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NOISE STANDARDS FOR AIRCRAFT TYPE CERTIFICATION (MODIFICATIONS TO FAR PART 36)

AUGUST 1976

U.S. Environmental Protection Agency
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16. ABSTRACT

This document presents and discusses the background data used by the Agency in the development of proposed noise control regulations for promulgation by the FAA in conformance with the Noise Control Act of 1972. The proposed regulations pertain to control of airplane noise at the source and would amend the existing Federal Aviation Regulations PART 36 (FAR 36).

FAR 36 was the first type certification regulation for aircraft noise prescribed by any nation. It is a comprehensive rule containing highly technical appendices whose purposes are to require the maximum feasible use of noise control technology, to set standards for the acquisition of noise levels, and to obtain data useful for predicting the noise impact in airport neighborhood communities. Since the promulgation of FAR 36 in 1969, noise control technology has advanced substantially, the significance of community noise impact is much better understood, and the techniques and equipment for data acquisition and reduction have improved considerably. It is appropriate, therefore, to consider amendments to FAR 36 with the objective of strengthening and extending the original purposes, and, in particular, to eliminate any ambiguities that may exist.

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PROJECT REPORT

NOISE STANDARDS FOR AIRCRAFT TYPE CERTIFICATION (MODIFICATIONS TO FAR PART 36)

2 AUGUST 1976

PREPARED BY

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF NOISE ABATEMENT AND CONTROL
WASHINGTON, D.C. 20460

SUMMARY

Federal Aviation Regulations Part 36 (FAR 36) was the first type certification regulation for aircraft noise prescribed by any nation. It is a comprehensive rule containing highly technical appendixes whose purposes are to require the maximum feasible use of noise control technology, to set standards for the acquisition of noise levels, and to obtain data useful for predicting the noise impact in airport neighborhood communities. Since the promulgation of FAR 36 in 1969, noise control technology has advanced substantially, the significance of community noise impact is much better understood, and the techniques and equipment for data acquisition and reduction have improved considerably. It is appropriate, therefore, to consider amendments to FAR 36 with the objective of strengthening and extending the original purposes, and, in particular, to close any loopholes that may exist.

In the following, the analyses in Section 5 examine every section of the technical appendixes and provide recommendations for changes where appropriate. The final recommendation is that two NPRMs be proposed, each independent of the other, containing a total of 24 amendments. The first NPRM would be concerned primarily with the compliance noise levels and the airplane flight procedures. The second NPRM would be concerned primarily with the methodology for the noise measurement and evaluation procedures. The reason for the development of two separate NPRMs is to avoid as much as possible any controversies whereby one would delay implementation of the other.

Compliance noise levels were developed to represent three time-dependent noise control options identified as current, available, and future technology. Levels pertaining to current technology would be implemented immediately, available technology in 1980, and future technology in 1985. The latter requirements are best estimates at this time for the lowest noise limits below which it is impractical or even impossible to proceed.

The health and welfare and cost considerations in Section 6 examines two individual single runway airports (air carrier and general aviation) as indicators of the noise impact resulting from the implementation of various options for compliance noise levels. Rectangles enclosing the runways, whose dimensions are compatible with the FAR 36 measuring points, can be considered as indicators of the minimum land areas that suffer substantial noise impact. The areas of the rectangles (roughly 3 and 2 square miles for air carrier and general aviation runways, respectively) are examined for the noise contours, in terms of the day-night level (Ldn), that lie within them. The smaller the value of the contour completely enclosed by the rectangle, the more effective will be the related compliance noise level option in protecting the public health and welfare.

The areas enclosed by the rectangles should be devoid of single family residences and should be under the control of the airport authority or be controlled by the local political jurisdictions. In many cases, most, if not all, of the enclosed areas will be airport property and the ultimate objective would be to have the Ldn 55 contour (EPA long range goal) to lie within the airport property fence. The indicator rectangles serve the purpose of providing a standard fence which permits the effectiveness of the compliance noise level options to be examined in a single and consistent manner.

The analysis for air carrier airports shows that compliance with any of the options, even the future technology noise levels, would not result in Ldn 55 contours lying within the 3 square mile rectangle without severe restrictions on the number of aircraft operations. The conclusion is that some compromise would have to be made. Either a goal of Ldn 60 or even Ldn 65 should be accepted as adequately stringent for those airports instead of Ldn 55, or noise compatible land use should be directed to areas greater than 3 square miles.

The analysis for general aviation airports shows that compliance with the future technology noise levels could be met without unduly severe limitations on the number of operations. For these airports, most of which are situated in suburban or rural locations, the Ldn 55 goal is probably not too stringent.

It is estimated that abuse of existing procedures for noise measurement and analysis can result in a 3 to 4 dB noise exposure disbenefit to the public. Therefore, the recommended modifications to those procedures would provide benefits to the noise exposed public by ensuring that the source noise reductions actually would comply with the noise level requirements.

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1. INTRODUCTION AND PERSPECTIVES

In 1968, Public Law 90-411 amended Section 611 of the Federal Aviation Act of 1958 to require that, in order to afford present and future relief and protection to the public from unnecessary aircraft noise and sonic boom, the Federal Aviation Administration (FAA) shall prescribe and amend such regulations as the FAA may find necessary to provide for the control and abatement of aircraft noise and sonic boom. In addition, PL 90-411 provided detailed specifications that must be considered by the FAA in prescribing and amending aircraft noise and sonic boom regulations.

The Noise Control Act of 1972 (Public Law 92-574) supersedes Public Law 90-411 and further amends Section 611 of the Federal Aviation Act of 1958 to include the concept of "health and welfare" and to define the responsibilities of and interrelationships between the FAA and the Environmental Protection Agency (EPA) in the control and abatement of aircraft noise and sonic boom. Specifically, the Noise Control Act requires that, in order to afford present and future relief and protection to the public health and welfare from aircraft noise and sonic boom, the FAA, after consultation with EPA, shall prescribe and amend such regulations as the FAA may find necessary to provide for the control and abatement of aircraft noise and sonic boom.

The Noise Control Act also requires that EPA shall submit to the FAA proposed regulations to provide such control and abatement of aircraft noise and sonic boom (including control and abatement through the exercise of any of the FAA's regulatory authority over air commerce or transportation or over aircraft or airport operations) as EPA determines is necessary to protect the public health and welfare. The regulations proposed by EPA are to be based upon, but not submitted before completion of, a comprehensive study to be undertaken by the EPA and reported to Congress.

The Aircraft/Airport Noise Study, which was completed in August 1973, was required to investigate the:

(1) adequacy of Federal Aviation Administration flight and operational noise controls;

(2) adequacy of noise emission standards on new and existing aircraft, together with recommendations on the retrofitting and phaseout of existing aircraft;

(3) implications of identifying and achieving levels of cumulative noise exposure around airports; and

(4) additional measures available to airport operators and local governments to control aircraft noise.

The study was implemented by a task force composed of six task groups whose product consisted of a report to Congress and six volumes of supporting data (one volume for each task group). The reports are identified as References 1 through 7.

Concurrent with the Aircraft/Airport Noise Study, the EPA prepared a general document of criteria in conformance with Section 5(a)(1) of the Noise Control Act (Reference 8). This "Criteria Document" reflects the scientific knowledge useful in indicating the kind and extent of identifiable effects on the public health and welfare which may be expected from differing quantities of noise.

In addition, as required by Section 5(a)(2) of the Noise Control Act, the EPA has prepared a document on the levels of environmental noise, the attainment and maintenance of which in defined areas under various conditions are requisite to protect the public health and welfare with an adequate margin of safety (Reference 9).

The key findings of the "Levels Document" may be summarized as follows:

(1) The preferred measure for cumulative noise exposure is Leq, the energy average A-weighted sound level integrated over a 24-hour period, or Day-Night Level, Ldn. Ldn is essentially the same as Leq, except that the sounds occurring during night hours (2200 to 0700) are weighted by an adjustment factor of 10 dB to account for increased annoyance of noise during night hours.

(2) An Ldn of 55 dB has been identified as the noise exposure level which should not be exceeded in order to protect persons against annoyance, with an adequate margin of safety.

(3) An Leq of 70 dB has been identified as that noise exposure level which should not be exceeded in order to protect persons against permanent hearing impairment, with an adequate margin of safety.

Both of the foregoing levels are daily averages over long periods of time, rather than maximum allowables for single exposures.

As a result of the Aircraft/Airport Noise Study, EPA determined that an effective program to protect the public health and welfare with respect to aircraft noise would require the development and proposal to the FAA of regulations in three complementary areas:

(1) Flight procedures regulations standardizing various modes of noise abatement operations,

(2) Type and airworthiness certification regulations controlling noise source emissions in the design of new aircraft and by modification or phaseout of certain portions of the existing fleet,

(3) An airport noise regulation, which would limit the cumulative exposure received by noise-sensitive land areas in communities surrounding airports. Such a regulation, by acting as a performance standard for the airport as a complex source, would require achievement of mutually compatible airport operational and land use patterns.

The first two types of regulations have been classified within the following eight aircraft noise regulatory projects to be proposed by the EPA for promulgation by the FAA under Section 611 of the Federal Aviation Act as amended.

Flight Procedures

(1) Takeoff

Individual airports, or runways of the airports, can be placed into the following three main categories regarding community noise exposure: sideline noise sensitive; near downrange noise sensitive; and far downrange noise sensitive. A set of three standard takeoff procedures suitable for safe operation of each type of civil turbojet airplanes shall be considered for use, as appropriate, to minimize the noise exposure of the noise sensitive communities.

(2) Approach and Landing

Standardized approach procedures, suitable for safe operation of each type of civil turbojet airplanes, shall be considered for use as appropriate to minimize community noise exposure. Examples include reduced flap setting and two segment approach (approximately 6/3 degrees).

(3) Minimum Altitudes

Minimum safe altitudes, higher than are presently specified in the Federal Aviation Regulations, shall be considered for the purpose of noise abatement, applicable to civil turbojet powered airplanes regardless of category.

Type and Airworthiness Certification

(4) Retrofit/Fleet Noise Level

Approximately 2500 existing turbojet propelled airplanes, having about 5,000,000 operations per year in the United States are not covered by any noise rule but are the major source of noise impact in the vicinity of at least 500 airports. Regulations shall be considered for the purpose of minimizing the noise of the existing civil aircraft fleet to levels as low as feasible by current technology.

(5) Supersonic Civil Aircraft

Regulations shall be considered which would limit the noise generated by future types of civil supersonic aircraft to levels commensurate with those required for contempory civil subsonic transports.

(6) Modifications to Federal Aviation Regulations (FAR 36)

Modifications to FAR 36 shall be considered for lowering the compliance noise levels for all new airplane types commensurate with technology capability. In addition, various amendments shall be considered which would improve accuracy, close loopholes, simplify techniques, and in general, make the rule clearer and more effective.

(7) Propeller Driven Small Airplanes

Noise regulations and standards shall be considered for propeller driven small airplanes applicable to new type designs, newly produced airplanes of older type designs, and to the prohibition of "acoustical changes" in the type design of those airplanes.

(8) Short Haul Aircraft

Noise regulations and standards shall be considered for all aircraft capable of vertical, short, or reduced takeoff or landing operations. The required lengths of runways for these operations are being considered as: 1,000 ft for VTOL; 2,000 ft for STOL; and 4,000 ft for RTOL.

The regulations developed for the above eight projects will represent a package which, in toto, is expected to bring about a substantial reduction in the noise environment due to aircraft. While no one regulation by itself, nor the total package, will solve all of the community noise problems due to aircraft, each one, as a building block, will result in appreciable improvement. In other words, it is anticipated that the regulations individually or collectively will effectuate a marked reduction in the number of persons exposed to undesirably high levels of aircraft noise. This effect will be additive to the improvement expected over the next decade or so as the older, noisier aircraft in the U.S. aviation fleet are retired and replaced with newer, quieter types with greater functional capabilities.

In prescribing and amending standards and regulations, Section 611 of the Federal Aviation Act as amended requires that the FAA shall consider whether any proposed standard or regulation is:

(1) consistent with the highest degree of safety in air commerce or air transportation in the public interest;

(2) economically reasonable;

(3) technologically practicable; and

(4) appropriate for the particular type of aircraft, aircraft engine, appliance, or certificate to which it will apply.

The above considerations of safety, economics, and technology are constraints on the noise regulatory actions which must be made compatible with the requirement of protection to the public health and welfare. To achieve compatibility, the regulations must be carefully constructed, comprehensive, and definitive instruments for exploiting the most effective and feasible technology, flight procedures, and operating controls available.

The regulations proposed by the EPA for promulgation by the FAA must be practically as complete and comprehensive as the FAA would propose on their own initiative. Otherwise, conflicts between the regulatory constraints of safety, economics, and technology and the requirement of protection to the public health and welfare could delay constructive action needlessly.

The development of an aircraft noise regulation starts with the preparation of a project report, which is primarily a background document providing as much information as possible on such matters as health and welfare; current, available, and future technology, cost-effectiveness, and recommended criteria for levels, measurements, and analyses. The project report provides the basic input necessary for the preparation of a notice of proposed rulemaking (NPRM), which is the format of each regulation to be proposed by the EPA to the FAA.

The EPA published a "Notice of Public Comment Period" in the Federal Register on 19 February 1974 concerning aircraft and airport noise regulations (Reference 10). This Notice identified the eight areas discussed above as candidates for regulatory actions which could be effective in controlling aircraft noise. The purpose of the Notice was to invite interested persons to participate in EPA's development of the regulations to be proposed, by submitting such written data, views, or arguments as they may desire. The Notice was not definitive in regard to any particular proposed regulation but referred to them in a general way. Information was solicited relating to the basic requirement that the regulations contribute to the promotion of an environment for all Americans free from noise that jeopardized their health or welfare, and to the four statutory constraints pertaining to safety, economics, and technology. The aviation community, therefore, was put on notice in early 1974 that regulatory activities were underway by the EPA and were informed of the general nature of the proposed regulations. Subsequent developments have not changed the direction to any appreciable extent.

2. SYSTEMS CONTROL OF AIRCRAFT NOISE

Protection to the public health and welfare from aircraft noise is accomplished most effectively by exercising four noise control options taken together as a system:

(1) Source control consisting of the application of basic design principles or special hardware to the engine/ airframe combination which will minimize the generation and radiation of noise;

(2) Path control consisting of the application of flight procedures which will minimize the generation and propagation of noise;

(3) Receiver control consisting of the application of procedures susceptible to control by airport communities such as restrictions on the type and use of aircraft at the airport which will minimize community noise exposure; and

(4) Land use control consisting of the development or modification of airport surroundings for maximum noise compatible usage.

In general, the primary approach for noise abatement is to attempt to control the noise at the source to the extent that the aircraft would be acceptable for operations at all airports and enroute. And in principle, aircraft noise can be controlled extensively at the source by massive implementation of technology. In practice, however, the technological capability for complete control without exorbitant penalties is not yet available and may never be. A regulation requiring full protection to the public health and welfare by source control, therefore, would have the effect of preventing the development of most new aircraft and grounding the existing civil fleet.

Path control, for most cases, can be an effective option for substantial reduction of aircraft noise. Furthermore, it has the advantage that the results are additive to those obtained by source control. However, specialized flight procedures are limited because of the need to maintain the highest degree of safety. Therefore, a regulation requiring full protection to the public health and welfare by flight procedures is not feasible at this time and probably never will be. Nevertheless, all aircraft can be flown safely in various modes that produce a wide range of noise exposure. And, at the least, those safe modes, which will minimize the generation and propagation of noise, should be identified and standardized.

The major problem with aircraft noise in terms of numbers of people exposed, occurs in the vicinity of airports. This problem could be relieved by the application of various operating restrictions at the airport. Extensive use of airport restrictions, however, is cost-effective only if all feasible source and path control options have been implemented. Unless this has been done, the airport restrictions may result in unnecessary damage to the local and national economy.

A concept under consideration at this time is that the airport authorities in some cases, and the FAA in other cases, would impose restrictions on the aircraft operators as needed (curfews, quotas, weight and type limitations, preferential runway use, noise abatement takeoff and approach procedures, landing fees, etc.) to ensure that the airport neighborhood communities are noise-compatible consistent with the requirements of health and welfare. The restrictions available to the airport operator would be those approved by the FAA, CAB, and EPA. The highest degree of safety must be maintained and interstate and foreign commerce requirements must be considered. Restrictions involving flight safety and air traffic control would be the sole responsibility of the FAA.

As an example of this concept, determination of runway usage to minimize community noise impact would be made by the airport operator after consultations with the municipal authorities of the airport neighborhood communities. High priority should be given to maximum implementation of long range land use planning for noise compatibility. If the FAA agrees with the operator's runway designations, the FAA would decide which takeoff and approach procedures would be implemented by aircraft using the designated runways. In all cases, pilots and air traffic controllers would be given discretionary authority over operating procedures for safety and air traffic reasons.

After all feasible noise control measures have been applied to the aircraft by design, treatment, or modification of the source, by flight and air traffic control procedures, and by proper design, location and use of airports, aircraft noise may still be a problem at some locations. In this event, noise compatible land use is probably the only remaining solution. The land use control option is more easily exercised in the development of new airports than as a remedial measure for existing noise impacted communities. For the latter case, the costs of land use control may be so high that maximum effort should be devoted to implementing the source, path, and receiver control options taken together as a system.

The extent to which the control options should be regulated is dependent upon the meaning and quantification of public health and welfare. Three important considerations must be emphasized. First, the EPA-proposed and the FAA-prescribed noise regulations have the requirement of protection to the public health and welfare. Second, the regulations are constrained by safety, economics, and technology. Third, although the requirement and the constraints may appear to be in opposition to each other, resolution can be accomplished by implementation of the noise control options taken together as a system.

The foregoing discussion is relevant to the basic fact that aviation is a needed element of the national transportation system. If regulations intended to protect the public health and welfare imposed such a burden that the survival of the national aviation system were threatened, this result would not be in the national interest. On the other hand, well-conceived regulations which optimally exploit the available alternatives would protect the public health and welfare and, by improving the acceptability of aircraft, encourage continuing development of the aviation system.

If it could be established that any of the three options involving design techniques or hardware applications, flight procedures, or airport restrictions could feasibly satisfy the requirements for protection to the public health and welfare from airport noise, then that option probably should be used. It is unlikely, however, that any single option, within the legislative constraints of safety, economics and technology, could completely satisfy the requirements for such protection. Consequently, a systems implementation of the four noise control options should be considered as the most feasible method for accomplishing the desired objectives and equitably sharing the costs of noise control among all segments of the aviation community and that portion of the public that benefits from aviation.

Noise regulations that pertain to source emissions or flight procedures of specific types of aircraft not yet produced cannot be expected to predict such unknowns as the quantity of these aircraft that eventually will be produced, from what airports (or runways) they will be operated, or what noise-compatible land use can or may be implemented in the vicinity of these airports. Consequently, source emissions or flight procedures regulations should be developed with the understanding that protection to the public health and welfare will be accomplished by implementation of the total system concept.

The regulations should be of the "umbrella" type in the sense that those aircraft regulated can all comply by use of current technology although some may be capable of and are achieving lower noise levels than others. The various aircraft/engine types have different weights, thrust, engine characteristics, and flight performance characteristics, all of which influence their noise generation and reduction capabilities. Consequently, it is not reasonable to expect that a particular source or flight procedures regulation should require equal noise level compliance from all types of aircraft. However, all aircraft should be required to implement current noise control technology to the maximum extent feasible for their type. Also, various models of aircraft within a specific type classification may not have the same capability for generating or controlling noise because of differences in size, weight, powerplant, etc. The regulations should be flexible enough to consider the effect of these growth factors on noise and attempt to control the levels to the maximum practical extent.

"Umbrella" type regulations do not mean that the worst offenders would be permitted to comply without penalty. On the contrary, a properly constructed set of regulations, representing components of a system of noise control options, probably would require ultimately the greatest sacrifice from the worst offender. As an example, FAR 36 has several features that discriminate, in the "umbrella" sense, among the various classes of airplanes. Greater weight airplanes are permitted higher compliance levels; four engine airplanes are permitted greater sideline distances; but four engine airplanes are not permitted as much percent thrust reduction at takeoff. The above discriminating features contained in the same source control regulation permit some airplanes to make more noise than others. In the end, however, the airplanes producing the most noise will be the primary candidates for operating restrictions at the airports as necessary to protect the public health and welfare. Implementation of these restrictions is likely to impose the greatest burden on the noisiest airplanes.

The airport restrictions would provide incentive for the aircraft manufacturers and operators to conduct thorough investigations and consider maximum utilization of current noise control technology. The fact that an aircraft manufacturer or operator has barely complied with an "umbrella" type certification or flight procedure regulation should not ensure unlimited acceptance of a particular airplane at all airports. The possibility that airport restrictions might inhibit use, would, therefore, encourage the aircraft operators and manufacturers to satisfy the FAA regulations by maximum utilization of the source emissions and flight procedures noise control technology within their capability and not merely to comply with specified limits.

3. BACKGROUND OF EXISTING AIRCRAFT NOISE REGULATIONS

Five regulations, or amendments thereto, have been prescribed which have a significant influence on aircraft noise and sonic boom. These rules, identified as References 11 thru 15, accomplish the following:

(1) Reference 11 (FAR 36) prescribes noise standards for the issue of type certificates, and changes to those certificates, for subsonic transport category airplanes, and for subsonic turbojet powered airplanes regardless of category. This rule initiated the noise abatement regulatory program of the FAA under the statutory authority of Public Law 90-411.

(2) Reference 12 is an operating rule prohibiting supersonic flights of civil aircraft except under terms of a special authorization to exceed the speed of sound (Mach 1.0). Authorization to operate at a true Mach number greater than unity over a designated test area may be obtained for special test purposes. Authorization for a flight outside of a designated test area at supersonic speeds may be made if the applicant can show conservatively that the flight will not cause a measurable sonic boom overpressure to reach the surface.

(3) Reference 13 requires new production turbojet and transport category subsonic airplanes to comply with FAR 36, irrespective of type certification date. This rule established the following dates by which new production airplanes of older type designs must comply with FAR 36.

- 1 December 1973 for airplanes with maximum weights greater than 75,000 pounds, except for airplanes that are powered by Pratt and Whitney JT3D series engines.
- 31 December 1974 for airplanes with maximum weights greater than 75,000 pounds which are powered by Pratt and Whitney JT3D series engines.
- 31 December 1974 for airplanes with maximum weights of 75,000 pounds and less.

(4) Reference 14 is an amendment to FAR 36 whose purpose is to tighten the conditions under which an applicant for an acoustical change approval must show that modifications of certain turbojet or transport category airplanes will not increase the takeoff or sideline noise levels of those airplanes. Three changes are made to the acoustical change provision of FAR 36 which will significantly decrease community noise impact by preventing methods of circumventing that provision. The three changes which effectively close loopholes are:

- Thrust reduction is not permitted.
- Test airspeed is more precisely specified.
- The quietest approved configuration for the highest approved takeoff weight must be used.

(5) Reference 15 prescribes noise standards for:

- The issue of normal, utility, acrobatic, transport, and restricted category type certificates for propeller driven small airplanes (12,500 pounds maximum weight).

- The issue of standard airworthiness certificates and restricted category airworthiness certificates for newly produced propeller driven small airplanes of older type designs.
- The prohibition of "acoustical changes" in the type design of those airplanes that increase their noise levels beyond specified limits.

It should be noted that the EPA has objected to the regulation of Reference 15 as being too lenient and has proposed one significantly more stringent which was published in the Federal Register on the same date as Reference 15 (40 FR 1061).

FAR 36 was the first type certification regulation for aircraft noise prescribed by any nation. It is a comprehensive, highly technical rule appropriate to the sophisticated sound source (aircraft) it is designed to regulate. The development of the basic concepts inherent in FAR 36 was, for the most part, the result of the experience of government and industry not only of the United States but of France and the United Kingdom as well. Government representatives of these nations formed a "Tripartite" working group which provided most of the initial ideas and coordinated the technology upon which FAR 36 is based. Subsequently, representatives of Germany, Japan, the Netherlands, and Sweden participated in the working group and made valuable contributions. The seven nations involved represented the major aircraft manufacturing nations of the world (except for the U.S.S.R.) and were able to pool their specialized knowledge and experience to provide a substantial technology base for the development of aircraft noise regulations.

It must be emphasized that various national and international organizations* provided valuable background data in such areas as noise measurement procedures, electronic equipment characteristics, atmospheric attenuation of sound, and noise evaluation measures. Where these organizations had issued approved citable documents that were relevant, they were included as references in FAR 36 In many cases, however, the areas were so new that the only documents available were draft working papers. Where appropriate, such material was included (but not referenced) in FAR 36.

The United States was the first nation to take advantage of this wealth of information and include it in a noise control regulation published in November 1969 as FAR 36. Shortly thereafter, in December 1969, the International Civil Aviation Organization (ICAO) recommended standards (Reference 16) which, subsequently, were adopted by the Council of ICAO in April 1971 as Annex 16 to the Convention of International Civil Aviation (Reference 17). FAR 36 and Annex 16 are essentially the same rules; FAR 36, however, being slightly more stringent. Most nations have adopted Annex 16 as their type certification rule for aircraft noise and because the rules are so similar, no major problems have arisen in regard to reciprocity between the United States rule FAR 36 and Annex 16 for the rest of the world.

* American National Standards Institute (ANSI), International Electrotechnical commission (IEC), International Standards Organization (ISO), Society of Automotive Engineers (SAE).

4. OBJECTIVE

The objective of this project is to propose a rule which will control the noise of certain turbojet and propeller driven airplanes to levels as low as is consistent with safe technological capability, and which:

(1) will be fully responsive to the recommendations of Reference 9 for protection to the public health and welfare,

(2) will not impose unreasonable economic burdens on the national aviation system,

(3) will not degrade the environment in any manner, and

(4) will not cause a significant increase in fuel consumption.

The intent of this project report is to provide as much definitive information as possible on such matters as health and welfare, technology, cost effectiveness, and recommended criteria for levels, measurements, and analyses. This project report will provide the basic input for the preparation of a notice of proposed rule making (NPRM) which will be the format of the regulation to be proposed by the EPA for promulgation by the FAA in conformance with the Noise Control Act of 1972.

The noise rule should have the earliest practical effective date, should be a requirement for the operation of certain turbojet and propeller driven airplanes in the United States and thereby:

(1) insure that future community noise exposure due to the operation of these aircraft has been reduced to the lowest feasible levels and smallest practical areas commensurate with the current state of the art,

(2) provide a regulatory maximum noise level limit on these airplanes to form a basis for meaningful long-range land use planning in the vicinity of airports,

(3) provide economic incentives for the development of quieter airplanes by limiting the development of noisy ones,

(4) permit the fullest practical range of airplane design options so that cost-effective noise reduction can be achieved.

Specifically, what is under consideration here is an amendment to the existing Federal Aviation Regulation Part 36 (FAR 36), Reference 11. FAR 36 is a type certification regulation which applies to certain kinds of airplanes designated as types. Only one airplane of each type need be tested and the results of the tests are assumed valid for all individual airplanes produced of that type. A type certificate signifies that an aircraft type design has been demonstrated to conform to FAA standards on airworthiness and noise. Each aircraft requires an airworthiness certificate that signifies that the specific aircraft has been manufactured in accordance with its FAA certified type design and has subsequently been maintained according to regulations.

FAR 36 has several purposes. Its main purpose is to provide requirements which will influence the design of aircraft to include implementation of noise source control technology to the maximum extent feasible. As defined in Section 2, source control consists of the application of basic design principles or special hardware to the engine/airframe combination which will minimize the generation and radiation of noise. And as used here, feasibility means that the noise control technology shall be compatible with the regulatory constraints of safety, economics, and technology discussed in Section 1. In other words, the technology shall: (1) be consistent with the highest degree of safety; (2) be economically reasonable; (3) be technologically practicable; and (4) be appropriate for the particular type of aircraft.

Another purpose of FAR 36 is to provide meaningful noise levels for specific types of aircraft which will be useful in predicting the noise impact in airport neighborhood communities. It must be understood that since FAR 36 is a type certification regulation, the data resulting from the certification process will be limited in its extent insofar as community noise impact studies are concerned. Nevertheless, FAR 36 should require the acquisition and reporting of data which can be utilized in such studies.

Another purpose of FAR 36 which is fundamental to the other purposes is the setting of standards for the acquisition and reduction of aircraft noise and flight performance data. Without standards, noise measurements of aircraft have no real credibility. Without good standards, noise requirements may not be effective. Imprecise meanings, careless terminology, or inadequate testing procedures can lead to circumvention of the intent of the rule. In other words, loopholes should not exist which can be exploited by those manufacturers who have airplanes that have problems meeting the noise requirements.

The objectives of the amendment to FAR 36, as developed and proposed in this project report, are to strengthen and extend the original purposes of FAR 36. Since the promulgation of FAR 36 in 1969, noise control technology has advanced substantially. The noise compliance requirements should reflect this technology growth and be structured with respect to time to encourage the application of future technology whenever it is determined to be feasible.

The methods for determining community noise impact are better understood now than in 1969. Consequently, amendments to FAR 36 should include requirements for the acquisition and/or reporting, to a reasonable extent, of data useful for predicting the impact of aircraft noise.

The procedures for type certification of aircraft noise also are better understood now than five years ago. The considerable experience gained in the United States and abroad should be utilized to simplify techniques, improve accuracy, and eliminate ambiguities. Advancements in the electronic data acquisition and reduction systems should be reflected in the standards in order to improve efficiency and reduce costs.

The major aircraft manufacturing nations, including the United States, have been active in coordinating their experience and working toward amending Annex 16 to reflect their aggregate experience and update the standards for the acquisition and reduction of aircraft noise and flight performance data. The results of this work were discussed as Agenda Item 3 during the fourth meeting of the ICAO Committee on Aircraft Noise (CAN/4) held in Montreal 27 January - 14 February 1975. In preparation for CAN/4, the working papers and other documents listed as References 18 thru 42 were circulated. Most of the working papers reflect national or organizational interests and should be considered accordingly. However, the report of ICAO Working Group D (Reference 19) represents the work of many nations, including the United States. It presents a very comprehensive set of recommendations for amending Annex 16 to make the noise specifications more severe.

It is desirable but not necessary that amendments to FAR 36 and Annex 16 be similar. The United States has its own requirements (Noise Control Act of 1972) which, in many respects, are more stringent than those of most other nations. Consequently, the recommendations of Working Group D and those of the other working papers were examined for their relevancy and used accordingly. Nevertheless, the international aviation community has done outstanding work in the area of aircraft noise and its control and their results are referred to extensively in the following Analyses section.

5. ANALYSES

A. Technology Options and Applications for Source Noise Control

Source noise control, as defined previously, is the application of basic design principles or special hardware to the engine/airframe combination which will minimize the generation and radiation of noise. The technology of source noise control is time-dependent in the sense that it is based upon the results of past, present and future programs of research, development, and demonstration (RD & D) which can be classified as follows:

(1) Current technology includes "shelf item" hardware and commonly known (state of the art) techniques and procedures which have been used effectively by most manufacturers for many applications.

(2) Available Technology includes "shelf item" hardware and commonly known (state of the art) techniques and procedures which have been used effectively by some manufacturers for some applications. Also included are the results of RD&D which have not been put into practice but are available for implementation. Some performance testing may still be necessary but this technology has been certificated for airworthiness or, by adequate ground and/or flight testing, determined to be capable of being certificated.

(3) Future technology represents the outcome of RD & D programs now in progress which have not been verified but the results to date indicate high potential to a reasonable degree of confidence.

Included are present RD&D programs which are being conducted with sufficient resources of manpower, funding, and time to carry the programs to conclusion. Definitive results are expected in the relatively near future for acoustical and operational performance, economics, and flight safety. The nature of the expectations is positive because predictions of non-viable results would have been cause for earlier termination of the RD&D programs.

The application of source noise control technology is directed to either existing or new aircraft. In the case of existing aircraft, source control is applied by retrofitting modified engines or acoustical treatment to the engines / nacelles during a non-operative or shutdown period.* In the case of new production aircraft, source control is applied during the manufacturing process.

The source control measures available for existing and for newly produced aircraft of the same type design will be essentially the same. Acoustical treatment that is effective for one will be effective for the other as well. Also, there is opportunity for making some, but limited, changes in the basic engine/airframe design of the older type aircraft. The extent of these changes will be governed by the amount of their influence on the function of other parts of the aircraft and on overall safety, performance, and cost. For example, modifying an aircraft

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* As used here, acoustical treatment means any hardware or mechanical device, applied either singly or combined to the inlet and primary and secondary exhausts, that either will absorb sound or otherwise effect a noise reduction at one or more of the FAR 36 measurement points.

to obtain a higher thrust to weight ratio would require larger size engines which might require revisions to the landing gear, pylons, wing and tail structure, the addition of ballast, etc. Obviously, if at all justifiable, such modifications are more cost effective for newly produced aircraft than for existing aircraft.

The most effective use of technology to achieve maximum noise control is in the design and development of new aircraft types. Applications of basic design principles and acoustical treatment for the control of noise can be exploited optimally when they can be integrated from the beginning into the overall aircraft/engine design. Modifications such as retrofit hardware are always the least efficient, but sometimes necessary, use of technology.

Regulations for the control of aircraft noise, such as FAR 36, should be constructed to fully represent the use of the three time-dependent technology options and to be applicable to the four classes of aircraft listed as follows:

(a) Noise Control Technology Options

(1) Current

(2) Available

(3) Future

(b) Aircraft Classes

(1) Existing Aircraft

(2) New Production Aircraft-Older Type Design

(3) New Production Aircraft Acoustical Changes to Older Type Designs

(4) New Production Aircraft-New Type Design

The compliance noise levels of FAR 36 as effective to date, which includes the original version (Reference 11) and three amendments (References 13 thru 15), are applicable to all four classes of aircraft but are not representative of the current, available, and future technology options. Only pre-1969 acoustical technology is represented. Additional amendments to FAR 36 should correct this deficiency by specifying compliance noise levels to be met at specified dates representative of available, and future technology, as well as current. The dates for future technology must, of course, be an estimate because no matter how favorable technology of the future appears, the final results of the RD&D programs could be negative. Consequently, the compliance dates for future technology should be flexible and be capable of being extended if necessary.

Furthermore, in order to insure that the flexibility of compliance dates are maintained, it is recommended that FAR 36 be reviewed every five years or oftener. Appropriate sections of FAR 36 should be updated where feasible to reflect the technology options and measurement standards, practices, and procedures that are practicable and appropriate for the aircraft types at that time. Consideration should be given at each quinquennial review to the inclusion of the previous experience in noise certification and on such matters as whether the noise control technology is sufficiently advanced to be considered for retrofitting operational aircraft and requiring newly produced aircraft of older type designs to comply with more stringent noise levels.

B. Technical Standards of FAR 36

Aircraft are very complex equipment producing a great deal of mechanical power necessary for propulsion; a portion of this power is wasted as noise. Aircraft noise signatures, reflecting the complexity of the source, are among the most intricate of the common noise sources. They involve complicated interrelated spectral, temporal, and spatial functions of sound pressure, all of which are important because of the high sensitivity of the human ear. The control of aircraft noise is complicated by the fact that the human ear, because of its sensitivity, is able to be adversely affected by relatively small quantities of acoustical power. The acoustical power of an aircraft is only a very small fraction of the total mechanical power which it produces. Hence, noise suppression techniques are handicapped by the need to provide a radical change to a small fraction of the total mechanical power without significantly affecting the power needed for propulsion.

As discussed in Section 3, the main purpose of FAR 36 is to provide requirements which will influence the design of aircraft to include implementation of noise source control technology to the maximum extent feasible. The setting of standards to accomplish this purpose is difficult because the control of the noise itself is difficult, for the reasons discussed above. If, for example, the requirements for testing, measuring, and evaluating the noise are not defined accurately, the noise control techniques used by the manufacturer are apt to be misdirected, resulting in wasted performance and cost. Consequently, the standards of FAR 36 should be examined and updated periodically to insure that the latest experience and technological advancements are exploited so that such problems are minimized.

The technical standards of FAR 36 are contained in Appendixes A, B, C, and F of FAR 36. Appendix A contains the test and measurement conditions, the correcting and reporting of measured data, the corrections for the atmospheric attenuation of sound, the corrections for flight procedures, and the specifications for electronic data acquisition, reduction, and analysis equipment. Appendix B contains the methodology for computing the noise evaluation measure, Effective Perceived Noise Level (EPNL) in units of EPNdB, including the effects of spectral irregularities and noise duration. And Appendix C contains the specifications for the noise measuring points, the compliance noise levels, and the takeoff and approach flight test conditions. Appendix F pertains exclusively to propeller driven small airplanes and will not be discussed here.

The following discussions of this section (Analyses) will be organized according to the individual sections of Appendixes A, B, and C of FAR 36. Pagination throughout the remainder of the Analyses Section is keyed to the appropriate Appendix; e.g., pages 5A-1, 5B-1, and 5C-1 initiate the discussions relating to Appendixes A, B, and C of FAR 36, respectively. Specific items in those sections will be examined for accuracy (or relevancy) in view of the experience gained, both in the United States and abroad, in noise certification procedures. The experience of the international aviation community, including the United States, is well documented by the ICAO Working Group D report (Reference 19) and will be evaluated in depth. In fact, the correspondence between the material in Appendixes A, B, and C of FAR 36 and that in Appendixes CI and C of the Working Group D report is very close as can be seen by the comparisons in Table 1. Also, the experience of other organizations, both United States and foreign, will be evaluated individually in relation to specific topics.

The intent of the Analyses Section is: (1) to delineate the problem areas inherent in Appendixes A, B, and C of FAR 36; (2) to identify problems that can and should be corrected at this time and recommend methods of solution; and (3) to provide material appropriate for amending the appendixes. Whenever it is reasonable to do so, the amendments will be structured to be compatible with the recommendations of CAN/4. However, other sources of information will be considered as well. National and International standards as appropriate will be cited as references in accordance with United States regulatory procedures [1 CFR Part 51]. For example, References 43 thru 113 are various standards, recommended practices, and information reports pertinent to aircraft noise measurement, evaluation, and control which were evaluated and considered for citation. Although some of the cited documents have draft and not final status, they were included on the basis that their information represents the latest available ideas of some portions of the scientific community. It is important to the public health and welfare that FAR 36 be amended soon and that as many concepts for modifications as possible be evaluated. It is not prudent, therefore, to wait until standards setting organizations have issued final documents, which may take many years, before taking action on FAR 36. The purpose, ideally, is to work toward truly international standards so that all aircraft throughout the world are evaluated and regulated for noise identically. However, as mentioned previously, the United States has its own requirements which in some cases may be more stringent than those of other Nations.

C. Noise Certification Test and Measurement Conditions (§A36.1 of FAR 36).

(C1) General

This section of Appendix A of FAR 36 prescribes the general test conditions under which aircraft noise type certification tests must be conducted, the testing procedures and the measurements that must be taken to determine the aircraft noise.

Experience in noise certification testing conducted since 1969 in the United States and other nations has shown that various aspects of the test and measurement conditions should be clarified and strengthened. The modifications recommended in the following discussion will have the effect of imposing more restrictive test provisions which will further limit the periods of time during which some test facilities may be used for certification test purposes. They will also increase the amount of meteorological data required to demonstrate that the required conditions have been met. Imposing these changes, will however, disallow testing under conditions which produce results which are not representative, reliable, or reasonably consistent with what might be expected under standard conditions.

(C2) General Test Conditions

§A36.1(b)(2) specifies that:

> "Locations for measuring noise from an aircraft in flight must be surrounded by relatively flat terrain having no excessive sound absorption characteristics such as might be caused by thick, matted, or tall grass, shrubs or wooded areas."

In a draft chapter on noise type certification for the FAA Regional Offices (Reference 114) the FAA has indicated that: §A36.1(b)(2) does not clearly define surfaces having no excessive sound absorption characteristics; the intent of the section is to insure diffuse reflection, not to permit the use of a surface with anechoic properties such as loosely spaded earth, grass over a few inches in height, or any vegetation (particularly when wet). The FAA also indicated that: variations in one-third octave band sound pressure levels can be as much as 6dB if the surface is completely absorptive as compared with completely reflective, and that research and development efforts to provide a more accurate and concise definition of excessive surface absorption were in process. In this regard, an FAA report (Reference 115) indicates that some tests were conducted wherein the effects of variation in the type of microphone ground plane on aircraft noise were studied; however, the results of those tests are not reported in Reference 115.

Other organizations have also indicated that there has been some concern about being more specific about the nature of the terrain (or ground plane) in the immediate vicinity of the microphones. For instance; in June 1974, a draft proposal of the International Standards

Organization's (ISO) Recommendations R507 and R1761, "Procedure for Describing Aircraft Noise Heard on the Ground", provided the following specification:

> "The ground surface over an area 6 m x 6 m surrounding the microphone position shall consist of concrete or asphalt or plywood at least 12 mm thick or an equivalent highly reflecting material. For measurements directly under the nominal flight path the microphone shall be in the center of the square. For other measurements the microphone shall be positioned so that at least 5 m of the reflecting surface is between the aircraft and the microphone. Within a radius of one metre centred on the microphone position the surface shall be flat within ± 5 mm; elsewhere within the square it shall be flat within ± 30 mm. Overall the surface shall be horizontal within a tolerance of ± 3%."

In September 1974, the U.S. Committee reviewing the draft proposal noted that the attempt to better the definition of "excessive absorption" was commendable, objected to the use of plywood, and recommended the entire restrictive subclause be removed from the document. At a meeting of the ISO/TC43/SC1/WG2 in October 1974, the restrictions were downgraded to an advisory note and a suggestion that a hard concrete surface was desirable.

Although the ISO draft recommendations were considered by the ICAO CAN/4 Working Group D, this group did not propose any changes to the ICAO Annex 16 in this regard; therefore, those provisions of Annex 16 remain essentially identical to the vague provisions of §A36.1 (b)(2) of FAR Part 36.

The irregularity of the surface and the uncertain impedance of the terrain in the vicinity of the microphone position has contributed to the unmanageable variability in the noise measurements of aircraft for certification purposes. Until measurement conditions such as this are more rigorously defined and controlled, the overall effect of unspecified ground plane on the EPNL will remain uncertain and debates on such matters as ground-to-ground propagation as a function of elevation angle, shielding and some "pseudo tones" will continue unresolved except through the use of increased sample size to overcome the variability of the data.

Specifying more restrictive characteristics for the terrain in the immediate vicinity of the microphones has the disadvantage of limiting the number of useful tests sites and, in fact, may eliminate the use of some sites previously used for this purpose. This is particularly true for sideline noise measurements where a multiplicity of measurement sites are required in order to locate the point where the sideline noise is demonstrated to be a maximum.

At the potential expense of measurement site selection, but in the interest of achieving more consistent. reliable and understandable results, the ground plane in the immediate vicinity of the microphone should be more restrictively defined. The language of ISO/TC43/SC1/WG2, quoted above, without reference to a plywood surface, would be appropriate for this purpose.

§A36. 1(b)(2) also specifies that "No obstructions which significantly influence the sound field from the aircraft may exist within a conical space above the measurement position, the cone being defined by an axis normal to the ground and by a half-angle 75 degrees from this axis." The recent proposal to modify a similar restriction in ICAO's

Annex 16 (Reference 19) included a modification to increase the cone's half-angle to 80 degrees from 75 degrees. The above cited draft of ISO R507 and R1761 also specifies a clear zone half-angle of 80 degrees.

However, from the FAA draft report on Project No. AEQ-75-5-R, the FAA is considering moving in the opposite direction; that is, allowing a less restrictive specification to "temper the requirement in A36.1(b)(2)" (page 4, Reference 116). The FAA has presented no information or data to justify its proposal which would allow off-the-line-of-sight obstructions (potential reflectors) to interfere with sideline noise measurements.

In the interest of ensuring adequate clear space, especially for the sideline noise measurements, and being consistent with the more restrictive international standards (ICAO and ISO) consideration should be given to modifying §A36.1(b)(2) to specify a half-angle of 80 degrees instead of the currently specified 75 degrees. This modification is simple; should cause no additional measurement site location or logistics problems; and have, compared to the unspecified ground plane, little effect on previous or future measurements.

In consideration of the above, the recommended wording for §A36.1 (b)(2) is as follows:

(2) Location for measuring noise from an aircraft in flight must be surrounded by relatively flat terrain. The ground surface over an area at least 6 meters (19.69 feet) square surrounding the microphone position shall consist of highly sound reflecting material such as concrete, asphalt, or other approved

material at least 12 millimeters (0.47 inches) thick. For measurements directly under the nominal flight path, the microphone shall be in the center of the reflective surface. For other measurements, the microphone shall be positioned so that at least 5 meters (16.40 feet) of the reflecting surface is between the aircraft and the microphone. Within a radius of one meter (3.28 feet) centered on the microphone position, the surface shall be flat within ± 30 millimeters (1.18 inches). Overall, the surface shall be horizontal within a tolerance of ± 3 percent. No obstructions which significantly influence the sound field from the aircraft shall exist within a conical space above the point on the ground vertically below the microphone, the cone being defined by an axis normal to the ground and by a half-angle 80 degrees from this axis.

§A36.1(b)(3) prescribes the following weather conditions:

"(i) No rain or other precipitation.
(ii) Relative humidity not higher than 90% or lower than 30%.
(iii) Ambient temperature not above 86°F and not below 41° F at 10 meters above ground.
(iv) Airport reported wind not above 10 knots and crosswind component not above 5 knots at 10 meters above the ground.
(v) No temperature inversion or anomalous wind conditions that would significantly affect the noise level of the aircraft when the noise is recorded at the measuring points defined in Appendix C of this part."

FAA experience in developing the noise definition of the DC-8-61 aircraft (Reference 32), and more recently, during some tests using a DC-9 (Reference 115), the FAA has demonstrated the significant influence atmospheric conditions may have on aircraft noise measurements and the necessity of prescribing a more restrictive range of atmospheric conditions under which aircraft noise certification tests may be conducted. In order to attain more accurate and consistent noise certification data and to establish greater confidence in ICAO's Annex 16, the U.S. delegation to CAN 4 recently proposed (Reference 32) adoption of a revised temperature and relative humidity test envelope. The proposal would modify the current limits to exclude testing outside a temperature/relative humidity window defined by 41 to 95 degrees F (5 to 35 degrees C) and 30 to 95 percent relative humidity and when the rate of atmospheric attenuation exceeds 10 decibels/100 meters for the one-third octave band centered at 8,000 Hertz. The ICAO proposal further specified that these limits be imposed at the surface and along the contiguous noise path to the test airplane.

The ICAO proposal is slightly more restrictive than the ISO recommendations R507 and R1761 upon which it is based. The ISO recommendations simply restricted testing under conditions which would result in atmospheric absorption in excess of 10 dB/100 meters in the one-third octave band centered at 8 kHz but did not impose the additional temperature and relative humidity limits. The difference between the ICAO proposal and the ISO recommendations is illustrated in Figure 1.

In consideration of the above, the recommended wording for §A36.1 (b)(3) is as follows:

(3) The tests must be carried out under the following atmospheric conditions:

(i) No precipitation.

(ii) Relative humidity not higher than 95 percent nor less than 30 percent.

(iii) Ambient air temperature not above 95 degrees F (35 degrees C) nor below 41 degrees F (5 degrees C).

(iv) Airport reported wind not above 10 knots and crosswind component not above 5 knots at 10 meters (32.80 feet) above ground.

(v) No temperature inversion or anamolous wind or humidity conditions that would significantly affect the noise level of the aircraft when the noise is recorded at the measuring points defined in Appendix C of this Part. The relative humidity and ambient temperature over the entire noise path between ground and airplane must be such that the sound attenuation in the third octave band centered on 8 kHz will not be greater than 10 dB per 100 meters (328.08 feet).

(C3) Aircraft Testing Procedures

§A36.1 (c)(3) states:

> "(3) The aircraft position along the flight path must be related to the noise recorded at the noise measurement locations by means of synchronizing signals. The position of the aircraft must be recorded relative to the runway from a point at least 4 nautical miles from threshold to touchdown during the approach and at least 6 nautical miles from the start of roll during takeoff."

ICAO CAN/4-WP/20 (Reference 19) contains the same specification; however, in an FAA review (Reference 110) of the CAN/4-WP/20, the FAA has indicated that the specification should be changed to state that:

> "The position of the aeroplane shall be recorded relative to the runway for sufficient periods to assure adequate data on aircraft position during the period that the noise is within ten (10) decibels of the maximum value of PNLT during the takeoff."

Experience as a result of FAA noise certification tests conducted since 1969 has shown that the aircraft position data requirement should be specified in terms sufficient to assure that the aircraft's position is known during relevant portions of the noise time history as opposed to over a specific range of the flight paths. Providing aircraft position data over the relevant period of time as opposed to a specific portion of the flight path is, in fact, the current acceptable practice (Reference 114).

Acquiring aircraft position data in strict accordance with the provisions of §A36.1(c)(3) has been most difficult to implement and, in most cases, such data far exceeds the need for correcting acoustic data to reference conditions.

The EPA agrees with the FAA in concept and further believes that the actual practice should be reflected in the regulation. Therefore, the recommended wording for §A36.1(c)(3) is as follows:

(3) The aircraft position along the flight path must be related to the noise recorded at the noise measurement locations by means of synchronizing signals over a distance sufficient to assure adequate data during the period that the noise is within 10 dB of the maximum value of PNLT.

(C4) Measurements

Experience as a result of FAA noise certification testing conducted since 1969 has shown that the temperature and humidity measurements procedures should be strengthened to yield more reliable data. The recommended wording for §A36.1(d)(3) and (4) is as follows:

(3) Acoustic data must be corrected by the methods of §A36.3(d) of this Appendix to standard pressure at sea level, an ambient temperature of 77 degrees F (25 degrees C), and a relative humidity of 70 percent. For acoustic data correction purposes, the test ambient temperature and the test relative humidity shall be the mean of the samples measured in accordance with the methods of §A36.1(d)(4) of this Appendix. Acoustic data corrections must also be made for a minimum distance of 370 feet (112.78 meters) between the aircraft's approach path and the approach measuring point, a takeoff path vertically above the flyover measuring point, and for differences of more than 20 feet (6.10 meters) in elevation of measuring locations relative to the elevation of the nearest point of the runway.

(4) Ambient temperature, wind speed and direction, and relative humidity must be measured in the vicinity of each of the sideline, takeoff, and approach microphone stations. The measurements must be made near the surface, at approximately 100 feet (30.48 meters) above ground, and at approximately every 100 feet (30.48 meters) of height

thereafter up to and including a height of approximately 1100 feet (335.28 meters) or the reference height of the aircraft for maximum takeoff noise, whichever is greater. The mean ambient temperature and mean relative humidity shall be the arithmetic mean of the height samples, including the sample taken in the vicinity of the microphone near the surface. The height of the near surface sensors must be greater than 2 meters (6.56 feet) but not greater than 11 meters (36.09 feet) above the ground. Instrumentation for and methods of acquiring atmospheric parameter measurements must be approved prior to the conduct of the tests.

D. Measurement of Aircraft Noise Received on the Ground (§A36.2 of FAR 36).

(D1) General.

This section of Appendix A of FAR 36 prescribes the acoustical measurement system, specifies acceptable characteristics for the electronic equipment, and identifies the noise measurement procedures. Some, but not all, of the equipment performance specifications and characteristics were provided by reference to International Electrotechnical Commission (IEC) publications. Those equipment characteristics and performance specifications which are not provided by reference are detailed in various subparagraphs.

The results of noise certification testing conducted since 1969 has shown that various aspects of the measurement system and electronic equipment need better definition. Furthermore, improvements in in electronic equipment have been made and the requirements of this section should be modified to reflect these advancements.

(D2) Measurement System

§A36.2(b)(1) describes the measurement system as consisting of five major parts or subsystems as follows:

"(i) A microphone system with frequency response compatible with measurement and analysis system accuracy as stated in paragraph (c) of this section.

(ii) Tripods or similar microphone mountings that minimize interference with the sound being measured.

(iii) Recording and reproducing equipment characteristics, frequency response, and dynamic range compatible with the response and accuracy requirements of paragraph (c) of this section.

(iv) Acoustic calibrators using sine wave or broadband noise of known sound pressure level. If broadband noise is used, the signal must be described in terms of its average and maximum r.m.s. value for a nonoverload signal level.

(v) Analysis equipment with the response and accuracy requirements of paragraph (d) of this section."

The frequency response of the system (from sensing to reproduction) is provided by reference to paragraph (c) which limits the applicable frequency range to that of 45 to 11,200 Hertz and in turn makes reference to an early edition of IEC Publication 179 (Ref. 63) which stated:

> "...the characteristics of an apparatus for accurately measuring certain weighted sound pressure levels. The weighting applied to each sinusoidal component of the sound pressure is given as a function of frequency by three standard reference curves, called A, B, C."

One can assume that the "A" and "B" weighted curves provided in the reference are not appropriate and that the "C" weighted curve is the one that is required. That may be what was intended; but, as evident from the above, the required frequency response characteristics of the sensing/reproduction system are not currently clearly and definitely specified.

In an attempt to identify other possible substitutes for IEC Publication 179, the relevant recommended practices of the Society of Automotive Engineers were investigated. For example, a draft revision to ARP 796 (Ref. 86) states:

> "The response of the complete system to a sensibly plane progressive sinusoidal wave of constant amplitude shall lie within the tolerance limits

specified in ANSI S1.4-1971 (Type I) over the frequency range 45 to 11200 Hz."

However, ANSI S1.4-1971 (Type I) is also a performance specification for weighted sound level meters and, therefore, is no more useful than the IEC Publication 179 for this purpose. In addition, this revision to ARP 796 is still in draft form and therefore does not qualify as a source of reference in a rule or regulation.

If equipment specifications are to be provided by reference to other publications, the relative frequency response should not be provided by reference to specifications for weighted sound level meters but by reference to specifications for instrument quality sound recording and reproducing equipment or systems. If this reference cannot be made, then the specific response of the entire system or parts of the system should be stated explicitly and listed in the regulation.

From the above discussion, it is evident that paragraph (c) of this section of Appendix A does not clearly provide the measurement and analysis system accuracy referred to in §A36.2(b)(1)(i) nor does it provide the response and accuracy requirements referred to in §A36.2(6)(1)(iii). A similar analysis would show that paragraph (d) does not clearly provide the analysis system response and accuracy requirements referred to in §A36.2(b)(1)(v).

In consideration of the above, the recommended wording for §A36.2(b)(1)(i), (iii) and (v) is as follows;

(i) A microphone system with frequency response characteristics as stated in paragraph (c) of this section.

(iii) Recording and reproducing equipment with performance characteristics as stated in paragraph (c) of this section.

(v) Analysis equipment with characteristics as stated in paragraph (d) of this section.

It should be noted that §A36.2(b)(1)(ii) and §A36.2(b)(1)(iv) would remain unchanged and paragraphs (c) and (d) will probably require modification in order to clearly provide the information indicated above.

(D3) Sensing, Recording and Reproducing Equipment.

This section, §A36.2(c), of Appendix A provides essential performance characteristics of certain equipment to be used in sensing, recording and reproducing the aircraft noise. As it now stands this section provides a disorganized mixture of recording/reproducing system characteristics, §A36.2(c)(3) and (5), and system component characteristics, §A36.2(c)(1), (2) and (6).

The following discussion treats each of the §A36.2(c) paragraphs in numerical order. The recommended rewording of the entire §A36.2(c) follows these discussions.

With respect to recording and reproducing equipment, §A36.2(c)(1) states:

> "The sound produced by the aircraft shall be recorded in such a way that the complete information, time history included, is retained. A magnetic tape recorder is acceptable."

This paragraph is intended to convey at least two requirements. First; a magnetic tape recorder, or the equivalent, is required to make a complete recording of the acoustic signal after being sensed and conditioned by the microphone/preamplifier equipment. Second; this recorder must provide a mechanism to simultaneously record time or other information which will allow the acoustic signal to be correlated with the aircraft position data.

Experience has shown that; first, there is no reasonable equivalent substitute for a multiple-channel magnetic tape recorder and, second, the mimumum performance characteristic of the recorder should be further specified. With regard to the latter, a draft IEC Publication (Ref. 108) provides performance specifications for an acceptable tape recorder system for this purpose.

These include:

"4.1 In any selected 1/3-octave frequency range between 112 Hz and 11.2 kHz the amplitude response shall be flat to within 0.5 dB, and in any band between 45 Hz and 112 Hz shall be flat within 1 dB.

Note: To meet these tolerances may well require the use of an F-M tape recorder.

4.2 The amplitude stability of a 1 kHz sinusoidal signal recorded at the standard recording level (i.e. 10 dB below the 3% distortion level) shall be within ± 0.3 dB throughout any one reel of magnetic tape, and from day to day for a given reel of tape at the tape speed used in the certification test. Measurements to verify this shall be made using a device with an averaging time equal to that used in the measuring chain (see §7.2).

4.3 The performance of the system must be such that the background noise in any 1/3-octave band is:

a) at least 45 dB below full scale level,

b) at least 5 dB below the weakest signal level measured during all the measurement. Only those bands which contribute more than 0.5% to the total perceived noisiness should be considered.

Note: To help achieve this specification with sharply falling spectra appropriate pre-emphasis/de-emphasis networks may be included. An example of one possible pre-emphasis curve is shown in Fig. 3."

In order to be capable of adequately handling an aircraft position synchronizing signal, the recorder specification should include a requirement for another recording channel with the provisions for electrical and physical isolation from the acoustic data channel.

§A36.2(c)(2) provides the characteristics for the microphone and amplifier by reference to IEC Publication 179. The inadequacy of this specification for this purpose was discussed in the previous section of this report. An acceptable microphone/preamplifier specification for aircraft noise certification test purposes is proposed in the latest draft of IEC Publication 29C (Ref. 108).

The IEC recommended microphone system specification includes:

"The microphone must be a pressure-sensitive capacitive type.

In order to obtain the best linear frequency response in the relevant conditions of measurement, it is recommended that a pressure response microphone cartridge be used instead of the normal free-field type. This is because the former has a near flat response to sound arriving at grazing incidence (see Fig. 2.).

The variation of microphone and preamplifier sensitivity within an angle of $\pm$ 20° of grazing (70°- 110°) from the normal through the diaphragm) shall not exceed $\pm$ 2 dB for any frequency over the range 40 - 12500 Hz. The variation of microphone sensitivity in the plane of the diaphragm shall not exceed $\pm$ 0.5 dB over the same frequency range.

The over-all free-field frequency response at 90° (grazing incidence) of the combined microphone, preamplifier, windshield, and microphone support shall be determined, using pure tones at each preferred 1/3-octave frequency from 40 Hz to 12.5 kHz.

Specifications concerning sensitivity to environmental factors such as temperature, relative humidity, and vibration shall be in accordance with the requirements of IEC Publication 179 Precision Sound Level Meters."

When introduced by Working Group D as a proposed change to ICAO Annex 16, some delegates to ICAO CAN/4 took objection to this specification on the basis that it was too restrictive with respect to the type of microphone that might be used for this purpose. An ICAO

Ad Hoc Working Group has been formed to resolve the issue and report back to the committee. The issue can be resolved by simply eliminating the first two paragraphs of the above quoted specification and incorporating the last three paragraphs. Of the last three paragraphs, the first one provides the required performance characteristics, the second paragraph provides a procedural requirement, and the last paragraph provides by reference, adequate environmental considerations.

§A36.2(c)(3) provides some of the recording and reproducing system performance specifications and states:

> "The response of the complete system to a sensibly plane progressive sinusoidal wave of constant amplitude must lie within the tolerance limits specified in IEC Publication No. 179, over the frequency range 45 to 11,200 Hz."

This paragraph does specify the proper frequency band limits (45 to 11,200 Hertz) for the system; however, the response tolerances specified by reference to IEC Publication 179, as previously discussed, are not adequately specified in this paragraph.

§A36.2(c)(4) provides a provisional specification requiring pre-emphasis and de-emphasis on the recording/reproducing system. This paragraph states:

> "If limitations of the dynamic range of the equipment make it necessary, high frequency pre-emphasis must be added to the recording channel with the converse de-emphasis on playback. The pre-emphasis must be applied such that the instantaneous recorded sound pressure level of the noise signal between 800 and 11,200 Hz does not vary more than 20 dB between the maximum and minimum one-third octave bands."

In view of the spectral distribution of noise produced by many of the current jet-powered aircraft, the attenuating characteristics of the atmosphere, and the limited dynamic range of recording systems the need for high frequency pre-emphasis is properly anticipated. However, the specification quoted above requires minor modification to indicate that the less than 20 dB difference is between the maximum and minimum band levels not the maximum and minimum bands. A more complete specification would also include a minimum signal-to-noise ratio for the band containing the minimum signal level.

It should also be noted that, given the high degree of variability in all of the parameters involved, circumstances may arise wherein adequate signal-to-noise ratio or pre-emphasis may not be achieved using standard flight test procedures. This possibility is recognized by the EPA and, for these cases, a standard alternate flight test procedure has been recommended in a subsequent section of this report.

§A36.2(c)(5) states:

> "The equipment must be acoustically calibrated using facilities for acoustic free-field calibration and electronically calibrated as stated in paragraph (d) of this section."

This paragraph does not provide a system or equipment performance specification. However, it does indicate a requirement for a procedural specification, specifically, calibration. Being procedural in nature, the essential information in this paragraph and that portion of paragraph (d) referenced in this paragraph should be inserted in more appropriate section of the Appendix, §A36.2(e), Noise Measurement Procedures.

§A36. 2(c)(6) states:

> (6) A windscreen must be employed with the microphone during all measurements of aircraft noise when the wind speed is in excess of 6 knots. Corrections for any insertion loss produced by the windscreen, as a function of frequency, must be applied to the measured data and the corrections applied must be reported.

Again, as in the previous paragraph, the information in this paragraph does not provide a performance specification for a windscreen. It does however, cover a procedural matter, specifically, under certain conditions a windscreen must be used and insertion losses accounted for and reported. Being procedural in nature, the information in this paragraph should be inserted in a more appropriate section of the Appendix. However, since a windscreen is required under certain circumstances, the characteristics of acceptable windscreens for this purpose should be provided in this section.

In view of the above discussions on §A36. 2(c)(1) through §A36. 2(c)(6), the paragraph requires reorganization and an expansion to include the essential performance characteristics for the equipment indicated in §A36. 2(b)(i) and (iii). The following wording is recommended for the entire paragraph.

> §A36. 2(c) Sensing, recording and reproducing equipment. (1) Minimum equipment required to sense the aircraft sound and transform the sound into an electrical signal suitable for recording on a magnetic tape recorder will include, a microphone, a microphone support, a microphone windscreen, a microphone preamplifier and a microphone ealibrator.

(i) The variation of microphone sensitivity in the plane of the diaphragm may not exceed $\pm$ 0.5 dB, relative to the sensitivity at 1000 Hertz, over the frequency range of 40 to 12,500 Hertz.

(ii) The variation of sensitivity of the microphone and microphone preamplifier combination may not exceed $\pm$ 2 dB, relative to the sensitivity at 1000 Hertz, within the angles of 70 to 110 degrees from the axis normal to the diaphragm ($\pm$ 20 degrees about grazing incidence) over the frequency range of 40 to 12,500 Hertz.

(iii) The overall free-field frequency response at 90 (grazing incidence) of the combined microphone (including incidence corrector, if applicable), preamplifier, windscreen, and microphone support shall be determined using pure tones at each preferred one-third octave frequency from 40 Hz to 12,500 Hz. The frequency response of the system shall be flat within the following tolerances:

44-3550 Hz ..... $\pm$ 0.25 dB

3550-7100 Hz ..... $\pm$ 0.5 dB

7100-11200 Hz ..... $\pm$ 1.0 dB

(iv) Specifications concerning the microphone and microphone preamplifier sensitivity to environmental factors such as temperature, temperature gradients, relative humidity, shock and vibration must be in accordance with those of International Electrotechnical Commission (IEC) Publication 179. The text and specifications of IEC Publication No. 179 entitled: "Precision Sound Level Meters", which is incorporated by reference into this Part, are made a part thereof as provided in 1 CFR Part 51. This publication was published in 1965 by the Bureau Central de la Commission Electrotechnique Internationale located at 1, rue de Varembe, Geneva, Switzerland, and copies may be purchased at that place. Copies of this publication are available for examination at the DOT Library, the FAA Office of Environmental Quality and at the FAA Regional Offices.

(v) The microphone windscreen must be properly fitted to the microphone, be preferably of plastic foam or nylon mesh material, and have a diameter not less than 0.09 meter (0.295 feet).

(vi) The microphone/preamplifier combination must be of such construction as to allow tests and calibrations to be performed by applying an electrical signal to the preamplifier and to allow self-noise tests to be performed by substituting an equivalent electrical impedance for the microphone.

(vii) The microphone support and holder must be of such construction as to provide a minimum of interference (physical and acoustical) with the microphone system, tests and calibrations. The holder and support should be of such construction as to allow easy adjustment to the microphone height and orientation. The stand should provide steady and secure support for interconnecting cables in order to minimize noise caused by wind induced cable motion and vibration.

(viii) A battery powered pistonphone calibrator which provides a known sound pressure level at a known frequency on the diaphragm of the microphone is required. Adjustable audio signal generating equipment suitable for system tests is suggested.

(2) Minimum equipment required to record and reproduce the transformed aircraft noise signal and aircraft position synchronization signals will include a multiple-channel magnetic tape recorder, the aircraft noise signal preconditioning equipment and, possibly, synchronization signal preconditioning equipment. Depending upon the particular recorder design, the aircraft noise signal preconditioning equipment may include pre-emphasis networks, amplifiers or attenuators.

(i) The magnetic tape recorder amplitude response at a recording level 10 dB below the 3% distortion level will be a constant $\pm$ 0.50 dB at all band center frequencies in the one-third octave bands from 160 to 12,500 Hertz, and that constant $\pm$ 1.5 dB at all band center frequencies in the one-third octave bands from 40 to 163 Hertz.

(ii) The magnetic tape recorder amplitude stability of a 1000 Hertz sinusoidal signal recorded at a level 10 dB below the 3% distortion level must remain constant ± 0.5 dB throughout the recording of any reel of magnetic tape.

(iii) The magnetic tape recorder background noise level in any one-third octave band shall be 45 dB below the recording level which causes a 3% distortion.

(iv) Amplifiers or attenuators used to precondition the aircraft noise signal shall operate in equal integral decibel steps and the error between the indicated gain or loss and the actual gain or loss for any setting shall not exceed 0.2 dB.

(v) If limitations of the dynamic range of the equipment make it necessary, high frequency pre-emphasis may be used. Pre-emphasis and de-emphasis networks, if used, and applied to the aircraft noise signal recording and subsequent playback shall be matched such that the two networks serially combined shall be constant ± 0.5 dB at each of the band center frequencies for all one-third octave bands from 40 to 12,500 Hertz.

(D4) Analysis Equipment

§A36.2(d) provides specifications for equipment to be used in the frequency analysis of the recorded airplane noise levels. When FAR 36 was originally drafted, no single referenceable national or international standard or specification was available. This situation exists today. The most recent effort to produce an internationally acceptable specification for the analysis equipments is incorporated as part of a draft IEC Document (Ref. 108). This part, as well as other previously mentioned parts, of that publication are still being reviewed and evaluated as part of the proposed changes to ICAO Annex 16. On a national basis, the A-21 committee of the Society of Automotive Engineers (SAE) is developing an Aerospace Recommended Practice (ARP 1264, Reference 109) to provide recommended characteristics for the analysis system. Until the IEC or the SAE documents have gained further acceptance, neither may be used, by direct reference, in FAR 36. However, selected portions may be extracted and used where it can be shown to provide an improved definition or specification of the analysis equipments. Individual paragraphs (specifications) included in this section are discussed below.

§A36.2(d)(1) and (2), combined, specify that; (1) a one-third octave band spectral analysis of the acoustic signal must be performed, (2) the range of the analysis shall include the twenty-four (24) consecutive one-third octave bands starting at a geometric mean frequency of 50 Hz, and (3) the filters used for the analysis must comply with the recommendations given in the International Electrotechnical Commission (IEC) Publication 225.

The draft IEC publication provides the following specification for the filters:

"The 1/3-octave band filters shall satisfy the requirements of IEC Publication 225 and additionally have less than 0.5 dB ripple. In each case the correction for effective band-width relative to the centre frequency response shall be determined by measuring the filter response to sine-wave signals at a minimum of twenty equally spaced frequencies between the two adjacent preferred 1/3-octave frequencies."

The draft SAE document provides the following specification for the filters and the performance test of the filters:

"2.1 Specifications

A set of one-third octave filters to be used for a noise analyzer should contain twenty-four consecutive filters. The first filter of the set should be centered at 50 Hz, and the last at 10 kHz. The intermediate center frequencies should be those specified in the American National Standard S1.6-1967, 'Preferred Frequencies and Band Numbers for Acoustical Measurements.'

2.2 Test

It should be demonstrated that the filters in the set meet the requirements of the following specification:

American National Standard S1.11, 1966 (Class III) 'Specification for Octave, Half-Octave, and Third-Band Filter Sets.' "

A modification to bring FAR 36 in conformance with the draft IEC publication could be accomplished by changing §A36.2(d)(2) to include a statement that each filter shall satisfy the requirements of IEC Publication 225 and additionally have less than 0.5 dB ripple. This modification would eliminate undesirable "notches" or low response in any selected portion of a one-third octave band.

The balance of §A36.2(d)(3) through §A36.2(d)(9), provides the performance specifications for the one-third octave band output signal analyzer. These performance specifications were written to allow the continued use of a wide variety of analog, digital or combination of both types of equipments for this purpose. In addition, there is a stated preferred, but not mandatory, sequence of analyzer operations. This preferred sequence is; squaring of the one-third octave filter output, then averaging or integrating, and finally, converting from a linear to a logarithmic measure of the level.

To continue to allow a wide variety of processes and processors to be used for this purpose allows the possibility of having a systematic difference (error) of as much as 1.5 dB between instrumentation systems for a constant noise source. With a time varying noise source, as experienced in aircraft flyovers, the magnitude of the difference between instrumentation systems is dependent, in part, upon the rate of change of the level in any sampling period.

Most recent efforts by organizations preparing performance requirements for equipment have not concentrated on the variability arising from the use of different types of data processors, but appear to be continuing to try to develop performance specifications and demonstration tests for a variety of analyzer equipment and processes.

If aircraft flyover measurements and analysis taken at different test sites and processed by different equipment are expected to be reliably related to each other, more stringent and restrictive analysis equipment specifications than currently exist in FAR 36 and any of the other drafts being considered by SAE or IEC must be developed. Until these specifications can be developed, improvement in the

FAR 36 specifications related to the analyzer can be achieved by extracting certain portions of the draft publications on this subject (Refs. 108, 109 and 65).

In consideration of the above, the recommended wording for §A36.2(d)(1) through (8) is as follows:

(d) Analysis equipment.

(1) A frequency analysis of the acoustical signal shall be performed using a set of 24 consecutive one-third octave filters. The first filter of the set must be centered at a geometric mean frequency of 50 Hz and the last filter at a geometric mean frequency of 10 kHz. Each filter shall satisfy the requirements of IEC Publication 225 and additionally, have less than 0.5 dB ripple.

IEC Publication 225 entitled "Octave, Half-Octave and Third-Octave Band Filters Intended for the Analysis of Sounds and Vibrations" is incorporated by reference herein and made a part of this regulation. This publication is also available at those places referred to in §A36.2(c)(1)(iii).

(2) Each of the filtered output signals must be processed to obtain an indication of the true root-mean-square signal level. The required sequence of signal processing is squaring of the filter output signal, then averaging or integrating over a period of time, and then determining the signal level by converting the averaged or integrated value to a decibel (logarithmic) form.

(3) The indicated output of the signal processor shall be the true root-mean-square value of the signal level within a tolerance of ± 1.0 dB.

The within tolerance output level may be indicated either directly or by use of conversion factors derived from calibrations using nonsinusoidal, time varying signals over the full dynamic range of the processor.

(4) The analyzer detector or detectors shall operate over a minimum dynamic range of 60 dB and shall perform, within the specified tolerances, as true mean square devices for sinusoidal tone bursts having crest factors of up to 3. Over the range from 0 to 30 dB below full scale the accuracy shall be within $\pm$ 0.5 dB; from greater than 30 to 40 dB below full scale the accuracy shall be within $\pm$1.0 dB; at greater than 40 dB the accuracy shall be within $\pm$ 2.5 dB.

(5) If other than a true integrator is used, the standard deviation of a sample of the detected and integrated output levels of each detector-integrator shall be 0.48 $\pm$ 0.06 dB at a 95 percent confidence level. To demonstrate compliance with this performance specification the input test signal shall consist of white noise filtered by a one-third octave band filter at a center frequency of 200 Hertz with a statistical bandwidth of 46 $\pm$ 1 Hertz, and the detected-integrated output level shall be sampled at intervals of no less than 5 seconds.

(6) If other than true integration is used, the rise and decay response to a burst of constant sinusoidal signal at the respective one-third octave filter center frequencies shall be:

(a) For the rise response the detected-integrated level shall be -4.00 ± 1.00 dB and -1.75 ± 0.75 dB below the steady state level at 0.50 and 1.00 seconds after the onset of the input signal, respectively.

(b) For the falling response the detected-integrated level shall be such that the arithmetic sum of the decibel reading (below the steady state level) and the corresponding rise response reading is -6.50 ± 1.00 dB at both 0.50 and 1.00 seconds after the interruption of the input signal, respectively.

(7) An analyzer using true integration cannot meet the requirements of paragraphs (5) and (6) of this section. Furthermore, when using true integration some dead-time may occur during which read-out and integrator re-setting takes place; in such cases, no more than 5 percent of the total sample time shall be used for this purpose.

(8) The amplitude resolution of the analyzer output must be 0.25 dB or less.

(D5) Noise Measurement Procedures.

In addition to those procedures which are currently specified under §A36.2(e) there are procedural matters in §A36.2(b), (c) and (d), all of which are system or equipment performance specifications. The EPA believes that all procedural matters, especially those dealing with required calibration procedures, should be properly placed in the regulation; that is, under a section having a procedural title. Therefore, the EPA should propose to amend §A36.2(e) to include those matters currently in other sections. Recommended wording for these additional sections is:

(e) Noise Measurement Procedures.

(1) The microphone must be oriented so that the diaphragm of the microphone is in the plane defined by the nominal flight path of the aircraft and the measuring position; that is, with the aircraft noise arriving at grazing incidence. The microphones must be placed so that their sensing elements are 4.0 $\pm$0.1 feet (1.22 $\pm$ 0.033 meters) above the ground.

(2) Immediately before and immediately after each series of test runs and each day's testing, a recorded acoustic calibration of the system must be made in the field to check the acoustic reference level for the analysis of the sound level data. The ambient noise, including both the acoustical background and the electrical background of the measurement systems, must be recorded during the period beginning at least 20 seconds

before and ending at least 20 seconds after each recorded measurement. During that period, each component of the system must be set at the gain-levels used for aircraft noise measurement.

(3) The mean background noise spectrum must contain the sound pressure levels, which, in each preferred third octave band in the range of 50 Hz to 10,000 Hz, are the averages of the energy during at least 20 seconds of the sound pressure levels in every preferred third octave. When analyzed in PNL, the resulting mean background noise level must be at least 20 PNdB below the maximum PNL of the aircraft.

(4) Within the five days before the beginning of each test series, the complete data acquistion system (including cables) must be electronically calibrated for frequency and amplitude by the use of a pink noise signal of known amplitude covering the range of signal levels furnished by the microphone. For purposes of this section, a "pink noise" is defined as a noise whose noise-power/unit-frequency is inversely proportional to frequency at frequencies within the range of 45 Hz to 11,200 Hz. The signal used must be described in terms of its average root-mean-square (rms) values for a nonoverload signal level. This system frequency response calibration must be repeated within five days of the end of each test series.

(5) Immediately before and after each day's testing, a recorded acoustic calibration of the system must be made in the field with an acoustic calibrator to check the system sensitivity and provide an acoustic reference level for the analysis of the sound level data. The performance of equipment in the system will be considered satisfactory if, during each day's testing, the variation does not exceed 0.5 dB.

(6) For the purpose of minimizing equipment or operator error, immediately before and immediately after recording aircraft noise data, field calibrations must be supplemented with the use of a device to place a known electrical signal at the input of the microphone.

(7) A normal incidence pressure calibration of the combined microphone/preamplifier must be performed with pure tones at each preferred one-third octave frequency from 50 Hz to 10,000 Hz. This calibration must be completed within the 30 days before the beginning of each test series.

(8) Each reel of magnetic tape must -

(i) Be pistonphone calibrated; and

(ii) At its beginning and end, carry a calibration signal consisting of a 30 second burst of pink noise, as defined in paragraph (c)(1) of this section.

(9) Data obtained from tape recorded signals will be considered reliable if the difference between the pink noise signal levels,

before and after the tests in each one-third octave band, does not exceed 0.5 dB.

(10) The one-third octave filters must have been demonstrated to be in conformity with the recommendations of IEC Publication 225, dated 1966, during the six calendar months preceding the beginning of each test series. The correction for effective bandwidth relative to the center frequency response must be determined for each filter by measuring the filter response to sinusoidal signals at a minimum of twenty frequencies equally spaced between the two adjacent preferred one-third octave frequencies.

(11) A performance calibration analysis of each piece of calibration equipment, including pistonphones, reference microphones, and voltage calibration devices, must have been made during the 12 calendar months preceding the beginning of each day's test series. Each calibration must be traceable to the National Bureau of Standards.

(12) The analysis equipment required under paragraph (d) of this section must be subjected to a frequency and amplitude electrical calibration by the use of sinusoidal or broadband signals at frequencies covering the range of 45 to 11,200 Hz, and of known amplitudes covering the range of signal levels furnished by the microphone. If broadband signals are used, they must be described in terms of their average and maximum rms values for a nonoverload signal level.

E. Reporting and Correcting Measured Data (§A36.3 of FAR 36).

(E1) General

§A36.3(a) provides a general statement requiring that all data acquired from physical measurements be provided in permanent form and appended to the certification records. It also requires that an estimate of "individual errors inherent in each of the operations employed in obtaining the final data" be made. Neither the purpose, extent, nor methodology for this last requirement are explicit. If the purpose is to provide a qualitative assessment of the overall accuracy of the test procedures, then a more explicit statement of the items or operations to be evaluated and the allowable tolerances on their measurement should be specified. If no specific use of this assessment is to be made, then the requirement should be deleted.

(E2) Data Reporting

§A36.3(b) provides a specific list of noise data, aircraft parameters, and meteorological data to be supplied in the certification test report. With the exception that it does not require EPNL values to be reported (in this section, at least) the existing text is satisfactory insofar as its inclusion of basic parameters is concerned. It does not require reporting of reference flight paths to be used in A36.3(d), and should be amended to do so.

A more serious deficiency is the lack of a requirement to report data that can be used to derive information for noise produced at other than the specified three measurement locations or for other than maximum aircraft weight conditions. Further, these data need to be supplied in a format suitable for planning purposes.

The Administrator of the EPA, under authority granted in the Noise Control Act of 1972 (Public Law 92-574), has announced to all federal agencies (Reference 112) his intention of specifying a standard measure to be used to describe the magnitude of community noise exposure levels. In his announcement the Administrator indicated that the Agency intends to specify the use of either the Equivalent Sound Level (Leq) or, as appropriate, the Day-Night Level (Ldn).

In view of this announced intention, it is assumed that where measurements or estimates of community noise exposure levels are required for planning or regulatory purposes one or both of these measures will be required. Both measures are based upon the time-integrated mean square A-weighted sound level. Where direct measurements of community noise exposure levels resulting from existing operations are concerned, no extraordinary problems are expected. However, where estimates or predictions of community noise exposure levels resulting from future, or otherwise hypothesized, operations are concerned, reliable results may not be obtained without a reasonable knowledge of each individual source's noise characteristics. These characteristics include the source noise level (appropriately weighted) as a function of the source's operational mode, the distance between the source and the community, and the intervening sound propagation path. For aircraft, because of the wide variation in each of these influencing parameters, this requirement represents a comprehensive set of noise tables and related operational data. However, previous and on-going programs within the USAF, FAA, NASA, and EPA to develop aircraft noise estimating methods have resulted in some methods which can be used to derive the required comprehensive set of tables from a fairly small and simple set of noise measurements and aircraft performance characteristics. All of the necessary basic information and data are either used or obtained in the ordinary conduct of a noise certification program as currently prescribed by FAR 36. However, in order to make the basic information and data routinely available and more useful to the public, the reporting requirements of §A36.3(b) will require modification.

Aircraft noise and operating data should be reported for the following three flight conditions:

1. Certification takeoff conditions, as measured at 3.5 nautical miles from the start of takeoff roll on the

extended centerline of the runway, or alternate (a) below. Alternate (a) must be used if the aircraft height at the 3.5 nautical mile point exceeds 2000 feet.

(a) Horizontal flight, with aircraft height of 1000 feet, takeoff thrust, and V2 + 10 knots airspeed at maximum takeoff weight.

2. Horizontal flight, with aircraft height of 1000 feet, maximum climb thrust, V2 + 10 knots airspeed, at maximum takeoff weight.

3. Certification approach conditions, as measured at a point 1 nautical mile from the runway threshold on the extended centerline of the runway.

Data should be obtained from certification tests but are to be adjusted to reference day conditions (77 degrees F, and 70% relative humidity at sea level).

For each of the three conditions specified above, the following data are to be provided:

1. Aircraft height, ft.
2. Engine net thrust, lbs. (Note 1).
3. Airspeed, knots.
4. Flap settings, degrees.
5. Ratio of Lift to Drag Coefficients (Cl/Cd). (Note 2).
6. Effective perceived noise level (EPNL), EPNdB.
7. Sound exposure level (SEL), SEdB (Note 3).
8. Maximum perceived noise level (PNLM), PNdB.

9. Maximum tone-corrected perceived noise level (PNLTM), PNdB.

10. Maximum A-level (ALM), ALdB.

11. Angle of noise radiation from aircraft at time of PNLM, (ϕ_1), degrees (Note 4).

12. Angle of noise radiation from aircraft at time of ALM, (ϕ_2), degrees (Note 4).

13. One-third octave band sound pressure levels (SPL) on ground at time corresponding to ϕ_1, dB.

14. One-third octave band SPL on ground at time corresponding to ϕ_2, dB.

Note 1. In order to interpret aircraft operational procedures executed by pilots using cockpit instrumentation, information is to be provided to relate engine power or thrust with the primary power setting parameter used by the pilot. For turbojet or turbofan aircraft, this requirement can be met by charts or tables showing the relation between net thrust and engine pressure ratio (EPR) or fan speed (N).

Note 2. Ratio of lift to drag coefficients for zero flap and all other flap positions certified for takeoff, approach and /or landing with and without gear down should be reported.

Note 3. The sound exposure level (SEL), in dB, is the level of the time-integrated mean square A-weighted sound pressure for an event, with a reference time of one second:

$$\mathrm{SEL} = 10 \log \qquad \mathrm{ant}(AL/10)dt \qquad (1)$$

For planning purposes the aircraft noise evaluation unit, SEL, is to be computed from A-levels sampled at discrete intervals of 0.5 seconds or less over the time interval d (in seconds) during which the A-level is within 10 dB of the maximum A-level (ALM). Thus the working expression for SEL becomes:

$$\mathrm{SEL} = 10 \log \sum_{k=1}^{k=d/\Delta t} \mathrm{ant}[AL(k)/10] \qquad (2)$$

where Δt is the time interval (in seconds) between noise level samples.

<u>Note 4</u>. Directivity angles, ϕ_1 and ϕ_2, are to be determined by taking into account both aircraft speed and sound propagation speed. The angles may be calculated by:

$$\sin \phi = \frac{h(1-v^2/c^2) \cos \gamma}{[(h \cos \gamma)^2 (1-v^2/c^2)+(vt)^2]^{1/2}-v^2t/c} \qquad (3)$$

where h = aircraft height, ft.

v = aircraft true airspeed, ft/sec

c = speed of sound, ft/sec

ϕ = climb angle, degrees

t = interval between time of aircraft passing overhead and time of maximum noise level (PNLM and ALM), sec.

§A36.3(c) defines the reference conditions to which all test results must be corrected. §A36.3(c)(1) defines the meteorological reference conditions and there is no need to change those which are specified. §A36.3(c)(2) defines the aircraft reference weight conditions for take-off and landing and the reference approach flight path and there is no need to change those which are specified.

(E4) Data Corrections

§A36.3(d) provides for the process of correcting test conditions to reference conditions in accordance with §A36.6.

§A36.3 (d)(3) specifies that corrections in measured sound pressure levels shall be made if they do not exceed the background (ambient) levels by at least 10 decibels. A number of possible methods for making these corrections have been advanced by different technical groups, including the ICAO CAN working groups. No method has achieved general acceptability at this time. It seems appropriate that the existing text be retained until such time as a generally acceptable method has been adopted by an appropriate technical body or standards activity.

F. Symbols and Units (§A36.4 of FAR 36).

(F1) General.

§A36.4 of Appendix A of FAR Part 36 provides a listing of all symbols, the physical units and meaning of all symbols used in Appendix A and B of Part 36. Additional symbols, units and definitions will be required in order to accommodate a discussion or specification of the additional reporting requirements and/or approved alternative procedures. These will be extracted from this report and tabulated as a proposed revision to §A36.4.

G. Atmospheric Attenuation of Sound (§A36.5 of FAR 36).

(G1) General.

Corrections to sound spectra are required when atmospheric conditions differ from the specified reference conditions. §A36.5 provides two methods of determining the atmospheric attenuation of sound for a variety of ambient temperature and relative humidity conditions. One method is that provided by reference to certain portions of the Society of Automotive Engineers (SAE) Aerospace Recommended Practice (ARP) 866; the other, a simplified method, is presented in detail in §A36.5. The simplified method was introduced as an alternative in cases or situations where computer assisted computations were not practicable or feasible. This situation however has proven to be rare and has rendered the simplified method, for practical purposes, of no value. The SAE ARP 866 has recently undergone substantial revision to make it more useful, especially in computer assisted processes and analyses.

In view of the above, consideration should be given to specifying only one method of determining the atmospheric attenuation; that is, the method provided in SAE ARP 866A as revised in March 1975. This will require changing §A36.5(a) and the elimination of paragraphs §A36.5(b) and (c) including the referenced Figure therein.

The recommended rewording of §A36.5(a) is as follows:

(a) General. The atmospheric attenuation of sound must be determined using the atmospheric absorption coeffecients for one-third octave bands of noise as presented in Table 2 of Appendix B of SAE ARP 866A as revised in March 1975. SAE ARP 866A is an Aerospace Recommended Practice published by the Society of Automotive Engineers entitled: "Standard Values of Atmospheric Absorption as a Function of Temperature and Humidity". The recommended atmospheric attenuation coeffecients as provided therein are incorporated by reference into this Part and are made a part hereof as provided in 1 CFR Part 51. This publication is published by the Society of Automotive Engineers, Inc. located at 400 Commonwealth Drive, Warrendale, Pa., 15096, and copies may be purchased at that place. Copies of this publication are available for examination at the DOT Library, the FAA Office of Environmental Quality and the FAA Regional Offices.

H. Detailed Correction Procedures (§A36. 6 of FAR 36).

If the noise type certification test conditions are not equal to the noise type certification reference conditions, corrections must be made to the value of EPNL calculated from the measured data. The type of corrections and the methods of applying these corrections are detailed in §A36. 6 of Appendix A of Part 36.

The present text of §A36. 6(a) provides a general discussion of corrections for atmospheric absorption, flight paths different from reference, and test weights less than maximum. No discussion is provided for the effect of test day thrust being different than reference thrust, or the effect of test airspeed being different than reference airspeed. Further, the discussion of the effect of weight corrections is not easily related to the physical situation and experience has shown it to be impractical to implement. Therefore, modifications to certain parts of §A36. 6 are required in order to provide practical and meaningful methods of accounting for differences in reference and test conditions; not only for atmospheric absorption, flight paths and weights, but also for thrust and airspeed.

The proposed modifications include: (1) changing the general discussion of §A36. 6(a) which is introductory and explanatory in nature, (2) changing the discussion and method of atmospheric absorption correction procedures in §A36. 6(d) to provide for corrections to be made by either one or two methods, depending upon test atmospheric conditions, (3) changing the discussion and method of duration corrections provided in §A36. 6(e) to provide for a correction in duration due to differences in reference and test airspeeds and (4) deleting the discussions and methods of providing weight and approach angle corrections of §A36. 6(f) and (g), respectively, and (5) substituting a discussion and method of applying corrections for differences in reference and test thrust.

Paragraphs A36. 6(b) and (c) discuss the structure of takeoff and approach profiles, respectively, and the geometrical relationships between reference and test profiles for each of these operations. These paragraphs include references to Figures A2 through A7. The text and nomenclature in these sections and figures are clear and unambiguous and there appears to be no need for any change in either paragraph.

A36. 6(e) describes a correction for effective duration based on the difference in slant distance to the aircraft from the ground position between test and reference conditions. In addition to this correction, allowance for difference in true airspeed, V, between test and reference conditions (Vt and Vr) should be applied. The modified expression for Δ 2 under takeoff conditions should be:

$$\Delta 2 = -10 \log (KR/KRc). \qquad (4)$$

For approach conditions, the expression should be:

$$\Delta 2 = -10 \log (NT/369). \qquad (5)$$

No duration correction is presently specified for the sideline measurement. An airspeed correction should be made in the same manner as for takeoff and approach. The appropriate expression is:

$$\Delta 2 = 10 \log \ (Vt/Vr) \qquad (6)$$

Note that the reference true airspeeds for takeoff and sideline measurements are likely to be slightly different in that they will most likely occur when the aircraft is at different heights. It is accepted practice to perform tests at a constant <u>indicated</u> airspeed, which thus results in a difference in true airspeed as a function of height due to the decrease in atmospheric density with height.

A36.6(f) states that corrections for aircraft weight are to be applied, based on "approved data... as indicated in Figures A8 and A9." No discussion is provided as to how such data are to be obtained. A similar form of correction is specified in A36.6(g) for approach angle corrections. In practice neither of these corrections, as specified, is really useful.

There is no question that corrections need to be made for the effect of different aircraft weights. Just as clearly, a correction for the effect of thrust different than reference thrust needs to be made. From an acoustical viewpoint, the noise on the ground is specified by distance to the aircraft, aircraft height, airspeed, and engine power/thrust. Similarly from a performance viewpoint, variation in the position of the aircraft (in a fixed configuration) with time is a function of weight, net thrust, airspeed, and lift/drag ratios.

The geometric effects on sound pressure levels due to weight, power, and airspeed are completely accounted for in the corrections made for differences in flight paths and in duration corrections due to airspeed differences. The remaining acoustical effect is the variation in acoustical power radiated at different engine power settings. This correction can be derived from noise measurements obtained from a series of level flyovers in which EPNL is determined as a function of engine power (described in terms of referred net thrust or referred fan rotor speed) when normalized to reference airspeeds and heights.

It is recommended that A36.6(f) and (g) be replaced with a correction procedure that properly accounts for variations between test and reference power/thrust conditions, based on data derived from specified flight tests.

I. Aircraft Noise Evaluation Under Section 36.103 (§B36.1 of FAR 36)

I. General.

Appendix B specifies the detailed procedures and standards to be used to determine a single-number, noise evaluation quantity designated as Effective Perceived Noise Level (EPNL). This measure is derived from analysis of a specified portion of each of the filtered and corrected time-data samples of the noise. The required procedure includes the following, where the symbol "(k)" refers to the k-th time data sample:

"(a) The 24 one-third octave bands of sound pressure level are converted to perceived noisiness by means of a noy table. The noy values are combined and then converted to instantaneous perceived noise levels, PNL (k).

(b) A tone correction factor, C(k) is calculated for each spectrum to account for the subjective response to the presence of the maximum tone.

(c) The tone correction factor is added to the perceived noise level to obtain tone corrected perceived noise levels, PNLT(k), at each one-half second increment of time. The instantaneous values of tone corrected perceived noise level are noted with respect to time and the maximum value, PNLTM, is determined.

$$PNLT(k) = PNL(k) + C(k)$$

(d) A duration correction factor, D, is computed by integration under the curve of tone corrected perceived noise level versus time.

(e) Effective perceived noise level, EPNL, is determined by the algebraic sum of the maximum tone corrected perceived noise level and the duration correction factor.

$$EPNL = PNLTM + D"$$

Each step in the above described process, including a mathematical formulation of the noy tables, is detailed in a separate paragraph of

Appendix B. Under 1 CFR Part 51, information such as this detailed computational procedure and the associated tables and formulas may be provided by reference to a readily available and maintained document. Referenceable sources of the material covered in Appendix B might include either the appropriate sections of Appendix 1 of the International Civil Aviation Organization's (ICAO) Annex 16 or the appropriate Aerospace Recommended Practices (ARPs) of the Society of Automotive Engineers (SAE) or an appropriate recommendation or standard of the American National Standards Institute (ANSI).

On July 10, 1973, the ANSI approved, as S6.4-1973, the June 1972 version of the SAE ARP 1071 entitled "Definitions and Procedures for Computing the Effective Perceived Noise Level for Flyover Aircraft Noise". The June 1972 issue of SAE ARP 1071 was later edited and revised in October 1973.

Therefore, the detailed material provided in Appendix B could be eliminated entirely by inserting the necessary reference to SAE ARP 1071. Such a proposed amendment to Part 36 would not only simplify the regulation but provide specific reference to a nationally accepted standard and practice. The recommended wording to accomplish this change is as follows:

§B36.1 General.

> The physical properties of the noise measured and corrected as prescribed by Appendix A of this Part are to be used to determine the noise evaluation quantity designated as effective perceived noise level, EPNL. The definitions

and procedures for determining EPNL shall be those provided in the Society of Automotive Engineers' Aerospace Recommended Practice (SAE ARP) 1071 as revised in October 1973. This publication entitled: "Definitions and Procedures for Computing the Effective Perceived Noise Level", and other SAE publications by reference therein, are incorporated by reference into this Part and are made a part thereof as provided in 1 CFR Part 51. This publication was published in October 1973, by the Society of Automotive Engineers, Inc., located at 400 Commonwealth Drive, Warrendale, Pa., 15096, and copies may be purchased at that place. Copies of this publication are available for examination at the DOT Library, the FAA Office of Environmental Quality and the FAA Regional Offices.

Additional comments on subdivisions of Appendix B material as it currently exists in FAR 36 and improvements incorporated in SAE ARP 1071 are provided in the following paragraphs of this report.

J. Perceived Noise Level (§B36.2 of FAR 36).

The general principles of an internationally accepted three-step method of determining the perceived noise level, PNL, from a set of 24 one-third octave band sound pressure levels are outlined in FAR 36, §B36.2; in Appendix I, ICAO Annex 16, Paragraph 4.2; and in SAE ARP 865A.

Step 1 of the method presented in each of the documents refers to tabulated perceived noisiness (noy) values which are, in turn, based upon referenced formulations. Further discussion of the differences in the referenced noy tables and the formulas upon which they are based is provided in Section "O" of this report. Except for matters concerned with presentation of noy formulas or tables, the only material difference between the three documents is in the third step of the method. Both FAR 36 and ICAO Annex 16 state:

> "Step 3. Convert the total perceived noisiness, N(k), into perceived noise level, PNL(k), by the following formula:
>
> $$PNL(k) = 40.0 + 33.3 \log N(k)".$$

The method outlined in ARP 865A for Step 3 states:

> "$\underline{N}$ is converted into perceived noise level (PNL) in PNdB by the following expression:
>
> $$PNL = 40 + 33.22 \log_{10} \underline{N}".$$

The most recent report of the ICAO Committee on Aircraft Noise (CAN 4) recommends that the formula in Step 3 of Paragraph 4.2 of Appendix I to Annex 16 be changed to read as follows:

$$"PNL(k) = 40.0 + [(10/\log 2)\log N(k)]".$$

Since the quantity $10/\log 2 = 33.22$, to the nearest one-hundreth, it appears that is what was intended in ARP 865A, and that Step 3 of FAR 36 §B36.2 will also require modification.

To correct the above discussed error, the following formula for Step 3 under §B36.2 is recommended:

$$PNL(k) = 40.0 + 33.2 \log N(k). \tag{7}$$

This error would also be corrected by replacing the entire Appendix B material with SAE ARP 1071, since this ARP makes use of ARP 865A for the computation of PNL and is included by reference therein.

K. Correction for Spectral Irregularities (§B36.3 of FAR 36).

The presence of tonal components in aircraft and other sources of noise has been determined to have the effect of increasing the annoyance caused by the noise. A 10-step method of determining the possible presence of tonal components by examination of a one-third octave band spectrum of the noise and an adjustment to the corresponding PNL was developed and the details are provided in §B36.3 of FAR 36. This method, which was essentially duplicated in Appendix 1 of ICAO Annex 16, was derived from a working draft of SAE ARP 1071. Experience with this method has shown that its use can produce anomalous "pseudotones" in certain cases, and can not properly account for tonal components that appear in contiguous frequency bands. For these reasons the SAE, after the promulgation of FAR 36, continued work to develop an improved method. This effort resulted in the 7-step procedure of ARP 1071 which was approved by the SAE and first issued in June 1972. These procedures were revised by SAE and submitted to the American National Standards Institute. The document was subsequently published as ANSI S6.4-1973 (Ref. 110). The EPA was notified of these actions by the SAE A-21 Committee on Aircraft Noise in July 1974 (Ref. 111).

The method of accounting for spectral irregularities currently incorporated in FAR 36 and Annex 16 and the method approved by the SAE and ANSI differ in two ways. One is the method of smoothing and examining the spectrum to identify irregularities, and the other is in the tone penalty for Level Differences (F) of less than 3 dB.

Recently, during the fourth meeting of the ICAO Committee on Aircraft Noise (CAN/4), Working Group D recommended a modification in the Annex 16 method which would have incorporated one of the features of the SAE/ANSI procedure. The recommended change would eliminate the Annex 16 practice of ignoring the Level Differences (F) of less than 3 dB when determining the Tone Correction factor (C). The practice was originally incorporated in order to avoid extraordinary difficulties with what are known as "psuedo-tones" (spectral, discontinuities caused by phenomena other than, or in addition to, tones in the source noise, particularly, those caused by ground plane reflections). The Working Group D recommendation to change Annex 16 met with considerable opposition by some delegates, including the United States. An ICAO Ad Hoc Working Group has been formed to resolve the issue on this recommendation and report back to the committee.

The latest report of the ICAO Committee on Aircraft Noise (Ref. 35)indicates that the committee is recommending a modification of Annex 16 which will incorporate the treatment of Level Differences of less than 3 dB as provided in the SAE/ANSI procedure.

Since the ICAO CAN 4 meeting, the SAE A-21 Committee, at the specific request of the FAA Office of Environmental Quality, has begun a reexamination of its ARP 1071.

However, on the basis that the new and improved method has been scrutinized within several standards groups, representing the aircraft industry as well as a wide segment of other opinions, it is unlikely that the SAE and ANSI will either: (1) find substantial technical reasons to retrogress and approve the method as currently provided in FAR 36 or (2) easily or quickly, develop a further improved method for this purpose.

In view of the above, it is concluded that (1) the 7-step procedure of SAE ARP 1071 (ANSI S6.4-1973) provides a more efficient analysis of the tonal components in aircraft noise, and (2) there are no significant differences between the 7 and 10-step procedures in evaluating annoyance (or any other health and welfare effects) caused by the tonal components. It is recommended, therefore, that §B36.3 of FAR 36 be amended to incorporate SAE ARP 1071 (ANSI S6.4-1973) by reference.

L. Maximum Tone Corrected Perceived Noise Level (§B36.4 of FAR 36).

§B36.4 defines the maximum tone corrected perceived noise level as the maximum value of the tone corrected perceived noise level calculated in accordance with the procedure of the previous section, §B36.3, of this Appendix. An illustrated example of the determination of the maximum tone corrected perceived noise level is also provided in this paragraph. There is no need to change this section of Appendix B if it is retained.

M. Duration Correction (§B36.5 of FAR 36).

The duration of a noise event has been demonstrated to be one of the characteristics of noise associated with annoyance. Therefore, a measure of the noise duration is included in the computation of EPNL. The method by which the duration correction factor, D, of EPNL is currently determined is specified in §B36.5 of Part 36, Appendix B. The method is dependent upon a determination of the time period, d, during which the tone corrected perceived noise level (PNLT) is within 10 decibels of the maximum tone corrected perceived noise level (PNLTM). This method appears to be reasonable except that the method also states: "If the value of PNLT (k) at the 10 dB-down point is 90 PNdB or less, the value of d may be taken as the time interval between the initial and the final times for which PNLT(k) equals 90 PNdB." By so allowing a 90 PNdB limit (or "floor") to be used in determining the duration factor, a false and misleading measure of the duration of the noise, and therefore, a false and misleading measure of the EPNL is determined and reported. This deficiency in determining the duration correction factor may be corrected by simply eliminating the 90 PNdB floor.

In practice, other relatively minor difficulties in determining the proper duration correction factor using the currently specified method have been noted. For instance, the duration time, d, is specified to be the "time interval to the nearest 1.0 second." Since PNLT(k) values are calculated for time increments of 0.5 second, no apparent purpose is served by restricting the duration to an even number of half-seconds.

The more appropriate duration could be determined to the nearest 0.5 second. Also, the method specifies that if the 10 dB-down points fall between calculated PNLT(k) values, the applicable time history limits must be chosen from the PNLT(k) values "closest" to the 10 dB-down threshold. When this requirement is combined with the foregoing restriction to an even number of samples, a rather inexact determination of the real duration may be made.

The "significant noise time history" is defined as that portion of flyover during which PNLT(k) is within 10 dB of PNLTM. Values below the 10 dB-down threshold could reasonably be considered insignificant, and always be excluded. Or, since, in fact, these points contribute only slightly to the calculated duration correction factor, the closest point below the threshold at each end of the flyover noise recording could always be included. Sample calculations indicate that, on the average, the latter procedure provides a closer approximation to the real answer than the former. It is probable that, at a slight increase in complexity, an even closer approximation to the real answer can be obtained by using both of the foregoing rules - one at each end of the time history. For example, at the initial threshold crossing, the point at or immediately below the threshold would be used as the initial value, while at the final threshold, the point at or immediately above the threshold would be used as the final value. Appropriate language might be: "If a 10 dB-down point falls between two calculated PNLT(k) values (the usual case), the value preceding the threshold crossing should be chosen as the limit for the duration time."

Also, there appears to be a need to clarify the method and procedures to be used when the noise time history of PNLT contains more than one excursion above the 10 dB-down threshold. This is a situation that can occur often with moving sources having both forward and aft noise directive characteristics.

N. Effective Perceived Noise Level (§B36.6 of FAR 36).

§B36.6 defines the effective perceived noise level as being the algebraic sum of the maximum tone corrected perceived noise level and the duration correction as calculated under §B36.4 and §B36.5, respectively. There is no need to change this section of the Appendix B if it is retained.

O. Mathematical Formulation of Noy Tables (§B36.7 of FAR 36).

§B36.7 provides a method of computing the perceived noisiness or noy, n, values listed in Table B1 (referred to in §B36.2). Except for some errors and a slight rearrangement of some of the material, Paragraph 7 of ICAO Annex 16, Appendix 1 is identical to this section of FAR 36. Both the FAR 36 and the ICAO material appear to have been derived as limited cases (noy, $n \geq 1.0$ and level, $SPL \leq 150$) of the more general case (noy, $n \geq 0.1$ and level, $SPL \leq 150$) provided in ARP 865A.

In considering changes to this part of Annex 16, the most recent report of the ICAO Committee on Aircraft Noise (CAN 4) recommends: (1) correcting the errors inherited from FAR Part 36, (2) correcting the errors in the original Paragraph 7, and (3) expanding the noy tables to provide noy values below 1.0 and those noy values for $SPL \geq 140$ and frequencies above 1000 Hertz which were not included in any of the original (ARP 865A, FAR 36 and Annex 16) tables. However, while the ICAO CAN-4 recommendation provides expanded noy tables, the recommended modifications to Paragraph 7 do not include the computational method for the additional values where $0.1 \leq n < 1.0$. Since the tabulated noy values for $0.1 \leq n < 1.0$ and the method to be used to calculate these values are provided in ARP 865A, this document remains the most complete and error free reference for tabulated noy values and procedures for computing these values.

A rather major modification would be required to provide this same information in §B36.7. It would include providing the equations and expanding the table of constants (Table B4 of §B36.7) to allow the computation of noy values when $0.1 \leq n \leq 0.3$ and $0.3 \leq n \leq 1.0$ and providing the additional noy values in Table B1 of § 36.2.

All of the above can be accomplished most simply by incorporating SAE ARP 865A by reference, either directly or through the use of SAE ARP 1071 (ANSI S6.4-1973) as a substitute for the entire Appendix B.

P. Noise Measurement and Evaluation (§C36. 1 of FAR 36).

Appendix C of FAR 36 specifies the noise measuring points and the airplane takeoff and approach test conditions that must be maintained to achieve the compliance noise levels. §C36. 1 of FAR 36 simply states that:

> "Compliance with this Appendix must be shown with noise levels measured and evaluated as prescribed, respectively, by Appendix A and Appendix B of this Part or under approved equivalent procedures".

The above wording is not clear in regard to approved equivalent procedures applicable to Appendix C. Approved equivalent test procedures (including location of measuring points and takeoff and approach test conditions) have at times been necessary or convenient to the Government and type certificate applicant. Therefore, the wording of §C36. 1 should clearly indicate that approved equivalent procedures are permitted in Appendix C when demonstrated to be necessary. The recommended wording for §C36. 1, therefore, is as follows:

> Compliance with this Appendix must be shown with noise levels measured and evaluated as prescribed, respectively, by Appendix A and Appendix B of this Part, or under approved equivalent procedures. Approved equivalent procedures may also be permitted for compliance with the procedures of this Appendix.

In order to insure consistent results, amendments made to this appendix should include specifications which would standardize equivalent test procedures wherever the need can be identified.

Furthermore, this appendix should be amended so far as feasible to insure that results of the noise certification testing would be useful for analyzing community noise impact and for land use planning. Takeoff and approach test procedures should yield results that are compatible with normal safe airplane operations. This requirement does not mean that the test procedures specified in Appendix C (or approved equivalent) may not deviate from normal operations for specific airplanes. Standards (including test procedures) applicable to a wide variety of airplanes, having a large range of noise levels, are designed to insure that all airplanes are tested in a consistent and fair manner. The standards in FAR 36 cannot be expected to (and need not) duplicate exactly the preferred or normal operating conditions for each airplane, nor yield the exact noise levels for those normal conditions. However, the standards should include correction techniques so that the measured noise levels, if not directly applicable, can be adjusted to be representative of normal operating conditions.

Q. Noise Measuring Points (§C36.3 of FAR 36).

§C36.3 of FAR 36 specifies that the compliance noise levels must be achieved at the following measuring points:

"(a) For takeoff, at a point 3.5 nautical miles from the start of the takeoff roll on the extended centerline of the runway;

(b) For approach, at a point 1 nautical mile from the threshold on the extended centerline of the runway; and

(c) For the sideline, at the point, on a line parallel to and 0.25 nautical miles from the extended centerline of the runway, where the noise level after liftoff is greatest, except that, for airplanes powered by more than three turbojet engines, this distance must be 0.35 nautical miles."

(Q1) Takeoff

Experience as a result of noise certification since 1969 has shown that the measuring point for takeoff (3.5 nautical miles from brake release) is satisfactory for determining noise levels which are produced by relatively noisy airplanes. However, for airplanes which have substantial applications of noise control technology and/or have relatively large takeoff climb angles, significant portions of the spectrum of the noise signal received at the 3.5 nautical mile point may be masked by normal background noise at the test site. For these cases FAR 36 permits FAA approved "equivalent procedures" which generally have been those proposed by the manufacturer and approved on a case-by-case basis. This practice has merit, but an approved equivalent procedure which may be reasonable for a particular airplane, may not permit valid comparisons to be made with other airplanes and/or other procedures.

To insure consistent results, an equivalent test procedure should be standardized for those airplanes whose noise measured at the takeoff point would not be reliable because signal to noise ratios (S/N) are too small. Such an amendment to FAR 36 would be particularly appropriate at this time because application of current, available, and future technology should result in significantly lower noise levels for new type design airplanes.

Two procedures would solve the S/N problem and could be standardized. The first would be to have an alternate noise measuring point located nearer to the runway. The microphone, therefore, would be nearer to the airplane flight path thus increasing the signal to noise ratio. The second procedure would be to retain the standard distance (3.5 nm from brake release or approved equivalent) but change the flight procedure so that the airplane flight path would be nearer to the microphone. Both procedures have merit but the second one has a precedent established for propeller driven small airplanes and is the preferred "equivalent procedure" for the reasons identified below. Also, both procedures would require additional analyses of the data and the development of correction techniques.

Small propeller airplanes are now required to demonstrate compliance with the noise level requirements of Reference 15 by means of horizontal flights over a noise measuring station at a height of 1000 ft. The noise levels determined by means of the 1000 ft horizontal flight procedure are corrected for climb performance. The correction formula yields a level in decibels which, when added algebraically to the measured noise level at 1000 ft (horizontal flyover), approximates the noise level at a specified reference distance from brake release. The EPA proposal (References 117 and 118) to amend the current propeller noise regulations (Reference 15) supports the 1000 ft horizontal flight procedure, but proposes a revised correction formula based upon both climb performance and speed. Since the precedent has been established, it is reasonable to extend the horizontal flight procedure to all airplanes which cannot be measured reliably at the 3.5 nm point.

Another reason for using the horizontal flight procedure (as opposed to an alternate measuring point) is that it is more convenient.

The preferred test procedure for demonstrating compliance with the takeoff noise level requirement is for an airplane to execute its normal takeoff and climbout procedures with the microphone at 3.5 nm from brake release. All airplanes should perform this procedure at least once. In most cases the signal to noise ratio can be judged satisfactorily during the flyover. If the S/N is adequate, the airplane should continue the testing by executing additional normal takeoffs. If the S/N is not adequate, the airplane should conduct the remainder of the testing by flying horizontally over this or any other approved microphone for the required number of tests. No delay would be required for moving the microphone and setting up at a new station.

In principal, the noise levels at an alternate takeoff measuring point could be corrected to approximate the levels at the 3.5 nm reference distance. However, in practice the results for some applications would be less reliable than those derived from the horizontal flight procedure. The reason is that airplanes generally are not stabilized with respect to configuration, speed, and climb angle until they have reached a height above airport of at least 400 ft and that it is not considered safe to execute thrust cutback for noise abatement below about 700 ft. Consequently, the use of an alternate measuring point, located nearer to the climb path than the 3.5 nm point, might result in noise levels that have been significantly influenced by the airplane climb performance below heights of 400 and 700 ft, contrary to the intent of the takeoff test procedure.

Another consideration is that as successful experience is acquired with the use of the horizontal flight procedure, both as the only procedure for propeller driven small airplanes and as an equivalent takeoff procedure for all other airplanes, a decision might be made to replace the currently specified takeoff and approach procedures with horizontal flyovers. Such a decision would result in more convenience and less cost to the manufacturers and offer the potential for the acquisition of a wide range of data suitable for community noise impact studies.

It is recommended, therefore, that the noise measuring point for takeoff be retained at 3.5 nm from the start of takeoff roll and that the use of alternate measuring points, for the purpose of increasing signal to noise ratios, not be permitted. A 1000 ft horizontal flyover procedure should be required for all cases where the S/N is not adequate. A correction formula should be developed which yields a level in decibels which, when added to the noise level determined by means of the 1000 ft horizontal flight procedure, approximates the noise level at 3.5 nm from brake release. The correction formula should be based upon both climb perfomance and speed.

In accordance with the above recommendation, the wording describing the takeoff measuring point in §C36.3(a) of FAR 36 is clear and precise and changes are unnecessary. Details of the 1000 ft horizontal flight procedure and the correction formula are included under Section 5S, "Takeoff Test Conditions", of this Project Report.

(Q2) Approach

Experience as a result of FAA noise certification tests since 1969 has shown that the measuring point for approach (1 nautical mile from threshold) is satisfactory for determining airplane noise levels that result from stabilized approach operations conducted along a single segment constant glide angle. However, if other approach procedures such as a two-segment approach are standardized, then an additional measuring point (or points) farther from the runway should be specified for noise certification testing. The wording describing the approach measuring point in §C36.3(b) of FAR 36 is clear and precise and changes are unnecessary until other than single segment stabilized approaches are required.

(Q3) Sideline

Experience as a result of FAA noise certification tests since 1969 has shown that the sideline measuring point, on a line parallel to and 0.25 nautical miles from the extended centerline of the runway, is satisfactory for all airplanes regardless of number of engines. Consequently, it is recommended that the alternative distance of 0.35 nautical miles, applicable to airplanes powered by more than three engines, be eliminated. The recommended wording for §C36.3(c), therefore, is as follows:

(c) For the sideline, at the point, on a line parallel to and 0.25 nautical miles from the extended centerline of the runway, where the noise level after liftoff is greatest.

R. Noise Levels (§C36.5 of FAR 36)

§C36.5(a) of FAR 36 specifies that flight tests must show that the noise levels of an airplane, measured at the measuring points described in §C36.3 of FAR 36, do not exceed the following values:

"(1) For approach and sideline, 108 EPNdB for maximum weights of 600,000 lbs. or more, less 2 EPNdB per halving of the 600,000 lbs. maximum weight down to 102 EPNdB for maximum weights of 75,000 lbs. and under."

(2) For takeoff, 108 EPNdB for maximum weights of 600,000 lbs. or more, less 5 EPNdB per halving of the 600,000 lb. maximum weight down to 93 EPNdB for maximum weights of 75,000 lbs. or under."

§C36.5(b) of FAR 36 permits the noise levels specified above to be exceeded (traded off) at one or two of the measuring points if:

"(1) The sum of the exceedance is not greater than 3 EPNdB;

(2) No exceedance is greater than 2 EPNdB; and

(3) The exceedances are completely offset by reduction at other required measuring points."

§C36.5(c) of FAR 36 permits a greater exceedance for special prior applications as follows:

"For applications made before December 1, 1969, for airplanes powered by more than three turbojet engines with bypass ratios of two or more, the value prescribed in (b)(1) of this section may not exceed 5 EPNdB and the value prescribed in paragraphs (b)(2) of this section may not exceed 3 EPNdB."

(R1) Tradeoff and Prior Applications

The tradeoff provisions of §C36.5(b) were justified in the preamble of FAR 36 as follows:

> "However, the trade-off feature is maintained since the total noise exposure created by an airplane is related to the noise transmitted to all three measuring points (sideline, approach, and takeoff). It would, therefore, not be rational to deny a type certificate to an aircraft that only slightly exceeds the required noise levels at one or two points if the exceedances can, in fact, be made up or offset at the remaining measuring point(s), so that the net result is an aircraft whose total noise exposure is no worse than that of an aircraft that barely met the requirements at all three measuring points."

Experience as a result of FAA noise certification tests conducted since 1969 has shown no evidence that the above justification is not still valid. The wording in §C36.5(b), therefore, is clear and precise and changes are unnecessary.

However, the provision that applications made before 1 December 1969 may have a greater exceedance is no longer needed. Therefore, it is recommended that §C36.5(c) be deleted.

(R2) Compliance Noise Levels Proposed by FAA and ICAO

Experience as a result of FAA noise certification tests since 1969 has shown that current technology airplanes are capable of complying with substantially lower noise levels than the requirements of §C36.5(a) listed above. The FAA has recognized this fact and proposed lower compliance noise levels in Reference 28 (hereafter designated FAA WP/39). Also, the ICAO Committee on Aircraft Noise (ICAO CAN/4) in Reference 35 (hereafter designated ICAO WP/64) has proposed lower compliance noise levels which, generally, are less stringent than those of FAA WP/39.

Figures 2(a), (b), and (c) illustrate the compliance noise levels of FAR 36 specified in §C36.5 compared with the levels proposed in FAA WP/39. The FAR 36 levels are designated 69 FAR 36 because they were first effective in the year 1969 (and are effective to date). The FAA WP/39 levels are dependent upon the number of engines required for propelling the airplanes for sideline and takeoff, but are independent of number of engines for approach. The FAA WP/39 levels represent reductions from the 69 FAR 36 levels that are dependent upon airplane weight and number of engines within the following ranges:

Sideline (5 to 9 dB),

Takeoff (1 to 10 dB), and

Approach (3 to 4 dB).

Figures 3(a), (b), and (c) illustrate the compliance noise levels of 69 FAR 36 compared with the ICAO WP/64 levels. The latter are independent of number of engines and agree with the FAA WP/39 levels in only two cases (sideline four engines and approach). The ICAO WP/64 levels represent reductions from the 69 FAR 36 levels that are dependent upon airplane weight within the following ranges:

Sideline (5 to 6 dB),

Takeoff (2 to 4 dB), and

Approach (3 to 4 dB).

The formulae for the compliance noise level curves of all three sets of requirements (69 FAR 36, FAA WP/39, and ICAO WP/64) are listed in Table 2. It is interesting to note that the slopes of the curves for 69 FAR 36 and ICAO WP/64 are identical for all three measuring points. However, the slopes of the curves for FAA WP/39 agree with the other two sets of requirements only for sideline and approach. The slope of the FAA WP/39 curve for takeoff is lower (4 versus 5 dB per halving of weight) than that for 69 FAR 36 and ICAO WP/64.

(R3) Noise Levels of Existing Airplanes

Figures 4 (a) thru (g) show airplane noise levels, listed in Tables 3 (a) through (h), compared with the compliance noise level curves for the three sets of requirements. The levels are plotted in terms of number of engines relative to the sideline and takeoff measuring points in order to facilitate comparisons with the requirements of FAA WP/39. The data from Tables 3 (complied from the sources listed in Ref 119) represent both certificated and estimated noise levels. The data points shown in Figures 4 represent the noise levels of pre-1969 technology airplanes as well as those for current technology airplanes, the latter defined as those which can comply with 69 FAR 36.

The purpose of Figures 4 is to illustrate the wide range of noise levels produced by the existing airplanes. The range for all of the airplanes shown is over 40 decibels, varying from a low of about 78 EPNdB at takeoff to nearly 119 EPNdB at approach. Many of the data points are above the 69 FAR 36 curves but most are below. Subsequent Figures will illustrate how the range for new aircraft can be narrowed to levels substantially below 69 FAR 36 by application of current and available technology.

(R4) Current and Available Technology: Existing Airplanes

Figures 5 (a), (b), and (c) show the airplane noise levels listed in Table 4 compared with the compliance noise level curves for 69 FAR 36. The 17 airplanes listed were chosen from Tables 3 on the basis that they all meet the requirements of 69 FAR 36 by original design and not with the use of retrofit hardware. Airplanes that can comply with 69 FAR 36 are designated "current technology" airplanes and those that cannot comply are designated "pre-1969 technology" airplanes. The 17 current technology airplanes were selected, where feasible, to include two models of each type; one at the low end and one at the high end of their weight range. Hence, the sample of current technology airplanes includes the influence of growth.

In order to be economically viable, most new aircraft (especially transport category) must have a certain and defined growth potential. One reason for this is that the first models of airframe and engine combinations may not be as efficient in terms of range, payload, operating, costs, etc., as they can be after they have had the opportunity to be tested and evaluated in service. Another reason is that by the nature of the market, the first models are designed for U.S. domestic operations for the anticipated level of traffic. Growth versions are developed to satisfy the requirements of long-range international operations. Generally, the most significant changes are made in the engine in terms of increased thrust while maintaining an adequate margin of safety. Increased thrust can be translated into increased flight range with the same payload, increased payload for the same range, or some combination of both. Without growth guaranteed by the manufacturers, most new aircraft types would have such a limited market that, probably, they would not be developed.

The question has been asked that, from an environmental standpoint, why should aircraft types be permitted to have new models (growth versions) if those new models produce higher noise levels than the original models? The answer is in two parts, one pertaining to economics and the other to environment.

The economics answer is based upon the fact that many, if not all, airlines have need for aircraft which operate efficiently over various ranges and with different payloads, and which allow for the desirable growth in passenger and cargo traffic that is expected to occur with time. Several models of a particular type would satisfy those requrements while one model would not. One alternative for the airlines would be to acquire additional types of aircraft (e.g., short, medium, and long range). This alternative, however, would likely not be economically reasonable because it would require more expensive maintenance and spare parts facilities to service several types of aircraft, than would be required to service several models of a single type of aircraft.

The environmental answer is based upon several considerations. First, from a noise standpoint it makes little difference whether the range and capacity requirements are met by a variety of types of aircraft or by a variety of models of a given type. Second, if noise regulations were to prohibit the noise of future models from exceeding the levels of the initial model, the manufacturers probably would design the initial models to comply with levels no lower than the maximum permissible. This would be the only logical way of insuring that noise regulations would not inhibit growth potential. The result, of course, would be to produce greater noise than necessary from initial models. Third, the airlines could operate only long range models of a particular type of aircraft over all of their routes. This alternative would not only be economically unreasonable but degrading to the environment as well. The result would be that the largest and noisiest aircraft would be operating at many airports where smaller and less noisy models would operate if they were available. Fourth, the airlines could operate only short range models of a particular type over all of their routes. Like the former, this alternative would be both economically unreasonable and degrading to the environment. Many of those aircraft would be forced to refuel at some airports (hence produce noise) which longer range models would overfly if they were available. Thus, the number of exposures at a given airport would be greater than it otherwise would be.

The 17 airplane sample does not include models of pre-1969 technology airplanes which can now comply with 69 FAR 36 by means of retrofit applications of Quiet Nacelles (QN). The QN airplanes are not current technology airplanes in the sense of original design, although they can be and are being, in some cases, newly produced and may continue to be for many years. Therefore, while the QN airplanes can meet 69 FAR 36, they are not included in the 17 airplane sample despite their potential for long term existance.

Three curves are shown in Figures 5: the 69 FAR 36 requirements; the least squares mean of the 17 airplane sample; and the mean less three decibels. Note that the mean was determined over the range of maximum aircraft weights from 10,000 to 1,000,000 pounds. The upper curves (69 FAR 36) are existing requirements and only pre-1969 technology airplanes cannot comply. In fact most current technology airplanes can comply with substantially lower noise levels which fact is indicated by the middle curves (mean). Consequently, if FAR 36 is to be amended for lower compliance noise levels representative of current technology airplanes, the mean curves should be considered as candidates along with those for FAA WP/39 and for ICAO WP/64.

The lower curves (mean -3 dB) represent a compromise choice of compliance noise levels for available technology airplanes. It must be understood that "available technology", as used here and defined previously, includes techniques and procedures which have been used effectively by some manufacturers for some applications. Consequently, some set of curves through the lower range of the data scatter would satisfy the above definition. The problem is to determine a reasonable set of curves taking into consideration the fact that the various types of airplanes do not all have the same purpose or mission. In other words, available noise abatement technology which may be appropriate for one type of airplane may not be appropriate for another.

In arriving at the lower curves of Figures 5 as the compromise choices for available technology, consideration was given to the number of airplanes of the seventeen that could comply with the mean, the mean less one decibel, the mean less two decibels, etc., tabulated as follows:

	Mean	Mean -1 dB	Mean -2 dB	Mean -3 dB	Mean -4 dB	Mean -5 dB
Sideline	9	9	7	3	0	0
Takeoff	10	9	7	5	2	1
Approach	11	5	3	2	0	0

It is seen from the above listing that the majority of the 17 airplanes could comply with the mean and only one with the mean less five decibels. The most reasonable set of curves for which some airplanes could comply is the mean less three decibels which was chosen as the compromise between the mean and the mean less five decibels, for which only one airplane could comply.

Note that the airplane complying with the mean-5dB is the initial model of the A300 B which has a relatively high thrust to weight (T/W) ratio for a transport category airplane. In general, for a given weight, the airplane with the largest T/W ratio would reach the greatest height over the takeoff measuring point and have the greatest thrust reduction when power cutback is utilized. Both of these effects help reduce noise levels at the takeoff measuring point. The A300 B illustrates two important points. First, the initial version is substantially less noisy than other airplanes in its weight class which probably would not be the case if noise were not permitted to increase at a reasonable rate with increase in maximum airplane weight. Second, a greater than usual T/W ratio is an accessible technique for controlling aircraft noise at takeoff and may not necessarily be wasteful of energy.

An important consideration that influenced the choice for the lower curves (mean -3 dB) of Figures 5 was that the airplanes which could comply should represent as much of the full weight range as possible. For example, for takeoff one airplane can comply with the curves for the mean less five decibels and two airplanes with the mean less four decibels. However, both of these airplanes are in the moderately high weight range and there is no representation in the lower weight range. On the other hand, of the five airplanes which can comply with the curves for mean less three decibels, two are in the low weight range and three in the moderately high weight range. The fact that the middle and highest weight ranges are not represented is unnecessary. The lowest and moderately high weight ranges are adequately far apart and the missions and purposes of the airplanes sufficiently disparate to be indicative of the availability of the noise control technology for the entire weight range.

It should be pointed out that ten airplanes can comply with the mean -3dB curves on an individual measuring point basis. That does not mean that ten of the seventeen control group airplanes can comply with the mean-3dB curves collectively. Nevertheless, the data of Figures 5 show that six airplanes have noise levels less than the mean at all three measuring points, and two more airplanes can comply with the aid of the 3/2 dB tradeoff provision. Therefore, it is not unreasonable to assume that technology is available to "fine tune" the noise control of these existing airplanes for a maximum of three decibels more noise reduction, at each of the three noise measuring points, by the use of such techniques as sound absorption material (SAM), thrust cutback, increased thrust/weight ratios, improved lift/drag ratios, reduced approach flaps, etc. Consequently, with available noise control technology capability, new type design airplanes, that is airplanes that are not constrained to existing airframes or engines, should be able to comply with noise levels at least three decibels lower than existing airplanes such as the Cessna, Learjet, Falcon, Airbus, Corvette, DC-10, L-1011, and B-747.

The formulas for the mean curves of the 17 airplane sample, for the range of maximum weights from 10,000 to 1,000,000 pounds, and the reduction in noise levels from the 69 FAR 36 levels are as follows:

	Formulas	Reduction, dB	
Sideline:	EPNL = 7 Log (W) + 59:	7 to 15	(8a)
Takeoff:	EPNL = 12 Log (W) + 32:	3 to 13	(8b)
Approach:	EPNL = 7 Log (W) + 63:	3 to 11	(8c)

The constants of the above formulas have been rounded off so that the equations will yield levels within a fraction of a decibel of the exact mean.

An additional discussion on the mean concept for the development of compliance noise levels representing current and available noise control technology is given in Reference 120.

(R5) Comparisons of Proposed Compliance Noise Levels

Figures 6 (a), (b), and (c) compare the mean curves of the 17 airplane sample with the curves of FAA WP/39. It is apparent that the mean curves are more stringent (have lower levels) than those of FAA WP/39, except for the following:

> Sideline. The mean curve has levels slightly higher (one decibel or less) than the 3 engine curve for aircraft weights above about 200,000 pounds and the 2 engine curve for aircraft weights above about 75,000 pounds.
>
> Takeoff. The mean curve has levels up to four decibels higher than the 2 engine curve for aircraft weights above about 40,000 pounds and up to one decibel higher than the three engine curve for aircraft weights above about 75,000 pounds.

Figures 7 (a), (b), and (c) compare the mean curves of the 17 airplane sample with the curves of ICAO WP/64. Coinciding curves of FAA WP/39 are also shown for reference. It is seen that the mean curves have lower levels than ICAO WP/64 in all cases except for takeoff at a range of weights from about 75,000 to 150,000 pounds where the mean curve is up to one decibel greater.

Three sets of curves have been considered as candidates for compliance noise levels, namely, FAA WP/39, ICAO WP/64, and the mean of the 17 airplane sample. Each of these candidates has merit. Support for FAA WP/39 and ICAO WP/64 are given in References 28 and 35, respectively, and support for the mean has been presented in the previous discussion and in Reference 120. For the most part, the mean curves are the most stringent of the three.

In some cases, however, the levels of the mean are less stringent than those of FAA WP/39 and ICAO WP/64. Consideration should be given, therefore, to the concept of proposing compliance noise levels which would be the most stringent combination of the three candidate sets of curves. The results of the most stringent combination of noise levels represented by the curves for FAA WP/39, the curves for the mean of the 17 airplane sample and the mean -3dB are shown in Figures 8 (a), (b), and (c) and Figures 9 (a), (b), and (c). The curves representing ICAO WP/64 were disregarded on the basis that, except for a very small portion of the airplane weight range, they were less stringent and the exception was not significant.

Consequently there is one set of curves representing pre 1969 technology (69 FAR 36); four candidates sets of curves representing current technology (ICAO WP 64, FAA WP/39, mean, and modified mean); and two candidate sets of curves representing available technology (mean -3dB and modified mean -3dB). The applicability is recommended as follows:

1. Newly produced airplanes of older type designs, which are 69 FAR 36 requirements in accordance with Reference 13.
2. New type designs applied for on or after 1 January 1975, which are current technology requirements.
3. Airplanes with "major acoustical changes" to older type designs which are newly produced on or after 1 January 1975, which are current technology requirements.

4. New type designs applied for on or after 1 January 1980, which are available technology requirements.

The choice of the mean levels for current technology requirements would have in its favor, simplicity and the fact that the levels represent known and demonstrated noise control technology. In other words, the state of the art includes efficient, high performance airplanes such as the B-747, L-1011, DC-10, Corvette, Airbus, Falcon, Learjet, and Cessna, all of which can comply with the mean levels.

However, any one of the four candidate sets of curves for current technology has merit in the sense that the compliance noise levels for new type design airplanes would be significantly lowered from those of 69 FAR 36. There is not a great deal of difference in stringency between any of the candidates except for the lower weight range which corresponds mainly to general aviation aircraft. Therefore, any one of the four candidates would be acceptable provided they are applicable only to current technology airplanes. In other words, any one of the four sets of curves (or a compromise among them) would not be unreasonable choices for immediate implementation considering that the available technology requirements would follow after the lapse of several years. Furthermore, the current technology levels would be applicable to major acoustical changes of older type designs.

Major acoustical changes to older type design airplanes would include new type engines or radically modified existing type engines such as the JT8D "Refan" included on newly produced existing type airplanes. However, a major acoustical change would not include modifications to existing type airplanes such as "Quiet Nacelles", uprated or growth versions of original equipment engines, and existing type engines different from the original equipment engines.

In regard to available noise control technology, the modified mean -3dB set of curves are more stringent than the mean -3dB set only for two engine takeoff where they are one decibel or less more stringent over part of the weight range. Considering the convenience of the single line to outweigh any possible benefits due to one decibel or less stringency, it is recommended that the compliance noise levels for available technology be represented by the mean -3dB curves. The formulas and reductions in noise levels from the 69 FAR 36 levels, for the range of maximum weights from 10,000 to 1,000,000 pounds, are as follows:

	Formulas	Reduction, dB	
Sideline:	EPNL = 7 Log(W) + 56:	10 to 18	9(a)
Takeoff:	EPNL = 12 Log(W) + 29:	6 to 16	9(b)
Approach:	EPNL = 7 Log(W) + 60:	6 to 14	9(c)

(R6) Alternate Schemes for Current Technology

Two sets of noise levels, represented by the curves shown in Figures 5, have been proposed as modifications to 69 FAR 36. The development of these proposed noise level modifications was based upon a scheme where a control group of seventeen 2, 3, and 4 turbojet engine airplanes, all of which can comply with 69 FAR 36, were chosen as typical examples of the application of current noise abatement technology.

A least squares mean set of curves was derived for the 17 airplane sample and denoted as candidates, along with the curves for FAA WP/39 and ICAO WP/64, for compliance noise levels representing current noise control technology. Further analysis indicated that the mean -3dB set of curves would be suitable choices for compliance noise levels representing available noise control technology. Comparison of the curves for the mean, FAA WP/39, and ICAO WP/64 show that, for the most part, the mean curve is the most stringent of the three. Minor exceptions occur for takeoff, for part of the weight range and only for 2 and 3 engines.

Alternate schemes to the above for modifying the compliance noise levels of 69 FAR 36 have been proposed in addition to the specific recommendations of FAA WP/39 and ICAO WP/64. Other schemes or philosophies, are discussed in References 121 thru 125. A general concept that is emphasized in those references is that noise is more closely related to thrust and thrust/weight ratio than to weight for turbojet propelled airplanes. In particular, some contend that, for takeoff, maximum climb thrust (as opposed to maximum takeoff thrust) is the more important variable.

In addition, the point is made that various airplane design requirements (such as safety regulations pertaining to engine performance during climb, wing loading, lift/drag ratios, and range/ payload) which affect the choices of size of engine, number of engines, and thrust/weight ratio, are more influential parameters governing aircraft noise than maximum aircraft weight. Consequently, it is claimed (e.g., References 122 and 125) that a scheme which relates compliance noise levels for turbojet airplanes to maximum weight only is an over-simplification which may be more stringent for some airplanes than for others.

There is no doubt that aircraft are very complex sound sources and that many interrelated parameters strongly influence the generation and radiation of noise. The control of aircraft noise, therefore, is most effective when planned in the design stage and when as many as possible of those influential parameters are identified and controlled. However, it is not reasonable, nor expected, that noise standards should be equivalent to design procedures. The noise standards should be as simple as possible without inequities. Each aircraft/ engine manufacturer has his own design procedures suited to his equipment, professional skills, and aircraft mission. One set of aircraft noise standards could not possibly satisfy the design requirements of all manufacturers and aircraft missions.

Furthermore, since aircraft noise is a very important public issue, attempts should be made, to the maximum extent reasonable, to base the standards upon easily understood and readily obtainable parameters. The public has a right to be informed on this issue with a minimum of confusion. This is not to say that the standards should be compromised in order to inform the public but, on the contrary, the standards should not be complicated in order to provide a design service to the manufacturer which at the same time might be confusing to the public.

In view of the preceding discussion, effort was devoted to analyzing the available noise data in terms of maximum thrust, thrust/weight ratio, and number of engines. The purpose was to determine whether those parameters would lead to significantly better correlations with noise than does maximum aircraft weight. The intent was that if the correlation would be substantially better with those parameters, then perhaps, more fundamental design characteristics (climb thrust, lift/drag, wing loading, etc.) should be evaluated as well.

The analysis began with the 17 airplane sample representing typical examples of 2, 3, and 4 engine airplanes which can comply with 69 FAR 36. These airplanes, to various degrees, have applications of current noise control technology. Furthermore, these airplanes are relatively new, competitive, and can be operated at a profit. There is no reason why new type design airplanes (or major acoustical changes to older type designs) should be permitted to produce greater noise.

Figure 10(a) shows the relationship between maximum airplane thrust and maximum airplane weight for the 17 airplane sample. The equation of the least squares mean through the data points is given by:

$$\text{Log}(T) = 0.923\ \text{Log}(W) - 0.107 \quad (10)$$

where T and W are given in pounds.

It is seen that the correlation between maximum thrust and maximum weight is excellent, indicating that if noise correlates well with thrust, it would, for all practical purposes, correlate equally well with weight.

Figure 10(b) shows the relationship between the thrust/weight ratio (maximum value in each case) and maximum aircraft weight for the 17 airplane sample. The equation of the least squares mean is given by:

$$\text{Log}(T/W) = -0.077\ \text{Log}(W) - 0.107 \quad (11)$$

The correlation is good but not as good as for thrust versus weight. It is seen that there is a modest trend for thrust/weight ratio to decrease with increasing weight. However, it cannot be concluded that lighter airplanes always have greater thrust/weight ratios than heavier airplanes. Nor can it be concluded that thrust/weight ratios always decrease with increasing number of engines.

Figures 11 (a), (b), and (c) show the relationship between noise level and maximum aircraft thrust for the 17 airplane sample. The equations of the least square mean are given by:

$$\text{Sideline:} \quad \text{EPNL} = 7\ \text{Log}(T) + 63 \quad (12a)$$

$$\text{Takeoff:} \quad \text{EPNL} = 13\ \text{Log}(T) + 33 \quad (12b)$$

$$\text{Approach:} \quad \text{EPNL} = 7\ \text{Log}(T) + 67 \quad (12c)$$

The constants of the above formulas have been rounded off so that the equation will yield levels within a fraction of a decibel of the exact mean. It is seen by comparing Figures 5 and 11 that the correlation between noise and maximum thrust is no better than between noise and maximum weight.

The slopes of the relationship between noise and thrust are given by:

Sideline: 2.107 dB per double thrust

Takeoff: 3.913 dB per double thrust

Approach: 2.107 dB per double thrust

The values for the slopes compare favorably with the views expressed by others (e.g., References 122 and 125) that noise increases about three decibels for each doubling of thrust.

Figure 12 (a) shows the relationship between noise levels normalized for weight and the number of engines. The normalization was performed in conformance with Equations (8a), (8b), and (8c) which are the formulas for the mean curves in terms of weight. It is seen from Figure 12(a) that some 3 and 4 engine airplanes have lower normalized levels than some 2 engine airplanes. Also, some 4 engine airplanes have lower normalized levels than some 3 engine airplanes. It can be concluded, therefore, from analysis of the 17 airplane sample that there is no indication that the stringency of compliance noise levels should increase for decreasing number of engines. That is, 2 engine airplanes should not be required to meet lower noise levels than 3 engine airplanes, etc.

Figure 12 (b) shows, in a similar manner, the relationship between noise levels normalized for thrust and the number of engines. The normalization was performed in conformance with Equations (12a), (12b), and (12c) which are the formulas for the mean curves in terms of thrust. The same observations can be made from Figure 12(b) that were made from Figure 12(a). That is, there is no indication that the stringency of compliance noise levels should increase for decreasing number of engines. Furthermore, the correlation of number of engines with respect to noise is about the same whether normalized with respect to thrust or to weight.

Figure 13 shows the relationship between thrust/weight ratio and number of engines for the 17 airplane sample. This is simply another way of illustrating the conclusions reached from Figure 10(b). That is, although there is a trend for thrust/weight ratio to decrease with increasing number of engines, it cannot be concluded that airplanes with fewer engines always have higher thrust/weight ratios.

The foregoing analysis examined the 17 airplane control sample for evidence that noise could be correlated better with more basic airplane/engine parameters than weight. Thrust, thrust/weight ratio, and number of engines were considered and the correlation was no better than for weight alone. It must be understood that maximum thrust and maximum weight were used in the analysis, and the possibility exists that the correlation might be better if the actual thrusts and weights for each operational mode were considered. For example, if actual thrust for sideline (based upon thrust lapse rate), climb thrust for takeoff, and landing thrust and weight for approach were used instead of the maximum values, the correlation with noise might have been better.

However, more basic parameters than maximum aircraft weight are performance data which are not readily available and, in some cases, might be proprietary. The extra effort needed to acquire that data does not appear to be warranted because if significantly better correlation would result, some evidence of that trend should have been indicated by the maximum values. Any such trend, if it exists, is not very strong.

(R7) Future Technology

The substantial achievements in noise reduction, such as manifested by the mean curves, has encouraged predictions that aircraft noise at the FAR 36 measuring points can be reduced ten decibels or more (e.g., the CARD Study, Reference 126). These achievements came as a result of research, development, and demonstration (RD&D) initiated before the promulgation of 69 FAR 36. Noise control RD&D, funded both by Government and industry, are continuing and their results should be included in the designs of new aircraft types some time in the future, probably beyond 1985.

The National Aeronautics and Space Administration is the single largest contributor to RD&D on aircraft noise control. A comprehensive report on the NASA noise reduction technology programs and plans, as of March 1973, is given in Reference 127. Although that report has not been revised in the past three years, the material is pertinent and the NASA programs and plans discussed therein should have a strong influence on future aircraft design. Reference 128, published subsequent to the NASA report, provides a brief summary of the large amount of information available on air transport noise control and future needs and research trends. Reference 129 contains a status report on propulsion noise RD&D conducted by NASA. These later references, therefore, serve a function of partially updating the earlier NASA report.

The noise reduction accomplishments to date and the extensive programs in progress do indeed hold promise for further substantial gains. Nevertheless, there has to be a limit, or floor, beyond which it is technologically impractical, or even impossible to proceed. The following three sources of noise have been identified as potential noise floors which may be relatively near at hand: jet exhaust stream, engine core, and flow surface interactions (References 5, 121, 125, 127 through 131).

Noise from the jet engine exhaust stream mainly results from the mixing of the high velocity gas discharge with the ambient air. The noise sources are usually defined as acoustical quadrupoles whose overall strength is proportional to the relative jet stream velocity to the eighth power. The absolute noise level for any given velocity is dependent upon various factors such as exhaust nozzle size and shape and various influences upstream of the nozzle such as geometry, roughness, turbulence scale, etc. Current methods of jet noise reduction involve the use of exhaust noise suppressors which break up the main jet and, in effect, change the manner in which it mixes with the ambient air. Such suppressors have been most effective at the higher jet velocities, where the noise is greatest, but are accompanied with significant penalties in thrust, drag, fuel consumption, and airplane empty weight.

The most effective procedure to control jet stream noise without excessive penalties is to reduce the jet velocity but maintain thrust by increasing the mass flow. The technique used for turbofan engines is to increase the bypass ratio. Incidentally, high bypass ratio turbofan engines which are efficient for subsonic airplanes were not developed originally, nor specifically, for noise control but rather to improve fuel economy. The noise levels at the lower jet exhaust velocities are higher than would be expected based on jet mixing noise only. There is evidence that other sources of noise are important in this velocity range. For example, sources generated inside the engine, commonly referred to as core engine noise, may dominate.

Core engine noise is defined (Reference 5) as the noise produced by the gas generator portion of the gas turbine engine, either solely, or as influenced or amplified by the fan discharge, tail pipe, and any other portion of the exhaust system. Core engine noise is assumed to radiate only in the aft quadrant of the engine, and its sources are generated upstream of the tail pipe exit plane. Core engine noise does not include compressor-generated noise radiating from the engine inlet nor fan-generated noise radiating from either the engine inlet or exhaust ducts. It may, however, include compressor-generated noise transmitted downstream through the engine flow passages or fan-generated noise enhanced by interaction with the core engine noise or with the gas stream.

Flow surface interaction noise is produced by the interaction of flows with solid surfaces of the aircraft, and can result from propulsive and nonpropulsive sources. An example of a propulsive source is a powered-lift aircraft where the interaction of the jet engine exhaust with the wing and flap surfaces can be significant noise sources. Nonpropulsive noise is produced by aerodynamic boundary layers or the turbulence produced by air passing over and around the airframe and its various components, such as flaps, landing gear, landing gear cavities and doors, and other protuberances or cavities that tend to disrupt smooth flow.

It is becoming more apparent that nonpropulsive noise (also referred to as airframe, aerodynamic, or selfnoise) must be considered in the design of future aircraft if significant further noise reduction is to result. Airframe noise is that which would be radiated by an aircraft in flight with the engines inoperative. Of the three FAR 36 measuring points, it would be most noticeable at approach because engine power and distance to the microphone are least. There is evidence that aircraft noise is approaching the level which would limit the feasibility of further engine noise control. There would be no point in new and expensive engine noise control programs if airframe noise is the limiting factor.

Figure 14 shows the estimated range of nonpropulsive noise at the approach measuring point for typical airplanes. The range is constructed from the ranges given in References 128 and 130. It is interesting to note that the upper limit of the range is less than one decibel below the mean-3dB compliance noise level curve and has the same slope. Reference 131(a) reports the results of an analysis of about ten commercial and military airplanes which substantiates the validity of that range of levels, including the slope. The conclusion of Reference 131(a) is that the trend of the data is a line which has a slightly greater slope than the 69 FAR 36 minus 10 dB curve. Such a line would lie within the range shown whose limits have a slope equal to 2.107 dB per doubling of weight which is slightly greater than the

2.000 dB per doubling of weight of the 69 FAR 36 curve for approach.

It is apparent from Figure 14 that the compliance noise levels for approach, defined by the mean-3dB curve, have nearly reached the upper boundary of the airframe noise floor. Further reductions in the compliance noise levels for approach are contingent upon the development of technology for reducing the nonpropulsive noise sources. Note that the range of Figure 14 pertains to typical airplanes which contain a substantial number of protuberances or cavities that tend to disrupt smooth flow and generate noise. A reasonably clean airplane would be expected to have an airframe noise floor lower than the upper boundary shown. The development of compliance noise levels representative of future noise control technology, would, therefore, be dependent upon the ability to identify and predict the lower limits of airframe noise for all three measuring points.

Figures 15 (a), (b), and (c) show predictions for nonpropulsive noise floors of aerodynamically clean airplanes. The predictions were derived from data presented in Reference 131(b) based upon calculated noise spectra radiating from aerodynamically clean wings sized for 600,000 lb airplanes. Of course, no real airplane can ever be equivalent to a clean wing and the predictions shown simply represent ideal minimum levels. The slopes of the curves for the ideal noise floors are assumed to be the same as shown in Figure 14, that is, the same as the slope of the mean-3dB approach curve. Also, the distance from the clean airplane to the microphone was assumed constant for the full weight range which is reasonable for the sideline and approach measuring points. The assumption of a constant height of 1000 feet for the takeoff measuring point is reasonable for the 600,000 lb airplane but probably not for lighter weight airplanes. The height of an airplane above the microphone is dependent upon airplane climbout performance which, generally, is inversely related to airplane weight. Thus, a 10,000 lb airplane would be expected to have a greater height at 3.5 nautical miles from brake release than a 600,000 lb airplane.

The development of compliance noise levels representing future noise control technology is dependent upon determining the limiting levels resulting from the three likely floor sources (jet exhaust stream, engine core, or airframe). It appears at this time that airframe noise is the limiting source in the sense that there is no demonstrated technology which will permit noise levels lower than the self noise generated by a reasonably clean airframe. Although it is possible that the levels of jet stream or core engine noise may bottom out before airframe noise, the technological capability for substantially lowering the levels of the jet and core sources appears to be more promising than for the airframe source. Consequently, the following development of future noise control technology curves will pertain to estimated limits for airframe noise.

In the development of the noise predictions for the aerodynamically clean wing included in Reference 131(b), about five decibels was estimated to account for the noise effects of the normal cavities and protuberances (flaps, landing gear, etc.) during approach operations. For sideline and takeoff operations, the difference in noise levels between clean and dirty configurations would be expected to be about the same or slightly greater than for approach. The reason is that airframe noise is a function of airspeed and the magnitude of the protuberances; the speed being greater for sideline and takeoff operations than for approach and the effect of protuberances being slightly less. The above statement is based upon the assumption that takeoff flaps and landing gear would be fully deployed when the noise is measured at the sideline and takeoff measuring points. Rapid cleanup (gear and flap retraction as soon as feasible) would reduce the level of the estimated airframe noise at the sideline and takeoff measuring points. If rapid cleanup is eventually included as part of the FAR 36 flight test procedures, the above assumptions may need to be revised.

The specific incremental levels chosen for representing the differences between a clean wing and a reasonably clean airframe cannot be established with absolute certainty at this time. Nevertheless, the values chosen are logical choices based upon available data and are adjusted to yield round numbers at the maximum aircraft weight limits. The assumed incremental levels are:

(a) Sideline, 7.5 dB;

(b) Takeoff, 7.5 dB;

(c) Approach, 5.5 dB.

The increment for approach is approximately five decibels in accordance with the recommendation of Reference 131(b). The increments for sideline and takeoff have been assumed to be equivalent because the airplane speeds and configuration should be about the same. A two decibel difference between the increments for sideline and takeoff and for approach appears reasonable considering the differences in speed and configuration.

Figures 16 (a), (b), and (c) show the proposed compliance noise level curves representing available and future noise control technology derived from the mean -3dB of the 17 airplane sample and the foregoing analysis for future technology. The two curves are further identified as 80 FAR 36 and 85 FAR 36 to indicate representative time periods for implementation.

The future technology curves for sideline and approach require little explanation; they are the curves of Figures 15 (a) and (c) with the levels adjusted linearly upwards by 7.5 and 5.5 decibels, respectively. The curve of 85 FAR 36 for takeoff requires a more detailed explanation because the modifications to Figure 15(b) include a slope adjustment as well as a linear level adjustment.

The slope of the noise floor curve shown in Figure 15 (b) results from the assumption that the airplane has a constant 1000 feet height above the takeoff measuring point. As discussed previously, this assumption is not realistic because a 10,000 pound airplane would be expected to be substantially higher than a 600,000 pound airplane at 3.5 nautical miles from brake release. Probably, the lighter airplane would be two to four times as high as the larger airplane depending upon climbout performance. Since the estimated levels of airframe noise are tenuous, especially for levels applicable to airplanes about ten years in the future, the slope of the 85 FAR 36 curve for takeoff was chosen for convenience to be the same as for the 80 FAR 36 curve. This assumption resulted in a slope adjustment equivalent to nine decibels difference between the 10,000 and 600,000 pound airplanes. A noise level difference of nine decibels would result from a height ratio of about 2.82, assuming an inverse square relationship. Therefore, if the height of a 600,000 pound airplane is assumed to be 1000 feet, the 10,000 pound airplane would be at a height of 2820 feet. This is a reasonable assumption and greater refinement probably is unnecessary.

It must be emphasized that the future technology noise compliance curves shown in Figures 16 represent airframe noise floors predicted at this time. The predictions are, admittedly, rough and it is conceivable that the results of RD&D within the next ten years could lead to even lower noise levels. For example, it was assumed, based upon rather simple predictions, that the ultimate lower limit would be the noise levels produced by an aerodynamically clean wing. In addition, a further assumption was made that noise levels of practical airframes could approach those of clean wings by only 7.5 dB for sideline and takeoff and 5.5 for approach. Therefore, RD&D should be conducted with objectives which include the determination of airframe noise levels for clean airframes and the development of design data for practical airframes which would narrow the airframe noise gap between clean and practically clean airframes.

(R8) Compliance Curves Compared with CARD Study Goals

The 1970-1971 Civil Aviation Research and Development (CARD) Policy Study (Reference 126) conducted "...a comprehensive review of policies affecting civil aviation, of the problems confronting it, and of the potential it possesses for future contributions to the Nation." The CARD Study determined that there are a number of serious aviation related problems that are rapidly growing more severe, including the impact of civil aviation on the environment. The impact, according to the CARD Study, was evident in the public concern regarding noise, air pollution, water pollution, esthetics, ecological disturbances, and meterological changes. Of these effects, the CARD Study judged noise to be most important and a critical constraint to the future growth of civil aviation.

The CARD Study recommended that "Research goals should be established on the basis of the desired end result; that is, the achievement of noise levels permitting the introduction of new systems compatible with future environmental goals. This will require the acceptance of these systems by local communities so airports can be located, and suitable operations conducted, where they will satisfy the transportation needs in an optimum way." The objectives for meeting these goals, according to the CARD Study, "... should be aircraft operations in which the observed noise levels, at or beyond the airport boundaries, are compatible with ambient or background levels for specified land use."

The specific noise level research goal recommendations of the CARD Study for 1981 are shown in Figure 17 (a) compared with the levels for 69 FAR 36. The top line of the CARD Study recommendations pertains to compliance noise levels at the FAR 36 measuring points for sideline, takeoff, and approach. No distinction is made, however, between the levels at each of the three measuring points. The bottom line of the recommendations represent the maximum noise levels of aircraft perceived at airport boundaries when operating in accordance with optimum approach and climbout procedures. Thus, the two lines represent a range or envelope of levels that should not be exceeded by new aircraft by 1981. However, the full width of the range is not necessarily relevant to type certification of aircraft as represented by FAR 36 or modifications thereto. For comparison purposes, the 69 FAR 36 levels are shown as a range also. It is seen that the CARD Study recommendations are that, by 1981, noise from all new airplanes should be reduced at least 10 decibels below 69 FAR 36 and possibly as much as 22 decibels, depending upon the measuring point and the airplane weight.

The CARD Study research goal recommendations for 1981 are shown compared with the range of mean levels of the 17 airplane sample in Figure 17(b). The range of levels for each case, as explained previously, is the envelope of levels pertaining to the three measuring points except for the lower limits of the CARD Study range which represent noise levels at airport boundaries. It is seen that part of the range of the mean includes part of the range of the CARD Study. Specifically, the upper limits of the CARD Study are bettered by as much as 3 decibels for aircraft weights below 18,000 pounds. Comparing the two ranges, the CARD Study recommendations are that, by 1981, the noise from all new airplanes should be reduced by a minimum of about 0 to 8 decibels below the mean and possibly as much as about 18 decibels, depending upon the measuring point and the airplane weight.

The CARD Study research goal recommendations for 1981 are shown in Figure 17 (c) compared with the range of levels for 80 FAR 36. It is seen that part of the range of 80 FAR 36 is below the CARD Study range. Specifically, the upper limits of 80 FAR 36 would better the CARD Study recommendations by as much as 6 decibels for aircraft weights below 32,000 pounds. Comparing the two ranges, the CARD Study recommendations are that, by 1981, the noise from all new airplanes should be reduced by a minimum of about 0 to 5 decibels below 80 FAR 36 and possibly as much as about 15 decibels, depending upon the measuring point and the airplane weight. It is apparent, therefore, that implementation of available noise control technology (represented by 80 FAR 36) would very nearly meet the minimum goals recommended by the CARD Study.

Figure 17 (d) compares the ranges of 85 FAR 36 and the CARD Study research goal recommendations for 1981. It is seen that the CARD Study upper limits are bettered for all aircraft weights except for less than one decibel at about 75,000 pounds. Furthermore, the CARD Study lower limits are bettered by as much as 7 decibels for aircraft weights below about 40,000 pounds. In summary, the CARD Study goals can nearly be achieved by the 80 FAR 36 levels and can be achieved fully by the 85 FAR 36 levels.

(R9) Predicted Noise Levels for Major Acoustical Change Airplanes.

As defined in FAR Part 21, changes in type design are classified as minor and major. A "minor change" is one that has no appreciable effect on the weight, balance, structural strength, reliability, operational characteristics, or other characteristics affecting the airworthiness of the aircraft. All other changes are "major changes" which may include an "acoustical change" which is a change in the type design which may increase the noise levels created by the airplane. However, as used here, a major acoustical change in older type design airplanes is a special kind of acoustical change which consists of the application of current noise control technology equipment to older type design airplanes. It would not include, however, modifications such as "Quiet Nacelles", updated or growth versions of original equipment engines, and existing type engines different from original equipment engines.

It is important that a distinction be made between changes in type designs that are a result of normal growth of older technology equipment and those that are a result of the application of current technology equipment. It is reasonable to expect that the latter should include the noise reduction benefits inherent in the current technology, particularly if the current technology was funded and developed for the purpose of noise control (e.g., NASA Refan). In this regard, growth versions of the original JT8D-109 refan engine (specifically engine models JT8D-209 or JT8D-217) should not be permitted to make more noise than the initial JT8D-109 engine developed by NASA.

Figures 18 (a), (b), and (c) show the predicted noise levels for the potential major acoustical change airplanes listed in Table 5 compared with the mean curve of the 17 airplane sample representing current technology. The levels of these eleven airplanes are given in References 132.

By comparison of the sideline noise levels of the eleven airplanes with the levels represented by the mean curve, it is seen that all but three of the airplanes (Nos. 4, 10, and 11) comply. For takeoff, only No. 10 cannot comply and for approach, all but four (Nos. 1, 3, 10, and 11) comply. However, of the eleven airplanes, only two (Nos. 10 and 11) exceed the mean curve by more than two decibels, while the remaining three (Nos. 1, 3, and 4) can comply by exercising the 3/2 decibels tradeoff provision. Therefore only two (Nos. 10 and 11) of the eleven proposed airplanes that would correspond to the major acoustical change classification have predicted noise levels that could not meet the mean levels of the current airplane types.

The results shown in Figure 18, which indicate that airplane No. 10 (B-727-300B) would not be able to comply with the mean curve could have significant environmental implications according to the manufacturer (Boeing). If, for example, a new rule pertaining to major acoustical change airplanes was too stringent for the B-727-300B, that airplane would not be produced. Instead, newly produced airplanes of older type designs, which would be required to comply only with the 69 FAR 36 curve, might be produced as alternatives. The alternative airplanes, according to Boeing, would have a greater negative impact on the community noise environment although the noise levels at the FAR 36 measuring points would be approximately the same.

It should be recognized that, while Boeing has a vested interest in marketing the B-727-300B, their point may be valid. Therefore, the following statement, quoted from Reference 132(e), is included to insure that the manufacturer's position is presented correctly and completely.

> "The 727-300B is in the final design stages and will incorporate the noise reduction advantages of the NASA refan program. The design makes use of the technology developed on the refan program, but within the practical constraints of adopting a modified engine to an existing design. Limitations on the refan installation include numerous configuration as well as performance and economic considerations, all of which must be traded to arrive at a practical airplane design incorporating community noise reduction.
>
> Based on full scale ground static JT8D-109 and -115 test data, and a comprehensive 727 - JT8D flight data base, community noise reductions relative to today's operational 727-200 of nominally 4 to 6 at high power and 6 to 8 on landing are expected. These anticipated operational noise reductions have been obtained in conjunction with an increase in airplane capacity that is probably adequate to result in a saleable product.
>
> Technology advances planned to be incorporated into the -300B installation include advanced inlet lining, a low noise rotor / stator system, engine / rotor / stator lining, maximum fan case lining, nacelle fan/turbine/core lining, a jet exhaust noise mixer and a core noise plug suppressor. In addition, aerodynamic changes have been made that improve noise - performance including a wing tip extension and leading edge high lift devices. Comparing noise levels of current operational 727-200 airplanes with the -300B shows a reduction in noise under the flight path on takeoff and approach, reduced sideline noise, and reduced footprint area at all noise levels. The airplane will comply with FAR-36 and has the longer term potential of compliance with reduced FAR-36 requirements. These advances are the result of the NASA refan technology development program, as well as agressive noise reduction efforts at The Boeing Company and at Pratt & Whitney Aircraft."

However, in opposition to Boeing's position, it must be emphasized that of the eleven airplanes shown in Figure 18, only the B-727-300B and the BAC-111-700 cannot comply. Therefore, it is not a foregone conclusion that alternative airplanes must be those which can comply only with the 69 FAR 36 curve. It is reasonable to assume that competition will insure the development of major acoustical change airplanes which can comply with any one of the four candidate sets of requirements for current technology airplanes.

Note, at this date, the 727-300 B program is no longer active and the foregoing discussion concerning that airplane is academic. Nevertheless, the 727-300 B illustrates the concept of a major acoustical change and the need for establishing requirements to insure that new airplanes are implemented with current noise control technology to the maximum feasible extent.

(R10) Predicted Noise Levels for New Type Airplanes

Figures 19 (a), (b), and (c) show predicted noise levels for new type design airplanes listed in Tables 6(a) and (b) compared with the mean curves and the two sets of compliance noise level curves representing available and future noise control technology. The data for the thirty three listed airplanes are given in References 133.

The significance of the comparisons shown in Figures 19 is that the data represent predicted noise levels of new types of airplanes and two of the curves represent proposed requirements that must be met after the indicated dates of application. First, airplanes whose type certificates are applied for on or after 1980 and before 1985 would be required to meet 80 FAR 36. Second, airplanes whose type certificates are applied for on or after 1985 would be required to meet 85 FAR 36 which is the estimated noise floor. That is, as perceived at this time, noise levels lower than 85 FAR 36 are not feasible for practical airplanes.

By comparison of the sideline noise levels of the airplanes with the levels represented by the curves, it is seen that sixteen airplanes comply with the mean, eight comply with 80 FAR 36, and three with 85 FAR 36. Similarly for takeoff; twenty airplanes comply with the mean, eleven with 80 FAR 36, and seven with 85 FAR 36. And for approach; ten airplanes comply with the mean, seven with 80 FAR 36, and three with 85 FAR 36. Considering all three measuring points, and exercising the 3/2 decibels tradeoff provision, nine airplanes can comply with the mean, five with 80 FAR 36, and three with 85 FAR 36.

It is interesting to note by comparing Figures 5 and 19, that some of the airplanes proposed as new type designs are predicted to produce noise levels greater than those of existing airplanes of comparable weight. For example, the four engine airplanes listed as new type designs, but with existing type engines (Nos. 13 thru 16) have predicted noise levels that exceed the levels of the B-747 airplanes (powered by the same engines) listed in Table 4. Similarly, the three-engine airplanes listed as new type designs, but with existing type engines (Nos. 9 thru 12), exceed the levels of the DC-10 and L-1011 airplanes listed in Table 4. These proposed new type design airplanes obviously were not considered with full application of current and available noise control technology.

The previous discussion clearly indicates that unless FAR 36 is amended to require new type airplanes to be designed to include the results of noise control RD&D, some manufacturers will continue to be constrained only by the 69 FAR 36 levels. In other words, a voluntary program of noise reduction cannot be counted on to effect significant source noise control. This does not rule out, however, fortuitous noise reductions that result from efficient design practices. This has occured in the past (e.g., high bypass ratio engines) and no doubt will occur in the future. It only points out that noise control and performance are not necessarily counteractive.

An explanation for the apparent noise floor violations (Nos. 7, 18, 26, 27, 28, 29, 30 and 33) is that the sources of the data may have based their predictions on engine noise control technology and overlooked or ignored the airframe noise floor. For example, airplane

No. 7 represents the orginal NASA goal for the "Quiet Engine" which was established before significant studies and tests were conducted on the airframe noise floor concept. It is interesting, however, that NASA has predicted that the propulsive noise floor will not "bottom out" below the nonpropulsive noise floor. Furthermore, it should be pointed out that airplane No. 8 is similar to the Airbus (A-300B), listed as airplane No. 7 in Table 4, which has been certificated for noise in conformance with Annex 16. The takeoff noise level of the Airbus would lie approximately on the curve representing future noise control technology. It may be that the initial model of the Airbus, with its high thrust to weight ratio and with the use of a substantial amount of thrust cutback before reaching the 3.5 nautical mile measuring point, has indeed reached the airframe noise floor during a noise certification test demonstration for takeoff operations.

Another explanation, of course, is that the 85 FAR 36 (future technology) curve is simply too high. More definitive information should be on hand for the next quinquennial review, at which time, the compliance noise levels representing future technology can be adjusted.

(R11) Recommendations for Noise Levels

In view of the previous discussion on noise levels, it is recommended that §C36.5 of FAR 36 be modified as appropriate to include the following requirements for complaince noise levels.

(a) Pre-1969 Technology Airplanes.

The compliance noise levels defined as 69 FAR 36, which are existing requirements applicable to newly produced airplanes of older type designs, are adequate, except for some acoustical changes, and need not be modified.

(b) Current Technology Airplanes.

Compliance noise levels, applicable to new type design airplanes for which an application for a type certificate is made on or after the date this NPRM is issued, shall be chosen from the following four options:

(1) ICAO WP/64 (Figures 3),

(2) FAA WP/39 (Figures 2),

(3) Mean (Figures 5),

(4) Modified Mean (Figures 8).

The above four sets of compliance noise levels are listed in order of overall increasing stringency, although for some portions of the airplane maximum weight range this would not be true. However, there is not a great deal of difference in stringency between any one of the candidates except for applications to general aviation aircraft. Any one of the candidates (or a compromise among them) would effect significant improvement and, therefore, would be an acceptable choice for immediate application to current technology airplanes.

(c) Available Technology Airplanes.

Compliance noise levels, applicable to new type design airplanes for which an application for a type certificate is made on or after 1 January 1980 and before 1985, shall be represented by the set of curves in Figures 16 identified as "available" or 80 FAR 36.

(d) Future Technology Airplanes.

Compliance noise levels, applicable to new type design airplanes for which an application for a type certificate is made on or after 1 January 1985, shall be represented by the set of curves in Figures 16 identified as "future" or "85 FAR 36".

(e) Major Acoustical Change Airplanes.

Compliance noise levels and their effective dates, applicable to airplanes with major acoustical changes to older type designs, shall be equivalent to those prescribed for current technology airplanes.

S. Takeoff Test Conditions (§C36.7 of FAR 36).

§C36.7 of FAR 36 specifies takeoff test conditions relative to (1) the power or thrust which must be maintained to a specific height above airport (HAA), (2) the permitted power or thrust cutback, (3) the airplane speed, and (4) the airplane configuration. Experience as a result of FAA noise certification tests since 1969 has shown that changes should be made to items (1) and (2) above and that additional requirements should be provided.

(S1) Power or Thrust

FAR 36 requires takeoff power or thrust be used from the start of takeoff roll to 1000 feet HAA for two and three engine powered airplanes and to only 700 feet HAA for airplanes powered by four or more engines. The FAA noise certification tests show that it is both practicable and reasonable (as well as safer and less noise polluting) for four engine current technology airplanes to reach 1000 feet HAA over the takeoff measuring point. Therefore, the EPA believes that there is no longer need for such discrimination. Consequently, it is recommended that the alternative height of 700 feet HAA, applicable to airplanes powered by more than three engines, be eliminated. The recommended wording for §C36.7(b), therefore, is as follows:

(b) Takeoff power or thrust must be used from the start of takeoff roll to the point at which a height of at least 1000 feet above the runway is reached.

(S2) Reduction of Power or Thrust

FAR 36 permits a power or thrust cutback to specified limits. The original purpose for such a reduction was to establish a safe operating procedure (and associated noise levels) for minimizing the noise impact on near-downrange noise sensitive communities. However, that particular procedure was never used to any significant extent in normal airline operations. The FAR 36 cutback procedure became little more than a subterfuge to meet the required noise levels for some airplanes that could not otherwise comply.

Several standard takeoff procedures, other than that of FAR 36 but suitable for safe operation of civil turbojet airplanes, are being investigated by the EPA for use, as appropriate, to minimize the noise exposure of noise sensitive communitites. The FAR 36 cutback procedure provides substantial thrust and noise reduction before the takeoff noise measuring point (3.5 nautical miles) is overflown. Other cutback procedures, however, with less thrust reduction may be more effective in reducing the noise impact beyond 3.5 nautical miles, particularly in far-downrange noise sensitive communities and even provide greater overall noise reduction.

The FAR 36 cutback procedure should remain as a compliance option in Takeoff Test Conditions (§C36.7) until takeoff operating procedures are required by regulation for routine line operations. At the very least, the FAR 36 cutback procedure approximates the maximum noise reduction that can be expected close to the airport by safe operating procedures. However, since the FAR 36 cutback procedure is not now used for routine takeoff operations nor anticipated for such use, it has little direct value for analyzing community noise impact and for land use planning. Nevertheless, the FAR 36 cutback procedure will permit noise to be related to thrust and distance which information is valuable for determining community noise impact and for land use planning.

Consequently, it is recommended that the noise levels of airplanes should be measured at the takeoff measuring point with the engines at takeoff power or thrust for the purpose of providing information. If the airplanes can comply with the noise level requirements at takeoff power or thrust, then the cutback procedure would not be necessary. If the airplanes can comply only with the cutback procedure, then additional testing at takeoff power or thrust should be required in order to provide official and reliable information for use in analyzing community noise impact and for land use planning. The recommended wording for §C36.7(c), therefore, is as follows:

(c) Upon reaching the height specified in paragraph (b) of this section, the power or thrust may not be reduced below that power or thrust that will provide level flight with one engine inoperative, or below that power or thrust that will maintain a climb gradient of at least 4 percent, whichever power or thrust is greater. If compliance with the noise levels of §C36.5 is met with power or thrust reduction, additional takeoff tests must be conducted without power or thrust reduction for information purposes.

(S3) Airplane Speed

FAR 36 requires the airplane minimum speed to be V2 + 10 knots which must be attained as soon as practical after liftoff and maintained throughout the takeoff noise test. Experience as a result of FAA noise certification tests since 1969 has shown that this requirement permits too wide a variation in the duration correction inherent in EPNL. Also, for some airplanes, the all engines operating speed is greater than V2 + 10. Therefore, it is recommended that §36.7 (d) be amended to read as follows:

(d) A speed of V2+10 knots or the all-engines-operating speed at 35 feet (for turbine engine powered airplanes) or 50 feet (for reciprocating engine powered airplanes) whichever speed is greater must be attained as soon as practicable after liftoff and must be maintained throughout the takeoff noise test. These tests must be conducted within tolerance speeds of $\pm$ 3 knots and the noise values measured at the test day speeds must be corrected to the acoustic day reference speeds.

(S4) Airplane Configuration

FAR 36 requires a constant takeoff configuration which must be maintained throughout the takeoff noise test except that the landing gear may be retracted. There is no reason to change this requirement at this time. However, if standard takeoff procedures for routine operations become mandatory, this requirement may need revisions in order to be compatible with the configurations used in the standard procedures.

(S5) Horizontal Flight Procedures

If an airplane is relatively quiet, and/or has relatively good climb performance, the airplane noise received at the sideline and takeoff measuring points may be masked by the normal background noise. That is, the signal to noise ratio (S/N) may be too small in one or more of the required one third octave bands for satisfactory identification and analysis of the airplane noise. In this event, a horizontal flyover procedure at 1000 feet HAA should be conducted in lieu of the requirements of §C36.7(b) and (c) of FAR 36. The result usually will be an adequate S/N, thus permitting satisfactory description of the airplane noise. However, for the noise measurements to be meaningful for certification and for community noise impact, they must be related to the reference distance of 3.5 nautical miles from brake release and be corrected for both climb performance and speed.

A measure of the community noise impact caused by an airplane is the population residing on the land contained within the boundary of a specified equal noise level contour (the locus of points on the ground which are exposed to a particular level of noise). The size of the contour area is dependent upon both the noise energy and the performance of the aircraft. The noise energy generated will be constant for a given engine power or thrust setting (such as takeoff or maximum climb) but the noise radiated to the ground also is dependent upon the airline climb path and speed. At a given point on the extended centerline of the runway, the steeper the climb, the higher the airplane, and the lower the noise level. Likewise; the greater the climb speed, the shorter the duration of the noise, and the lower the Effective Perceived Noise Level.

The horizontal flight noise certification test, by itself, will not provide sufficient information to make a judgment on the relationship between airplane climb performance and noise exposure on the ground. Two airplanes with the same engines at the same power setting would be expected to produce about the same noise level over the measuring station at a height of 1000 feet, even though the total weight of one airplane might be substantially greater than the other. However, the higher performance airplane (e.g., greater thrust/weight ratio) would be expected, by virtue of its superior climb capability, to produce smaller contour areas and, hence, less community noise impact.

This deficiency in the horizontal flyover procedure can be remedied by a correction formula with factors relating to airplane performance (both climb and speed) and the reference distance (3.5 nautical miles or 21266 feet). The development of the correction formula for climb performance, applicable to turbojet - engine propelled airplanes, is given in Figure 20. The resulting expression is:

$$C = 60 - 20 \log [(21266 - D35) \sin \alpha + 35] \qquad (13)$$

where

$$\alpha = \text{arcsine} [(R/C) / (VY)] . \qquad (14)$$

The climb correction C is the value in decibels which, when added algebraically to the measured noise level at 1000 feet (horizontal flyover), approximates the noise level at the 3.5 nautical miles (21266 feet) reference distance. The climb angle α in degrees is dependent upon the rate of climb (R/C) in feet per minute corresponding to the airplane climb speed (VY) in feet per minute equivalent to V2 + 10 knots, or the all-engines-operating speed whichever is greater.

The takeoff distance D35 (or D50 for propeller-driven airplanes) in feet is the horizontal projection from brake release to a point on the runway at which the airplane is at a height of 35 feet above the runway. The climb correction formula is based upon the assumption that the angle of climb is relatively small which is appropriate for all FAR 36 airplanes (the error is less than 0.5 dB at 12 degrees).

The climb correction C adjusts the measured noise level under test conditions to the expected noise level at the reference distance (3.5 nm) from start-of-roll. In addition, under test conditions (horizontal flight, maximum thrust at 1000 feet height above the test site) the aircraft may accelerate over the test site at speeds greater than the takeoff climb speed. Therefore, the duration of the sound (a factor to be considered in human subjective reaction to noise and included in EPNL), would be less under the horizontal flight path than under the climb path. In order to make a proper assesment of the noise measured under the simplified test conditions, the noise level corrected for climb performance must be further corrected to account for the change in speed which results in a change in noise duration. The speed correction formula appropriate for this purpose is:

$$S = 10 \log (VH / VY) \tag{15}$$

VH is the speed, averaged for all test flights, at the aircraft position for which the tone corrected perceived noise level is maximum with the aircraft operating at takeoff thrust and in horizontal flight 1000 feet over the measuring point. S is the speed correction in decibels to be added algebraically to the measured noise level. The speed correction S corrects the measured noise level to the EPNL levels that would result from the actual climb speed.

In summary, the resulting performance correction, expressed in dB, which should be added algebraically to the noise levels, expressed in EPNdB, measured 1000 feet below a turbojet airplane in horizontal flight at maximum thrust is:

$$P = C + S \quad \text{(For turbojet airplanes)}$$

$$= 60 - 20 \log [(21266 - D35) \sin\alpha + 35] + 10 \log (VH / VY) \qquad (16)$$

For propeller driven airplanes, the only change in the performance correction P is the takeoff distance included in the climb correction C as follows:

$$P = C + S \quad \text{(For propeller airplanes)}$$

$$= 60 - 20 \log [(21266 - D50) \sin\alpha + 50] + 10 \log (VH / VY) \qquad (17)$$

The takeoff distance D50 in feet is the horizontal projection from brake release to a point on the runway at which the airplane is a height of 50 feet above the runway. All other symbols have been defined previously.

T. Approach Test Conditions (§C36.9 of FAR 36)

§C36.9 of FAR 36 specifies approach test conditions relative to (1) the airplane's configuration, (2) the glide angle, (3) the approach speed, and (4) the power or thrust. Experience as a result of FAA noise certification tests conducted since 1969 has shown that the approach test conditions are satisfactory except for the configuration requirements.

(T1) Airplane Configuration

FAR 36 requires that the airplane's configuration used in showing compliance with the noise levels of §36.5 must be the same as used in showing compliance with the airworthiness requirements. If more than one configuration is certified for airworthiness, the configuration that is most critical from a noise standpoint must be used. There is no longer any purpose for determining the maximum noise levels on approach. On the contrary, it makes sense to require compliance for one flap position less than the maximum landing flap setting certificated for airworthiness. The reason is that some airplanes now conduct normal landing operations at reduced flap setting for both noise reduction and fuel conservation. All airplanes should be encouraged to do so except when safety considerations dictate otherwise. Furthermore, the EPA has proposed the reduced flap setting procedure to the FAA for promulgation as a regulation.

In consideration of the above, the recommended wording for §C36.9(b) is as follows:

(b) The airplane's configuration must be that used in showing compliance with the landing requirements in the airworthiness regulations constituting the type certification basis of the airplane. If more than one flap setting is used in showing compliance with the landing requirements in the airworthiness regulations constituting the type certification basis of the airplane, one flap position less than the maximum certified must be used.

(T2) Glide Angle

FAR 36 requires that the approaches must be conducted with a steady glide angle of 3 $\pm$ 0.5 degrees and must be continued to a normal touchdown with no airframe configuration change. The wording in §C36.9(c) is clear and precise and changes are unnecessary.

(T3) Approach Speed

FAR 36 requires that a steady approach speed of not less than 1.30 Vs + 10 knots must be established and maintained over the approach measuring point. The wording in §C36.9(d) is clear and precise and changes are unnecessary.

(T4) Power or Thrust

FAR 36 requires that all engines must be operating at approximately the same power or thrust. The wording in §C36.9(e) is clear and precise and changes are unnecessary.

6. HEALTH AND WELFARE AND COST CONSIDERATIONS

A. General

Fundamental to EPA's mandate, under the Noise Control Act of 1972, is the objective of attaining and maintaining a noise environment that is consistent with public health and welfare requirements. In striving for this objective, the agency is cognizant of FAA's requirement under Section 7 of the Act to take into account the availability of technology and cost of compliance in arriving at the balance of judgment as to the degree of noise suppression required.

The Noise Control Act of 1972 defines environmental noise as "the intensity, duration, and the character of sounds from all sources". The EPA has chosen the equivalent A-weighted sound pressure level (Leq) as its basic measure for environmental noise (References 1, 4, 8, and 9). There are two time intervals of interest in the use of Leq for noise impact assessment. The smallest interval of interest is one hour usually considered the "design hour" of a day. The primary interval of interest for residential land uses is a twenty four hour period, with a weighting applied to nighttime noise levels to account for the increased sensitivity with the decrease in background noise at night. This twenty-four hour weighted equivalent level is denoted the Day-Night Level (Ldn).

In its report to Congress (Reference 1) the EPA recognized that the direct readily quantifiable effects of noise on public health and welfare are: the potential for producing a permanent loss in hearing acuity, interference with speech communications, and the generation of annoyance. The Levels Document (Reference 9) specifically identified two long-term average levels of cumulative noise exposure as those levels which should not be exceeded in order to protect the public health and welfare with an adequate margin of safety:

- A Day-Night Level (Ldn) no greater than 55 dB, to protect against annoyance (including interference with speech communication) and
- An Equivalent Noise Level (Leq) no greater than 70 dB, to protect against significant adverse effects on hearing.

Although the potential of indirect effects of noise exists, there are not sufficient data to quantify them at this time.

The foregoing effects of noise can adversely influence an exposed person's daily activity schedule and enjoyment. Typical results of the primary adverse effects of noise are:

- The relative attractiveness of real estate is degraded,
- The delivery of public services is disturbed, e.g., interruptions of educational instruction,
- Interpersonal relationships are aggravated,
- Continual or repetitive annoyance is manifested as tension and stress, and
- On the job performance, i.e., productivity, is diminished.

These results demonstrate the insidious nature of noise in a person's or community's physiological, social, and economic well-being.

The underlying concept for noise impact assessment is to express the change in human response expected from the people exposed to the environmental noise exposure being considered. Three steps are involved: (a) definition of initial acoustical environment; (b) definition of final acoustical environment; (c) definition of the relationship between the specified noise environment and the degree of its "impact" in terms of its expected human response.

The first two components of the assessment are entirely site or system specific, relating to either estimates or measurement of the environmental noise before and after the action being considered. The same approach is used, conceptually, for the examination of a house near a proposed road, the entire highway system, or the totality of the nation's airports. The methodology for estimating the noise environment will vary widely with the scope and type of problem, but the concept remains the same.

In contrast to the widely varying methodologies that may be used for estimating the noise environment in each case, the relationships to human response can be quantified by a single methodology for each site or noise producing system considered in terms of the number of people in occupied places exposed to noise of a specified magnitude. This does not mean that individuals exhibit the same susceptibility to noise; they do not. Even groups of people may vary in response depending on previous exposure, age, socio-economic status, political cohesiveness and other social variables. In the aggregate, however, for residential locations the average response of groups of people is quite stably related to cumulative noise exposure as expressed in a measure such as the average yearly Ldn. The response considered is the general adverse reaction of people to noise which consists of a combination of such factors as speech interference, sleep interference, desire for a tranquil environment, and the ability to use telephones, radio, or TV satisfactorily. The measure of this response is related to the percentage of people in a population that would be expected to indicate a high annoyance to living in a noise environment of a specified level of exposure.

The foregoing considerations permit the specification of numerical values for noise levels in spaces devoted to various types of uses which, if not exceeded, would provide entirely acceptable acoustical environments. Thus, if those values are not exceeded, it could be assumed that there would be no impact from environmental noise.

Specific noise criteria level values for those land uses or occupied spaces generally encountered in noise impact assessments are provided in Table 7. Each of the levels provided in the table is specified as an outdoor noise level, even though the use of many of the spaces is usually indoors. The noise reduction for typical building construction has been used to arrive at an outdoor noise level that would provide an acceptable indoor environment, since in any general environmental impact study it is only an outdoor noise level that can be predicted in any practical application. Also, it has been assumed in the table that industrial and commercial applications are zero impacted at any environmental noise level.

Reduction of the noisiness of the environment will reduce the magnitude of adverse effects such as those listed above. However, the costs of these adverse effects are not well defined so that the benefits of noise reduction cannot be readily related to compatible cost reductions. For example, Figure 21, taken from References 134 and 135, is an estimate of the number of people on a national basis impacted by aircraft noise. Population is presented as a function of Ldn and Noise Exposure Forecast (NEF) but there is no accurate quantification of the relative reduction in costs that would accrue in removing one person from an Ldn 80 environment vis-a-vis removing two persons from an Ldn 70 environment. That is, sufficient research to quantify the cost benefits of noise reduction has not been performed to date. Consequently, as in many environmental situations, not having quantitative estimates of the benefits of noise reduction precludes analysis of the amount of environmental noise reduction that is justified on a cost-benefit basis; therefore, the subsequent analyses will use a cost-effectiveness framework.

A cost-effectiveness analysis can, however, yield valuable information on the merits of the noise control options. To begin with, it is necessary to consider the reduction in noise levels and the corresponding reduction in land areas exposed to specific noise levels.

Protection to the public health and welfare from aircraft noise can be realized by combinations of reducing source noise and protecting noise sensitive receivers. Reduction of noise can be accomplished by replacing noisy aircraft with less noisy types, retrofitting existing aircraft with source noise abatement hardware, implementing noise abatement takeoff and landing procedures, and exercising airport operational control such as preferential runways, restrictions on flight frequencies, etc. Protection of noise sensitive receivers can be accomplished through the soundproofing of residential and other sensitive structures or through the relocation of existing incompatible land uses.

The technological practicability for the reduction of noise by source and flight procedures control is limited. It should be recognized also, that there exists a limit to the effectiveness of soundproofing. For those receivers exposed to noise which cannot be effectively reduced to compatible levels by soundproofing, the only remaining alternative is relocation. The technological limitations of soundproofing and the estimated costs are discussed in Reference 5.

The cost of achieving any given Ldn is defined as being the cumulative costs of implementing noise source and flight procedures control, airport restrictions, and the resource requirements for soundproofing or relocating those noise sensitive receivers which remain after the other options have been employed. The economic problem to be solved is what combinations of these options result in the most efficient or cost-effective, approach to realize several values of Ldn (e.g., 80, 70, 60) around the nation's airports.

To implement a noise controlled airplane or modified airplane into the existing fleet requires time to demonstrate acoustical and flight performance, to certify the aircraft for safety, and to fabricate and install production kits. The time element plays an important role in the dynamics of noise level achievement in that the total costs of a noise control program, the fleet mix, levels of operations, and urban growth vary with time. As an example, by the 1985 time period, fleet noise levels are expected to be lower than those produced by today's fleet because not as many, if any, pure turbojet-powered aircraft will be operating in the fleet and the capacity represented by these aircraft, and all other retired aircraft, will have been replaced by less noisy current technology aircraft. Lower fleet noise levels translate into reductions in the areas of Ldn contours around airports which in turn imply smaller impacted populations, if and only if, land use development around airports does not result in increased population densities surrounding the airport.

B. Indicators of Noise Impact

Two single one-way runway airports were chosen to be indicators of the noise impact resulting from the implementation of the various options for compliance noise levels. The first runway pertains to large air-carrier airports and the second to general aviation airports as shown in Figure 22. The air-carrier airport is represented by a runway 15,000 ft in length enclosed by an imaginary rectangle whose dimensions are 27,000 x 3,000 ft(2.91 sq mi). The general aviation airport is represented by a runway 6,000 ft in length enclosed by an imaginary rectangle whose dimensions are 18,000 x 3,000 ft(1.94 sq mi). These dimensions were chosen to be compatible with the FAR 36 measuring points except that the takeoff point for the general aviation airport was reduced from 3.5 nautical miles to 2.0 nautical miles to provide symmetry and to be more representative of the smaller land areas characteristic of those airports.

The rectangles enclosing the airports can be considered as indicators of land areas that, typically, suffer substantial noise impact. Land areas which are noise impacted by aircraft operations should be owned or controlled by airport authorities for airport functional purposes; or the land should be used and can reasonably be expected to continue to be used in a way which is compatible with the noise levels to which it is exposed; or the development rights of such land should be purchased such that only development compatible with the airport noise levels is allowed.

It is generally agreed that a Ldn level of 75 dB is an unacceptable exposure level for people in normally constructed homes. A Ldn level of 65 dB is a reasonable objective for airport neighborhood communities because present limited data indicate that, at some airports, a Ldn contribution of noise from aircraft of less than 65 dB is difficult to distinguish from other ambient noise, given the environmental noise levels (other than from aircraft) around those airports. However, as indicated in the Levels Document, effects from noise occur at Ldn levels below 65 dB and further analysis is needed in the future to refine further practical objectives for airport noise abatement.

The indicator rectangles serve the purpose of providing a standard fence within which the effectiveness of the compliance noise level options may be compared in a meaningful and consistent manner. The particular dimensions of the rectangles are significant because they are compatible with the FAR 36 measuring points. Thus, the voluminous amount of noise data, such as contained in Tables 3, can be utilized directly without the need for lengthy computations. Furthermore, the rectangular dimensions are large enough to enclose meaningful noise exposure contours and small enough to implement noise control through compatible land use without experiencing unreasonable costs.

Many airports, of course, have more than one runway with mixed directional operations and a single one-way runway airports may not be a realistic representation of those airports. Nevertheless, for airports with more than one runway, appropriate rectangles could be superposed on each of the runways with the composite perimeter indicative of a standard fence.

Figures 23(a) through (e) permit comparisons to be made of the effectiveness of the eight compliance noise levels in terms of specific Ldn contours lying within the rectangle enclosing the air-carrier runway. For example, Figure 23(a) shows that, for 420 takeoffs and landings each per day of a mix of aircraft containing 33.3 percent 4-engine aircraft, if all aircraft complied with the 69 FAR 36 levels, the Ldn 80 contour would lie within the rectangle. If all aircraft complied with the future levels, the Ldn 70 contour would lie within the rectangle. On the other hand, for the same number of operations per day of a mix of aircraft containing no 4-engine aircraft, if all aircraft complied with the 69 FAR 36 levels, the Ldn 78 contour would lie within the rectangle. And, if all aircraft complied with the future levels, the Ldn 67 contour would lie within the rectangle.

Figures 24(a) through (d) permit comparisons of the effectiveness of the eight compliance noise levels to be made for cases of constant percentage aircraft mix and variable operations per day. For example, Figure 24(a) shows that if all aircraft complied with the levels of 69 FAR 36, 441 takeoffs and landings each per day would result in the Ldn 80 contour lying within the rectangle. On the other hand, for the Ldn 55 contour to lie within the rectangle, all aircraft would have to comply with the future levels and the takeoff and landing operations each per day would have to be reduced to 14.

Figures 25 (a) through (e) permit similar comparisons to the foregoing to be made for general aviation aircraft. For example, Figure 25(a) shows that if all aircraft complied with the levels of 69 FAR 36, 400 takeoffs and landings each per day would result in the

Ldn 75 contour lying within the rectangle. On the other hand, for the Ldn 55 contour to lie within the rectangle, the takeoff and landing operations per day would have to be reduced to 4. If, however, all aircraft could comply with the future levels, the number of operations per day would not have to suffer as much of a reduction in order for the Ldn contour to lie within the rectangle. Slightly less than 127 takeoffs and landings each per day would achieve that result.

Table 8 summarizes the relationships between the number of operations per day and the noise exposure contour levels that would lie within the rectangles, for both air carrier and general aviation airports, resulting from the implementation of each of the eight sets of compliance noise levels. In regard to air carrier airports, Table 8(a) shows that for 420 takeoffs and landings, no proposed compliance noise levels would permit the Ldn 65 contour to lie within the rectangle. In other words, the Ldn 65 contour would lie outside the rectangle and more than 3 square miles would have to be directed to noise compatible land use. On the other hand, Table 8 (b) shows that compliance with the future technology noise levels would result in the Ldn 65 contour lying within the indicator rectangle when the number of operations has been reduced from 441 to 141. For most air carrier airport runways, 441 takeoff and landing operations each per day are too large, while 141 or less are realistic. Certainly having the Ldn 70 and Ldn 65 contours lying within three square miles, due to 441 and 141 operations, respectively, are noteworthy achievements especially since that accomplishment would result exclusively from source noise control. Additional noise abatement for the same number of operations can be achieved by implementing noise abatement approach and departure procedures.

In regard to general aviation airports, Table 8 (c) shows that compliance with the available and future technology noise levels would result in the Ldn 65 contours lying within the indicator rectangle for all numbers of operations listed. Furthermore, for future technology compliance, the Ldn 55 contour would almost lie within the indicator rectangle when the number of operations per day has been reduced from 400 to 127. For most general aviation airport runways, 127 takeoff and landing operations each per day for turbojet powered airplanes and large propeller driven airplanes are more realistic than 400.

For the case of general aviation airports, most of which are sited in suburban or rural locations, the Ldn 55 goal is not too stringent. It should be understood that while the airport neighborhood population is less dense for general aviation airports compared with large air-carrier airports, there are many more of the former and their neighbors are exposed, in general, to less ambient noise and, therefore, expect less noise intrusion.

C. Costs

It is difficult to identify the costs, if any, to the aircraft manufacturers resulting from regulatory actions such as the proposed amendments to FAR 36. Nevertheless, it should be expected that the manufacturers' position will be that substantial increased costs will be incurred with the extent depending upon the particular amendment. The fact that such claims may be made does not mean they are valid. Not only may the estimated costs be overly conservative but they may not be properly counter balanced by the benefits that may accrue.

For example, the compliance noise levels representing current and available technology are capable of being met by many aircraft being produced today. The industry may claim, however, that if noise was of no consideration, those airplanes could be produced and operated at less cost. The weakness in this argument is that, to some extent the lower noise levels of those quieter airplanes coincide with improved performance. It is a well known fact that noise represents wasted energy and properly designed noise control can direct some or all of that energy to performance. The problems, of course, are to determine whether the wasted energy is of sufficient magnitude to be worth recovering and the recovery costs.

In addition, there is another aspect that is somewhat intangible and difficult to quantify. Since noise represents a small percent of the total energy, until comparatively recently it has been considered by the aircraft and engine designers to be a second order effect in optimizing performance and, therefore, was neglected. As noise became important, and techniques were developed for its abatement and control, the designers found that there were benefits beyond those that could be attributed to the relatively small energy transfer of noise to performance. In other words, there was a fallout of performance improvement resulting from the increased knowledge of aircraft and engine design which can be attributed to the requirements for noise control. This phenomenon is a recent development which should become more effective with time. The effectiveness will depend upon the extent of the pressures (requirements) for noise control up to the point where the noise floor is conclusively identified.

The costs of noise control by compatible land use are very high and, in general, are the least cost-effective method of all. Those costs, therefore, will be minimized when the control of aircraft noise at the source results in Ldn contours lying within the indicator rectangles that are as low in level as can be accomplished by safe, technologically practicable, and economically reasonable techniques.

In regard to the amendments related to noise measurement and evaluation, the costs identified with the closing of loopholes should be dismissed as irrelevant. Other possible costs related to the improvement of procedures and techniques may be counter balanced by the benefits of simplification and repeatibility. In any event, they are difficult to quantify and may be negligible.

7. CONCLUSIONS AND RECOMMENDATIONS

Source noise control is the application of basic design principles or special hardware to the engine/airframe combination which will minimize the generation and radiation of noise. The technology of source noise control is time-dependent in the sense that it is based upon the results of past, present, and future programs of research, development, and demonstration (RD&D) which can be classified as (1) current, (2) available, or (3) future noise control technology. The applications of source noise control should be directed to the following classifications of aircraft; (1)existing, (2) new production of older type designs, (3) new production with acoustical changes to older type designs, and (4) new production of new type designs.

The capability exists today for producing new airplanes that have significantly lower noise levels than those required by the existing FAR 36 regulations (69 FAR 36). Furthermore, noise control technology is sufficiently advanced such that technologically practicable and economically reasonable compliance noise levels can be proposed to be effective at time periods five to ten years in the future. The fact that this capability exists, however, does not mean that it will be implemented. Some motivation is necessary to insure that the aviation community will use the technology and to continue to develop new technology for future use. Regulations can be an effective technique for exploiting noise control technology and, if properly constructed and implemented, can provide the necessary incentive to insure that continuing effort is directed to technological advancements.

FAR 36, which is a type certification regulation applicable to certain kinds of airplanes designated as types, has the following three purposes:

(1) to provide requirements which will influence the design of aircraft to include implementation of source noise control technology to the maximum extent feasible,

(2) the setting of standards and recommended practices for the acquisition and reduction of aircraft noise and flight performance data, and

(3) to provide meaningful noise levels for specific types of aircraft which will be useful in predicting the noise impact in airport neighborhood communities.

Since the promulgation of FAR 36 in 1969, noise control technology has advanced, noise measurement and analysis equipment has improved, and noise certification experience has identified significant weaknesses in the original requirements. The objectives of proposed modifications (or amendments) to FAR 36, therefore, are to strengthen the foregoing purposes in accordance with increased technological capability.

The recommendations for the proposed modifications are very comprehensive and, as a consequence, are provided as supplements to the discussions in the appropriate portions of this project report. Detailed recommendations, therefore, will not be presented here. However, it is recommended that two separate NPRMs be proposed, which for simplicity can be denoted as NPRM(A) and NPRM(B). The former would provide ten amendments pertaining principally to Appendix C of FAR 36 and the latter to fourteen amendments pertaining principally to Appendixes A and B of FAR 36.

The ten amendments recommended for inclusion in NPRM(A) are summarized as follows:

(1) Amendments are applicable to propeller driven large airplanes (maximum weight greater than 12,500 lb),

(2) Acoustical and major acoustical change approvals are included (preamble only),

(3) Approved equivalent procedures may be used,

(4) Sideline measuring point for airplanes with more than three engines must be 0.25 nautical mile.

(5) Noise Levels

- Available Technology effective on 1 January 1980
- Future " " " 1 January 1985

(6) Thrust reduction height for airplanes with more than three engines must not be less than 1000 feet above the runway,

(7) If compliance is met with thrust reduction, additional tests must be conducted without thrust reduction and the noise levels reported for information purposes,

(8) The flight demonstration tests must be conducted at a speed of V2 + 10 knots or the all engines operating speed at 35 feet for turbine engine powered airplanes (or 50 feet for reciprocating engine powered airplanes) whichever speed is greater, within a tolerance of $\pm$ 3 knots.

(9) If signal to noise ratios are too small for satisfactory identifi-

cation and analysis of the airplane noise, a specified horizontal flyover procedure must be conducted, and

(10) If more than one flap setting is used to show compliance with the landing requirements for airworthiness, one flap position less than the maximum must be used for noise certification.

The fourteen amendments recommended for inclusion in NPRM(B) are summarized as follows:

(1) Microphone ground plane (terrain surrounding mircophone specified to be highly reflective),

(2) Adequate clear space (larger viewing angle to reduce possibility of interference with noise measurements),

(3) Temperature and humidity (weather test conditions modified to eliminate ambiguities and prevent erroneous results),

(4) Aircraft position data (tracking requirements for aircraft flight path modified to be more practical and less costly),

(5) Tape recorder (specifications provided),

(6) Microphone (specifications updated),

(7) Pre-emphasis/de-emphasis (specifications updated),

(8) Calibration Procedures (specifications updated, expanded and reorganized),

(9) Windscreen (specifications provided),

(10) Analysis equipment (specifications updated and expanded),

(11) Reporting data (requirements clarified and expanded),

(12) Atmospheric attenuation of sound (updated to include use of current SAE practice and obsolete method deleted),

(13) Detailed correction procedures (updated to include corrections

for test versus reference airspeed and thrust), and

(14) Noise evaluation (updated to include use of current SAE/ANSI practices and standards).

Furthermore, it is recommended that FAR 36 be reviewed every five years or oftener. Appropriate sections of FAR 36 should be updated where feasible to reflect the technology options and measurement standards, practices, and procedures that are practicable and appropriate for the aircraft types at that time. Consideration should be given at each quinquennial review to the inclusion of the benefits of previous experience in noise certification and on such matters as whether the noise control technology is sufficiently advanced to justify retrofitting operational aircraft and requiring newly produced aircraft of older type designs to comply with more stringent noise levels.

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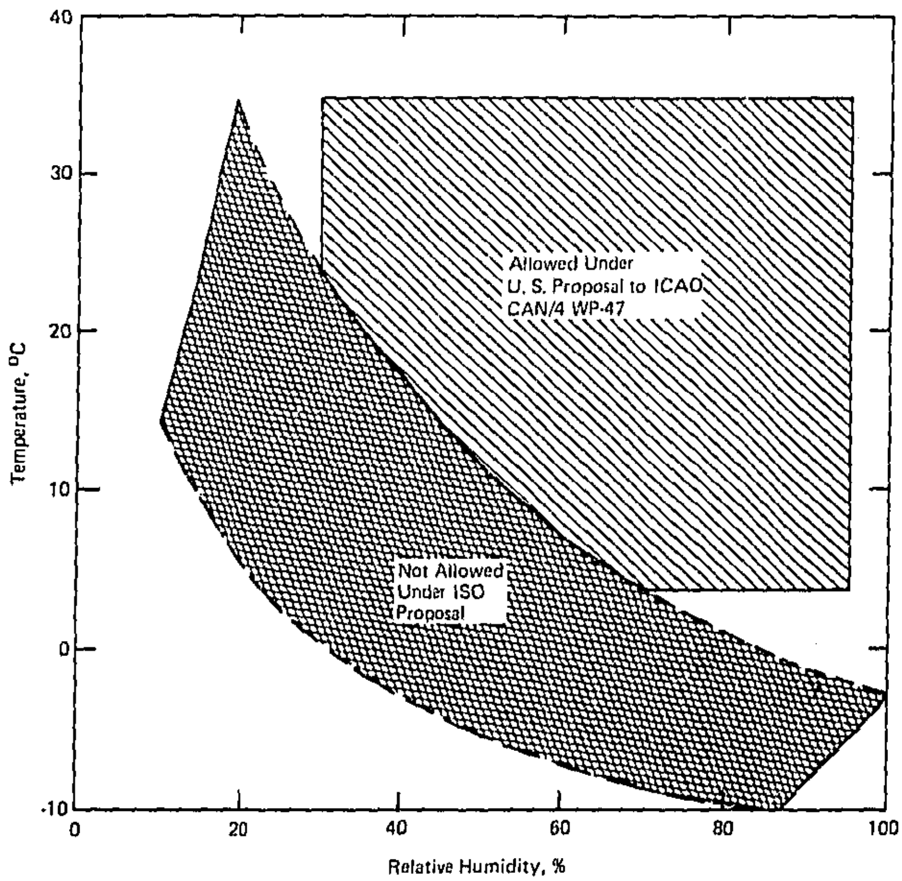


FIGURE 1. COMPARISON OF ISO AND ICAO PROPOSALS FOR TEMPERATURE AND RELATIVE HUMIDITY TEST CONDITIONS.

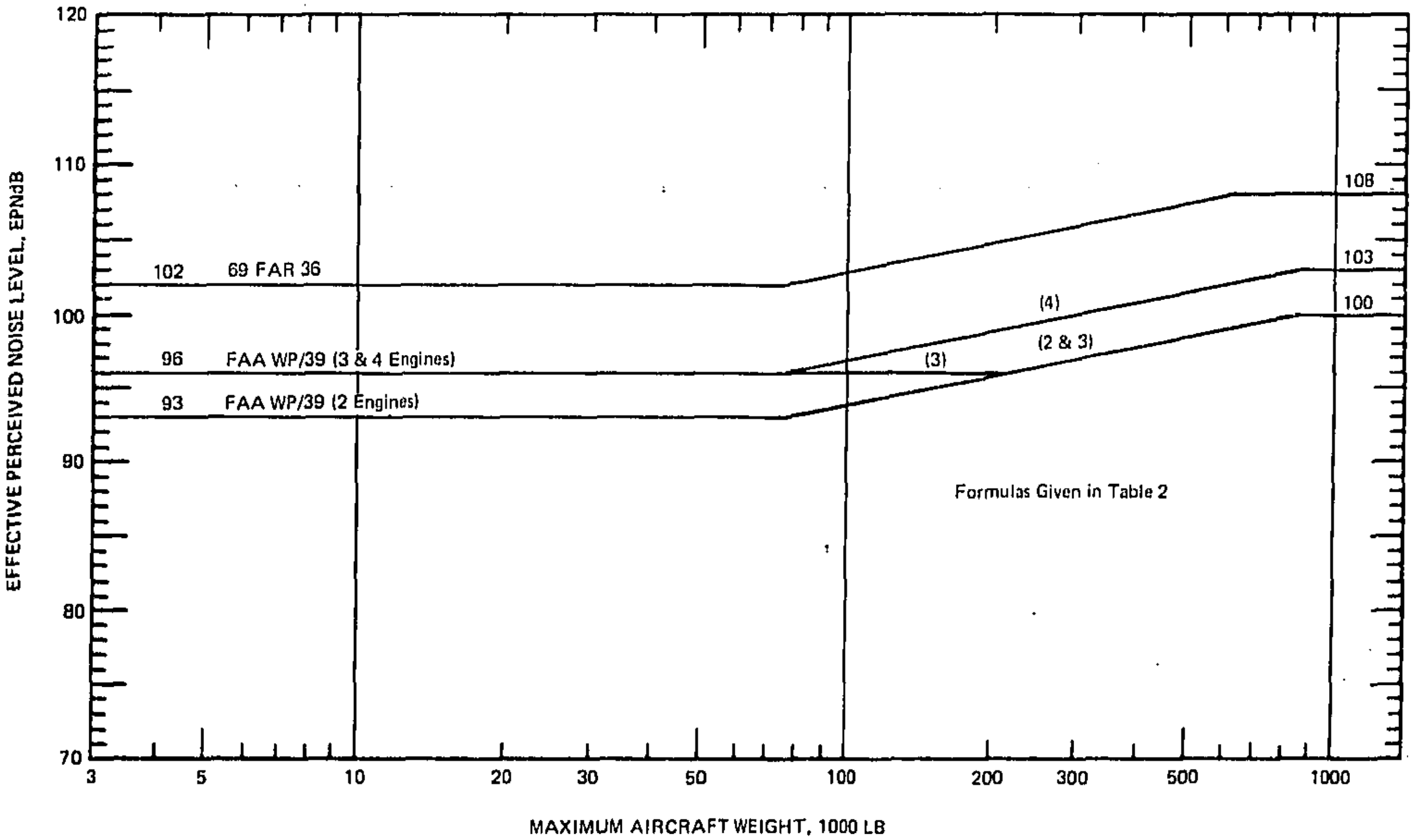


FIGURE 2. COMPLIANCE NOISE LEVELS PROPOSED BY FAA.
(a) SIDELINE AT 0.35 NAUTICAL MILE (463 METERS).

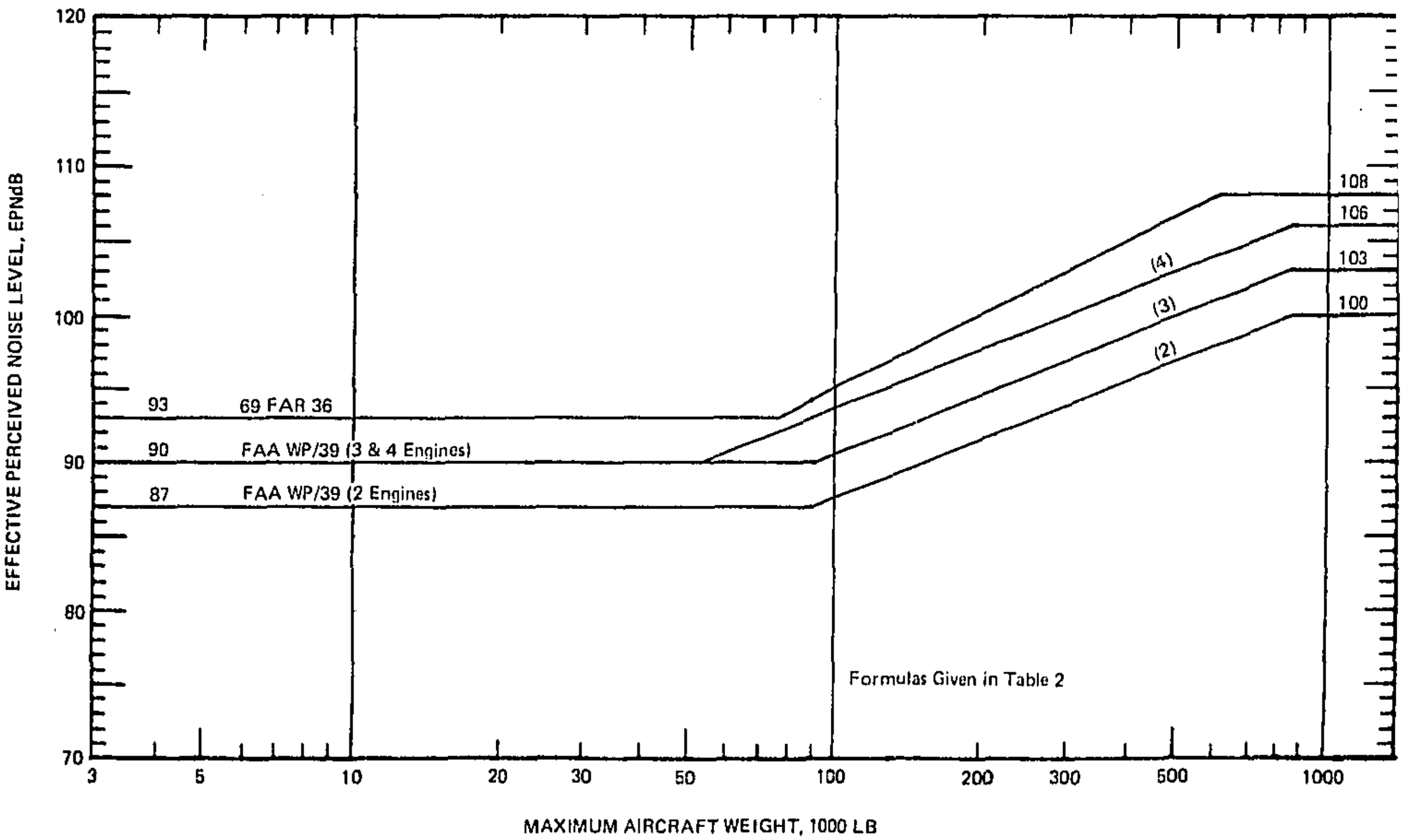


FIGURE 2. COMPLIANCE NOISE LEVELS PROPOSED BY FAA.
(b) TAKEOFF AT 3.5 NAUTICAL MILES (6,482 METERS).

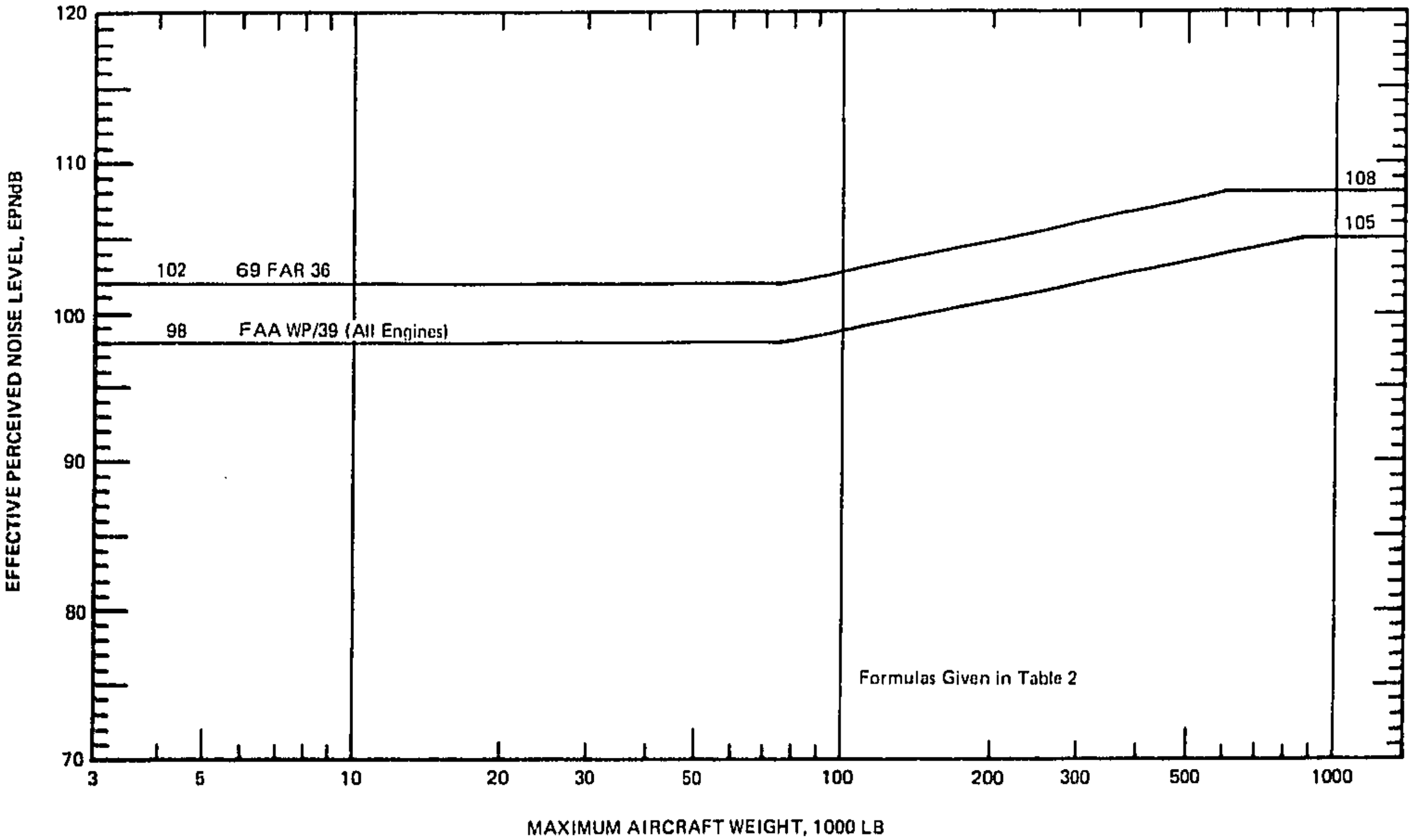


FIGURE 2. COMPLIANCE NOISE LEVELS PROPOSED BY FAA.
(c) APPROACH AT 1.0 NAUTICAL MILE (1,852 METERS).

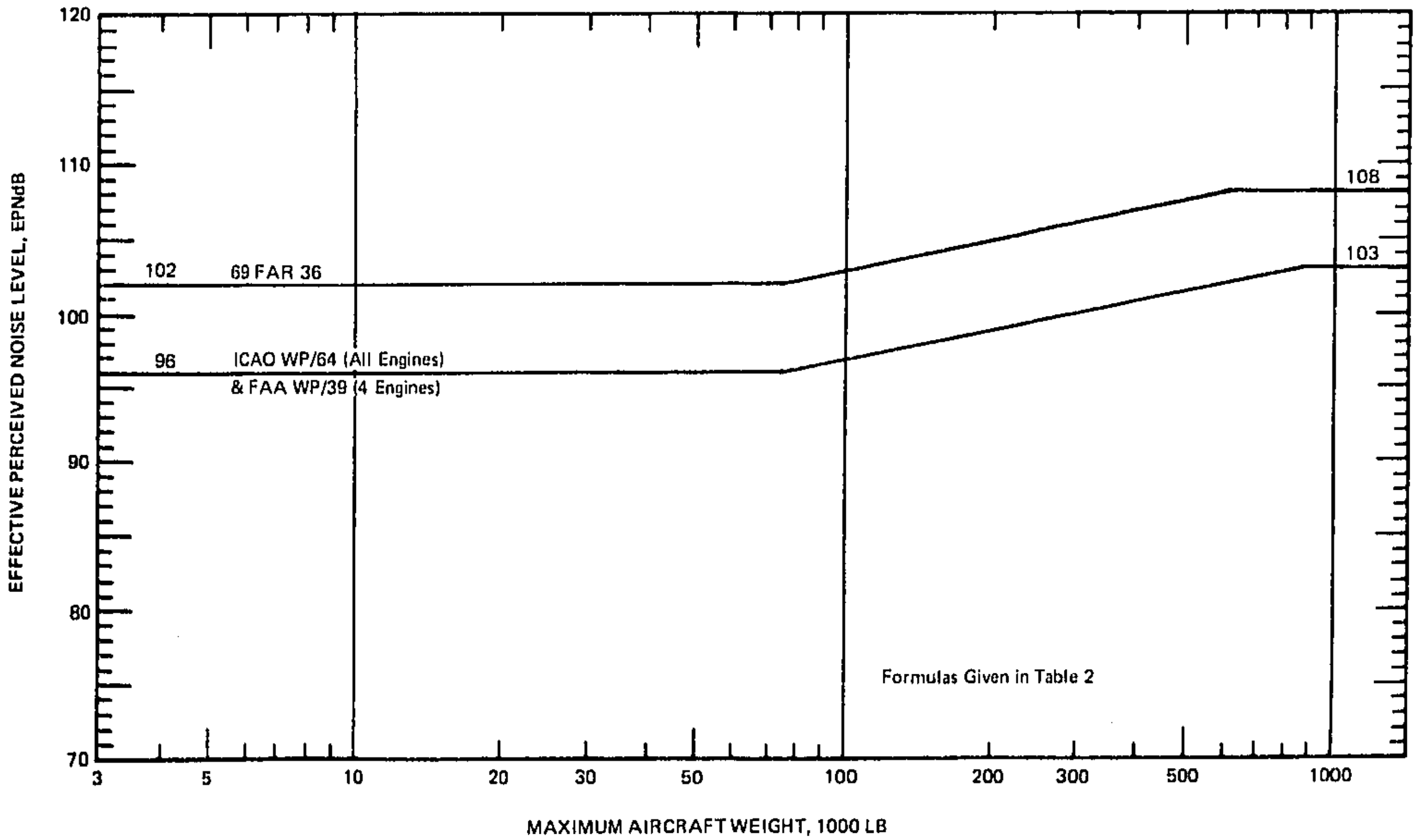


FIGURE 3. COMPLIANCE NOISE LEVELS PROPOSED BY ICAO.
(a) SIDELINE AT 450 METERS (0.24 NAUTICAL MILE).

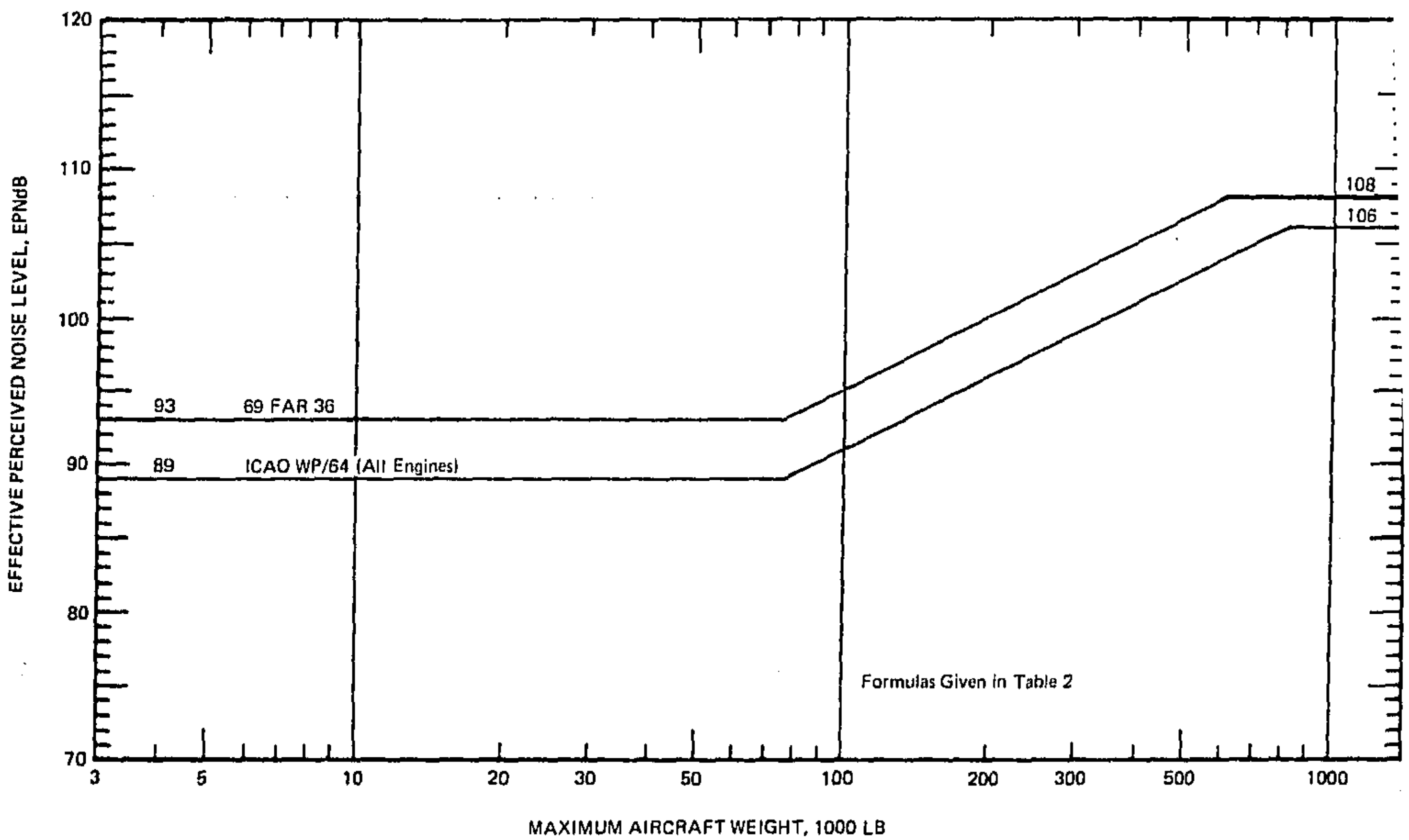


FIGURE 3. COMPLIANCE NOISE LEVELS PROPOSED BY ICAO.
(b) TAKEOFF AT 6,500 METERS (3.51 NAUTICAL MILES).

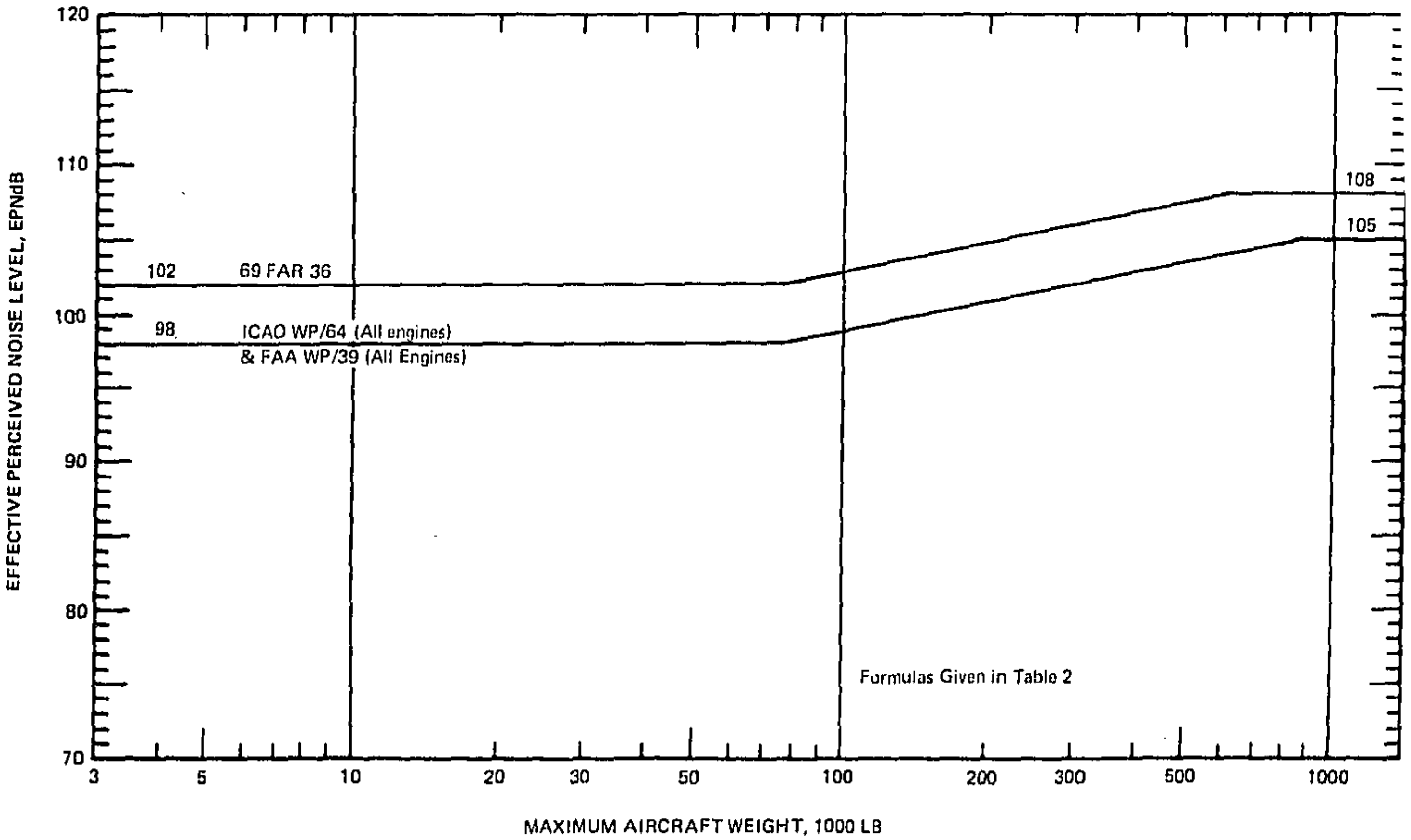


FIGURE 3. COMPLIANCE NOISE LEVELS PROPOSED BY ICAO.
(c) APPROACH AT 2,000 METERS (1.08 NAUTICAL MILES).

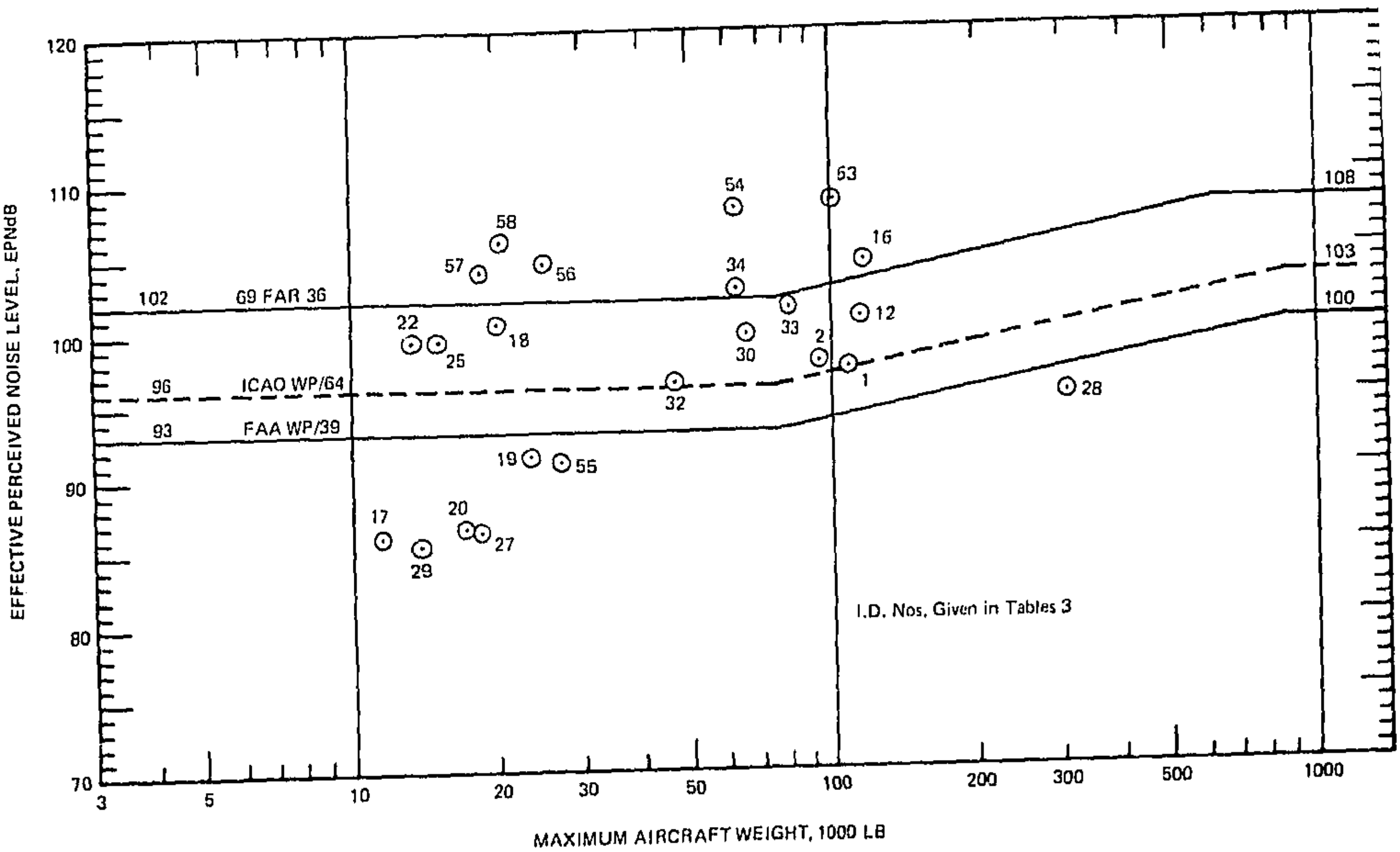


FIGURE 4. AIRPLANE NOISE LEVELS COMPARED TO FAA AND ICAO RECOMMENDATIONS.
(a) SIDELINE (2 ENGINES) AT 0.25 NAUTICAL MILES (463 METERS).

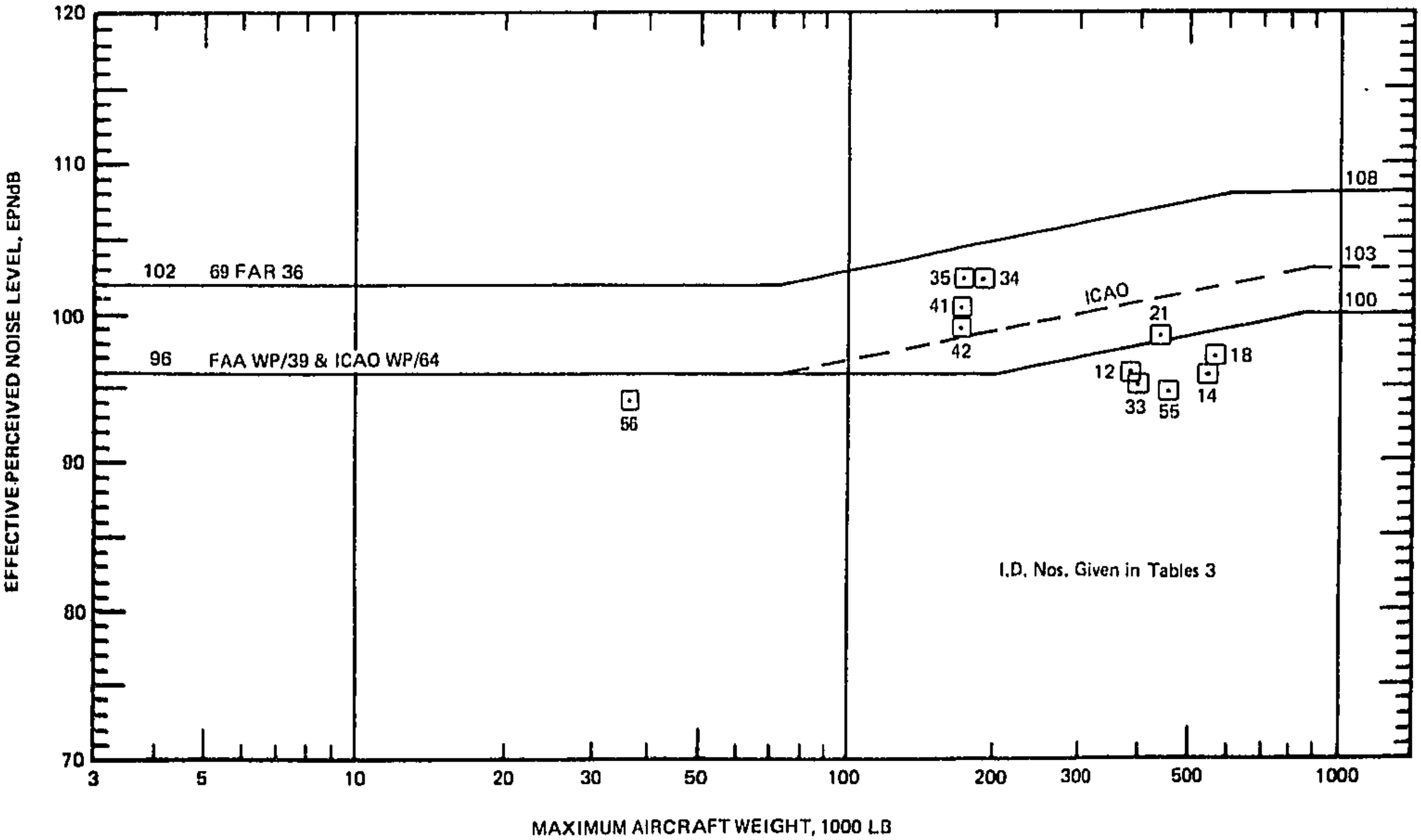


FIGURE 4. AIRPLANE NOISE LEVELS COMPARED TO FAA AND ICAO RECOMMENDATIONS.
(b) SIDELINE (3 ENGINES) AT 0.25 NAUTICAL MILE (463 METERS).

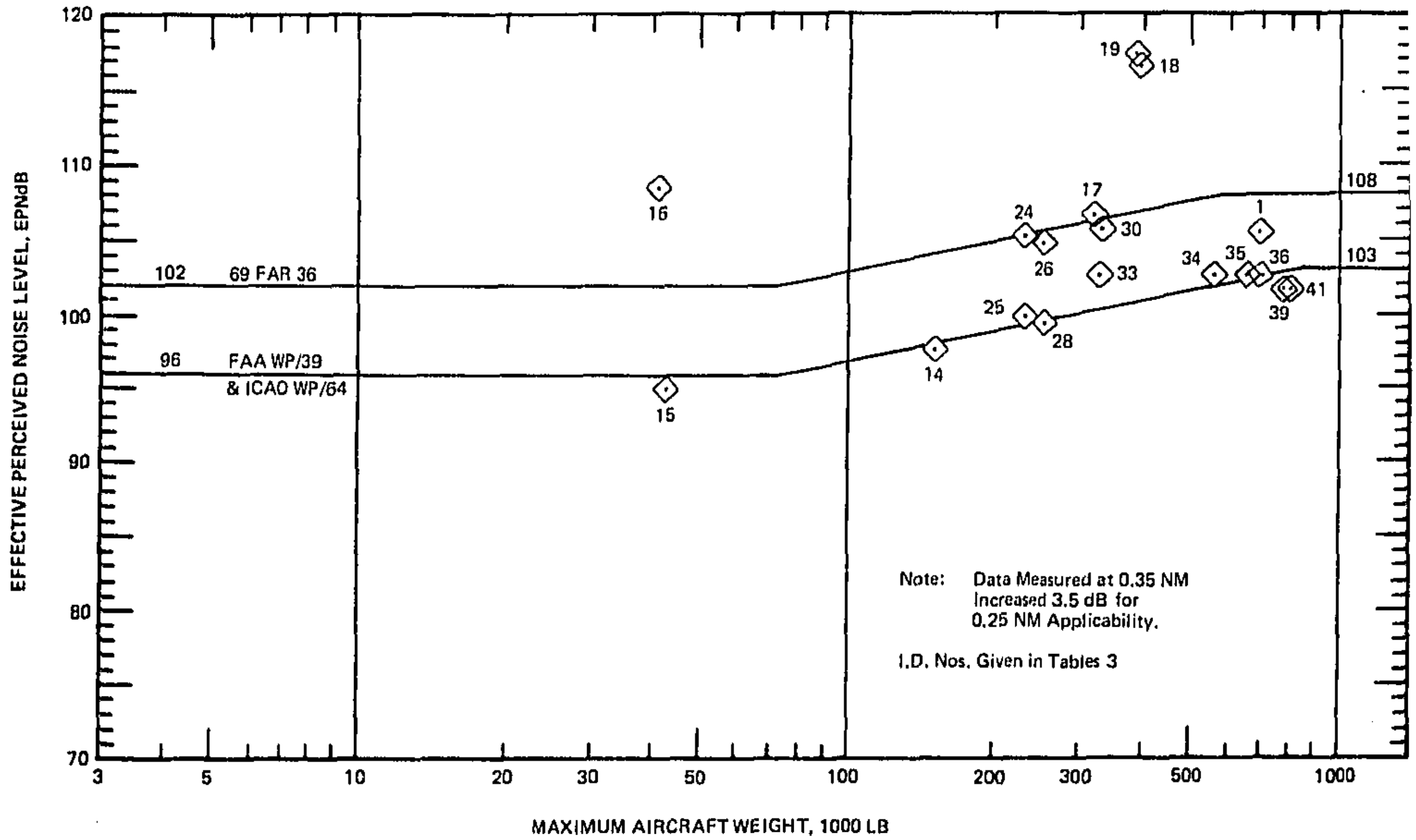


FIGURE 4. AIRPLANE NOISE LEVELS COMPARED TO FAA AND ICAO RECOMMENDATIONS.
(c) SIDELINE (4 ENGINES) AT 0.25 NAUTICAL MILE (463 METERS).

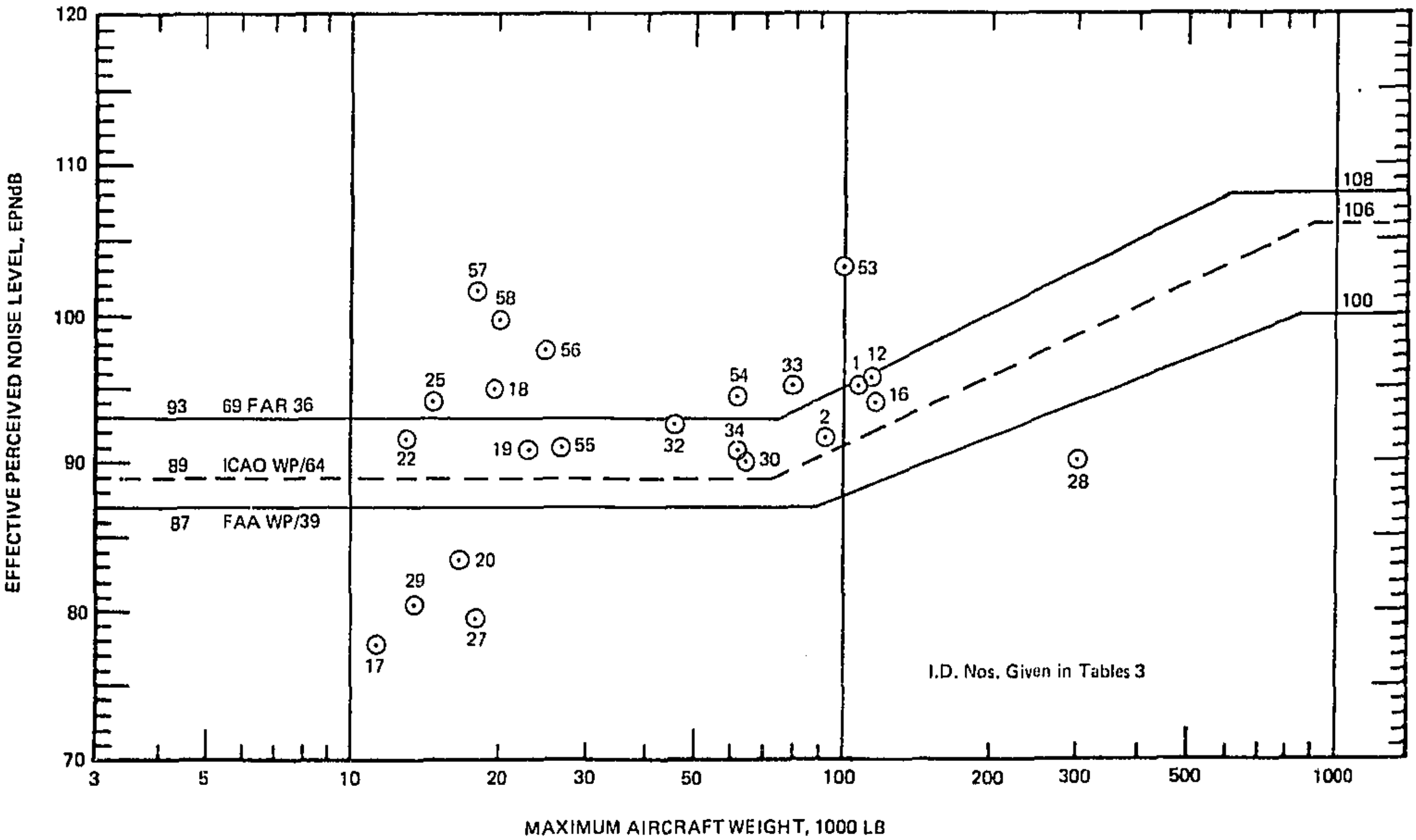


FIGURE 4. AIRPLANE NOISE LEVELS COMPARED TO FAA AND ICAO RECOMMENDATIONS.
(d) TAKEOFF (2 ENGINES) AT 3.5 NAUTICAL MILES (6,482 METERS).

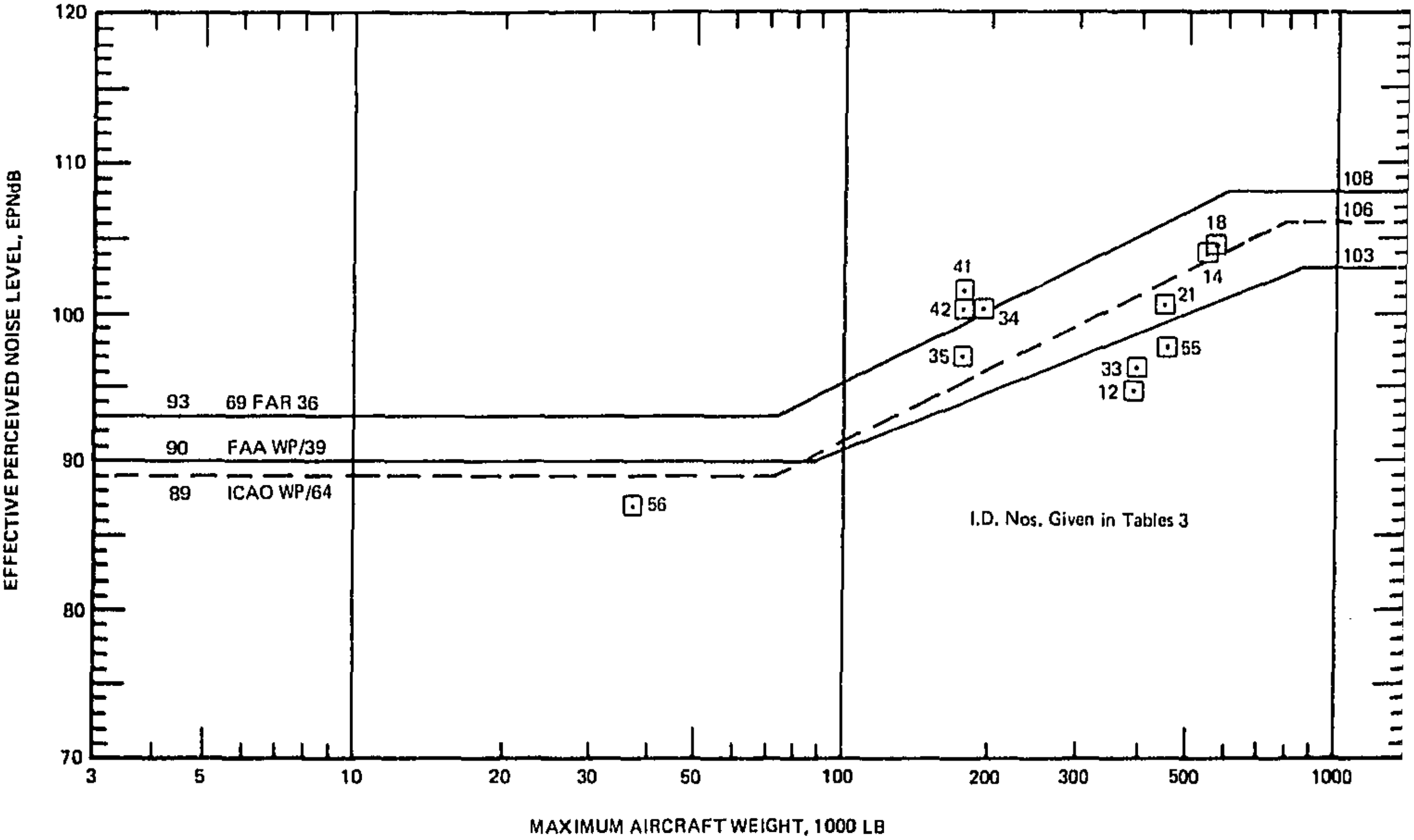


FIGURE 4. AIRPLANE NOISE LEVELS COMPARED TO FAA AND ICAO RECOMMENDATIONS.
(e) TAKEOFF (3 ENGINES) AT 3.5 NAUTICAL MILES (6,482 METERS).

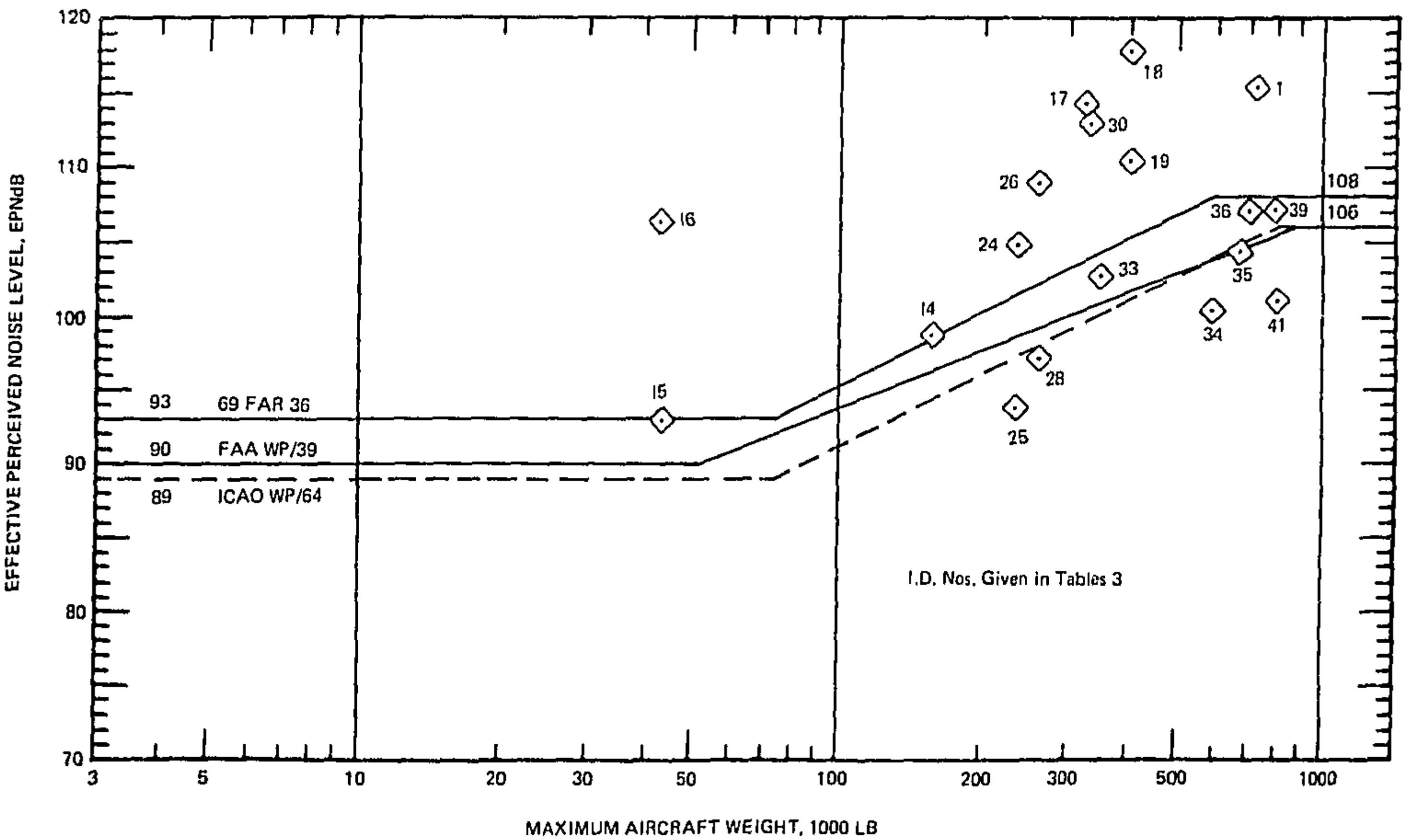


FIGURE 4. AIRPLANE NOISE LEVELS COMPARED TO FAA AND ICAO RECOMMENDATIONS
(f) TAKEOFF (4 ENGINES) AT 3.5 NAUTICAL MILES (6,482 METERS).

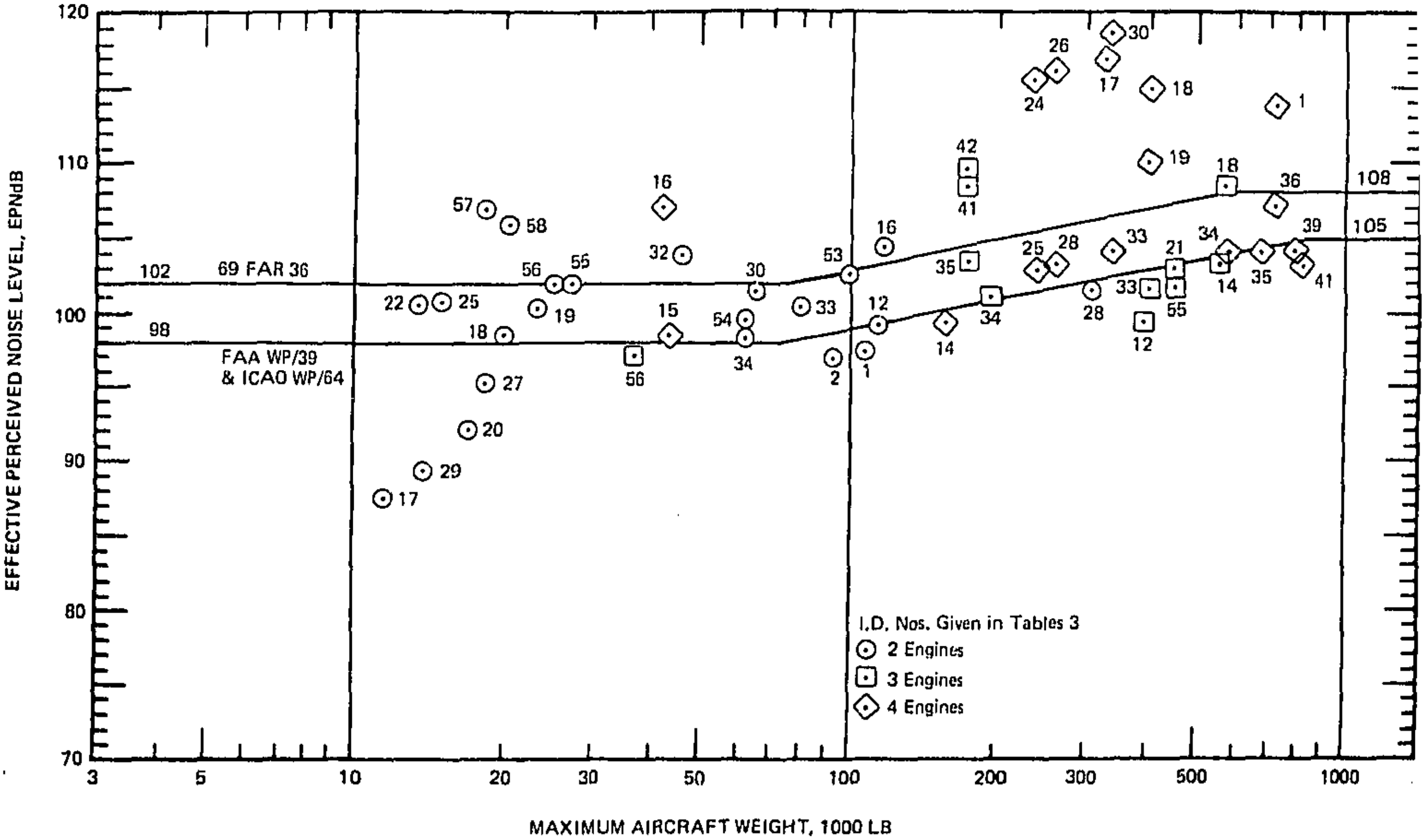


FIGURE 4. AIRPLANE NOISE LEVELS COMPARED TO FAA AND ICAO RECOMMENDATIONS.
(g) APPROACH (2, 3, and 4 ENGINES) AT 1.0 NAUTICAL MILE (1,852 METERS).

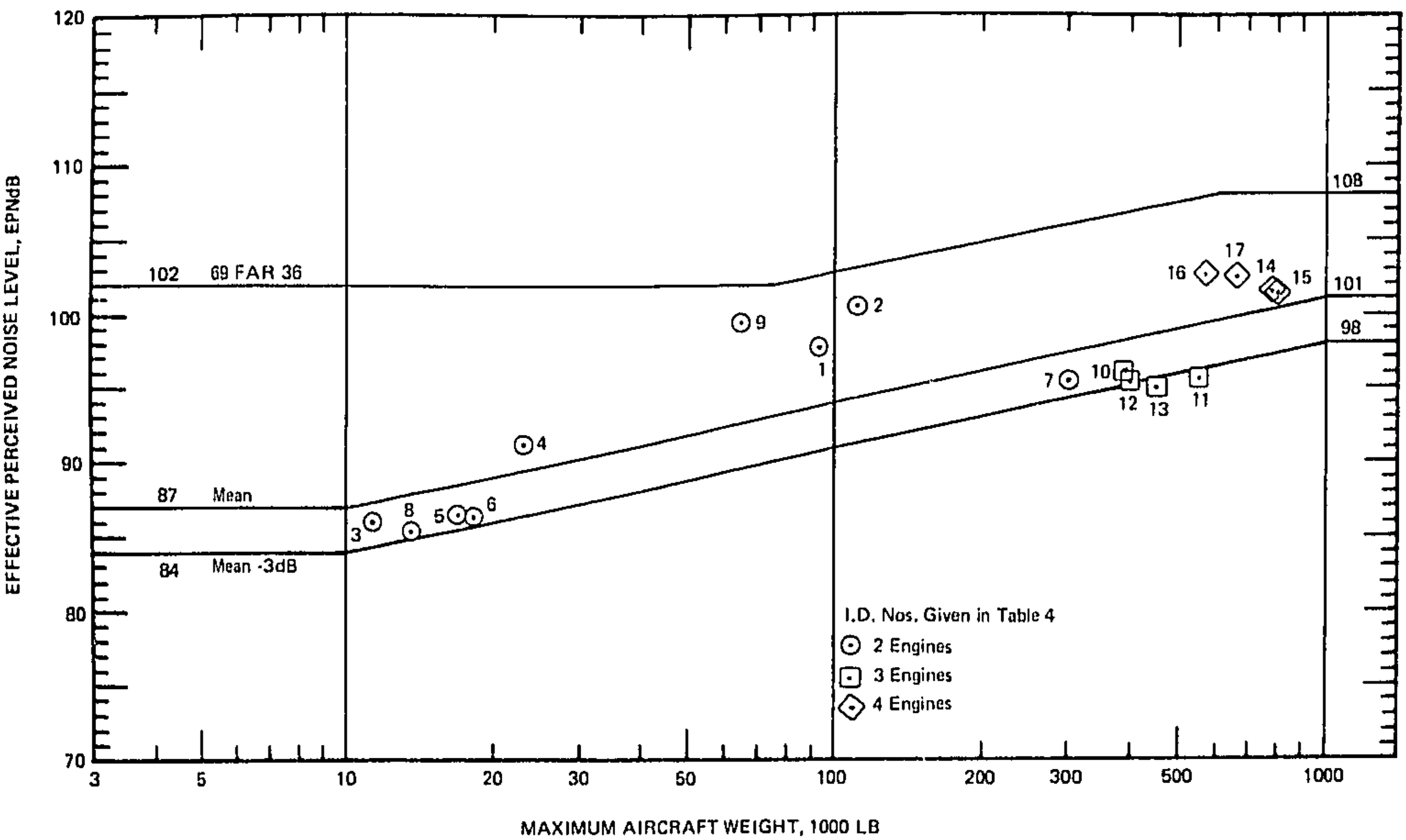


FIGURE 5. NOISE LEVELS VS WEIGHT FOR CURRENT TECHNOLOGY EXISTING AIRPLANES.
(a) SIDELINE AT 0.25 NAUTICAL MILE (463 METERS).

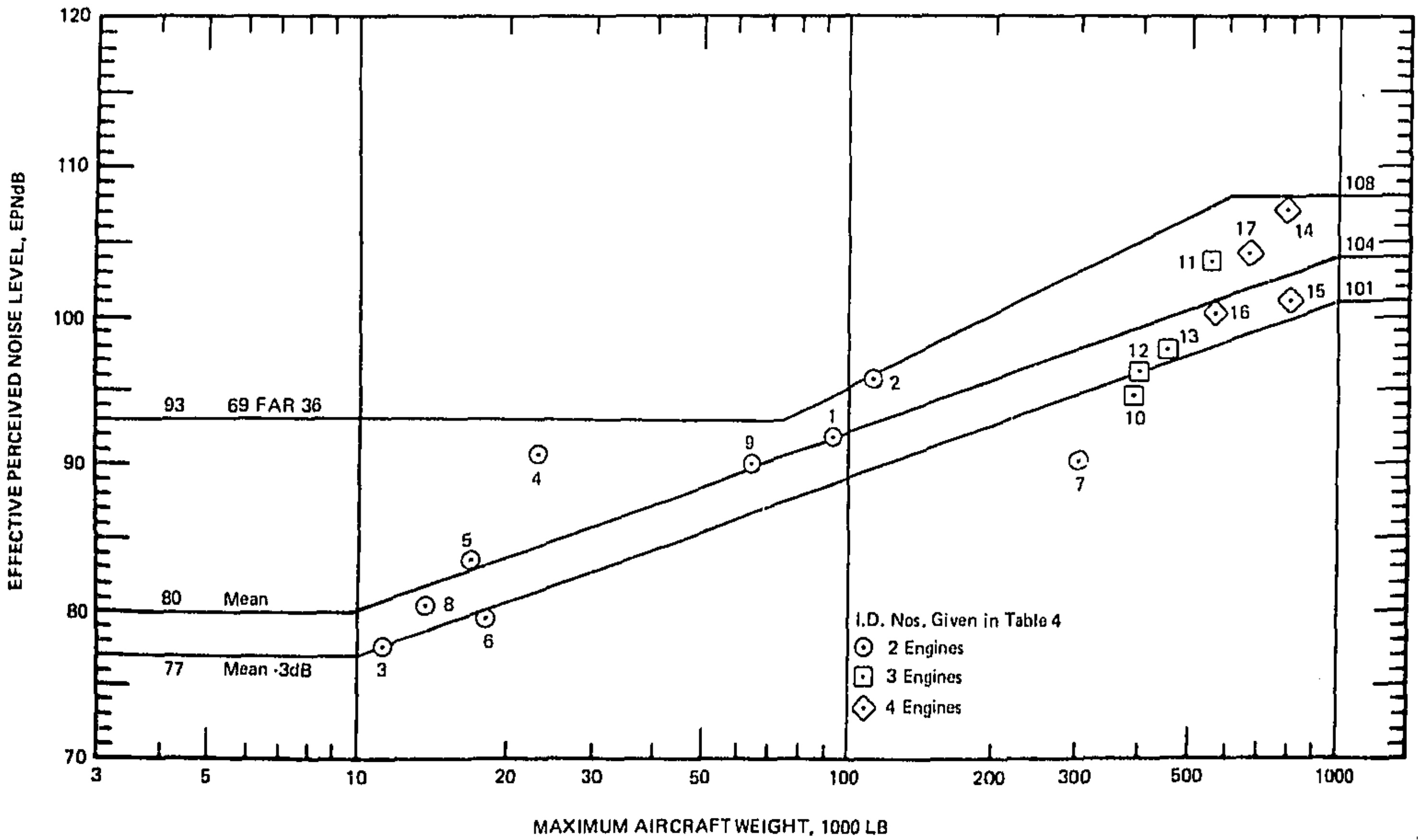


FIGURE 5. NOISE LEVELS VS WEIGHT FOR CURRENT TECHNOLOGY EXISTING AIRPLANES.
(b) TAKEOFF AT 3.5 NAUTICAL MILES (6,482 METERS).

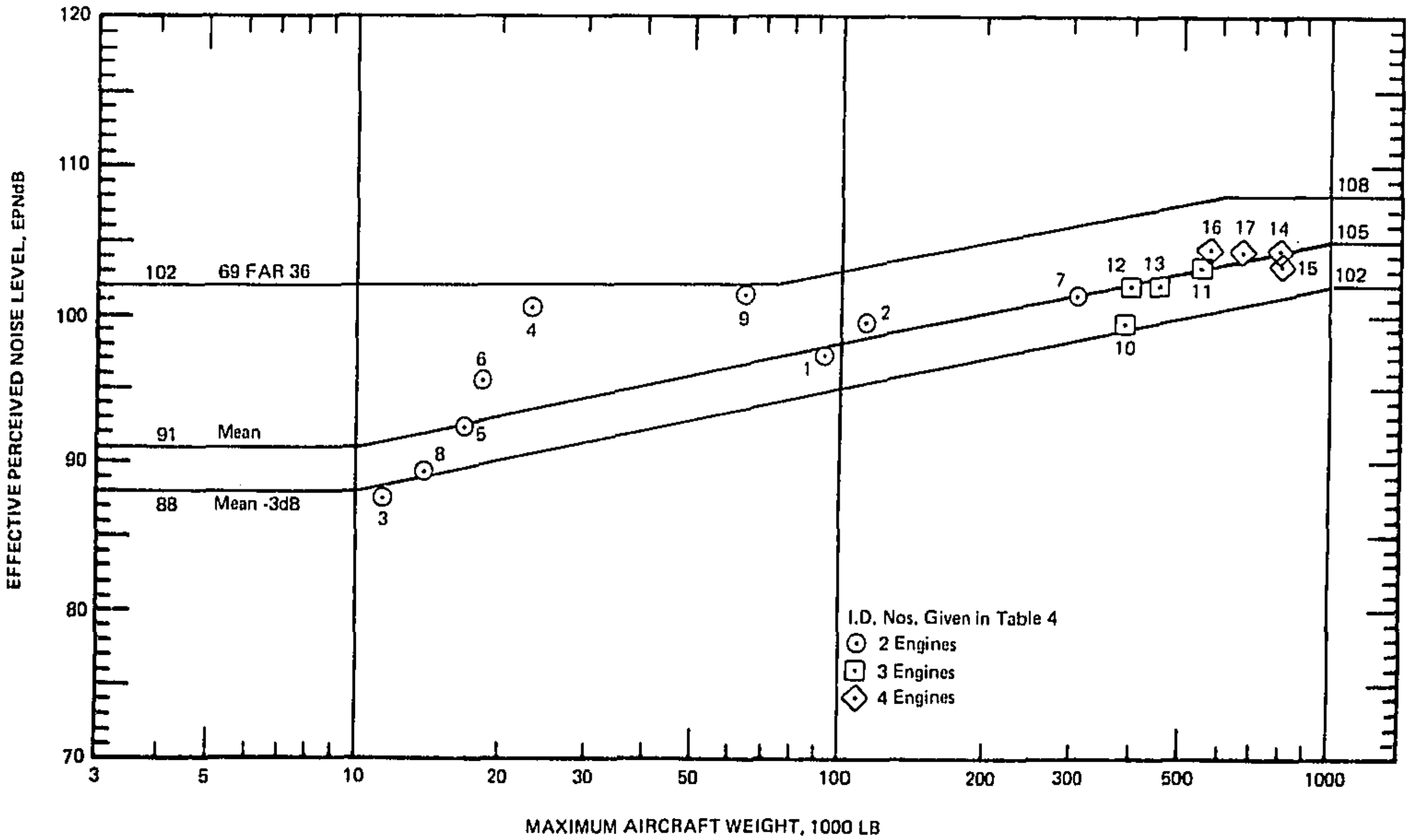


FIGURE 5. NOISE LEVELS VS WEIGHT FOR CURRENT TECHNOLOGY EXISTING AIRPLANES.
(c) APPROACH AT 1.0 NAUTICAL MILE (1,852 METERS).

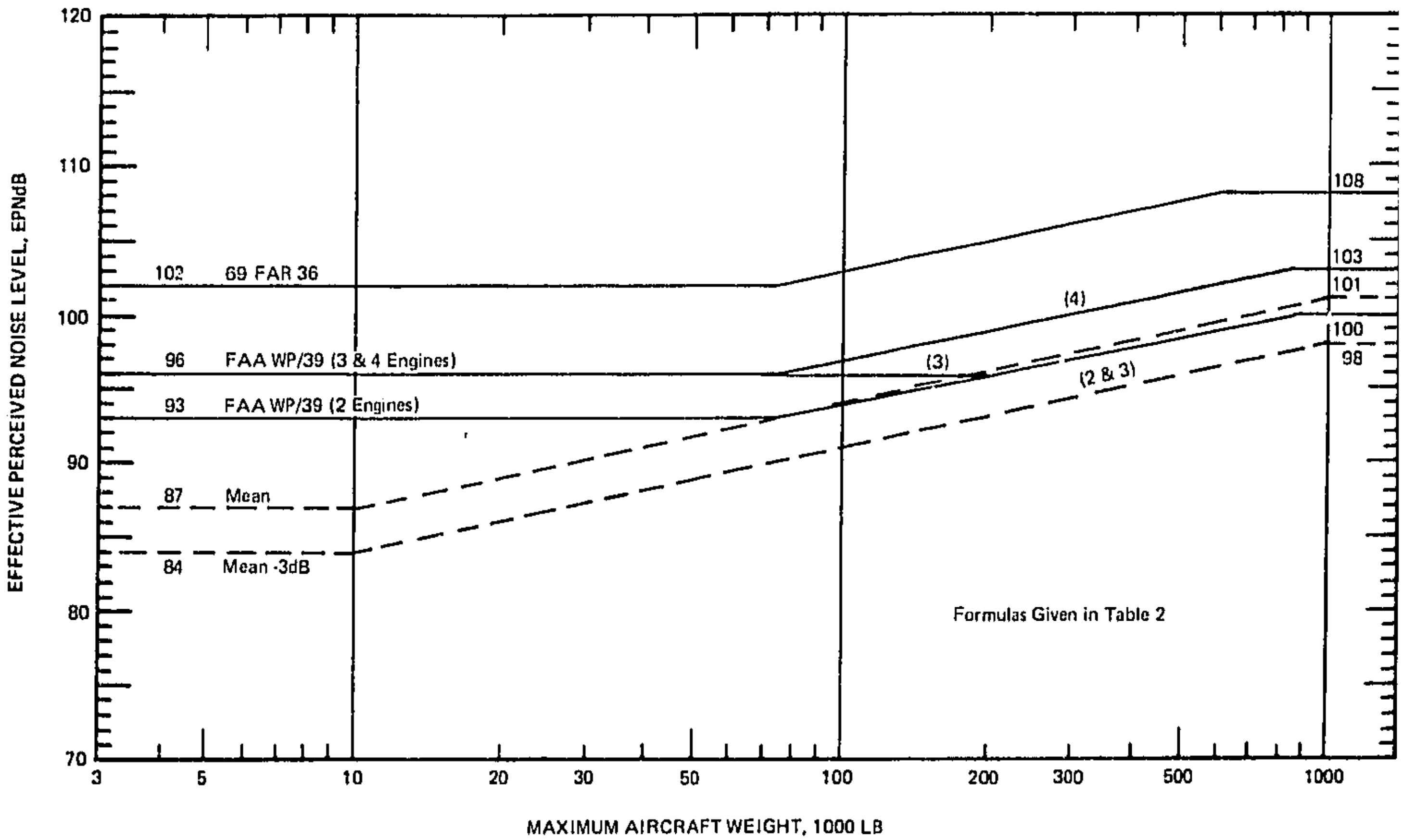


FIGURE 6. COMPARISON OF FAA LEVELS WITH MEAN LEVELS OF CURRENT TECHNOLOGY AIRPLANES.
(a) SIDELINE.

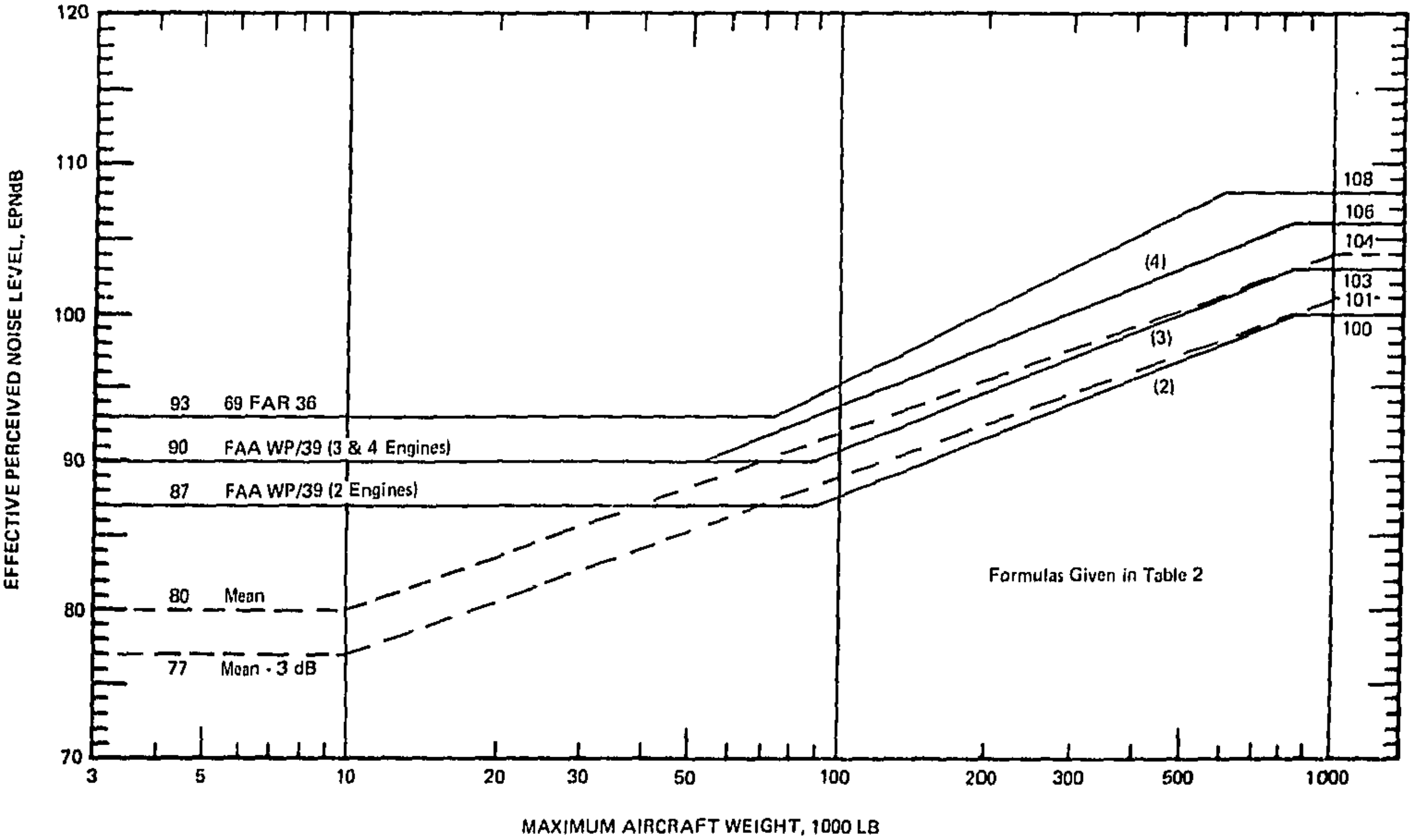


FIGURE 6. COMPARISON OF FAA LEVELS WITH MEAN LEVELS OF CURRENT TECHNOLOGY AIRPLANES.
(b) TAKEOFF.

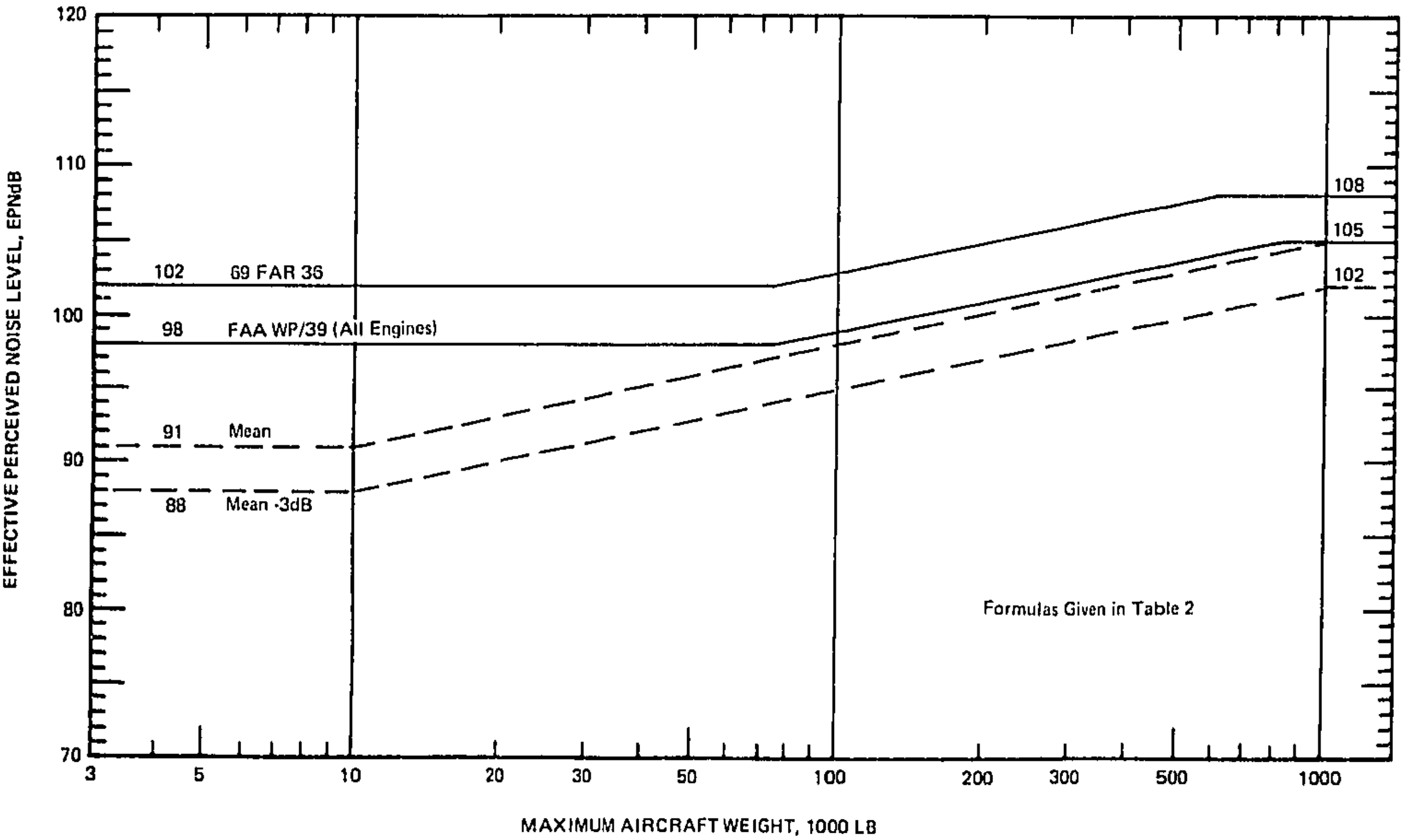


FIGURE 6. COMPARISON OF FAA LEVELS WITH MEAN LEVELS OF CURRENT TECHNOLOGY AIRPLANES. (c) APPROACH.

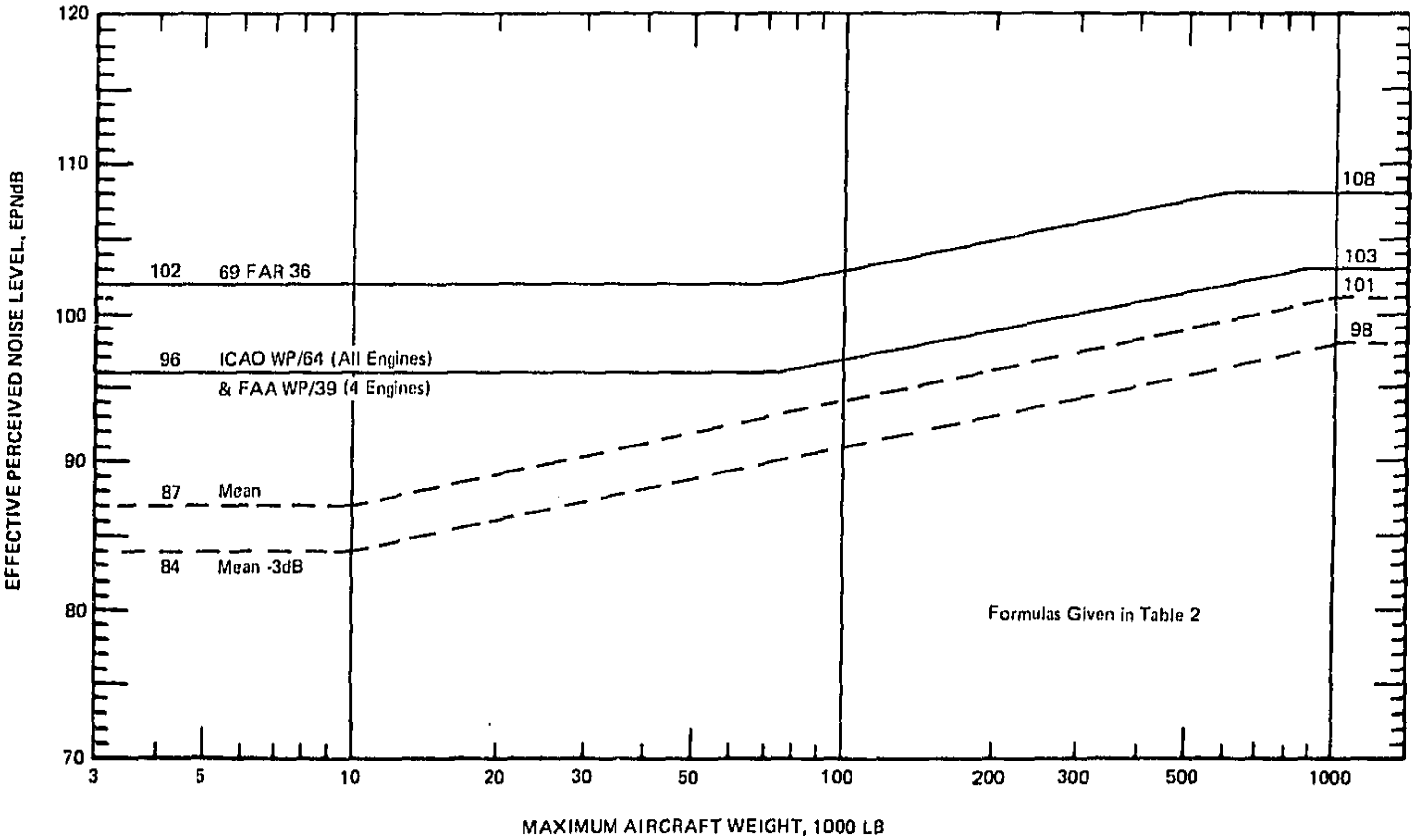


FIGURE 7. COMPARISON OF ICAO LEVELS WITH MEAN LEVELS OF CURRENT TECHNOLOGY AIRPLANES.
(a) SIDELINE.

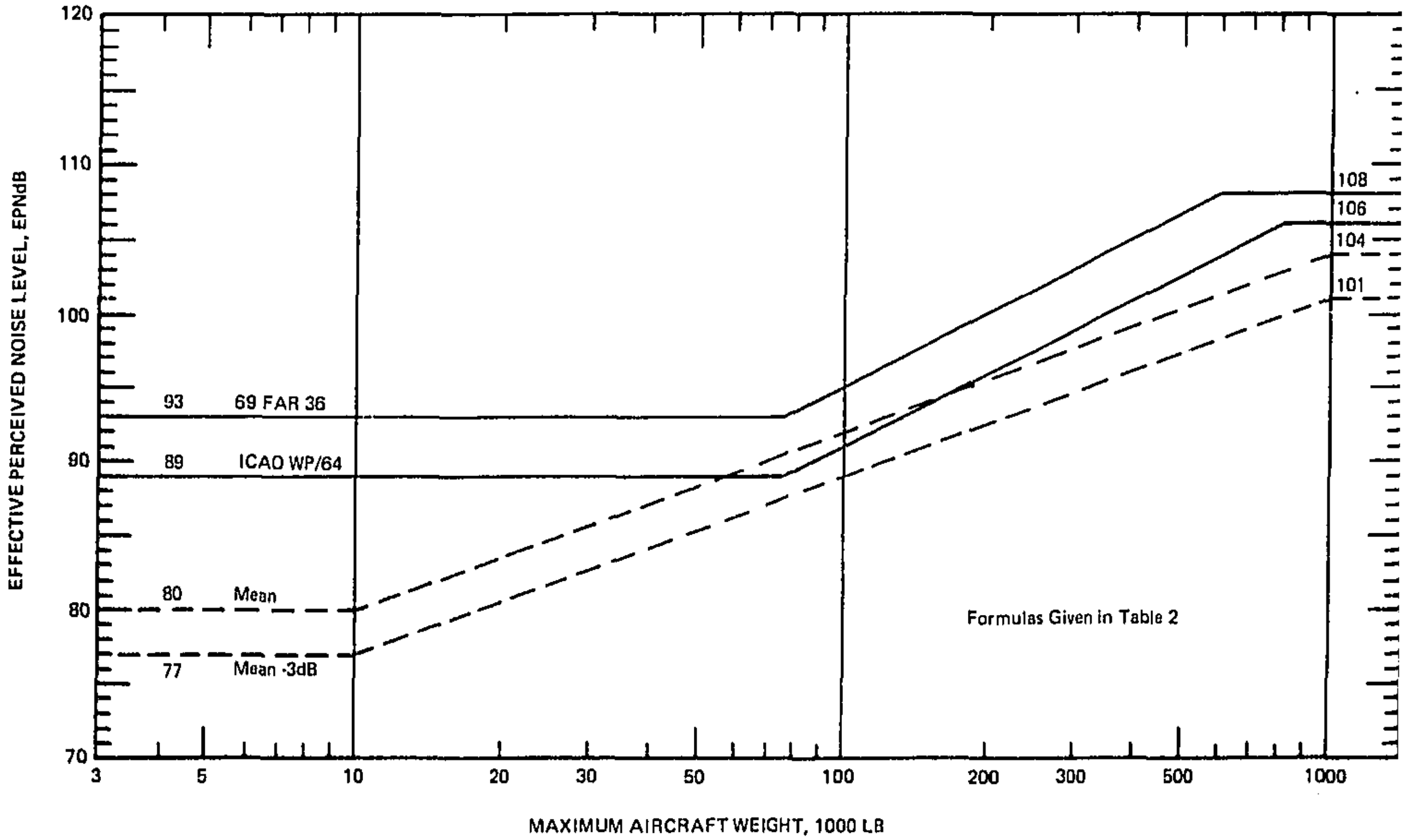


FIGURE 7. COMPARISON OF ICAO LEVELS WITH MEAN LEVELS OF CURRENT TECHNOLOGY AIRPLANES.
(b) TAKEOFF.

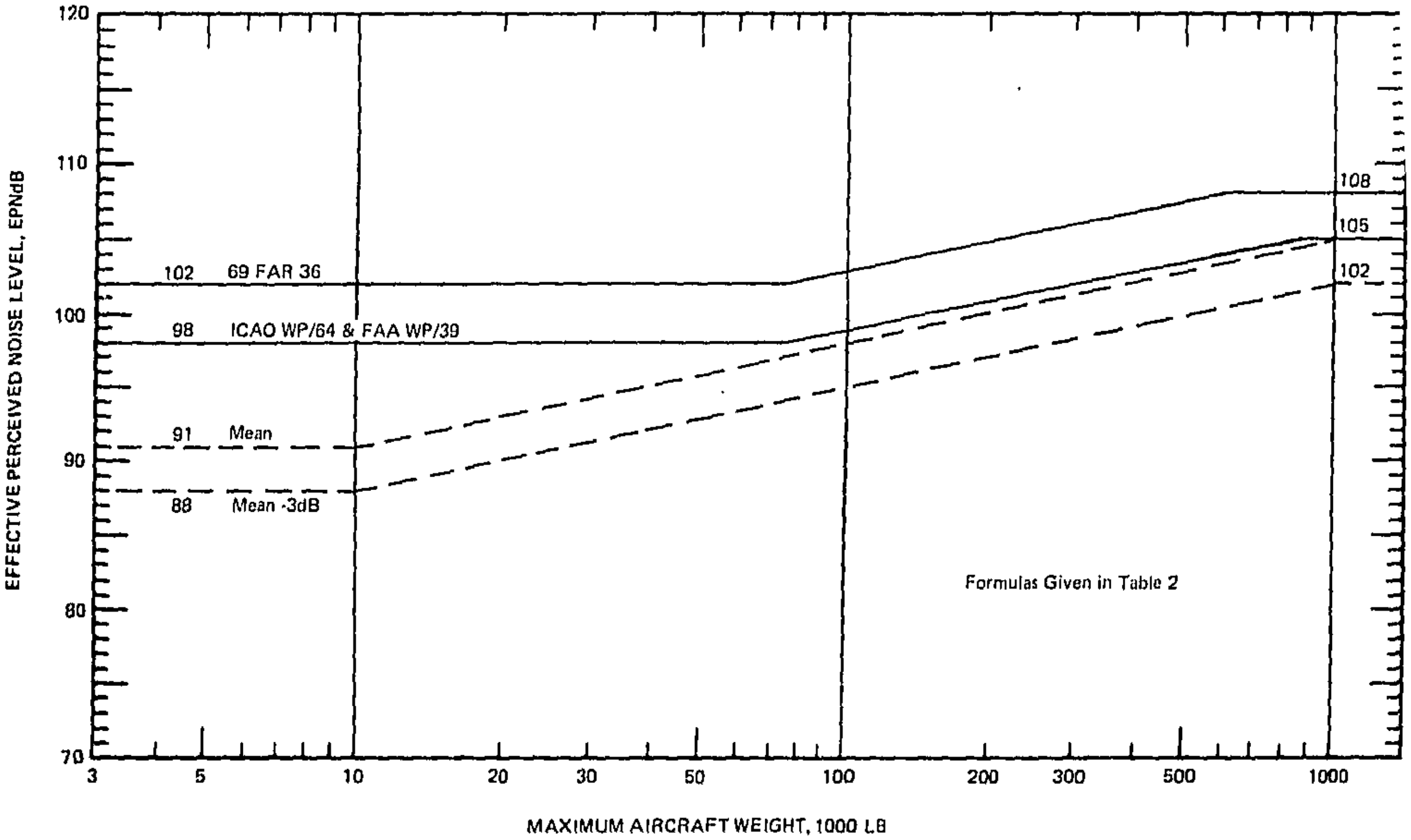


FIGURE 7. COMPARISON OF ICAO LEVELS WITH MEAN LEVELS OF CURRENT TECHNOLOGY AIRPLANES.
(c) APPROACH

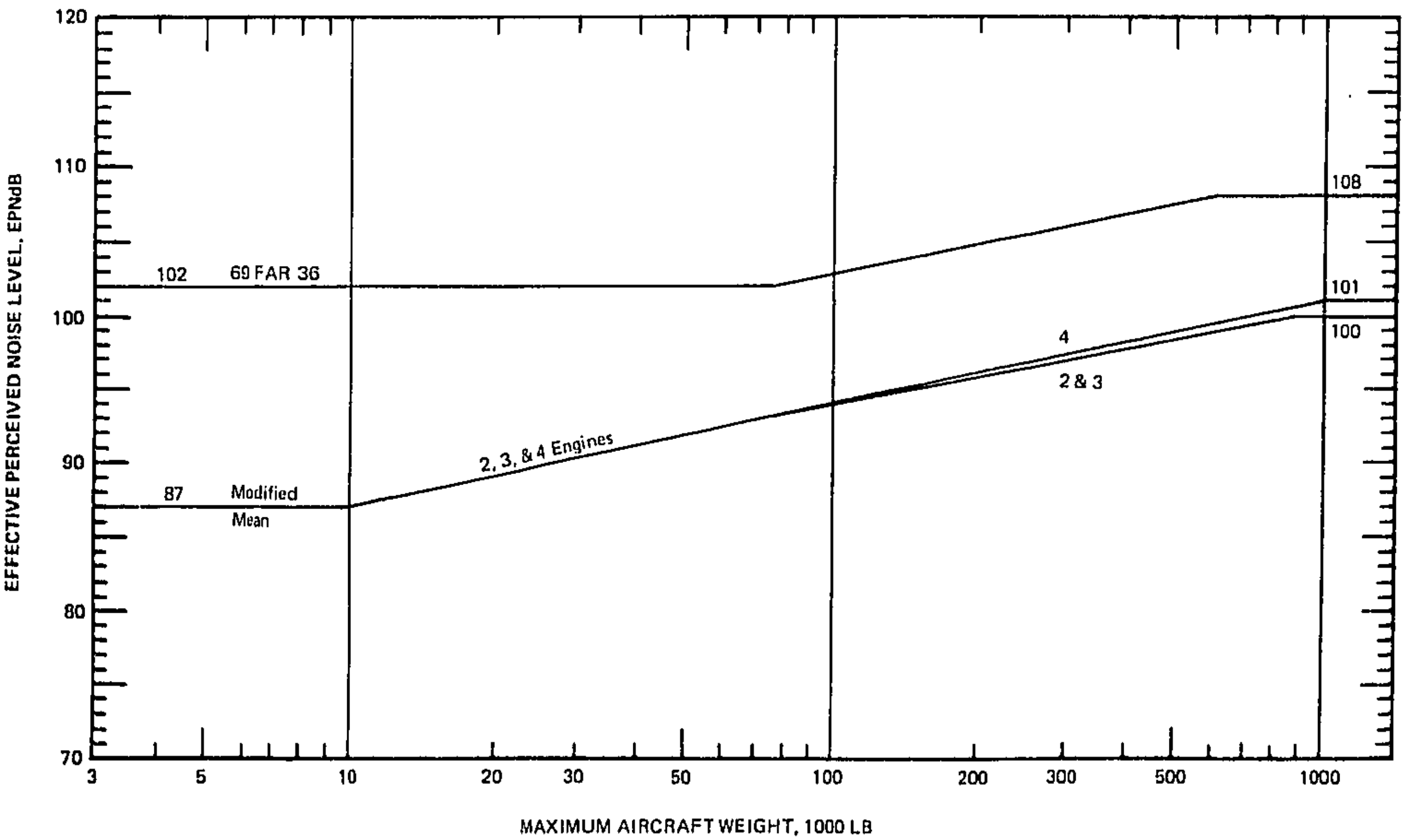


FIGURE 8. MODIFIED MEAN NOISE LEVELS FOR CURRENT TECHNOLOGY AIRPLANES.
(a) SIDELINE.

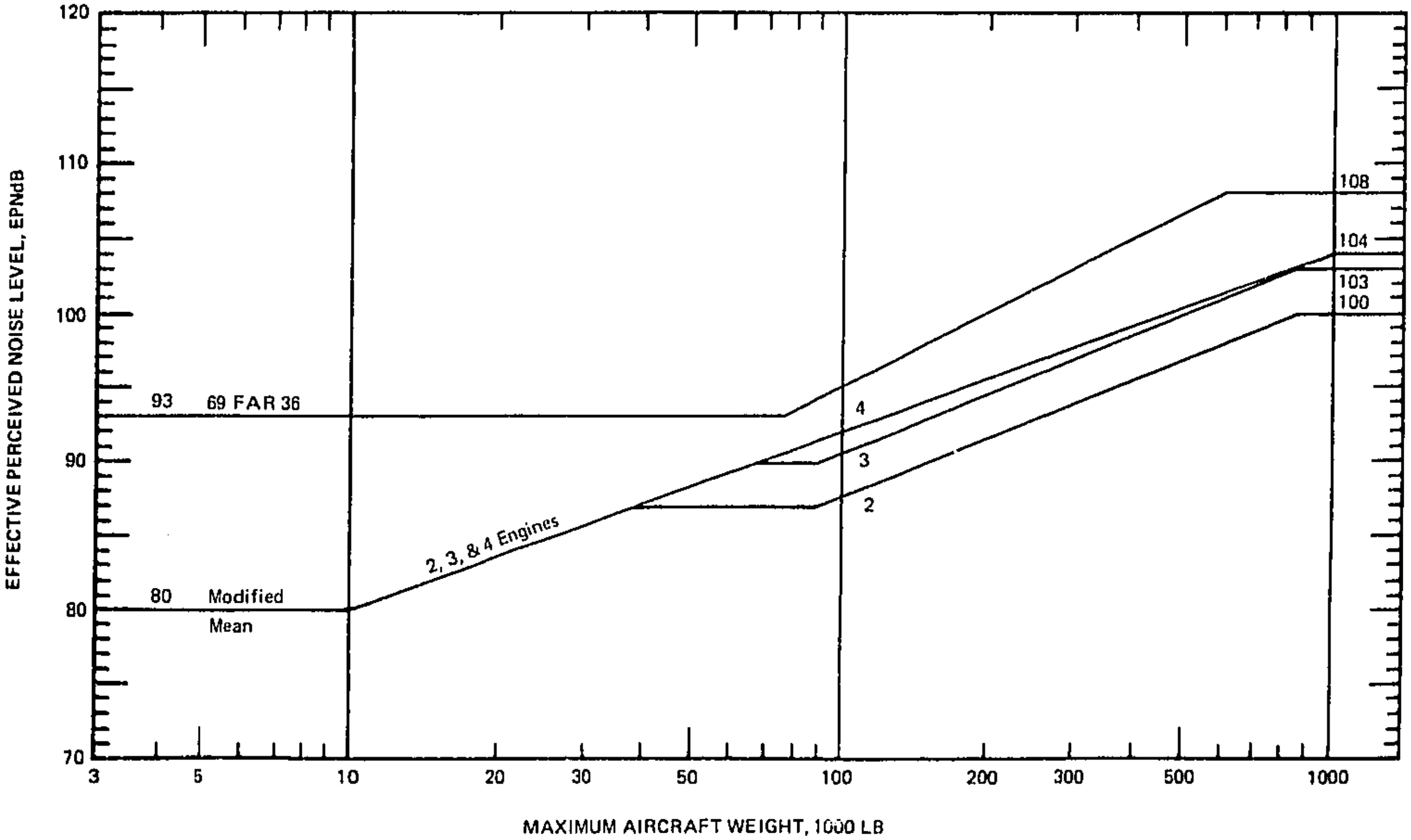


FIGURE 8. MODIFIED MEAN NOISE LEVELS FOR CURRENT TECHNOLOGY AIRPLANES.
(b) TAKEOFF.

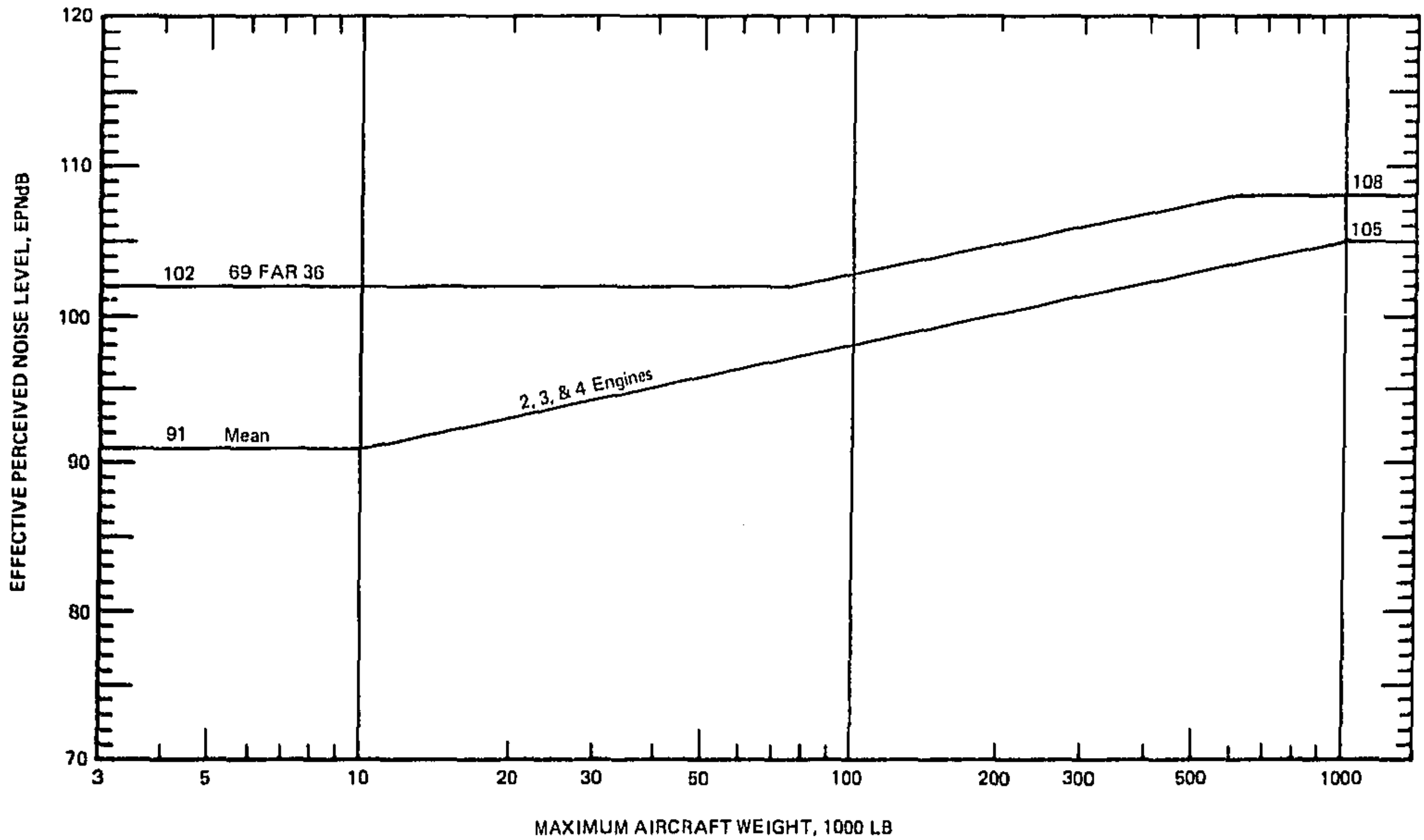


FIGURE 8. MODIFIED MEAN NOISE LEVELS FOR CURRENT TECHNOLOGY AIRPLANES.
(c) APPROACH.

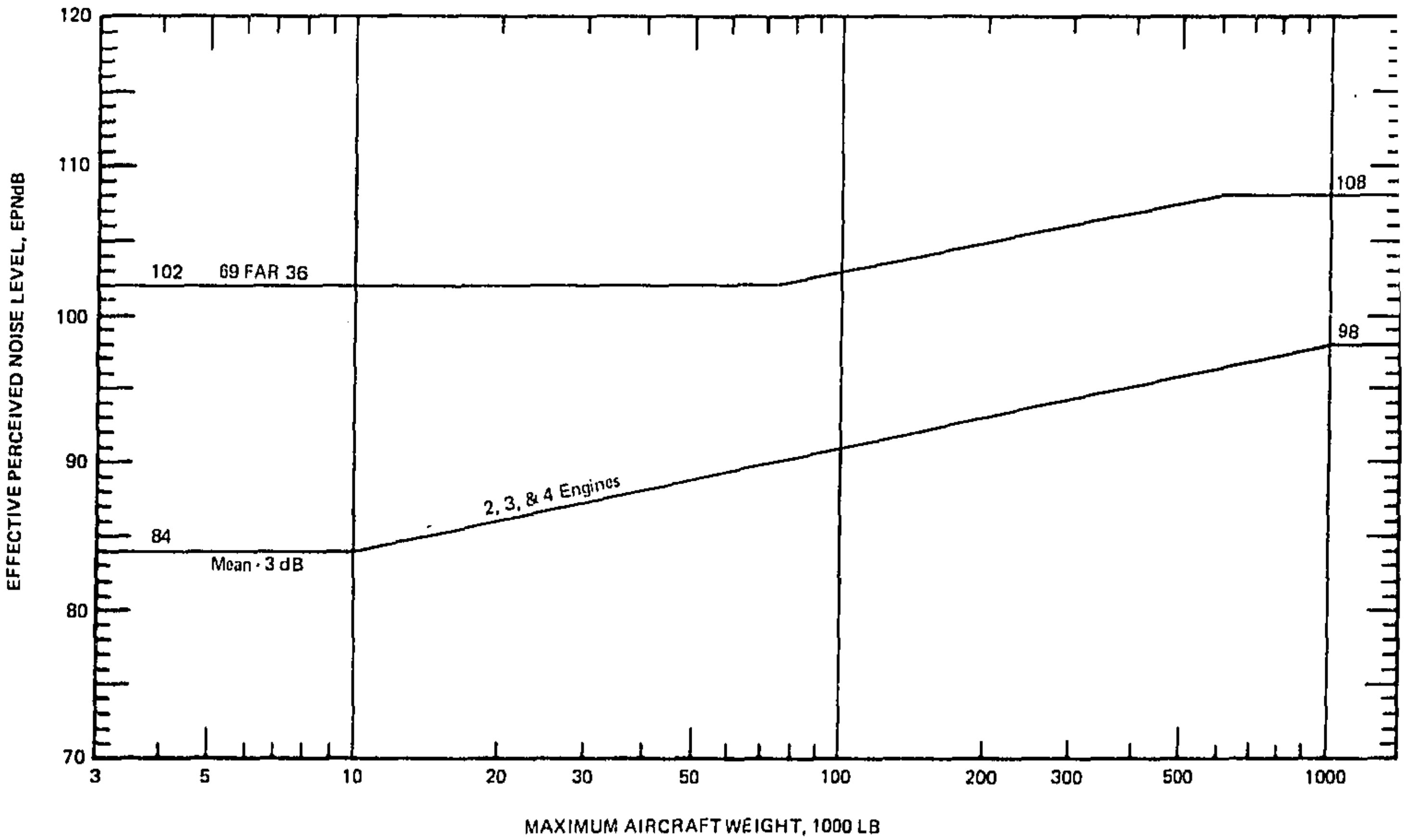


FIGURE 9. MODIFIED MEAN -3 dB NOISE LEVELS FOR AVAILABLE TECHNOLOGY AIRPLANES.
(a) SIDELINE.

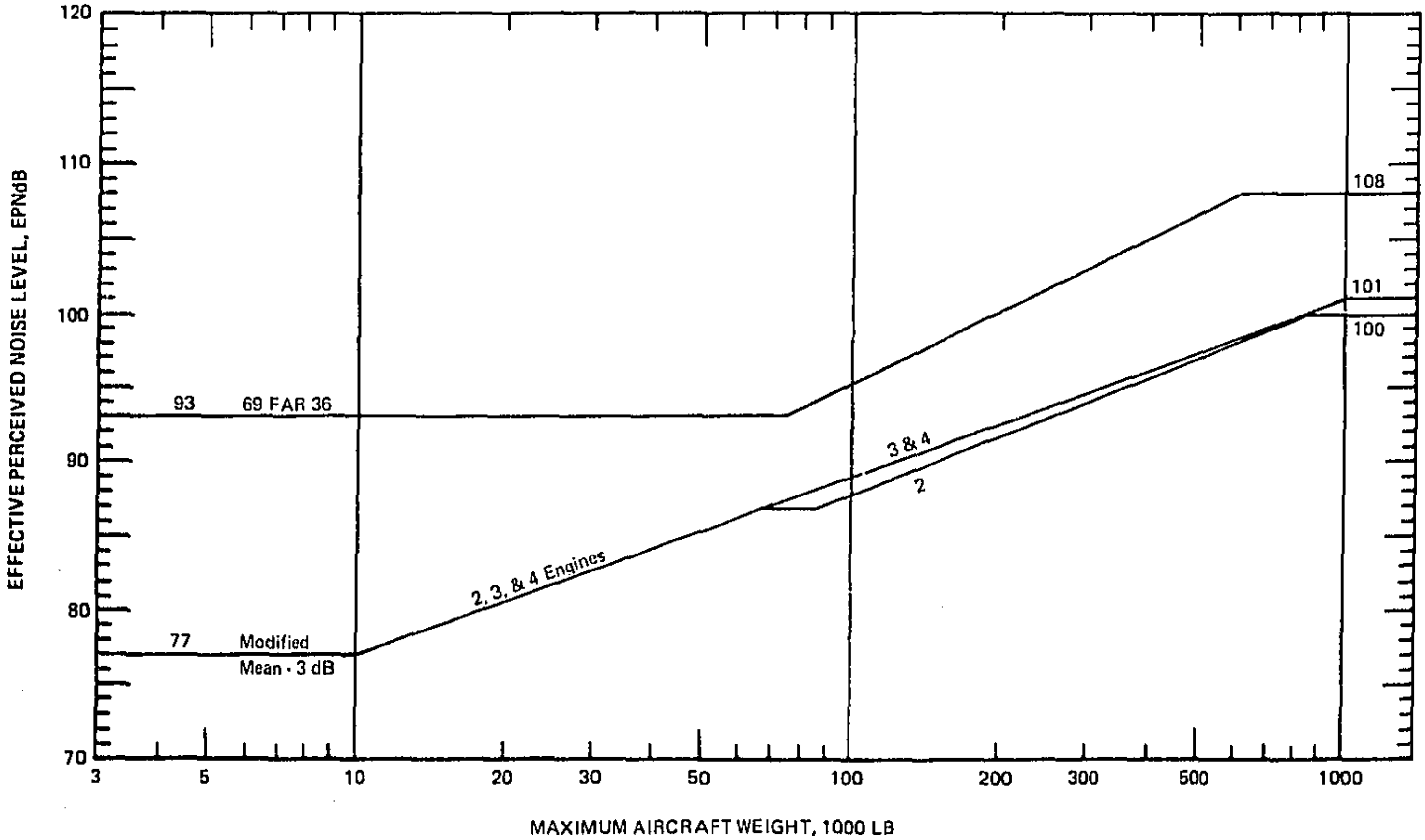


FIGURE 9. MODIFIED MEAN -3 dB NOISE LEVELS FOR AVAILABLE TECHNOLOGY AIRPLANES.
(b) TAKEOFF.

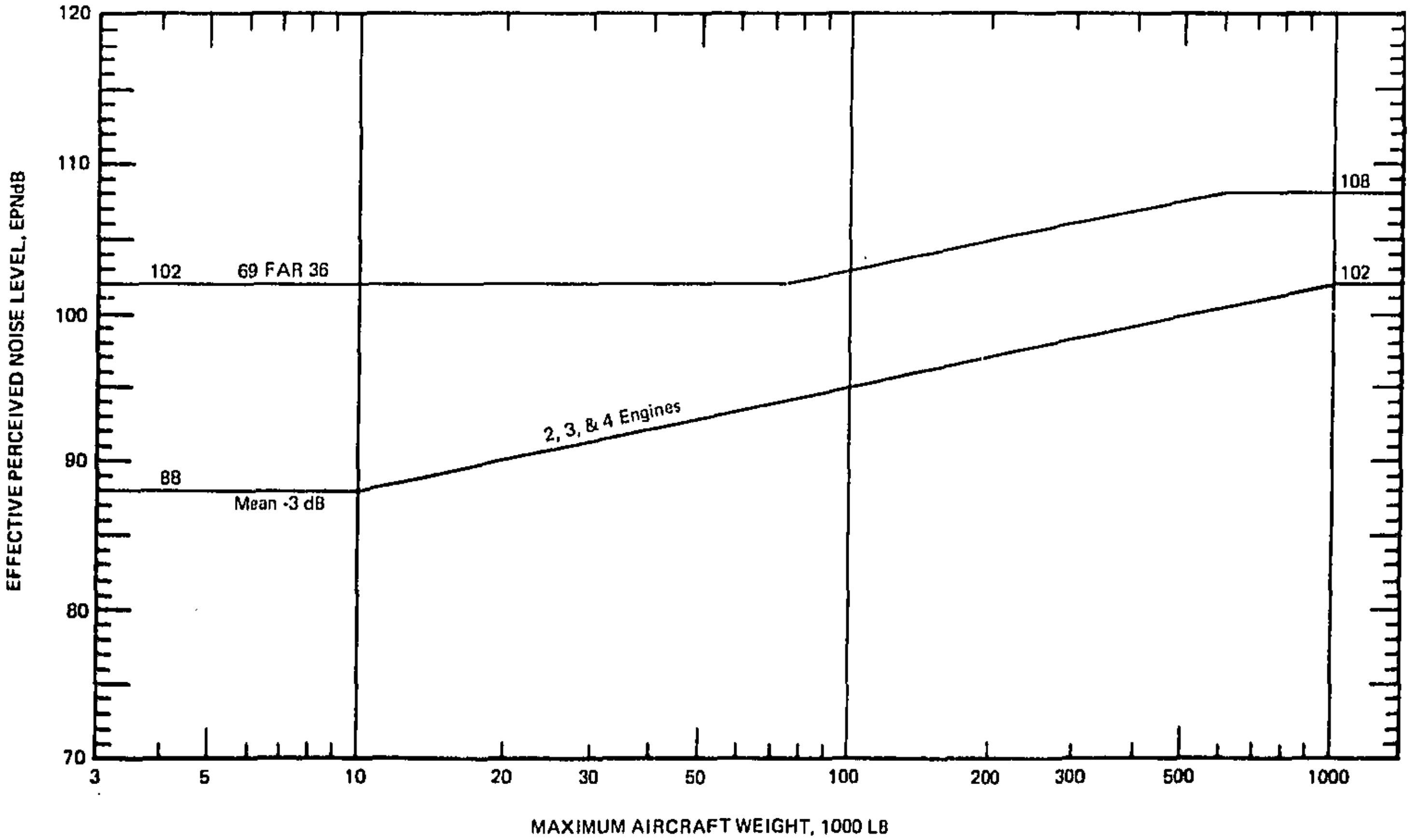


FIGURE 9. MODIFIED MEAN -3 dB NOISE LEVELS FOR AVAILABLE TECHNOLOGY AIRPLANES.
(c) APPROACH.

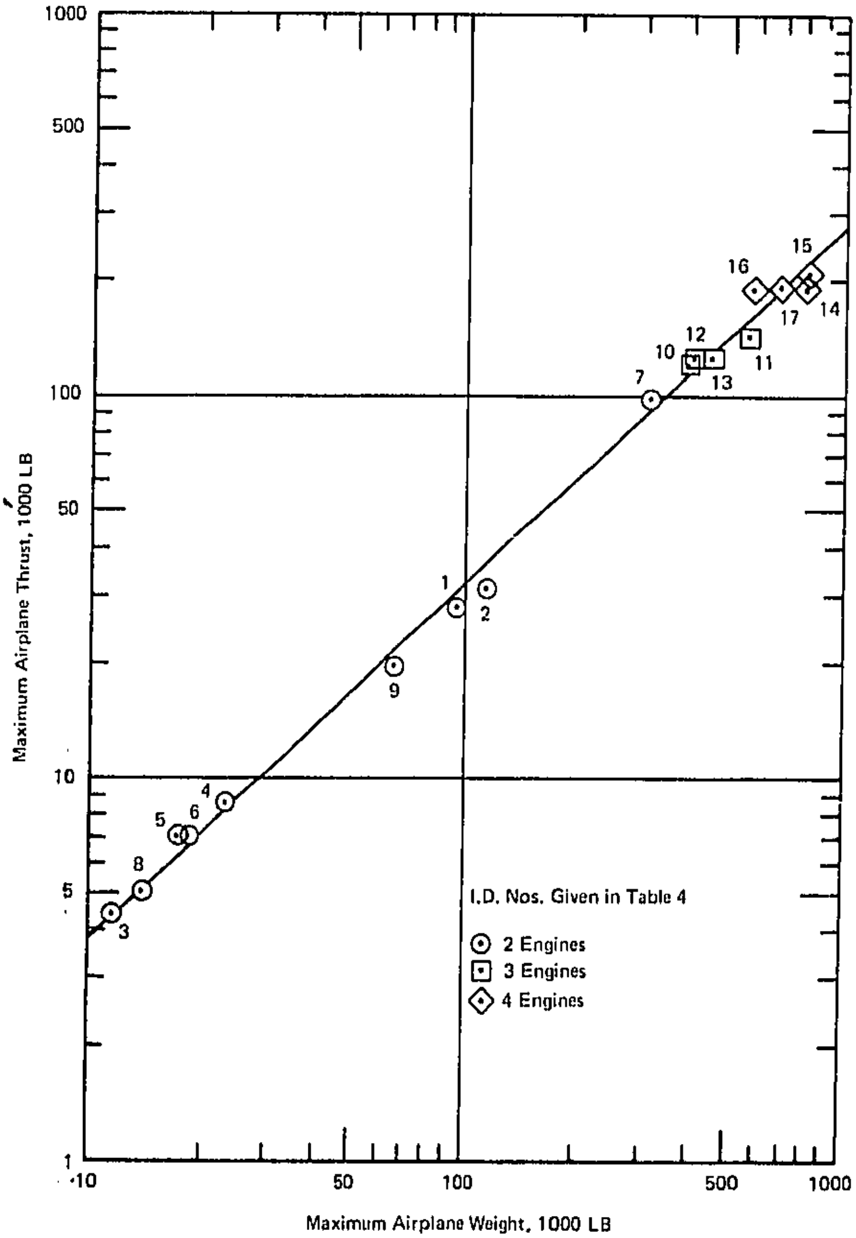


FIGURE 10. PROPULSION VS WEIGHT FOR CURRENT TECHNOLOGY AIRPLANES.
(a) MAXIMUM THRUST.

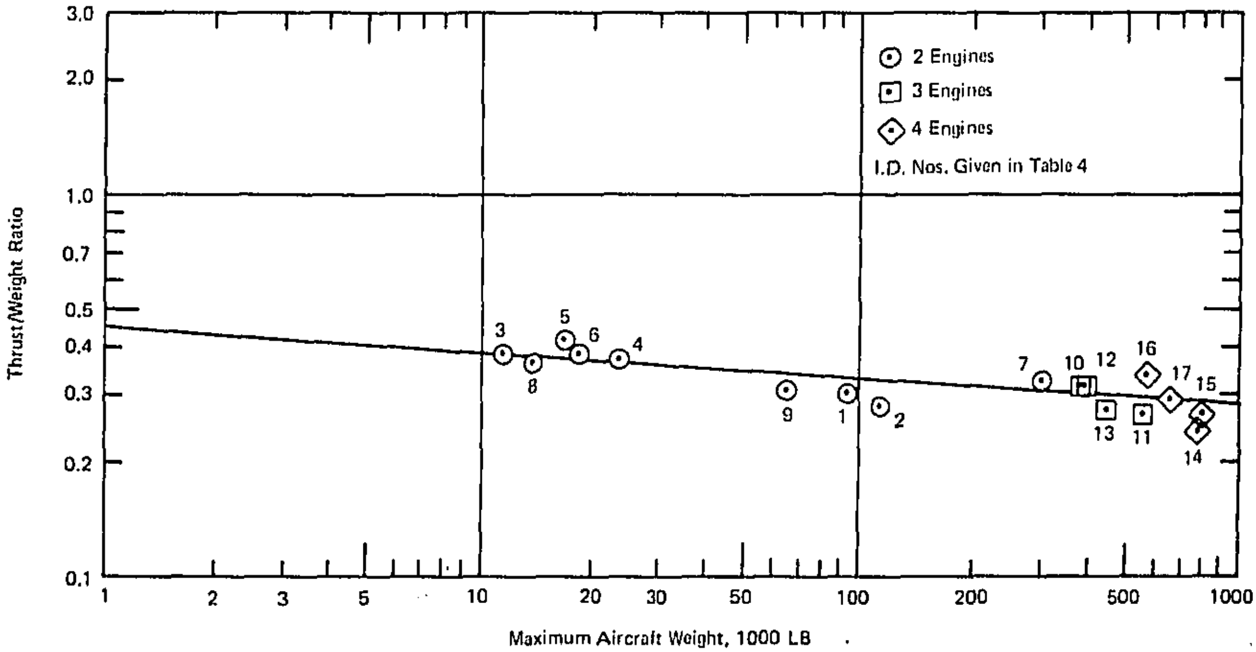


FIGURE 10. PROPULSION VS WEIGHT FOR CURRENT TECHNOLOGY AIRPLANES.
(b) MAXIMUM THRUST/WEIGHT RATIO.

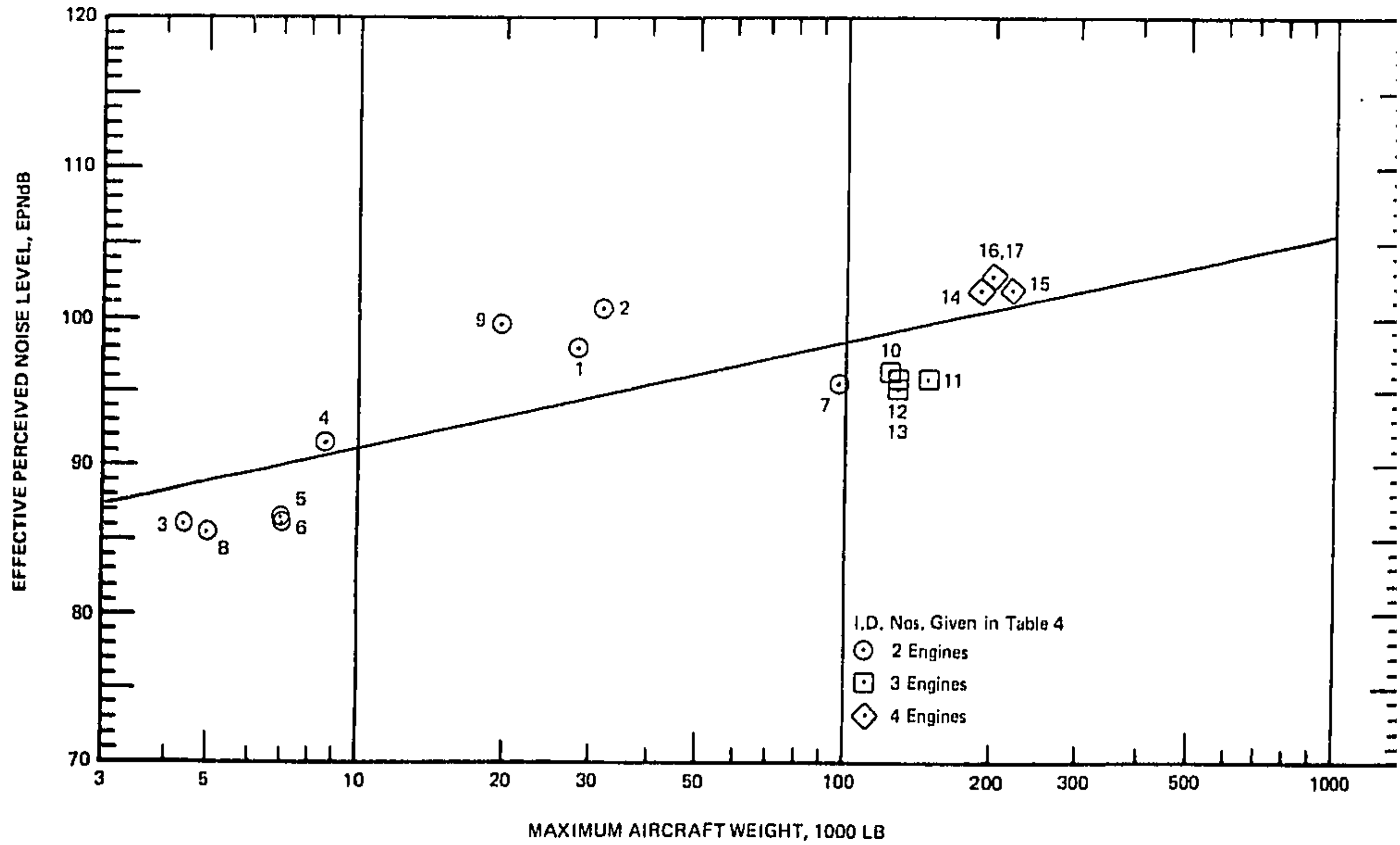


FIGURE 11. NOISE LEVELS VS THRUST FOR CURRENT TECHNOLOGY AIRPLANES.
(a) SIDELINE.

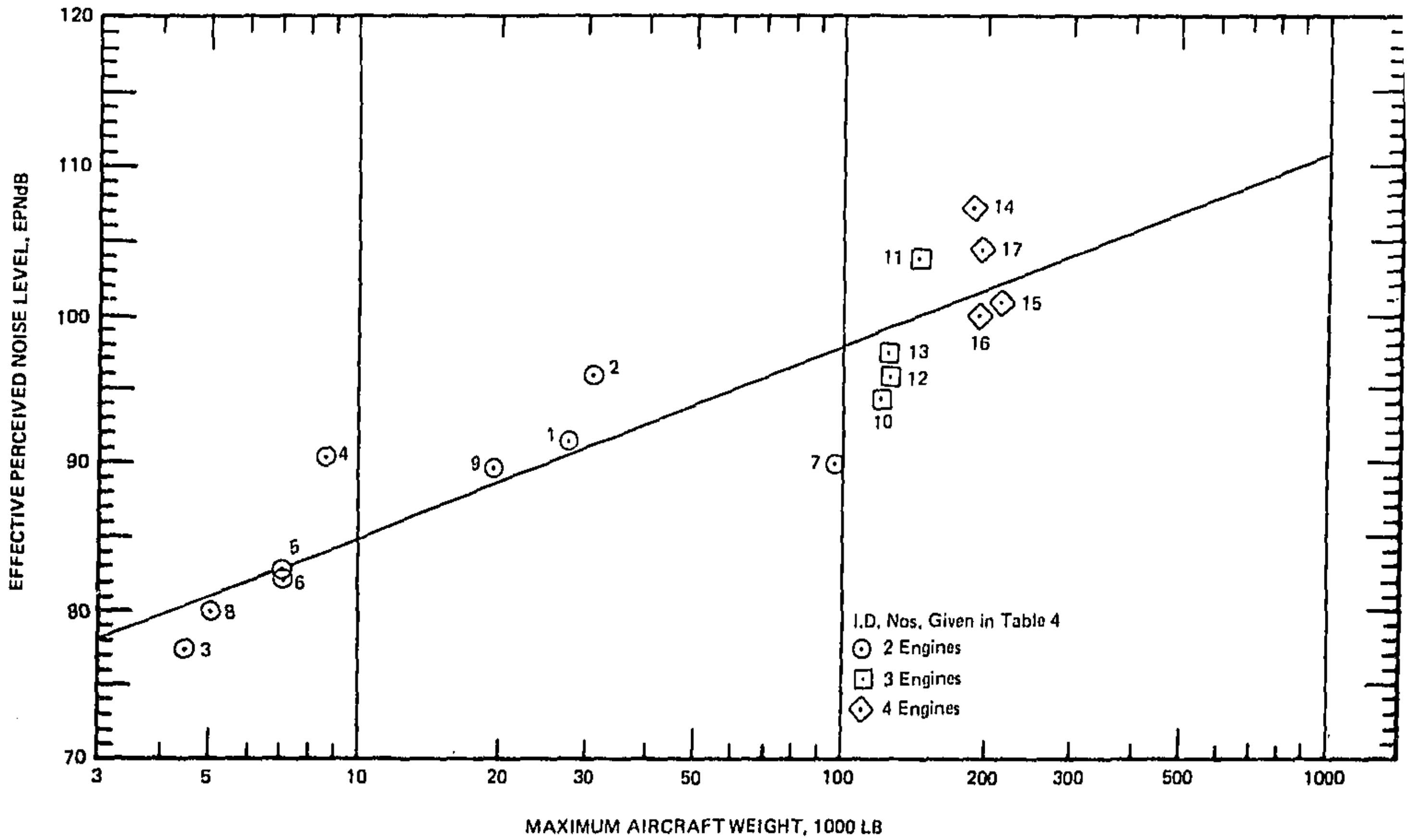


FIGURE 11. NOISE LEVELS VS THRUST FOR CURRENT TECHNOLOGY AIRPLANES.
(b) TAKEOFF.

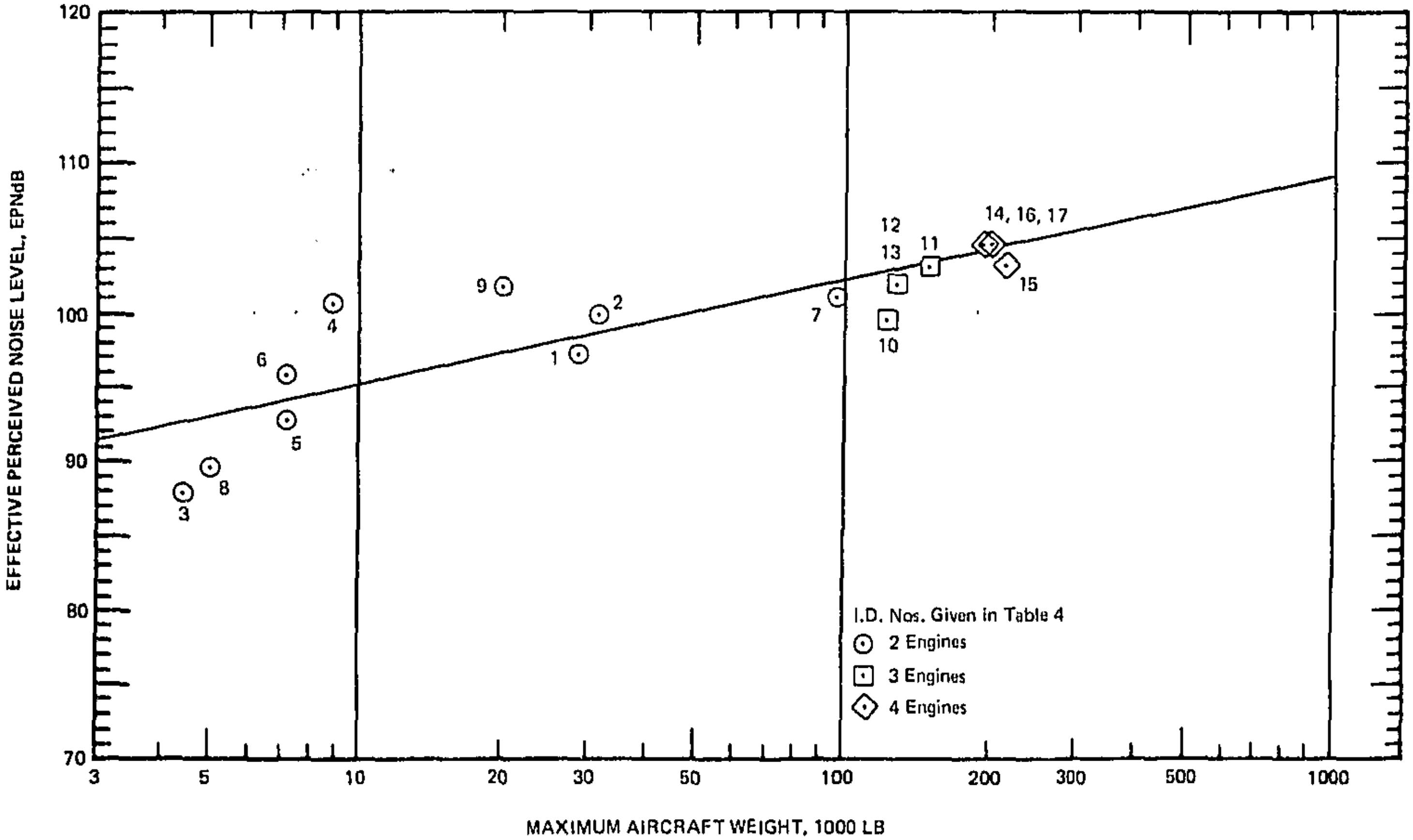


FIGURE 11. NOISE LEVELS VS THRUST FOR CURRENT TECHNOLOGY AIRPLANES.
(c) APPROACH.

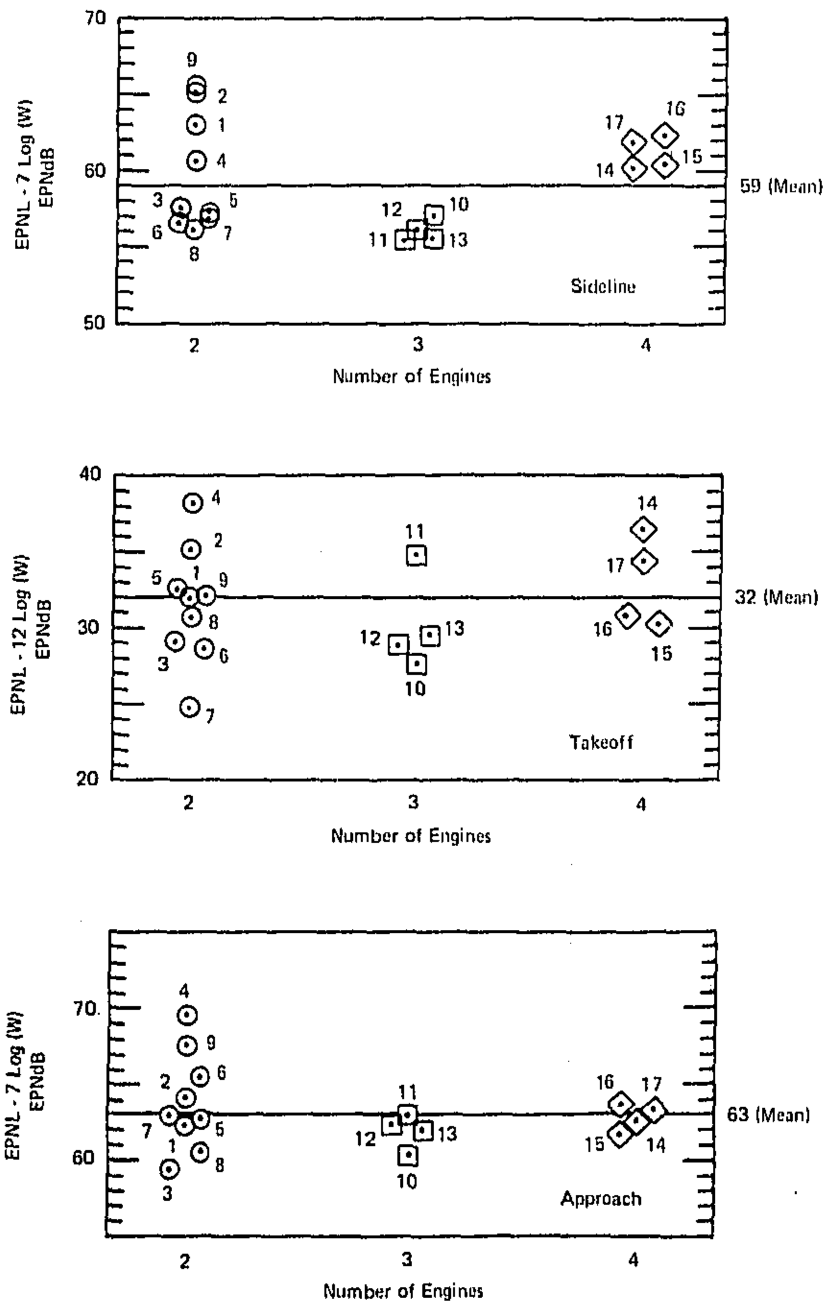


FIGURE 12. NOISE LEVELS VS NUMBER OF ENGINES FOR CURRENT TECHNOLOGY AIRPLANES.
(a) NORMALIZED FOR WEIGHT.

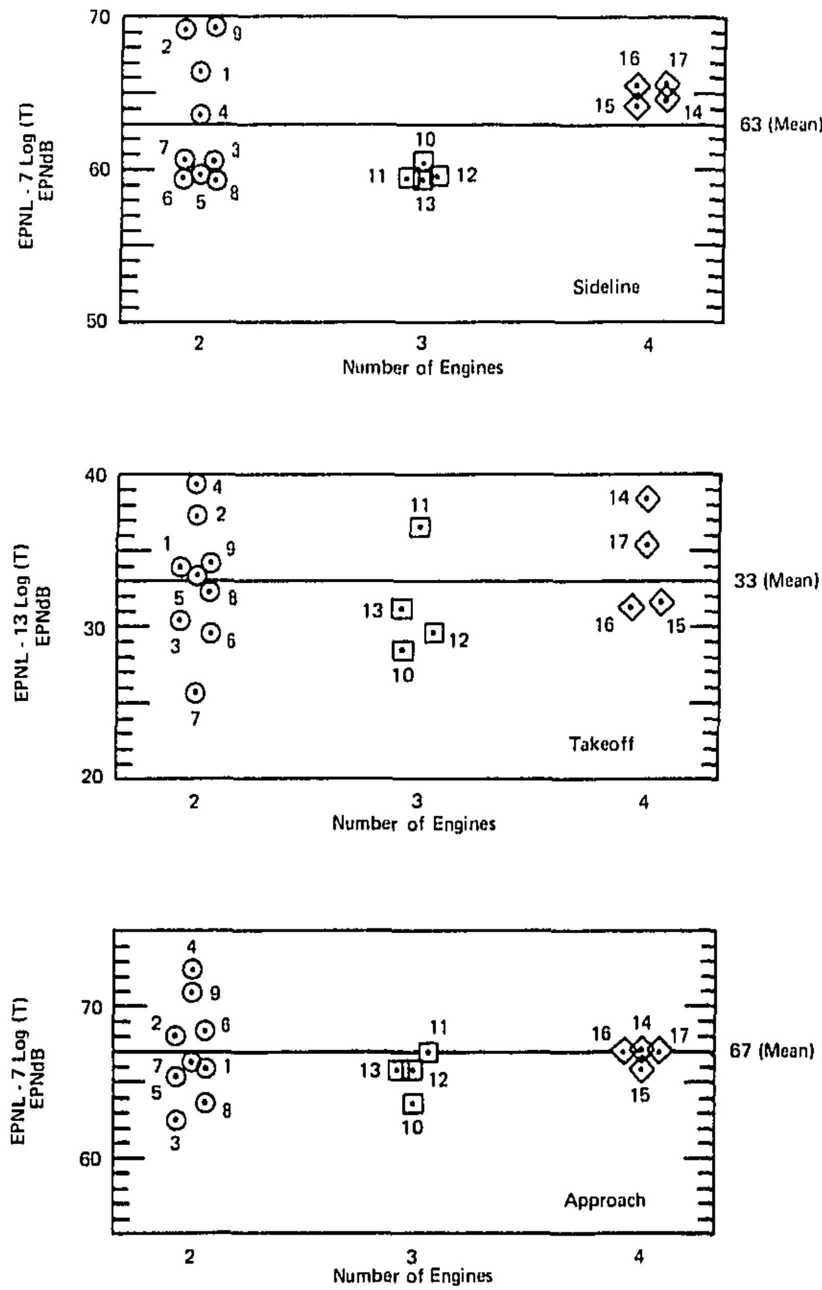


FIGURE 12. NOISE LEVELS VS NUMBER OF ENGINES FOR CURRENT TECHNOLOGY AIRPLANES.
(b) NORMALIZED FOR THRUST.

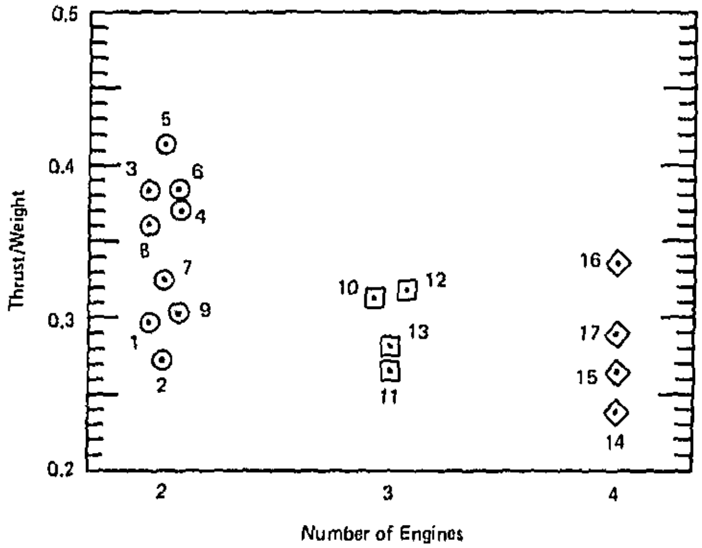


FIGURE 13. THRUST/WEIGHT RATIO VS NUMBER OF ENGINES FOR CURRENT TECHNOLOGY AIRPLANES.

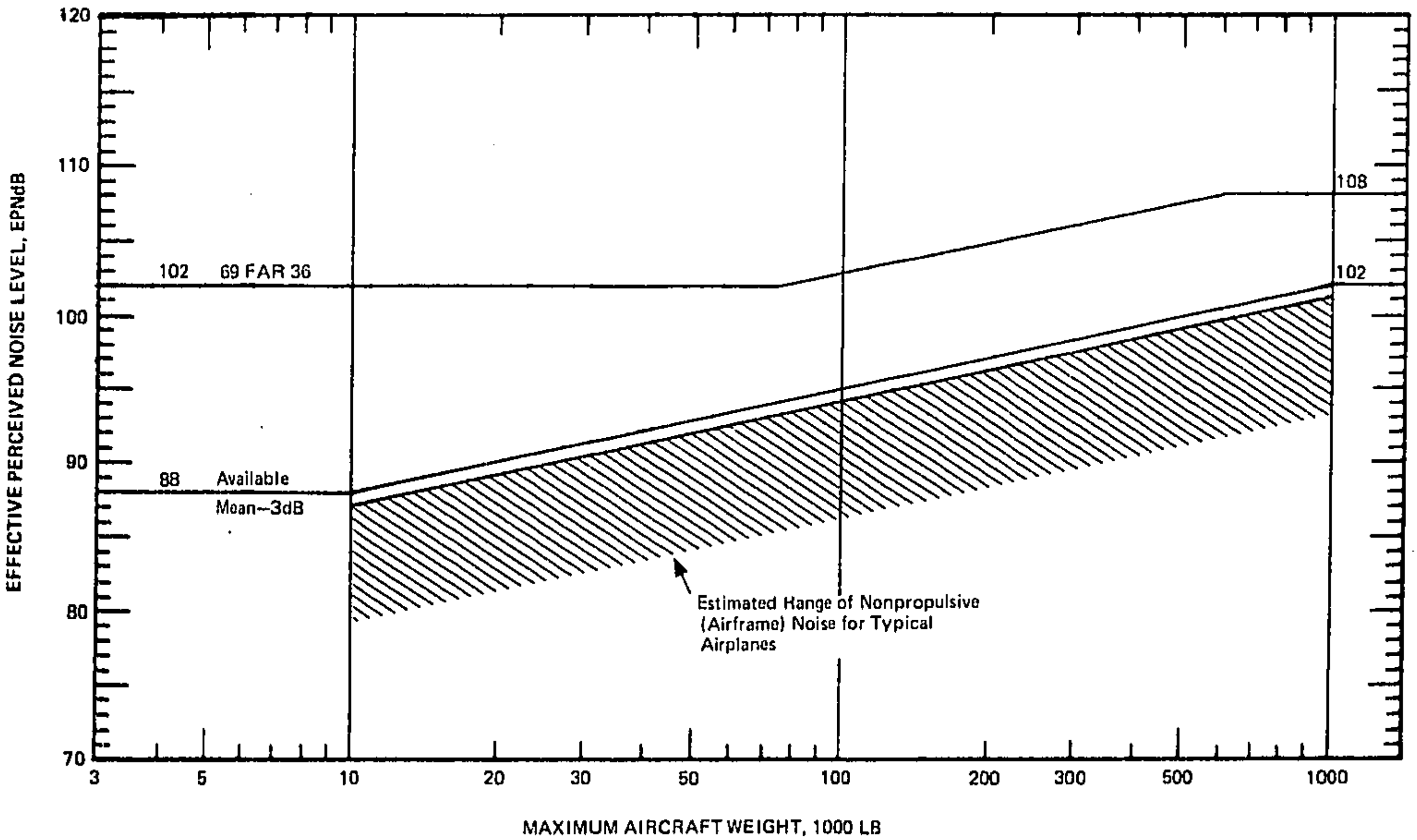


FIGURE 14. NONPROPULSIVE APPROACH NOISE FOR TYPICAL AIRPLANES.

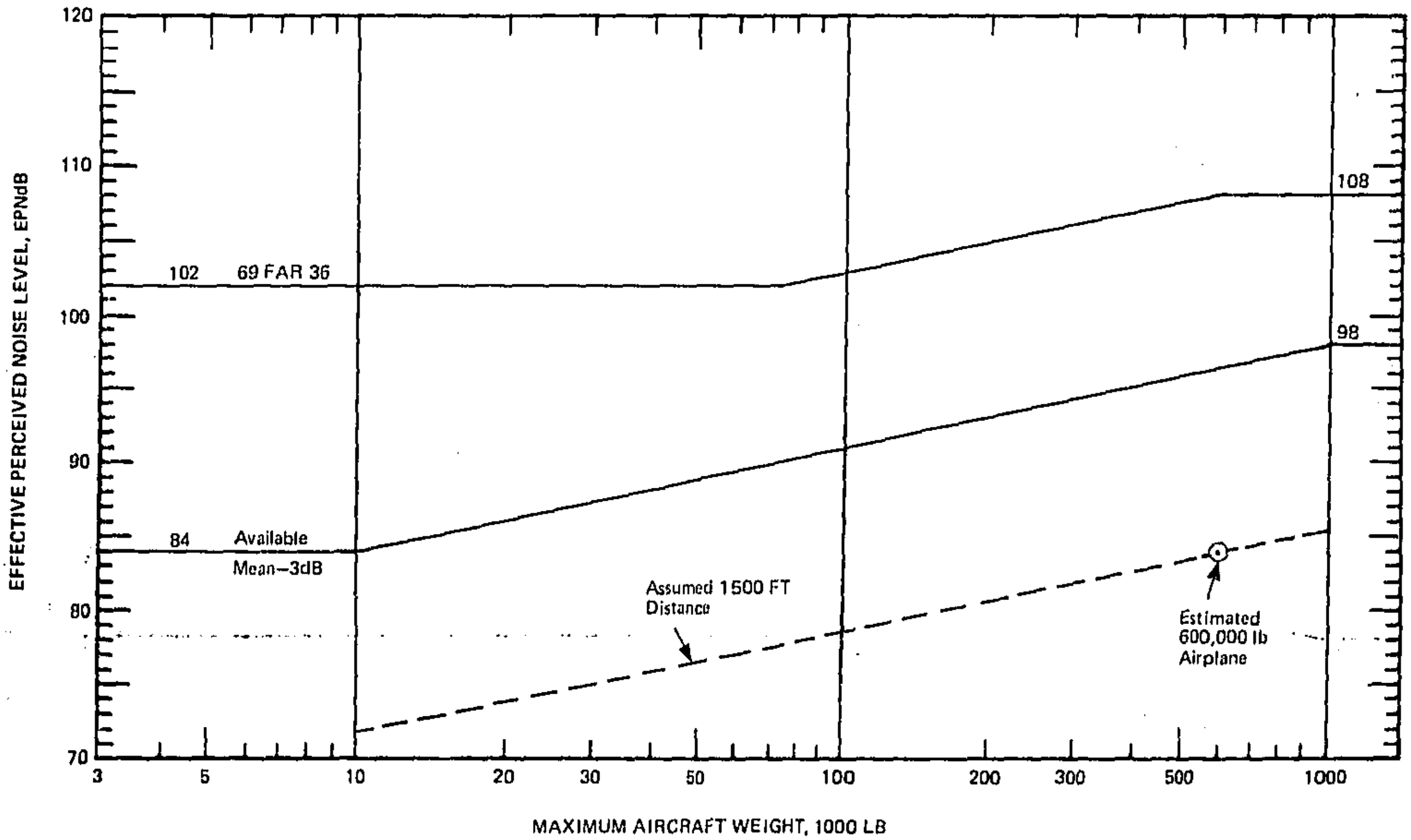


FIGURE 15. NONPROPULSIVE NOISE FLOOR FOR AERODYNAMICALLY CLEAN AIRPLANES.
(a) SIDELINE.

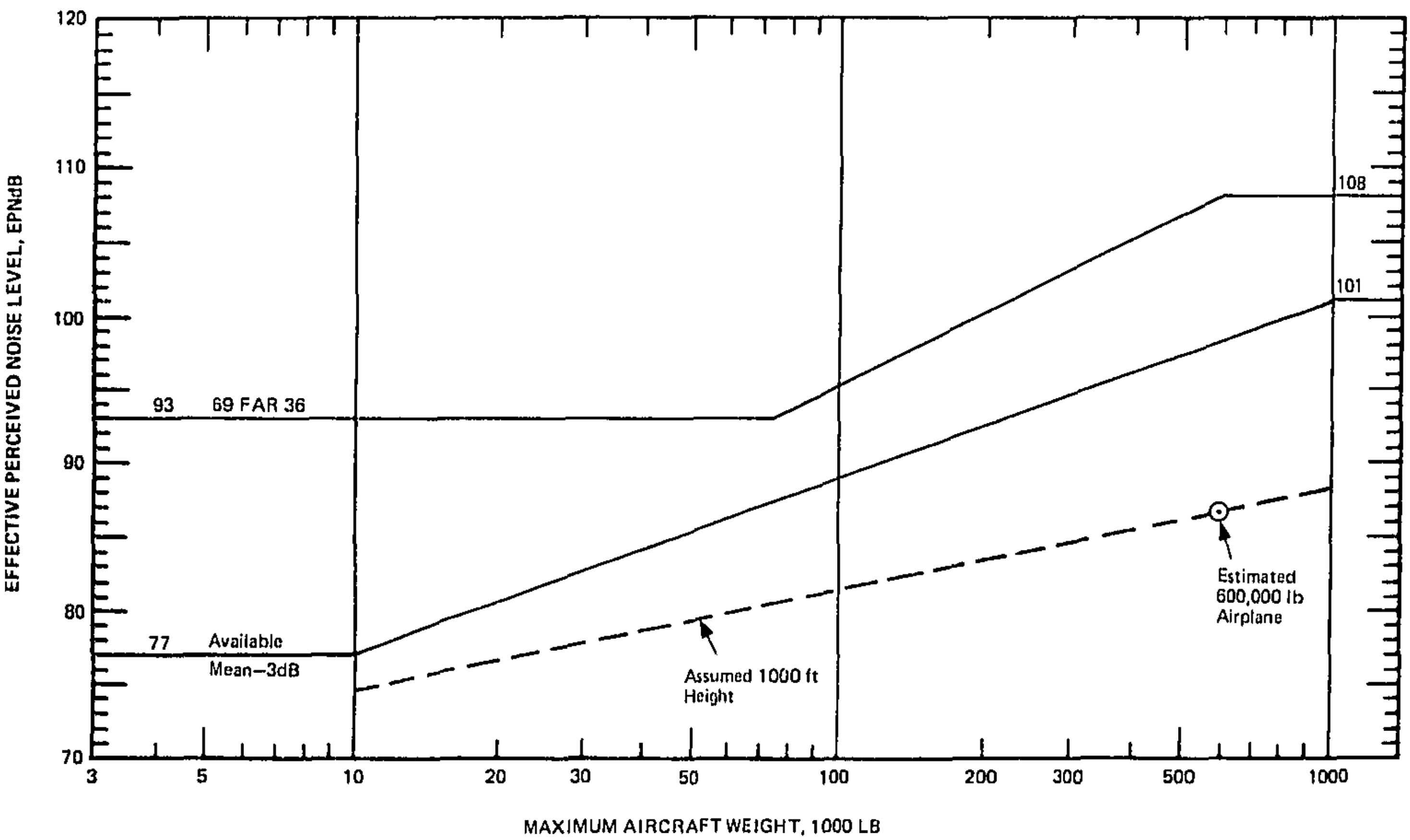


FIGURE 15. NONPROPULSIVE NOISE FLOOR FOR AERODYNAMICALLY CLEAN AIRPLANES.
(b) TAKEOFF.

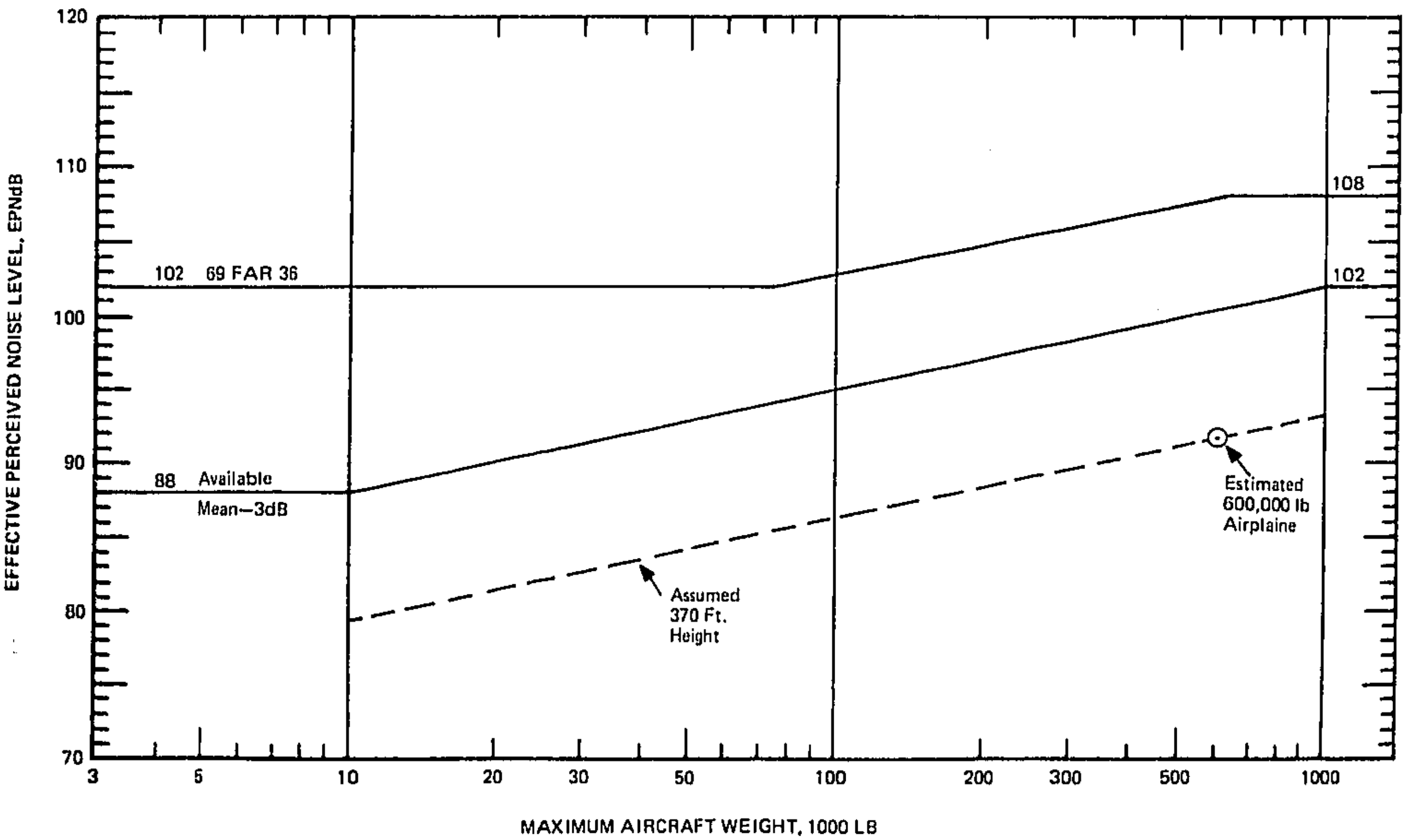


FIGURE 15. NONPROPULSIVE NOISE FLOOR FOR AERODYNAMICALLY CLEAN AIRPLANES.
(c) APPROACH.

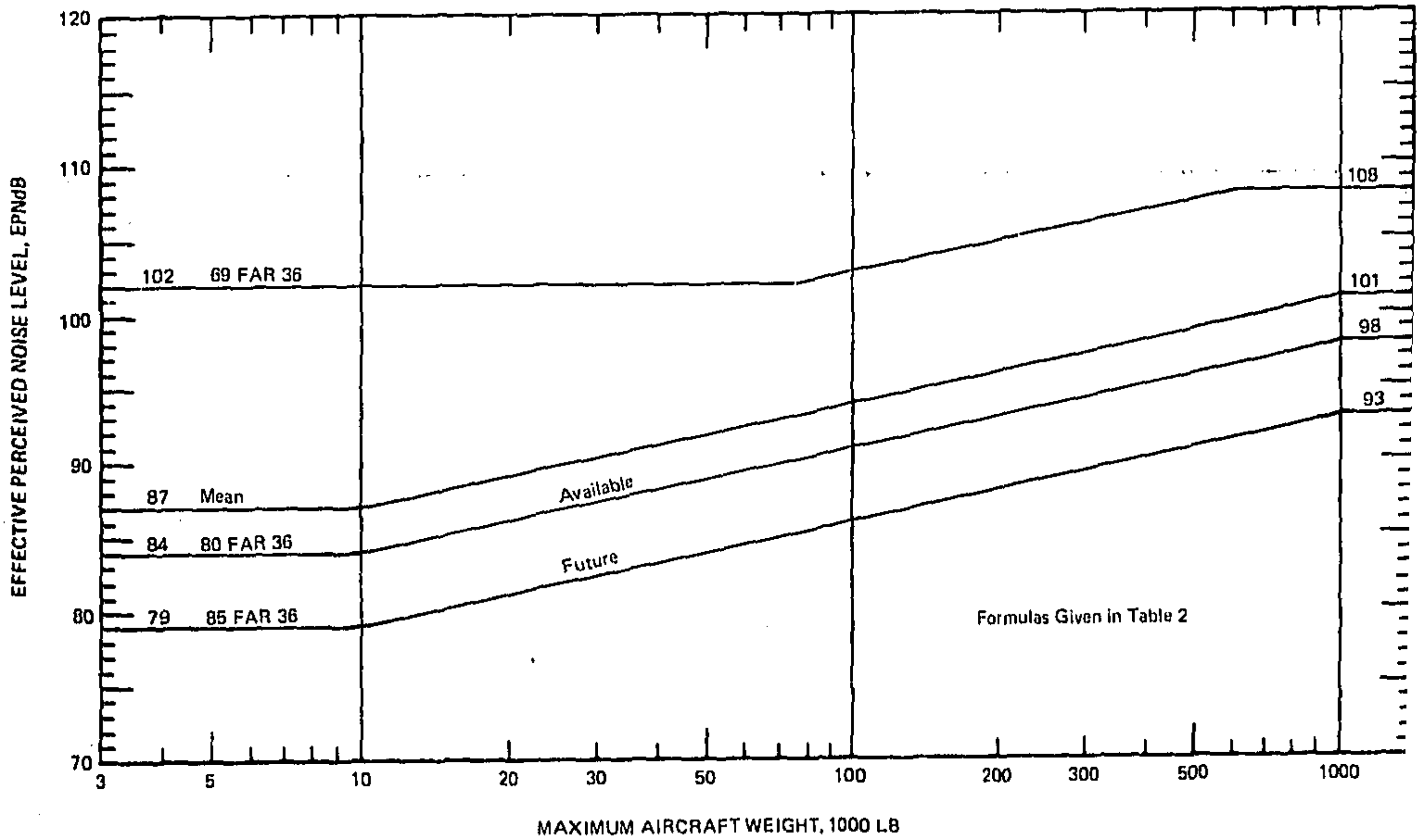


FIGURE 16. COMPLIANCE NOISE LEVELS FOR AVAILABLE AND FUTURE TECHNOLOGY AIRPLANES.
(a) SIDELINE AT 0.25 NAUTICAL MILE (463 METERS).

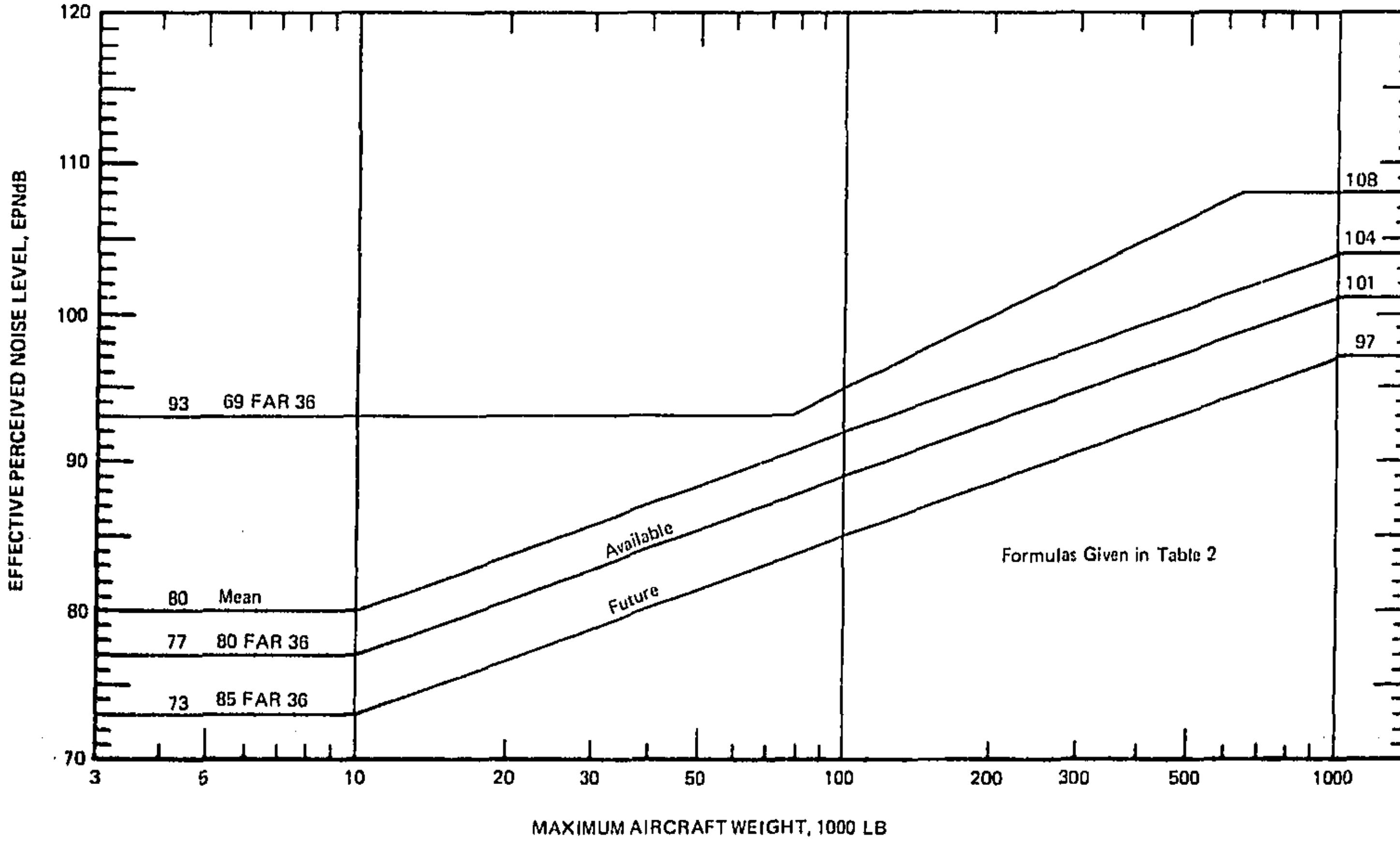


FIGURE 16. COMPLIANCE NOISE LEVELS FOR AVAILABLE AND FUTURE TECHNOLOGY AIRPLANES.
(b) TAKEOFF AT 3.5 NAUTICAL MILES (6,482 METERS).

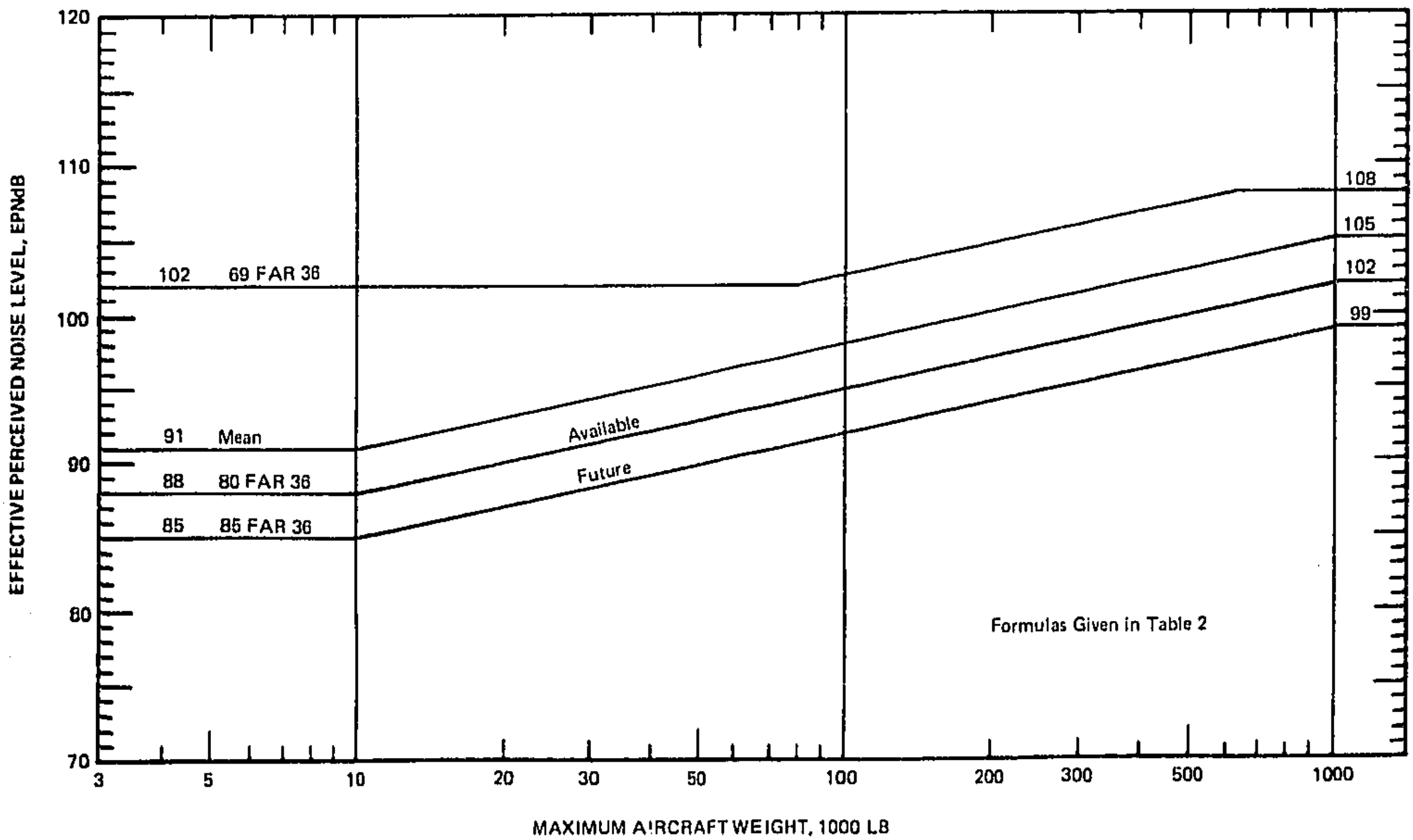


FIGURE 16. COMPLIANCE NOISE LEVELS FOR AVAILABLE AND FUTURE TECHNOLOGY AIRPLANES.
(c) APPROACH AT 1.0 NAUTICAL MILE (1,852 METERS).

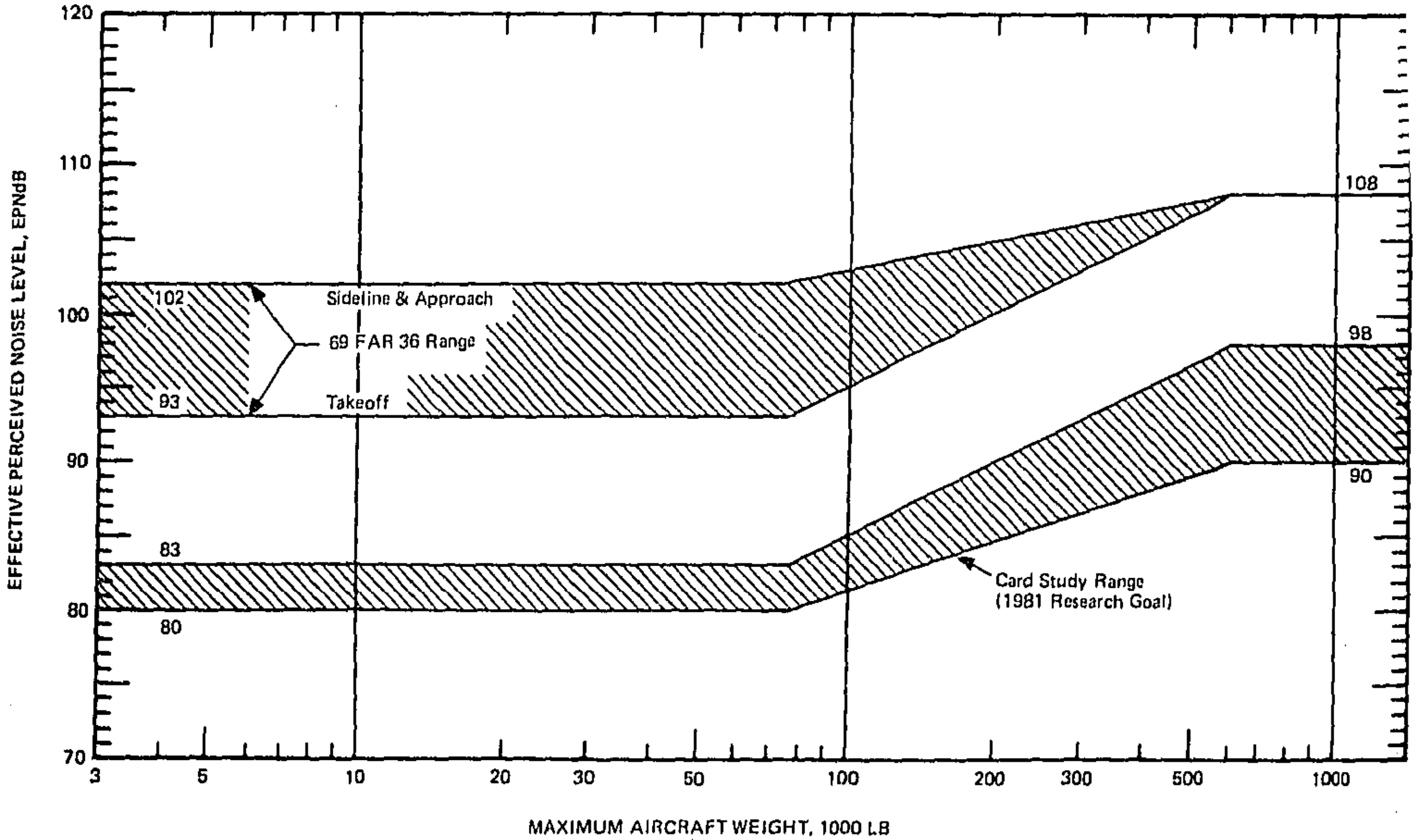


FIGURE 17. RANGE OF COMPLIANCE NOISE LEVELS FOR SIDELINE, TAKEOFF, AND APPROACH RECOMMENDED BY CARD STUDY:
(a) COMPARED WITH 69 FAR 36.

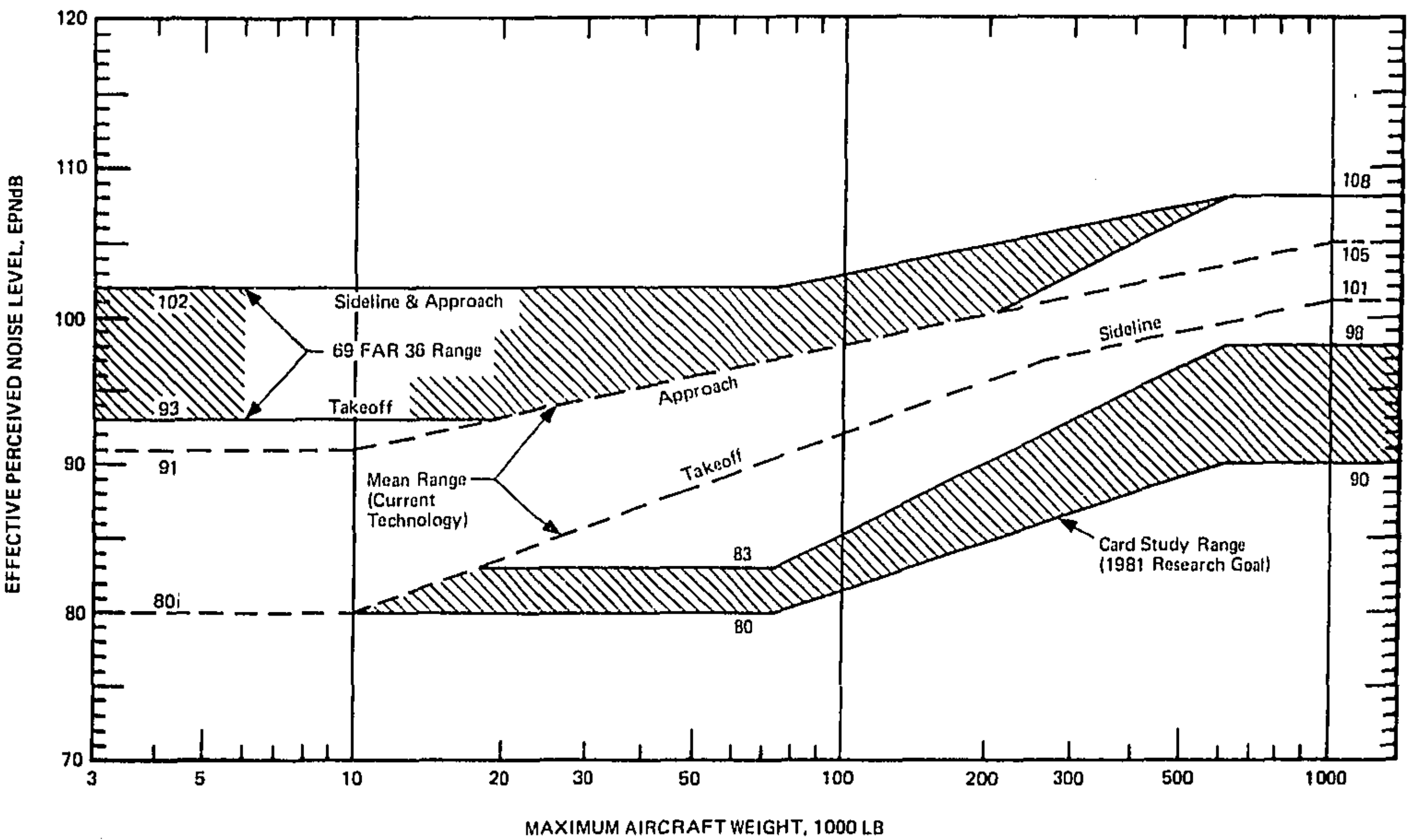


FIGURE 17. RANGE OF COMPLIANCE NOISE LEVELS FOR SIDELINE, TAKEOFF, AND APPROACH RECOMMENDED BY CARD STUDY:
(b) COMPARED WITH MEAN LEVELS OF 17 AIRPLANE SAMPLE.

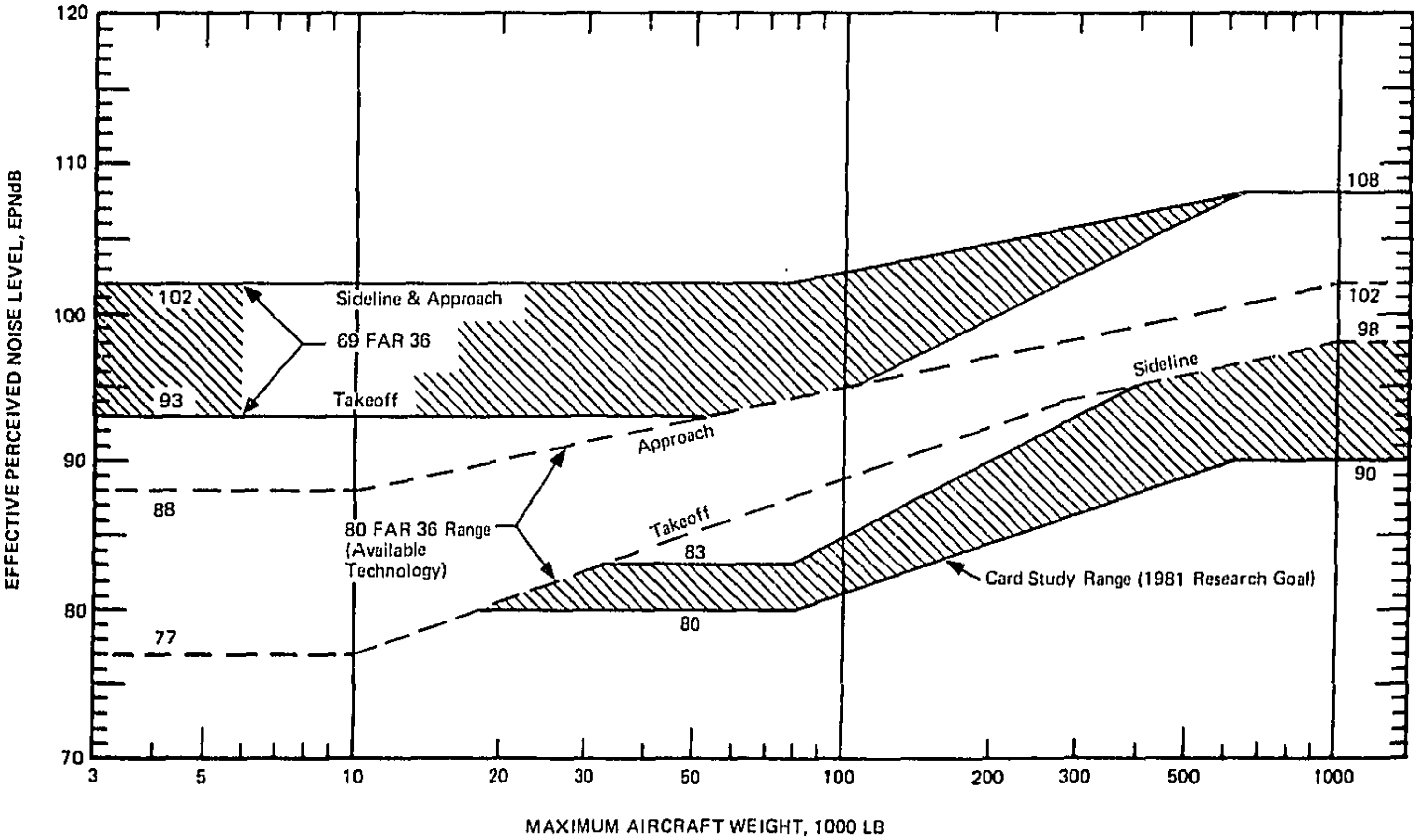


FIGURE 17. RANGE OF COMPLIANCE NOISE LEVELS FOR SIDELINE, TAKEOFF, AND APPROACH RECOMMENDED BY CARD STUDY:
(c) COMPARED WITH 80 FAR 36.

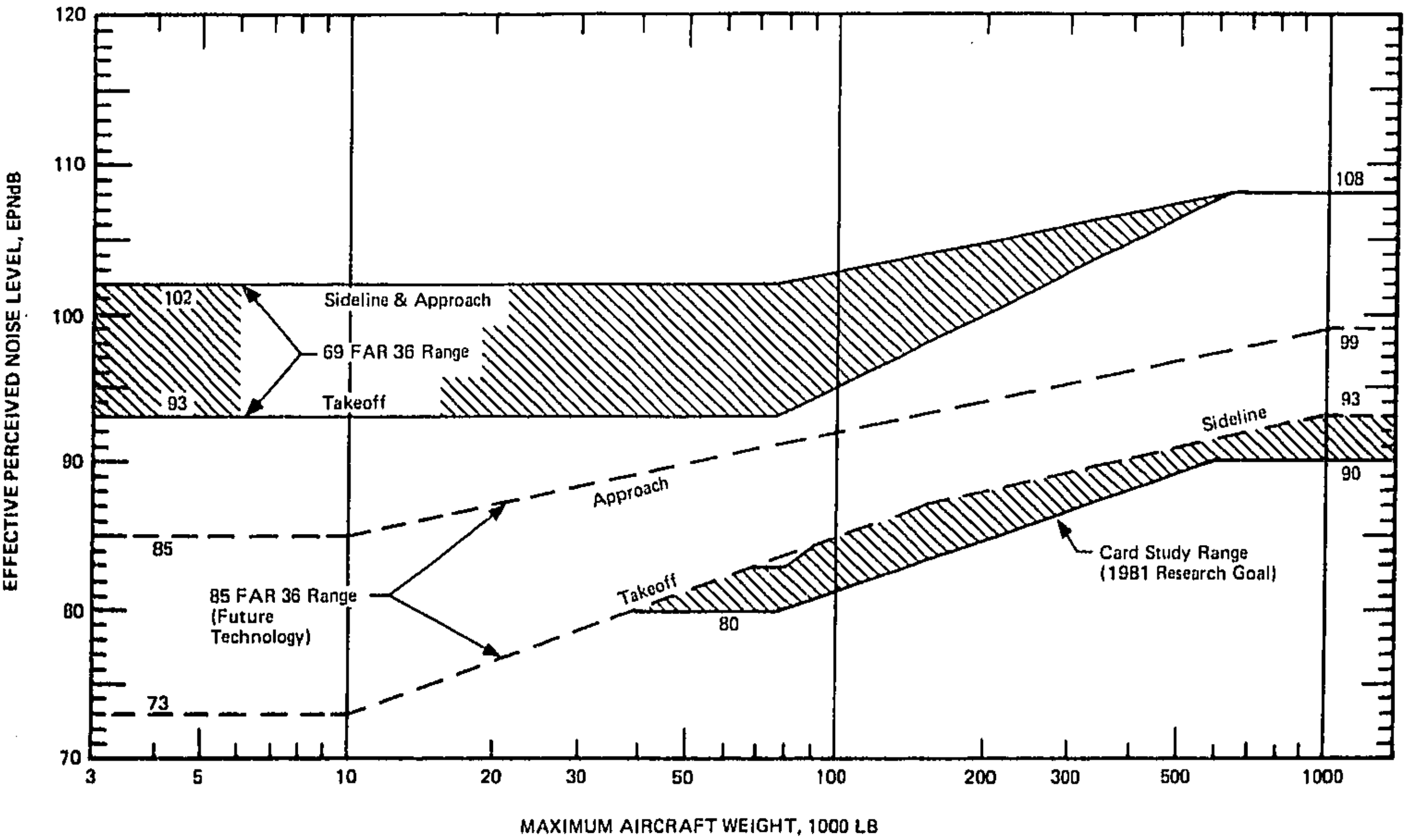


FIGURE 17. RANGE OF COMPLIANCE NOISE LEVELS FOR SIDELINE, TAKEOFF, AND APPROACH RECOMMENDED BY CARD STUDY:
(d) COMPARED WITH 85 FAR 36.

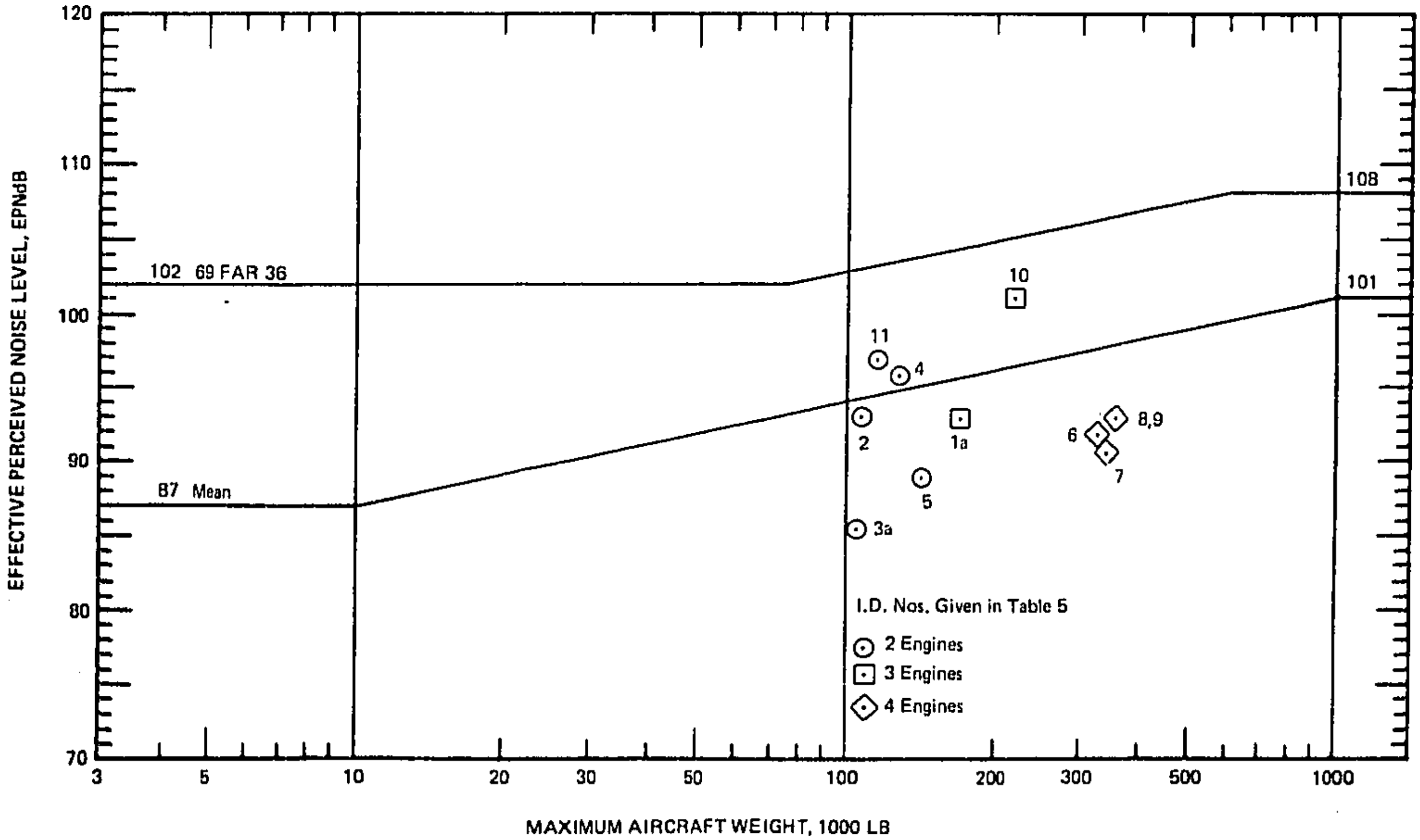


FIGURE 18. PREDICTED NOISE LEVELS FOR MAJOR ACOUSTICAL CHANGE AIRPLANES.
(a) SIDELINE.

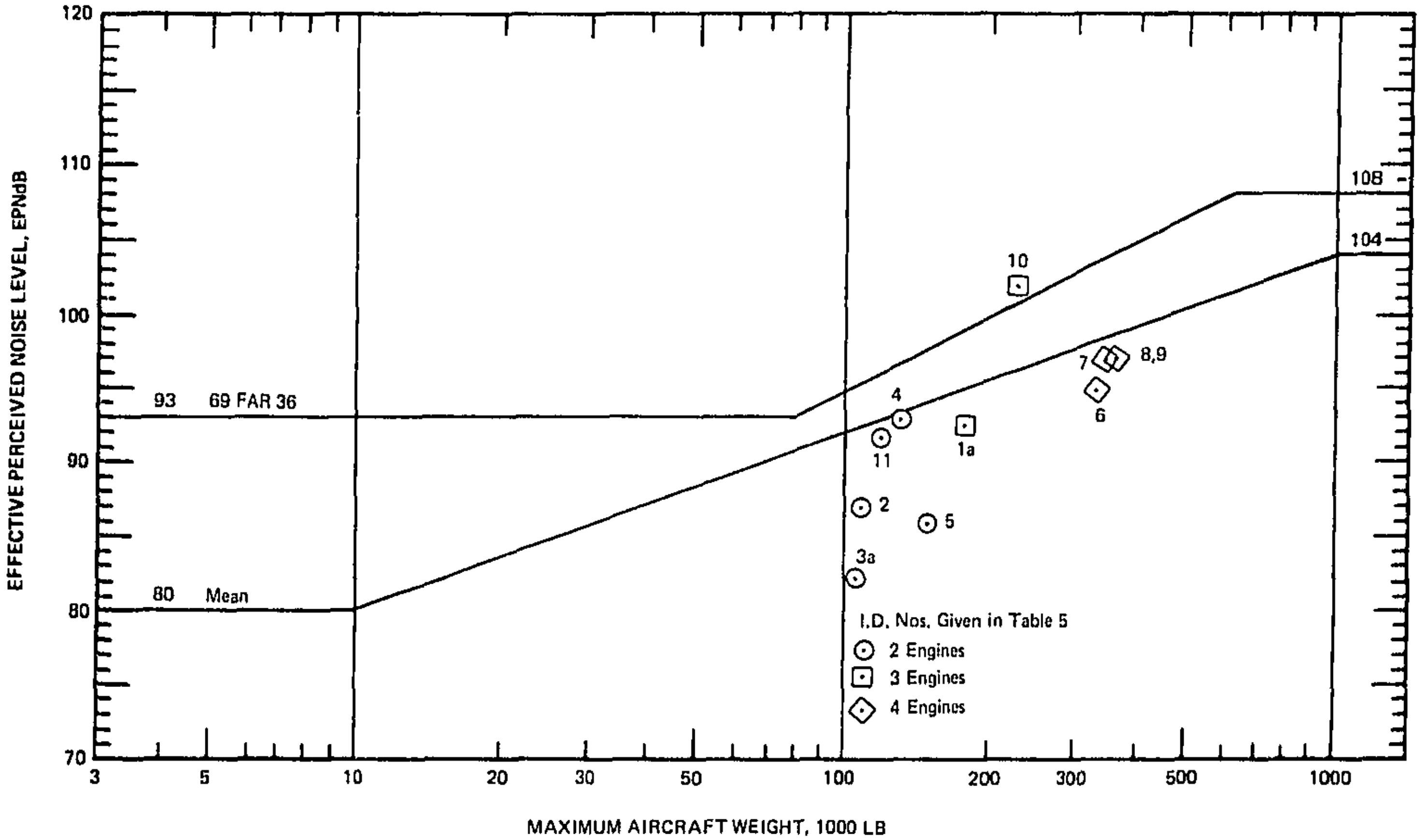


FIGURE 18. PREDICTED NOISE LEVELS FOR MAJOR ACOUSTICAL CHANGE AIRPLANES.
(b) TAKEOFF.

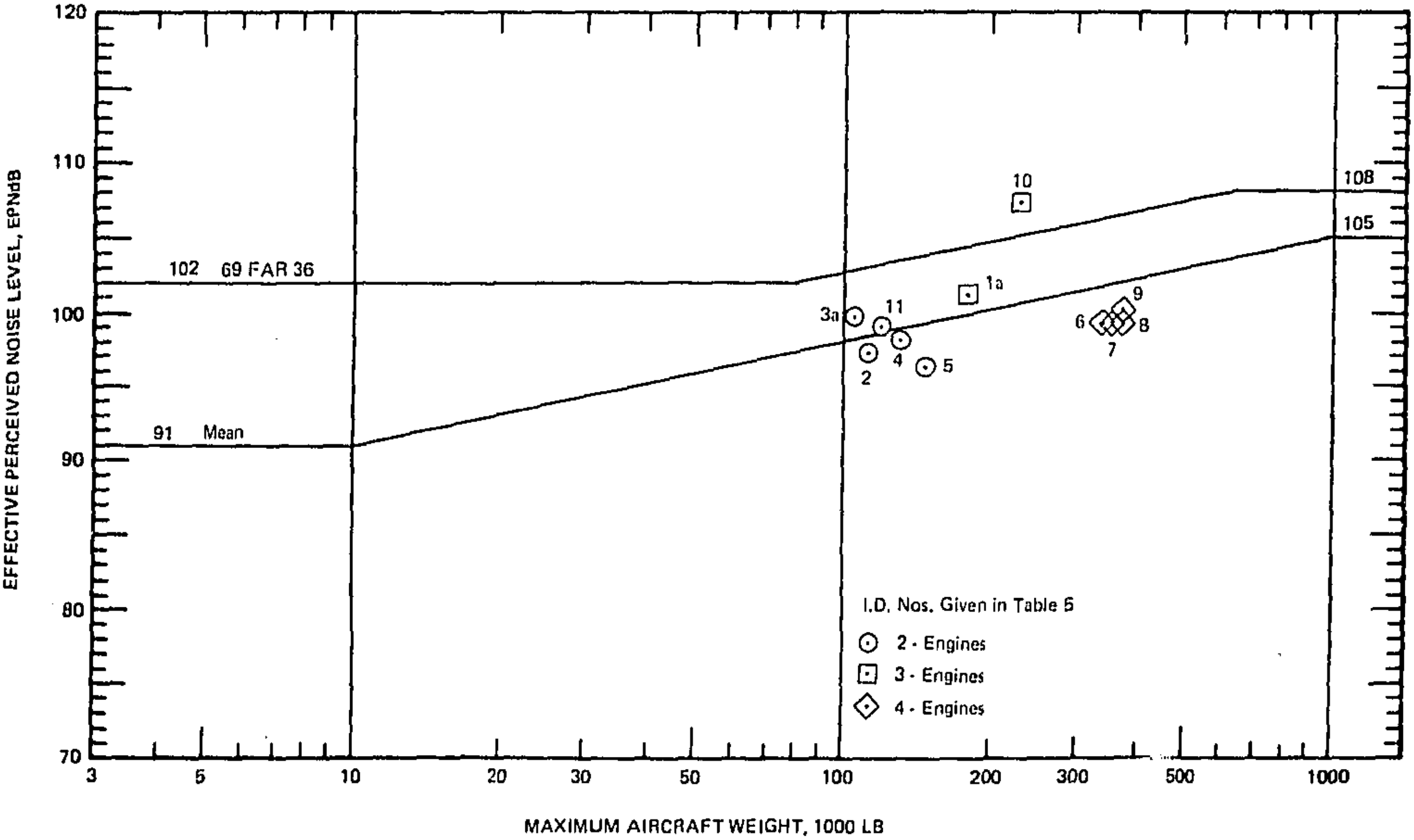


FIGURE 18. PREDICTED NOISE LEVELS FOR MAJOR ACOUSTICAL CHANGE AIRPLANES.
(c) APPROACH.

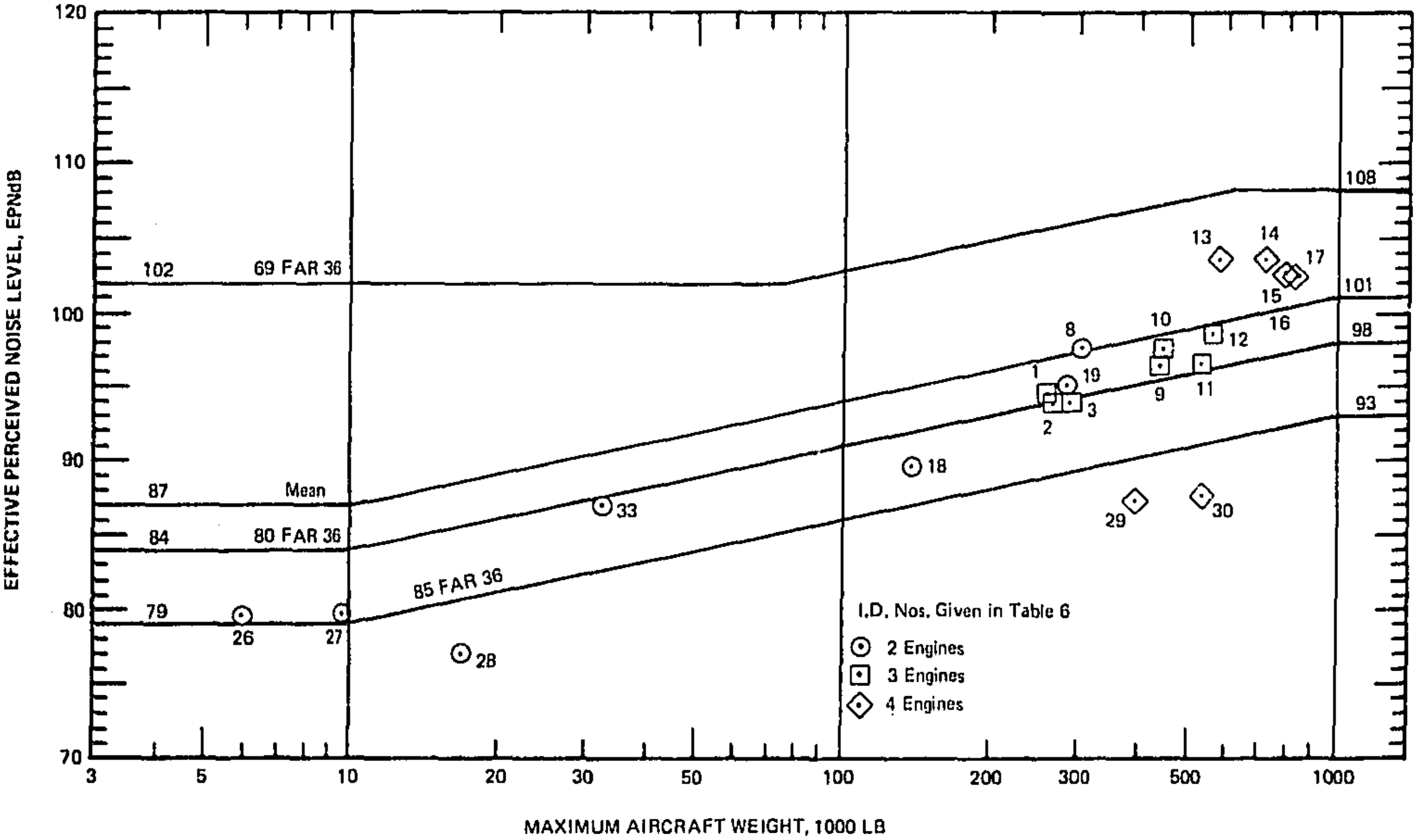


FIGURE 19. PREDICTED NOISE LEVELS FOR NEW TYPE DESIGN AIRPLANES.
(a) SIDELINE.

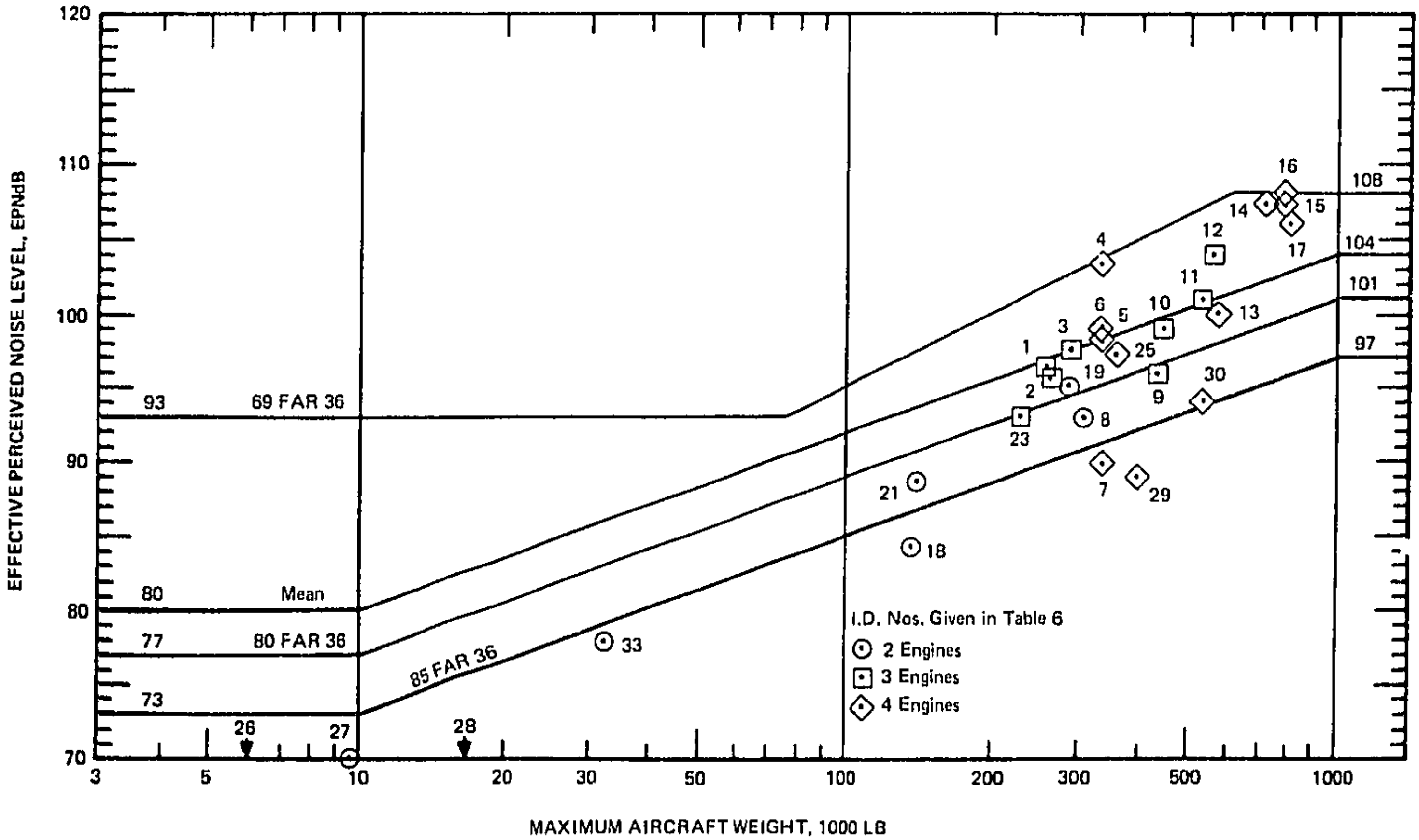


FIGURE 19. PREDICTED NOISE LEVELS FOR NEW TYPE DESIGN AIRPLANES.
(b) TAKEOFF.

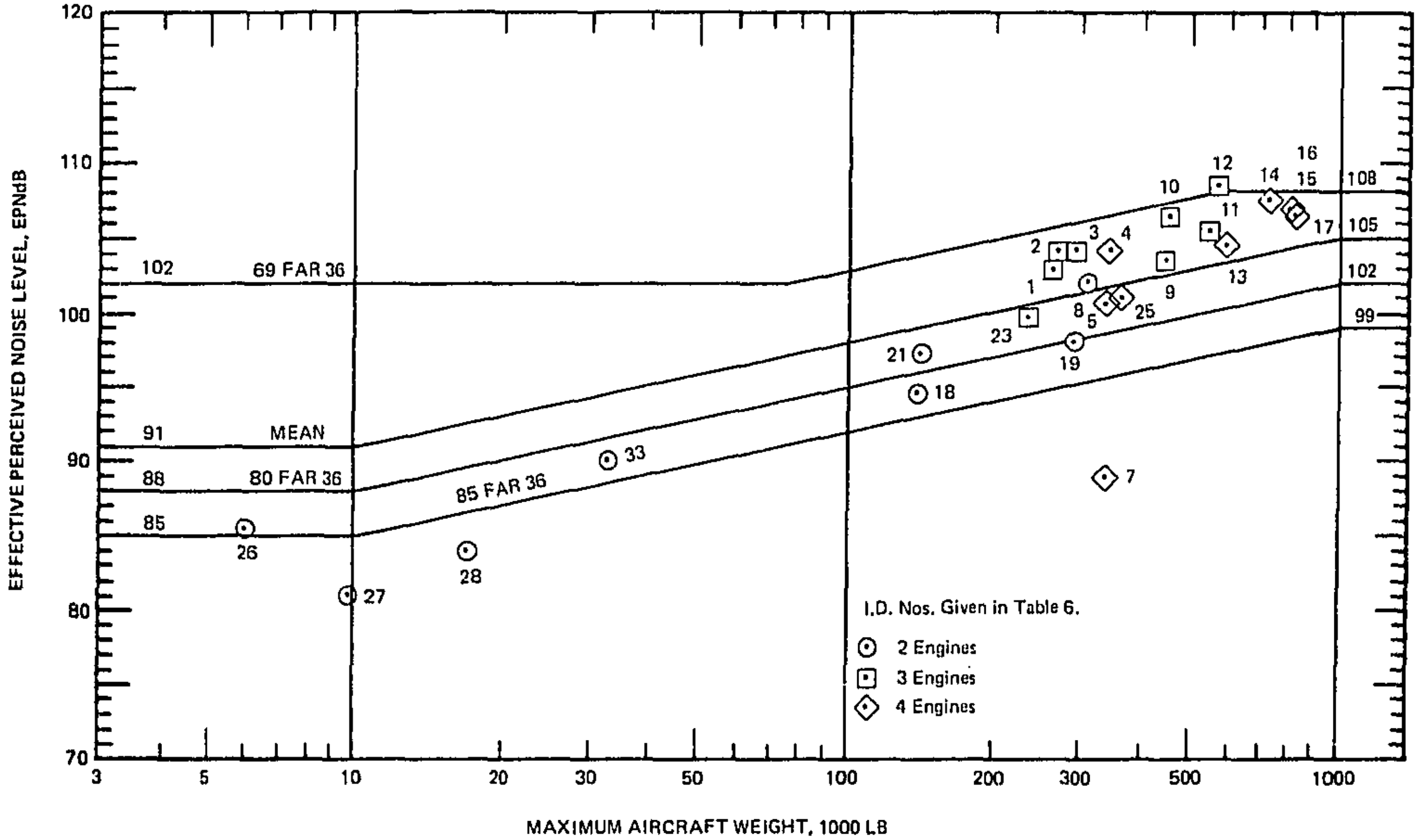
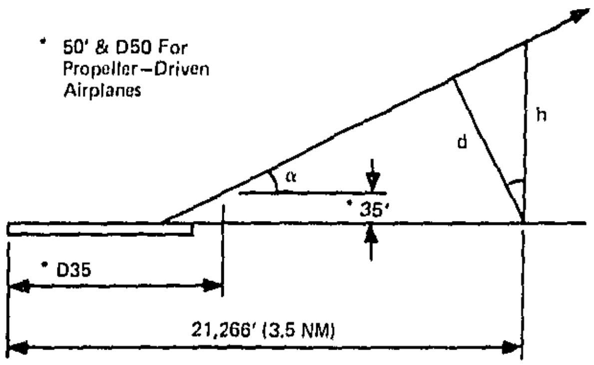
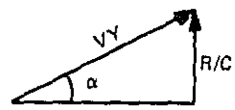


FIGURE 19. PREDICTED NOISE LEVELS FOR NEW TYPE DESIGN AIRPLANES.
(c) APPROACH.



Flight Profile @ Takeoff



Velocity Vectors @ Takeoff

$$\sin \alpha = \frac{R/C}{VY}$$

$$\operatorname{Tan} \alpha = \frac{h - 35}{21266 - D35}$$

- HEIGHT

$$h = (21266 - D35)\ \operatorname{Tan} \alpha + 35$$

- CLOSEST POINT OF APPROACH (CPA)

$$d = h \cos \alpha = \left[(21266 - D35)\ \operatorname{Tan} \alpha + 35 \right] \cos \alpha$$

- CLIMB CORRECTION REFERRED TO 1000 FT

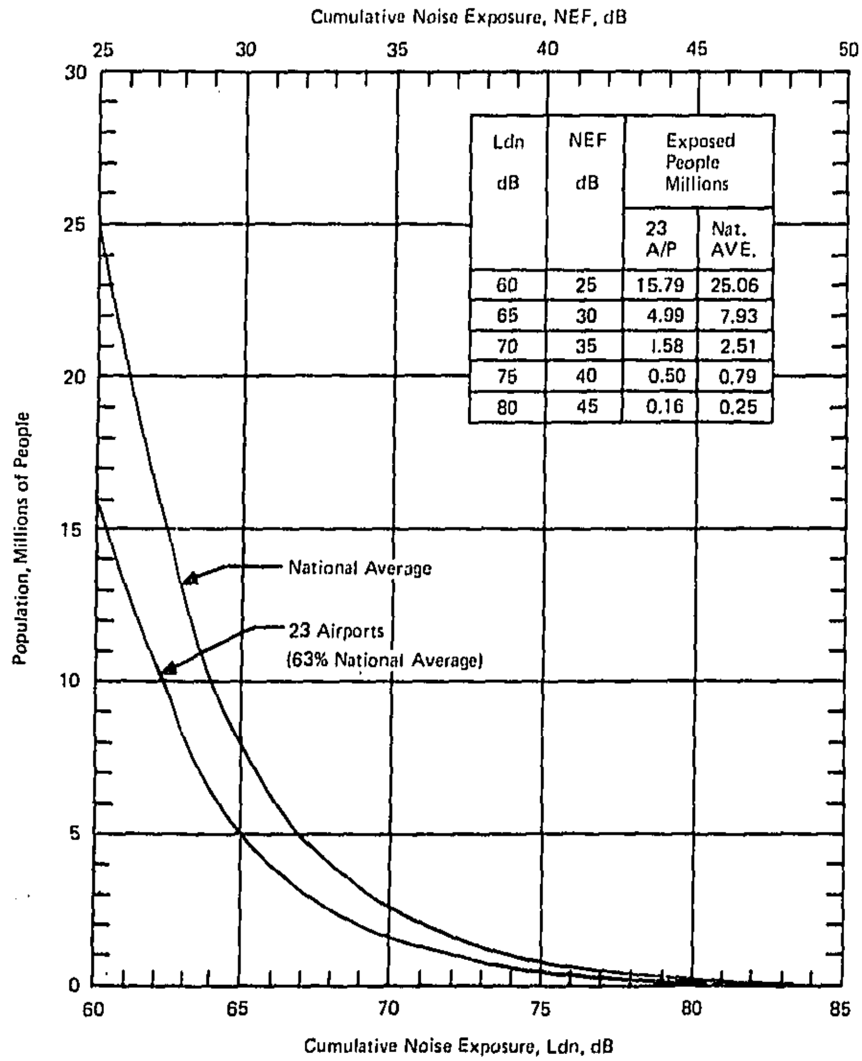
$$C = 20 \log \frac{1000}{d} = 60 - 20 \log d$$

$$= 60 - 20 \log \left[(21266 - D35)\ \sin \alpha + 35 \cos \alpha \right]$$

FOR SMALL α

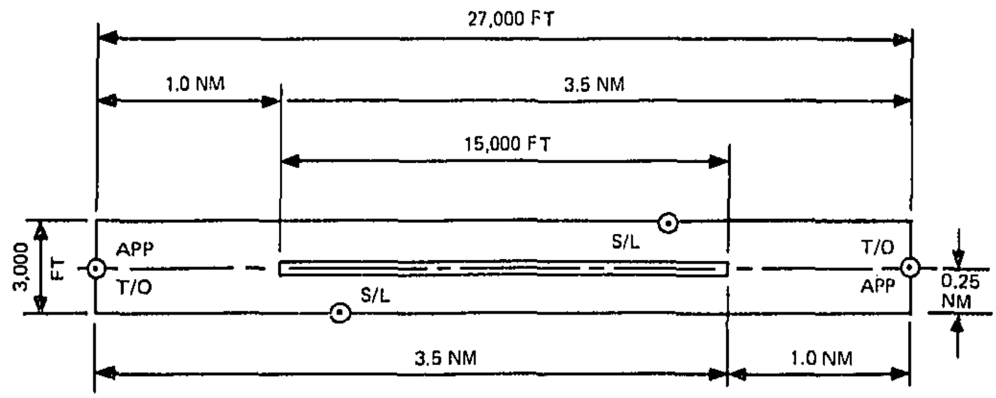
$$C \cong 60 - 20 \log \left[(21266 - D35)\ \sin \alpha + 35 \right]$$

FIGURE 20. CLIMB CORRECTION FOR HORIZONTAL FLIGHT PROCEDURE.

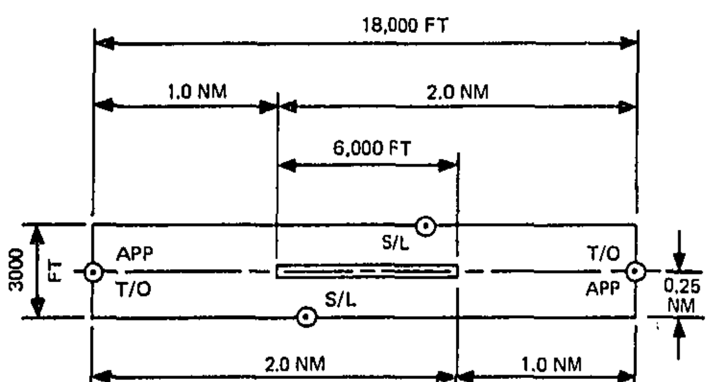


Ldn dB	NEF dB	Exposed People Millions 23 A/P	Exposed People Millions Nat. AVE.
60	25	15.79	25.06
65	30	4.99	7.93
70	35	1.58	2.51
75	40	0.50	0.79
80	45	0.16	0.25

FIGURE 21. NUMBER OF PEOPLE IMPACTED BY AIRCRAFT NOISE: 1972 BASELINE.

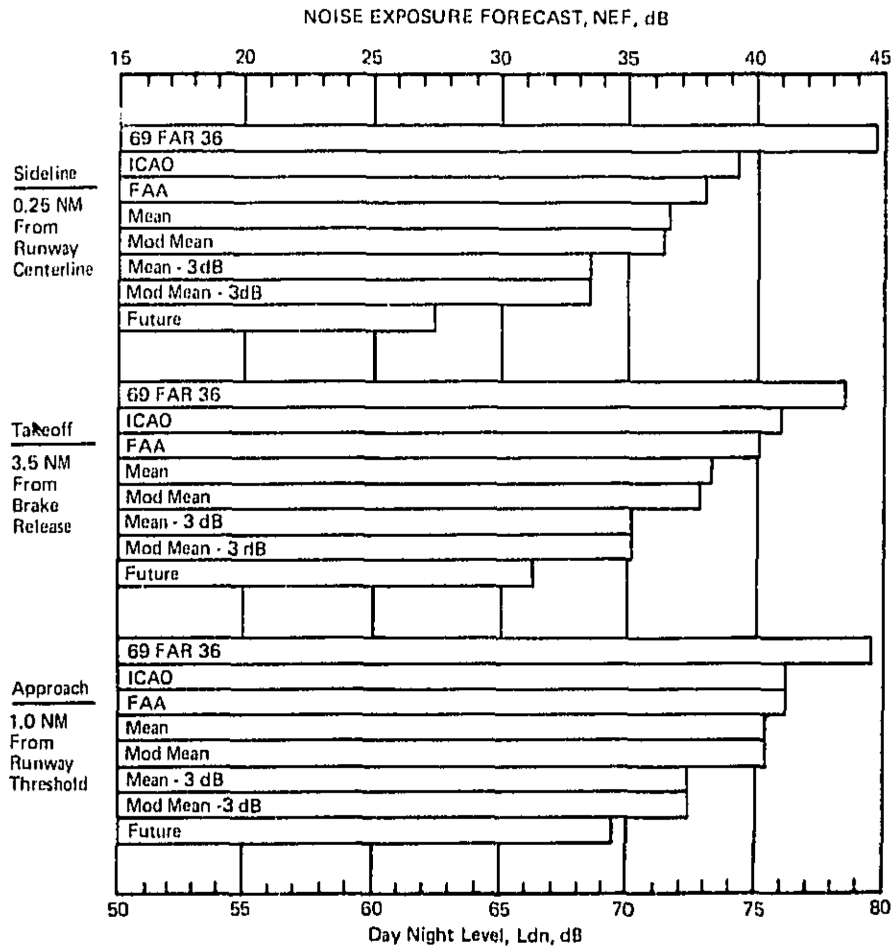


(a) Large Air-Carrier Airport



(b) General Aviation Airport

FIGURE 22. ONE-WAY RUNWAY AIRPORTS FOR INDICATORS OF NOISE IMPACT.



Aircraft Mix		A
No. Eng.	Max. Wt. KLB	No. T/O & App. Ops/Day
4	800	140
3	500	89
3	200	81
2	300	30
2	150	34
2	25	46

Total Ops = 2 x 420 = 840 Per Day (0700 - 2200)

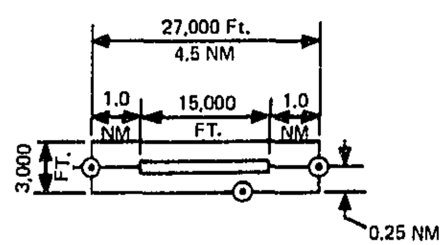
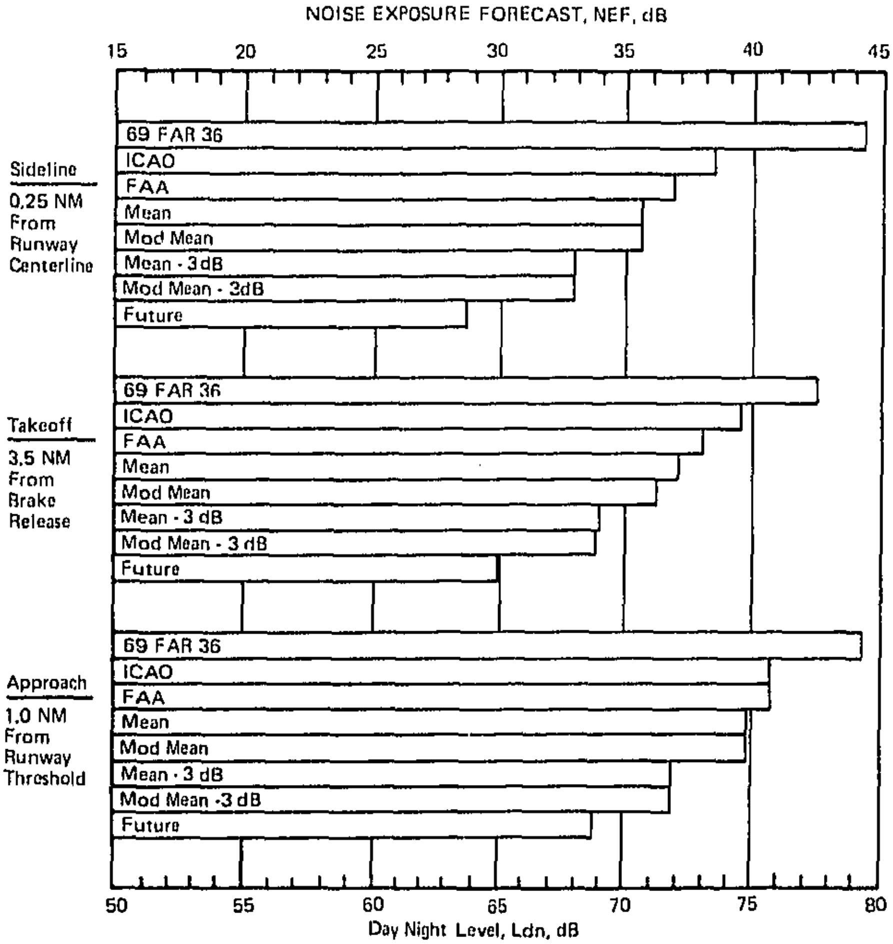


FIGURE 23. CUMULATIVE NOISE EXPOSURE AT ONE-WAY RUNWAY FOR LARGE AIR CARRIER AIRPORT: 840 OPERATIONS WITH VARIABLE PERCENT MIX.
(a) AIRCRAFT MIX A. (33.3% 4-ENGINE AIRCRAFT).



Aircraft Mix	B	
No. Eng.	Max. Wt. KLB	No. T/O & App. Ops/Day
4	800	70
3	500	70
3	200	70
2	300	70
2	150	70
2	25	70

Total Ops = 2 x 420 = 840 Per Day (0700 - 2200)

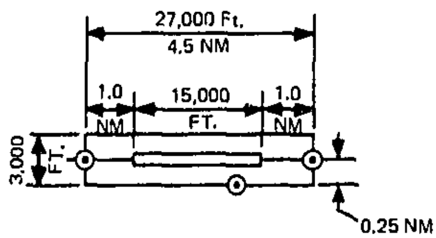
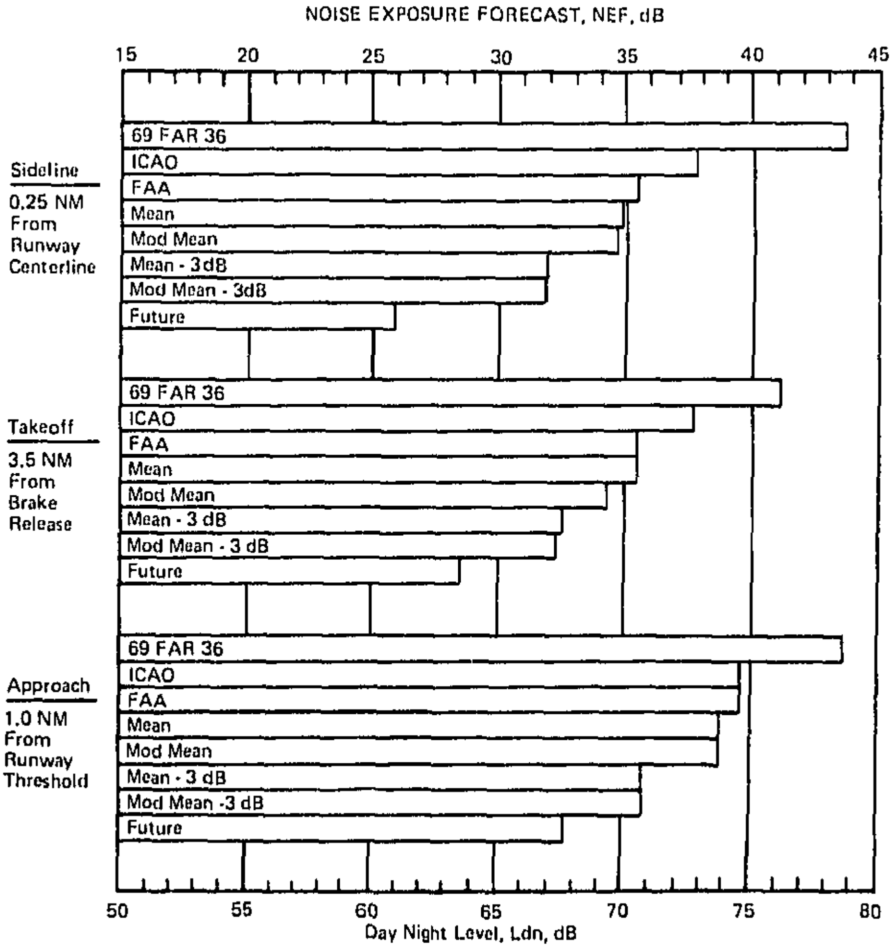


FIGURE 23. CUMULATIVE NOISE EXPOSURE AT ONE-WAY RUNWAY FOR LARGE AIR CARRIER AIRPORT: 840 OPERATIONS WITH VARIABLE PERCENT MIX. (b) AIRCRAFT MIX B. (16.7% 4-ENGINE AIRCRAFT).



Aircraft Mix		C
No. Eng.	Max. Wt. KLB	No. T/O & App. Ops/Day
4	800	30
3	500	60
3	200	60
2	300	90
2	150	90
2	25	90

Total Ops = 2 x 420 = 840 Per Day (0700-2200)

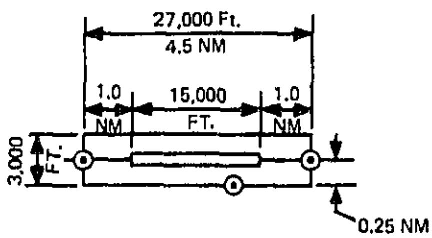
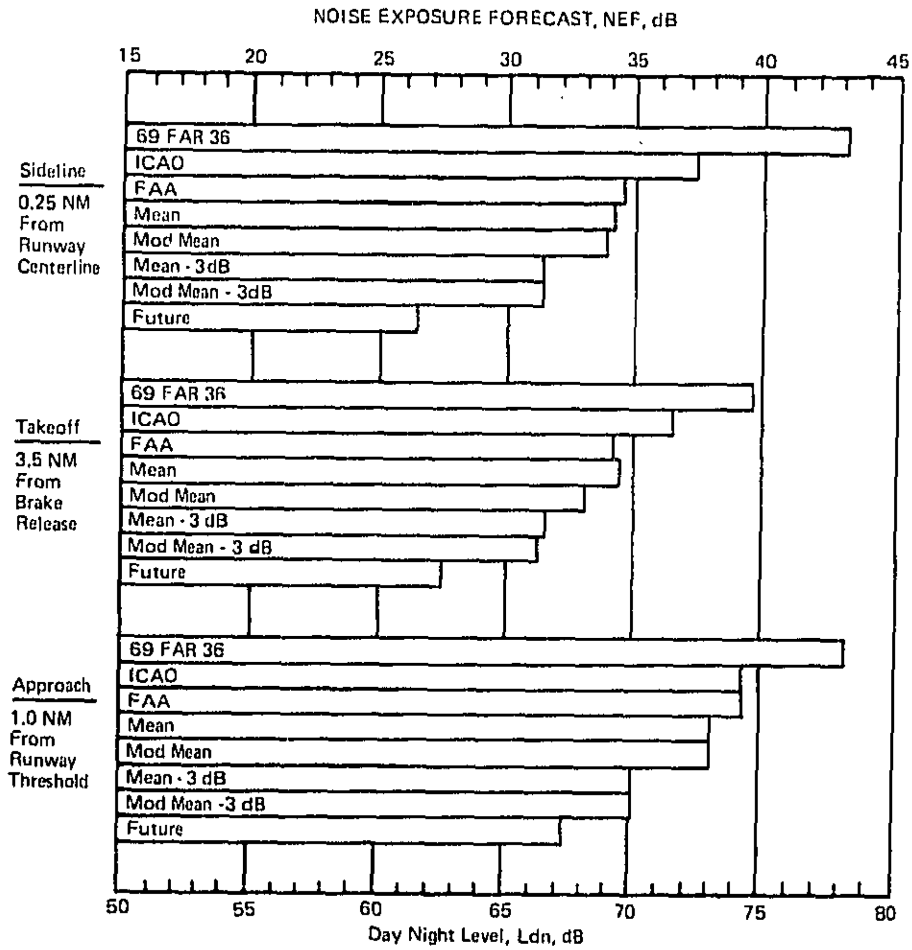


FIGURE 23. CUMULATIVE NOISE EXPOSURE AT ONE-WAY RUNWAY FOR LARGE AIR CARRIER AIRPORT: 840 OPERATIONS WITH VARIABLE PERCENT MIX. (c) AIRCRAFT MIX C. (7.14% 4-ENGINE AIRCRAFT).



Aircraft Mix		D
No. Eng.	Max. Wt. KLB	No. T/O & App. Ops/Day
4	800	20
3	500	40
3	200	60
2	300	80
2	150	100
2	25	120

Total Ops = 2 x 420 = 840 Per Day (0700 - 2200)

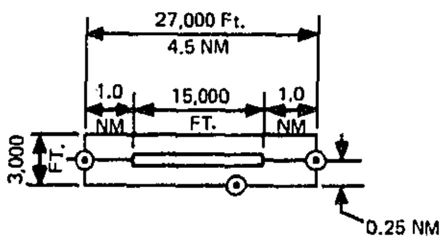
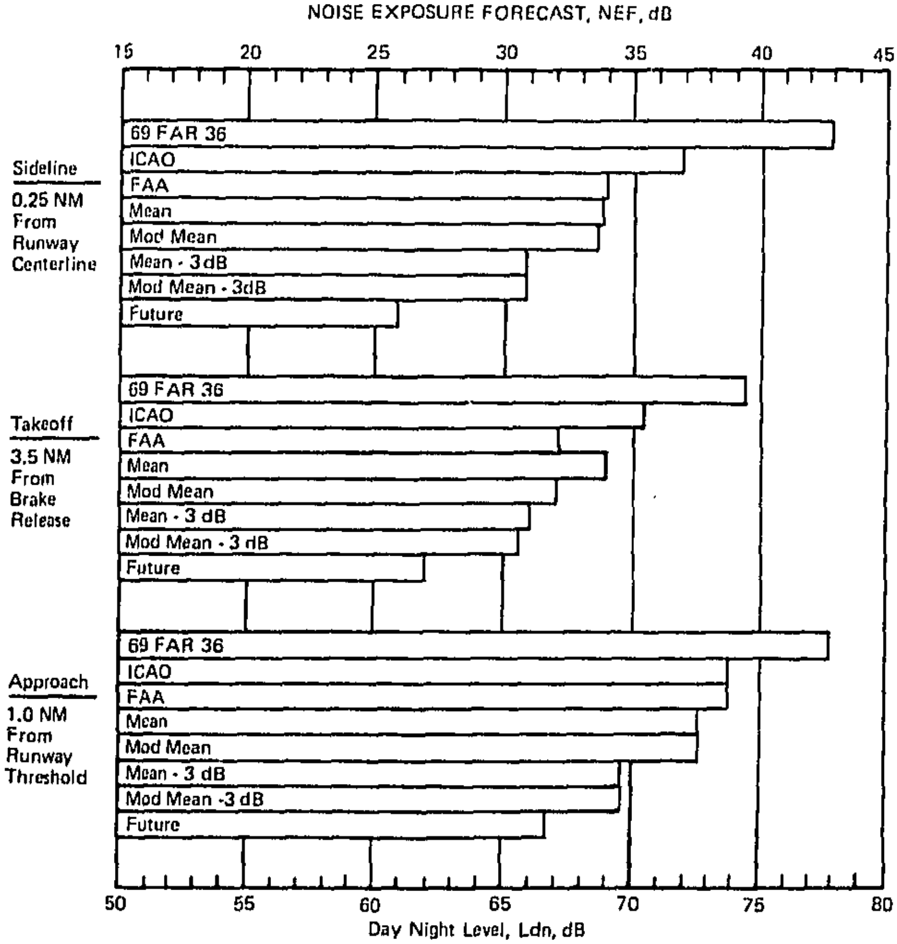


FIGURE 23. CUMULATIVE NOISE EXPOSURE AT ONE-WAY RUNWAY FOR LARGE AIR CARRIER AIRPORT: 840 OPERATIONS WITH VARIABLE PERCENT MIX. (d) AIRCRAFT MIX D. (4.76% 4-ENGINE AIRCRAFT).



Aircraft Mix		E
No. Eng.	Max. Wt. KLB	No. T/O & App. Ops/Day
4	800	0
3	500	50
3	200	65
2	300	85
2	150	100
2	25	120

Total Ops = 2 x 420 = 840 Per Day (0700 - 2200)

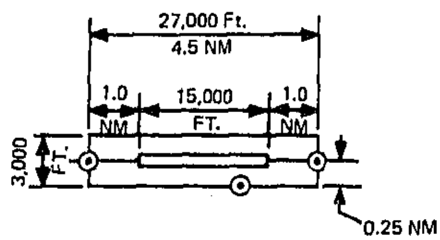
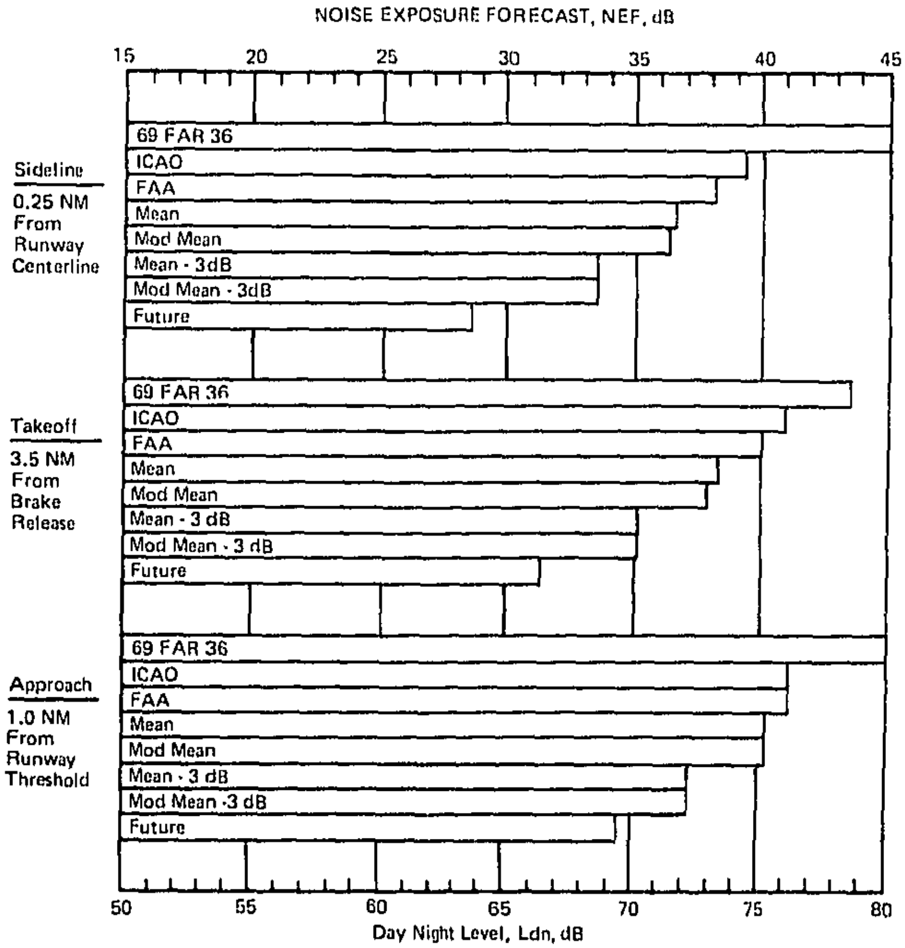


FIGURE 23. CUMULATIVE NOISE EXPOSURE AT ONE-WAY RUNWAY FOR LARGE AIR CARRIER AIRPORT: 840 OPERATIONS WITH VARIABLE PERCENT MIX. (e) AIRCRAFT MIX E. (0% 4-ENGINE AIRCRAFT).



Aircraft Mix		F
No. Eng.	Max. Wt. KLB	No. T/O & App. Ops/Day
4	800	147
3	500	93
3	200	85
2	300	32
2	150	36
2	25	48

Total Ops = 2 x 441 = 882 Per Day (0700 - 2200)

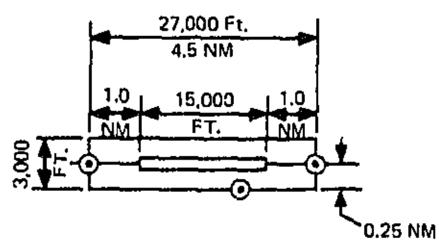
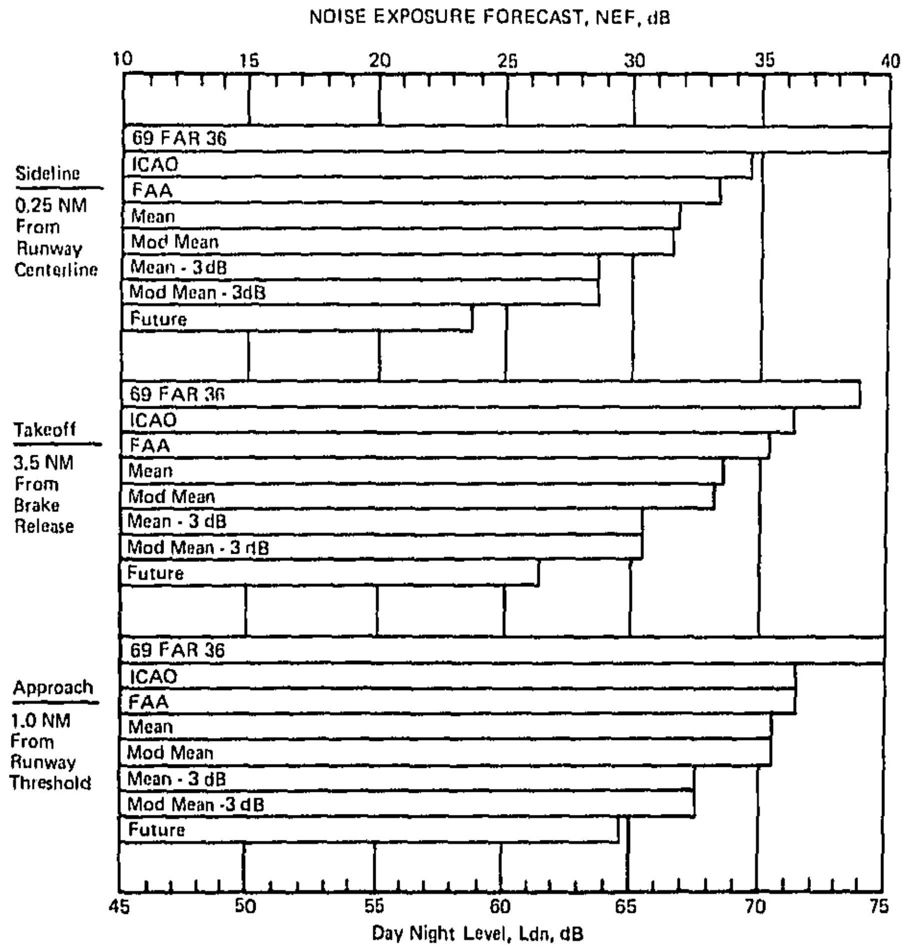


FIGURE 24. CUMULATIVE NOISE EXPOSURE AT ONE-WAY RUNWAY FOR LARGE AIR CARRIER AIRPORT: VARIABLE OPERATIONS WITH CONSTANT PERCENT MIX. (a) 882 OPERATIONS.



Aircraft Mix		G
No. Eng.	Max. Wt. KLB	No. T/O & App. Ops/Day
4	800	46
3	500	30
3	200	27
2	300	10
2	150	12
2	25	15

Total Ops = 2 x 140 = 280 Per Day (0700 - 2200)

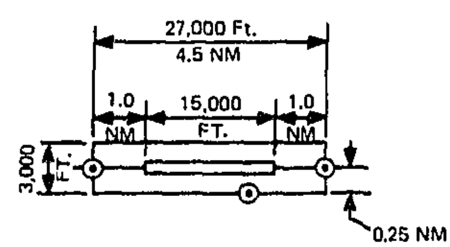
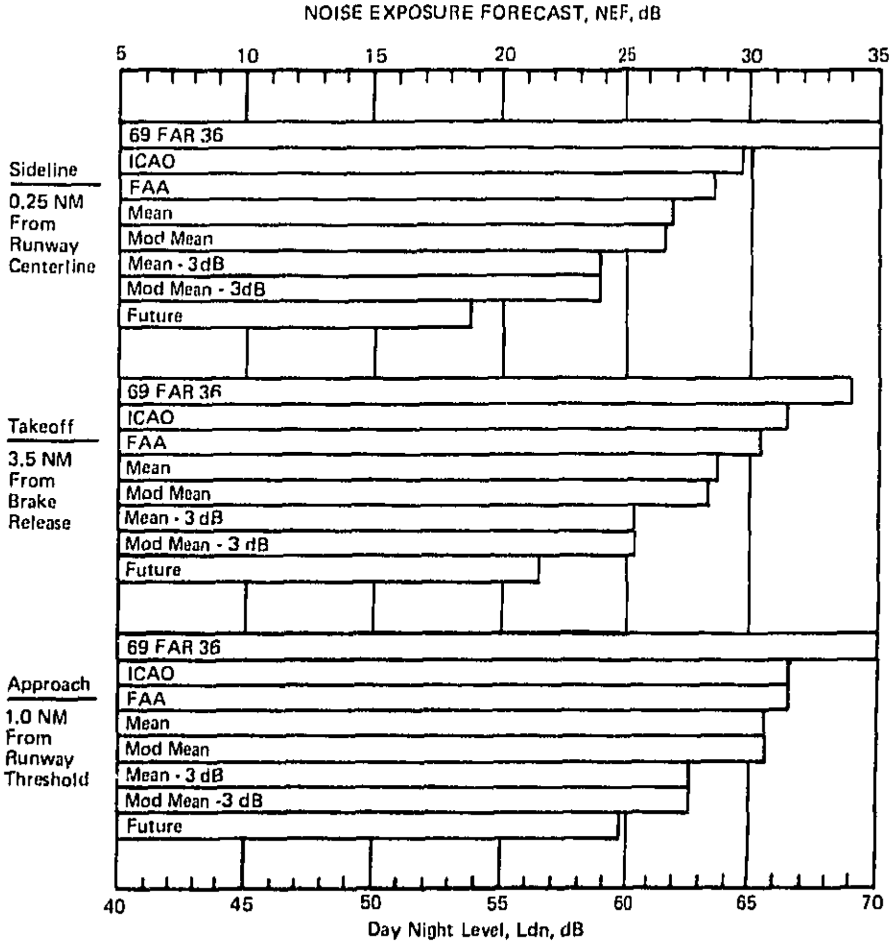


FIGURE 24. CUMULATIVE NOISE EXPOSURE AT ONE-WAY RUNWAY FOR LARGE AIR CARRIER AIRPORT: VARIABLE OPERATIONS WITH CONSTANT PERCENT MIX. (b) 280 OPERATIONS.



Aircraft Mix		H
No. Eng.	Max. Wt. KLB	No. T/O & App. Ops/Day
4	800	14
3	500	9
3	200	9
2	300	3
2	150	4
2	25	5

Total Ops = 2 x 44 = 88 Per Day (0700 - 2200)

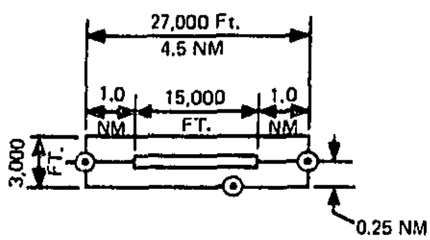
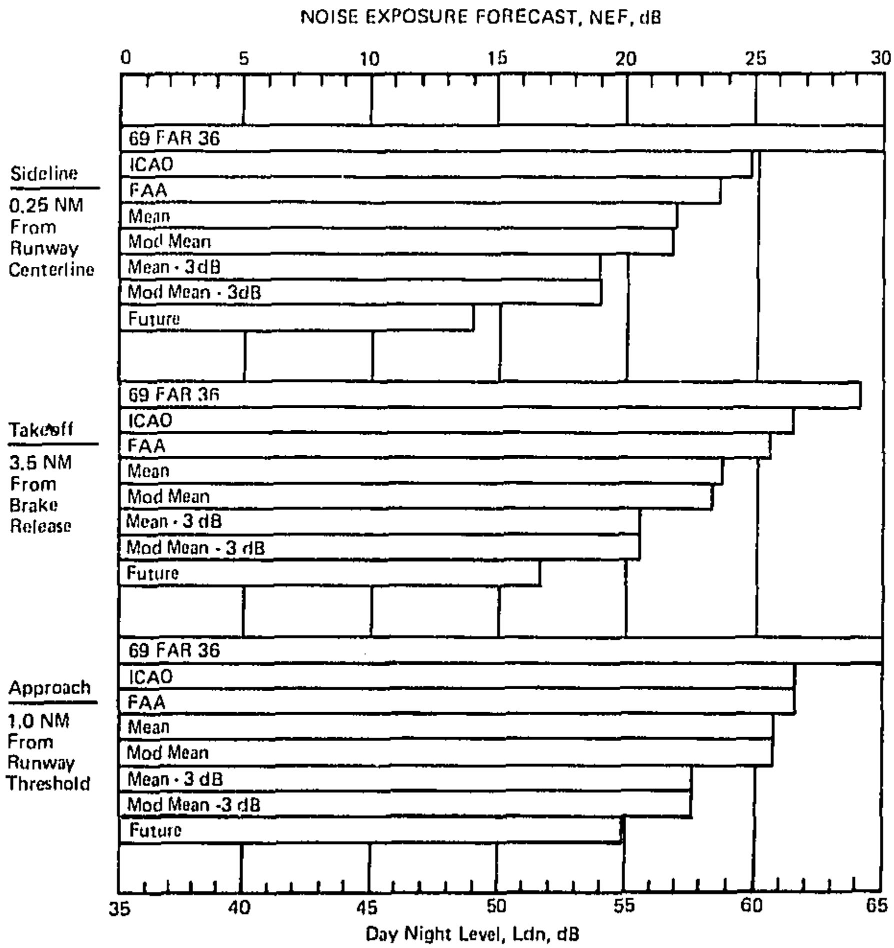


FIGURE 24. CUMULATIVE NOISE EXPOSURE AT ONE-WAY RUNWAY FOR LARGE AIR CARRIER AIRPORT: VARIABLE OPERATIONS WITH CONSTANT PERCENT MIX. (c) 88 OPERATIONS.



Aircraft Mix	I	
No. Eng.	Max. Wt. KLB	No. T/O & App. Ops/Day
4	800	4
3	500	3
3	200	3
2	300	1
2	150	1
2	25	2

Total Ops = 2 x 14 = 28 Per Day (0700 - 2200)

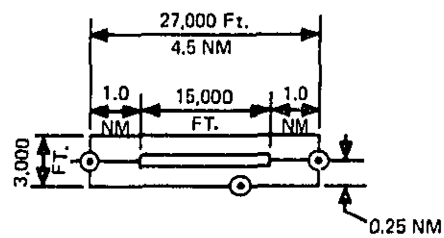
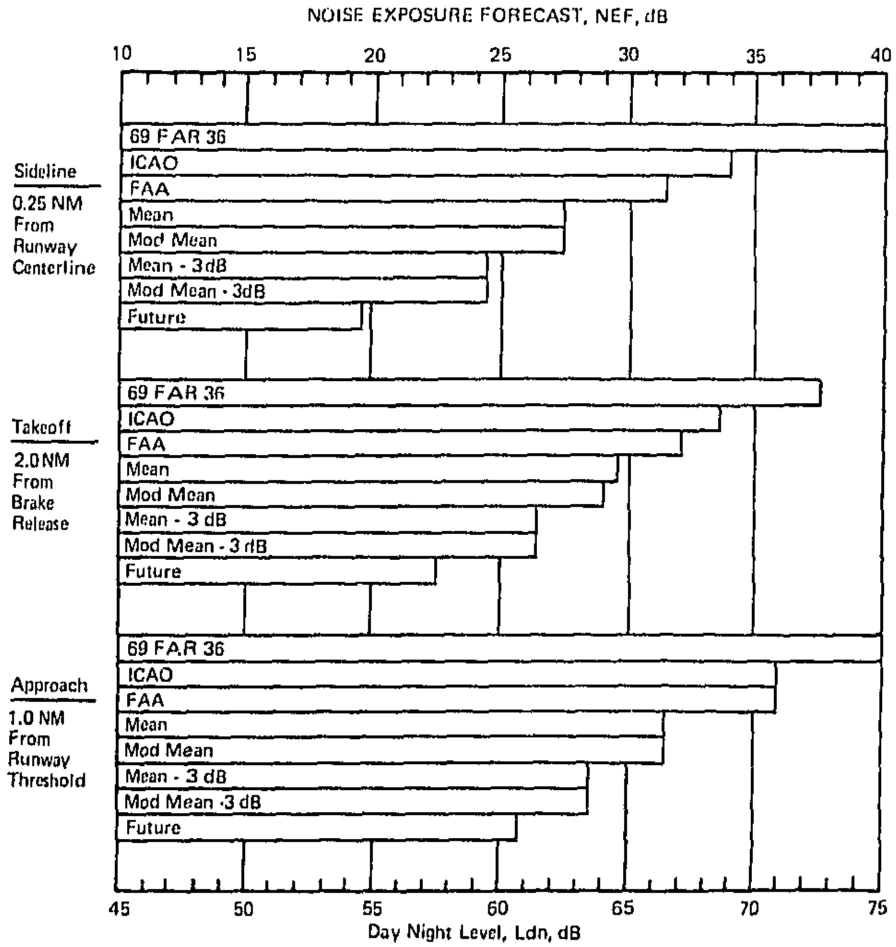
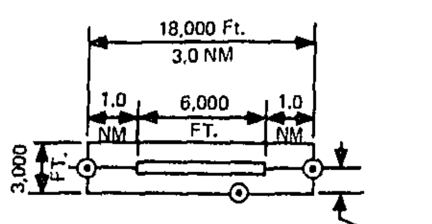


FIGURE 24. CUMULATIVE NOISE EXPOSURE AT ONE-WAY RUNWAY FOR LARGE AIR CARRIER AIRPORT: VARIABLE OPERATIONS WITH CONSTANT PERCENT MIX. (d) 28 OPERATIONS.

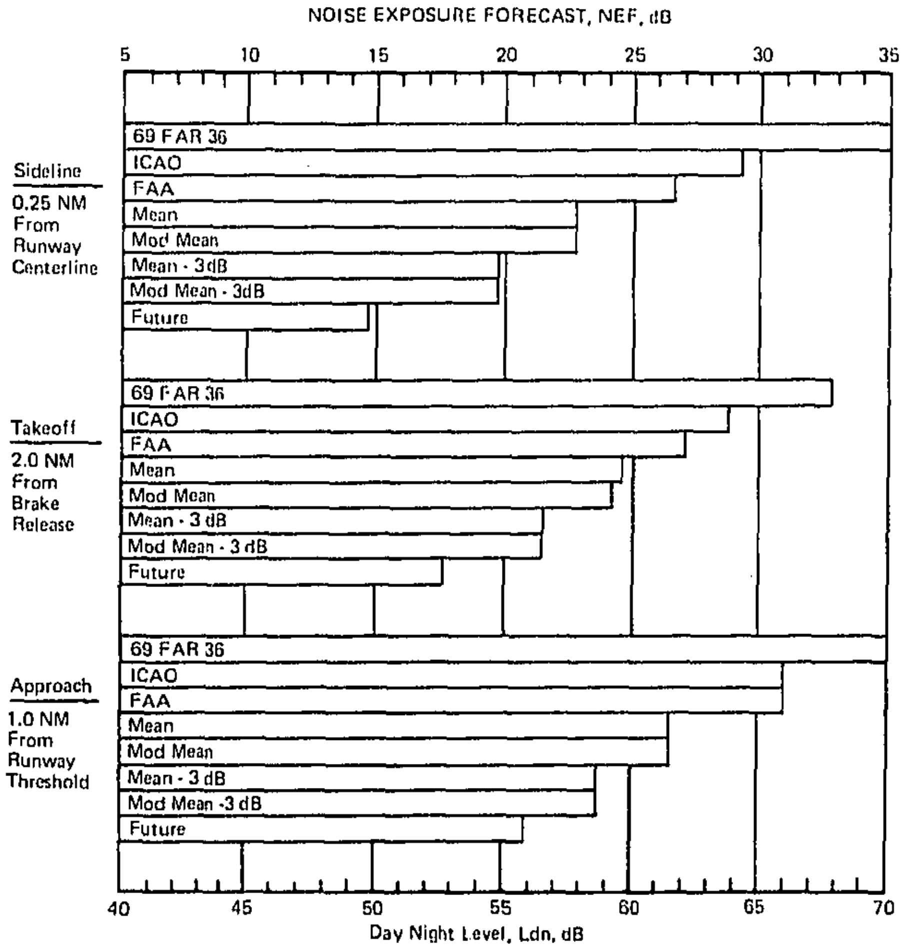


Aircraft Mix		A
No. Eng.	Max. Wt. KLB	No. T/O & App. Ops/Day
2	15	118
2	20	115
2	25	94
4	45	42
2	60	31

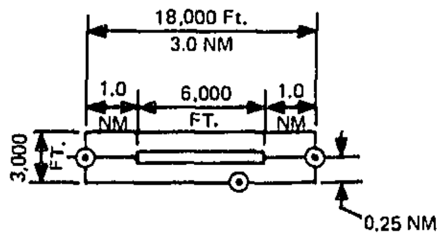


Total Ops = 2 x 400 = 800 Per Day (0700 - 2200)

FIGURE 25. CUMULATIVE NOISE EXPOSURE AT ONE-WAY RUNWAY FOR GENERAL AVIATION AIRPORT: VARIABLE OPERATIONS WITH CONSTANT PERCENT MIX. (a) 800 OPERATIONS.

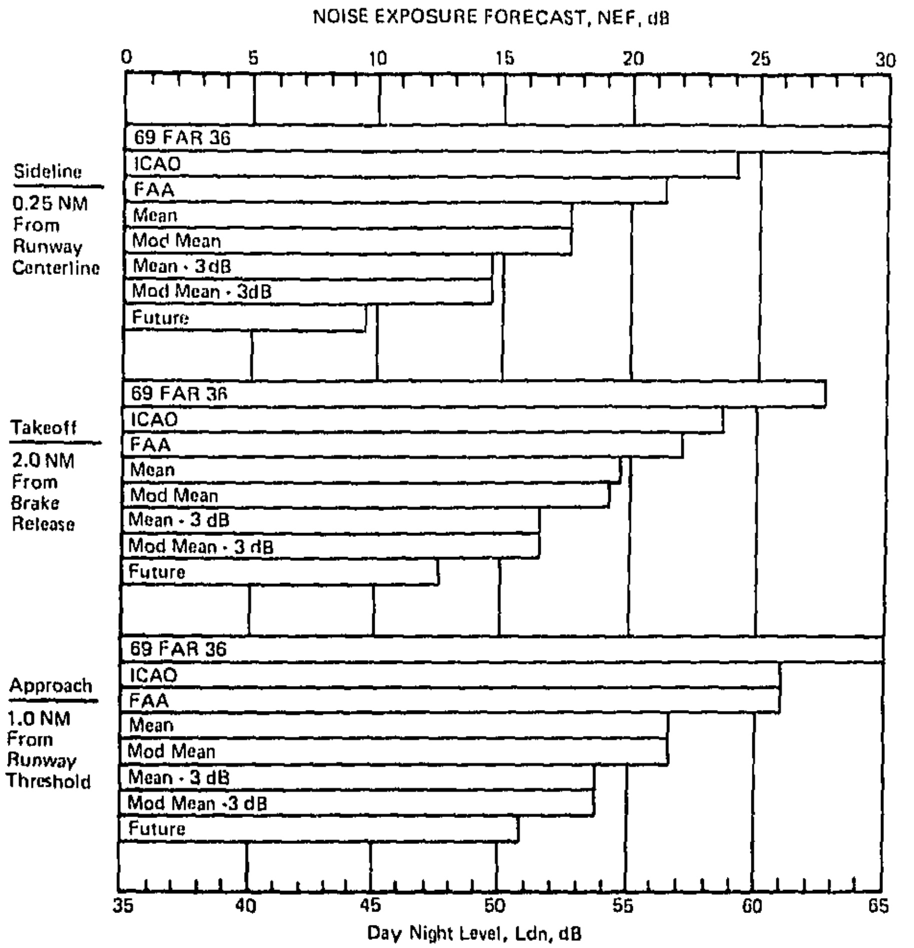


Aircraft Mix		B
No. Eng.	Max. Wt. KLB	No. T/O & App. Ops/Day
2	15	37.0
2	20	37.0
2	25	30.0
4	45	13.0
2	60	10.0

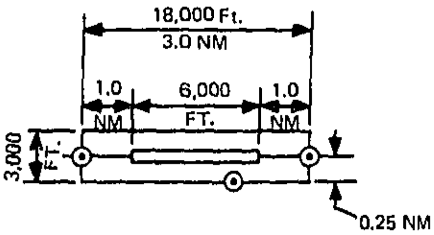


Total Ops = 2 x 127 = 254 Per Day (0700 - 2200)

FIGURE 25. CUMULATIVE NOISE EXPOSURE AT ONE-WAY RUNWAY FOR GENERAL AVIATION AIRPORT: VARIABLE OPERATIONS WITH CONSTANT PERCENT MIX. (b) 254 OPERATIONS.

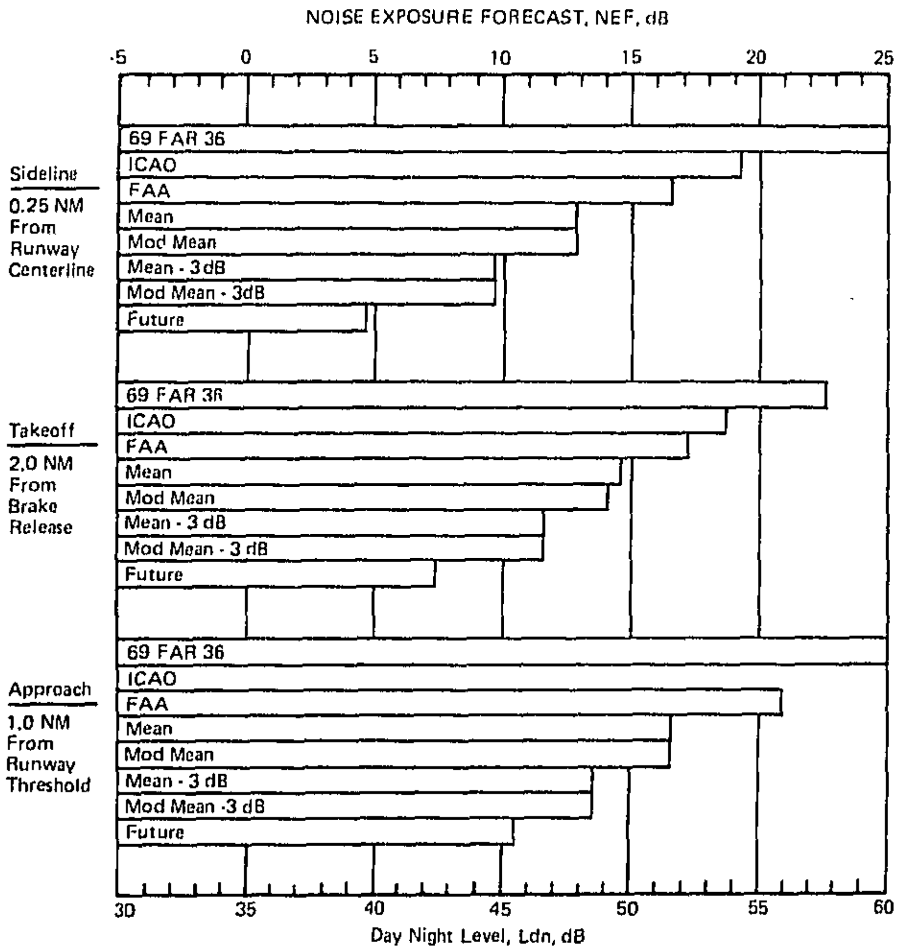


Aircraft Mix		C
No. Eng.	Max. Wt. KLB	No. T/O & App. Ops/Day
2	15	12.0
2	20	12.0
2	25	9.0
4	45	4.0
2	60	3.0

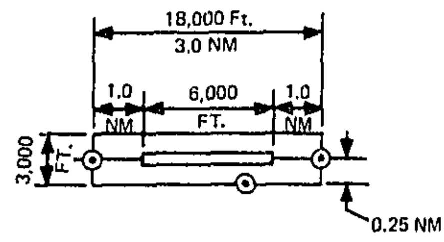


Total Ops = 2 x40.0 = 80 Per Day (0700 - 2200)

FIGURE 25. CUMULATIVE NOISE EXPOSURE AT ONE-WAY RUNWAY FOR GENERAL AVIATION AIRPORT: VARIABLE OPERATIONS WITH CONSTANT PERCENT MIX. (c) 80 OPERATIONS.

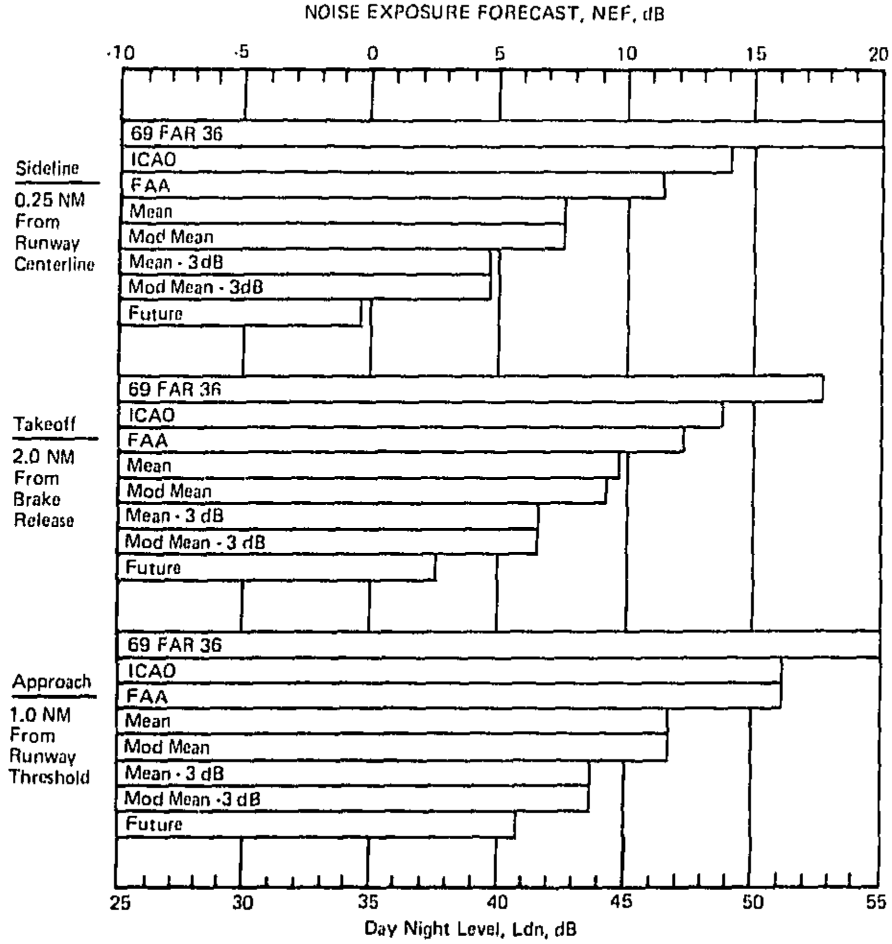


Aircraft Mix	D	
No. Eng.	Max. Wt. KLB	No. T/O & App. Ops/Day
2	15	4.0
2	20	4.0
2	25	3.0
4	45	1.0
2	60	1.0

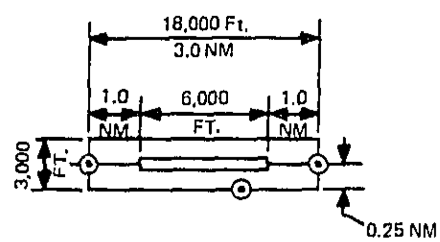


Total Ops = 2 x 13.0 = 26 Per Day (0700 - 2200)

FIGURE 25. CUMULATIVE NOISE EXPOSURE AT ONE-WAY RUNWAY FOR GENERAL AVIATION AIRPORT: VARIABLE OPERATIONS WITH CONSTANT PERCENT MIX. (d) 26 OPERATIONS.



Aircraft Mix		E
No. Eng.	Max. Wt. KLB	No. T/O & App. Ops/Day
2	15	1.2
2	20	1.2
2	25	0.9
4	45	0.4
2	60	0.3



Total Ops = 2 x 4.0 = 8 Per Day (0700 - 2200)

FIGURE 25. CUMULATIVE NOISE EXPOSURE AT ONE-WAY RUNWAY FOR GENERAL AVIATION AIRPORT: VARIABLE OPERATIONS WITH CONSTANT PERCENT MIX. (e) 8 OPERATIONS.

APPENDIX, SECTION, AND TITLE

FAR 36		CAN/4 - WP/20	
A36.1.	Noise Certification Test and Measurement Conditions	CI2.	Noise Certification Test and Measurement Conditions
A36.2.	Measurement of Aircraft Noise Received on the Ground	CI3.	Measurement of Aeroplane Noise Received on the Ground
A36.3.	Reporting and Correcting Measured Data	CI5.	Reporting of Data to the Certificating Authorities and Correcting Measured Data
A36.4.	Symbols and Units	CI6.	Nomenclature
A36.5.	Atmospheric Attenuation of Sound	CI8.	Sound Attenuation in Air
A36.6.	Detailed Correction Procedures	CI9.	Flight Test Results Transposition Methods
B36.1.	General	CI4.	Calculation of Effective Perceived Noise Level from Measured Noise Data
B36.2.	Perceived Noise Level	CI4.	Ditto
B36.3.	Correction for Spectral Irregularities	CI4.	Ditto
B36.4.	Maximum Tone Corrected Perceived Noise Level	CI4.	Ditto
B36.5.	Duration Correction	CI4.	Ditto
B36.6.	Effective Perceived Noise Level	CI4.	Ditto
B36.7.	Mathematical Formulation of the Noy Table	CI7.	Mathematical Formulation of the Noy Table
C36.1.	Noise Measurement and Evaluation	C2.2.	Noise Certification Reference Procedures
C36.3.	Noise Measuring Points	C2.4.	Noise Measurements
C36.5.	Noise Levels	C2.5.	Maximum Noise Levels
C36.7.	Takeoff Test Conditions	C2.2.	Noise Certification Reference Procedures
C36.9.	Approach Test Conditions	C2.2.	Ditto

TABLE 1. COMPARISON BETWEEN TECHNICAL STANDARDS OF FAR 36 AND ICAO CAN/4-WP/20

General Formula: EPNL = A LOG(W) + B

Case	Meas. Point	No. of Engines	Constants, dB		Limits				Slope dB Per W/2
					Lower		Upper		
			A	B	W 1000 lb.	EPNL EPNdB	W 1000 lb	EPNL EPNdB	
69 FAR 36	S/L	ALL	6.644	69.611	75	102	600	108	– 2.000
	T/O		16.610	12.027		93			– 5.000
	APP		6.644	69.611		102			– 2.000
FAA WP/39	S/L	2	6.644	60.611	75	93	850	100	– 2.000
		3		60.611	212	96		100	
		4		63.611	75	96		103	
	T/O	2	13.288	21.222	89	87	850	100	– 4.000
		3		24.222	89	90		103	
		4		27.222	53	90		106	
	APP	All	6.644	65.611	75	98	850	105	– 2.000
ICAO WP/64	S/L	All	6.644	63.611	75	96	850	103	– 2.000
	T/O		16.610	8.027		89	800	106	– 5.000
	APP		6.644	65.611		98	850	105	– 2.000
Mean of 17 Airplane Sample	S/L	All	7.000	59.000	10	87	1000	101	– 2.107
	T/O		12.000	32.000		80		104	– 3.612
	APP		7.000	63.000		91		105	– 2.107
80 FAR 36 Available Technology	S/L	All	7.000	56.000	10	84	1000	98	– 2.107
	T/O		12.000	29.000		77		101	– 3.612
	APP		7.000	60.000		88		102	– 2.107
85 FAR 36 Future Technology	S/L	All	7.000	51.000	10	79	1000	93	– 2.107
	T/O		12.000	25.000		73		97	– 3.612
	APP		7.000	57.000		85		99	– 2.107

TABLE 2. FORMULAS FOR COMPLIANCE NOISE LEVEL CURVES.

I.D. No.	Airplane Type	Engine		Max. Wt. W KLB	Max. Thrust		T/W	Noise Level, EPNdB				Notes & Source of Data
		No.	Type		Per Eng. KLB	Tot. T KLB		S/L @ 0.25 NM	T/O @ 3.5 NM With C/B	T/O @ 3.5 NM No C/B	App @ 1.0 NM	
1	DC-9-30	2	JT8D-7A	108.0	14.0	28.0	0.259	97.3	95.1	–	97.3	(1) FAA
2	DC-9-30	2	JT8D-7A	94.0	14.0	28.0	0.298	97.8	91.7	–	97.0	(1) FAA
3	DC-9-30	2	JT8D-9	110.0	14.5	29.0	0.264	98.8	96.1	–	99.1	(1) FAA
4	DC-9-30	2	JT8D-9	108.0	14.5	29.0	0.269	98.8	95.5	–	99.0	(1) FAA
5	DC-9-30	2	JT8D-9	103.0	14.5	29.0	0.282	99.0	94.3	–	–	– FAA
6	DC-9-30	2	JT8D-15	114.0	15.5	31.0	0.272	100.5	95.8	–	99.0	(1) FAA
7	DC-9-30	2	JT8D-15	110.0	15.5	31.0	0.282	100.6	94.7	–	98.8	(1) FAA
8	DC-9-30	2	JT8D-15	108.0	15.5	31.0	0.287	100.7	94.2	–	98.4	(1) FAA
9	DC-9-30	2	JT8D-15	98.0	15.5	31.0	0.316	101.1	91.2	–	–	– FAA
10	DC-9-40	2	JT8D-11	114.0	15.0	30.0	0.263	99.9	96.8	–	99.4	(1) FAA
11	DC-9-40	2	JT8D-11	107.0	15.0	30.0	0.280	99.6	95.2	–	–	– FAA
12	DC-9-40	2	JT8D-15	114.0	15.5	31.0	0.272	100.5	95.8	–	99.4	(1) FAA
13	DC-9-40	2	JT8D-15	105.0	15.5	31.0	0.295	100.8	93.3	–	–	– FAA
14	B-737-200-QN	2	JT8D-15	115.5	15.5	31.0	0.268	103.2	94.8	–	103.8	(2) FAA
15	B-737-200-QN	2	JT8D-9	115.5	14.5	29.0	0.251	100.6	95.4	–	103.8	(2) FAA
16	B-737-200-QN	2	JT8D-17	117.0	16.0	32.0	0.274	104.4	94.0	–	104.4	– FAA
17	CESSNA 500	2	JT15D-1	11.5	2.2	4.4	0.383	86.1	–	77.7	87.7	(3) FAA
18	SABRE-NA265-60	2	JT12A-8	20.0	3.3	6.6	0.330	100.3	–	95.0	98.5	(4) FAA
19	SABRE-NA265-80	2	CF700-2D-2	23.3	4.32	8.63	0.370	91.3	–	90.7	100.2	(5) FAA

Approach Flaps: (1) 50°, (2) 30°, (3) 40°, (4) 23.5°, (5) 25°

TABLE 3. SUMMARY NOISE LEVELS FOR TURBOJET PROPELLED AIRPLANES.
(a) 2 ENGINES

I.D. No.	Airplane Type	Engine No.	Engine Type	Max. Wt. W KLB	Max. Thrust Per Eng. KLB	Max. Thrust Tot. T KLB	T/W	Noise Level, EPNdB S/L @ 0.25 NM	T/O @ 3.5 NM With C/B	T/O @ 3.5 NM No C/B	App @ 1.0 NM	Notes & Source of Data
20	Learjet-35/36	2	TFE 731-2	17.0	3.5	7.0	0.412	86.7	–	83.4	92.2	(1) FAA
21	Learjet-24D	2	CJ610-6	13.5	2.95	5.9	0.437	97.3	–	90.1	99.1	(1) FAA
22	Learjet-24 Mod	2	CJ610-6	13.5	2.95	5.9	0.437	99.3	–	91.8	100.7	(1) FAA
23	Learjet-24 Mod	2	CJ610-6	13.5	2.95	5.9	0.437	99.3	–	91.8	101.7	(1) FAA
24	Learjet-25 B, C	2	CJ610-6	15.0	2.95	5.9	0.393	97.1	–	91.3	99.6	(1) FAA
25	Learjet-25 Mod	2	CJ610-6	15.0	2.95	5.9	0.393	99.3	–	94.0	100.8	(1) FAA
26	Learjet-25 Mod	2	CJ610-6	15.0	2.95	5.9	0.393	99.3	–	94.0	102.7	(1) FAA
27	Falcon-10	2	TFE 731-2	18.3	3.5	7.0	0.383	86.4	79.6	82.9	95.3	(2) FAA
28	Airbus-300B	2	CF6-50A	302.0	49.0	98.0	0.325	95.3	90.2	–	101.3	(3) FAA
29	Corvette-SN-601	2	JT15D-4	13.89	2.5	5.0	0.360	85.4	–	80.4	89.5	(4) FAA
30	F28-Mk1000	2	Spey 555-15	65.0	9.85	19.7	0.303	99.5	90.0	–	101.2	(5) FAA
31	F28-Mk2000	2	Spey 555-15	65.0	9.85	19.7	0.303	99.5	90.0	–	101.8	(5) FAA
32	HS-748-2A	2	Dart Mk 532-2L	46.5	TURBO	PROP	–	96.3	92.5	–	103.8	(6) FAA
33	BAC-111-200	2	Spey 512-14DW	80.0	12.55	25.10	0.314	101.3	–	95.0	100.3	(7) FAA
34	Gulfstream II	2	Spey 511-8	62.0	11.8	23.6	0.381	102.7	90.9	–	98.2	(8) FAA
35	HS-125-400	2	Viper 522	23.3	3.36	6.72	0.288	99.0	90.0	–	104.0	Rolls-Royce
36	VFW-614	2	SNECMA M45-01	44.0	7.6	15.2	0.345	92.0	90.0	–	97.0	Fokker
37	Caravelle 10	2	JT8D-7	64.3	14.0	28.0	0.435	101.0	99.5	–	106.0	Rolls-Royce
38	B-737-200	2	JT8D-9	103.5	14.5	29.0	0.280	100.9	91.3	–	111.5	(1) Boeing
39	B-737-200	2	JT8D-9	103.5	14.5	29.0	0.280	100.9	91.3	–	107.1	(2) Boeing

Approach Flaps: (1) 40°, (2) 52°, (3) 20° Slats, (4) 35°, (5) 42°, (6) 27.5°, (7) 45°, (8) 39°.

TABLE 3. SUMMARY NOISE LEVELS FOR TURBOJET PROPELLED AIRPLANES
(b) 2 ENGINES (CONTINUED)

I.D. No.	Airplane Type	Engine		Max. Wt. W KLB	Max. Thrust		T/W	Noise Level, EPNdB				Notes & Source of Data
		No.	Type		Per Eng. KLB	Tot. T KLB		S/L @ 0.25 NM	T/O @ 3.5 NM		App @ 1.0 NM	
									With C/B	No C/B		
40	B-737-200-QN	2	JT8D-9	103.5	14.5	29.0	0.280	100.9	91.3	–	104.9	(1) Boeing
41	B-737-200-QN	2	JT8D-9	103.5	14.5	29.0	0.280	100.9	91.3	–	100.8	(2) Boeing
42	B-737-200 Adv	2	JT8D-9	115.5	14.5	29.0	0.251	100.6	95.3	101.7	111.7	(1) Boeing
43	B-737-200 Adv	2	JT8D-9	115.5	14.5	29.0	0.251	100.6	95.3	101.7	107.7	(2) Boeing
44	B-737-200 Adv-QN	2	JT8D-9	115.5	14.5	29.0	0.251	100.6	95.3	101.7	105.1	(1) Boeing
45	B-737-200 Adv-QN	2	JT8D-9	115.5	14.5	29.0	0.251	100.6	95.3	101.7	101.1	(2) Boeing
46	DC-9-30	2	JT8D-9	108.0	14.5	29.0	0.269	99.0	96.0	–	105.0	(3) Boeing
47	DC-9-30-QN	2	JT8D-9	108.0	14.5	29.0	0.269	99.0	96.0	–	99.0	(3) Boeing
48	DC-9-30	2	JT8D-11	114.0	15.0	30.0	0.263	100.0	97.0	–	105.0	(3) Boeing
49	DC-9-30-QN	2	JT8D-11	114.0	15.0	30.0	0.263	100.0	97.0	–	99.0	(3) Boeing
50	DC-9-50-QN	2	JT8D-15	120.0	15.5	31.0	0.258	101.0	97.0	–	100.0	(3) Boeing
51	A-300B	2	CF6-50A	302.1	51.0	102.0	0.338	95.0	90.0	92.0	102.0	(4) Boeing
52	A-300B	2	CF6-50A	302.1	51.0	102.0	0.338	95.0	90.0	92.0	101.0	(5) Boeing
53	BAC-111-500	2	Spey 512-14DW	100.0	12.55	25.1	0.251	108.5	103.0	–	102.5	EPA
54	Gulfstream 2	2	Spey 512-8	62.0	11.4	22.8	0.368	108.0	94.5	102.5	99.5	EPA
55	Falcon 20	2	CF 700-2D	27.3	4.25	8.5	0.311	91.0	–	91.0	102.0	EPA
56	HS-125-601	2	Viper 601	25.2	3.75	7.5	0.298	104.5	–	97.5	102.0	EPA
57	Westwind 1121	2	CJ610-9	18.5	3.1	6.2	0.335	104.0	–	101.5	107.0	EPA
58	Westwind 1123	2	CJ610-9	20.5	3.1	6.2	0.302	106.0	99.5	–	106.0	EPA
59	F28 Mk 6000	2	Spey 655-15H	73.0	9.85	19.70	0.270	93.3	93.3	–	98.0	Fokker
60	F28-Mk 6000	2	Spey 555-15H	70.8	9.85	19.70	0.278	98.6	92.4	–	96.6	Fokker

Approach Flaps: (1) 40°, (2) 30°, (3) 50°, (4) 25°, (5) 15°.

TABLE 3. SUMMARY NOISE LEVELS FOR TURBOJET PROPELLED AIRPLANES.
(c) 2 ENGINES (CONCLUDED)

I.D. No.	Airplane Type	Engine		Max. Wt. W KLB	Max. Thrust		T/W	Noise Level, EPNdB				Notes & Source of Data
		No.	Type		Per Eng. KLB	Tot. T KLB		S/L @ 0.25 NM	T/O @ 3.5 NM With C/B	T/O @ 3.5 NM No C/B	App @ 1.0 NM	
1	DC-10-10	3	CF6-6D	440.0	39.3	117.9	0.268	95.1	–	99.0	100.3	(1) FAA
2	DC-10-10	3	CF6-6D	440.0	39.3	117.9	0.268	95.1	–	99.0	105.4	(2) FAA
3	DC-10-10	3	CF6-6D	430.0	39.3	117.9	0.274	95.2	–	98.2	99.7	(1) FAA
4	DC-10-10	3	CF6-6D	430.0	39.3	117.9	0.274	95.2	–	98.2	104.7	(2) FAA
5	DC-10-10	3	CF6-6D	410.0	39.3	117.9	0.288	95.6	–	96.8	99.2	(1) FAA
6	DC-10-10	3	CF6-6D	410.0	39.3	117.9	0.288	95.6	–	96.8	104.2	(2) FAA
7	DC-10-10	3	CF6-6D	377.5	39.3	117.9	0.312	95.8	–	94.6	–	– FAA
8	DC-10-10	3	CF6-6D1	440.0	40.3	120.9	0.275	95.4	–	98.2	100.3	(1) FAA
9	DC-10-10	3	CF6-6D1	440.0	40.3	120.9	0.275	95.4	–	98.2	105.4	(2) FAA
10	DC-10-10	3	CF6-6D1	430.0	40.3	120.9	0.281	95.6	–	97.4	99.7	(1) FAA
11	DC-10-10	3	CF6-6D1	430.0	40.3	120.9	0.281	95.6	–	97.4	104.7	(2) FAA
12	DC-10-10	3	CF6-6D1	386.5	40.3	120.9	0.313	96.0	–	94.6	99.2	(1) FAA
13	DC-10-10	3	CF6-6D1	386.5	40.3	120.9	0.313	96.0	–	94.6	104.2	(2) FAA
14	DC-10-30	3	CF6-50A	550.0	48.4	145.2	0.264	95.7	–	103.7	103.0	(1) FAA
15	DC-10-30	3	CF6-50A	550.0	48.4	145.2	0.264	95.7	–	103.7	108.4	(2) FAA
16	DC-10-30	3	CF6-50A	519.6	48.4	145.2	0.279	96.0	–	102.1	102.6	(1) FAA
17	DC-10-30	3	CF6-50A	519.6	48.4	145.2	0.279	96.0	–	102.1	108.2	(2) FAA
18	DC-10-30	3	CF6-50C	565.0	51.0	153.0	0.271	97.3	–	104.4	108.4	(2) FAA
19	DC-10-30	3	CF6-50C	555.0	51.0	153.0	0.276	97.3	–	104.0	103.0	(1) FAA
20	DC-10-30	3	CF6-50C	534.4	51.0	153.0	0.287	97.6	–	103.2	108.2	(2) FAA
21	DC-10-30	3	CF6-50C	440.0	51.0	153.0	0.348	98.5	–	100.2	102.6	(1) FAA

(1) 35-Deg. App. Flaps: (2) 50-Deg. App. Flaps:

TABLE 3. SUMMARY NOISE LEVELS FOR TURBOJET PROPELLED AIRPLANES.
(d) 3 ENGINES

I.D. No.	Airplane Type	Engine No.	Engine Type	Max. Wt. W KLB	Max. Thrust Per Eng. KLB	Max. Thrust Tot. T KLB	T/W	Noise Level, EPNdB S/L @ 0.25 NM	T/O @ 3.5 NM With C/B	T/O @ 3.5 NM No C/B	App @ 1.0 NM	Notes & Source of Data
22	DC-10-40	3	JT9D-20	530.0	49.4	148.2	0.280	94.3	–	100.7	100.4	(1) FAA
23	DC-10-40	3	JT9D-20	530.0	49.4	148.2	0.280	94.3	–	100.7	105.4	(2) FAA
24	DC-10-40	3	JT9D-20	484.0	49.4	148.2	0.306	94.3	–	98.4	99.2	(1) FAA
25	DC-10-40	3	JT9D-20	484.0	49.4	148.2	0.306	94.3	–	98.4	104.6	(2) FAA
26	DC-10-40	3	JT9D-20	430.0	49.4	148.2	0.345	94.3	–	95.8	98.5	(1) FAA
27	DC-10-40	3	JT9D-20	430.0	49.4	148.2	0.345	94.3	–	95.8	103.8	(2) FAA
28	L-1011-1	3	RB211-22C	430.0	42.0	126.0	0.293	95.0	–	97.0	103.4	(4) FAA
29	L-1011-1	3	RB211-22C	416.0	42.0	126.0	0.303	95.1	–	96.1	102.1	(3) FAA
30	L-1011-1	3	RB211-22C	416.0	42.0	126.0	0.303	95.1	–	96.1	101.5	(3) FAA
31	L-1011-1	3	RB211-22C	430.0	42.0	126.0	0.293	95.2	–	97.9	103.4	(4) FAA
32	L-1011-1	3	RB211-22C	422.0	42.0	126.0	0.299	95.0	–	97.7	102.1	(3) FAA
33	L-1011-1	3	RB211-22C	396.0	42.0	126.0	0.318	95.2	–	96.0	101.5	(3) FAA
34	B-727-200-QN	3	JT8D-15	190.5	15.5	46.5	0.244	102.2	100.0	–	101.0	(5) FAA
35	B-727-200-QN	3	JT8D-15	175.0	15.5	46.5	0.266	102.3	97.0	–	103.2	(6) FAA
36	L-1011-1	3	RB211-22B	430.0	42.0	126.0	0.293	95.0	–	96.0	102.8	(4) FAA
37	L-1011-1	3	RB211-22B	403.0	42.0	126.0	0.313	95.1	–	94.1	101.8	(3) FAA
38	L-1011-1	3	RB211-22B	403.0	42.0	126.0	0.313	95.1	–	94.1	101.2	(3) FAA
39	L-1011-100	3	RB211-22B	466.0	42.0	126.0	0.270	94.8	–	98.5	102.8	(4) FAA
40	L-1011-100	3	RB211-22B	450.0	42.0	126.0	0.280	94.9	–	97.4	101.9	(3) FAA

(1) 35-Deg. App. Flaps: (3) 33-Deg. App. Flaps: (5) 30-Deg. App. Flaps:
(2) 50-Deg. App. Flaps: (4) 42-Deg. App. Flaps: (6) 40-Deg. App. Flaps:

TABLE 3. SUMMARY NOISE LEVELS FOR TURBOJET PROPELLED AIRPLANES.
(e) 3 ENGINES (CONTINUED)

I.D. No.	Airplane Type	Engine		Max. Wt. W KLB	Max. Thrust		T/W	Noise Level, EPNdB				Notes & Source of Data
		No.	Type		Per Eng. KLB	Tot. T KLB		S/L @ 0.25 NM	T/O @ 3.5 NM With C/B	T/O @ 3.5 NM No C/B	App @ 1.0 NM	
41	B-727-200	3	JT8D-9	172.5	14.5	43.5	0.252	100.4	101.2	107.8	108.2	(1) Boeing
42	B-727-200	3	JT8D-9	172.5	14.5	43.5	0.252	99.9	100.0	107.4	109.5	(2) Boeing
43	B-727-200-QN	3	JT8D-9	172.5	14.5	43.5	0.252	100.4	99.0	107.0	100.4	(1) Boeing
44	B-727-200-QN	3	JT8D-9	172.5	14.5	43.5	0.252	99.9	97.5	106.6	103.2	(2) Boeing
45	B-727-200-Adv-QN	3	JT8D-15	190.5	15.5	46.5	0.244	102.2	100.0	109.8	100.4	(3) Boeing
46	B-727-200-Adv-QN	3	JT8D-15	190.5	15.5	46.5	0.244	102.2	100.0	109.8	103.2	(2) Boeing
47	DC-10-10	3	CF6-6D1	440.0	41.0	123.0	0.280	96.0	–	99.0	106.0	(4) Boeing
48	DC-10-10	3	CF6-6D1	440.0	41.0	123.0	0.280	96.0	–	99.0	102.0	(5) Boeing
49	DC-10-30	3	CF6-50A	555.0	49.0	147.0	0.264	96.0	–	104.0	108.0	(4) Boeing
50	DC-10-30	3	CF6-50A	555.0	49.0	147.0	0.264	96.0	–	104.0	103.0	(5) Boeing
51	DC-10-40	3	JT9D-20 Dry	530.0	49.4	148.2	0.280	95.0	–	101.0	105.0	(4) Boeing
52	DC-10-40	3	JT9D-20 Dry	530.0	49.4	148.2	0.280	95.0	–	101.0	101.0	(5) Boeing
53	L-1011-1	3	RB211-22C	430.0	42.0	126.0	0.293	95.0	–	97.0	103.0	(6) Boeing
54	L-1011-1	3	RB211-22C	430.0	42.0	126.0	0.293	95.0	–	97.0	102.0	(7) Boeing
55	L-1011-100	3	RB211-22B	450.0	42.0	126.0	0.280	94.9	–	97.4	101.5	(7) Lockheed
56	Falcon 50	3	TFE 731-3	36.6	3.7	11.1	0.303	94.0	87.0	–	97.0	AW&ST
57	Trident 3B	3	Spey 512	158.8	12.0	36.0	0.227	105.5	104.5	–	110.0	Rolls-Royce

(1) 30-Deg. App. Flaps & 15 Deg. T/O Flaps
(2) 40-Deg. App. Flaps & 15 Deg. T/O Flaps
(3) 30-Deg. App. Flaps & 5 Deg. T/O Flaps
(4) 50-Deg. App. Flaps
(5) 35-Deg. App. Flaps
(6) 42-Deg. App. Flaps
(7) 33-Deg. App. Flaps

TABLE 3. SUMMARY NOISE LEVELS FOR TURBOJET PROPELLED AIRPLANES.
(f) 3 ENGINES (CONCLUDED)

I.D. No.	Airplane Type	Engine No.	Engine Type	Max. Wt. W KLB	Max. Thrust Per Eng. KLB	Max. Thrust Tot. T KLB	T/W	Noise Level, EPNdB S/L @ 0.35 NM	Noise Level, EPNdB T/O @ 3.5 NM With C/B	Noise Level, EPNdB T/O @ 3.5 NM No C/B	Noise Level, EPNdB App @ 1.0 NM	Notes & Source of Data
1	B-747-100	4	JT9D-3 Dry	710.0	43.5	174.0	0.245	101.9	–	115.0	113.6	(2) FAA
2	B-747-100	4	JT9D-3A Wet	735.0	45.0	180.0	0.245	103.3	112.4	–	114.4	(2) FAA
3	B-747-100A	4	JT9D-7 Wet	735.0	47.0	188.0	0.256	102.1	–	110.6	114.4	(2) FAA
4	B-747-100A	4	JT9D-7 Wet	735.0	47.0	188.0	0.256	102.1	–	110.6	109.0	(1) FAA
5	B-747-100C	4	JT9D-7 Wet	735.0	47.0	188.0	0.256	102.0	–	110.3	112.3	(2) FAA
6	B-747-100C	4	JT9D-3A Wet	735.0	45.0	180.0	0.245	99.5	–	107.6	106.8	(2) FAA
7	B-747-100C	4	JT9D-3A Wet	735.0	47.0	188.0	0.256	99.5	–	107.2	106.9	(2) FAA
8	B-747-200B	4	JT9D-7 Wet	773.0	47.0	188.0	0.243	101.0	–	112.6	111.5	(2) FAA
9	B-747-200 B, C, F	4	JT9D-7 Wet	775.0	47.0	188.0	0.243	98.2	–	107.0	106.2	(2) FAA
10	B-747-200 B, C, F	4	JT9D-7 Wet	775.0	47.0	188.0	0.243	98.2	–	107.0	106.8	(2) FAA
11	B-747-200 B, C, F	4	JT9D-3A Wet	773.0	47.0	188.0	0.243	97.8	–	107.5	106.8	(2) FAA
12	B-747-200 B, C, F	4	CF6-50E	775.0	52.5	210.0	0.271	98.4	–	105.3	105.0	(2) FAA
13	B-747-200 B, C, F	4	CF6-50E	800.0	52.5	210.0	0.263	98.3	–	106.1	106.1	(2) FAA
14	L-382EIG	4	All 501-D22A	155.0	–	–	–	93.9	–	98.4	99.1	(3) FAA
15	Jetstar 2	4	TFE-731-3	43.8	3.7	14.8	0.338	91.5	93.0	–	98.5	AW&ST
16	Jetstar Dash 8	4	JT12A-8	42.5	3.3	13.2	0.311	105.0	106.0	–	107.0	AW&ST
17	DC-8-61	4	JT3D-3B	325.0	18.0	72.0	0.222	103.0	114.0	–	117.0	EPA
18	Concorde	4	Olympus 593	400.0	38.05	152.2	0.381	112.0	117.8	–	114.9	FAA/EIS
19	TU-144	4	NK-144	396.0	44.0	176.0	0.444	114.0	110.0	–	110.0	EPA
20	Comet 4	4	Avon 29	162.0	11.4	45.6	0.281	103.5	103.5	–	112.5	Rolls-Royce
21	Convair 880	4	CJ805-3	185.0	11.65	46.6	0.252	109.0	116.0	–	106.0	Rolls-Royce
22	Convair 990	4	CJ805-23B	255.0	16.1	64.4	0.252	112.0	120.0	–	112.0	Rolls-Royce

(1) 25-Deg. App. Fl.: (2) 30-Deg. App. Fl.: (3) Turboprop

TABLE 3. SUMMARY NOISE LEVELS FOR TURBOJET PROPELLED AIRPLANES.
(g) 4 ENGINES

I.D. No.	Airplane Type	Engine		Max. Wt. W KLB	Max. Thrust		T/W	Noise Level, EPNdB				Notes & Source of Data
		No.	Type		Per Eng. KLB	Tot. T KLB		S/L @ 0.35 NM	T/O @ 3.5 NM With C/B	T/O @ 3.5 NM No C/B	App @ 1.0 NM	
23	VC-10	4	Conway 42	312.0	20.37	81.5	0.261	114.0	110.0	–	115.0	Rolls-Royce
24	B-720 B	4	JT3D-1	234.0	17.0	68.0	0.291	101.6	104.7	–	115.5	(1) Boeing
25	B-720 B-QN	4	JT3D-1	234.0	17.0	68.0	0.291	96.3	93.8	–	102.6	(1) Boeing
26	B-707-120B	4	JT3D-1	258.0	17.0	68.0	0.264	101.3	108.7	–	116.0	(1) Boeing
27	B-707-120B	4	JT3D-1	258.0	17.0	68.0	0.264	101.3	108.7	–	114.0	(2) Boeing
28	B-707-120B-QN	4	JT3D-1	258.0	17.0	68.0	0.264	95.8	97.1	–	103.0	(1) Boeing
29	B-707-120B-QN	4	JT3D-1	258.0	17.0	68.0	0.264	95.8	97.1	–	107.0	(2) Boeing
30	B-707-320 B, C	4	JT3D-3B	333.6	18.0	72.0	0.216	102.1	113.0	113.6	118.5	(1) Boeing
31	B-707-320 B, C	4	JT3D-3B	333.6	18.0	72.0	0.216	102.1	113.0	113.6	116.8	(2) Boeing
32	B-707-320 B, C-QN	4	JT3D-3B	333.6	18.0	72.0	0.216	99.2	102.2	110.8	106.3	(1) Boeing
33	B-707-320 B, C-QN	4	JT3D-3B	333.6	18.0	72.0	0.216	99.2	102.2	110.8	104.0	(2) Boeing
34	B-747-SR	4	JT9D-7A	570.0	47.67	190.7	0.335	99.0	–	100.0	104.0	(4) Boeing
35	B-747-SP	4	JT9D-7A	660.0	47.67	190.7	0.289	99.0	–	104.0	104.0	(3) Boeing
36	B-747-100	4	JT9D-7	710.0	47.0	188.0	0.265	99.0	–	107.0	107.0	(3) Boeing
37	B-747-100	4	JT9D-7	710.0	47.0	188.0	0.265	99.0	–	107.0	105.0	(4) Boeing
38	B-747-200B	4	JT9D-7W	785.0	47.0	188.0	0.239	98.0	–	107.0	106.0	(3) Boeing
39	B-747-200B	4	JT9D-7W	785.0	47.0	188.0	0.239	98.0	–	107.0	104.0	(4) Boeing
40	B-747-200B	4	CF6-50E	800.0	52.5	210.0	0.263	98.0	101.0	107.0	106.0	(3) Boeing
41	B-747-200B	4	CF6-50E	800.0	52.5	210.0	0.263	98.0	101.0	107.0	103.0	(4) Boeing
42	B-747-200F	4	JT9D-7W	785.0	47.0	188.0	0.239	98.0	–	107.0	107.0	(3) Boeing
43	B-747-200F	4	JT9D-7W	785.0	47.0	188.0	0.239	98.0	–	107.0	104.0	(4) Boeing

(1) 50-Deg. App. Fl.: (2) 40-Deg. App. Fl.: (3) 30-Deg. App. Fl.: (4) 25-Deg. App. Fl.

TABLE 3. SUMMARY NOISE LEVELS FOR TURBOJET PROPELLED AIRPLANES.
(h) 4 ENGINES (CONCLUDED)

I.D. No.	Airplane Type	Engine No.	Engine Type	Max. Wt. W KLB	Max. Thrust Per Eng. KLB	Max. Thrust Tot. T KLB	T/W	Noise Level, EPNdB S/L @ 0.25 NM	T/O @ 3.5 NM With C/B	T/O @ 3.5 NM No C/B	App @ 1.0 NM	Notes & Source of Data
1	DC-9-30	2	JT8D-7A	94.0	14.0	28.0	0.298	97.8	91.7	–	97.0	(1) FAA
2	DC-9-40	2	JT8D-15	114.0	15.5	31.0	0.272	100.5	95.8	–	99.4	(1) FAA
3	Cessna 500	2	JT15D-1	11.5	2.2	4.4	0.383	86.1	–	77.7	87.7	(2) FAA
4	Sabre NA265-80	2	CF700-2D-2	23.3	4.32	8.63	0.370	91.3	–	90.7	100.2	(3) FAA
5	Learjet 35, 36	2	TFE 731-2	17.0	3.5	7.0	0.412	86.7	–	83.4	92.2	(2) FAA
6	Falcon 10	2	TFE 731-2	18.3	3.5	7.0	0.383	86.4	79.6	82.9	95.3	(4) FAA
7	Airbus A 300B	2	CF6-50A	302.0	49.0	98.0	0.325	95.3	90.2	–	101.3	(5) FAA
8	Corvette SN-601	2	JT15D-4	13.89	2.5	5.0	0.360	85.4	–	80.4	89.5	(6) FAA
9	F-28-1000	2	SPEY 555-15	65.0	9.85	19.7	0.303	99.5	90.0	–	101.2	(7) FAA
10	DC-10-10	3	DF6-6D	386.5	40.3	120.9	0.313	96.0	–	94.6	99.2	(6) FAA
11	DC-10-30	3	CF6-50A	550.0	48.4	145.2	0.264	95.7	–	103.7	103.0	(6) FAA
12	L-1011-1	3	RB 211-22C	396.0	42.0	126.0	0.318	95.2	–	96.0	101.5	(8) FAA
13	L-1011-100	3	RB 211-22B	450.0	42.0	126.0	0.280	94.9	–	97.4	101.5	(8) Lockheed
14	B-747-200B	4	JT9D-7W	785.0	47.0	188.0	0.239	101.5	–	107.0	104.0	(3) Boeing
15	B-747-200B	4	CF6-50E	800.0	52.5	210.0	0.263	101.5	101.0	107.0	103.0	(3) Boeing
16	B-747-SR	4	JT9D-7A	570.0	47.67	190.7	0.335	102.5	–	100.0	104.0	(3) Boeing
17	B-747-SP	4	JT9D-7A	660.0	47.67	190.7	0.289	102.5	–	104.0	104.0	(9) Boeing

Approach Flaps: (1) 50°, (2) 40°, (3) 25° (4) 52°, (5) 20° Slats, (6) 35°, (7) 42°, (8) 33°, (9) 30°.

TABLE 4. NOISE LEVELS FOR CURRENT TECHNOLOGY EXISTING AIRPLANES.

I.D. No.	Airplane Type	Engine		Max. Wt. W KLB	Max. Thrust		T/W	Noise Level, EPNdB				Notes & Source of Data
		No.	Type		Per Eng. KLB	Tot. T KLB		S/L @ 0.25 NM	T/O @ 3.5 NM With C/B	T/O @ 3.5 NM No C/B	App @ 1.0 NM	
1a	B-727-200	3	JT8D-109	172.5	16.6	49.8	0.289	92.8	92.4	98.9	100.9	(1) NASA
1b	B-727-200	3	JT8D-109	172.5	16.6	49.8	0.289	92.8	92.4	98.9	102.5	(2) NASA
2	DC-9-32	2	JT8D-109	108.0	16.6	33.2	0.307	93.0	87.0	93.0	97.0	(3) NASA
3a	B-737-200	2	JT8D-109	103.0	16.6	33.2	0.322	85.7	82.5	84.0	99.5	(1) NASA
3b	B-737-200	2	JT8D-109	103.0	16.6	33.2	0.322	85.7	82.5	84.0	100.8	(2) NASA
4	DC-9	2	JT8D-209	127.0	18.0	36.0	0.283	96.0	93.0	99.0	98.0	Douglas
5	DC-9	2	CFM56/JTIOD	142.0	–	–	–	89.	86.0	91.0	96.0	Noise Levels
6	DC-8-61	4	CFM56/JT10D	325.0	–	–	–	92.0	95.0	98.0	99.0	± 3 dB and
7	DC-8-62	4	CFM56/JT10D	335.0	–	–	–	91.0	97.0	98.0	99.0	Max. App.
8	DC-8-63	4	CFM56/JT10D	355.0	–	–	–	93.0	97.0	100.0	99.0	Flaps
9	DC-8-63F	4	CFM56/JT10D	355.0	–	–	–	93.0	97.0	100.0	100.0	
10	B-727-300B	3	JT8D-217	222.0	19.0	57.0	0.257	101.0	102.0	–	107.0	Boeing
11	BAC-111-700	2	Spey 604-14	117.0	16.9	33.8	0.289	97.0	92.0	–	99.0	BAC

Approach Flaps; (1) 30°, (2) 40°, (3) 50°

TABLE 5. PREDICTED NOISE LEVELS FOR MAJOR ACOUSTICAL CHANGE AIRPLANES.

I.D. No.	Airplane Type	Engine		Max. Wt. W KLB	Max. Thrust		T/W	Noise Level, EPNdB				Notes & Source of Data
		No.	Type		Per Eng. KLB	Tot. T KLB		S/L @ 0.25 NM	T/O @ 3.5 NM		App @ 1.0 NM	
									With C/B	No C/B		
1	B-7x7	3	CFM56/JT10D	255.0	–	–	–	94.5	–	96.5	102.9	(1) Boeing
2	B-7x7	3	CFM56/JT10D	263.0	–	–	–	93.9	–	95.7	104.1	(1) "
3	B-7x7	3	CFM56/JT10D	285.0	–	–	–	93.9	–	97.7	104.1	(1) "
4	Narrow Body	4	Quiet Eng. A	330.0	–	–	–	–	–	103.3	104.1	(1) (2) "
5	Narrow Body	4	Quiet Eng. A	330.0	–	–	–	–	–	98.2	100.6	(1) (3) (4) "
6	Narrow Body	4	Quiet Eng. A	330.0	–	–	–	–	–	98.9	–	(1) (3) (5) "
7	Narrow Body	4	Quiet Eng. A	330.0	–	–	–	–	–	90.0	89.0	(3) (6) "
8	New Type Design	2	CF6	302.0	–	–	–	97.5	–	93.0	102.0	(1) "
9	New Type Design	3	RB-211	430.0	–	–	–	96.5	–	96.0	103.5	(1) "
10	New Type Design	3	CF6	440.0	–	–	–	97.5	–	99.0	106.5	(1) "
11	New Type Design	3	JT9D	530.0	–	–	–	96.5	–	101.0	105.5	(1) "
12	New Type Design	3	CF6	555.0	–	–	–	98.5	–	104.0	108.5	(1) "
13	New Type Design	4	JT9D	570.0	–	–	–	103.5	–	100.0	104.5	(1) "
14	New Type Design	4	JT9D	710.0	–	–	–	103.5	–	107.2	107.6	(1) "
15	New Type Design	4	JT9D Wet	775.0	–	–	–	102.5	–	107.2	106.9	(1) "
16	New Type Design	4	JT9D Dry	775.0	–	–	–	102.5	–	108.0	106.9	(1) "
17	New Type Design	4	CF6	800.0	–	–	–	102.5	–	106.1	106.5	(1) "
18	BAC-111-800	2	CFM56	137.0	22.0	44.0	0.321	89.7	84.4	–	94.7	(1) BAC
19	DC-X-200	2	CF6-50C	283.0	51.0	102.0	0.360	95.0	–	95.0	98.0	(1) AW&ST

(1) Max. App. Flaps: (2) Peripheral Sam: (3) Inlet & Exhaust Sam Rings:
(4) Boeing Nacelle: (5) GE Nacelle: (6) NASA Original Goal:

TABLE 6. PREDICTED NOISE LEVELS FOR NEW TYPE DESIGN AIRPLANES.
(a) I.D. NOS. 1 THRU 19

I.D. No.	Airplane Type	Engine No.	Engine Type	Max. Wt. W KLB	Max. Thrust Per Eng. KLB	Max. Thrust Tot. T KLB	T/W	Noise Level, EPNdB S/L @ 0.25 NM	Noise Level, EPNdB T/O @ 3.5 NM With C/B	Noise Level, EPNdB T/O @ 3.5 NM No C/B	Noise Level, EPNdB App @ 1.0 NM	Notes & Source of Data
20	Twin-Jet	2	CFM56	140.0	22.0	44.0	0.314	–	–	89.75	98.75	(1) GE Co.
21	Twin-Jet	2	CFM56	140.0	22.0	44.0	0.314	–	–	88.75	97.25	(2) "
22	Tri-Jet	3	CFM56	230.0	22.0	66.0	0.287	–	–	94.75	101.50	(1) "
23	Tri-Jet	3	CFM56	230.0	22.0	66.0	0.287	–	–	93.00	99.75	(2) "
24	Quad-Jet	4	CFM56	355.0	22.0	88.0	0.248	–	–	98.75	102.25	(1) "
25	Quad-Jet	4	CFM56	355.0	22.0	88.0	0.248	–	–	97.25	101.00	(2) "
26	G.A. Twin-Jet	2	QCGAT	6.0	1.290	2.58	0.430	79.5	–	68.5	85.5	NASA
27	G.A. Twin-Jet	2	QCGAT	9.8	2.224	4.45	0.454	79.5	–	70.0	81.0	
28	G.A. Twin-Jet	2	QCGAT	17.0	4.369	8.74	0.514	77.0	–	69.0	84.0	
29	LH2 Subsonic	4	Liq. Hydrogen	391.7	28.70	114.80	0.293	87.2	–	89.2	–	ICAO
30	Jet A Subsonic	4	Fossil-Fuel	532.2	32.69	130.78	0.246	87.8	–	94.2	–	Bulletin
31	LH2 Supersonic	4	Liq. Hydrogen	368.0	46.01	184.04	0.500	105.9	–	104.3	–	
32	Jet A Supersonic	4	Fossil-Fuel	750.0	89.51	358.04	0.477	108.0	–	108.0	–	
33	Lear Star 600	2	Lycoming ALF502	32.5	7.50	15.00	0.460	87.0	78.0	–	90.0	AW&ST

(1) Short Duct; (2) Long Duct

TABLE 6. PREDICTED NOISE LEVELS FOR NEW TYPE DESIGN AIRPLANES.
(b) I.D. NOS. 20 THRU 33

Observer Category	Land Use	Outdoor/Indoor Noise Reduction		Noise Level Criteria	
		Level dB**	Windows	Ldn dB	Leq dB
1	Residential	15	Open	55	–
2	Hospital	15	Open	55	–
3	Motel and Hotel	15	Open	60	–
4	School Buildings and Outdoor Teaching Areas	15	Open	–	60
5	Church	25	Closed	–	60
6	Office Buildings	25	Closed	–	70
7	Theater	35	Closed	–	70
8	Playgrounds and Active Sports	NA	NA	–	70
9	Parks	NA	NA	–	60
10	Special Purpose Outdoor	NA	NA	–	*

* Intruding noise shall not exceed existing Leq minus 5 dB.
** Where knowledge of structure indicates a difference in noise reduction from these values, the criterion level may be altered accordingly.

TABLE 7. CRITERIA FOR NOISE IMPACT ANALYSIS OF SENSITIVE LAND AREAS.

Takeoffs & Landings Each		Ldn Contour Levels, dB							
Total No.	4-Engine Aircraft %	69 FAR 36	ICAO	FAA	Mean	Modified Mean	Available (Mean −3 dB)	Modified Mean −3 dB	Future
420	33.3	79.8	76.2	76.2	75.5	75.5	72.5	72.5	69.7
420	16.7	79.1	75.3	75.3	74.5	74.5	71.5	71.5	68.5
420	7.14	78.6	74.7	74.7	73.8	73.8	70.8	70.8	67.8
420	4.76	78.1	74.2	74.2	73.2	73.2	70.2	70.2	67.2
420	0	78.0	74.0	74.0	72.9	72.9	69.9	69.9	66.9

(a) Air Carrier Airport: Constant operations and variable percent mix.

441	33.3	80.0	76.4	76.4	75.7	75.7	72.7	72.7	69.7
140	33.3	75.0	71.4	71.4	70.7	70.7	67.7	67.7	64.7
44	33.3	69.9	66.3	66.3	65.6	65.6	62.6	62.6	59.6
14	33.3	64.8	61.2	61.2	60.5	60.5	57.5	57.5	54.5

(b) Air Carrier Airport: Variable operations and constant percent mix.

400	28.3	75.0	71.0	71.0	66.7	66.7	63.7	63.7	60.7
127	28.3	70.1	66.1	61.5	61.8	61.8	58.8	58.8	55.8
40	28.3	65.0	61.0	56.4	56.7	56.7	53.7	53.7	50.7
13	28.3	60.1	56.1	51.5	51.8	51.8	48.8	48.8	44.9
4	28.3	55.0	51.0	46.4	46.7	46.7	43.7	43.7	39.8

(c) General Aviation Airport: Variable operations and constant percent mix.

TABLE 8. CONTOUR LEVELS ENCLOSED BY NOISE INDICATOR RECTANGLES.

ENVIRONMENTAL PROTECTION AGENCY
Office of Noise Abatement and Control
AW 471
Washington, D.C. 20460

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