior and Exterior Noise Levels

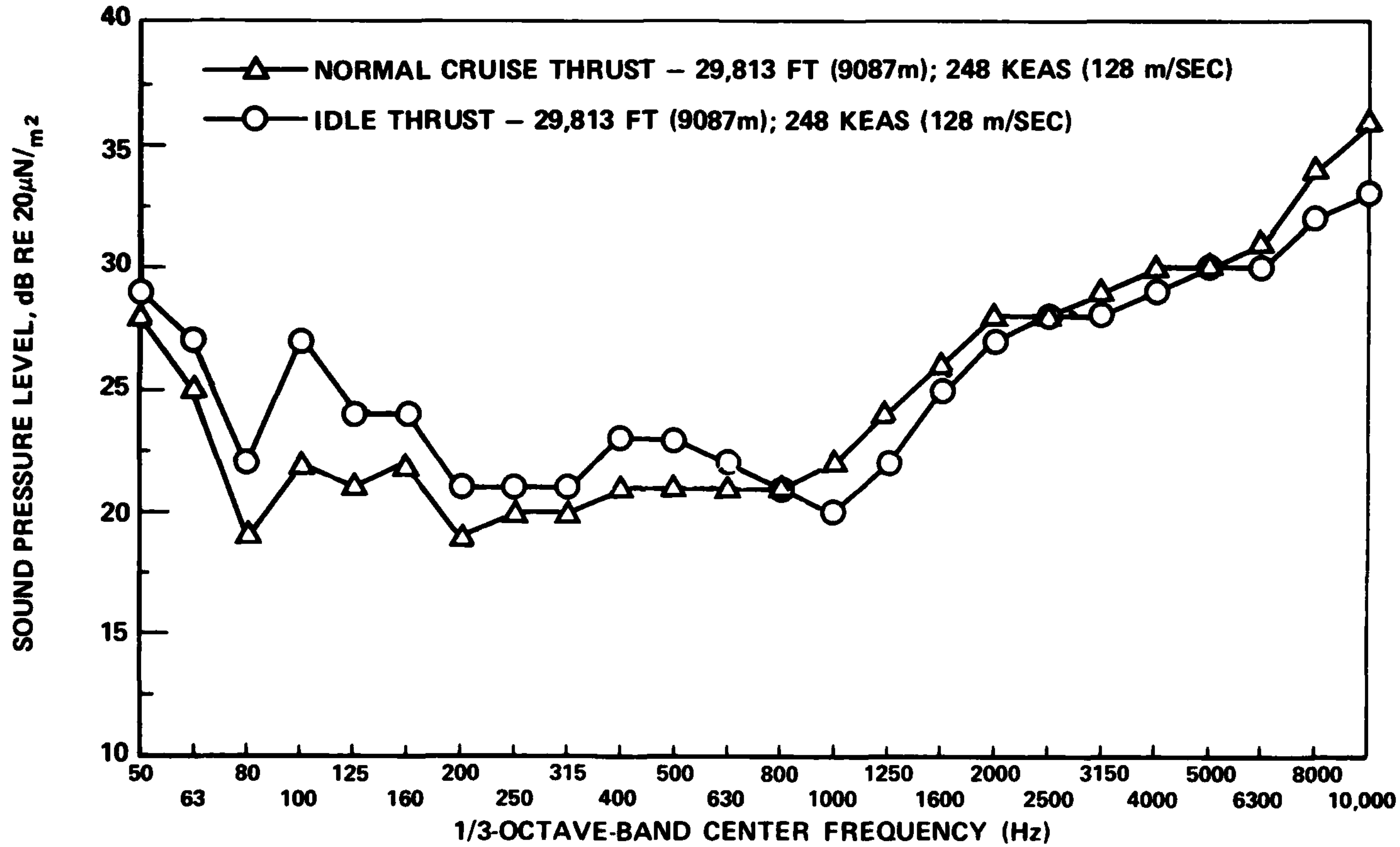


Figure 65. Measured In-Flight Noise Reduction

8. CONCLUSIONS

Ground and flight measurements of the noise levels on the fuselage and the resulting structural vibration and interior noise levels on the first jet-powered EBF STOL vehicle were successfully acquired and recorded on magnetic tape. These data were obtained in two series of YC-15 measurements.

It has been concluded that the data acquired in this program are of high quality. The factors indicating high data quality include:

(1) Precision electro-magnetic data acquisition equipment was used.

(2) Standard calibration procedures were followed.

(3) Acceptable signal-to-noise ratios were obtained.

(4) The recorded data are unsaturated.

(5) Only a small number of discrepancies were observed and identified in the data.

(6) Consistent trends were identified in the ground data.

(7) Flight and ground data were obtained during continuous aircraft operation without changing the acquisition system. Therefore, good ground data also indicate good flight data.

(8) High altitude cruise data agreed well with predicted levels.

In addition to the data quality, preliminary observations concerning the measured environments were made.

The general trends and observations made from the ground test data are:

(1) The relationship between overall levels and thrust for the static configuration was observed to be $p^2 \propto (F/\delta)^{3.8}$.

(2) Jet/flap interaction noise contributes significantly to the noise levels below about 500 Hz and increases with increase in flap setting.

(3) The vibratory energy seems to exhibit a high degree of circumferential mobility.

(4) Structurally-borne noise transmitted through the wing structures does not appear to be a major contributor to interior noise levels.

The general trends and observations made from the flight test data are:

(1) The STOL landing/approach condition contributes noticeably to the noise levels on the fuselage and in the interior below about 500 Hz.

(2) Measured values of boundary layer noise agree reasonably well with predicted values.

(3) Engine-generated noise controls the interior acoustic environment at cruise conditions.

(4) The distribution of interior acoustic energy is much the same for takeoff, landing approach, and cruise conditions.

(5) The YC-15 fuselage structure provides significantly more noise reduction at cruise conditions than for takeoff or landing conditions.

It is emphasized that these conclusions have resulted from only a preliminary examination of the data and are related to the specific aircraft configuration that was used and specific tests that were conducted.

9. RECOMMENDATIONS

The data discussed in this report have been gathered to support investigations in the areas of EBF exterior noise and interior noise predictions as described in Reference 4. Primary objectives include the development of methodology for the prediction of the fuselage exterior and interior noise levels and the development of noise suppression techniques that will provide acceptable interior noise levels compatible with other aircraft requirements, such as performance and community noise. Analytical studies, experimental investigations, and systems studies should be undertaken which will emphasize the following objectives:

(1) The development of methodology for predicting the exterior fuselage acoustic loads.

(2) The evaluation and improvement of existing methods to calculate interior noise resulting from the transmission of external energy into the interior.

(3) The evaluation and/or development of techniques for reducing interior noise levels.

(4) The assessment of the compatibility of interior noise reduction techniques with other STOL transport aircraft requirements.

Specific areas that should be investigated through further reduction and analysis of these data in support of these goals are:

(1) The effects of flap setting, engine power level, jet velocity, forward speed, and ground reflections on fuselage acoustic loads.

(2) Correlation analyses with the blown flap, exterior fuselage, shell vibration, and interior measurements to define and investigate the statistical characteristics of the environment, isolate noise sources, identify high radiation areas, and evaluate in-flight transmission loss.

(3) The importance of interior acoustic modes.

(4) An evaluation of existing aircraft interior noise prediction schemes.

(5) Differences between laboratory-measured sound transmission loss (TL) of aircraft structures and the TL achieved under flight conditions. An attempt should be made to identify and understand the TL effects due to geometrical differences of size and shape, stiffness due to curvature and pressurization, differences in the characteristic acoustical impedances of the exterior and interior environments, differences in the exciting acoustic fields, etc.

In addition, types of aircraft structure which would provide maximum acoustical isolation from the type of acoustic fields generated by STOL EBF aircraft should be investigated.

Completion of these tasks should provide a clear indication of the next steps required to fulfill the above-stated objectives.

REFERENCES

1. Flight Test Plans - YC-15 Ground and Flight Data Acquisition for NASA and AFFDL: Interior Noise, EBF Aero-Acoustic Loads and Thermal Environment, and Engine Inlet Acoustics. MDC-J6055. Douglas Aircraft Company, Long Beach, California, April 1976.

2. Warnix, J. L. and Lockman, C. S. YC-15 Interior Noise Measurements - Data. MDC-J7199. Douglas Aircraft Company, Long Beach, California, December 1976.

3. Cockburn, J. A. and Jolly, A. C. Structural-Acoustic Response, Noise Transmission Losses and Interior Noise Levels of an Aircraft Fuselage Excited by Random Pressure Fields. AFFDL-TR-68-2, August 1968.

4. Ground and Flight Test Plan - YC-15 Interior Noise Measurements. MDC-J6047. Douglas Aircraft Company, Long Beach, California. August 1975.

APPENDIX

PROPULSION SYSTEM PERFORMANCE RELATED PARAMETERS

1. INTRODUCTION

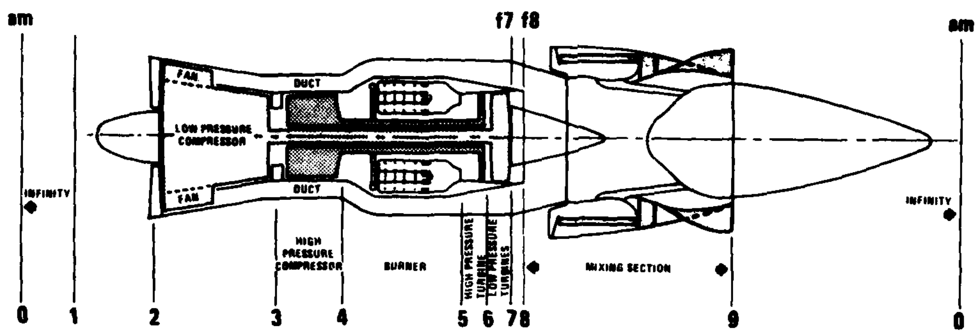
In the subsequent analysis of the test data acquired in this program it will be necessary to derive several propulsion system performance related parameters. Parameters of interest include gross thrust and exhaust nozzle exit Mach number, velocity, and dynamic pressure. The latter, in view of the non homogeneous nature of the exhaust nozzle exit gas flow, must be, by definition, mean quantities. Thus, different values may well be obtained depending upon the assumptions or procedures adopted in their derivation. Clearly, consistency in their derivation must be retained in any subsequent analysis of the data presented herein. A suggested procedure, one which utilizes available engine performance characteristics in conjunction with measured quantities, namely, atmospheric conditions, altitude, flight speed, and engine pressure ratio (i.e., EPR), is presented below.

2. EXHAUST NOZZLE EXIT PARAMETERS

In determining the required exhaust nozzle exit parameters it will be necessary to first derive several engine performance parameters, parameters which are functions of atmospheric conditions, altitude, flight speed, and engine pressure ratio. It will be assumed that these designated parameters are computed through the use of the "JT8D-17 Turbofan Engine Estimated Engine Performance Computer Program".*

*User's Manual for JT8D-17 Turbofan Engine Estimated Engine Performance Customer Computer Deck No. 0242-04.0, Pratt & Whitney Aircraft Report No. PWA INST 684, August 15, 1975.

2.1 Definition of Symbols.



NOTE - The engine station designations illustrated above are generally used as subscripts.

Symbols	Definition	Name*
A	Area, ft^2	
C_p	Specific heat at constant pressure, BTU/lb/°R	
F	Thrust, lb	
F_g	Gross thrust, lb	FG
g	Acceleration due to gravity, 32.174 ft/sec^2	
J	Joules constant, 778.26 ft-lb/BTU	
M	Mach number	
P	Absolute pressure, lb/ft^2	
q	Dynamic pressure, lb/ft^2	
R	Gas constant, $ft^2/sec^2/°R$	
T	Absolute temperature, °R	
V	Velocity, ft/sec	
w	Rate of flow, lb/sec	
δ	Relative absolute pressure, static or total, P/P_o	
θ	Relative absolute temperature, static or total, T/T_o	
γ	Ratio of specific heats	

Symbols	Definition	Name*
Subscripts		
a	Air	
am	Ambient	
bl	Bleed	
f	1. Fan	
	2. Fuel	
j	Derived jet parameters assuming homogeneous flow at station 9	
o	Sea level static (standard)	
p	Primary (engine)	
t	Total	
0 1,2,3 .	Station locations referred to engine	
Superscript		
*	Derived jet parameters assuming an isentropic flow process from the assumed homogeneous state at station 9 to downstream infinity.	
Terms		
h	Altitude	GALT
P_{am}	Ambient pressure	PAM
EPR	Engine pressure ratio, P_{t1}/P_{t2}	GEPR
T_{am}	Ambient temperature	TAM
T_{t2}	Total temperature at low pressure compressor and fan inlet, °R	TT2
T_{t8f}	Fan duct total temperature at mixing plane, °R	TT8D
T_{t8p}	Primary (engine) total temperature at mixing plane, °R	TT8E
W_{af}	Fan airflow, lb/sec	WAD
W_{ap}	Primary (engine) airflow, lb/sec	WAE
W_f	Engine fuel flow, lb/hr	WF

*P&W Computer Program CCD No. 0242-04.0

2.2 Definitions and Relationships

The definitions and relationships presented below are to be used in deriving the required parameters to be used in the subsequent analysis of the data presented herein. The flow process is assumed to be adiabatic between stations 8 and 9 and isentropic between station 9 and far downstream where the static pressure is P_{am}. Further, the static pressure of the "outer" flow at station 9 is assumed to be P_{am}. In other words if M_j is less than one $P_j = P_{am}$.

● Jet Velocity Infinitely Far Downstream:

$$V_j^* = \frac{gF_g}{(w_{af8} + w_{ap8})} \quad \ldots\ldots\ldots \quad (1)$$

where $w_{af8} = (w_{af} - w_{blf})$ and $w_{ap8} = (w_{ap} - w_{blp} + w_f)$. It should be noted that the definition of gross thrust used here will not be consistent with the conventional definition of engine gross thrust (i.e., $F_g = \frac{(w_{af8} + w_{ap8})}{g} V_9 + (P_9 - P_{am}) A_9$) if $P_9 \neq P_{am}$.

● Jet Mach Number Infinitely Far Downstream:

$$M_j^* = \frac{V_j^*}{\sqrt{\gamma_j R_j T_{tj}}} \left[1 - \frac{(\gamma_j - 1)\, V_j^{*2}}{2\gamma_j\, R_j\, T_{tj}}\right]^{-1/2} \quad \ldots\ldots\ldots \quad (2)$$

From continuity and energy considerations, it can be readily shown that the jet total temperature, T_{tj}, in equation (2) can be expressed as follows:

$$T_{tj} = \frac{c_{pf8} w_{af8} T_{tf8} + c_{pp8} w_{ap8} T_{tp8}}{c_{pj}(w_{af8} + w_{ap8})} \quad \ldots\ldots\ldots \quad (3)$$

and that from "GIBBS - DALTON" considerations:

$$c_{pj} = \frac{w_{af8} c_{pf8} + w_{ap8} c_{pp8}}{w_{af8} + w_{ap8}} \quad \ldots\ldots\ldots \quad (4)$$

and

$$R_j = \frac{R_{f8} w_{af8} + R_{p8} w_{ap8}}{w_{af8} + w_{ap8}} \quad \ldots\ldots\ldots \quad (5)$$

from which γ_j is derived, namely:

$$\gamma_j = \frac{gJc_{pj}}{gJc_{pj} - R_j} \quad \ldots\ldots\ldots\ldots \quad (6)$$

• Exhaust Nozzle Exit Pressure Ratio:

$$\frac{P_{tj}}{P_{am}} = \left[1 + \frac{\gamma_j - 1}{2} M_j^{*2}\right]^{\frac{\gamma_j}{\gamma_j - 1}} \quad \ldots\ldots\ldots\ldots \quad (7)$$

• Exhaust Nozzle Exit Mach Number:

$$\left.\begin{aligned} M_j &= M_j^* \, , \left(\frac{P_{tj}}{P_{am}} \leq \left(\frac{\gamma_j + 1}{2}\right)^{\frac{\gamma_j}{\gamma_j - 1}}\right) \\ &= 1.0 \, , \left(\frac{P_{tj}}{P_{am}} \geq \left(\frac{\gamma_j + 1}{2}\right)^{\frac{\gamma_j}{\gamma_j - 1}}\right) \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots \quad (8)$$

• Exhaust Nozzle Exit Velocity:

$$\left.\begin{aligned} V_j &= V_j^* \, , \left(\frac{P_{tj}}{P_{am}} \leq \left(\frac{\gamma_j + 1}{2}\right)^{\frac{\gamma_j}{\gamma_j - 1}}\right) \\ &= \sqrt{\frac{2\gamma_j R_j T_{tj}}{\gamma_j + 1}} \, , \left(\frac{P_{tj}}{P_{am}} \geq \left(\frac{\gamma_j + 1}{2}\right)^{\frac{\gamma_j}{\gamma_j - 1}}\right) \end{aligned}\right\} \quad \ldots\ldots\ldots \quad (9)$$

• Exhaust Nozzle Exit Dynamic Pressure Ratio:

$$\left.\begin{aligned} \frac{q_j}{P_{am}} &= \frac{1}{2} \gamma_j M_j^2 \, , \left(\frac{P_{tj}}{P_{am}} \leq \left(\frac{\gamma_j + 1}{2}\right)^{\frac{\gamma_j}{\gamma_j - 1}}\right) \\ &= \frac{1}{2} \gamma_j \left(\frac{\gamma_j + 1}{2}\right)^{-\frac{\gamma_j}{\gamma_j - 1}} \frac{P_{tj}}{P_{am}} \, , \left(\frac{P_{tj}}{P_{am}} \geq \left(\frac{\gamma_j + 1}{2}\right)^{\frac{\gamma_j}{\gamma_j - 1}}\right) \end{aligned}\right\} \quad \ldots \quad (10)$$

The conventional definition of gross thrust in terms of the "homogeneous" exhaust nozzle exit parameters derived earlier can be calculated from the following equation:

$$
\left.\begin{aligned}
\frac{F_j}{P_{am}A_j} &= \gamma_j M_j^2 \ , \left(\frac{P_{tj}}{P_{am}} \leq \left(\frac{\gamma_j+1}{2}\right)^{\frac{\gamma_j}{\gamma_j-1}}\right) \\
&= 2^{\frac{\gamma_j}{\gamma_j-1}} \left(1+\gamma_j\right)^{-\frac{1}{\gamma_j-1}} \frac{P_{tj}}{P_{am}} - 1 \ , \left(\frac{P_{tj}}{P_{am}} \geq \left(\frac{\gamma_j+1}{2}\right)^{\frac{\gamma_j}{\gamma_j-1}}\right)
\end{aligned}\right\} \quad (11)
$$

It should be noted that F_j will not necessarily equal F_g if A_j is taken as the geometric area of the exhaust nozzle at station 9. It should not, therefore, be used in any analysis of performance.

2.3 Sample Calculations. Exhaust nozzle exit parameters for several engine pressure ratios, altitudes, and flight speeds typical of those covered in the present ground and flight test program are presented in the following table. Changes in specific heats with combustion and temperature have been neglected and γ_j is assumed equal to 1.4. Curve number INST 29792 of the Pratt & Whitney JT8D Commercial Installation Handbook illustrates the anticipated variation in γ_j as a function of T_{t2} and the overall fuel-air ratio of the JT8D-17. It is important to note here that γ_j can vary between 1.37 and 1.402.

TABLE - TYPICAL PROPULSION S\`TEM PERFORMANCE RELATED PARAMETERS

ALT ft	$M^{\dagger}$	EPR	F_g lb	W_{af8} lb/sec	W_{ap8} lb/sec	T_{tf8} °R	T_{tp8} °R	V_j^* ft/sec	T_{tj} °R	M_j^*	$\frac{P_{Tj}}{P_{am}}$	M_j	V_j ft/sec	$\frac{g_j}{P_{am}}$	$V_j^*-V^{\dagger}$ ft/sec
2302	0	1.053	945	54.4	27.8	535	1203	370	761	.28	1.05	.28	370	.053	370
2302	0	1.601	8690	138.0	107.6	604	1303	1138	910	.82	1.55	.82	1138	.470	1138
2302	0	1.900	11986	149.4	133.2	633	1402	1364	995	.96	1.81	.96	1364	.645	1364
2302	0	2.200	15043	151.5	153.5	667	1556	1587	1115	1.08	2.07	1.00	1494	.767	1587
2302	.134	1.600	8937	140.2	109.1	607	1306	1153	913	.83	1.57	.83	1153	.483	1005
2302	.134	2.186	15218	153.3	154.3	668	1553	1592	1112	1.08	2.09	1.00	1492	.772	1443
2302	.158	2.186	15311	153.9	154.8	669	1554	1596	1113	1.09	2.10	1.00	1493	.775	1421
18000	.417	1.399	4728	85.1	59.5	539	1127	1052	781	.82	1.55	.82	1052	.469	617
18000	.524	1.600	6950	97.8	74.8	570	1130	1296	856	.99	1.87	.99	1296	.684	749
18000	.706	1.900	11211	115.3	102.9	621	1372	1653	975	1.23	2.53	1.00	1397	.937	915
30000	.666	2.001	6766	69.9	65.6	567	1282	1606	913	1.24	2.56	1.00	1352	.945	944
3000	.666	0.970	1906	52.6	26.1	472	838	779	593	.68	1.37	.68	779	.326	117

NOTE:

- Standard Atmospheric Conditions
- γ_j assumed equal to 1.4

† Aircraft Flight Mach Number and Velocity

☆U.S.Government Printing Office: 1981 — 757-002/500

LME