NASA TECHNICAL MEMORANDUM NASA TM X-71950

COPY NO.

NASA TM X-71950

(NASA-TM-X-71 50) ACOUSTIC LOADS ON AN EXTERNALLY BL WN FLAP SYSTEM DUE TO IMPINGEMENT A TF-34 JET ENG E EXHAUST (20 p HC $4.00 CSCL 01C N74-20651

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G3/02 35318

ACOUSTIC LOADS ON AN EXTERNALLY BLOWN FLAP SYSTEM DUE TO IMPINGEMENT OF A TF-34 JET ENGINE EXHAUST

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INTRODUCTION

One of the powered lift systems currently being considered for use on STOL vehicles obtains additional lift by impinging the flow of a jet exhaust on the flaps and turning it downward. This direct impingement subjects large areas of the flap to the fluctuating pressure loads of the turbulent jet flow; these loads have the potential for causing high vibration levels and sonic fatigue failures. To obtain data on these fluctuating loads, a cooperative effort between Lewis Research Center and Langley Research Center was undertaken. A test was conducted on a full-scale mockup of an externally blown flap system, which consisted of a TF-34 engine and a section of a wing having a triple-slotted flap. Data were obtained and evaluated on the fluctuating pressures on the flaps and it is the purpose of this paper to present some of the results describing the loads.

OBJECTIVES

MEASURE AND DEFINE THE FLUCTUATING LOADS ON AN EXTERNALLY-BLOWN FLAP SYSTEM DUE TO IMPINGEMENT OF A TF-34 JET ENGINE EXHAUST

Figure 1.-

SCHEMATIC OF TEST SETUP
(Figure 2)

Shown schematically in the figure is a cross-section of the test setup. The flaps are positioned in a typical landing configuration, i.e., the flap angles are 15°, 35°, and 55° relative to the wing chord. The nozzle exit was located at 7.8 percent of the wing chord with the centerline 1.1 exit diameters below the chord plane. The nozzle centerline was directed upwards at an angle of 5° to the chord plane. With the flaps deflected to the landing configuration shown in the sketch, the engine centerline intersected the flaps near the trailing edge of the second flap and the exit to flap distance was about 4.0 exit diameters.

A second test configuration used flap angles of 0°, 20°, and 40° to represent takeoff conditions. The distance between the nozzle and the flaps was 4.5 exit diameters and the engine centerline intersected the 30 percent chord of the third flap.

SCHEMATIC OF TEST SET-UP

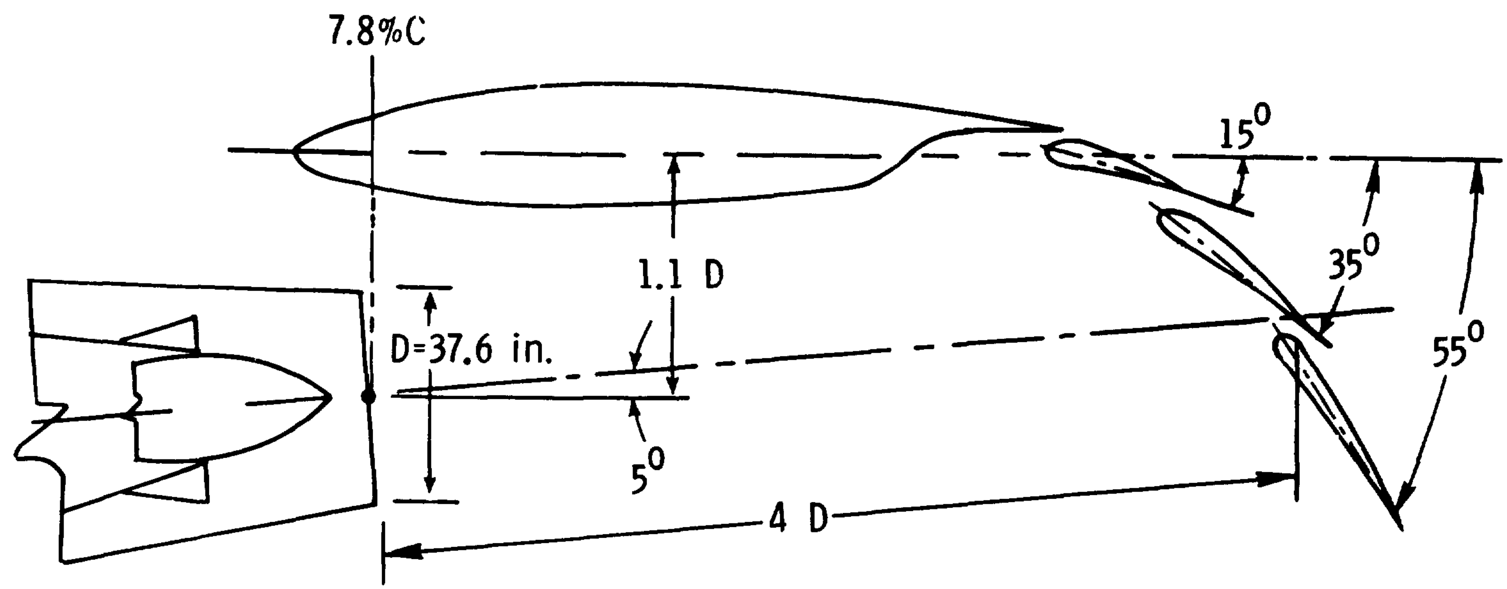


Figure 2.-

TEST ARRANGEMENT
(Figure 3)

For these tests the wing-flap section is rotated 90° from the normal horizontal attitude of the aircraft, thus placing the lower surface, shown in figure 3, in a vertical plane. The fuselage centerline would be located roughly at ground level. To minimize the effects of vibration on the fluctuating pressures, the wing and flaps were of boiler plate construction and were rigidly attached to the ground through the test fixture. Measurements were made at 16 locations: 6 on the second flap and 9 on the third flap as shown by the tape marks. (Three locations cannot be seen on the third flap; two are washed out by the sun and the third one is on the upper surface of the flap.)

The engine is a TF-34 turbofan having a nominal thrust of 7,500 lbs, a nominal by-pass ratio of 6.5, and an average exhaust velocity at nominal thrust of 770 ft/sec. Mounted on the basic engine is an acoustically suppressed ground test nacelle. The exhaust system consists of an internal 12 lobe core mixer nozzle and an external convergent, circular nozzle with an exit diameter of 37.6 inches.

TEST ARRANGEMENT

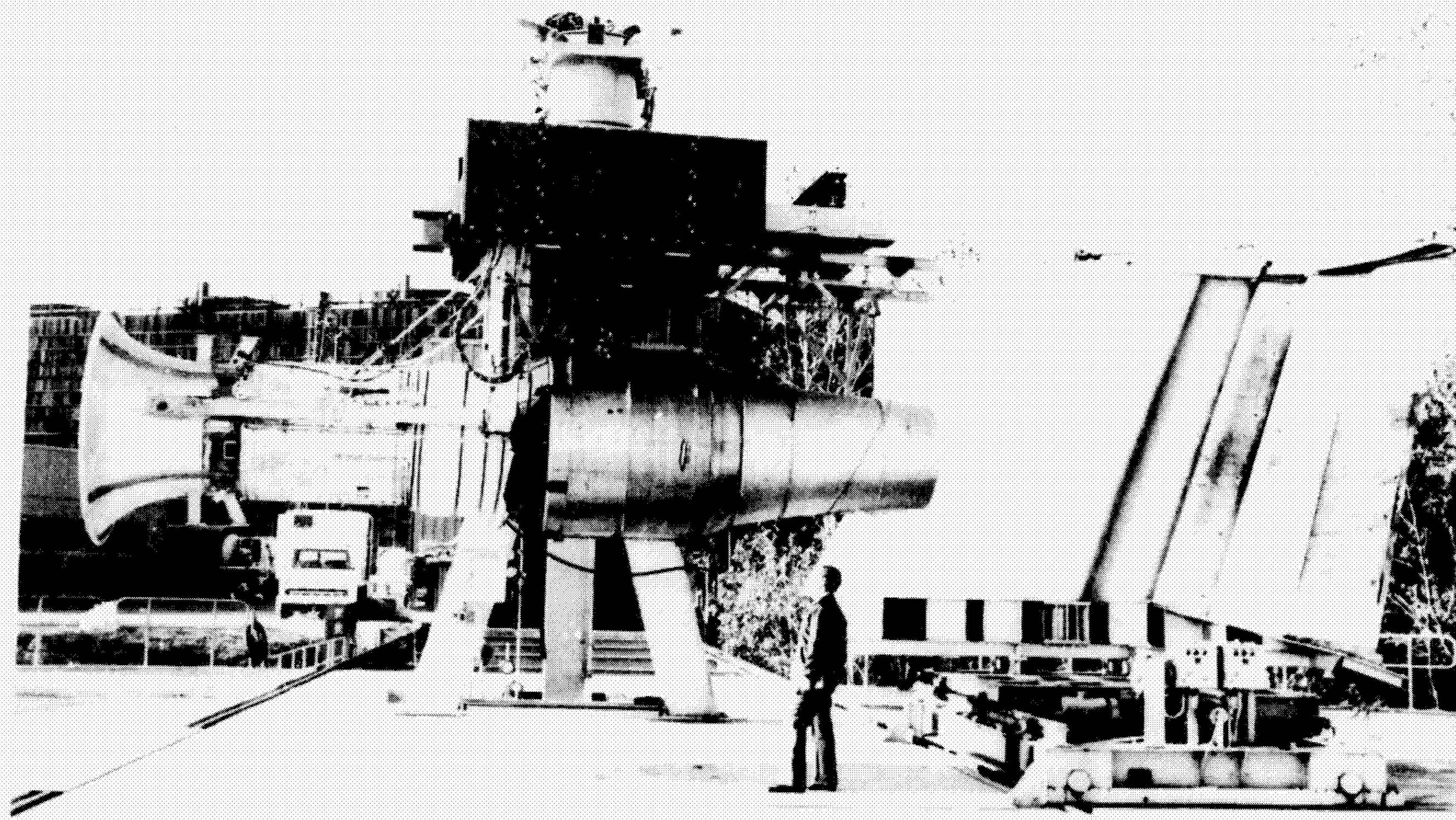


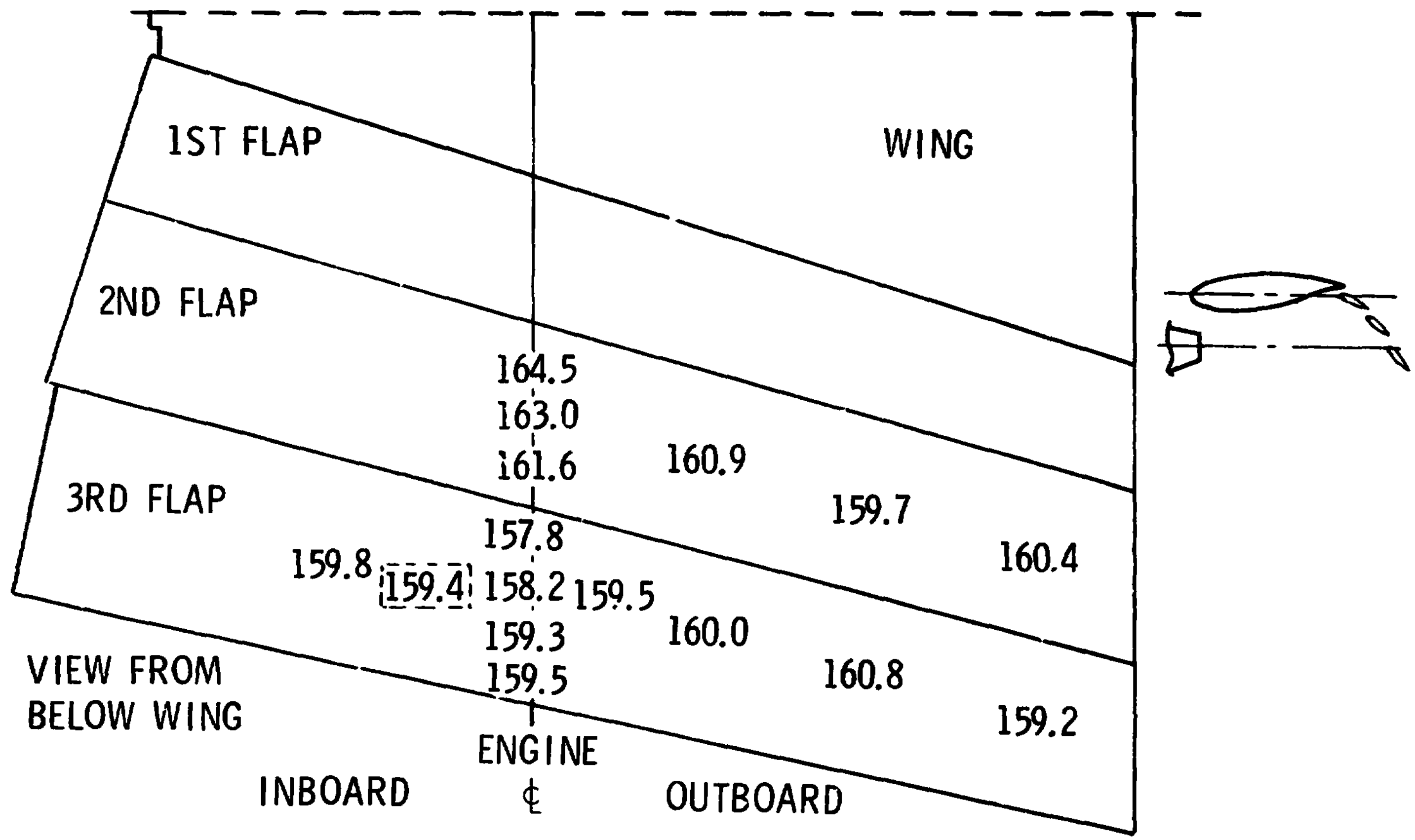
Figure 3.-

OVERALL FLUCTUATING PRESSURES
(Figures 4 and 5)

Figures 4 and 5 present the measured overall sound pressure levels in dB. A sketch at the right side shows a section view of the engine-wing-flap configuration and the view shown in the center is looking at the lower surface of the wing and flaps. The numbers represent the overall dB values and are placed at about the physical location of the transducers. The number in the dashed box represents the fluctuating pressure measured on the upper surface of the third flap. Listed at the lower left are the parameters which describe the test conditions. "Power setting" is the nominal thrust level in pounds, "flap setting" is the flap angles relative to the wing chord. The fluctuating pressures for the landing configuration (fig. 4) range from 164.5 dB at the leading edge of the second flap to 157.8 dB at the leading edge of the third flap, both lying in the vertical plane containing the engine centerline. The maximum level occurs at about a projection (along the engine centerline) of the top edge of the nozzle to the flap. The levels of the outboard measurements (r/D, ratio of distance from engine centerline to exit diameter, of 1.3) are about 5 dB down from the maximum value on the second flap but the levels are about the same (±1 dB) at all locations on the third flap.

OVERALL FLUCTUATING PRESSURES

LANDING



POWER SETTING = 7500
FLAP SETTING = 15-35-55
FLUCTUATING PRESSURE, dB RE 0.0002 μ BAR

Figure 4.-

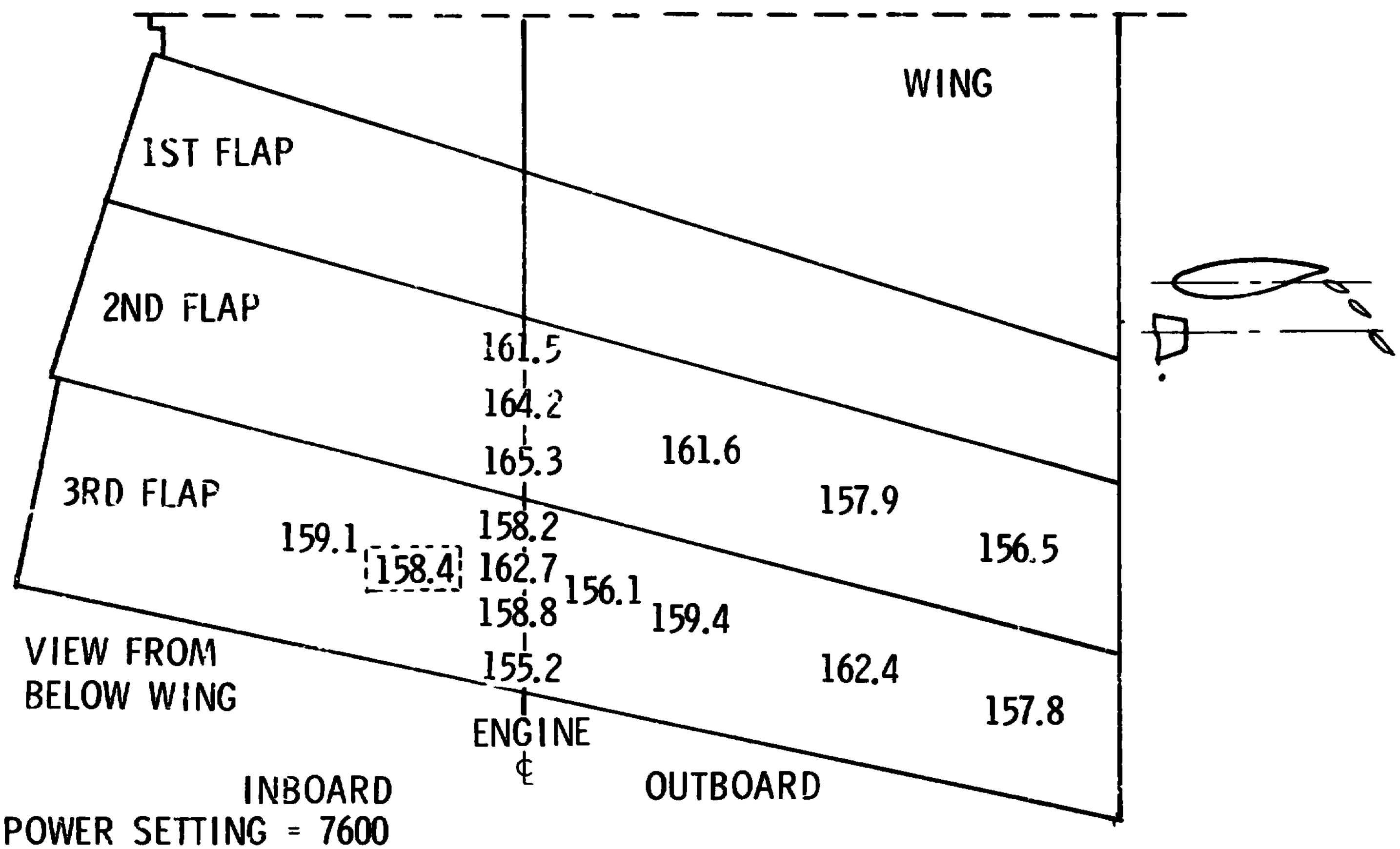
TAKEOFF
(Figure 5)

Figure 5 presents data from the maximum thrust condition and the takeoff flap setting. The fluctuating pressures range from 165.3 dB at the aft edge of the second flap (which also is located at about a projection of the top edge of the nozzle to the flap) to 155.2 dB at the aft edge of the third flap; a range of about 10 dB.

Figures 4 and 5 show that the fluctuating pressures were about the same for both flap settings and were about the same on the upper surface as on a corresponding lower surface location. The maximum level shown on these figures, 165.3 dB corresponds to a value of about 0.2 for the ratio of rms pressure to engine exhaust dynamic pressure. Values of this ratio reported in reference 1 were generally less than 0.15.

OVERALL FLUCTUATING PRESSURES

TAKE-OFF



POWER SETTING = 7600
FLAP SETTING = 0-20-40
FLUCTUATING PRESSURE, dB RE 0.0002 μ BAR

Figure 5.-

POWER SPECTRAL DENSITY VALUES
(Figure 6)

Shown in figure 6 is the power spectral density (PSD) on a log scale versus linear frequency for three locations on the engine centerline plane of the second flap. These spectra are for the takeoff flap configuration and are typical of all the measurements. The overall level variation for these three locations was 4 dB. The peak PSD occurred below 20 Hz for all three transducers. This frequency corresponds to a Strouhal number of less than 0.1, a frequency considerable lower than the 0.5 reported in reference 1. The -8 dB per octave reference line represents the PSD slope very closely from low frequencies to about 500 Hz.

POWER SPECTRAL LEVELS

2ND FLAP, ENGINE ¢

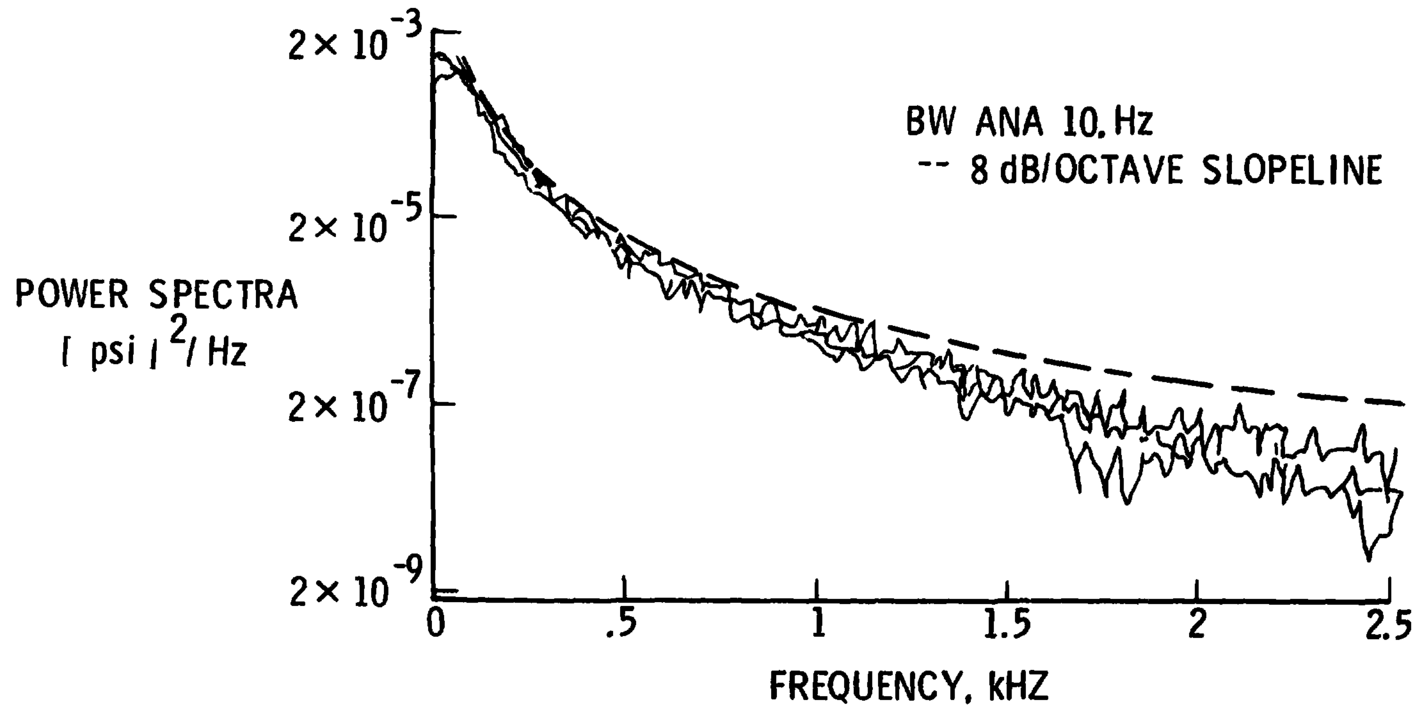


Figure 6.-

EDDY CONVECTION SPEEDS
(Figures 7 and 8)

The eddy convection speed of the turbulent flow on the flaps was obtained by measuring the cross-correlation function between adjacent transducers, determining the time delay, and calculating the velocity. In addition, using both the auto-correlation and cross-correlation functions, the correlation coefficients were calculated. The next two figures show the eddy convection speeds, the direction of this velocity, and the correlation coefficient. Figure 7 presents the results from the landing configuration. Along the plane of the centerline, the convection speeds all proceed from the leading edge of the flap toward the trailing edge at rates equivalent to 0.5 to 0.8 times the jet exhaust velocity. The relatively high correlation coefficients (0.5 to 0.9) particularly on the third flap, indicate that this is the primary "eddy-path." The convection speeds in the spanwise direction are about the same as the chordwise speeds along the engine centerline, with the correlation coefficient also similar. However, the second flap has relatively low correlation coefficients near the centerline which increase as the flow progresses outboard. This suggests that the eddy-paths near the centerline do not parallel the chord lines of the flaps immediately but do become parallel at some distance outboard.

EDDY CONVECTION SPEEDS, FPS

LANDING

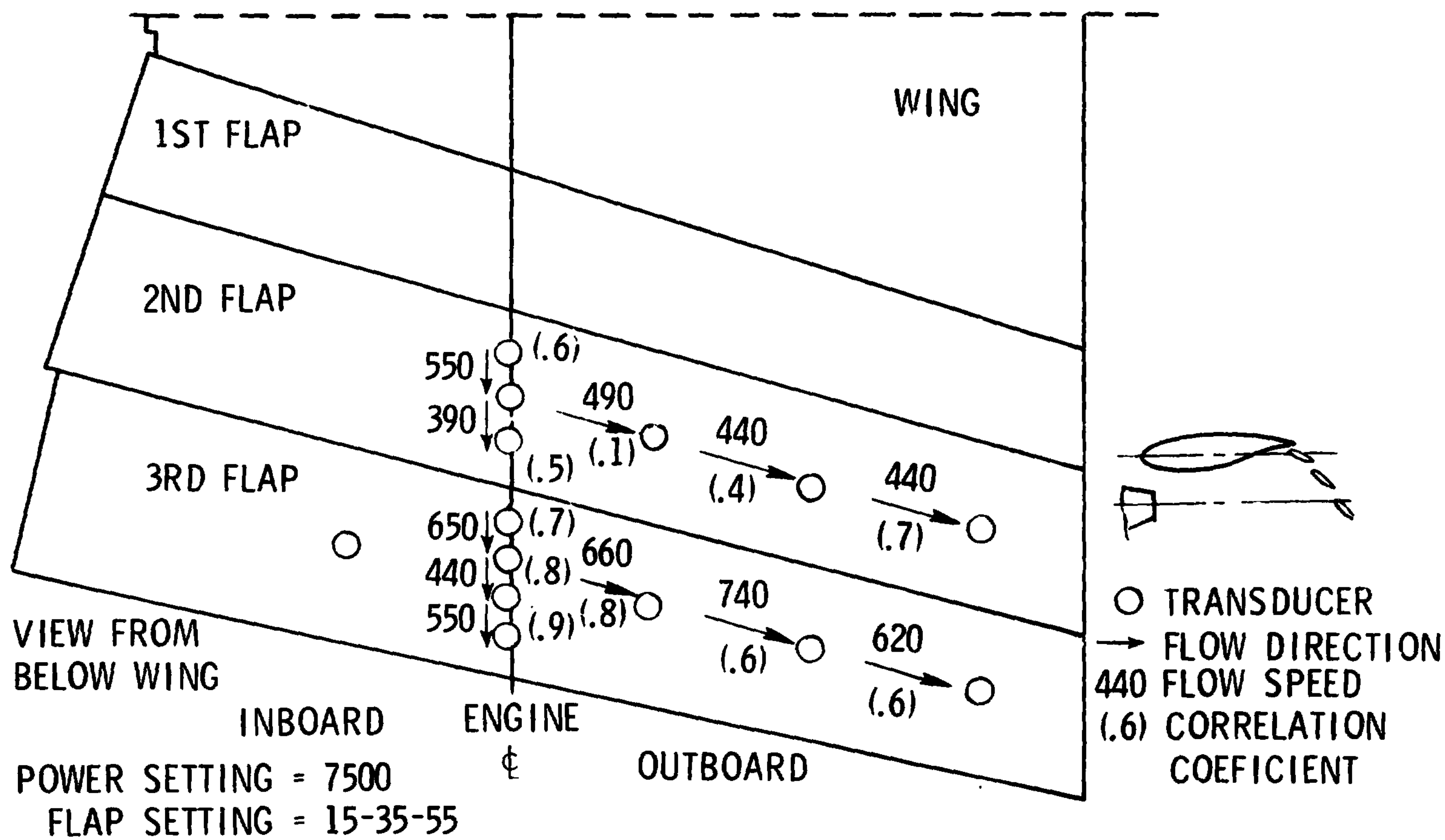


Figure 7.-

TAKEOFF
(Figure 8)

Figure 8 presents the results from the takeoff configuration (see sketch at right of figure). Similar results may be observed in this configuration both for the convective speeds and for the eddy paths on flap 3, however, the correlation coefficients are not as high on flap 2 either along the centerline or along the chordline close to the engine. The correlation coefficient again increased as the flow moved outboard on the flap.

EDDY CONVECTION SPEEDS, FPS

TAKE-OFF

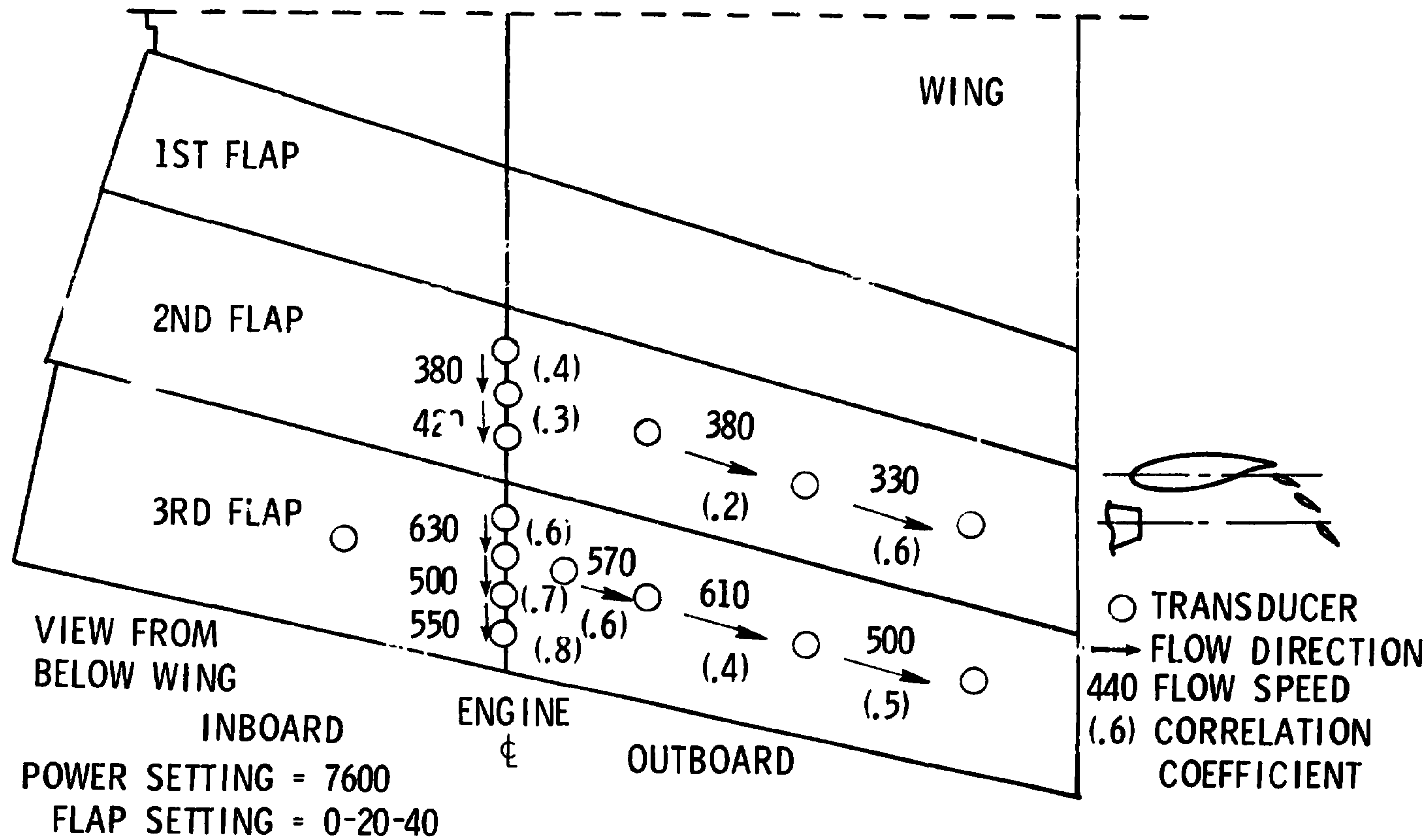


Figure 8.-

CONCLUSIONS

In summary, the loads measured on the flaps of the EBF configuration using a TF-34 engine may be described as follows. The maximum overall pressure level was 165 dB at an engine exhaust velocity of 770 ft/sec at the takeoff flap setting. Typical pressure PSD peaked at frequencies below 20 Hz and had a -8 dB/octave slope with increasing frequency. The eddy current speeds ranged from 0.4 to 0.9 times the engine exhaust velocities and the eddy paths, as indicated by the correlation coefficients, were from the leading edge of the flap to the trailing edge of the flap for locations directly behind the engine.

REFERENCE

1. Lansing, Donald L.; Mixson, John S.; Brown, Thomas J.; and Drischler, Joseph A.: Externally Blown Flap Dynamic Loads. STOL Technology, NASA SP-230, 1972.

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
TM X-71950		

4. Title and Subtitle	5. Report Date
ACOUSTIC LOADS ON AN EXTERNALLY BLOWN FLAP SYSTEM DUE TO IMPINGEMENT OF A TF-34 JET ENGINE EXHAUST	6. Performing Organization Code 26.300
7. Author(s) James A. Schoenster	8. Performing Organization Report No. TM X-71950
9. Performing Organization Name and Address NASA-Langley Research Center Hampton, VA 23665	10. Work Unit No. 760-61-02-09 11. Contract or Grant No N/A
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546	13. Type of Report and Period Covered Technical Memorandum 14. Sponsoring Agency Code

15. Supplementary Notes

Presented at the 87th Meeting of the Acoustical Society of America, April 23-26, 1974, New York City

16. Abstract

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17. Key Words (Suggested by Author(s)) (STAR category underlined)	18. Distribution Statement
Fluctuating Pressures, Externally Blown Flap System Acoustic Loads Jet Impingement	Unclassified Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	18	$3.00

*Available from { The National Technical Information Service, Springfield, Virginia 22151
STIF/NASA Scientific and Technical Information Facility, P.O. Box 33, College Park, MD 20740