HELICOPTER EXTERNAL NOISE REQUIREMENTS--FAA PERSPECTIVE

Charles R. Foster
Federal Aviation Administration

INTRODUCTION

Helicopter noise certification was formally initiated by the Federal Aviation Administration (FAA) with the issuance in December 1973 of an Advance Notice of Proposed Rule Making No. 73-32 entitled "Noise Standards for Short Haul Aircraft." Concurrently, the International Civil Aviation Organization's Committee on Aircraft Noise (ICAO/CAN) at its second meeting in November 1971 established a working group to investigate the problems of noise certification of vertical and short takeoff and landing aircraft. In those time frames, the dramatic growth of the helicopter industry to its present status was not anticipated--nor that the contribution of helicopters to community noise would grow correspondingly. Since helicopter operations over populated areas are becoming more frequent, public awareness of their noise intrusion is receiving more attention. In this context, enactment of helicopter noise certification standards for the control of noise impact contributing to community annoyance is necessary to ensure the future development of helicopters as an environmentally compatible air transportation mode.

REQUIREMENTS FOR NOISE STANDARDS

As a result of the unique operational capabilities of helicopters, approximately 20 different helicopter types are currently used in commercial operations. The operations include business and executive use, resources monitoring and exploration, firefighting, and a variety of emergency applications. The number of operational heliports has increased from a few hundred in the early 1960's to more than 3400 at present, while the number of helicopters using those heliports has grown to more than 7000 aircraft and is forecast to exceed 9000 by the year 1980. Faced with this past and projected growth of the helicopter industry as well as the increase of the public's awareness of aircraft noise, it is apparent that the development of helicopter noise standards will be necessary both for the protection of the environmental interest of the community and to ensure the orderly growth of the helicopter industry itself.

It is fortunate that the ICAO and FAA developments of noise standards are proceeding concurrently in view of the desirability of achieving consistency between domestic and international standards. Both efforts have developed complementary data bases, and certification concepts under consideration are being reviewed cooperatively. With the combined data base, it will be possible to develop standards which reflect more varied technical approaches to helicopter design. This, in turn, should provide a broader application of available noise control techniques and lead to acoustically improved helicopters. An additional, but not inconsequential, aspect of the commonality of domestic and international noise standards will result from the assurance that a manufacturer's product would have worldwide acceptability and will not be constrained in a few countries because of more restrictive environmental requirements.

REGULATORY BACKGROUND

The FAA issued subsonic transport category aircraft noise standards in 1969 under the provisions of the 1968 Amendments to the Federal Aviation Act. These standards, which were the first aircraft noise certification standards, were incorporated in the Federal Aviation Regulations (FAR's) as the now well-known Part 36 entitled "Noise Standards, Aircraft Type and Airworthiness Certification." The FAA, working with industry and the public through the administrative procedures process, developed the noise certification concept over approximately a 4-year period. The measurement concept consisted of measuring the aircraft noise at three locations as shown in figure 1, which provided an approximation of the expected noise impact at a typical airport runway. Associated with the choice of measurement locations, the certification test operational procedures and power settings were selected to be representative of those which might be used in normal aircraft/airport operation. The development of the certification concept required selection of a noise unit which was identified as the Effective Perceived Noise Decibel (EPNdB). This unit applies a frequency weighting to the noise spectra for consistency with human perception and also provides correction factors to encourage the elimination of objectional tonal characteristics and excessively long flyover time histories.

Using these measurement and evaluation techniques, the required noise levels were established for takeoff, sideline and approach measurement locations. The takeoff noise level requirements are shown in figure 2 along with noise measurement data for aircraft in the current commercial fleet. The initial standards are identified by the curve labeled December 1969, which varies from 93 EPNdB at low gross weights to 108 EPNdB at the higher takeoff weights. An additional set of curves labeled October 1977 for two-, three- and four-engine aircraft is shown to indicate an increase in stringency in the noise level requirements which has become possible as a result of approximately 9 years of noise certification and control experience.

This extensive background of certification experience with subsonic fixed-wing aircraft is logically being used in the development of the noise certification standards for helicopters. It was initially obvious, however, that the large technical and operational differences between helicopters and fixed-wing aircraft should be considered before finalization on noise standards for this unique class of aircraft. Accordingly, the approach to helicopter noise certification is based on an in-depth evaluation of the helicopter acoustic technology and consideration of regulatory concepts which could be considered appropriate for helicopters.

HELICOPTER ACOUSTIC TECHNOLOGY

Noise Sources

The acoustic technology of helicopters differs considerably from that of fixed-wing aircraft. One of the fundamental reasons for this difference is the introduction of several new noise sources resulting from the unsteady aerodynamics of rotary-wing aircraft (fig. 3). The main rotor noise results from the periodic and random loads on the primary lifting surfaces which usually are associated with a blade passing frequency varying between 10 and 20 Hz. This rotor noise source is strongly influenced by the blade tip Mach number, which if sufficiently high can introduce adverse compressibility effects. The main rotor loading, which contributes to the broadband noise, can also be dominated by air flow interactions resulting from the intersection of the wake or vortex generated by the preceding blade. The well-known phenomena of blade slap result from both interaction and compressibility effects. At lower speeds, the slap results primarily from dynamic pressure deficiencies, whereas at high speeds the slap can be related to shock-stall phenomena.

For single main rotor helicopters, the requirement for a tail rotor introduces a unique noise source. The tail rotor introduces rotational noise components and associated harmonics which occur in the frequencies range of 50 to 100 Hz. In addition to these basic components, since the tail rotor operates in a complex flow field, it produces fluctuating noises as a result of interaction with the flow field of the main rotor. Contributing further to this complexity, in some configurations there is also a tail rotor component introduced by the effect of the flow field distortions from shrouds or other fixed surfaces. The presence of the main rotor and tail rotor as noise sources tends to dominate the noise generation of the basic powerplant in many configurations. This, however, may not be the case for piston engine powerplants or for gas turbine engines which produce strong compressor tones or exhaust noises. Noise sources such as gear trains, aerodynamic noise or structural vibrations are generally not major contributors and can be treated on an individual component basis.

Technology Trends

In the interest of developing more versatile aircraft for the commercial field, many new technology innovations are being introduced in advanced helicopter designs. Advances in the field of materials, especially the use of plastics and in composite materials, have resulted in the ability to design and manufacture rotor blades with controlled thickness and twist distributions which provide both structural and aerodynamic advantages. These advantages can contribute to reduced configuration weight and hence less power required for a given operational speed with a corresponding noise reduction. The concept of reduced power requirements may also be realized by an extensive helicopter drag reduction effort. These improvements, which have a direct noise reduction potential, also have a secondary noise reduction potential since the advance designs will have improved specific fuel consumption, require less fuel for a given range, and, therefore, could operate at reduced weights. These technology advances could be incorporated in the future generation of high performance helicopters and their judicious use can provide quieter designs while minimizing performance penalties associated with noise control.

Design Noise Control

In addition to the broad technology advances which can result in quieter helicopter designs, specific concepts are currently being explored which are fundamental to the control of helicopter noise. In designing main rotors for noise control, the basic parameters for consideration are rpm, number of blades, airfoil selection, thickness distribution, aerodynamic loading, tip shape, sweep and/or tilt. Proper selection of these parameters can control broadband noise and can be used to delay the onset of compressibility effects with the resultant decrease in main rotor noise. Control of tail rotor noise is, in general, more complex; however, the same basic design parameters can also reduce the magnitude of this source. The tail rotor noise may also be controlled by changing blade numbers and by configurational rearrangement to avoid interactions. Many of the helicopter noise control techniques are configuration specific and, therefore, limited in application.

HELICOPTER REGULATORY CONCEPTS

In the approximately 6 years that the helicopter noise certification standards have been in an evolutionary process, many different concepts of certification have been suggested. One of the first proposals suggested for conducting the certification noise test was to simply measure the total acoustic radiation of a helicopter in a 1.5-meter (5-foot) wheel height hover as shown in figure 4. Using this concept, it was considered that noise sources could be identified and treated individually, thereby eliminating high noise level radiation in any direction. In the hover test, the pilot was to locate the aircraft centrally with respect to a circular array of microphones and rotate the aircraft in 45° steps to identify the lateral noise radiation in all directions. Unfortunately, when this technique was explored it was found to be highly susceptible to the influence of variations in wind velocity and was not effective in providing repeatable test data. The next proposal for certification paralleled the FAR Part 36 Appendix F requirements for small propeller-driven airplanes which consisted of a single horizontal overflight test over a single microphone (fig. 5). For helicopters, the basic concept of the level flyovers appeared attractive since it produced repeatable data under a condition corresponding to community overflights. The technique is still currently under active consideration for helicopter noise certification and, as shown in figure 6, consists of a 150-meter altitude overflight over an array of three microphones spaced perpendicular to the ground track. The current recommendation is that the three microphones aligned 150 meters apart would be averaged to develop a single flyover noise value from a minimum of six overflights with the helicopter stabilized at a speed of no less than 90 percent of the maximum speed in level flight with maximum continuous power (V_H) or of the never exceed speed (V_{NE}). The rotor speed would be stabilized at the maximum normal operating rpm and the flyover tests should be conducted at weights within +5 or -10 percent of the maximum certificated takeoff weight. These test speeds were chosen because they were considered to be approximately equal to the speed for best range in cruise which is not currently a defined airworthiness parameter. Since, in general, increased flyover speeds result in increased noise, regulatory consideration must be given to the control of noise in this operational mode.

At one time the flyover test alone was considered as the only test required. However, it later became apparent that the addition of an approach test might also be desirable to identify low speed blade wake interaction noise generated by most helicopters during approach (fig. 7). It was suggested that the approach test be conducted with a steady angle of 6° during six approaches at maximum normal operating rpm and speed for best rate of climb (V_Y) airspeed (fig. 8). The noise levels would be established by again averaging the readings of three microphones aligned 150 meters apart and perpendicular to the flight path. The microphones are positioned such that the overflight altitude is 120 meters below the approach path, which provides the opportunity for direct comparison with CTOL approach noise measurements. Experience to date has shown these tests to be repeatable and relatively easy to conduct.

The incorporation of a takeoff test has been a controversial concept that is also under consideration. While a takeoff test was considered desirable, it had previously been rejected as being too difficult to define and as too dependent on the pilot's operational technique. Recently, an expediency to avoid these complications was introduced; namely, a takeoff test utilizing the flight path intercept technique was proposed (fig. 9). This procedure is currently being evaluated. Using this technique, the test aircraft would establish the speed V_Y for best rate of climb in steady level flight at an altitude of 20 meters above ground level (AGL) prior to reaching a target point 500 meters before the three-microphone measurement area. The aircraft would then apply full power and initiate a steady climb at V_Y intersecting the climb path which has its apex at the target point. Some investigators have tried this technique and found it to be relatively simple and repeatable. The test should reward those aircraft which achieve quieting in the takeoff mode because of improved performance characteristics. It is believed to give a reliable measure of relative acoustic benefit attributable to good takeoff performance.

The current consensus on the noise evaluation unit is that the Effective Perceived Noise Level (EPNL) used in FAR 36 and ICAO Annex 16 should be retained. At this point in time there is, however, no consensus on the use of a correction to the unit for impulsiveness. The International Standards Organization in Technical Committee 43 has advanced a draft proposal #356 to ISO 3891 for the measurement of noise from helicopters including a blade-slap correction. Alternative proposals of considerably less complexity, having approximately the same correlation with psychoacoustic study results have been advanced. It is also considered that the duration correction, which is increased in magnitude because of impulsivity, may adequately correlate with psychoacoustic studies. This issue has recently been the subject of a joint NASA/FAA psychoacoustic overflight program and is also an issue which will be addressed during the present meeting in the Human Factors and Criteria Session this afternoon.

AVAILABLE NOISE LEVEL TEST DATA

The United States and other ICAO member nations have conducted helicopter test programs in accordance with the flight procedures outlined above. The resulting noise level measurements are presented in figures 10 to 12 for the flyover, approach, and takeoff tests, respectively. The FAA has a flight test program scheduled for June to complement this test data base. In the figures, approximate corrections for helicopter impulsivity are indicated. These data do not define proposed noise level limits but are considered indicative of noise levels that would be realized under certification conditions for in-service aircraft. In setting the noise level limits for certification standards, it is necessary to evaluate the economic implications as well as the technological practicability of meeting prescribed standards. In finalizing these standards it will be necessary to evaluate reasonable noise control design requirements and also to identify noise floors which are lower bounds for technically achievable limits.

An intermediate proposal suggested for the treatment of aircraft which exceed specified noise levels by a given amount would be to limit their operations to remote regions. Utilizing this concept would avoid the enforcement of environmental constraints on designs of specific purpose helicopters, if the benefit of those constraints was not made available to the public. For example, there are currently hundreds of flights daily transporting thousands of people to their jobs on off-shore oil rigs which take off from and return to remotely located heliports. The economic impact of noise control requirements on these operations probably would be excessive and it is considered reasonable to explore the development of concepts which would prevent this potential application of noise control requirements. The establishment of new limited use certification categories through the definition of restricted operational use, placarding, or through airport and/or airways use restrictions may be one way of accomplishing this objective.

CONCLUSION

The development of U.S. domestic helicopter noise standards is a process which will proceed in accordance with the requirements of the Administrative Procedures Act. It is believed that rationally developed standards will help the helicopter to realize its growth potential as an environmentally compatible transportation mode.

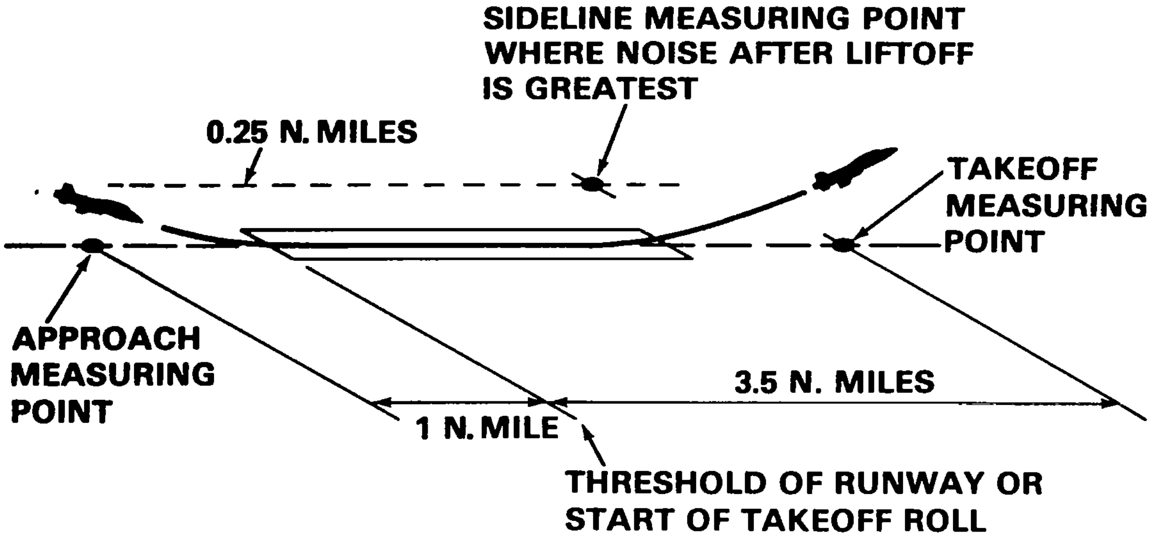

Figure 1.- Noise measuring points for airplane type certification.

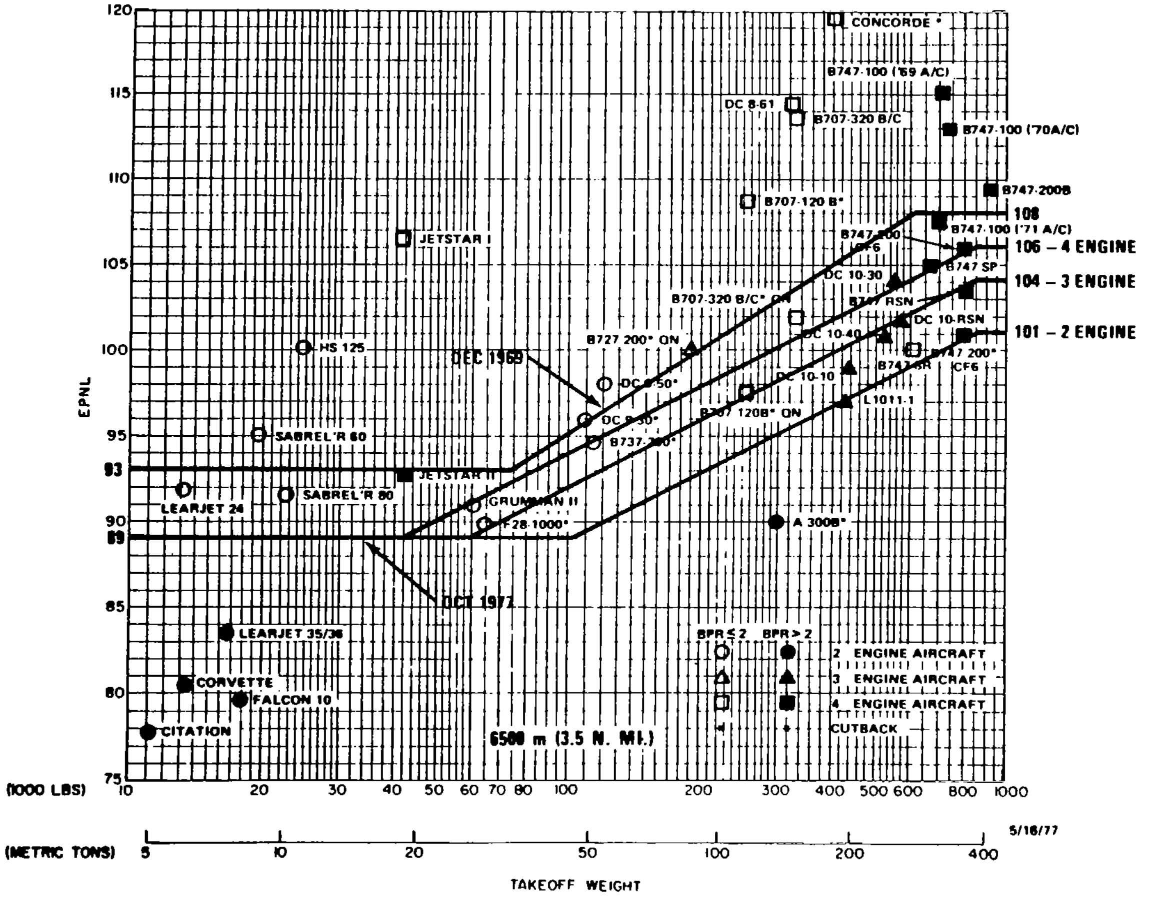

Figure 2.- FAR-36 takeoff noise.

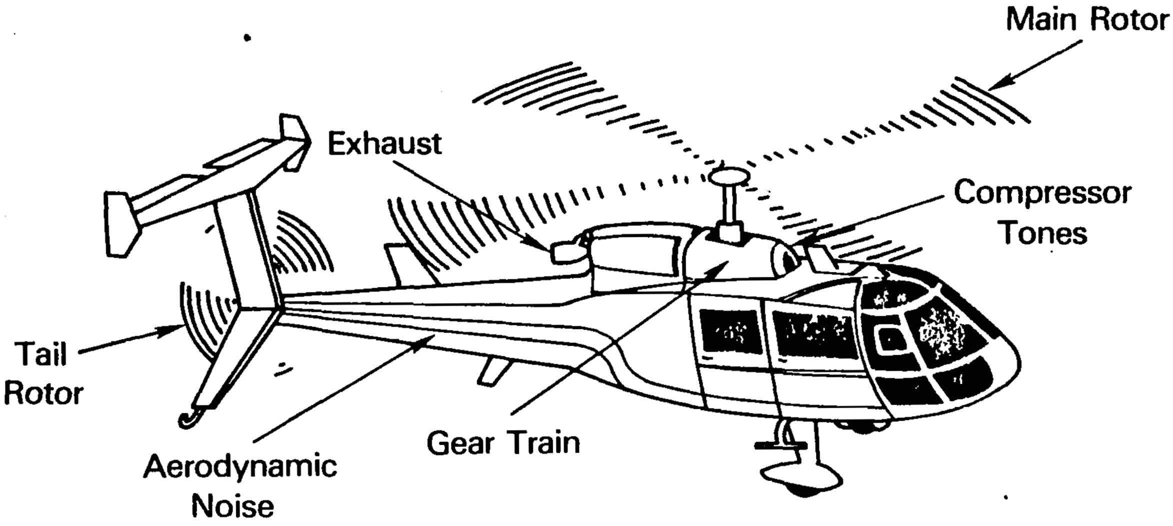

Figure 3.- Helicopter noise sources.

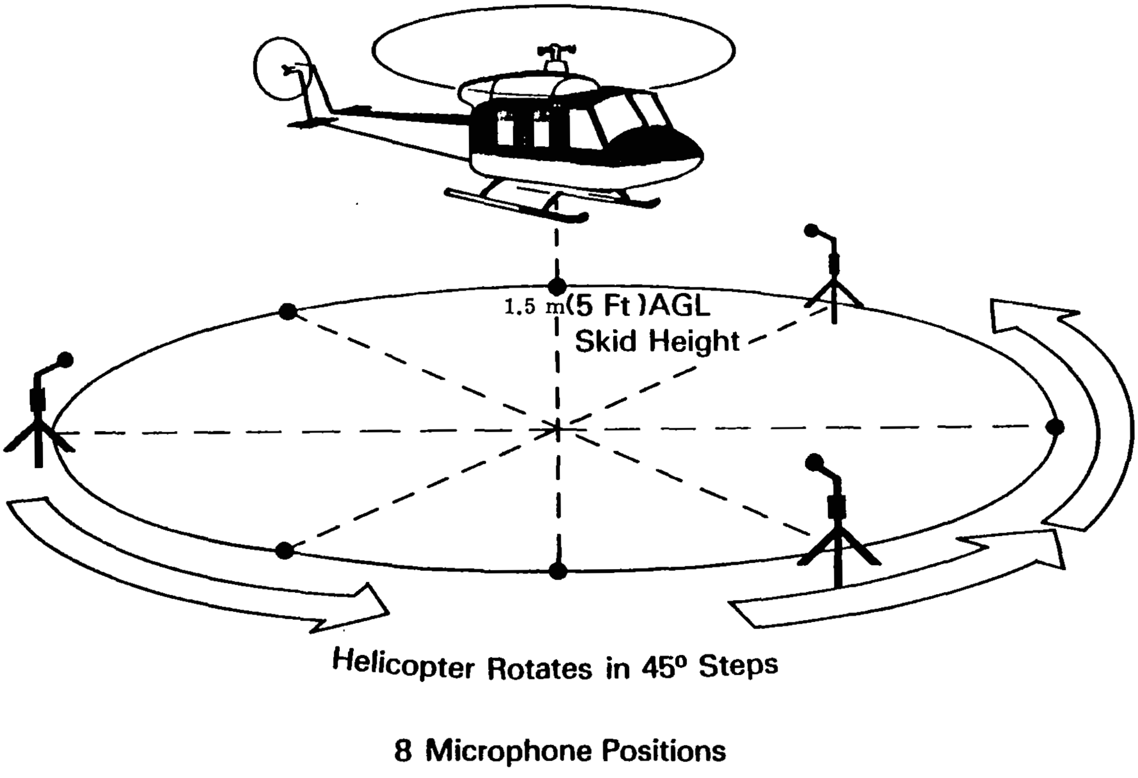

Figure 4.- Helicopter hover noise test.

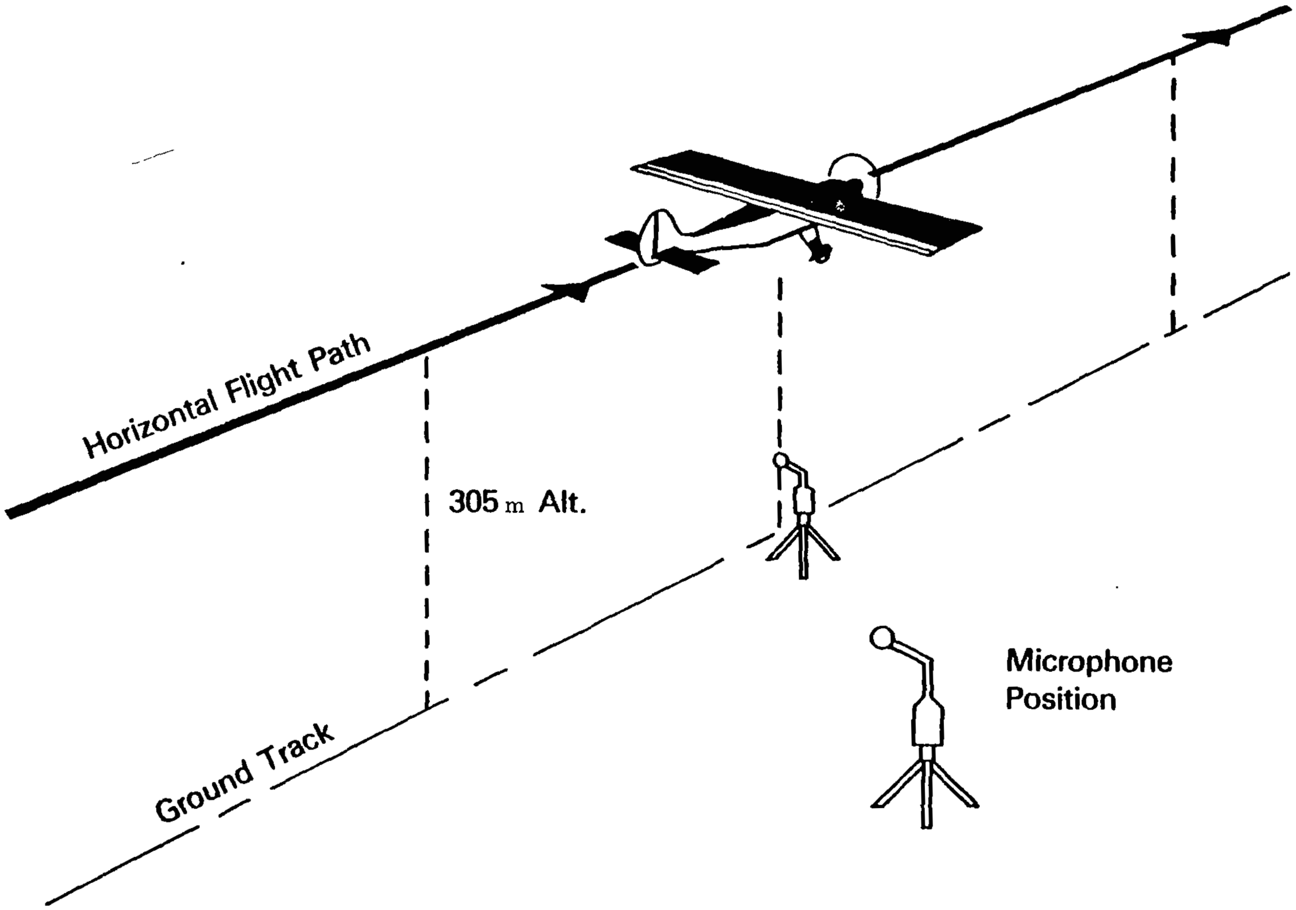

Figure 5.- Propeller-driven aircraft noise test. FAR Part 36 Appendix F.

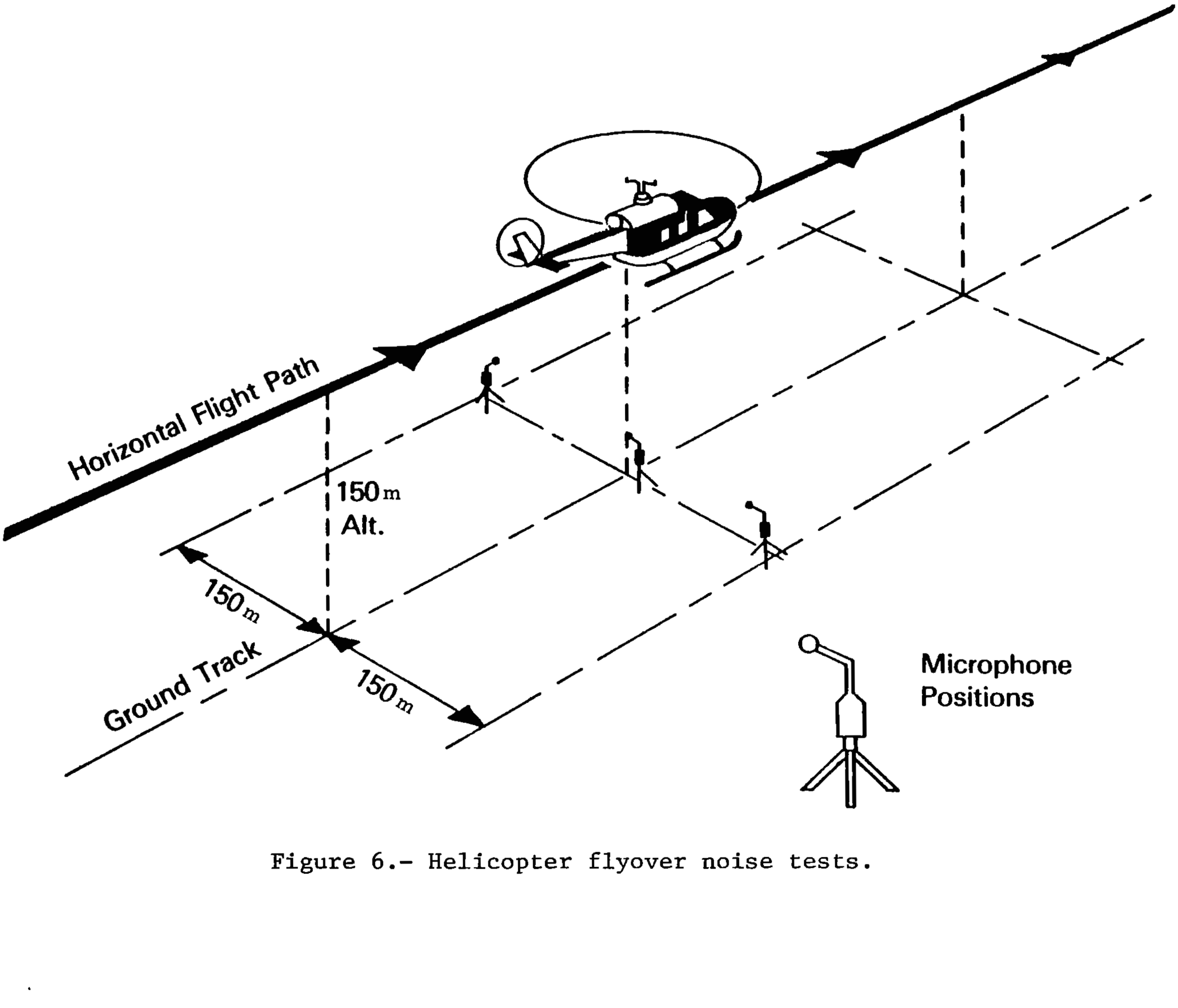

Figure 6.- Helicopter flyover noise tests.

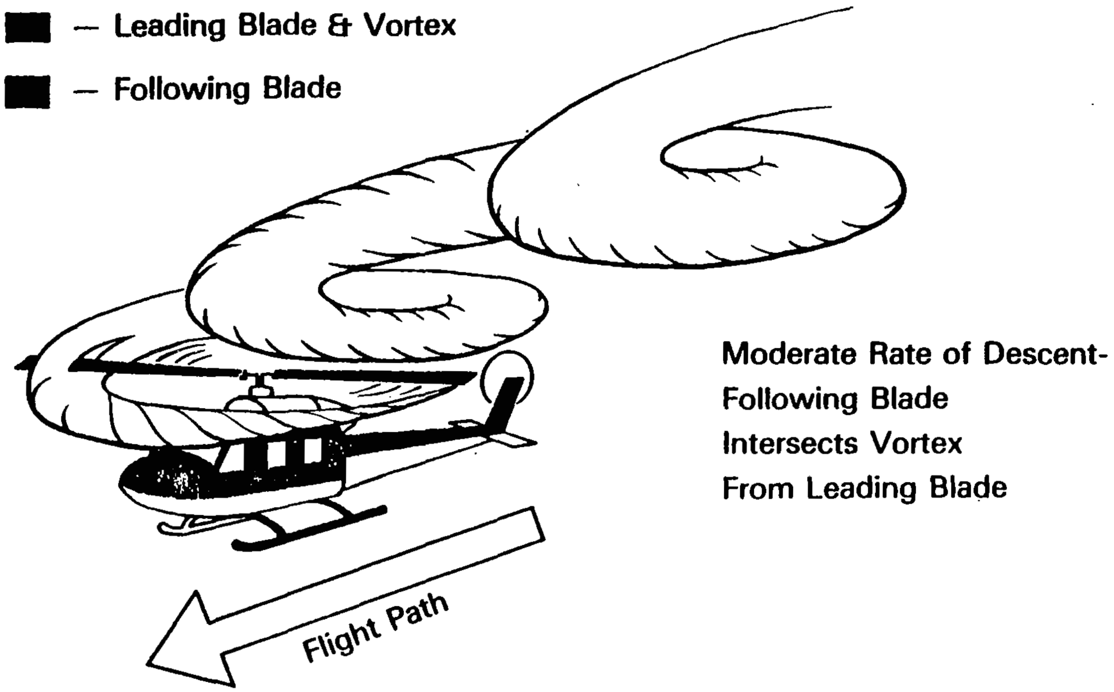

Figure 7.- Tip vortex interaction.

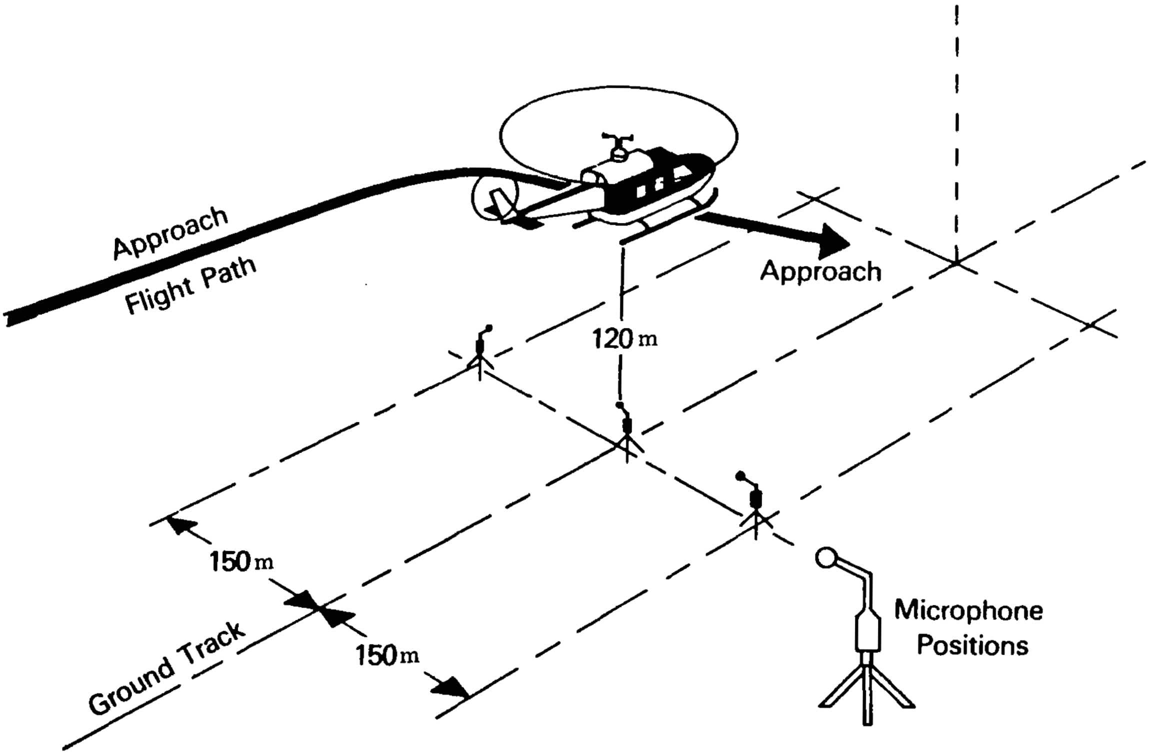

Figure 8.- Helicopter approach noise tests.

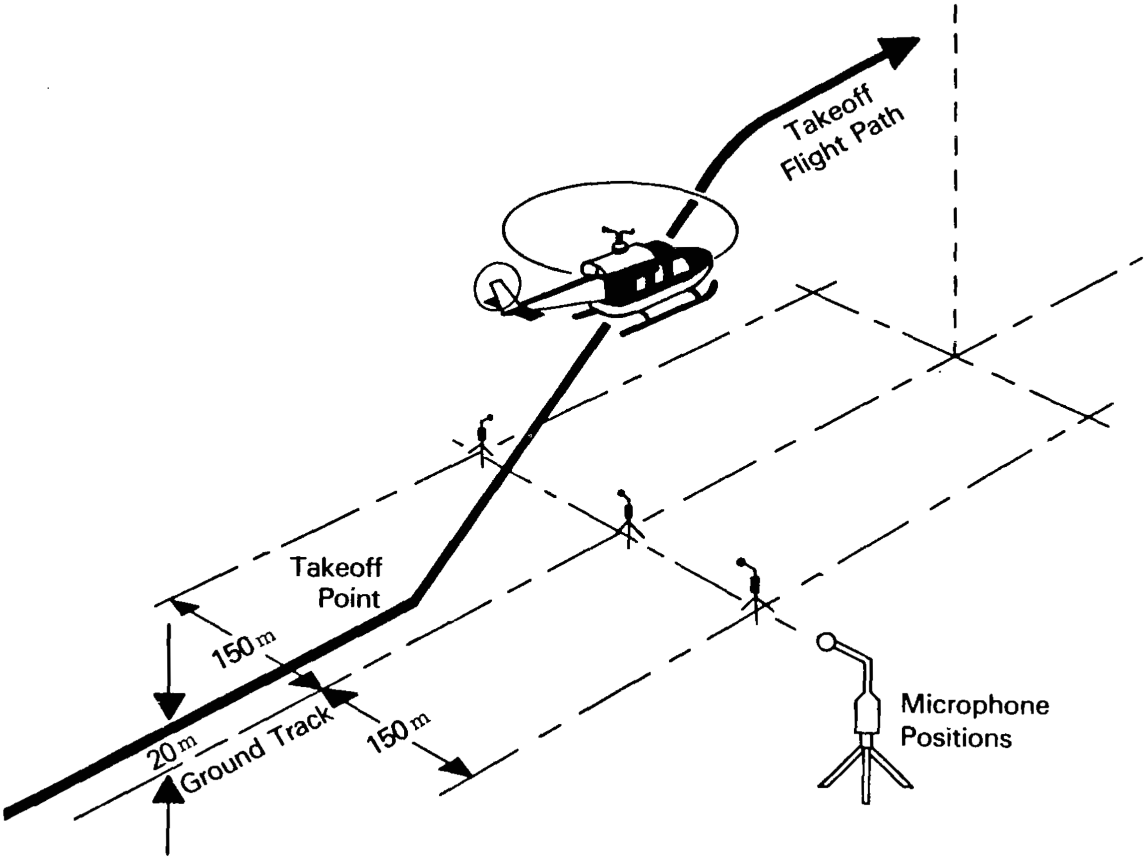

Figure 9.- Helicopter takeoff noise tests.

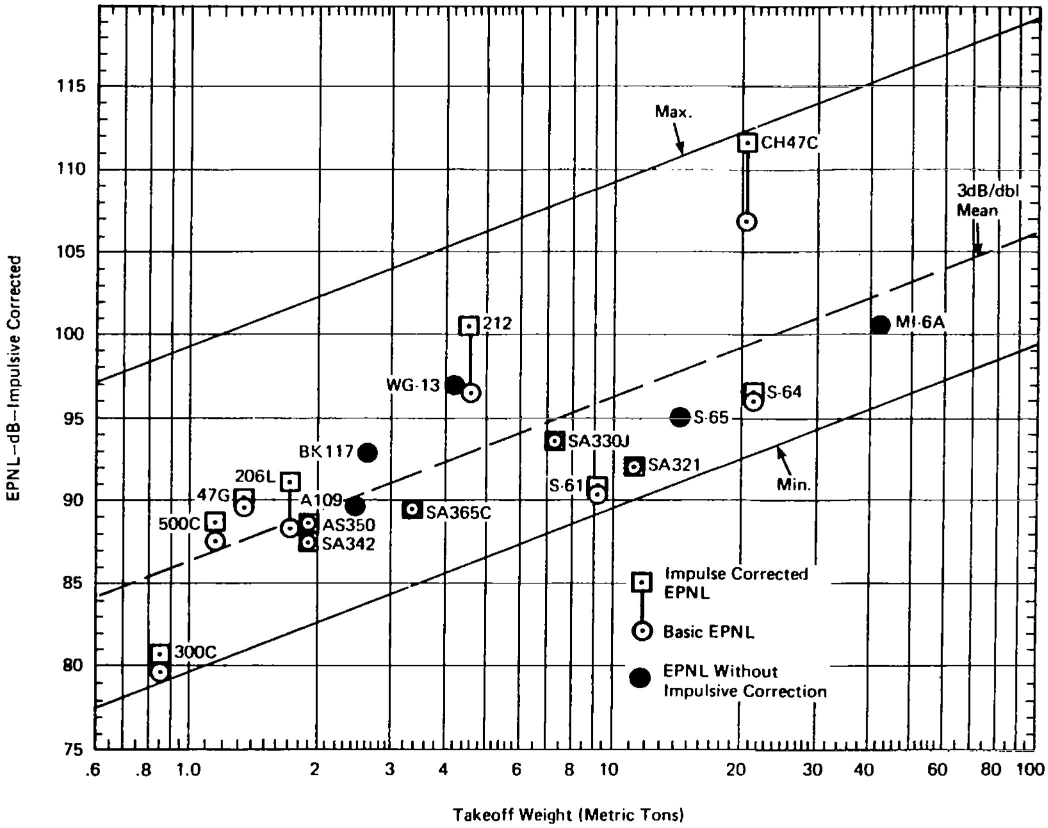

Figure 10.- Helicopter flyover noise levels.

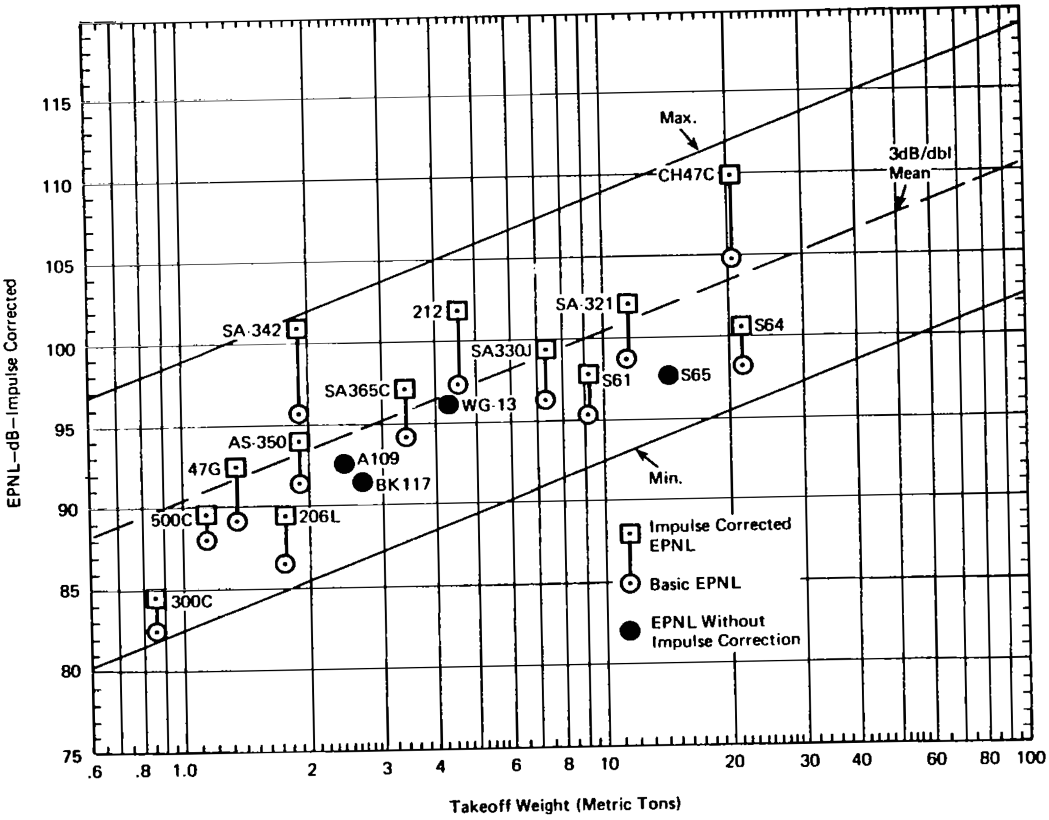

Figure 11.- Helicopter approach noise levels.

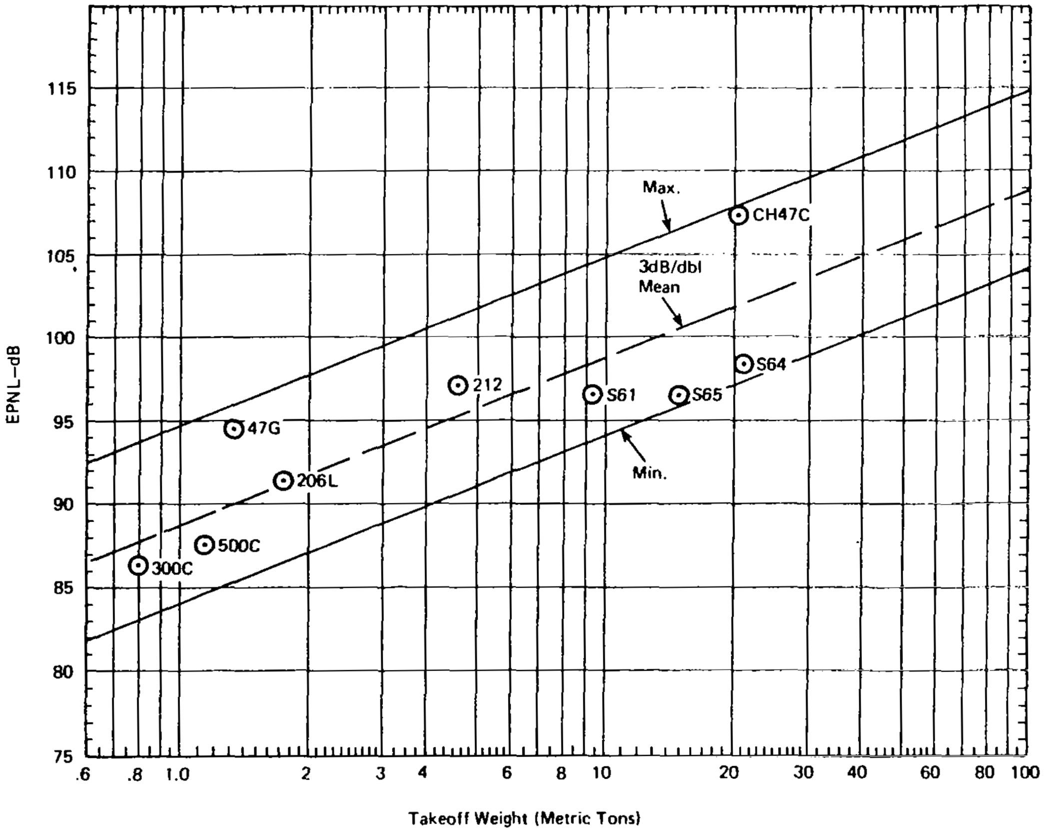

Figure 12.- Estimated takeoff noise levels.