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MEMORANDUM

NOISE PROBLEMS ASSOCIATED WITH GROUND

OPERATIONS OF JET AIRCRAFT

By Harvey H. Hubbard

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Langley Field, Va.

NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION

WASHINGTON

March 1959

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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SUMMARY

The nature of the noise-exposure problem for humans and the aircraft-structural-damage problem is each discussed briefly. Some discussion is directed toward available methods of minimizing the effects of noise on ground crews, on the aircraft structure, and on the surrounding community. A bibliography of available papers relating to noise-reduction devices is also included.

INTRODUCTION

The noise generated by the engines of jet aircraft during ground runup operation will lead to serious problems, particularly with regard to the ground-crew personnel, the structure of the aircraft, and, to a lesser extent, the surrounding community. The purpose of this paper is to review the nature of these problems and to focus attention on some of the more critical aspects. Brief mention is also made of various devices useful for noise reduction during ground operations. There will be only general discussion of some types of these devices and no attempt is made to include all the very large number currently available for use. (For further information see the bibliography.)

ALLOWABLE NOISE EXPOSURE

Some insight into the noise-exposure problem for humans is given by figure 1. These tentative criteria were obtained from reference 1 and are based largely on Air Force experience in operating jet aircraft. Noise exposure has two ingredients: the level of the noise and the time of exposure to that noise. It can be seen in the figure that the allowable exposure time is plotted as a function of the overall noise level in decibels. Three general regions are noted: (a) a region where no protection is needed, (b) a region where ordinary personal equipment such as ear plugs, helmets, or muffs would be adequate, and (c) a region to be avoided unless special equipment is provided. This special equipment could be custom-fitted ear-protection devices or devices for protecting the whole body. It was also noted from reference 1 that ear protection alone is not adequate for exposure to noise levels higher than 150 decibels even for a short time. Where no protection is required, it is noted that the average man can be exposed to 100 decibels of random noise for an 8-hour workday over a period of many years without adverse effects. As the noise level increases the allowable exposure time decreases until at a level of 135 decibels an exposure time of only a few seconds per day is permissible. It should be noted that the data of figure 1 apply directly for random noise and the allowable levels are about 10 decibels higher than they would be for discrete noise under otherwise comparable conditions.

The significance of these levels with regard to an actual engine running up on the ground is illustrated with the aid of figure 2. Shown in the figure are several contour lines of equal overall noise level for an engine with a flight-type muffler attached operating at 10,000 pounds of thrust (ref. 2). Also indicated in the figure are distances radially outward and forward and rearward of the nozzle-exit plane. It can be seen that in a large area where maintenance men might be required during engine runup, the levels range from 110 to about 150 decibels. As indicated in figure 1, it would be permissible to enter any part of the region ahead of the 130-decibel contour line without protection, provided the exposure time did not exceed 1 minute. For the region within the 130-decibel contour line some type of personal-protection device would be required even for short-term exposures.

NATURE OF THE AIRCRAFT-DAMAGE PROBLEM

Because of the very high noise levels in the region behind the engine near the exhaust, there is also a possibility of doing structural damage to the aircraft for long-term exposures. The damage areas on the airplane will occur generally rearward of the engine-exhaust exits. Shown schematically in figure 3 is a bottom view of a multi-engine jet airplane with pod-mounted engines. The shaded areas are those susceptible to damage by engine noise and are noted to be along the wing trailing edges and the rearward part of the fuselage.

Areas of the airplane located close to a given engine will be primarily affected by that particular engine and not significantly affected by the others. There are some areas of the airplane, however, in which excitation from more than one source is significant, as, for example, the rearward part of the fuselage. The damage referred to results from fatigue failures of the skin and other secondary structural members due to the fluctuating noise-pressure loads. These failures are generally not catastrophic in nature but may be costly to repair.

Other experience (refs. 3 and 4) has indicated that the severity of the damage due to noise is very much a function of the noise level of exposure. Of course, ground operation involves a variety of engine conditions with an associated range of noise levels. Data of this type were made available to NASA by Messrs. Laymon N. Miller and Robert M. Hoover[1] of Bolt Beranek and Newman, Inc. (Cambridge, Mass.) and are presented in figure 4 for the take-off, cruise, taxi, and idle conditions of the engines of a four-engine jet airplane with flight-type mufflers. The data are shown in the form of overall noise levels, measured at 200 feet, plotted as a function of azimuth angle measured from the front of the airplane. Unfortunately, near-field data of the type shown previously are not available for engine conditions other than the 100-percent-rpm condition shown in figure 2. It is believed, however, that the near-field data for these power conditions would be in the same order of rank and have about the same differences as those shown in figure 4. Of particular interest are the data at azimuth angles toward the rear where the noise levels are the highest. In this orientation it can be seen that the noise levels associated with take-off power are higher than those for any of the other engine conditions.

The significance of these data with reference to the damage problem is illustrated schematically with the aid of figure 5. Hours of structural life are shown as a function of noise level in decibels. The resulting curve is similar to a conventional S-N diagram. Its shape will thus depend on the stress level in the structure and the type of construction used. If it is assumed that a certain part of the airplane is designed for a satisfactory life of 100 hours of take-off time, then the usable life in the cruise condition might be of the order of 1,000 times that long because of the lower noise levels. The take-off condition is thus very important with regard to structural life and, for many parts of the aircraft, is a controlling factor in design. The noise levels associated with the taxi and idle conditions would, of course, be below the cruise noise level and would have essentially no effect on the life of the airplane. On the other hand, if a ground operator became careless and unknowingly operated the engines in such a way that the noise levels were higher than those at the take-off condition, the usable life of the airplane would then be greatly reduced. One point that can be made in connection with figure 5 is that operation at take-off power on the ground will directly affect the life of some parts of the airplane. With regard to those parts of the structure which receive excitation from more than one engine, it would be helpful if only one engine at a time were operated for the routine operational and maintenance checks that are performed, since that would tend to fix the operations on the lower segment of the curve.

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[1]Paper entitled "The Noise Characteristics of Some Commercial Jet Aircraft During Ground Operations" presented at the 55th Meeting of the Acoustical Society of America, Washington, D. C., May 7-10, 1958.

NOISE-REDUCTION DEVICES

Of course, another method of operating on the lower segment of the curve (fig. 5) is to use some noise-reduction devices in addition to those installed on the airplane. Schematic illustrations of some of these, along with an indication of the main principle of operation, are shown in figure 6.

The top diagram shows a nozzle shroud which is fitted to the flight-type suppression nozzle and extends behind it. Additional air is entrained by this method which results in more rapid mixing and additional noise reduction of about 5 decibels (ref. 5). A longer shroud than shown here would give larger noise reduction (ref. 6) and would thus be more effective in shielding the rearward part of the airplane.

Another possibility is to cause the exhaust gases to enter a perforated sleeve from which they would exit in a radial direction from many small jets (ref. 7). The total jet kinetic energy would be reduced and a reduction of 10 to 20 decibels might be obtained. It should be noted that skirt-type deflectors are provided to turn the exhaust flow away from the structure and also from the direction of the engine inlet.

The bottom sketch in figure 6 shows an enclosure containing absorbing materials arranged in such a manner as to absorb a large part of the noise energy before the exhaust reaches the free air. Many such devices are now commercially available for noise reductions of 20 decibels or more (ref. 8). Some proposed inlet silencers also operate on the principle of absorbing the noise energy, which in the case of the compressor is in a frequency range where many acoustic absorbing materials are very effective.

No attempt is made here to include discussions of all available or proposed noise-reduction devices; however, a bibliography is provided for those interested in the technical details. Some of the above studies indicate that the most practical ground-noise-reduction devices may very well incorporate more than one of several basic principles of operation.

Devices of the types illustrated in figure 6 would be suitable for both ground-crew personnel and structural problems and even for protection of the community. In some cases where protection is desired mainly for the community it may be possible to take advantage of the existing terrain features to reduce the noise at a distance as indicated in figure 7. As an illustration, if 1 mile separated the runup area and the community to be protected, noise reductions due to intervening terrain might vary from about 8 to 32 decibels in addition to normal spreading, depending on the type of foliage (ref. 9). It should be noted that in each case the terrain conditions cited are assumed to exist for the whole distance between noise source and observer. For a practical solution, a noise reduction of about 20 to 30 decibels due to foliage would be needed.

Reductions comparable to these could be obtained by the use of a shielding wall about 40 feet high and comparable to the wing span in length (ref. 10). To be most effective, the aircraft during runup would have to be located close to the wall. This would cause reflections back onto the aircraft and would result in higher noise levels at some locations than would ordinarily exist in an area free of reflections. Thus, care should be used in the case of ground running of engines close to shielding walls or buildings. As a word of caution, it is particularly undesirable to run up engines while the airplane is located between buildings or walls in such a manner that parts of the airplane are in a reverberant space. It should be noted that the noise reductions of figure 7 are for normal atmospheric wind and temperature gradients. They are thus higher than might be realized for some unusual atmospheric conditions as, for example, a temperature inversion.

CONCLUDING REMARKS

In conclusion, it has been pointed out that the ground runup operation of jet engines at full power with flight-type mufflers can present a hazard to the ground-crew personnel and can be detrimental to the airplane by reducing its usable fatigue life. Care should be taken to keep to a minimum all full-power engine operation for which additional noise reduction is not provided. Additional muffling can be obtained by conventional methods, and, if these are used properly, protection may be obtained for both the personnel and the structure of the airplane.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., November 6, 1958.

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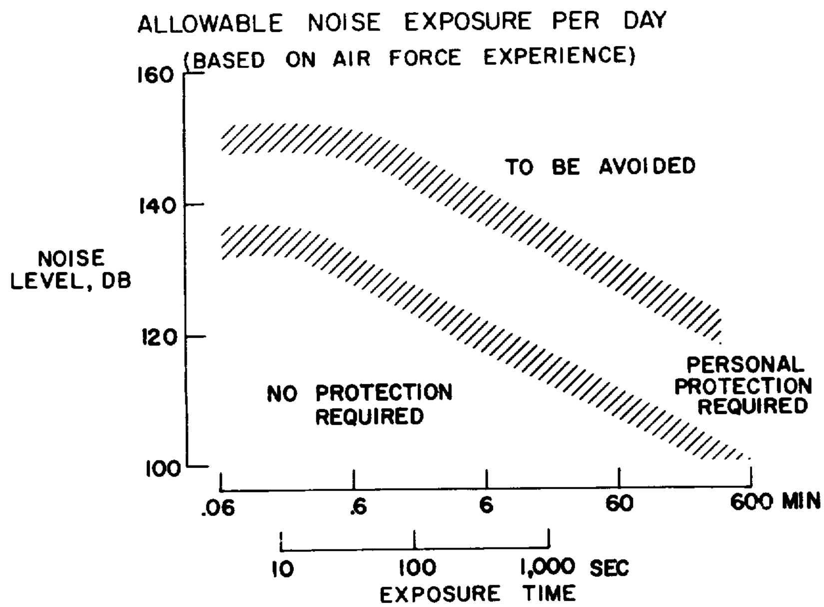

Figure 1

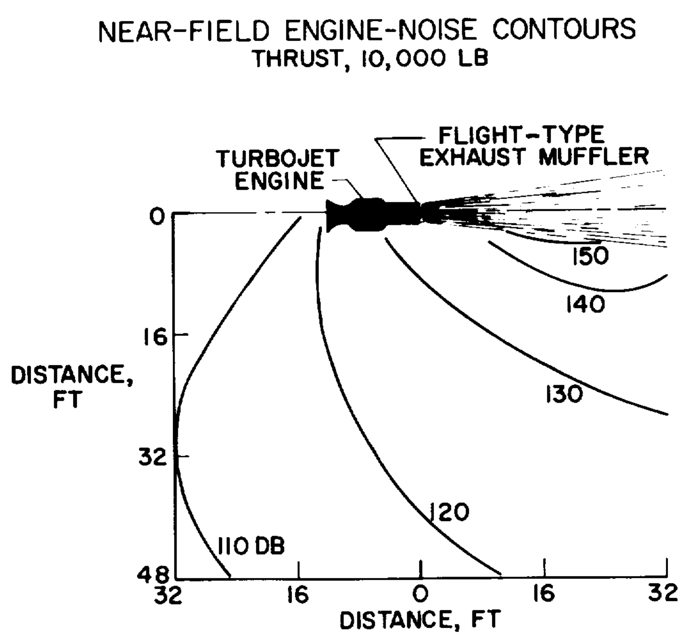

Figure 2

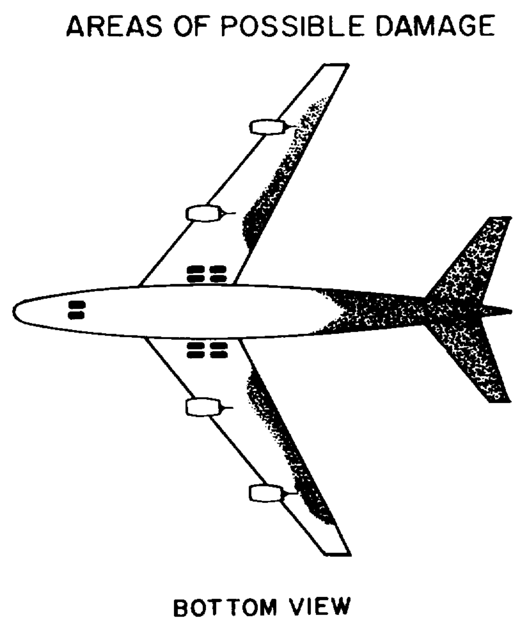

Figure 3

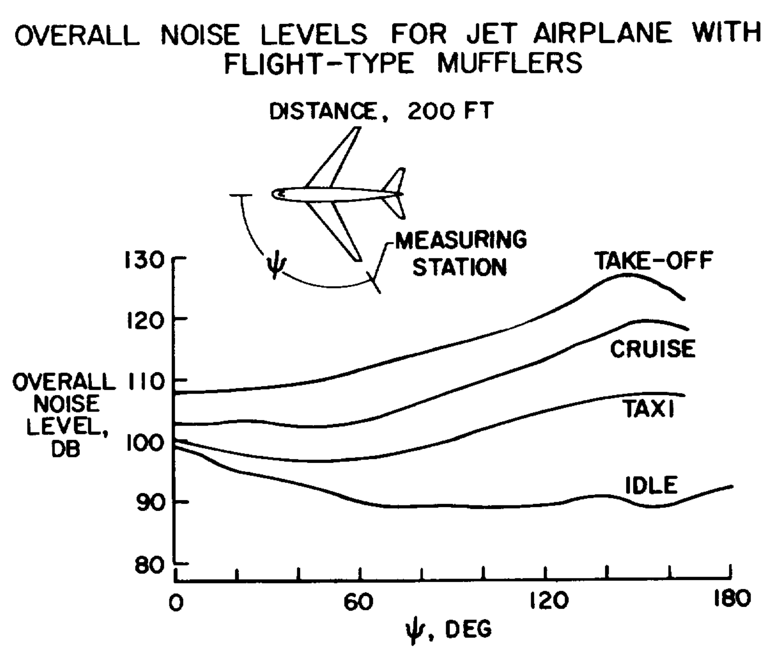

Figure 4

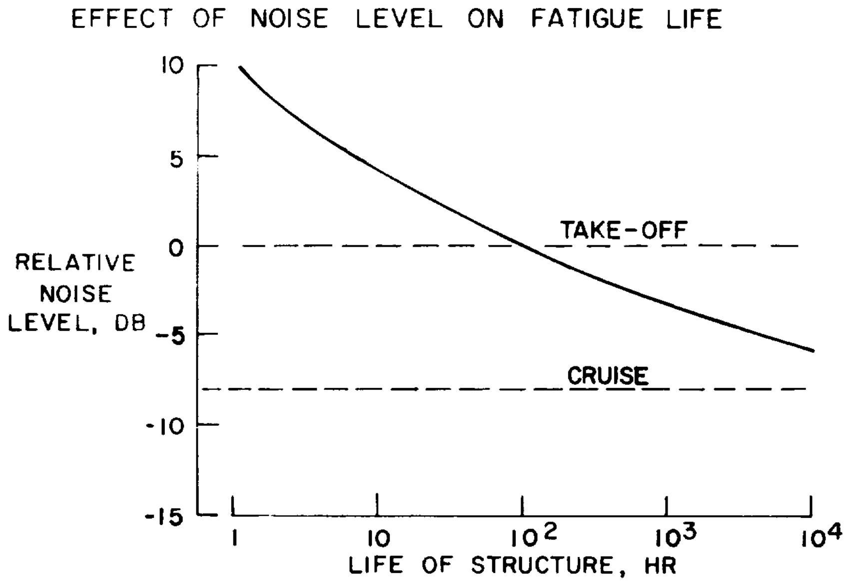

Figure 5

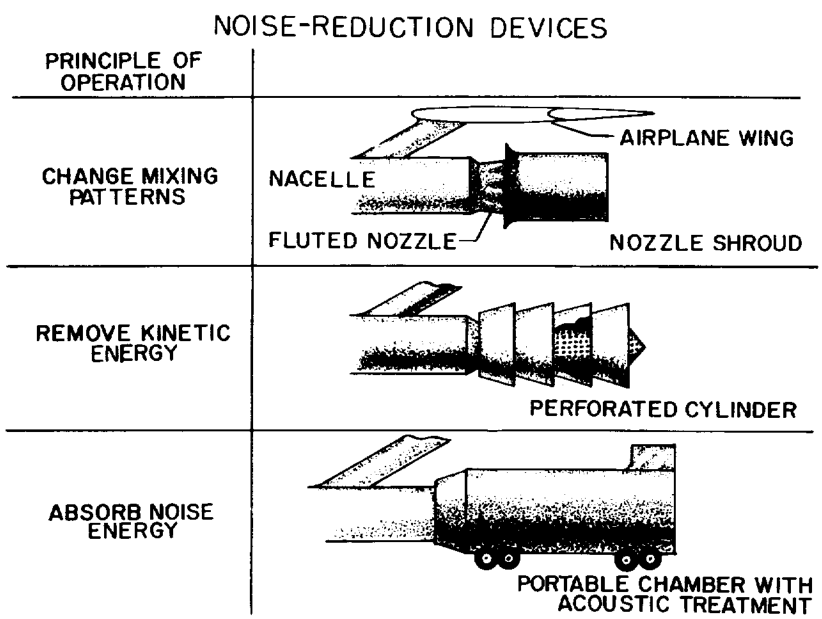

Figure 6

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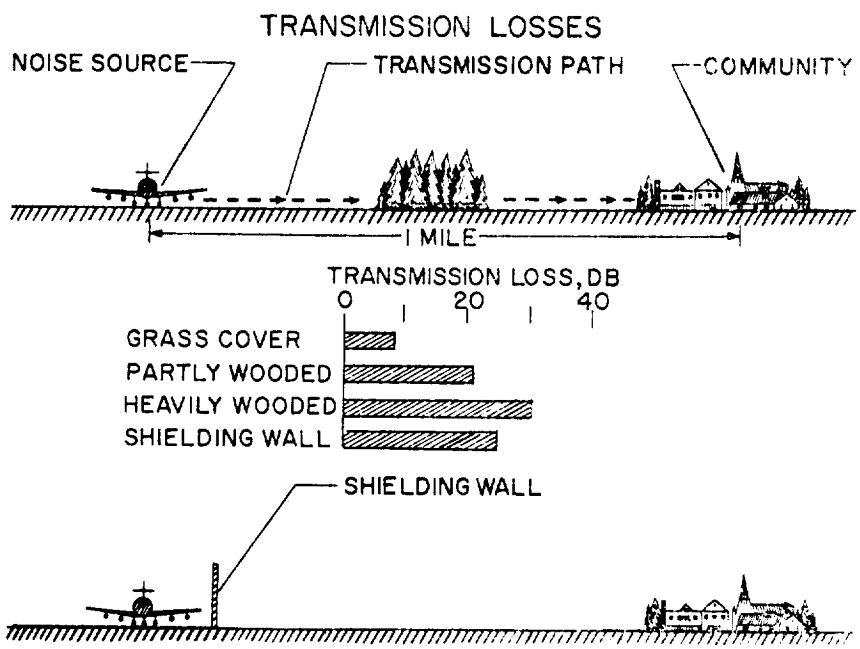

Figure 7

NASA MEMO 3-5-59L
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The nature of the noise-exposure problem for humans and the aircraft-structural-damage problem are each discussed briefly. Some discussion is directed toward available methods of minimizing the effects of noise on ground crews, on the aircraft structure, and on the surrounding community. A bibliography of available papers relating to noise-reduction devices is also included.

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2. Engines, Turbojet (3.1.3)
3. Noise (7.4)

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