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# Engine-Over-the-Wing Noise Research

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## Theme

DURING the past decade airplane propulsion systems have become louder, sprawling cities have moved closer to their airports and the general awareness of noise has made the public particularly sensitive to aircraft noise. A possible solution to the conventional, short, and reduced takeoff and landing (CTOL, STOL, and RTOL, respectively) noise problems is to place the engine over the wing. With such a configuration, the wing shields the ground from some of the engine noise and redirects it above the aircraft.

Engine-over-the-wing (EOW) acoustic tests made with small models[1-5] achieved good noise shielding by the wing for both powered (STOL, RTOL) and conventional (CTOL) lift applications. Based on these favorable results with small models, an EOW configuration consisting of a circular nozzle and wing section was scaled up to a large model from which: 1) noise levels and directivity patterns were measured; 2) acoustic scaling laws were checked; and 3) more accurate noise predictions can be made for full-sized aircraft.

## Contents

Air supplied to a convergent nozzle placed over a wing section simulated the EOW configuration for conventional lift. The nozzle exit diameter was 13 in. and the wing chord was 7 ft. For powered lift, a nozzle-flow deflector was used to obtain flow attachment to the upper surface of the wing and flaps for lift augmentation. Acoustic measurements of the vertically mounted model were taken on a 50 ft radius with flap positions assumed to be typical of takeoff and approach for a jet exhaust velocity range of 550 to 1000 fps.

Noise directivity patterns for an EOW configuration with powered lift are shown in Fig. 1. The directivity patterns are fairly uniform in the region in front of and under the wing (20° to 130°), and the corresponding noise levels are considerably less than above the wing (180° to 330°). Below the wing (20° to 130°), the decrease in over-all sound pressure level (OASPL) is up to 10 db for powered lift. It is this shielding of the noise by the wing that makes the EOW concept attractive. Similar results were obtained for a configuration with conventional lift.

Shielding of jet noise by the wing for the EOW concept is shown in Fig. 2. The noise was measured at angular locations corresponding to the maximum under-the-wing (or flyover) noise, and at velocities assumed to be representative for powered and conventional lift systems, respectively. For powered lift applications, the three spectra in Fig. 2a represent the nozzle alone, nozzle with deflector, and nozzle with deflector and wing. By adding the deflector, which is necessary to obtain powered lift with a simple circular nozzle, there is a large increase in noise with respect to the nozzle alone at the middle and high frequencies. The addition of the wing caused a sharp decrease in high frequency noise and shifted the peak sound pressure level (SPL) from 500 Hz to about 200 Hz. The wing and flaps act as a good shield for high-frequency noise, but generate low-frequency noise as the flow passes over the trailing edge of the last flap. For conventional lift applications, the spectra in Fig. 2b represent the nozzle alone, and nozzle over-the-wing configuration. The addition of the wing causes up to a 10 db decrease in high-frequency noise while just slightly increasing the low-frequency noise. The wing and flaps again act as a good shield for high-frequency noise, and because the jet flow is unattached to the flaps, there is little low-frequency trailing-edge noise for the configuration used.

In order to establish acoustic scaling relationships for the EOW configuration, this large model experiment was based on a similar smaller model configuration.[1-5] The large model was geometrically identical to and scaled up by a factor of 6.5 from a 2 in. diam nozzle and 13 in. wing chord. In order to compare ⅓-octave spectral data, it is necessary to normalize the magnitude of the sound pressure level and nondimensionalize frequency for each model size. The frequency is made nondimensional using the Strouhal relationship (St) between ($f$), jet exhaust velocity ($V$), and nozzle diameter ($D$). The magnitude of the SPL is converted to the Normalized SPL Spectral Density (SPL-OASPL + 10 log $V/D\ \Delta f$), where $\Delta f$ is the bandwidth for each corresponding center frequency.

Plots of the Normalized SPL Spectral Density with respect to Strouhal number for powered and conventional lift applications and large and small models are shown in Fig. 3. The data points shown are for the large model at nozzle exhaust velocities between 550 and 1000 fps. The solid curves shown were obtained from a fit to a similar set of

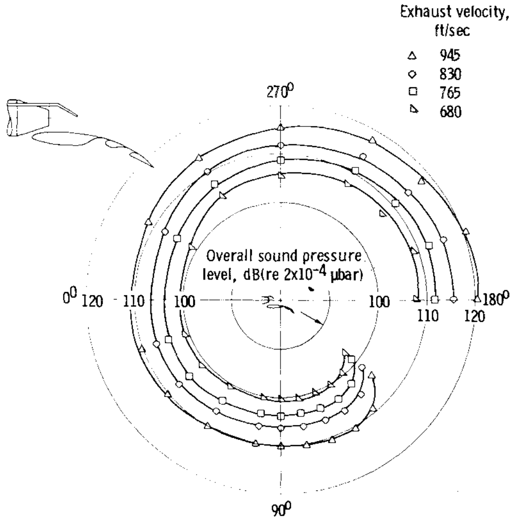

Fig. 1 Noise directivity patterns for the EOW configuration with powered lift. Flap position, 10°–20°. Flap slots closed.

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Index categories: Aircraft Noise, Aerodynamics (Including Sonic Boom); Aircraft Noise, Powerplant.

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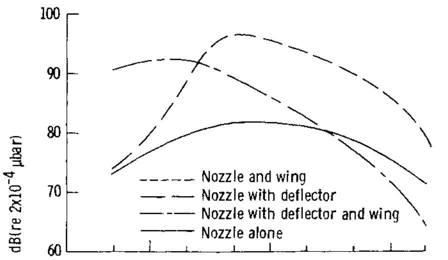
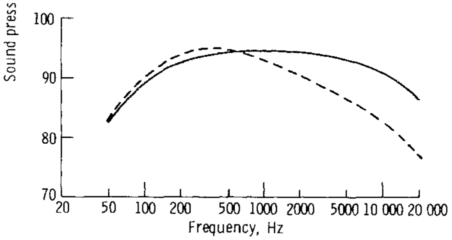


(a) Powered lift. Microphone angle, 100°; nozzle exhaust velocity, 765 ft/sec; flap slots closed.

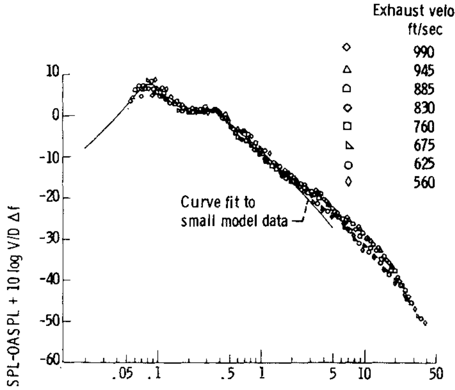


(b) Conventional lift. Microphone angle, 120°; nozzle exhaust velocity, 985 ft/sec; flap slots open.

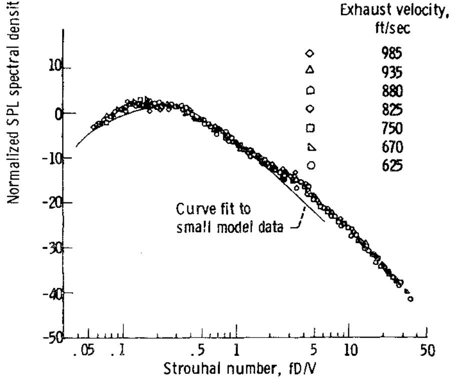
**Fig. 2 Effect of noise shielding by the wing on the EOW configuration. Flap position, 10°–20°. Corrected for ground reflections.**

small model data. The results shown in Fig. 3 indicate that the Strouhal relation correlates the large model data very well over the velocity range and that there is very good agreement between the large and small model data. The only significant discrepancy between the results of the two models is in the high-frequency slope, where the large model values of normalized SPL spectral density decrease at a somewhat lower rate with frequency.

Noise directivity measurements were taken for both the large and small models and the resulting directivity patterns were compared for their scaling characteristics. Under the wing, between 60° and 140° from the inlet, the data scale very well. However, above the wing, between 180° and 360° from the inlet, the large model data are up to 5 db greater than the scaled up small model data.



(a) Powered lift. Microphone angle, 100°; flap slots closed.



(b) Conventional lift. Microphone angle, 120°; flap slots open.

**Fig. 3 Correlation of large and small model data for the EOW configuration. Flap position; 10°–20°. Corrected for ground reflections.**

## Conclusions

A large model experimental investigation has been conducted in order to determine acoustic benefits of the engine-over-the-wing concept for both conventional and powered lift applications. By placing the engine over the wing, the region under the wing is acoustically shielded from the noise which is reflected away. The amount of noise shielding increases with increasing frequencies. This shielding benefit makes the EOW concept a contender for quiet aircraft.

The large model acoustic results were compared with small model data. In the region of primary interest, under the wing, the EOW noise data scale well for all models. Because of the good scaling in the region under the wing, models can be used as acoustical research tools and for preliminary acoustic predictions for full-sized aircraft.

## References

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