25. TWO METHODS OF EVALUATING CLIMBOUT NOISE

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SUMMARY

Data have been collected under controlled conditions on several jet-powered transport airplanes to determine operating procedures for minimizing noise exposures and to evaluate a proposed means for performing rapid acoustic evaluations of new airplanes.

Power cutbacks during climbout are shown to be beneficial in reducing noise levels under the climbout path, the amount of reduction being a function of the detail design of the airplane and its engines. A special flight procedure is described which produced sufficient level-flight parametric data for predicting the ground noise levels during climbout without the need for repeated take-offs and landings.

INTRODUCTION

25

Noise during take-off—climbout operations of jet-powered transport airplanes is an important consideration because of possible adverse reactions in communities near airports (ref. 1). Data have been collected under controlled conditions on a jet-powered transport airplane (ref. 2) to determine operating procedures for minimizing noise exposures and to evaluate a proposed means for performing rapid acoustic evaluations of new airplanes. The objective of this paper is to present some of the results of flight research studies in which the measured noise levels are closely correlated with airplane operations.

The material discussed in this paper is divided into two parts. The first part deals with climbout noise measurements and illustrates the effects of climbout profile and power and airplane configuration. The second part deals with the results of parametric studies which are used in a procedure for estimating the climbout noise for a particular profile when the altitude, power, flap angle, airplane speed, climb rate, and airplane weight are known.

CLIMBOUT OPERATIONS

Test Setup and Test Airplanes

A schematic diagram of the test arrangement for the climbout operations is shown in figure 1. These flight tests were conducted in the vicinity of the NASA Wallops Station, Wallops Island, Virginia. Various climbout procedures were flown, and airplanes were accurately tracked by ground radar during each flight. The flight tracks in all cases were made over an array of noise measurement stations deployed along the ground track at distances varying from 1.5 to 7.5 nautical miles from brake release.

The airplanes used in the test program are shown in figure 2. These test airplanes were: a four-engine turbojet owned and operated by the Federal Aviation Administration; a four-engine turbofan owned and operated by the Boeing Company; a three-engine turbofan owned and operated by Eastern Airlines; and a two-engine turbofan owned and operated by American Airlines.

Test Results

Figure 3 shows noise-measurement results obtained from the four-engine turbojet airplane, This figure illustrates different climbout procedures employed for noise evaluations and the measured perceived noise levels (PNL) associated with these respective climbout procedures. Progressively lower noise levels are obtained for the slower climb rates which involve lower levels of thrust.

Figure 4 illustrates a climbout procedure employed to reduce the noise over a small area. The four-engine turbojet airplane was used for this test. Take-off power was employed to a 1500-foot altitude. Power was then reduced to that required for a 500-foot/minute climb rate; this reduced power was maintained for 10 seconds and then was followed by a return to take-off power. This figure also shows the measured perceived noise levels resulting from this procedure. Relatively higher noise levels were experienced following the return to take-off power than when take-off power was maintained throughout.

The amount of noise-level reductions obtainable by power cutbacks will vary for airplanes having different types of jet power plants as illustrated in figures 5 and 6. Figure 5 demonstrates the amount of perceived-noise-level reductions as measured for a four-engine turbojet airplane and a four-engine turbofan airplane. Figure 5 shows that the reduction in perceived noise level for the four-engine turbojet airplane at the time of power cutback is of the order of 10 PNdB. Similar data for the four-engine turbofan airplane indicate a smaller perceived-noise-level reduction. The lesser reduction obtainable for the turbofan airplane is due to the presence of fan noise which reduces at a slower rate with reduced velocity than does jet noise.

Figure 6 illustrates the amount of perceived-noise-level reductions obtainable for two different airplanes powered by turbofan engines. This figure shows measured data for the three-engine and the two-engine turbofan airplanes. The same order of reductions is obtainable for both airplanes. The amount of noise-level reductions obtainable for the three-engine and two-engine turbofan airplanes is greater than those for the four-engine turbofan airplane. This difference results from special airplane and engine design features to reduce fan noise and from more favorable thrust-to-weight ratios which allow a greater power cutback than for the four-engine airplane.

PARAMETRIC FLIGHT STUDIES

Test Procedure

Several factors, such as airplane altitude, engine thrust level, flap setting, airplane speed, airplane climb rate, and airplane weight, may be important when predicting noise from climbout operations. A test procedure has been devised which involves controlled flights and noise measurements to account properly for all these factors. Figure 7 is a schematic diagram showing the nature of this test procedure. A four-engine turbofan airplane under radar control was flown in a level-flight attitude to the vicinity of the noise measurement range. Just prior to reaching the noise measurement range, the engine throttle settings were adjusted to provide various rates of climb from 750 to 2400 feet/minute. Each test flight was made over an array of noise measurement stations deployed along the ground-track center line. Data were recorded at each station as the airplane passed overhead. Tests were repeated for each of the climb rates with initial level-flight altitudes of 500, 800, and 1100 feet. These flights were conducted with flap settings of 0° and 14° which are representative settings for take-off and climbout operations for this particular airplane.

By this means acoustic data were obtained for various airplane altitudes, various engine thrust levels, and at the flap setting of interest. Results from this flight-test procedure have been plotted such that the noise levels during the climbout operations of the test airplane can be accurately predicted. The usefulness of such parametric data for predicting the noise for a given climbout profile is illustrated in figure 8.

Comparison of Measured and Predicted Noise Levels

Figure 8 shows a comparison of the measured and predicted noise levels of the four-engine turbofan airplane for a climbout profile employing take-off power with a 14° flap setting to a 1500-foot altitude, then a power reduction to that required for a climb rate of 500 feet/minute. This figure illustrates the range of altitudes associated with three nearly identical test flights for which noise data are also presented. The pilot was instructed to fly the same profile each time, and the hatching represents the variation in this operation. Perceived-noise-level data as measured from the three flights are shown in the sketch at the bottom of figure 8. For comparison, noise predictions (hatched bands) have been made for the flown profiles based on the parametric flight data. Good correlation exists between the measured and predicted levels.

Encouraging results such as those of figure 8 suggest that this simulation method of prediction may be very useful in evaluating the noise characteristic of various types of airplanes under various operating conditions. Parametric flight procedures can establish basic noise characteristics of a particular airplane and the range of noise leveis associated with various operations, and these can be accomplished without the need for repeated take-offs and landings or for an instrumented airport range.

CONCLUDING REMARKS

Power cutbacks during climbout are shown to be beneficial in reducing noise levels under the climbout path, the amount of reduction being a function of the detail design of the airplane and its engines. A special flight procedure is described which produced sufficient level-flight parametric data for predicting the ground noise levels during climbout without the need for repeated take-offs and landings.

REFERENCES

1. Jet Aircraft Noise Panel: Alleviation of Jet Aircraft Noise Near Airports. Office Sci. and Technol., Mar. 1966.
2. Copeland, W. Latham; Hilton, David A.; Huckel, Vera; Dibble, Andrew C., Jr.; and Maglieri, Domenic J.: Noise Measurement Evaluations of Various Take-Off—Climbout Profiles of a Four-Engine Turbojet Transport Airplane. NASA TN D-3715, 1966.

TEST ARRANGEMENT FOR CLIMBOUT STUDIES

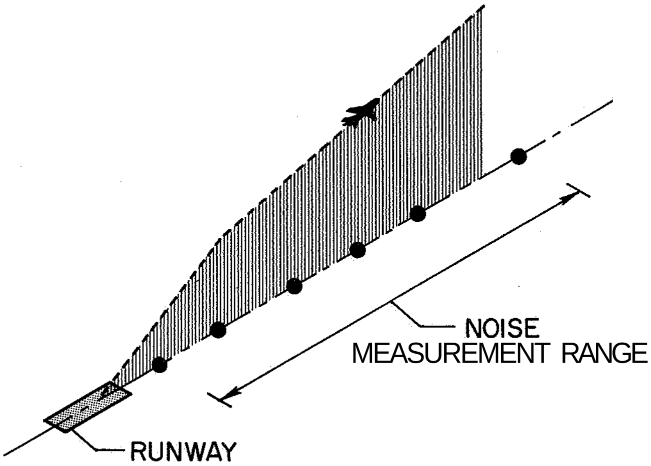

Figure 1

TEST AIRPLANES

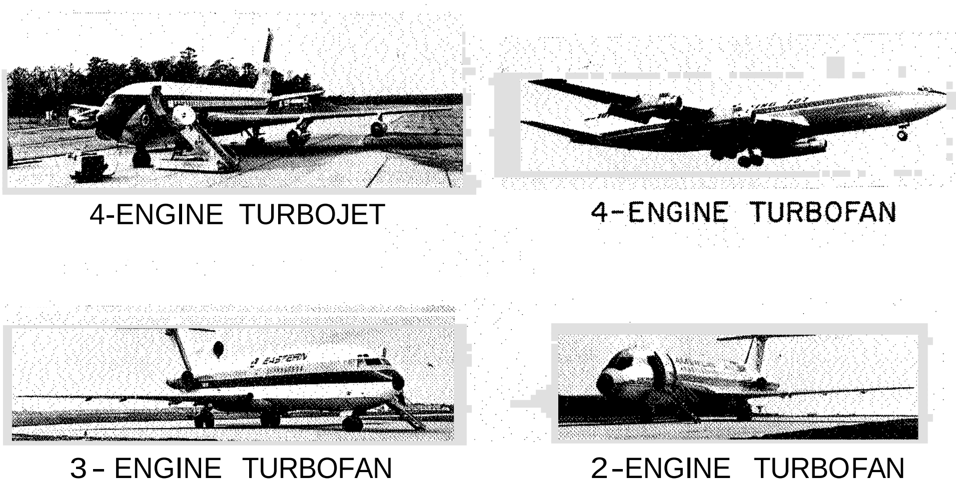

Figure 2

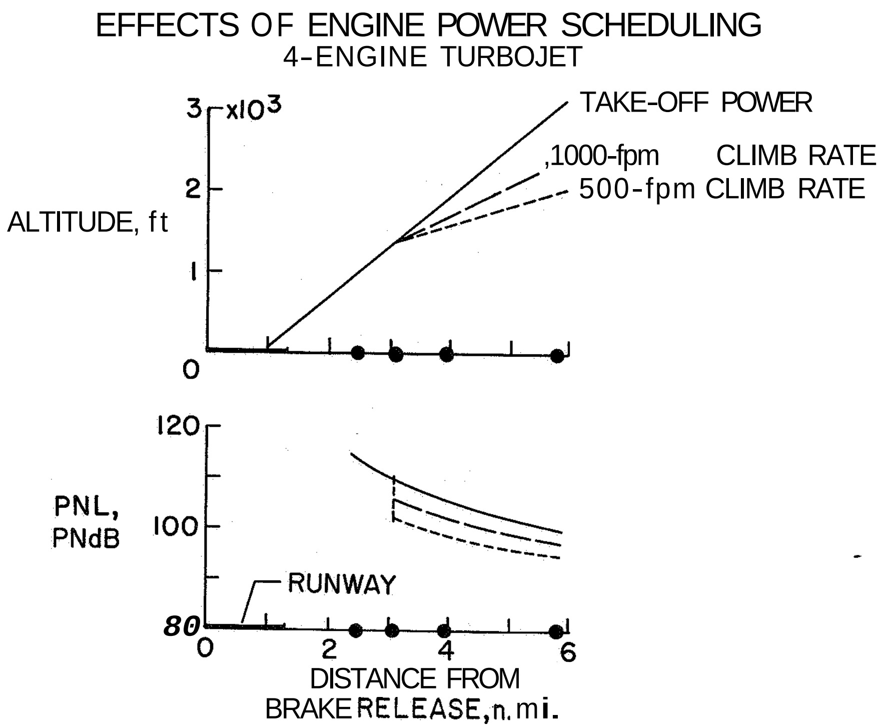

Figure 3

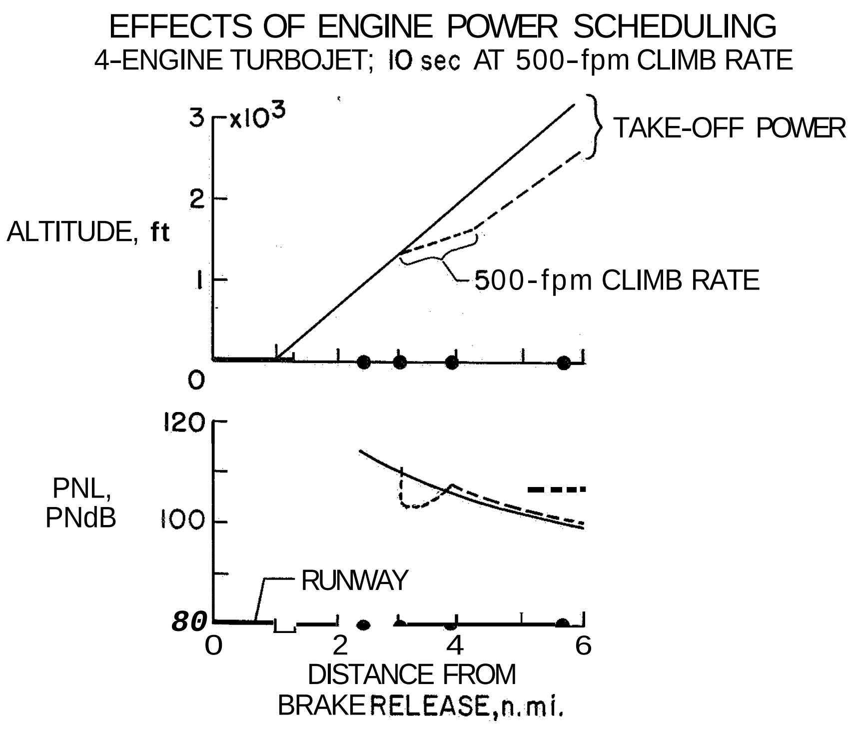

Figure 4

NOISE REDUCTIONS DUE TO POWER CUTBACK
4-ENGINE AIRPLANES

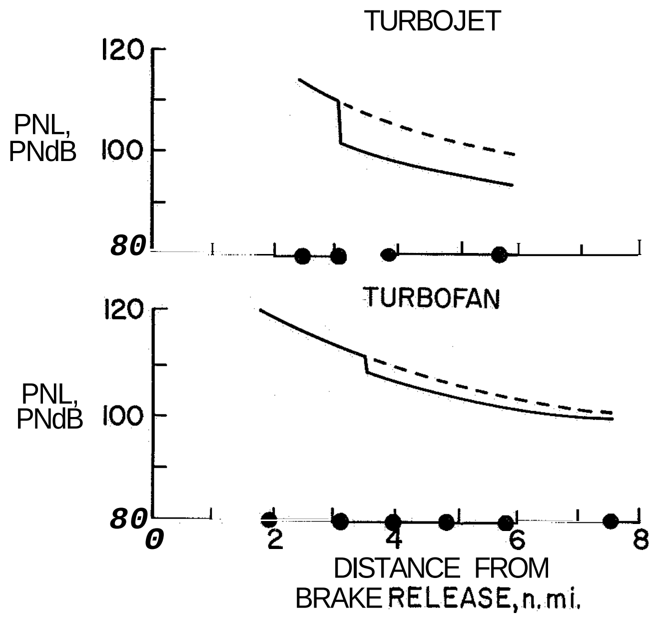

Figure 5

NOISE REDUCTIONS DUE TO POWER CUTBACK

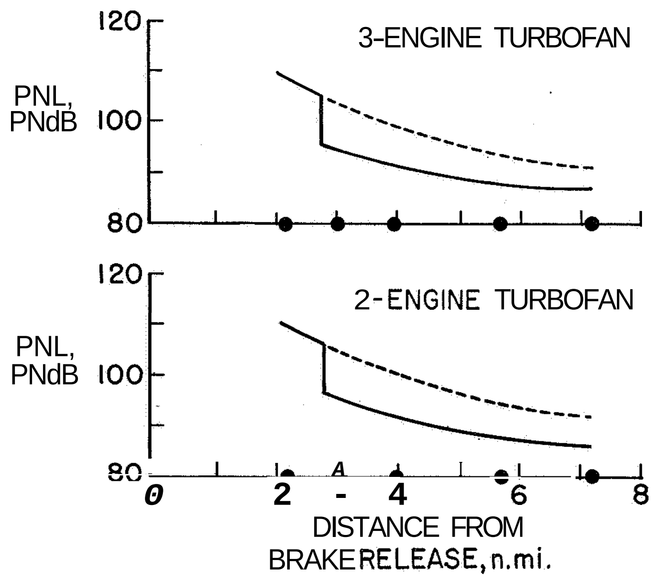

Figure 6

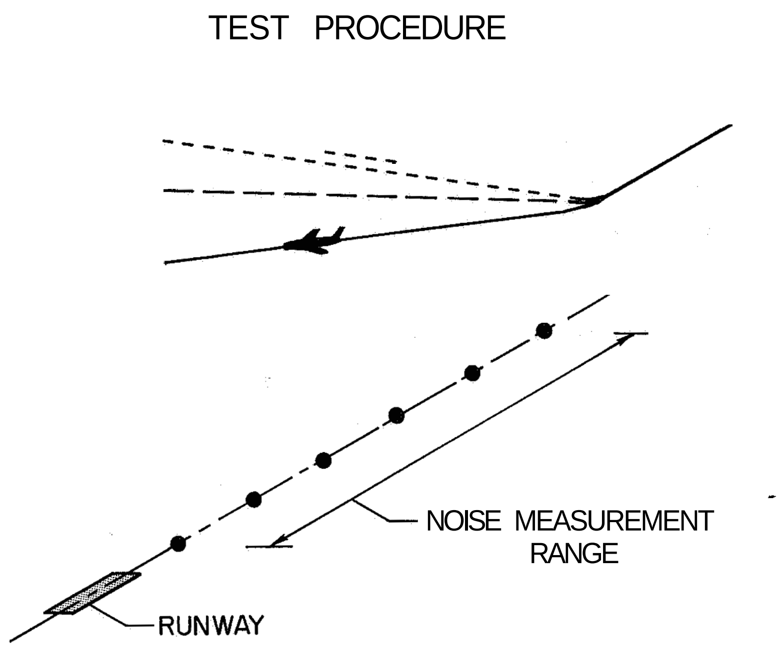

Figure 7

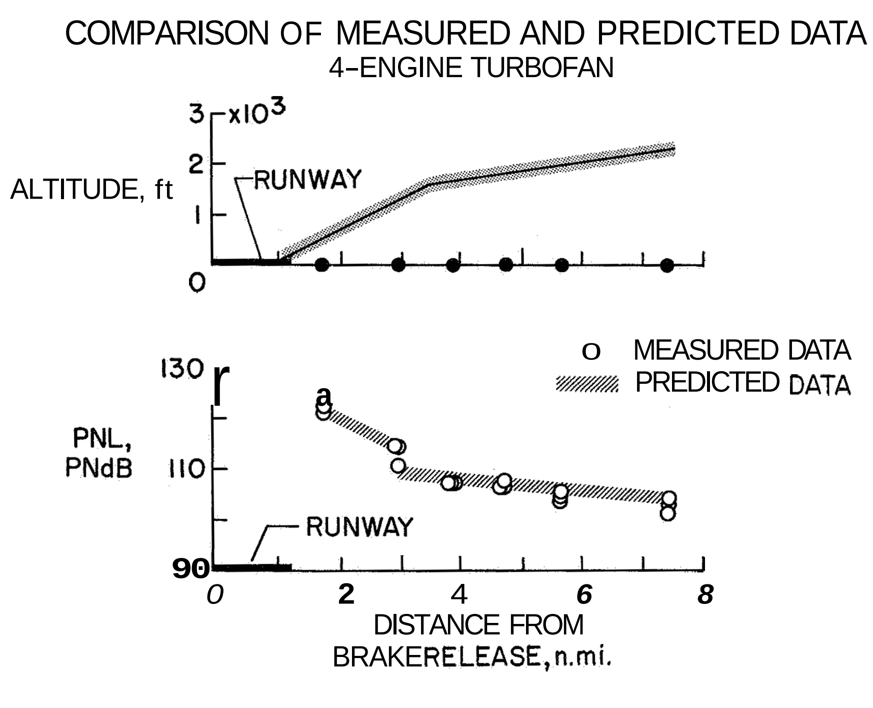

Figure 8