YC-15 INTERIOR NOISE MEASUREMENTS
Technical Discussion

McDonnell Douglas Corporation
Douglas Aircraft Company
Long Beach, California 90846

MARCH 1981

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

AIR FORCE FLIGHT DYNAMICS LABORATORY
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AIR FORCE SYSTEMS COMMAND
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This technical report has been reviewed and is approved for publication.

VINCENT R. MILLER
Project Engineer
USAF

JAMES A. SCHOENSTER
Technical Monitor
NASA/LaRC

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

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

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AIR FORCE/06780/27 April 1981 – 270
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.
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.
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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.
The centerlines of the inboard and outboard engines are at fuselage stations \( Z = 34.3, X = \pm 206.0 \) and \( Z = 33.5, X = \pm 331.0 \), 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.
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<td>SWEEP V°</td>
<td>9° 63' 6&quot;</td>
<td>4° 40' 12&quot;</td>
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<tr>
<td>ANHEALD</td>
<td>0°</td>
<td>3°</td>
<td>~</td>
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<tr>
<td>THICKNESS</td>
<td>13.90%</td>
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<td>.323 V° = 4.147'</td>
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CARGO COMPARTMENT SIZE
544" LENGTH (EXCLUDES WALKWAY)
140" WIDTH
138" HEIGHT (MIN.)

FLIGHT REFUEL
(SHIP 2 ONLY)
Figure 5. Location of Flap Instrumentation
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 MAA 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 Brüel 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 12. YC-15 Transducer Locations

NOTES:
- FLAP LOCATIONS ARE AT 1000 DTFM ENGINE. T.
- EXTERIOR FLUSH MOUNTED MICROPHONES.
- INDICATES MICROPHONES.
- INDICATES MICROPHONES, SURFACE.
- ENGINE STATION 141.0 ON L-5 FUSelage WING.
- INDICATES TRANSUCERS NO. 92, 91, AND 93.
- INDICATES TRANSUCERS NO. 92, 91, AND 93.
- INDICATES TRANSUCERS NO. 92, 91, AND 93.
- INDICATES TRANSUCERS NO. 92, 91, AND 93.
- INDICATES TRANSUCERS NO. 92, 91, AND 93.
- INDICATES TRANSUCERS NO. 92, 91, AND 93.
- INDICATES TRANSUCERS NO. 92, 91, AND 93.
- INDICATES TRANSUCERS NO. 92, 91, AND 93.
- INDICATES TRANSUCERS NO. 92, 91, AND 93.
- INDICATES TRANSUCERS NO. 92, 91, AND 93.
- INDICATES TRANSUCERS NO. 92, 91, AND 93.
- INDICATES TRANSUCERS NO. 92, 91, AND 93.
- INDICATES TRANSUCERS NO. 92, 91, AND 93.
- INDICATES TRANSUCERS NO. 92, 91, AND 93.
- INDICATES TRANSUCERS NO. 92, 91, AND 93.
<table>
<thead>
<tr>
<th>TRANSDUCER NUMBER</th>
<th>TRANSDUCER TYPE</th>
<th>X*</th>
<th>Y*</th>
<th>Z*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Exterior Flush-Mounted Microphones</td>
<td>-108</td>
<td>745</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>-108</td>
<td>818</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>-107</td>
<td>877</td>
<td>13</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>-105</td>
<td>897</td>
<td>24</td>
</tr>
<tr>
<td>5</td>
<td></td>
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<td>-7</td>
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<tr>
<td>6</td>
<td></td>
<td>-105</td>
<td>1009</td>
<td>24</td>
</tr>
<tr>
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<td></td>
<td>-99</td>
<td>1014</td>
<td>-41</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>-103</td>
<td>1094</td>
<td>25</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>-85</td>
<td>415</td>
<td>43</td>
</tr>
<tr>
<td>11</td>
<td>Accelerometers</td>
<td>-45</td>
<td>773</td>
<td>55</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>-45</td>
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<td>97</td>
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<td>-7</td>
</tr>
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<td>14</td>
<td></td>
<td>-108</td>
<td>877</td>
<td>3</td>
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<tr>
<td>15</td>
<td></td>
<td>-106</td>
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<td>24</td>
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<tr>
<td>16</td>
<td></td>
<td>-94</td>
<td>1077</td>
<td>13</td>
</tr>
<tr>
<td>17</td>
<td></td>
<td>-104</td>
<td>1104</td>
<td>14</td>
</tr>
<tr>
<td>18</td>
<td></td>
<td>-86</td>
<td>1160</td>
<td>20</td>
</tr>
<tr>
<td>21</td>
<td>Interior Centerline Microphones</td>
<td>-45</td>
<td>769</td>
<td>53</td>
</tr>
<tr>
<td>22</td>
<td></td>
<td>0</td>
<td>700</td>
<td>0</td>
</tr>
<tr>
<td>23</td>
<td></td>
<td>0</td>
<td>900</td>
<td>0</td>
</tr>
<tr>
<td>24</td>
<td></td>
<td>0</td>
<td>1100</td>
<td>0</td>
</tr>
<tr>
<td>25</td>
<td>Interior Sidewall Microphones</td>
<td>-104</td>
<td>818</td>
<td>-7</td>
</tr>
<tr>
<td>26</td>
<td></td>
<td>-104</td>
<td>877</td>
<td>3</td>
</tr>
<tr>
<td>27</td>
<td></td>
<td>-102</td>
<td>1020</td>
<td>24</td>
</tr>
<tr>
<td>28</td>
<td></td>
<td>-100</td>
<td>1104</td>
<td>14</td>
</tr>
<tr>
<td>29</td>
<td></td>
<td>-86</td>
<td>1145</td>
<td>18</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Transducer Type</th>
<th>Recorder #1</th>
<th>Recorder #2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group Number</td>
<td>Group Number</td>
</tr>
<tr>
<td>Exterior Microphones</td>
<td>3, 4, 5</td>
<td>2, 1</td>
</tr>
<tr>
<td>Accelerometer</td>
<td>14</td>
<td>11</td>
</tr>
<tr>
<td>Interior Microphones</td>
<td>23, 26</td>
<td>22, 21</td>
</tr>
</tbody>
</table>

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**

<table>
<thead>
<tr>
<th>No.</th>
<th>Tape Recorder</th>
<th>Transducers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Honeywell Model 5600C - #1</td>
<td>2, 5, 6</td>
</tr>
<tr>
<td>2</td>
<td>Honeywell Model 5600C - #2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Ampex Model AR-200</td>
<td>4, 7, 8</td>
</tr>
<tr>
<td>4</td>
<td>Astro-Science Model M-14</td>
<td>9, 3, 1</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Acquisition System Type</th>
<th>Component</th>
<th>Manufacturer/Model</th>
<th>Instrument Error</th>
<th>Approx Instr Error W/Correction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interior Noise</td>
<td>1/2 in. Condenser Microphone</td>
<td>Bruel &amp; Kjaer/4131 with B&amp;K/226-16</td>
<td>± 1.5 dB</td>
<td>± 0.2 dB</td>
</tr>
<tr>
<td></td>
<td>Signal Conditioner</td>
<td>B&amp;K/226-16</td>
<td>± 0.5 dB</td>
<td>± 0.3 dB</td>
</tr>
<tr>
<td></td>
<td>Tape Recorder</td>
<td>Honeywell1/5600C</td>
<td>± 1.0 dB</td>
<td>± 0.3 dB</td>
</tr>
<tr>
<td></td>
<td>Pistonphone</td>
<td>B&amp;K/4220</td>
<td>± 0.2 dB</td>
<td>± 0.1 dB</td>
</tr>
<tr>
<td></td>
<td>Precision Noise Generator</td>
<td>Hewlett-Packard/8057A</td>
<td>± 0.5 dB</td>
<td>± 0.2 dB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ESTIMATED UNCORRECTABLE SYSTEM Error(1)</td>
<td>± 0.5 dB</td>
<td></td>
</tr>
<tr>
<td>Exterior Noise</td>
<td>Piezoelectric Microphone</td>
<td>ENDEVCO/2150M4A</td>
<td>± 1.5 dB</td>
<td>± 0.5 dB</td>
</tr>
<tr>
<td></td>
<td>Charge Amplifier</td>
<td>ENDEVCO/2760A and Unholtz-Dickie/Dll</td>
<td>± 0.4 dB</td>
<td>± 0.2 dB</td>
</tr>
<tr>
<td></td>
<td>Tape Recorder</td>
<td>Honeywell1/5600C</td>
<td>± 1.0 dB</td>
<td>± 0.3 dB</td>
</tr>
<tr>
<td></td>
<td>Pistonphone</td>
<td>B&amp;K/4220</td>
<td>± 0.2 dB</td>
<td>± 0.1 dB</td>
</tr>
<tr>
<td></td>
<td>Precision Noise Generator</td>
<td>Hewlett-Packard/8057A</td>
<td>± 0.5 dB</td>
<td>± 0.2 dB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ESTIMATED UNCORRECTABLE SYSTEM Error(1)</td>
<td>± 0.7 dB</td>
<td></td>
</tr>
<tr>
<td>Fuselage Vib.</td>
<td>Piezoelectric Accelerometer</td>
<td>Bolt Beranek &amp; Newman/501</td>
<td>± 1.2 dB</td>
<td>± 0.5 dB</td>
</tr>
<tr>
<td></td>
<td>with Preamplifier-Pwr Supply</td>
<td>Bolt Beranek &amp; Newman/P-10</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Voltage Amplifier</td>
<td>INTECH/2583</td>
<td>± 0.4 dB</td>
<td>± 0.2 dB</td>
</tr>
<tr>
<td></td>
<td>Tape Recorder</td>
<td>Honeywell1/5600C</td>
<td>± 1.0 dB</td>
<td>± 0.3 dB</td>
</tr>
<tr>
<td></td>
<td>Audio Oscillator</td>
<td>Hewlett-Packard/202B</td>
<td>± 0.4 dB</td>
<td>± 0.4 dB</td>
</tr>
<tr>
<td></td>
<td>Vacuum Tube Voltmeter</td>
<td>Hewlett-Packard/400H</td>
<td>± 0.2 dB</td>
<td>± 0.2 dB</td>
</tr>
<tr>
<td></td>
<td>Precision Noise Generator</td>
<td>Hewlett-Packard/8057A</td>
<td>± 0.5 dB</td>
<td>± 0.2 dB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ESTIMATED UNCORRECTABLE SYSTEM Error(1)</td>
<td>± 0.8 dB</td>
<td></td>
</tr>
</tbody>
</table>

**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 Brueel & Kjaer Type 2107 Frequency Analyzer
using the linear weighting network. These data were then recorded as time
history charts on a Brueel 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>
<thead>
<tr>
<th>TEST NUMBER</th>
<th>FLAP ANGLE</th>
<th>ENGINES @ EPR</th>
<th>ENGINES @ EPR</th>
</tr>
</thead>
<tbody>
<tr>
<td>G-1</td>
<td>1°</td>
<td>1.2,3,4 @ 1.05</td>
<td>1.2,3,4 @ 1.05</td>
</tr>
<tr>
<td>G-1</td>
<td>1°</td>
<td>1.2,3,4 @ 1.05</td>
<td>1.2,3,4 @ 1.05</td>
</tr>
<tr>
<td>G-2</td>
<td>2°</td>
<td>1.2,3,4 @ 1.05</td>
<td>1.2,3,4 @ 1.05</td>
</tr>
<tr>
<td>G-2</td>
<td>2°</td>
<td>1.2,3,4 @ 1.05</td>
<td>1.2,3,4 @ 1.05</td>
</tr>
<tr>
<td>G-3</td>
<td>2°</td>
<td>1.2,3,4 @ 1.05</td>
<td>1.2,3,4 @ 1.05</td>
</tr>
<tr>
<td>G-3</td>
<td>2°</td>
<td>1.2,3,4 @ 1.05</td>
<td>1.2,3,4 @ 1.05</td>
</tr>
<tr>
<td>G-3</td>
<td>2°</td>
<td>1.2,3,4 @ 1.05</td>
<td>1.2,3,4 @ 1.05</td>
</tr>
<tr>
<td>G-3</td>
<td>2°</td>
<td>1.2,3,4 @ 1.05</td>
<td>1.2,3,4 @ 1.05</td>
</tr>
<tr>
<td>G-4</td>
<td>2°</td>
<td>1.2,3,4 @ 1.05</td>
<td>1.2,3,4 @ 1.05</td>
</tr>
<tr>
<td>G-4</td>
<td>2°</td>
<td>1.2,3,4 @ 1.05</td>
<td>1.2,3,4 @ 1.05</td>
</tr>
<tr>
<td>G-4</td>
<td>2°</td>
<td>1.2,3,4 @ 1.05</td>
<td>1.2,3,4 @ 1.05</td>
</tr>
</tbody>
</table>

**TABLE 6 - YC-15 GROUND TESTS**
<table>
<thead>
<tr>
<th>TEST NUMBER</th>
<th>FIRST SERIES MEASUREMENTS</th>
<th>SECOND SERIES MEASUREMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ALITUDE</td>
<td>SPEED</td>
</tr>
<tr>
<td></td>
<td>FT (m)</td>
<td>(m/sec)</td>
</tr>
<tr>
<td>F-1</td>
<td>Field,2000 (610)</td>
<td>0</td>
</tr>
<tr>
<td>F-2</td>
<td>Field,2000 (610)</td>
<td>0</td>
</tr>
<tr>
<td>F-3</td>
<td>Approach,2300 (701)</td>
<td>85 (44)</td>
</tr>
<tr>
<td>F-4</td>
<td>Approach,2700 (823)</td>
<td>85 (44)</td>
</tr>
<tr>
<td>F-5.1</td>
<td>18,022 (5493)</td>
<td>195 (101)</td>
</tr>
<tr>
<td>F-5.2</td>
<td>17,897 (5455)</td>
<td>239 (123)</td>
</tr>
<tr>
<td>F-5.3</td>
<td>17,908 (5458)</td>
<td>280 (144)</td>
</tr>
<tr>
<td>F-5.4</td>
<td>17,883 (5451)</td>
<td>311 (171)</td>
</tr>
<tr>
<td>F-6</td>
<td>Go-Around Approach,2500 (762)</td>
<td>100 (51)</td>
</tr>
<tr>
<td>F-7.1</td>
<td>29,813 (9087)</td>
<td>248 (128)</td>
</tr>
<tr>
<td>F-7.2</td>
<td>29,813 (9087)</td>
<td>248 (128)</td>
</tr>
<tr>
<td>F-7.3</td>
<td>29,813 (9087)</td>
<td>248 (128)</td>
</tr>
<tr>
<td>F-7.4</td>
<td>29,813 (9087)</td>
<td>248 (128)</td>
</tr>
<tr>
<td>F-8</td>
<td>29,813 (9087)</td>
<td>248 (128)</td>
</tr>
</tbody>
</table>
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, \( F/\delta \), 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). \( F/\delta = M^2 \) is a good approximation for exhaust nozzle Mach numbers up to 1 (Equation 11 of Appendix) and \( F/\delta = (\text{velocity of expanded jet})^{1.7} \) is a good approximation for the JT8D-17 engine with an external mixer at sea level and for \( F/\delta \geq 7,000 \) 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 \((F/\delta)\) line presented in Figures 16 to 23 was obtained from the first series of tests by normalizing all of the \(0^\circ\) and \(24^\circ\) 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 \(F/\delta\) and 30 log \(F/\delta\) lines; the best visual fit being about 38 log \(F/\delta\).
TABLE 8 - YC-15 EXTERIOR NOISE MEASUREMENTS - FIRST SERIES GROUND TESTS - OVERALL SOUND PRESSURE LEVELS, dB re 20 μPa

<table>
<thead>
<tr>
<th>TEST NO.</th>
<th>FLAP ANGLE</th>
<th>ENGINE NO. @ EPR</th>
<th>THRUSTa (LBS)</th>
<th>MIC 1</th>
<th>MIC 2</th>
<th>MIC 3</th>
<th>MIC 4</th>
<th>MIC 5</th>
<th>MIC 6</th>
<th>MIC 7</th>
<th>MIC 8</th>
<th>MIC 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>G-1-1</td>
<td>1°</td>
<td>1,2,3,4 @ 1.05</td>
<td>1,000 (4400)</td>
<td>128</td>
<td>(b)</td>
<td>(c)</td>
<td>123</td>
<td>121</td>
<td>116</td>
<td>118</td>
<td>118</td>
<td>121</td>
</tr>
<tr>
<td>G-1.2</td>
<td>1°</td>
<td>1,2,3,4 @ 1.59</td>
<td>9,100 (40,500)</td>
<td>142</td>
<td>140</td>
<td></td>
<td>138</td>
<td>137</td>
<td>135</td>
<td>135</td>
<td>134</td>
<td>131</td>
</tr>
<tr>
<td>G-1.3</td>
<td>1°</td>
<td>1,2,3,4 @ 1.89</td>
<td>12,600 (56,000)</td>
<td>146</td>
<td>146</td>
<td></td>
<td>143</td>
<td>143</td>
<td>141</td>
<td>142</td>
<td>140</td>
<td>133</td>
</tr>
<tr>
<td>G-1.4</td>
<td>1°</td>
<td>1,2,3,4 @ 2.21</td>
<td>16,200 (72,100)</td>
<td>150</td>
<td>151</td>
<td></td>
<td>148</td>
<td>147</td>
<td>146</td>
<td>146</td>
<td>146</td>
<td>143</td>
</tr>
<tr>
<td>G-1.5</td>
<td>23°</td>
<td>1,2,3,4 @ 1.06</td>
<td>1,000 (4400)</td>
<td>128</td>
<td>125</td>
<td></td>
<td>124</td>
<td>122</td>
<td>117</td>
<td>118</td>
<td>116</td>
<td>122</td>
</tr>
<tr>
<td>G-1.6</td>
<td>23°</td>
<td>1,2,3,4 @ 1.59</td>
<td>9,100 (40,500)</td>
<td>142</td>
<td>142</td>
<td></td>
<td>140</td>
<td>140</td>
<td>135</td>
<td>137</td>
<td>134</td>
<td>131</td>
</tr>
<tr>
<td>G-1.7</td>
<td>23°</td>
<td>1,2,3,4 @ 1.90</td>
<td>12,800 (56,900)</td>
<td>148</td>
<td>148</td>
<td></td>
<td>146</td>
<td>146</td>
<td>141</td>
<td>142</td>
<td>140</td>
<td>133</td>
</tr>
<tr>
<td>G-1.8</td>
<td>23°</td>
<td>1,2,3,4 @ 2.21</td>
<td>16,400 (73,000)</td>
<td>151</td>
<td>152</td>
<td></td>
<td>150</td>
<td>149</td>
<td>146</td>
<td>147</td>
<td>144</td>
<td>135</td>
</tr>
<tr>
<td>G-1.9</td>
<td>46°</td>
<td>1,2,3,4 @ 1.06</td>
<td>1,000 (4400)</td>
<td>128</td>
<td>124</td>
<td></td>
<td>122</td>
<td>123</td>
<td>114</td>
<td>118</td>
<td>116</td>
<td>122</td>
</tr>
<tr>
<td>G-1.10</td>
<td>47°</td>
<td>1,2,3,4 @ 1.39</td>
<td>6,400 (28,500)</td>
<td>139</td>
<td>(b)</td>
<td></td>
<td>133</td>
<td>137</td>
<td>132</td>
<td>134</td>
<td>132</td>
<td>131</td>
</tr>
<tr>
<td>G-2.2</td>
<td>1°</td>
<td>1,4 @ 1.57</td>
<td>8,900 (39,600)</td>
<td>(d)</td>
<td>134</td>
<td></td>
<td>133</td>
<td>134</td>
<td>131</td>
<td>132</td>
<td>130</td>
<td>127</td>
</tr>
<tr>
<td>G-2.3</td>
<td>1°</td>
<td>1,4 @ 1.89</td>
<td>12,600 (56,000)</td>
<td>137</td>
<td>138</td>
<td></td>
<td>138</td>
<td>138</td>
<td>137</td>
<td>137</td>
<td>136</td>
<td>128</td>
</tr>
<tr>
<td>G-2.4</td>
<td>1°</td>
<td>1,4 @ 2.20</td>
<td>16,000 (71,200)</td>
<td>141</td>
<td>142</td>
<td></td>
<td>142</td>
<td>142</td>
<td>141</td>
<td>142</td>
<td>140</td>
<td>129</td>
</tr>
<tr>
<td>G-2.6</td>
<td>23°</td>
<td>1,4 @ 1.59</td>
<td>9,100 (40,500)</td>
<td>135</td>
<td>135</td>
<td></td>
<td>135</td>
<td>135</td>
<td>131</td>
<td>132</td>
<td>130</td>
<td>128</td>
</tr>
<tr>
<td>G-2.7</td>
<td>23°</td>
<td>1,4 @ 1.88</td>
<td>12,500 (55,600)</td>
<td>139</td>
<td>139</td>
<td></td>
<td>140</td>
<td>140</td>
<td>137</td>
<td>138</td>
<td>136</td>
<td>128</td>
</tr>
<tr>
<td>G-2.8</td>
<td>22°</td>
<td>1,4 @ 2.19</td>
<td>15,900 (70,700)</td>
<td>142</td>
<td>143</td>
<td></td>
<td>144</td>
<td>144</td>
<td>141</td>
<td>143</td>
<td>140</td>
<td>130</td>
</tr>
<tr>
<td>G-2.10</td>
<td>47°</td>
<td>1,4 @ 1.58</td>
<td>9,000 (40,000)</td>
<td>134</td>
<td>134</td>
<td></td>
<td>133</td>
<td>135</td>
<td>128</td>
<td>130</td>
<td>129</td>
<td>127</td>
</tr>
<tr>
<td>G-3.1</td>
<td>23°</td>
<td>2,3 @ 1.90</td>
<td>12,800 (56,900)</td>
<td>(d)</td>
<td>146</td>
<td></td>
<td>144</td>
<td>143</td>
<td>138</td>
<td>139</td>
<td>134</td>
<td>132</td>
</tr>
<tr>
<td>G-3.2</td>
<td>24°</td>
<td>2,3 @ 2.20</td>
<td>16,000 (71,200)</td>
<td>150</td>
<td>151</td>
<td></td>
<td>149</td>
<td>148</td>
<td>144</td>
<td>145</td>
<td>142</td>
<td>133</td>
</tr>
<tr>
<td>G-3.4</td>
<td>1°</td>
<td>2,3 @ 2.19</td>
<td>15,900 (70,700)</td>
<td>150</td>
<td>(d)</td>
<td></td>
<td>147</td>
<td>146</td>
<td>143</td>
<td>142</td>
<td>131</td>
<td></td>
</tr>
<tr>
<td>G-4</td>
<td>48°</td>
<td>1,2,3,4 @ 2.20</td>
<td></td>
<td>149</td>
<td>148</td>
<td>148</td>
<td>143</td>
<td>148</td>
<td>144</td>
<td>145</td>
<td>145</td>
<td>136</td>
</tr>
</tbody>
</table>

INSTRUMENTATION SYSTEM BACKGROUND LEVELS (POST FLIGHT)

<table>
<thead>
<tr>
<th>MIC 1</th>
<th>MIC 2</th>
<th>MIC 3</th>
<th>MIC 4</th>
<th>MIC 5</th>
<th>MIC 6</th>
<th>MIC 7</th>
<th>MIC 8</th>
<th>MIC 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>108</td>
<td>107</td>
<td>107</td>
<td>106</td>
<td>107</td>
<td>105</td>
<td>105</td>
<td>113</td>
<td>109</td>
</tr>
</tbody>
</table>

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.
| TEST NO. | FLAP ANGLE | ENGINE NO. @ EPR<sup>d</sup> | THRUST<sup>a</sup> LBS (N) | 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)             | 136  | 121  | 137  | 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  |
| 22°      | 2,3 @ 1.85 | 12,200 (54,300)            | 146  | 147  | 144  | 143  | 144  | 140  | 140  | 138  | 131  |
| G-3.1    | 22°        | 2,3 @ 2.21                 | 16,100 (71,600)           | 150  | 152  | 149  | 149  | 149  | 145  | 145  | 142  | 133  |
| G-3.2    | 22°        | 2,3 @ 2.21                 | 16,100 (71,600)           | 150  | 152  | 149  | 149  | 149  | 145  | 145  | 142  | 133  |
| G-4      | 46°        | 1,2,3,4 @ 1.60             | 9,200 (40,900)            | 144  | 143  | 142  | 142  | 142  | 137  | 138  | 136  | 134  |

**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 22. Exterior Fuselage Noise Levels — All Engines Operating — Microphone 8
Figure 23. Exterior Fuselage Noise Levels — All Engines Operating — Microphone 9
JT8D-17 ENGINE INSTALLED, NORMAL BLEED AVERAGE OF 4 ENGINES

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 $38 \log F/\delta$ 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 $OASPL = K + N \log F/\delta$ 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
Figure 26. Exterior Fuselage Noise Levels – 24-Deg Flaps – 16,400 Pounds Thrust
Figure 27. Exterior Fuselage Noise Levels – 46-Deg Flaps – 6,400 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, 46° FLAP
▽ INDICATES TRANSDUCERS NO. 25 - 29, INTERIOR MICROPHONES, SLIDEBAR
EXTERIOR FLUSH MOUNTED TRANSDUCER NO. 9 (○) IS LOCATED AT
FUSELAGE STATION Y+415.000 AND 4.5 INCHES ABOVE L13.
Figure 2. Exterior Fuselage Noise Levels - Two Versus Four Engines - Microphone 2

Overall Sound Pressure Level, db re 20μPa
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
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 $38 \log \frac{F}{\delta}$ 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
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

<table>
<thead>
<tr>
<th>TEST NO.</th>
<th>FLAP ANGLE</th>
<th>ENGINE NO. C @ EPR</th>
<th>THRUST LBS (N)</th>
<th>ACCELEROMETER - dB re $10^{-5}$ m/sec²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ACC 11</td>
</tr>
<tr>
<td>G-1.1</td>
<td>1°</td>
<td>1,2,3,4 @ 1.05</td>
<td>1,000 (4400)</td>
<td>128</td>
</tr>
<tr>
<td>G-1.2</td>
<td>1°</td>
<td>1,2,3,4 @ 1.59</td>
<td>9,100 (40,500)</td>
<td>130</td>
</tr>
<tr>
<td>G-1.3</td>
<td>1°</td>
<td>1,2,3,4 @ 1.89</td>
<td>12,600 (56,000)</td>
<td>132</td>
</tr>
<tr>
<td>G-1.4</td>
<td>1°</td>
<td>1,2,3,4 @ 2.21</td>
<td>16,200 (72,000)</td>
<td>134</td>
</tr>
<tr>
<td>G-1.5</td>
<td>23°</td>
<td>1,2,3,4 @ 1.06</td>
<td>1,000 (4400)</td>
<td>126</td>
</tr>
<tr>
<td>G-1.6</td>
<td>23°</td>
<td>1,2,3,4 @ 1.59</td>
<td>9,100 (40,500)</td>
<td>129</td>
</tr>
<tr>
<td>G-1.7</td>
<td>23°</td>
<td>1,2,3,4 @ 2.21</td>
<td>16,400 (72,900)</td>
<td>135</td>
</tr>
<tr>
<td>G-1.8</td>
<td>46°</td>
<td>1,2,3,4 @ 1.06</td>
<td>1,000 (4400)</td>
<td>125</td>
</tr>
<tr>
<td>G-1.9</td>
<td>47°</td>
<td>1,2,3,4 @ 1.39</td>
<td>6,400 (28,500)</td>
<td>126</td>
</tr>
<tr>
<td>G-2.2</td>
<td>1°</td>
<td>1,4 @ 1.57</td>
<td>8,900 (39,600)</td>
<td>(a)</td>
</tr>
<tr>
<td>G-2.3</td>
<td>1°</td>
<td>1,4 @ 1.89</td>
<td>12,600 (56,000)</td>
<td>129</td>
</tr>
<tr>
<td>G-2.4</td>
<td>1°</td>
<td>1,4 @ 2.20</td>
<td>16,000 (71,200)</td>
<td>131</td>
</tr>
<tr>
<td>G-2.6</td>
<td>23°</td>
<td>1,4 @ 1.59</td>
<td>9,100 (40,500)</td>
<td>129</td>
</tr>
<tr>
<td>G-2.7</td>
<td>23°</td>
<td>1,4 @ 1.88</td>
<td>12,500 (55,600)</td>
<td>130</td>
</tr>
<tr>
<td>G-2.8</td>
<td>23°</td>
<td>1,4 @ 2.19</td>
<td>15,900 (70,700)</td>
<td>131</td>
</tr>
<tr>
<td>G-2.10</td>
<td>47°</td>
<td>1,4 @ 1.58</td>
<td>9,000 (40,000)</td>
<td>128</td>
</tr>
<tr>
<td>G-3.1</td>
<td>23°</td>
<td>2,3 @ 1.90</td>
<td>12,800 (56,900)</td>
<td>131</td>
</tr>
<tr>
<td>G-3.2</td>
<td>24°</td>
<td>2,3 @ 2.20</td>
<td>16,000 (71,200)</td>
<td>134</td>
</tr>
<tr>
<td>G-3.4</td>
<td>1°</td>
<td>2,3 @ 2.19</td>
<td>15,900 (70,700)</td>
<td>133</td>
</tr>
<tr>
<td>G-4</td>
<td>48°</td>
<td>1,2,3,4 @ 2.20</td>
<td></td>
<td>134</td>
</tr>
</tbody>
</table>

**INSTRUMENTATION SYSTEM BACKGROUND LEVELS (POST FLIGHT)**

<table>
<thead>
<tr>
<th></th>
<th>107</th>
<th>111</th>
<th>114</th>
<th>115</th>
<th>113</th>
<th>105</th>
<th>111</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**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/6 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 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

<table>
<thead>
<tr>
<th>TEST NO.</th>
<th>FLAP ANGLE</th>
<th>ENGINE NO. b @ EPR</th>
<th>THRUST c LBS (N)</th>
<th>MIC 21</th>
<th>MIC 22</th>
<th>MIC 23</th>
<th>MIC 24</th>
<th>MIC 25</th>
<th>MIC 26</th>
<th>MIC 27</th>
<th>MIC 28</th>
<th>MIC 29</th>
</tr>
</thead>
<tbody>
<tr>
<td>G-1.1</td>
<td>1°</td>
<td>1,2,3,4 @ 1.05</td>
<td>1,000 (4400)</td>
<td>104</td>
<td>99</td>
<td>100</td>
<td>98</td>
<td>105</td>
<td>104</td>
<td>104</td>
<td>105</td>
<td>106</td>
</tr>
<tr>
<td>G-1.2</td>
<td>1°</td>
<td>1,2,3,4 @ 1.59</td>
<td>9,100 (40,500)</td>
<td>119</td>
<td>116</td>
<td>117</td>
<td>116</td>
<td>121</td>
<td>121</td>
<td>122</td>
<td>122</td>
<td>119</td>
</tr>
<tr>
<td>G-1.3</td>
<td>1°</td>
<td>1,2,3,4 @ 1.89</td>
<td>12,600 (56,000)</td>
<td>124</td>
<td>121</td>
<td>122</td>
<td>121</td>
<td>126</td>
<td>126</td>
<td>127</td>
<td>128</td>
<td>124</td>
</tr>
<tr>
<td>G-1.4</td>
<td>1°</td>
<td>1,2,3,4 @ 2.21</td>
<td>16,200 (72,000)</td>
<td>128</td>
<td>124</td>
<td>126</td>
<td>125</td>
<td>130</td>
<td>130</td>
<td>131</td>
<td>132</td>
<td>129</td>
</tr>
<tr>
<td>G-1.5</td>
<td>23°</td>
<td>1,2,3,4 @ 1.05</td>
<td>1,000 (4400)</td>
<td>103</td>
<td>99</td>
<td>101</td>
<td>99</td>
<td>104</td>
<td>104</td>
<td>104</td>
<td>103</td>
<td>110</td>
</tr>
<tr>
<td>G-1.6</td>
<td>23°</td>
<td>1,2,3,4 @ 1.59</td>
<td>9,100 (40,500)</td>
<td>121</td>
<td>117</td>
<td>119</td>
<td>117</td>
<td>123</td>
<td>123</td>
<td>124</td>
<td>123</td>
<td>121</td>
</tr>
<tr>
<td>G-1.7</td>
<td>23°</td>
<td>1,2,3,4 @ 1.90</td>
<td>12,800 (56,900)</td>
<td>125</td>
<td>122</td>
<td>124</td>
<td>122</td>
<td>128</td>
<td>129</td>
<td>128</td>
<td>128</td>
<td>126</td>
</tr>
<tr>
<td>G-1.8</td>
<td>23°</td>
<td>1,2,3,4 @ 2.21</td>
<td>16,400 (72,900)</td>
<td>129</td>
<td>126</td>
<td>127</td>
<td>126</td>
<td>131</td>
<td>131</td>
<td>132</td>
<td>132</td>
<td>130</td>
</tr>
<tr>
<td>G-1.9</td>
<td>46°</td>
<td>1,2,3,4 @ 1.06</td>
<td>1,000 (4400)</td>
<td>104</td>
<td>99</td>
<td>100</td>
<td>99</td>
<td>105</td>
<td>104</td>
<td>103</td>
<td>103</td>
<td>(a)</td>
</tr>
<tr>
<td>G-1.10</td>
<td>47°</td>
<td>1,2,3,4 @ 1.39</td>
<td>6,400 (28,500)</td>
<td>118</td>
<td>114</td>
<td>115</td>
<td>114</td>
<td>119</td>
<td>120</td>
<td>121</td>
<td>121</td>
<td>118</td>
</tr>
<tr>
<td>G-2.2</td>
<td>1°</td>
<td>1,4 @ 1.57</td>
<td>8,900 (39,600)</td>
<td>118</td>
<td>111</td>
<td>112</td>
<td>112</td>
<td>115</td>
<td>116</td>
<td>118</td>
<td>118</td>
<td>115</td>
</tr>
<tr>
<td>G-2.3</td>
<td>1°</td>
<td>1,4 @ 1.89</td>
<td>12,600 (56,000)</td>
<td>118</td>
<td>116</td>
<td>117</td>
<td>117</td>
<td>120</td>
<td>121</td>
<td>123</td>
<td>123</td>
<td>120</td>
</tr>
<tr>
<td>G-2.4</td>
<td>1°</td>
<td>1,4 @ 2.20</td>
<td>16,000 (71,200)</td>
<td>122</td>
<td>120</td>
<td>121</td>
<td>121</td>
<td>123</td>
<td>124</td>
<td>127</td>
<td>124</td>
<td>127</td>
</tr>
<tr>
<td>G-2.6</td>
<td>23°</td>
<td>1,4 @ 1.59</td>
<td>9,100 (40,200)</td>
<td>116</td>
<td>112</td>
<td>114</td>
<td>113</td>
<td>117</td>
<td>118</td>
<td>119</td>
<td>119</td>
<td>117</td>
</tr>
<tr>
<td>G-2.7</td>
<td>23°</td>
<td>1,4 @ 1.88</td>
<td>12,500 (55,600)</td>
<td>120</td>
<td>117</td>
<td>118</td>
<td>118</td>
<td>121</td>
<td>122</td>
<td>124</td>
<td>124</td>
<td>122</td>
</tr>
<tr>
<td>G-2.8</td>
<td>22°</td>
<td>1,4 @ 2.19</td>
<td>15,900 (70,700)</td>
<td>124</td>
<td>121</td>
<td>122</td>
<td>122</td>
<td>125</td>
<td>126</td>
<td>128</td>
<td>128</td>
<td>126</td>
</tr>
<tr>
<td>G-2.10</td>
<td>47°</td>
<td>1,4 @ 1.58</td>
<td>9,000 (40,000)</td>
<td>116</td>
<td>113</td>
<td>114</td>
<td>113</td>
<td>118</td>
<td>119</td>
<td>119</td>
<td>119</td>
<td>117</td>
</tr>
<tr>
<td>G-3.1</td>
<td>23°</td>
<td>2,3 @ 1.90</td>
<td>12,800 (56,900)</td>
<td>124</td>
<td>121</td>
<td>122</td>
<td>126</td>
<td>127</td>
<td>124</td>
<td>123</td>
<td>121</td>
<td></td>
</tr>
<tr>
<td>G-3.2</td>
<td>24°</td>
<td>2,3 @ 2.20</td>
<td>16,000 (71,200)</td>
<td>127</td>
<td>125</td>
<td>126</td>
<td>125</td>
<td>130</td>
<td>130</td>
<td>131</td>
<td>130</td>
<td>128</td>
</tr>
<tr>
<td>G-3.4</td>
<td>1°</td>
<td>2,3 @ 2.19</td>
<td>15,900 (70,700)</td>
<td>124</td>
<td>120</td>
<td>121</td>
<td>120</td>
<td>127</td>
<td>127</td>
<td>127</td>
<td>124</td>
<td>124</td>
</tr>
<tr>
<td>G-4</td>
<td>48°</td>
<td>1,2,3,4 @ 2.20</td>
<td>124</td>
<td>126</td>
<td>127</td>
<td>125</td>
<td>131</td>
<td>131</td>
<td>132</td>
<td>132</td>
<td>130</td>
<td></td>
</tr>
</tbody>
</table>

**INSTRUMENTATION SYSTEM BACKGROUND LEVELS**  
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 63. Exterior and Interior Containline 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

<table>
<thead>
<tr>
<th>TEST NO.</th>
<th>ALTITUDE (FT/m)</th>
<th>SPEED (m/sec)</th>
<th>FLAP ANGLE</th>
<th>ENGINE NO. C</th>
<th>MIC 1</th>
<th>MIC 2</th>
<th>MIC 3</th>
<th>MIC 4</th>
<th>MIC 5</th>
<th>MIC 6</th>
<th>MIC 7</th>
<th>MIC 8</th>
<th>MIC 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-1 Field</td>
<td>0</td>
<td>23°</td>
<td>1,2,3,4 @ 2.20 (a)</td>
<td>(a) 151</td>
<td>149</td>
<td>149</td>
<td>149</td>
<td>146</td>
<td>146</td>
<td>143</td>
<td>134</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F-2 Field</td>
<td>0</td>
<td>24°</td>
<td>1,2,4 @ 2.20 (a)</td>
<td>(a) 140</td>
<td>(b) 139</td>
<td>141</td>
<td>135</td>
<td>140</td>
<td>135</td>
<td>127</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F-3 Approach</td>
<td>85 (44)</td>
<td>48°</td>
<td>1,2,3,4 @ 1.60 (b)</td>
<td>142</td>
<td>142</td>
<td>140</td>
<td>141</td>
<td>139</td>
<td>134</td>
<td>138</td>
<td>132</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F-4 Approach</td>
<td>85 (44)</td>
<td>41°</td>
<td>1,2,4 @ 2.10 (b)</td>
<td>137</td>
<td>138</td>
<td>136</td>
<td>138</td>
<td>139</td>
<td>138</td>
<td>135</td>
<td>128</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F-5.1 18,022 (5493)</td>
<td>195 (101)</td>
<td>1°</td>
<td>1,2,3,4 @ 1.42 (b)</td>
<td>134</td>
<td>133</td>
<td>131</td>
<td>130</td>
<td>127</td>
<td>128</td>
<td>125</td>
<td>129</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F-5.2 17,897 (5455)</td>
<td>239 (123)</td>
<td>1°</td>
<td>1,2,3,4 @ 1.53 (b)</td>
<td>136</td>
<td>136</td>
<td>134</td>
<td>133</td>
<td>131</td>
<td>131</td>
<td>129</td>
<td>129</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F-5.3 17,908 (5458)</td>
<td>280 (144)</td>
<td>2°</td>
<td>1,2,3,4 @ 1.66 (b)</td>
<td>138</td>
<td>139</td>
<td>137</td>
<td>136</td>
<td>133</td>
<td>134</td>
<td>132</td>
<td>130</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F-5.4 17,883 (5451)</td>
<td>331 (171)</td>
<td>1°</td>
<td>1,2,3,4 @ 1.89 (b)</td>
<td>144</td>
<td>144</td>
<td>144</td>
<td>142</td>
<td>143</td>
<td>140</td>
<td>139</td>
<td>137</td>
<td>133</td>
<td></td>
</tr>
<tr>
<td>F-6 Go Around</td>
<td>100 (51)</td>
<td>48°</td>
<td>1,2,3,4 @ 1.40 (a)</td>
<td>(a) 137</td>
<td>(b) 135</td>
<td>136</td>
<td>136</td>
<td>128</td>
<td>132</td>
<td>130</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F-7.1 29,813 (9087)</td>
<td>248 (128)</td>
<td>3°</td>
<td>1,2,3,4 @ 2.01 (a)</td>
<td>(a) 140</td>
<td>138</td>
<td>138</td>
<td>133</td>
<td>134</td>
<td>131</td>
<td>128</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F-7.2 29,813 (9087)</td>
<td>248 (128)</td>
<td>3°</td>
<td>1,2,3,4 @ 2.01</td>
<td>141</td>
<td>140</td>
<td>138</td>
<td>139</td>
<td>134</td>
<td>134</td>
<td>131</td>
<td>128</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F-7.3 29,813 (9087)</td>
<td>248 (128)</td>
<td>3°</td>
<td>1,2,3,4 @ 2.01</td>
<td>140</td>
<td>140</td>
<td>138</td>
<td>138</td>
<td>133</td>
<td>134</td>
<td>131</td>
<td>128</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F-7.4 29,813 (9087)</td>
<td>248 (128)</td>
<td>3°</td>
<td>1,2,3,4 @ 2.01</td>
<td>140</td>
<td>140</td>
<td>138</td>
<td>138</td>
<td>133</td>
<td>134</td>
<td>131</td>
<td>128</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F-8 29,813 (9087)</td>
<td>248 (128)</td>
<td>3°</td>
<td>1,2,3,4 @ flight</td>
<td>129</td>
<td>132</td>
<td>129</td>
<td>128</td>
<td>129</td>
<td>128</td>
<td>127</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**INSTRUMENTATION SYSTEM BACKGROUND LEVELS (POST FLIGHT)**

|          | Idle          | 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. | ALTIMETER FT (m) | SPEED KEAS (m/sec) | FLAP ANGLE | ENGINE No. \(^a\) | 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        | 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)**

<table>
<thead>
<tr>
<th>MIC 1</th>
<th>MIC 2</th>
<th>MIC 3</th>
<th>MIC 4</th>
<th>MIC 5</th>
<th>MIC 6</th>
<th>MIC 7</th>
<th>MIC 8</th>
<th>MIC 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>105</td>
<td>111</td>
<td>108</td>
<td>108</td>
<td>113</td>
<td>111</td>
<td>113</td>
<td>108</td>
<td>115</td>
</tr>
</tbody>
</table>

**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

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Mic 1</th>
<th>Mic 2</th>
<th>Mic 3</th>
<th>Mic 4</th>
<th>Mic 5</th>
<th>Mic 6</th>
<th>Mic 7</th>
<th>Mic 8</th>
<th>Mic 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-1</td>
<td>--</td>
<td>+1</td>
<td>0</td>
<td>--</td>
<td>+1</td>
<td>+1</td>
<td>+1</td>
<td>+1</td>
<td>+8</td>
</tr>
<tr>
<td>F-5.1</td>
<td>+2</td>
<td>+2</td>
<td>+1</td>
<td>--</td>
<td>+1</td>
<td>+5</td>
<td>0</td>
<td>+1</td>
<td>+1</td>
</tr>
<tr>
<td>F-5.2</td>
<td>-1</td>
<td>+2</td>
<td>-4</td>
<td>--</td>
<td>+2</td>
<td>+1</td>
<td>0</td>
<td>+1</td>
<td>+2</td>
</tr>
<tr>
<td>F-5.3</td>
<td>+2</td>
<td>+1</td>
<td>+1</td>
<td>+2</td>
<td>+2</td>
<td>+2</td>
<td>0</td>
<td>+1</td>
<td>+1</td>
</tr>
<tr>
<td>F-5.4</td>
<td>0</td>
<td>+1</td>
<td>-1</td>
<td>+1</td>
<td>+1</td>
<td>0</td>
<td>0</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>F-7.1</td>
<td>--</td>
<td>0</td>
<td>--</td>
<td>--</td>
<td>+1</td>
<td>+1</td>
<td>0</td>
<td>0</td>
<td>+1</td>
</tr>
</tbody>
</table>

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

-- Lack of data
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>
<thead>
<tr>
<th>TEST NO.</th>
<th>ALTITUDE (FT (m))</th>
<th>SPEED (KEAS (m/sec))</th>
<th>FLAP ANGLE</th>
<th>ENGINE @ EPR</th>
<th>ACCELEROMETER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>11</td>
</tr>
<tr>
<td>F-1</td>
<td>Field</td>
<td>0</td>
<td>23°</td>
<td>1,2,3,4 @ 2.20</td>
<td>134</td>
</tr>
<tr>
<td>F-2</td>
<td>Field</td>
<td>0</td>
<td>24°</td>
<td>1,2,4 @ 2.20</td>
<td>132</td>
</tr>
<tr>
<td>F-3</td>
<td>Approach</td>
<td>85 (44)</td>
<td>48°</td>
<td>1,2,3,4 @ 1.60</td>
<td>131</td>
</tr>
<tr>
<td>F-4</td>
<td>Approach</td>
<td>85 (44)</td>
<td>41°</td>
<td>1,2,3,4 @ 2.10</td>
<td>131</td>
</tr>
<tr>
<td>F-5.1</td>
<td>18,022 (5493)</td>
<td>196 (101)</td>
<td>1°</td>
<td>1,2,3,4 @ 2.20</td>
<td>126</td>
</tr>
<tr>
<td>F-5.2</td>
<td>17,897 (5455)</td>
<td>239 (123)</td>
<td>1°</td>
<td>1,2,3,4 @ 1.53</td>
<td>126</td>
</tr>
<tr>
<td>F-5.3</td>
<td>17,908 (5458)</td>
<td>280 (144)</td>
<td>2°</td>
<td>1,2,3,4 @ 1.66</td>
<td>126</td>
</tr>
<tr>
<td>F-5.4</td>
<td>17,883 (5451)</td>
<td>331 (171)</td>
<td>1°</td>
<td>1,2,3,4 @ 1.89</td>
<td>128</td>
</tr>
<tr>
<td>F-6</td>
<td>Go around</td>
<td>100 (52)</td>
<td>48°</td>
<td>1,2,3,4 @ 1.40</td>
<td>129</td>
</tr>
<tr>
<td></td>
<td>Approach</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F-7.1</td>
<td>29,813 (9087)</td>
<td>248 (128)</td>
<td>3°</td>
<td>1,2,3,4 @ 2.01</td>
<td>125</td>
</tr>
<tr>
<td>F-7.2</td>
<td>29,813 (9087)</td>
<td>248 (128)</td>
<td>3°</td>
<td>1,2,3,4 @ 2.01</td>
<td>125</td>
</tr>
<tr>
<td>F-7.3</td>
<td>29,813 (9087)</td>
<td>248 (128)</td>
<td>3°</td>
<td>1,2,3,4 @ 2.01</td>
<td>124</td>
</tr>
<tr>
<td>F-7.4</td>
<td>29,813 (9087)</td>
<td>248 (128)</td>
<td>3°</td>
<td>1,2,3,4 @ 2.01</td>
<td>125</td>
</tr>
<tr>
<td>F-8</td>
<td>29,813 (9087)</td>
<td>248 (128)</td>
<td>3°</td>
<td>1,2,3,4 @ Idle</td>
<td>120</td>
</tr>
</tbody>
</table>

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

**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>
<thead>
<tr>
<th>TEST NO.</th>
<th>ALTITUDE (FT (m))</th>
<th>SPEED KEAS (m/sec)</th>
<th>FLAP ANGLE</th>
<th>ENGINE No. @ EPR</th>
<th>MIC 21</th>
<th>MIC 22</th>
<th>MIC 23</th>
<th>MIC 24</th>
<th>MIC 25</th>
<th>MIC 26</th>
<th>MIC 27</th>
<th>MIC 28</th>
<th>MIC 29</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-1 Field</td>
<td>0</td>
<td>23°</td>
<td>1,2,3,4 @ 2.20</td>
<td>128</td>
<td>125</td>
<td>127</td>
<td>125</td>
<td>130</td>
<td>131</td>
<td>131</td>
<td>131</td>
<td>129</td>
<td></td>
</tr>
<tr>
<td>F-2 Field</td>
<td>0</td>
<td>24°</td>
<td>1,2,4 @ 2.20</td>
<td>124</td>
<td>122</td>
<td>123</td>
<td>121</td>
<td>(a)</td>
<td>127</td>
<td>128</td>
<td>128</td>
<td>126</td>
<td></td>
</tr>
<tr>
<td>F-3 Approach</td>
<td>85 (44)</td>
<td>48°</td>
<td>1,2,3,4 @ 1.60</td>
<td>122</td>
<td>118</td>
<td>119</td>
<td>118</td>
<td>124</td>
<td>125</td>
<td>125</td>
<td>125</td>
<td>124</td>
<td></td>
</tr>
<tr>
<td>F-4 Approach</td>
<td>85 (44)</td>
<td>41°</td>
<td>1,2,4 @ 2.10</td>
<td>123</td>
<td>120</td>
<td>122</td>
<td>120</td>
<td>125</td>
<td>126</td>
<td>128</td>
<td>128</td>
<td>126</td>
<td></td>
</tr>
<tr>
<td>F-5.1 18,022 (5493)</td>
<td>195 (101)</td>
<td>1°</td>
<td>1,2,3,4 @ 2.20</td>
<td>109</td>
<td>106</td>
<td>107</td>
<td>105</td>
<td>112</td>
<td>110</td>
<td>112</td>
<td>111</td>
<td>107</td>
<td></td>
</tr>
<tr>
<td>F-5.2 17,897 (5455)</td>
<td>235 (123)</td>
<td>1°</td>
<td>1,2,3,4 @ 1.53</td>
<td>111</td>
<td>109</td>
<td>110</td>
<td>108</td>
<td>113</td>
<td>113</td>
<td>113</td>
<td>110</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F-5.3 17,908 (5458)</td>
<td>280 (144)</td>
<td>2°</td>
<td>1,2,3,4 @ 1.66</td>
<td>114</td>
<td>112</td>
<td>113</td>
<td>112</td>
<td>115</td>
<td>115</td>
<td>117</td>
<td>117</td>
<td>114</td>
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</tr>
<tr>
<td>F-5.4 17,883 (5451)</td>
<td>331 (171)</td>
<td>1°</td>
<td>1,2,3,4 @ 1.89</td>
<td>119</td>
<td>117</td>
<td>119</td>
<td>117</td>
<td>121</td>
<td>121</td>
<td>122</td>
<td>122</td>
<td>119</td>
<td></td>
</tr>
<tr>
<td>F-6 Go Around</td>
<td>100 (51)</td>
<td>48°</td>
<td>1,2,3,4 @ 1.40</td>
<td>118</td>
<td>113</td>
<td>115</td>
<td>113</td>
<td>119</td>
<td>119</td>
<td>120</td>
<td>121</td>
<td>119</td>
<td></td>
</tr>
</tbody>
</table>

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.
<table>
<thead>
<tr>
<th>ONE-THIRD OCTAVE FREQUENCY BAND (Hz)</th>
<th>TAKEOFF MIC 2 - MIC 25 = NR</th>
<th>APPROACH MIC 2 - MIC 25 = NR</th>
<th>CRUISE MIC 2 - MIC 25 = NR</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>130</td>
<td>127</td>
<td>123</td>
</tr>
<tr>
<td>63</td>
<td>130</td>
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<td>80</td>
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<td>127</td>
<td>126</td>
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<tr>
<td>100</td>
<td>132</td>
<td>127</td>
<td>126</td>
</tr>
<tr>
<td>125</td>
<td>130</td>
<td>124</td>
<td>126</td>
</tr>
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<td>160</td>
<td>132</td>
<td>124</td>
<td>127</td>
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<td>200</td>
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<td>127</td>
<td>128</td>
</tr>
<tr>
<td>250</td>
<td>136</td>
<td>129</td>
<td>129</td>
</tr>
<tr>
<td>315</td>
<td>138</td>
<td>130</td>
<td>131</td>
</tr>
<tr>
<td>400</td>
<td>140</td>
<td>130</td>
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<tr>
<td>500</td>
<td>142</td>
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<td>630</td>
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<tr>
<td>800</td>
<td>142</td>
<td>131</td>
<td>133</td>
</tr>
<tr>
<td>1000</td>
<td>141</td>
<td>130</td>
<td>135</td>
</tr>
<tr>
<td>1250</td>
<td>141</td>
<td>130</td>
<td>133</td>
</tr>
<tr>
<td>1600</td>
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<tr>
<td>2500</td>
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<tr>
<td>4000</td>
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<td>6300</td>
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<td>8000</td>
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<td>10000</td>
<td>133</td>
<td>126</td>
<td>129</td>
</tr>
</tbody>
</table>
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 66. 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 \( p^2 = (F/s)^{3.8} \).

(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


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".*

2.1 **Definition of Symbols.**

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

<table>
<thead>
<tr>
<th>Symbols</th>
<th>Definition</th>
<th>Name*</th>
</tr>
</thead>
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<tr>
<td>A</td>
<td>Area, ft²</td>
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</tr>
<tr>
<td>Cₚ</td>
<td>Specific heat at constant pressure, BTU/lb/°R</td>
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</tr>
<tr>
<td>F</td>
<td>Thrust, lb</td>
<td></td>
</tr>
<tr>
<td>F₉g</td>
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</tr>
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<td>Joules constant, 778.26 ft-lb/BTU</td>
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</tr>
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<td>Mach number</td>
<td></td>
</tr>
<tr>
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<td>Absolute pressure, lb/ft²</td>
<td></td>
</tr>
<tr>
<td>q</td>
<td>Dynamic pressure, lb/ft²</td>
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</tr>
<tr>
<td>R</td>
<td>Gas constant, ft²/sec²/°R</td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>Absolute temperature, °R</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>Velocity, ft/sec</td>
<td></td>
</tr>
<tr>
<td>w</td>
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</tr>
<tr>
<td>θ</td>
<td>Relative absolute temperature, static or total, T/T₀</td>
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</tr>
<tr>
<td>γ</td>
<td>Ratio of specific heats</td>
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</tr>
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<td>Definition</td>
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<tr>
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</tr>
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<tr>
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</tr>
<tr>
<td>bl</td>
<td>Bleed</td>
<td></td>
</tr>
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</tr>
<tr>
<td></td>
<td>2. Fuel</td>
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<tr>
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</tr>
<tr>
<td>o</td>
<td>Sea level static (standard)</td>
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</tr>
<tr>
<td>p</td>
<td>Primary (engine)</td>
<td></td>
</tr>
<tr>
<td>t</td>
<td>Total</td>
<td></td>
</tr>
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<td>Station locations referred to engine</td>
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<td>Derived jet parameters assuming an isentropic flow process from the assumed homogeneous state at station 9 to downstream infinity.</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>h</td>
<td>Altitude</td>
<td>GALT</td>
</tr>
<tr>
<td>Pam</td>
<td>Ambient pressure</td>
<td>PAM</td>
</tr>
<tr>
<td>EPR</td>
<td>Engine pressure ratio, P_{t1}/P_{t2}</td>
<td>GEPR</td>
</tr>
<tr>
<td>Tam</td>
<td>Ambient temperature</td>
<td>TAM</td>
</tr>
<tr>
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<td>Total temperature at low pressure compressor and fan inlet, °R</td>
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<td>TT8D</td>
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<tr>
<td>Tt8p</td>
<td>Primary (engine) total temperature at mixing plane, °R</td>
<td>TT8E</td>
</tr>
<tr>
<td>Waf</td>
<td>Fan airflow, lb/sec</td>
<td>WAD</td>
</tr>
<tr>
<td>Wap</td>
<td>Primary (engine) airflow, lb/sec</td>
<td>WAE</td>
</tr>
<tr>
<td>Wf</td>
<td>Engine fuel flow, lb/hr</td>
<td>WF</td>
</tr>
</tbody>
</table>

*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:

\[ V_j^* = \frac{gF_g}{(w_{af8} + w_{ap8})} \] \hspace{1cm} (1)

where $w_{af8} = (w_{af} - w_{b1f})$ and $w_{ap8} = (w_{ap} - w_{b1p} + w_{f})$. 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., $F_g = \frac{(w_{af8} + w_{ap8})}{g} V_j + (P_9 - P_{am}) A_g$) if $P_9 \neq P_{am}$.

*Jet Mach Number Infinitely Far Downstream:

\[ M_j^* = \frac{V_j^*}{\sqrt{\gamma_j R_j T_j}} \left[ \frac{1 - (\gamma_{j-1}) V_j^*}{2\gamma_j R_j T_j} \right]^{-1/2} \] \hspace{1cm} (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:

\[ T_{tj} = \frac{C_{pf8} w_{af8} T_{tf8} + C_{pp8} w_{ap8} T_{tp8}}{C_{pj}(w_{af8} + w_{ap8})} \] \hspace{1cm} (3)

and that from "GIBBS - DALTON" considerations:

\[ C_{pj} = \frac{w_{af8} C_{pf8} + w_{ap8} C_{pp8}}{w_{af8} + w_{ap8}} \] \hspace{1cm} (4)

and

\[ R_j = \frac{R_{f8} w_{af8} + R_{p8} w_{ap8}}{w_{af8} + w_{ap8}} \] \hspace{1cm} (5)

from which $\gamma_j$ is derived, namely:
\[ \gamma_j = \frac{g \Delta \rho_{pj}}{g \Delta \rho_{pj} - R_j} \quad \ldots \ldots \ldots \ldots \quad (6) \]

• Exhaust Nozzle Exit Pressure Ratio:

\[ \frac{P_{t1}}{P_{am}} = \left[ 1 + \frac{\gamma_j-1}{2} M_j^2 \right]^{\gamma_j \gamma_j-1} \quad \ldots \ldots \ldots \ldots \quad (7) \]

• Exhaust Nozzle Exit Mach Number:

\[ M_j = M_j^* \left\{ \begin{array}{ll}
\left( \frac{P_{t1}}{P_{am}} \leq \left( \frac{\gamma_j+1}{2} \right)^{\gamma_j \gamma_j-1} \right) \\
1.0 \left( \frac{P_{t1}}{P_{am}} \geq \left( \frac{\gamma_j+1}{2} \right)^{\gamma_j \gamma_j-1} \right)
\end{array} \right\} \quad \ldots \ldots \ldots \ldots \quad (8) \]

• Exhaust Nozzle Exit Velocity:

\[ V_j = V_j^* \left\{ \begin{array}{ll}
\left( \frac{P_{t1}}{P_{am}} \leq \left( \frac{\gamma_j+1}{2} \right)^{\gamma_j \gamma_j-1} \right) \\
\sqrt{\frac{2 \gamma_j R_j T_j}{\gamma_j+1}} \left( \frac{P_{t1}}{P_{am}} \geq \left( \frac{\gamma_j+1}{2} \right)^{\gamma_j \gamma_j-1} \right)
\end{array} \right\} \quad \ldots \ldots \ldots \ldots \quad (9) \]

• Exhaust Nozzle Exit Dynamic Pressure Ratio:

\[ \frac{q_j}{P_{am}} = \frac{1}{2} \gamma_j M_j^2 \left\{ \begin{array}{ll}
\left( \frac{P_{t1}}{P_{am}} \leq \left( \frac{\gamma_j+1}{2} \right)^{\gamma_j \gamma_j-1} \right) \\
\frac{1}{2} \gamma_j \left( \frac{\gamma_j+1}{2} \right) \left( \frac{P_{t1}}{P_{am}} \geq \left( \frac{\gamma_j+1}{2} \right)^{\gamma_j \gamma_j-1} \right)
\end{array} \right\} \quad \ldots \ldots \ldots \ldots \quad (10) \]

The conventional definition of gross thrust in terms of the "homogeneous" exhaust nozzle exit parameters derived earlier can be calculated from the following equation:
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 $\gamma_j$ is assumed equal to 1.4. Curve number INST 29792 of the Pratt & Whitney JT8D Commercial Installation Handbook illustrates the anticipated variation in $\gamma_j$ as a function of $T_{t2}$ and the overall fuel-air ratio of the JT8D-17. It is important to note here that $\gamma_j$ can vary between 1.37 and 1.402.
### TABLE - TYPICAL PROPULSION SYSTEM PERFORMANCE RELATED PARAMETERS

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<th>ALT ft</th>
<th>M</th>
<th>EPR</th>
<th>F(_g) lb</th>
<th>(w_{af}) lb/sec</th>
<th>(w_{ap}) lb/sec</th>
<th>T(_{tf}) (^{o})R</th>
<th>T(_{tp}) (^{o})R</th>
<th>V(_j)* ft/sec</th>
<th>T(_j)* (^{o})R</th>
<th>M(_j)*</th>
<th>P(<em>{Tj})/P(</em>{am})</th>
<th>M(_j)</th>
<th>V(_j) ft/sec</th>
<th>g(<em>j)/P(</em>{am})</th>
<th>V(_j)*-V(_j^j) ft/sec</th>
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**NOTE:**
- Standard Atmospheric Conditions
- \(V_j\) assumed equal to 1.4

† Aircraft Flight Mach Number and Velocity