EFFECTS OF ACOUSTIC SOURCES

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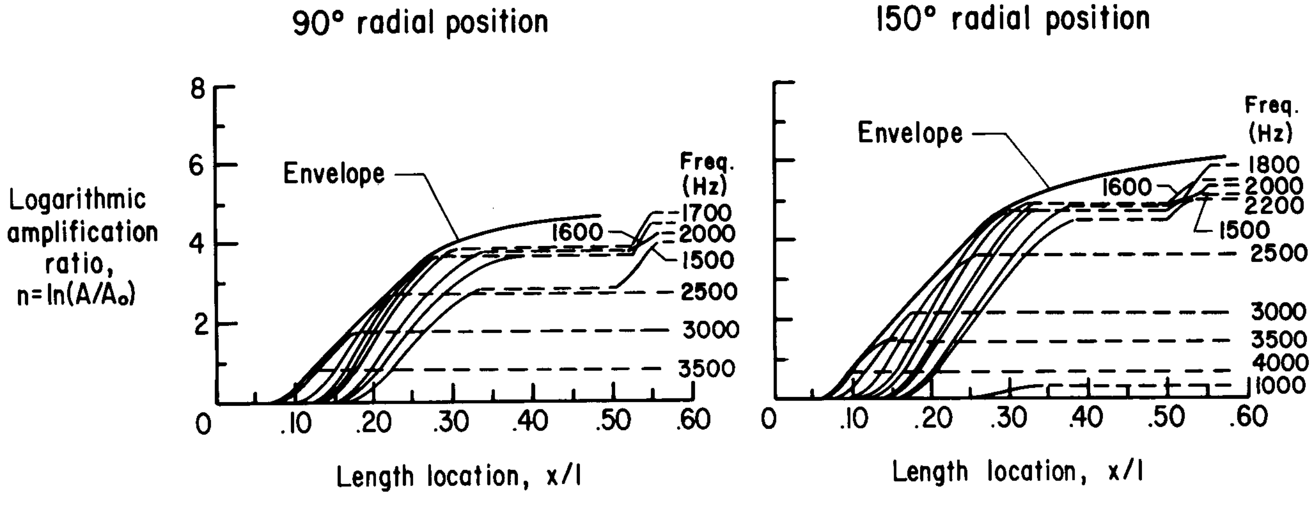
INSTABILITY WAVE GROWTH RATES USING THE PREDICTED PRESSURE DISTRIBUTIONS

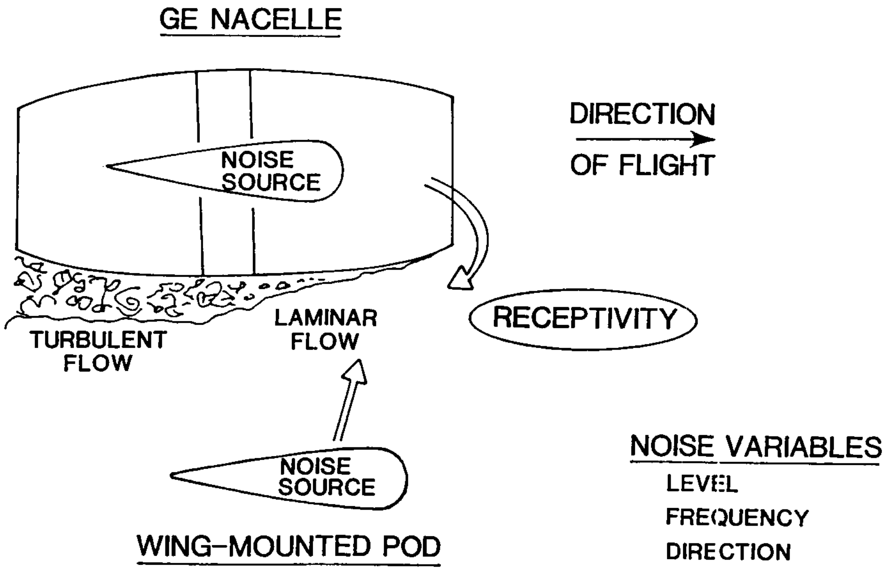
In order to understand the transition on the nacelle further, a laminar boundary-layer stability analysis for the 90° and 150° pressure rows was performed. This analysis used a method based on incompressible linear stability theory (Reference 3). The method used detailed boundary-layer profiles for several lengthwise stations on the nacelle, computed by the boundary-layer program described in Reference 4. The stability code is designed to compute the Tollmien-Schlichting (T-S) wave growth rates. The "n-factor" (or logarithmic disturbance amplitude ratio) serves as a measure of the growth of T-S waves within the laminar boundary layer. The disturbances analyzed in the boundary-layer stability calculations are periodic pressure fluctuations in the laminar boundary layer caused by rotational vorticity waves moving downstream very close to the surface. The effect of coupling between these T-S waves, and irrotational acoustic waves generated by an outside source is not considered in this analytical method.

This diagram shows n factors plotted for the two pressure rows previously defined (90° and 150°). As shown, the laminar boundary layer remains stable or at low growth rates (n<6.0) up to about 55% of the nacelle length. Further calculations could not be completed because of the predicted beginning of laminar separation. Although not always a direct comparison, the frequencies that dominate maximum amplification are in the range of frequencies selected for the noise source.



ACOUSTIC FLIGHT EXPERIMENT ON THE GE LAMINAR FLOW NACELLES

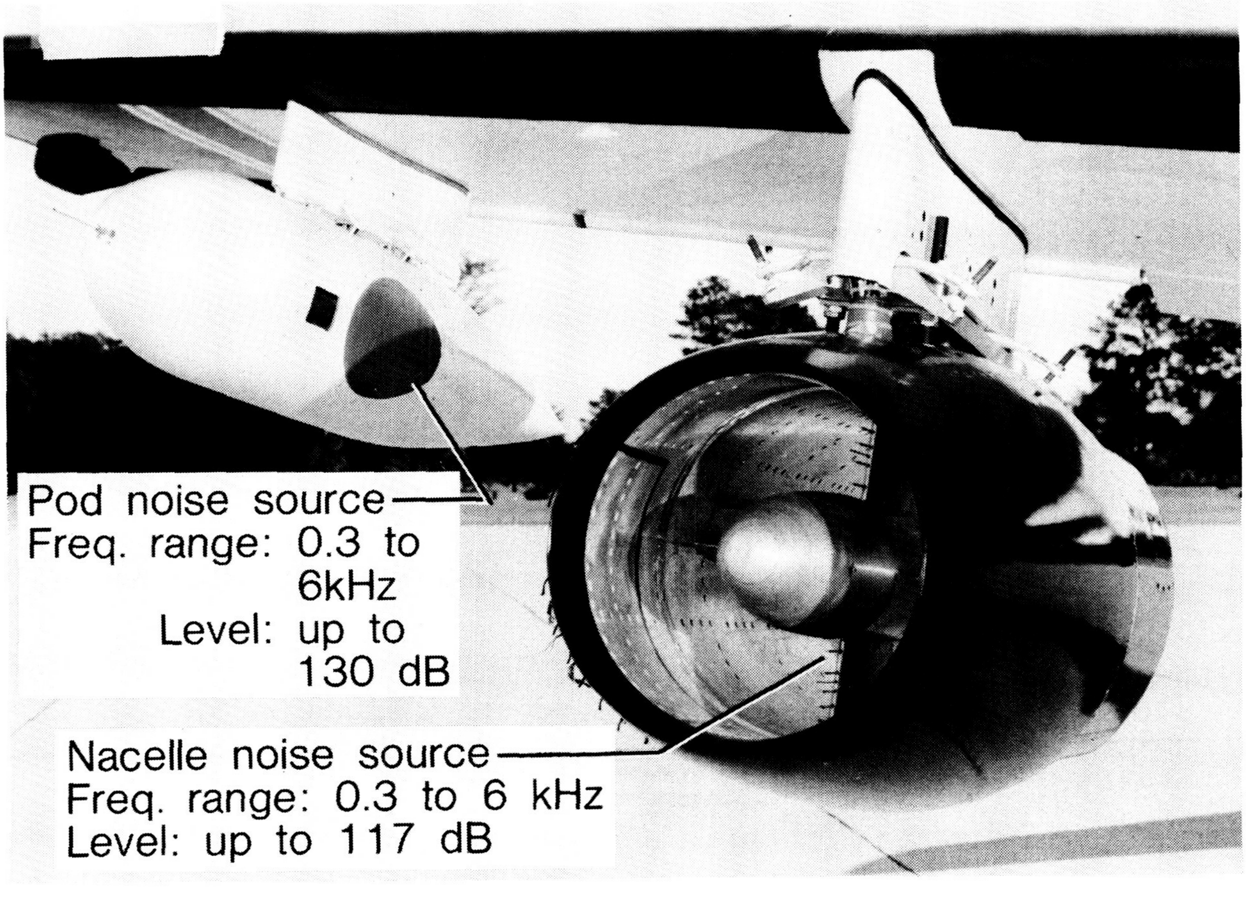
As discussed in the prior sections, this experiment is being primarily conducted to determine the effect of acoustics on the laminar flow on the side of a nacelle. A flight test was designed to meet this goal (section II) and a brief review of the purpose is shown in the figure. A nacelle with a significant length of laminar flow is mounted on the wing of the OV-1. Two noise sources are also mounted on the wing: One in the center body of the nacelle; the second in a wing-mounted pod outboard of the nacelle. Thse two noise sources allow for a limited study of the effect of source direction in addition to control of the acoustic level and frequency. To determine the range of most sensitive Tollmien-Schlichting frequencies, a stability analysis using the pressure coefficient distribution along the side of the nacelle is performed. Then by applying these frequencies and varying the acoustic level, a study of the receptivity of the boundary layer to the acoustic signal, as determined by the shortening of the length of laminar flow, may be conducted. Initial tests on GE nacelle number 2 did not provide any indication of sensitivity to acoustics, probably because the flow was laminar past the attachment joint, and transition was not caused by Tollmien-Schlichting growth but rather the bypass mechanism of the joint. It was for this reason that the change to GE nacelle number 3, which was designed to have less laminar flow, was made.



NOISE SOURCES ON THE OV-1 AIRCRAFT

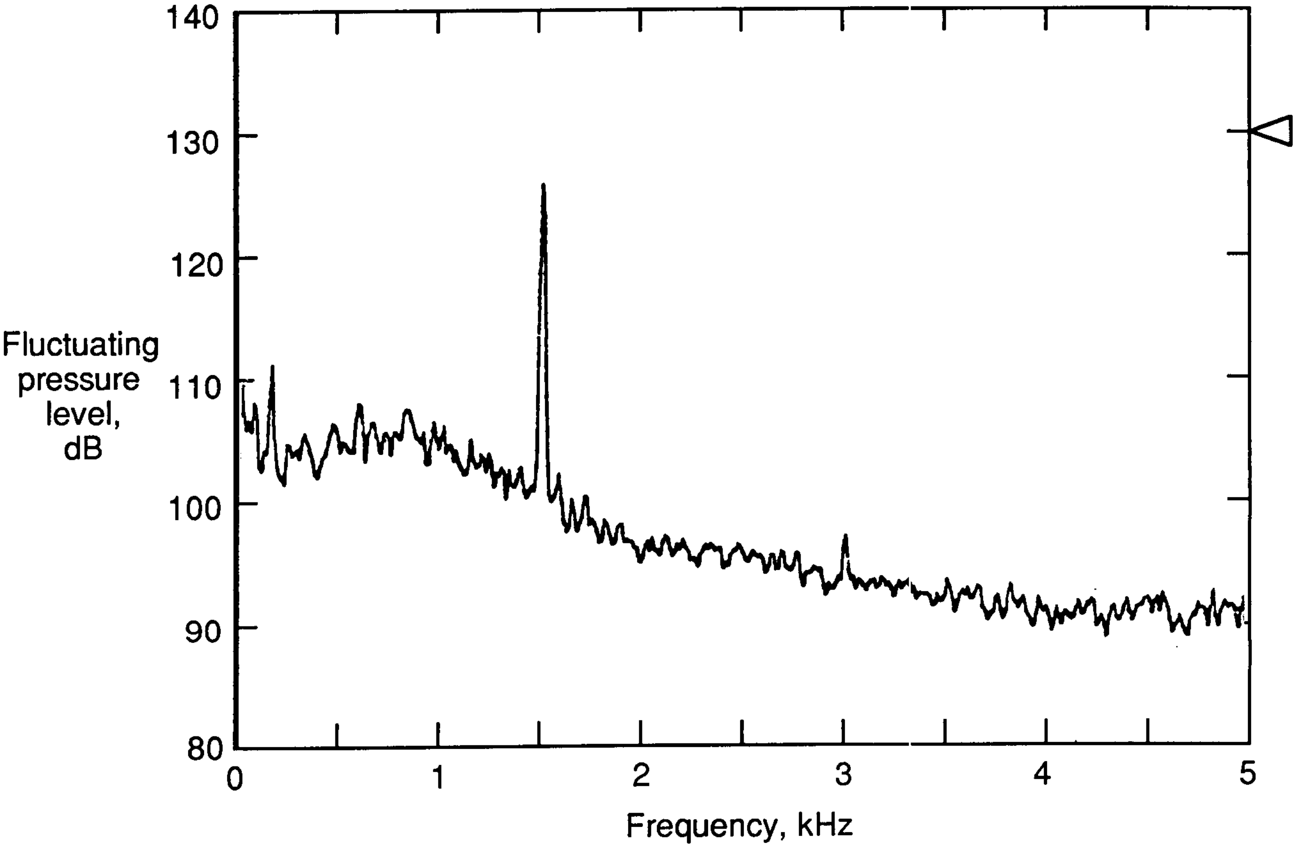
As noted, two noise sources were added to the OV-1 aircraft. One was enclosed in an external pod outboard of the nacelle, and the second was mounted internal to the nacelle in the centerbody section. Both noise sources consisted of JBL compression drivers, model 2483, with a throat diameter of 2 inches. They were designed to operate in the 0.3 to 6Khz range with 120 watts of power. The speakers were custom designed to fit into the area available and were not the most efficient speaker that could be used with the drives. The mouths of the horns were covered with a low-resistance, honeycomb-stiffener wire mesh screen to minimize aerodynamic turbulence. The addition of the screen was estimated to provide less than 1dB of sound pressure attenuation.

The horn/driver system was controlled by an audio oscillator with discrete step outputs and a high power audio amplifier. The oscillator controls were located in a area accessable from the co-pilots seat and were monitored online. Either one or both of the sources could be operated at one frequency per run.



SPECTRA ON SURFACE OF NACELLE

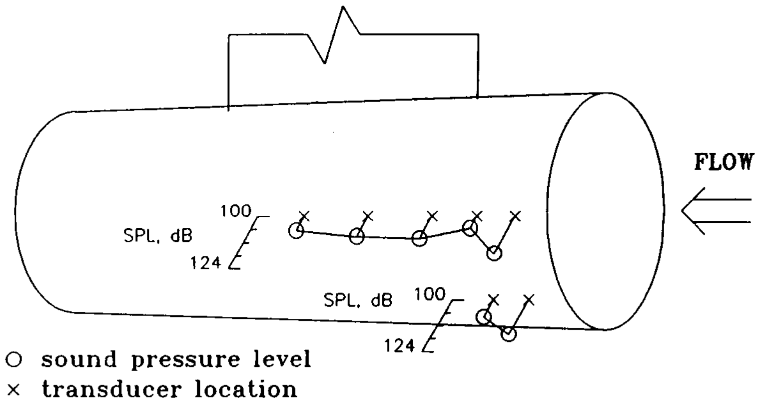
Shown in the figure is the spectra obtained by a surface-mounted, fluctuating-pressure transducer in flight at 1500 feet. The pod noise source was tuned to 1500 Hz. It may be seen that the broadband noise in the range of zero to 5 kHz varies from about 105 dB to 90 dB while the applied tonal signal at 1500 Hz is about 128 dB, 15 dB above the broadband signal. Control of these signals in flight varies from 0.3 to 6 kHz with the levels adjustable up to 130 dB for the pod source and 117 dB for the nacelle source, depending on the frequency.



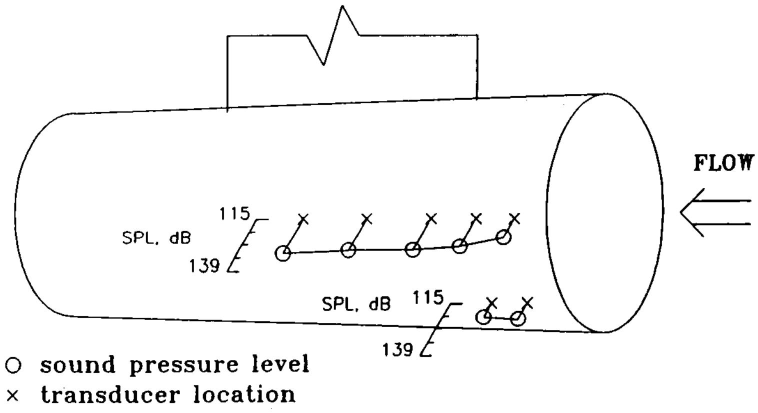
NOISE LEVELS ON THE NACELLE SURFACE

Several fluctuating-pressure measuring tranducers were mounted on the surface of the nacelle to determine the noise field from the two sources. One row of five tranducers (shown schematically) as "X" on the figure were mounted at 92° from the top of the nacelle at chord stations, x/c, equal to 0.06, 0.13, 0.21, 0.33, and 0.45. A pair of tranducers was also mounted a 152° at chord stations 0.06 and 0.13. The figures show the measured distributions for for the nacelle source and the pod source at the maximum output and 1,500 Hz. The maximum level at the leading edge (x/c = 0.06) for the nacelle source at 1,500 Hz was 117 at 92° and 116 dB at 152°. The pod source provided a maximum level of 124 dB and 122 dB at the same locations under similar conditions. These levels could be reduced in selected increments and as may be seen in the figures the distribution along the length of the nacelle is completely different for each source.

1500 Hz 80 v nacelle input

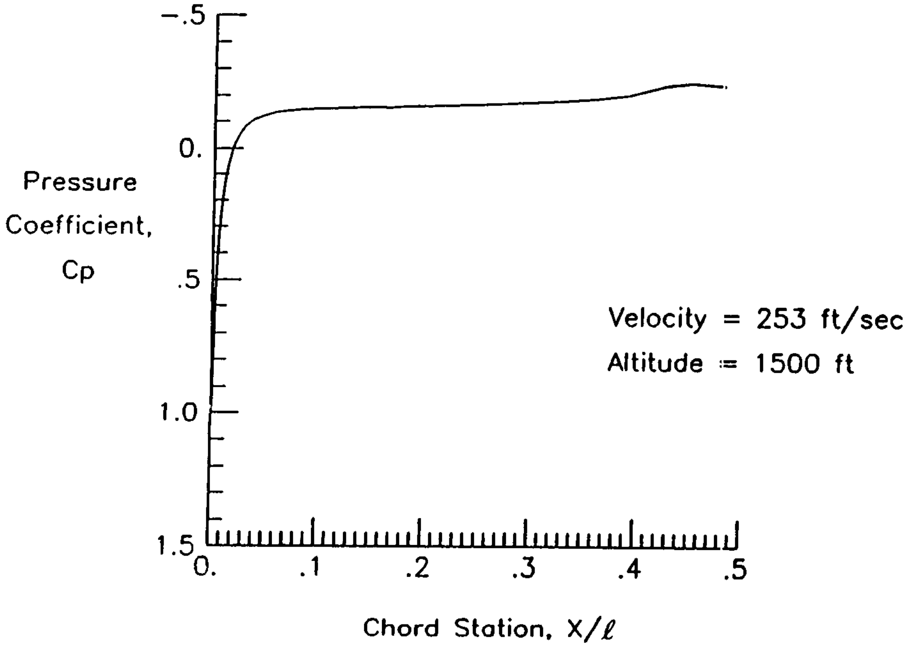


1500 Hz 80 v pod input



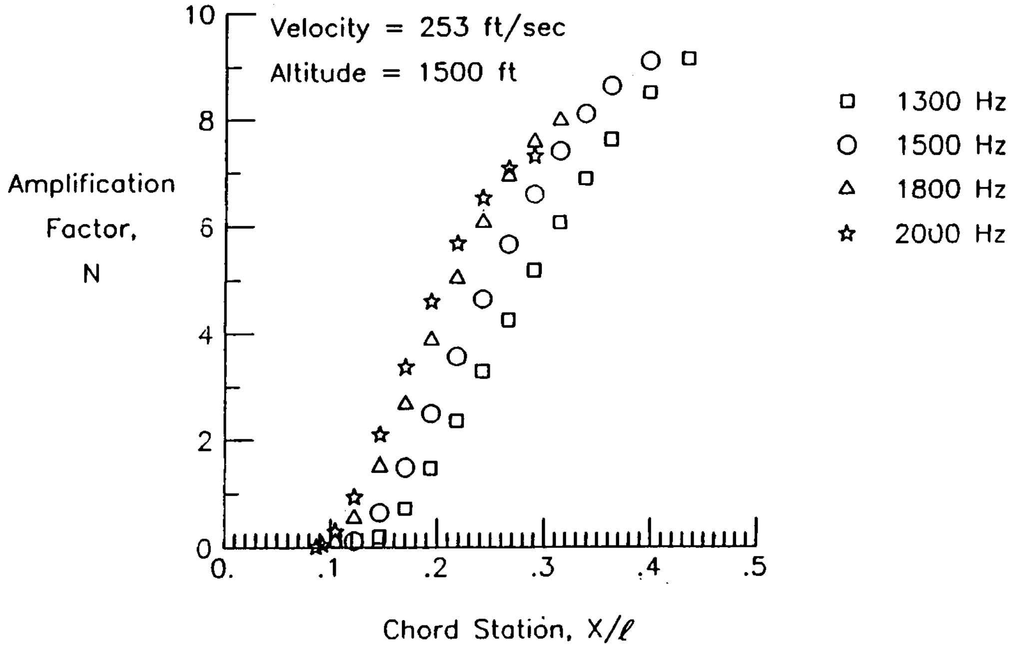
PRESSURE COEFFICIENT FOR THE GE-3 NLF NACELLE

The predicted pressure coefficient, C_p, for the GE-3 nacelle (from Section II) is shown again in this figure. This nacelle was designed to allow for the Tollmien-Schlichting (TS) waves to grow to the largest value of the three nacelles. The relatively flat curve provides a favorable pressure gradient up to about 45% chord. To determine a range of most sensitive TS frequencies, this curve was input to a Cebeci code (reference 1) to obtain boundary-layer profiles for use in the stability analysis.



TOLLMIEN-SCHLICHTING AMPLIFICATION FACTORS

Using the envelope method of the SALLY (Stability Analysis which is Local, Linear and Incompressible) program (reference 2) amplification factors for the flight test conditions shown by the C_p analysis of the prior figure were calculated. These factors for four frequencies 1,300 Hz, 1,500 Hz, 1,800 Hz and 2,000 Hz are shown in this figure, indicating the growth rate as a function of chord length. Maximum values reach about nine which would indicate that the laminar flow may be very close to transitioning without any external distrubance (e^n method, reference 3). While it is recognized that frequency and amplitude are not sufficient by themselves to determine if an acoustic signal will cause a higher level TS wave (i.e. therefore causing transition prior to "natural" transition) it was anticipated that a high enough level would have some effect. Therefore, a frequency of 1,500 Hz at the maximum output level was selected to determine if "premature" transition would take place in flight.



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