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AEROSPACE INFORMATION REPORT

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ESTIMATION OF ONE-THIRD-OCTAVE-BAND LATERAL ATTENUATION OF SOUND FROM JET-PROPELLED AIRPLANES

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REAFFIRMED

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PREPARED BY THE
GROUND REFLECTION MEASUREMENT
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AIRCRAFT NOISE

1. BACKGROUND: The determination of noise levels on the ground resulting from an airplane in flight is important for the estimation of noise levels around airports for land-use planning purposes and other applications. A significant component in the prediction of ground noise levels is the estimation of the attenuation of sound as it propagates from an airplane to locations on, or near, the ground plane. This sound attenuation depends on atmospheric absorption, sound wave divergence, effects associated with the ground, meteorological conditions, and details of the installation of the engines on an airplane. The principal effects of the ground are those associated with the interference of the direct and reflected sound waves (see Section 3). For propagation to the side of the flight path, the sound attenuation caused by factors which are not readily accounted for are referred to as lateral attenuation in this document. Factors that are embodied in the lateral attenuation include ground effects other than reflection (e.g., those associated with surface undulations); meteorological effects such as wind and temperature gradients; and engine shielding and/or installation effects.

The Society of Automotive Engineers' A-21 Committee on Aircraft Noise undertook the development of a uniform and consistent method for the prediction of the attenuation of noise propagating from an airplane to locations near the ground to the side of the flight path. The first phase of that project was the development of a prediction method for lateral attenuation in frequency-weighted and time-integrated measures of noise. That prediction procedure is contained in AIR 1751 (Reference 1)*. The prediction procedure in this AIR 1906 is a contribution toward the second phase of the project in which the attenuation of airplane noise, propagating toward a lateral ground location, is considered for individual one-third-octave-band sound pressure levels in a free-field environment (the data in AIR 1751 are not free-field) and as a function of sound-radiation angle (or time). Sources of the data used for the analyses to obtain values of lateral attenuation, which were subsequently used in the development of the prediction procedure, are given in Section 6. The need to include the dependence on sound-radiation angle (or time) requires a definition of lateral attenuation which is different from that in Reference 1 for time-integrated noise descriptors.

2. APPLICATIONS: Data presented in this AIR are in terms of differences between one-third-octave-band free-field sound pressure levels and are intended for use in estimating far-field aircraft noise. Allowance may be made for the acoustic impedance of the ground surface and sound pressure levels at any height above the ground plane may be estimated. For estimating the long-term time-averaged sound level at several locations around an airport served by a mix of airplane types under a variety of atmospheric conditions, airplane operational weights, and flight procedures, it would be more appropriate to use the method of prediction for lateral attenuation given in Reference 1.

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* References are given in Section 5.

2. APPLICATIONS (Cont'd.):

In developing the procedure in this AIR, no data from propeller-driven aircraft or helicopters were used. Because the acoustical characteristics of propeller and rotor noise sources are different from those of jet engines, the prediction procedure in this AIR should not be used to estimate the lateral attenuation of sound from propeller-driven airplanes and helicopters.

The lateral-attenuation prediction procedure in Reference 1 is in terms of subjective measures [i.e., those including a frequency weighting and time integration such as Effective Perceived Noise Level (EPNL) or Sound Exposure Level (SEL)]. The procedure in Reference 1 includes a variety of ground-reflection effects as an inherent and integral part of the method. The one-third-octave-band lateral-attenuation values determined by the procedure in this AIR may be used to estimate lateral attenuation in subjective measures. However, the effect of ground reflections on the under-the-flight-path and sideline one-third-octave-band sound pressure levels should be included prior to determining lateral attenuation in subjective measures.

3. ONE-THIRD OCTAVE BAND LATERAL ATTENUATION: For the purpose of this AIR, one-third-octave-band lateral attenuation, A_L, is defined as the difference between the free-field one-third-octave-band under-the-flight-path and sideline sound pressure levels, in a uniform atmosphere, where the propagation distance, R, and source radiation angle*, θ, associated with the two sound pressure levels are the same. One-third-octave-band lateral attenuation therefore includes the effects of sound propagation near the ground as well as a variety of airplane configuration and engine-installation effects and the effects of any airframe noise included in the data that were available for analysis. In the analysis it was assumed that there was a clear line of sight between the airplane and the observer for all times (or angles) of interest. The free-field conditions were those equivalent to radiation into free space with no ground plane present.

The effect of any reflection of a sound wave by the ground surface on the measured spectrum of the sound from an airplane depends on the geometric relationship between the airplane and observer, the acoustical properties of the ground surface, and the frequency components of the sound wave, see References 2 and 3. Unless special steps are taken with microphone mountings

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* Within the scatter of the available data there was no obvious correlation of lateral attenuation with sound-source radiation angle. However, it was noted during the balloting of this document that analysis of the lateral attenuation of the sound from one airplane did indicate a dependence on sound radiation angle. That data were not part of the data base available for the analyses described in this AIR and were not considered as invalidating the general results presented here. Further information is given in Section A.3.2 of the Appendix to corroborate the result that one-third-octave-band lateral attenuation was independent of sound-source radiation angle.

3. ONE-THIRD OCTAVE BAND LATERAL ATTENUATION (Cont'd.):

(i.e., ground-plane or elevated mountings) there may be considerable differences, in both magnitude and frequency distribution, in the effect of the reflected wave on the measured noise spectrum. The airplane noise measurements available for development of the prediction procedure in this AIR all contained spectral irregularities caused by ground reflection effects. Therefore, it was necessary to develop a procedure to remove the interference effects to obtain the required free-field sound pressure levels. The method of removing ground-reflection interference effects was based on that given in Reference 4 and, more fully, in Reference 5. The theory used in Reference 4 considers the reflection of a spherically-diverging wave propagating through a still, uniform atmosphere at the flat boundary between two semi-infinite media. The acoustic impedance of the ground surface was calculated using a porous absorber model as detailed in References 4 and 5.

One-third-octave-band values of lateral attenuation are presented in Figures 1 to 48 as a function of propagation distance, R, observer angle, ϕ, and nominal one-third-octave-band center frequency. The observer angle is defined as the angle in the vertical plane, between the line joining the observer and the centroid of the engine exhausts and the projection of that line onto the ground plane. Data are provided for far-field lateral attenuation of noise from subsonic, jet-powered airplanes with either of two common methods of installing the engines. Table 1 contains the key to the location of the specific Figure for the two engine installations. Sound pressure level differences are presented as a series of carpet plots in Figures 1 to 48. The plots were derived by empirical curve fitting through data obtained from field measurements of airplane noise.

In the Appendix, Section A.2 defines the various terms used, and Section A.3 provides a discussion of the analysis method, shows example correlations between measured and predicted lateral attenuation of one-third-octave-band sound pressure level and discusses the accuracy of the prediction of lateral attenuation provided by the data in Figures 1 to 48, or Tables 2 and 3.

4. PRESENTATION OF LATERAL ATTENUATION DATA: Two sets of one-third-octave-band lateral attenuation data are provided, one for each of two common engine installations:

a) wing-mounted engines,

and

b) side-fuselage-mounted or center-fuselage-mounted engines.

The noise level on the ground is the sum of the individual contributions from each engine plus the contribution of the sound produced by the passage of the airplane through the air (i.e., nonpropulsive or airframe noise). Ideally, the individual contributions from sources of engine noise should be

4. PRESENTATION OF LATERAL ATTENUATION DATA (Cont'd.):

calculated using lateral attenuation data appropriate to the specific engine location. However, when calculating far-field sound pressure levels using a single source to represent the total sound from all sources of airplane noise, the one-third-octave-band lateral attenuation from Figures 1 to 48, or Tables 2 and 3, should be considered to apply to sound from the most significant contributing source (e.g., for airplanes having two wing-mounted and one fuselage-mounted engine use Figures 1 to 24, or Table 2, for wing-mounted engines).

The values of one-third-octave-band lateral attenuation, A_L, are found for the given combination of propagation distance and observer angle by reading the value of A_L from the appropriate carpet plot on Figures 1 to 48. Alternatively, values of A_L may be found from Tables 2 or 3 where the digitized data presented in Figures 1 to 24, and 25 to 48, are listed. The tabulated data are provided to simplify the computer implementation of the prediction procedure for one-third-octave-band lateral attenuation. When using the tabulated values of A_L, it is recommended that a quadratic interpolation routine be used for variation in both observer angle and sound propagation distance, the interpolation being carried out on the nearest 3x3 matrix of values.

The magnitude of lateral attenuation increases with distance and, at low observer angles, increases with decreasing observer angle. At large distances, the value of lateral attenuation tends asymptotically to a value which depends on frequency and observer angle. For propagation distances greater than 1200 m, the lateral attenuation for a distance of 1200 m should be used.

Observer angles in Figures 1 to 48 are restricted to angles greater than five degrees. At observer angles less than five degrees, measured noise levels were considered to have been influenced by refraction effects arising from wind shear and temperature gradients, atmospheric turbulence near the ground, and undulations of the ground surface that may have given rise to shadow zones.

5. REFERENCES:

1. SAE Committee A-21 — Prediction method for lateral attenuation of airplane noise during take-off and landing. AIR 1751, Society of Automotive Engineers, March 1981.

2. SAE Committee A-21 — Acoustic effects produced by a reflecting plane. AIR 1327, Society of Automotive Engineers, January 1976.

5. REFERENCES (Cont'd.):

3. SAE Committee A-21 — Practical methods to obtain free-field sound pressure levels from acoustical measurements over ground surfaces. AIR 1672B, Society of Automotive Engineers, June 1983.

4. Chessell, C. I. — Noise propagation along an impedance boundary. J. Acoust. Soc. Am., Vol. 62, No. 4, pp. 825-834, October 1977.

5. ESDU — The correction of measured noise spectra for the effects of ground reflection. Item No. 80038, Engineering Sciences Data Unit, London, November 1980.

6. Fethney, P. Jelly, A. H. — Airframe self-noise studies on the Lockheed L-1011 TriStar aircraft. Tech. Rep. 80056, Royal Aircraft Establishment, Farnborough, United Kingdom, May 1980.

6. SOURCES OF DATA USED IN THE DEVELOPMENT OF THE ONE-THIRD-OCTAVE-BAND LATERAL ATTENUATION PREDICTION METHOD:

1. Rickley, E. J. — Meteorological effects noise tests. Letter Report DST 331-FA853-78-1; U.S. Department of Transportation, Transportation System Center, Kendall Square, Cambridge, Massachusetts, January 1978.

2. - — Unpublished information for the BAe 1-11. British Aerospace PLC, Aircraft Group, Weybridge-Bristol Division, United Kingdom.

3. - — Unpublished information for the Boeing 727. The Boeing Company, Seattle, Washington.

4. - — Unpublished information for the Lockheed C-141. Air Force Aerospace Medical Research Laboratory, Biodynamics and Bioengineering Division, Wright-Patterson Air Force Base, Ohio, May 1978.

5. - — Unpublished information for the Boeing E-3A. Air Force Aerospace Medical Research Laboratory, Biodynamics and Bioengineering Division, Wright-Patterson Air Force Base, Ohio, June 1978.

6. - — Unpublished information for the Lockheed L-1011. Royal Aircraft Establishment, Farnborough, United Kingdom, September 1979.

6. SOURCES OF DATA USED IN THE DEVELOPMENT OF THE ONE-THIRD-OCTAVE-BAND LATERAL ATTENUATION PREDICTION METHOD (Cont'd.):

7. - Unpublished information for the Boeing KC-135A. Air Force Aerospace Medical Research Laboratory, Biodynamics and Bioengineering Division, Wright- Patterson Air Force Base, Ohio, January 1980.

8. - Unpublished information for the Boeing 747. NASA Langley Research Center, Hampton, Virginia, November 1980.

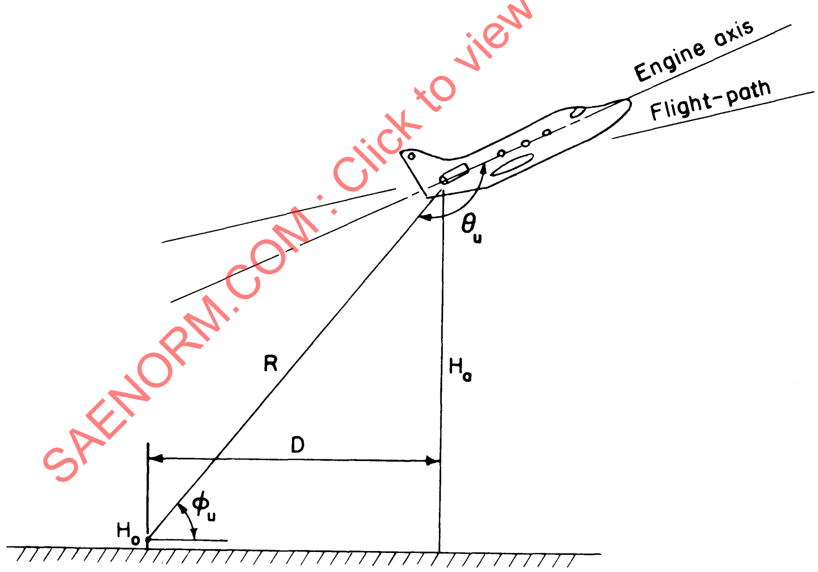
9. Willshire, W. L., Jr. Lateral attenuation of high-bypass-ratio engined aircraft noise. NASA Technical Memorandum 81968, April 1981.

APPENDIX

METHOD AND ACCURACY OF ANALYSIS FOR ONE-THIRD-OCTAVE-BAND LATERAL ATTENUATION

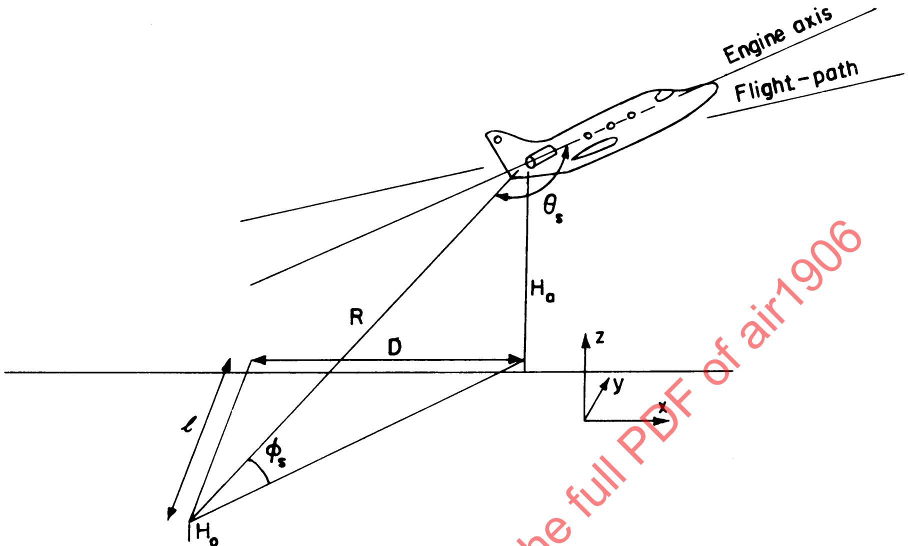
A.1 GENERAL: This Appendix provides further information on the definitions of terms and the analysis procedure used in the derivation of generalized differences between free-field one-third-octave-band sound pressure levels under the flight path of an airplane and those, at the same distance and sound-radiation angle, at locations to the side of the flight path.

A.2 DEFINITION OF TERMS: For any one-third-octave-band, lateral attenuation depends on propagation distance, R, and observer angle, ϕ. The geometric relationship between the single equivalent source and the observer is shown for under-the-flight-path locations (subscript u) in Sketch A.2.1a and for sideline locations (subscript s) in Sketch A.2.1b.



Sketch A.2.1a. Observer position, under-the-flight-path.

A.2 (Cont'd.):



Sketch A.2.1b: Observer position, sideline.

Propagation distance, R, is given by

$$R = [(H_a - H_o)^2 + D^2 + \ell^2)]^{1/2}, \quad \text{(A.2.1)}$$

where D is the separation between the airplane's position and observer's position projected onto the flight-track, and ℓ is the sideline or lateral distance, see Sketch A.2.1b. The definition here of sideline distance ℓ is consistent with the definition in Reference 1.

Observer angle ϕ is given by

$$\phi = \arcsin [(H_a - H_o)]/R] \quad \text{(A.2.2)}$$

Angle of radiation, θ, is measured from the forward direction and defined as the angle between the longitudinal axis through an engine, or engines of interest, projected onto the vertical plane or symmetry of the airplane, and the line between the observer and the centroid* of the exit planes of the engines' exhaust nozzles.

* Mean of the locations of the engine exit planes projected onto the airplane's vertical plane of symmetry.

A.3 ANALYSIS FOR DERIVATION OF ONE-THIRD-OCTAVE-BAND FREE-FIELD LATERAL ATTENUATION:

A.3.1 Outline of the Method of Analysis: Lateral attenuation data presented in this AIR were derived from empirical correlations of the one-third-octave-band lateral attenuation determined from measurements of the sound from several airplane types. One-third-octave-band lateral attenuation data were obtained using the following method.

Assuming steady engine conditions and a fixed airplane configuration (i.e., airspeed, flap settings, landing-gear position, etc.), the sound pressure level at some reference distance around the moving airplane, L_a, is solely a function of the radiation angle, θ. The sound pressure level measured at the position of the observer, L_{om}, is given by

$$L_{om} = L_a + G - P - A_L, \quad (A.3.1)$$

where G is the ground reflection effect, P is the attenuation due to spherical spreading (inverse square law) and atmospheric absorption assuming straight line propagation, and A_L is the attenuation from all other loss mechanisms.

Equation (A.3.1) applies to both sideline and under-the-flight-path measuring positions. Subtracting the measured sideline level, L_{osm}, from the measured under-the-flight-path level, L_{oum}, for a given airplane configuration and engine power setting, yields

$$L_{oum} - L_{osm} = (L_{au} - L_{as}) + (G_u - G_s) - (P_u - P_s) - (A_{Lu} - A_{Ls}). \quad (A.3.2)$$

Free-field sound pressure levels at the observer position are equal to the measured levels with ground-reflection effects removed (i.e. $L_{of} = L_{om} - G$). Therefore, for equal sound propagation distances in a uniform atmosphere ($P_u = P_s$), and free-field conditions, Equation (A.3.2) becomes

$$L_{ouf} - L_{osf} = (L_{au} - L_{as}) + (A_{Ls} - A_{Lu}). \quad (A.3.3)$$

Lateral attenuation is found from the variation with time of one-third-octave-band sound pressure level at sideline and under-the-flight-path locations at constant radiation angle, $\theta_u = \theta_s$. For constant airplane source conditions and sound radiation angles, the sound pressure level from the equivalent source of airplane noise should be the same for measurements under and to the side of the flight path. Thus, $L_{au} = L_{as}$ in Equation (A.3.3) and the attenuation difference reduces to,

$$A_{Ls} - A_{Lu} = L_{ouf} - L_{osf}. \quad (A.3.4)$$

Because the observer angle at the time of emission of the under-the-flight-path spectrum is usually large, many of the components of attenuation A_{Lu} will be negligibly small. Jet-by-jet shielding should

A.3.1 Outline of the Method of Analysis (Cont'd.):

be small because sound from each engine will usually propagate to the observer without passing through an adjacent jet efflux. Also, a large observer angle ensures that there is little overground sound propagation so that any attenuation associated with that propagation path should be negligible. Further, variations in the length and direction of the propagation path, that can occur at shallow observer angles due to wind and temperature gradients, should be minimal.

Therefore, neglecting A_{Lu} compared with A_{Ls} and referencing the lateral attenuation to the under-the-flight-path free-field one-third-octave-band sound pressure levels gives,

$$A_L = L_{ouf} - L_{osf}, \qquad (A.3.5)$$

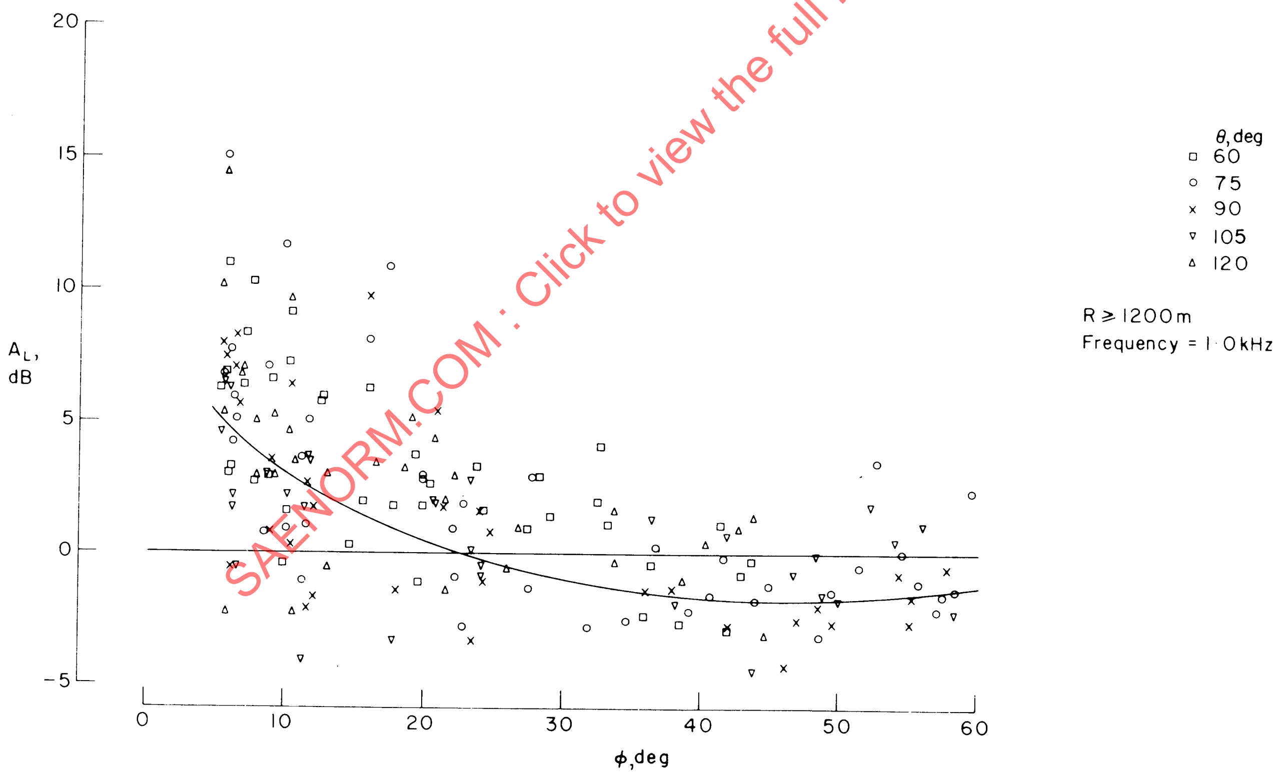
where A_L is the general letter symbol for the lateral attenuation of the one-third-octave-band sound pressure level for all loss mechanisms other than spherical wave divergence and atmospheric absorption.

Values of lateral attenuation were obtained, at fixed noise radiation angles within the range $60^\circ \leq \theta \leq 120^\circ$, for each of the one-third octave bands throughout the frequency range of the measured data. As a general principle, interfering levels of background noise were removed from the measured signal. However, when the measured sound pressure level in any one-third octave band was within 3 dB of the background noise level, no value of lateral attenuation was calculated for that band.

For one airplane, noise data were measured at low engine power with the airplane in a high drag configuration (i.e., flaps and undercarriage down). For that test condition, airframe noise could significantly contribute to the low frequency (less than 400 Hz) measured noise levels. Experimental test data, reported in Reference 6, suggest that, for an airplane in a high drag configuration airframe noise is omnidirectional. For an omnidirectional noise source the analysis procedure of comparing under-the-flight-path and sideline spectra at the same radiation angle to the engine axis is justified. Further, the assumption that the source of airframe noise was located at the centroid of the exit planes of the engine exhaust nozzles was considered to be reasonable for the airplane in question. These conclusions were validated by comparing the lateral attenuation derived from data having an airframe noise contribution with that from a similar configuration airplane tested at an engine power setting such that the sound pressure levels should not have been influenced by airframe noise. There was no detectable variation between the values of lateral attenuation of sound from the two airplanes indicating that the analysis for lateral attenuation was applicable to noise data having an airframe noise component.

A.3.2 Data Correlation: For each one-third-octave frequency band, the variation of lateral attenuation with elevation angle was investigated for bands of propagation distance. The bandwidth of these bands varied with propagation distance. At relatively short distances (less than 300 m), the bandwidth was one-half the maximum value of the propagation distance, and at long distances (greater than 1000 m), the ratio of propagation distance bandwidth to the maximum propagation distance in that band was approximately 1:5.

A typical example of the variation of one-third-octave-band lateral attenuation with observer angle, using data from one of the larger data sets (four engines below the wing), is presented in Sketch A.3.1. The different symbols indicate values of lateral attenuation for different sound-radiation angles. However, within the general data scatter it was not possible to identify any trend in the variation of lateral attenuation with sound-radiation angle. The line shown in this Sketch A.3.1 is the final correlation line, taken from Figure 14, for a propagation distance equal to, or greater than, 1200 m.

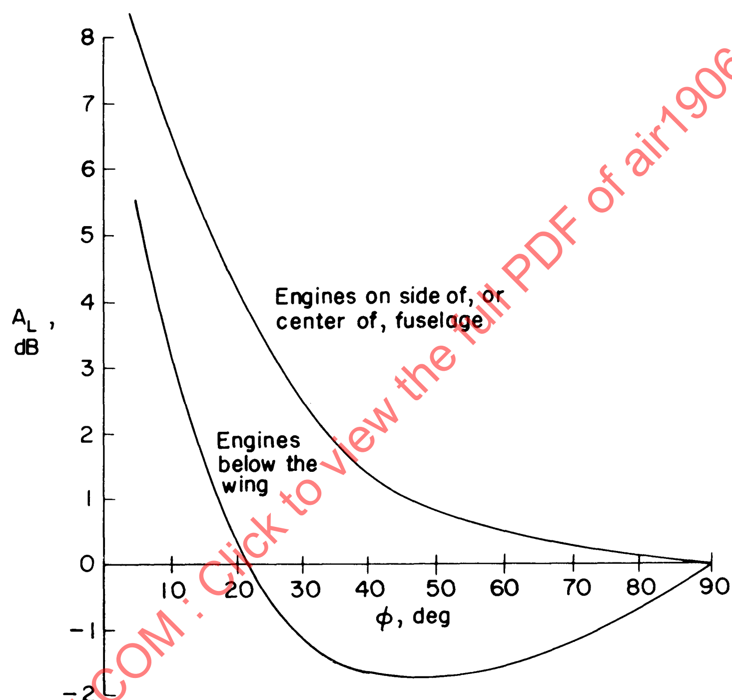


Sketch A.3.1 Variation of 1kHz one-third-octave-band lateral attenuation with observer angle.

From observations of the correlations of one-third-octave-band lateral attenuation against observer angle from different airplanes, the lateral attenuation data were divided into two categories: those for wing-mounted

A.3.2 Data Correlation (Cont'd.):

engine installations and those for engines mounted on the side of, or in the center of, the fuselage. Within each category the data showed consistent trends. For example, data for wing-mounted engine installations had negative values of lateral attenuation in all frequency bands at observer angles greater than 30 degrees, whereas the airplanes with only rear-mounted engines did not show this trend. Typical variations of lateral attenuation with observer angle for the two engine installations are presented in Sketch A.3.2.



Sketch A.3.2 Typical variations of lateral attenuation with observer angle.

The lines shown in Sketch A.3.2 were constrained, by definition, to be zero for a 90-degree observer angle. The difference between one-third-octave-band lateral attenuation for the two airplane/engine configurations may be caused by an installation effect, although, at the time this AIR was issued, no validated explanation was available for the negative attenuations* (i.e., increased sound pressure levels) at certain observer

*Possible reasons for the negative attenuations are effects associated with the airplane configuration and engine installation such as refraction effects that may have occurred when sound from wing-mounted engines propagated through the vortices shed from the wing tips or edges of extended flaps. Other possible reasons for negative attenuations include: refraction effects that may have occurred as the sound propagated through wind and temperature gradients or atmospheric turbulence; and nonlinear propagation effects for the higher-amplitude sound produced by older models of low-bypass-ratio turbofan engines. Data available for the development of the prediction method described in this AIR were not sufficient to verify these, or other, explanations for the negative attenuations.

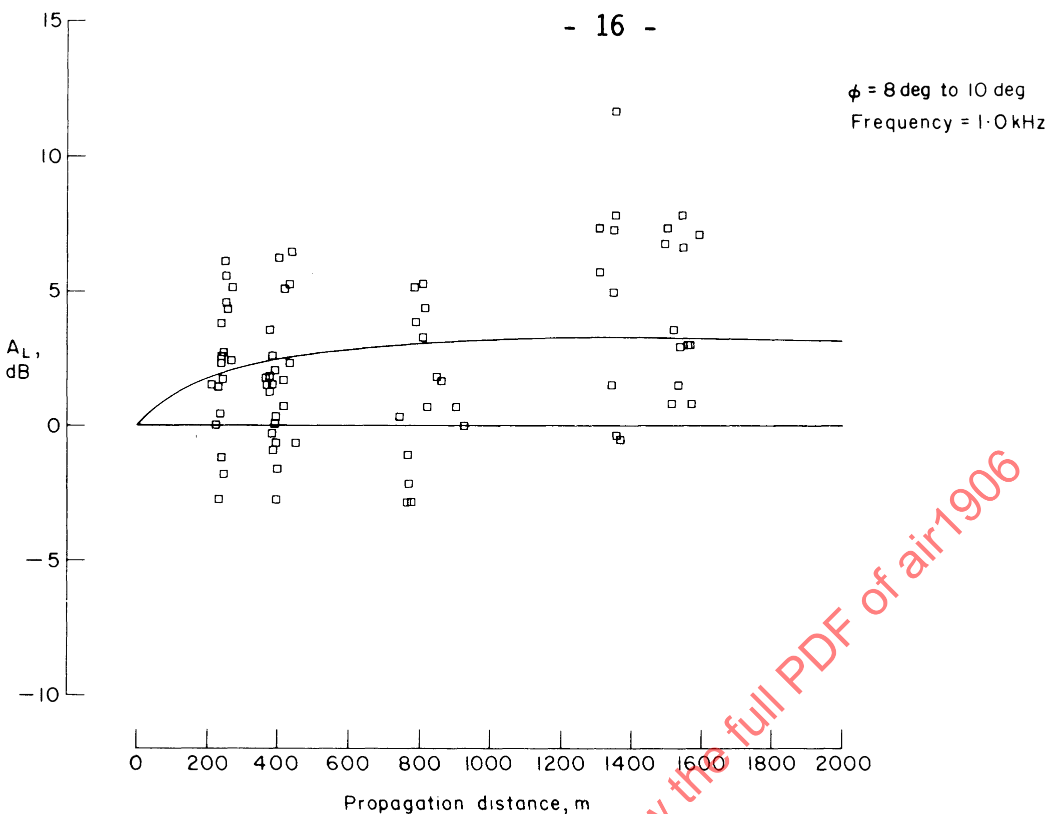
A.3.2 Data Correlation (Cont'd.):

angles. No negative attenuations are shown in Reference 1 for time-integrated, frequency-weighted quantities, although for one airplane with engines mounted below the wing, there were data used in the development of the method in that Reference that indicated negative attenuation at elevation angles greater than 35 degrees for effective perceived noise level and A-weighted sound exposure level.

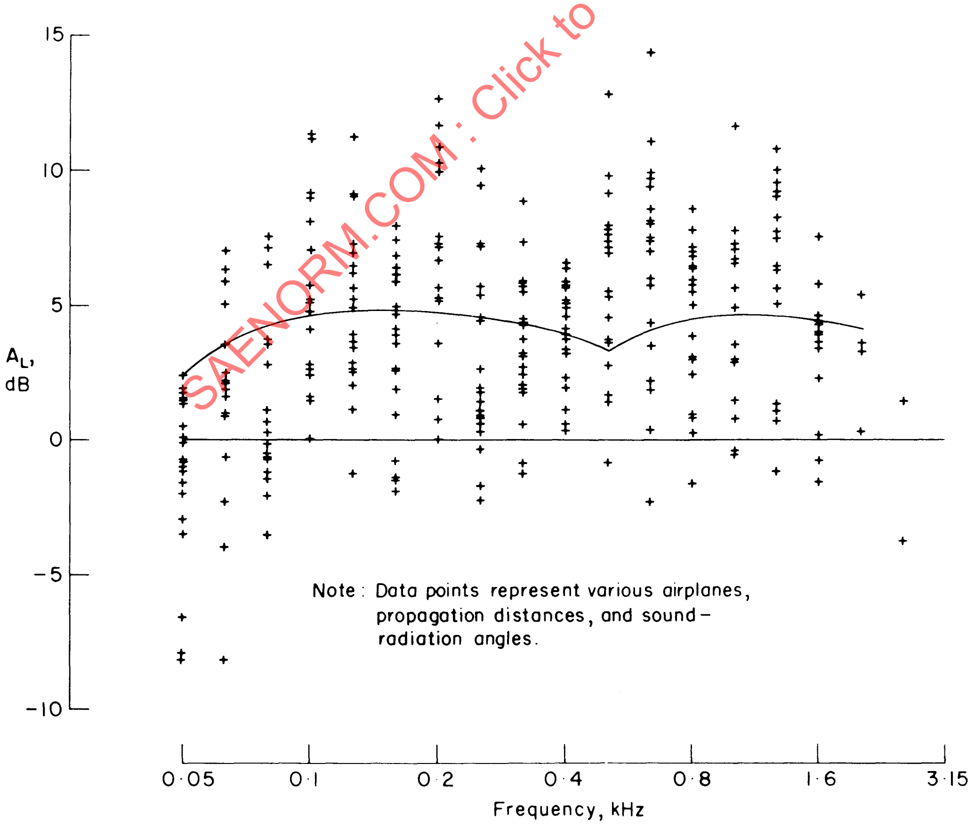
Investigation of the correlation of one-third-octave-band lateral attenuation against propagation distance and frequency, for limited ranges of observer angle, showed similar data scatter to that shown in Sketch A.3.1. Typical examples of these correlations for an airplane with engines below the wing are presented in Sketches A.3.3 and A.3.4. The correlation lines shown in these Sketches were taken from the data presented in Figures 1-24. In the case of the variation of lateral attenuation with propagation distance, the correlation lines were constrained by definition to be zero for a zero propagation distance.

Correlation of lateral attenuation and frequency, for the two engine installations, gave relationships of the form shown in Sketch A.3.5. Again, no validated explanation was available for the appearance of the minima in Sketch A.3.5. However, it is likely that the variation between the curves for the two engine installations may be at least partly explained by differences in airframe sound reflection and shielding effects between the two airframe/engine configurations.

A.3.3 Accuracy of Data: For the procedure used to determine one-third-octave-band lateral attenuation, it was necessary to estimate sound pressure levels, under-the-flight-path, at distances other than those at which measurements were taken. The calculation of the one-third-octave-band sound pressure levels at these distances involved the extrapolation of a reference spectrum using reference values of atmospheric attenuation rate. Consideration of the calculation of the reference spectrum, from under-the-flight-path spectra measured over a range of heights, provided an indication of the accuracy that was achieved in the analysis for lateral attenuation. Ground reflection effects were first removed from each one-third-octave-band sound pressure level spectrum measured under the flight path. The equivalent free-field sound pressure levels were then adjusted to a common distance of 100 m from the equivalent source of airplane noise. For each one-third octave band, a first order regression analysis was then carried out on the sound pressure levels as a function of slant distance. The slope of the regression line gave the prevailing atmospheric attenuation rate and the regression line value at 100 m gave the reference sound pressure level. The spectrum at the reference distance of 100 m and the derived test-day atmospheric absorption values were used to estimate the equivalent under-the-flight path spectrum at any distance greater than 100 m.

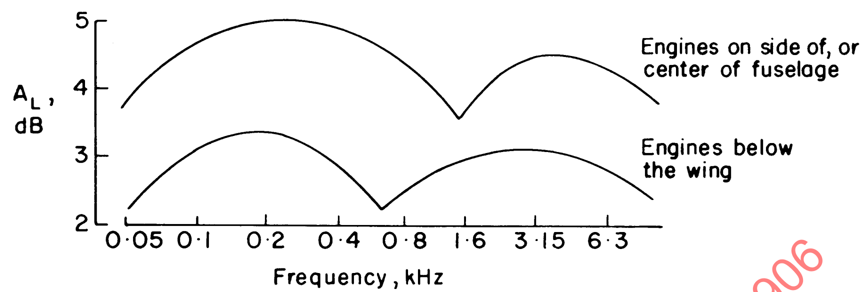


Sketch A. 3. 3 Variation of lateral attenuation with propagation distance.



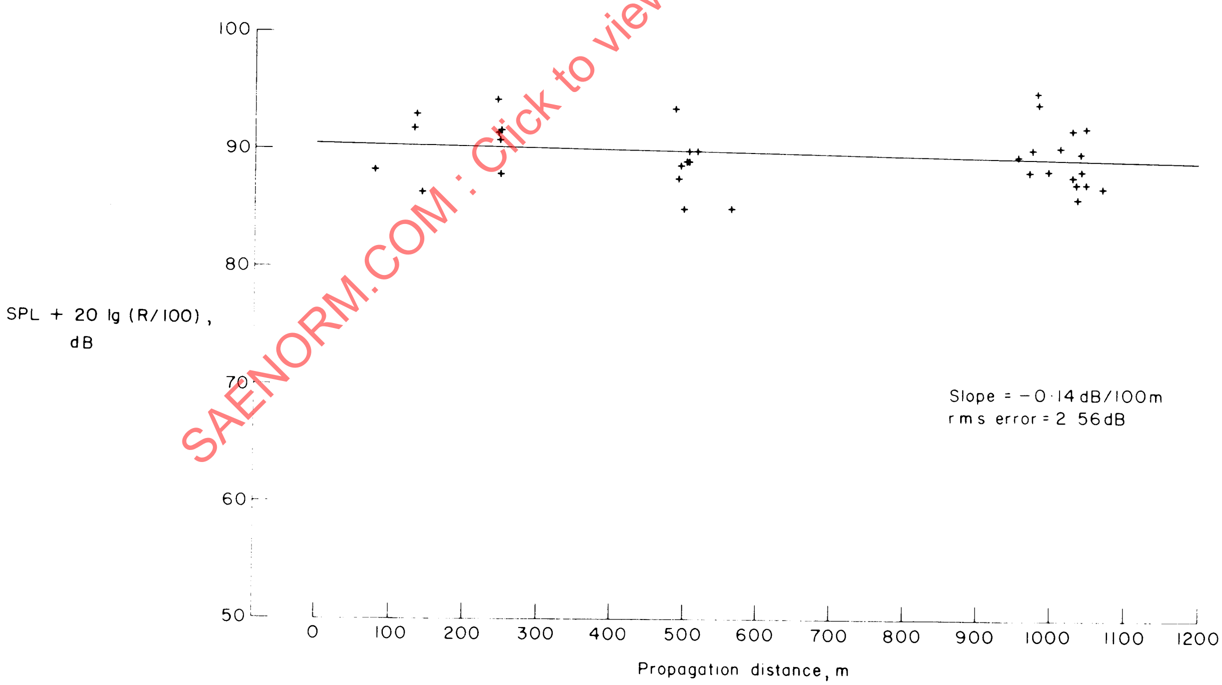
Sketch A. 3. 4 Variation of lateral attenuation with frequency.

A.3.3 Accuracy of Data (Cont'd.):



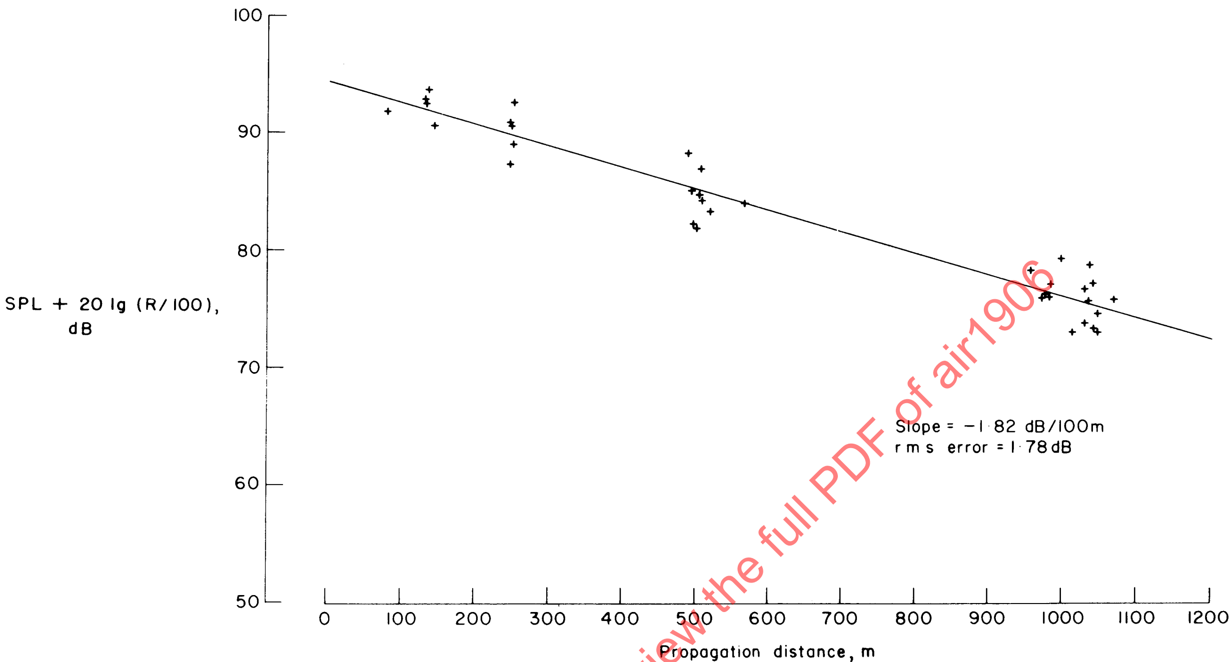
Sketch A.3.5 Typical variations of lateral attenuation with frequency.

Examples of the regression analysis for the one-third octave bands centered at 250 Hz and 2 kHz are presented in Sketches A.3.6 and A.3.7 respectively.



Sketch A.3.6 Regression analysis for the one-third-octave-band sound pressure level at 0·25 kHz, under the flight path.

A.3.3 Accuracy of Data (Cont'd.):

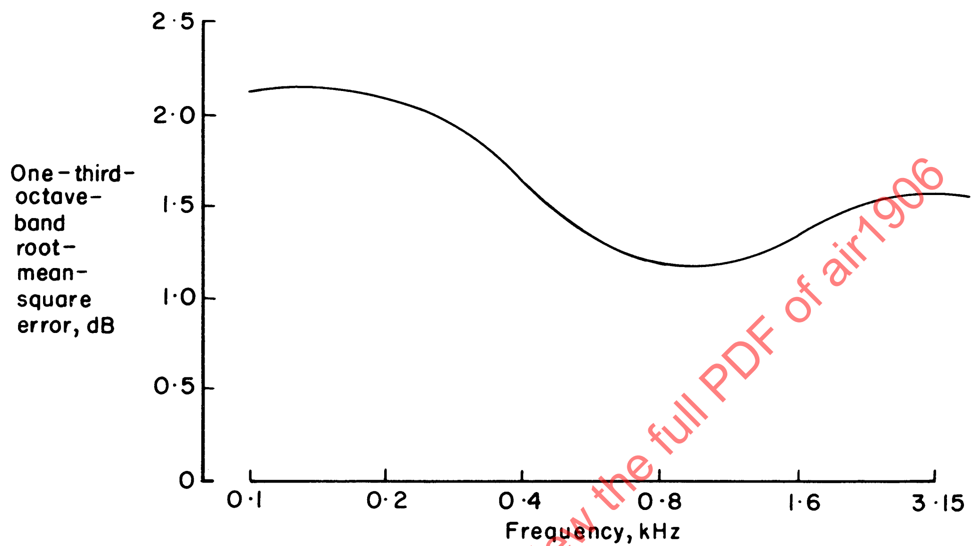


Sketch A.3.7 Regression analysis for the one-third-octave-band sound pressure level at 2·0 kHz, under the flight path.

The root-mean-square error* of the regression analysis was found to be frequency dependent and had a value of between 1.0 and 2.5 dB. An example of the variation with frequency of the one-third-octave-band root-mean-square error is presented in Sketch A.3.8.

$$* \text{ rms error} = \left\{\frac{\sum(\text{measured SPL} - \text{regression analysis SPL})^2}{\text{number of SPL measurements}}\right\}^{1/2}$$

A.3.3 Accuracy of Data (Cont'd.):

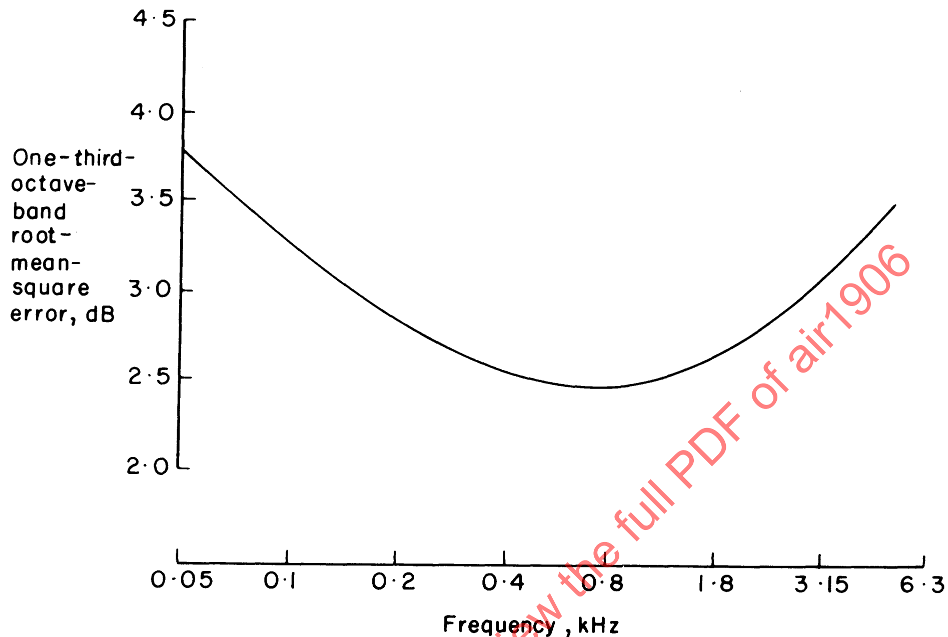


Sketch A.3.8 Variation with frequency of the rms error of the regression analysis.

As a further check on the internal consistency of the data-analysis procedure, the slopes of the regression lines were compared with atmospheric absorption coefficients from SAE ARP 866A. In general there was good agreement between the measured and calculated values of atmospheric attenuation.

Because lateral attenuation was calculated from differences between the extrapolated "free-field" under-the-flight-path sound pressure levels and the "free-field" sideline sound pressure levels, the error in the values of lateral attenuation is not less than that in the under-the-flight-path data. The variation of the root-mean-square error with frequency, derived from comparing the prediction procedure with the measured data, for one of the larger data sets is shown in Sketch A.3.9.

A.3.3 Accuracy of Data (Cont'd.):



Sketch A.3.9 Variation with frequency of the rms error of one-third-octave-band lateral attenuation.

The statistical error caused by insufficient sampling time increases as frequency decreases and may be significant for one-third octave bands at frequencies below 100 Hz for averaging times of 0.5 second, or less. At frequencies greater than 4 kHz, the true sound pressure level from the airplane noise source is often not measurable because the signal level is close to the level of the background noise. However, at the typical sideline distances over which the data are likely to be used, it is the sound pressure levels of the mid-frequency bands (0.5 to 2 kHz) where the rms errors are lowest. Sound pressure levels in that range of frequency normally determine the magnitude of frequency-weighted quantities such as A-weighted sound level and perceived noise level at sideline locations.

The considerable scatter in the data (see Sketches A.3.1, A.3.3 and A.3.4) may be the result of errors in source location and airplane tracking, the effect of a non-homogeneous and turbulent atmosphere (which would cause the measured levels to vary with time), and background noise from ambient sound or electronic noise in the instruments used for data acquisition and analysis. For airplanes with the same types of engine installation, it was not possible to differentiate between results for different sound radiation angles as the results lay within the data scatter. However, for the two general types of engine installations for which data were available, there were significant differences in the values of lateral attenuation, and hence data are presented separately in this AIR for airplanes having under-wing engines and fuselage-mounted engines.

A.3.4 Meteorological Conditions: During the flight tests to obtain the noise data analyzed for lateral attenuation, the meteorological conditions were generally good with no reported temperature inversions and with low wind speeds at ground level. Air temperatures and humidities aloft were within limits typically allowed for noise-certification tests. For good meteorological conditions the effect of refraction, caused by wind and temperature gradients, should have been small for the range of observer angles considered. However, for observer angles less than five degrees, there was an increase in the data scatter, even under good meteorological test conditions.

A.4 NOMENCLATURE:

A_L	one-third-octave-band lateral attenuation of free-field sound pressure level
D	distance along flight track between airplane and observer (see Sketch A.2.1)
G	ground-reflection effect (spectral irregularities plus a 3 dB or 6 dB factor for the influence of the ground plane on the sound pressure level measured by pole-mounted or ground-plane microphones, respectively)
H	height (see Sketch A.2.1)
L	far-field sound pressure level*
ℓ	sideline or lateral distance (see Sketch A.2.1b)
P	attenuation of sound pressure level due to spherical wave spreading and atmospheric absorption
R	sound propagation distance between centroid of engine exhausts and observer (see Sketch A.2.1)
x,y,z	cartesian coordinates (see Sketch A.2.1)
θ	angle of radiation relative to engine axis (see Sketch A.2.1)
ϕ	observer angle, i.e., angle in vertical plane, between line joining observer and centroid of engine exhausts and the projection of that line onto the ground plane (see Sketch A.2.1)

*The reference sound pressure is 20 micropascals for all sound pressure levels.

A.4 NOMENCLATURE (Cont'd.):

Subscripts

a	airplane
f	free-field
m	measured
o	observer
s	sideline
u	under-the-flight path

TABLE 1. Lateral attenuation data for the two engine-installation types.

	Figure Number	
one-third octave band nominal center freq., Hz	engines mounted below the wing	engines mounted on the side or the center of the fuselage
50	1	25
63	2	26
80	3	27
100	4	28
125	5	29
160	6	30
200	7	31
250	8	32
315	9	33
400	10	34
500	11	35
630	12	36
800	13	37
1 000	14	38
1 250	15	39
1 600	16	40
2 000	17	41
2 500	18	42
3 150	19	43
4 000	20	44
5 000	21	45
6 300	22	46
8 000	23	47
10 000	24	48

Note: On the figures R = 200 m and ø = 10 deg denote the horizontal scales of sound propagation distance and observer angle, respectively, for interpolation between the plotted carpet lines.

TABLE 2
One-third-octave-band lateral attenuation of sound for airplanes with wing-mounted engines

ø deg	R,m 0	200	400	600	800	1000	1200
One-third-octave-band center frequency= 50 Hz							
5	0.00	1.95	2.76	3.28	3.57	3.70	3.75
10	0.00	1.12	1.59	1.88	2.07	2.18	2.25
15	0.00	0.42	0.65	0.79	0.87	0.91	0.91
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	-0.51	-0.82	-1.07	-1.16	-1.18	-1.19
40	0.00	-0.83	-1.16	-1.35	-1.43	-1.53	-1.59
50	0.00	-0.70	-1.09	-1.31	-1.50	-1.61	-1.70
60	0.02	-0.59	-0.96	-1.20	-1.32	-1.43	-1.55
70	0.01	-0.47	-0.74	-0.90	-1.02	-1.12	-1.20
80	0.02	-0.28	-0.44	-0.53	-0.61	-0.67	-0.67
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 63 Hz							
5	0.00	2.27	3.13	3.55	3.75	3.83	3.86
10	0.00	1.29	1.79	2.07	2.25	2.36	2.40
15	0.00	0.57	0.82	0.91	0.97	0.98	0.99
20	0.00	0.06	0.08	0.09	0.09	0.09	0.09
30	0.00	-0.43	-0.67	-0.82	-0.92	-0.97	-0.99
40	0.00	-0.67	-0.97	-1.21	-1.39	-1.49	-1.51
50	0.00	-0.78	-1.19	-1.41	-1.58	-1.69	-1.74
60	0.00	-0.75	-1.10	-1.38	-1.50	-1.58	-1.65
70	0.00	-0.59	-0.87	-1.06	-1.17	-1.25	-1.30
80	0.00	-0.34	-0.53	-0.64	-0.69	-0.72	-0.74
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 80 Hz							
5	0.00	2.89	4.06	4.72	5.08	5.27	5.31
10	0.00	1.69	2.47	2.89	3.09	3.18	3.20
15	0.00	0.81	1.15	1.31	1.41	1.49	1.52
20	0.00	0.19	0.31	0.37	0.39	0.40	0.40
30	0.00	-0.46	-0.62	-0.77	-0.86	-0.92	-0.95
40	0.00	-0.77	-1.06	-1.25	-1.36	-1.48	-1.53
50	0.00	-0.75	-1.12	-1.27	-1.38	-1.48	-1.59
60	0.00	-0.63	-0.97	-1.14	-1.23	-1.35	-1.44
70	0.00	-0.50	-0.75	-0.88	-0.96	-1.04	-1.10
80	0.00	-0.26	-0.42	-0.50	-0.55	-0.58	-0.60
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 100 Hz							
5	0.00	3.11	4.40	5.11	5.51	5.73	5.81
10	0.00	1.89	2.75	3.17	3.40	3.52	3.62
15	0.00	0.95	1.36	1.60	1.72	1.79	1.81
20	0.00	0.20	0.36	0.43	0.49	0.51	0.51
30	0.00	-0.51	-0.65	-0.73	-0.80	-0.85	-0.89
40	0.00	-0.88	-1.11	-1.29	-1.41	-1.51	-1.59
50	0.00	-0.97	-1.30	-1.47	-1.59	-1.66	-1.68
60	0.00	-0.82	-1.11	-1.26	-1.38	-1.44	-1.46
70	0.00	-0.63	-0.83	-0.92	-0.99	-1.02	-1.03
80	0.00	-0.35	-0.42	-0.47	-0.51	-0.53	-0.55
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 2 (continued)
One-third-octave-band lateral attenuation of sound for airplanes with wing-mounted engines

ø deg	R,m 0	200	400	600	800	1000	1200
One-third-octave-band center frequency= 125 Hz							
5	0.00	3.21	4.62	5.42	5.81	6.03	6.09
10	0.00	1.98	2.87	3.40	3.71	3.85	3.88
15	0.00	1.00	1.53	1.76	1.87	1.93	1.95
20	0.00	0.28	0.43	0.51	0.54	0.57	0.57
30	0.00	-0.32	-0.58	-0.75	-0.84	-0.88	-0.90
40	0.00	-0.71	-1.02	-1.21	-1.35	-1.46	-1.54
50	0.00	-0.68	-1.07	-1.32	-1.47	-1.58	-1.67
60	0.00	-0.59	-0.92	-1.13	-1.29	-1.41	-1.48
70	0.00	-0.46	-0.68	-0.83	-0.95	-1.03	-1.10
80	0.00	-0.25	-0.38	-0.48	-0.53	-0.58	-0.60
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 160 Hz							
5	0.00	3.83	5.19	5.80	6.13	6.30	6.38
10	0.00	2.24	3.15	3.69	4.02	4.19	4.30
15	0.00	1.12	1.62	1.87	2.00	2.09	2.10
20	0.00	0.28	0.41	0.51	0.55	0.57	0.59
30	0.00	-0.44	-0.68	-0.85	-0.94	-1.00	-1.01
40	0.00	-0.77	-0.97	-1.14	-1.25	-1.35	-1.44
50	0.00	-0.79	-1.04	-1.20	-1.32	-1.42	-1.50
60	0.00	-0.68	-0.90	-1.05	-1.17	-1.27	-1.36
70	0.01	-0.51	-0.68	-0.80	-0.88	-0.97	-1.01
80	0.00	-0.30	-0.40	-0.45	-0.49	-0.53	-0.56
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 200 Hz							
5	0.00	4.02	5.52	6.07	6.33	6.45	6.49
10	0.00	2.60	3.63	4.05	4.20	4.29	4.30
15	0.00	1.46	2.03	2.20	2.29	2.30	2.31
20	0.00	0.39	0.58	0.69	0.76	0.79	0.81
30	0.00	-0.52	-0.75	-0.91	-1.01	-1.11	-1.19
40	0.00	-0.77	-1.11	-1.32	-1.47	-1.54	-1.58
50	0.00	-0.86	-1.21	-1.39	-1.47	-1.49	-1.50
60	0.00	-0.74	-1.02	-1.13	-1.17	-1.20	-1.22
70	0.00	-0.57	-0.72	-0.81	-0.86	-0.88	-0.89
80	0.00	-0.29	-0.39	-0.42	-0.46	-0.46	-0.46
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 250 Hz							
5	0.00	3.14	4.66	5.57	6.07	6.31	6.41
10	0.00	2.17	3.08	3.61	3.92	4.05	4.11
15	0.00	1.26	1.77	2.00	2.12	2.20	2.25
20	0.00	0.48	0.66	0.76	0.79	0.80	0.80
30	0.00	-0.45	-0.70	-0.81	-0.92	-1.00	-1.04
40	0.00	-0.75	-1.00	-1.21	-1.33	-1.42	-1.48
50	0.00	-0.79	-1.09	-1.26	-1.37	-1.45	-1.49
60	0.00	-0.69	-0.94	-1.11	-1.21	-1.29	-1.33
70	0.00	-0.49	-0.68	-0.80	-0.89	-0.92	-0.97
80	0.00	-0.27	-0.36	-0.42	-0.49	-0.50	-0.52
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 2 (continued)
One-third-octave-band lateral attenuation of sound for airplanes with wing-mounted engines

ø deg	R,m 0	200	400	600	800	1000	1200
One-third-octave-band center frequency= 315 Hz							
5	0.00	3.67	4.92	5.50	5.80	5.95	6.00
10	0.00	2.24	3.13	3.59	3.81	3.95	4.00
15	0.00	1.11	1.65	1.92	2.10	2.20	2.21
20	0.00	0.29	0.46	0.58	0.66	0.69	0.70
30	0.00	-0.59	-0.79	-0.90	-0.97	-0.99	-1.00
40	0.00	-0.88	-1.13	-1.25	-1.33	-1.41	-1.44
50	0.00	-0.88	-1.08	-1.23	-1.30	-1.34	-1.38
60	0.00	-0.74	-0.93	-1.06	-1.11	-1.14	-1.15
70	0.00	-0.53	-0.68	-0.76	-0.82	-0.83	-0.83
80	0.00	-0.30	-0.37	-0.40	-0.44	-0.44	-0.44
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 400 Hz							
5	0.00	2.97	4.19	4.78	5.08	5.24	5.34
10	0.00	1.75	2.41	2.86	3.14	3.30	3.37
15	0.00	0.82	1.12	1.33	1.41	1.48	1.50
20	0.00	0.12	0.18	0.21	0.22	0.23	0.23
30	0.00	-0.50	-0.89	-1.10	-1.19	-1.20	-1.20
40	0.00	-0.75	-1.17	-1.40	-1.51	-1.59	-1.60
50	0.00	-0.78	-1.13	-1.38	-1.48	-1.58	-1.63
60	0.00	-0.68	-0.98	-1.19	-1.29	-1.38	-1.39
70	0.00	-0.53	-0.71	-0.85	-0.91	-0.98	-1.04
80	0.00	-0.30	-0.40	-0.47	-0.50	-0.53	-0.55
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 500 Hz							
5	0.00	2.83	4.04	4.78	5.12	5.29	5.31
10	0.00	1.58	2.28	2.70	2.96	3.06	3.09
15	0.00	0.69	1.00	1.20	1.31	1.38	1.40
20	0.00	0.14	0.19	0.20	0.21	0.21	0.21
30	0.00	-0.44	-0.69	-0.85	-0.96	-1.03	-1.05
40	0.00	-0.61	-0.92	-1.10	-1.11	-1.17	-1.19
50	0.00	-0.59	-0.89	-1.05	-1.14	-1.20	-1.21
60	0.00	-0.50	-0.72	-0.86	-0.93	-0.99	-1.03
70	0.00	-0.38	-0.54	-0.64	-0.68	-0.71	-0.73
80	0.00	-0.21	-0.30	-0.36	-0.38	-0.38	-0.38
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 630 Hz							
5	0.00	2.25	3.62	4.46	4.91	5.10	5.20
10	0.00	1.43	2.22	2.70	2.98	3.11	3.16
15	0.00	0.69	1.06	1.25	1.38	1.44	1.48
20	0.00	0.17	0.26	0.32	0.36	0.38	0.38
30	0.00	-0.49	-0.69	-0.80	-0.85	-0.87	-0.87
40	0.00	-0.64	-0.90	-1.06	-1.14	-1.20	-1.25
50	0.00	-0.71	-0.94	-1.08	-1.16	-1.21	-1.26
60	0.00	-0.62	-0.85	-0.97	-1.02	-1.04	-1.04
70	0.00	-0.45	-0.63	-0.71	-0.75	-0.77	-0.77
80	0.00	-0.24	-0.33	-0.37	-0.39	-0.39	-0.40
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 2 (continued)
One-third-octave-band lateral attenuation of sound for airplanes with wing-mounted engines

ø deg	R,m 0	200	400	600	800	1000	1200
One-third-octave-band center frequency= 800 Hz							
5	0.00	2.76	3.86	4.44	4.72	4.37	4.93
10	0.00	1.71	2.42	2.84	3.01	3.11	3.15
15	0.00	0.81	1.24	1.45	1.55	1.59	1.60
20	0.00	0.25	0.37	0.42	0.48	0.49	0.50
30	0.00	-0.42	-0.61	-0.73	-0.80	-0.83	-0.84
40	0.00	-0.69	-0.97	-1.10	-1.20	-1.21	-1.20
50	0.00	-0.70	-0.94	-1.09	-1.18	-1.20	-1.21
60	0.00	-0.61	-0.83	-0.94	-0.98	-0.99	-1.02
70	0.00	-0.47	-0.63	-0.70	-0.73	-0.73	-0.74
80	0.00	-0.25	-0.35	-0.40	-0.40	-0.40	-0.40
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 1000 Hz							
5	0.00	2.65	3.67	4.28	4.67	4.90	4.98
10	0.00	1.58	2.29	2.71	2.96	3.08	3.11
15	0.00	0.75	1.14	1.36	1.51	1.59	1.62
20	0.00	0.27	0.40	0.47	0.50	0.51	0.52
30	0.00	-0.40	-0.65	-0.81	-0.86	-0.90	-0.93
40	0.00	-0.69	-1.01	-1.22	-1.30	-1.36	-1.39
50	0.00	-0.79	-1.19	-1.36	-1.44	-1.47	-1.49
60	0.00	-0.70	-1.01	-1.15	-1.21	-1.21	-1.22
70	0.00	-0.52	-0.75	-0.83	-0.88	-0.90	-0.90
80	0.00	-0.29	-0.40	-0.46	-0.48	-0.49	-0.49
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 1250 Hz							
5	0.00	2.55	3.75	4.61	5.12	5.38	5.45
10	0.00	1.58	2.32	2.78	3.08	3.28	3.33
15	0.00	0.90	1.32	1.56	1.69	1.76	1.78
20	0.00	0.34	0.47	0.54	0.56	0.56	0.57
30	0.00	-0.36	-0.51	-0.61	-0.65	-0.68	-0.69
40	0.00	-0.61	-0.88	-1.04	-1.15	-1.16	-1.19
50	0.00	-0.58	-0.93	-1.11	-1.20	-1.25	-1.28
60	0.00	-0.58	-0.79	-0.95	-1.05	-1.09	-1.10
70	0.00	-0.39	-0.59	-0.73	-0.80	-0.81	-0.81
80	0.00	-0.21	-0.31	-0.38	-0.42	-0.44	-0.44
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 1600 Hz							
5	0.00	2.92	4.42	5.09	5.37	5.50	5.56
10	0.01	1.99	2.93	3.33	3.50	3.57	3.59
15	0.00	1.01	1.51	1.76	1.89	1.96	2.00
20	0.00	0.42	0.60	0.69	0.74	0.78	0.78
30	0.00	-0.25	-0.43	-0.55	-0.62	-0.66	-0.68
40	0.00	-0.51	-0.76	-0.91	-1.00	-1.08	-1.09
50	0.00	-0.62	-0.84	-1.02	-1.10	-1.17	-1.18
60	0.00	-0.52	-0.79	-0.90	-0.95	-0.99	-1.03
70	0.00	-0.41	-0.59	-0.69	-0.72	-0.76	-0.76
80	0.00	-0.23	-0.34	-0.38	-0.41	-0.43	-0.43
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 2 (continued)
One-third-octave-band lateral attenuation of sound for airplanes with wing-mounted engines

ø deg	R,m 0	200	400	600	800	1000	1200
One-third-octave-band center frequency= 2000 Hz							
5	0.00	3.05	4.39	5.19	5.67	5.86	5.94
10	0.00	1.98	2.78	3.19	3.39	3.51	3.59
15	0.00	1.08	1.50	1.72	1.84	1.90	1.94
20	0.00	0.50	0.66	0.70	0.70	0.71	0.71
30	0.00	-0.20	-0.35	-0.42	-0.48	-0.50	-0.51
40	0.00	-0.54	-0.72	-0.82	-0.86	-0.90	-0.93
50	0.00	-0.61	-0.87	-0.98	-1.04	-1.04	-1.04
60	0.00	-0.55	-0.83	-0.92	-0.93	-0.95	-0.96
70	0.00	-0.42	-0.63	-0.69	-0.70	-0.70	-0.71
80	0.00	-0.24	-0.35	-0.37	-0.38	-0.39	-0.39
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 2500 Hz							
5	0.00	3.19	3.99	4.44	4.65	4.76	4.81
10	0.00	1.97	2.51	2.80	2.96	3.04	3.09
15	0.00	1.01	1.33	1.50	1.57	1.60	1.61
20	0.00	0.30	0.40	0.48	0.48	0.50	0.50
30	0.00	-0.31	-0.47	-0.55	-0.58	-0.59	-0.59
40	0.00	-0.45	-0.70	-0.79	-0.83	-0.86	-0.87
50	0.00	-0.56	-0.75	-0.86	-0.92	-0.95	-0.99
60	0.00	-0.53	-0.67	-0.76	-0.80	-0.86	-0.86
70	0.00	-0.39	-0.52	-0.56	-0.61	-0.62	-0.64
80	0.00	-0.21	-0.27	-0.30	-0.33	-0.36	-0.36
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 3150 Hz							
5	0.00	3.08	3.62	3.98	4.19	4.31	4.39
10	0.00	1.81	2.28	2.50	2.62	2.71	2.77
15	0.00	0.85	1.16	1.32	1.39	1.45	1.48
20	0.00	0.30	0.41	0.55	0.59	0.59	0.59
30	0.00	-0.25	-0.43	-0.51	-0.53	-0.53	-0.53
40	0.00	-0.43	-0.66	-0.78	-0.86	-0.89	-0.91
50	0.00	-0.51	-0.71	-0.85	-0.90	-0.95	-0.95
60	0.00	-0.45	-0.62	-0.71	-0.78	-0.80	-0.80
70	0.00	-0.33	-0.48	-0.53	-0.58	-0.59	-0.60
80	0.00	-0.17	-0.24	-0.30	-0.35	-0.35	-0.35
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 4000 Hz							
5	0.00	2.49	3.38	3.81	4.00	4.12	4.20
10	0.00	1.30	1.76	2.03	2.18	2.25	2.29
15	0.00	0.58	0.78	0.85	0.88	0.89	0.89
20	0.00	0.17	0.20	0.20	0.20	0.20	0.20
30	0.00	-0.30	-0.44	-0.53	-0.55	-0.56	-0.56
40	0.00	-0.50	-0.70	-0.79	-0.83	-0.88	-0.91
50	0.00	-0.57	-0.76	-0.82	-0.89	-0.89	-0.89
60	0.00	-0.51	-0.66	-0.71	-0.75	-0.74	-0.73
70	0.00	-0.41	-0.47	-0.51	-0.53	-0.53	-0.53
80	0.00	-0.20	-0.25	-0.28	-0.29	-0.29	-0.30
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 2 (concluded)
One-third-octave-band lateral attenuation of sound for airplanes with wing-mounted engines

ø deg	R,m 0	200	400	600	800	1000	1200
One-third-octave-band center frequency= 5000 Hz							
5	[illegible]	2.42	3.32	[illegible]	3.84	3.92	3.99
10	0.00	1.24	1.82	2.03	2.09	2.09	2.09
15	0.00	0.51	0.72	0.81	0.88	0.89	0.90
20	0.00	0.04	0.09	0.10	0.10	0.10	0.11
30	0.00	-0.34	-0.57	-0.62	-0.69	-0.72	-0.72
40	0.00	-0.45	-0.69	-0.81	-0.90	-0.98	-0.98
50	0.00	-0.41	-0.64	-0.77	-0.84	-0.90	-0.93
60	0.00	-0.35	-0.55	-0.64	-0.69	-0.75	-0.77
70	0.00	-0.27	-0.40	-0.49	-0.51	-0.53	-0.54
80	0.00	-0.15	-0.22	-0.28	-0.30	-0.30	0.30
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 6300 Hz							
5	0.00	1.01	1.63	1.94	2.09	2.19	2.21
10	0.00	0.72	1.02	1.19	1.31	1.37	1.38
15	0.00	0.42	0.57	0.64	0.67	0.68	0.68
20	0.00	0.13	0.18	0.17	0.18	0.18	0.18
30	0.00	-0.18	-0.30	-0.39	-0.40	-0.41	-0.42
40	0.00	-0.38	-0.48	-0.55	-0.57	-0.61	-0.64
50	0.00	-0.39	-0.59	-0.59	-0.61	-0.61	-0.61
60	0.00	-0.36	-0.42	-0.49	-0.49	-0.50	-0.51
70	0.00	-0.26	-0.33	-0.35	-0.35	-0.35	-0.35
80	0.00	-0.13	-0.15	-0.16	-0.16	-0.16	-0.16
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 8000 Hz							
5	0.00	0.76	1.03	1.19	1.29	1.30	1.30
10	0.00	0.53	0.73	0.81	0.81	0.83	0.83
15	0.00	0.26	0.29	0.31	0.31	0.31	0.31
20	0.00	0.11	0.12	0.12	0.12	0.12	0.12
30	0.00	-0.10	-0.19	-0.20	-0.23	-0.25	-0.25
40	0.00	-0.19	-0.30	-0.35	-0.41	-0.46	-0.46
50	0.00	-0.24	-0.38	-0.43	-0.47	-0.49	-0.49
60	0.00	-0.17	-0.23	-0.34	-0.37	-0.40	-0.41
70	0.00	-0.13	-0.19	-0.26	-0.28	-0.30	-0.31
80	0.00	-0.08	-0.12	-0.15	-0.15	-0.17	-0.17
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency=10000 Hz							
5	0.00	0.62	0.92	1.10	1.20	1.24	1.26
10	0.00	0.38	0.51	0.59	0.63	0.63	0.63
15	0.00	0.19	0.23	0.25	0.25	0.26	0.26
20	0.00	0.02	0.03	0.04	0.04	0.04	0.04
30	0.00	-0.11	-0.14	-0.17	-0.18	-0.19	-0.19
40	0.00	-0.14	-0.21	-0.25	-0.28	-0.29	-0.28
50	0.00	-0.15	-0.23	-0.25	-0.26	-0.26	-0.27
60	0.00	-0.14	-0.18	-0.20	-0.20	-0.21	-0.21
70	0.00	-0.10	-0.14	-0.15	-0.16	-0.16	-0.16
80	0.00	-0.06	-0.08	-0.10	-0.10	-0.10	-0.10
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 3
One-third-octave-band lateral attenuation of sound for airplanes with side-fuselage or center-fuselage-mounted engines

ø deg	R,m 0	200	400	600	800	1000	1200
One-third-octave-band center frequency= 50 Hz							
5	0.00	4.51	5.51	6.05	6.34	6.48	6.55
10	0.00	3.21	4.22	4.70	4.95	5.09	5.12
15	0.00	2.15	3.07	3.52	3.73	3.84	3.88
20	0.00	1.53	2.20	2.54	2.69	2.78	2.82
30	0.00	0.86	1.23	1.44	1.52	1.58	1.58
40	0.00	0.51	0.72	0.84	0.90	0.93	0.96
50	0.00	0.28	0.44	0.49	0.54	0.54	0.58
60	0.00	0.17	0.27	0.29	0.32	0.32	0.32
70	0.00	0.09	0.14	0.17	0.20	0.20	0.21
80	0.00	0.05	0.07	0.08	0.09	0.10	0.10
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 63 Hz							
5	0.00	4.22	5.74	6.42	6.80	6.99	7.10
10	0.00	3.30	4.40	4.89	5.14	5.31	5.38
15	0.00	2.45	3.19	3.56	3.79	3.92	3.98
20	0.00	1.79	2.38	2.68	2.85	2.94	2.97
30	0.00	1.00	1.43	1.61	1.76	1.76	1.80
40	0.00	0.58	0.85	0.99	1.03	1.03	1.03
50	0.01	0.35	0.49	0.55	0.57	0.57	0.57
60	0.00	0.19	0.27	0.33	0.33	0.33	0.33
70	0.00	0.10	0.13	0.17	0.18	0.19	0.19
80	0.00	0.04	0.07	0.08	0.09	0.09	0.10
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 80 Hz							
5	0.00	5.79	6.70	7.10	7.32	7.43	7.50
10	0.00	3.81	4.79	5.21	5.49	5.58	5.61
15	0.00	2.68	3.46	3.84	4.06	4.19	4.29
20	0.00	1.95	2.54	2.86	3.05	3.15	3.22
30	0.00	1.06	1.49	1.66	1.80	1.87	1.89
40	0.00	0.58	0.84	0.94	1.02	1.06	1.09
50	0.00	0.28	0.41	0.49	0.53	0.52	0.56
60	0.00	0.11	0.20	0.25	0.28	0.32	0.31
70	0.00	0.05	0.09	0.12	0.14	0.15	0.16
80	0.00	0.03	0.06	0.07	0.08	0.08	0.09
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 100 Hz							
5	0.00	4.98	6.32	7.12	7.61	7.32	7.91
10	0.00	3.79	4.84	5.51	5.85	6.04	6.09
15	0.00	2.79	3.60	4.00	4.23	4.39	4.48
20	0.00	2.03	2.70	3.04	3.21	3.29	3.33
30	0.00	1.14	1.58	1.82	1.94	1.98	1.98
40	0.00	0.61	0.86	1.05	1.13	1.19	1.17
50	0.00	0.31	0.47	0.52	0.58	0.58	0.58
60	0.00	0.16	0.22	0.27	0.30	0.31	0.31
70	0.00	0.07	0.11	0.15	0.17	0.18	0.18
80	0.00	0.03	0.05	0.06	0.07	0.07	0.08
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 3 (continued)
One-third-octave-band lateral attenuation of sound for airplanes with side-fuselage or center-fuselage-mounted engines

ø deg	R,m 0	200	400	600	800	1000	1200
One-third-octave-band center frequency= 125 Hz							
5	0.00	4.90	6.70	7.51	7.90	8.08	8.16
10	0.00	3.62	4.91	5.61	5.94	6.13	6.22
15	0.00	2.64	3.65	4.20	4.49	4.66	4.69
20	0.00	2.00	2.74	3.12	3.27	3.36	3.39
30	0.00	1.20	1.67	1.87	1.97	2.10	2.03
40	0.00	0.69	1.00	1.19	1.27	1.30	1.31
50	0.00	0.37	0.58	0.66	0.70	0.72	0.73
60	0.00	0.22	0.31	0.38	0.41	0.44	0.44
70	0.00	0.11	0.17	0.20	0.22	0.23	0.23
80	0.00	0.04	0.06	0.07	0.08	0.08	0.09
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 160 Hz							
5	0.00	5.55	6.34	7.51	7.96	8.13	8.22
10	0.00	4.16	5.21	5.76	6.07	6.19	6.28
15	0.00	3.05	3.80	4.19	4.39	4.52	4.56
20	0.00	2.34	2.91	3.18	3.36	3.45	3.50
30	0.00	1.39	1.76	1.93	2.03	2.10	2.11
40	0.00	0.78	1.02	1.14	1.22	1.24	1.27
50	0.00	0.41	0.57	0.68	0.71	0.74	0.74
60	0.00	0.24	0.35	0.41	0.42	0.43	0.43
70	0.00	0.13	0.17	0.21	0.22	0.23	0.23
80	0.00	0.03	0.06	0.07	0.08	0.08	0.09
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 200 Hz							
5	0.00	4.72	6.25	7.22	7.84	8.15	8.25
10	0.00	3.75	4.97	5.62	5.93	6.17	6.25
15	0.00	2.75	3.72	4.24	4.44	4.58	4.64
20	0.00	2.02	2.32	3.18	3.34	3.37	3.40
30	0.00	1.20	1.62	1.82	1.93	1.98	1.99
40	0.00	0.71	0.97	1.08	1.14	1.17	1.18
50	0.00	0.43	0.58	0.69	0.71	0.73	0.73
60	0.00	0.29	0.35	0.42	0.44	0.45	0.45
70	0.00	0.14	0.19	0.23	0.26	0.27	0.27
80	0.00	0.40	0.70	0.90	1.00	1.00	1.10
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 250 Hz							
5	0.00	5.51	6.90	7.65	8.00	8.15	8.20
10	0.00	4.14	5.14	5.56	5.78	5.88	5.95
15	0.00	3.12	3.86	4.09	4.20	4.32	4.32
20	0.00	2.28	2.91	3.08	3.18	3.21	3.21
30	0.00	1.31	1.74	1.92	2.01	2.07	2.08
40	0.00	0.84	1.18	1.32	1.38	1.42	1.45
50	0.00	0.59	0.78	0.89	0.97	0.99	0.99
60	0.00	0.36	0.54	0.60	0.62	0.64	0.64
70	0.00	0.20	0.30	0.35	0.34	0.36	0.40
80	0.00	0.07	0.12	0.12	0.12	0.12	0.17
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 3 (continued)
One-third-octave-band lateral attenuation of sound for airplanes with side-fuselage or center-fuselage-mounted engines

ø deg	R,m 0	200	400	600	800	1000	1200
One-third-octave-band center frequency= 315 Hz							
5	0.00	5.66	6.84	7.49	7.84	8.00	8.07
10	0.00	4.37	5.36	5.88	6.12	6.27	6.36
15	0.00	3.22	4.07	4.55	4.76	4.85	4.89
20	0.00	2.35	3.04	3.41	3.57	3.68	3.73
30	0.00	1.24	1.65	1.89	2.02	2.10	2.10
40	0.00	0.63	0.93	1.09	1.20	1.26	1.30
50	0.00	0.37	0.51	0.60	0.66	0.68	0.68
60	0.00	0.18	0.28	0.32	0.36	0.36	0.39
70	0.00	0.10	0.13	0.16	0.18	0.19	0.19
80	0.00	0.03	0.05	0.06	0.07	0.08	0.08
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 400 Hz							
5	0.00	5.21	6.66	7.33	7.66	7.85	7.98
10	0.00	4.28	5.52	6.07	6.37	6.50	6.59
15	0.00	3.41	4.33	4.78	5.01	5.16	5.23
20	0.00	2.60	3.32	3.67	3.86	3.99	4.08
30	0.00	1.38	1.85	2.09	2.25	2.34	2.38
40	0.00	0.73	1.01	1.16	1.23	1.27	1.32
50	0.00	0.42	0.61	0.70	0.78	0.78	0.81
60	0.00	0.23	0.36	0.43	0.48	0.49	0.50
70	0.00	0.12	0.20	0.24	0.28	0.29	0.30
80	0.00	0.06	0.10	0.11	0.12	0.13	0.13
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 500 Hz							
5	0.00	5.59	6.89	7.47	7.76	7.92	8.00
10	0.00	4.10	5.42	6.05	6.36	6.53	6.62
15	0.00	2.96	4.13	4.69	4.99	5.13	5.21
20	0.00	2.25	3.25	3.67	3.90	4.02	4.08
30	0.00	1.37	1.97	2.27	2.40	2.46	2.47
40	0.00	0.83	1.24	1.42	1.53	1.53	1.54
50	0.00	0.46	0.82	0.94	0.96	0.97	0.97
60	0.00	0.27	0.51	0.60	0.61	0.62	0.62
70	0.00	0.14	0.29	0.33	0.34	0.35	0.36
80	0.00	0.05	0.10	0.13	0.15	0.16	0.17
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 630 Hz							
5	0.00	5.37	6.46	7.05	7.38	7.54	7.70
10	0.00	4.36	5.29	5.72	6.00	6.15	6.24
15	0.00	3.47	4.29	4.65	4.81	4.94	4.99
20	0.00	2.72	3.34	3.67	3.81	3.88	3.88
30	0.00	1.58	1.99	2.20	2.33	2.38	2.40
40	0.00	0.94	1.17	1.24	1.35	1.37	1.41
50	0.00	0.53	0.68	0.72	0.77	0.80	0.82
60	0.00	0.29	0.40	0.43	0.44	0.45	0.45
70	0.00	0.14	0.20	0.22	0.24	0.25	0.25
80	0.00	0.60	0.91	0.10	0.11	0.12	0.12
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 3 (continued)
One-third-octave-band lateral attenuation of sound for airplanes with side-fuselage or center-fuselage-mounted engines

ϕ deg	R,m 0	200	400	600	800	1000	1200
One-third-octave-band center frequency= 800 Hz							
5	0.01	5.06	6.49	7.08	7.38	7.52	7.60
10	0.00	4.22	5.42	5.82	6.08	6.16	6.21
15	0.00	3.36	4.27	4.67	4.91	4.95	4.98
20	0.00	2.63	3.35	3.68	3.82	3.89	3.91
30	0.00	1.46	2.14	2.39	2.49	2.51	2.51
40	0.00	0.86	1.16	1.32	1.37	1.42	1.45
50	0.00	0.45	0.61	0.73	0.78	0.82	0.85
60	0.00	0.25	0.33	0.39	0.42	0.44	0.45
70	0.00	0.12	0.18	0.22	0.24	0.25	0.26
80	0.00	0.04	0.07	0.09	0.10	0.11	0.12
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 1000 Hz							
5	0.00	5.17	6.35	6.93	7.25	7.45	7.57
10	0.00	4.11	5.03	5.51	5.77	5.95	6.05
15	0.00	3.19	3.87	4.23	4.44	4.64	4.78
20	0.00	2.35	2.86	3.13	3.34	3.48	3.56
30	0.00	1.26	1.56	1.75	1.84	1.89	1.91
40	0.00	0.67	0.88	0.99	1.06	1.09	1.09
50	0.00	0.45	0.57	0.61	0.66	0.68	0.69
60	0.00	0.25	0.36	0.36	0.40	0.43	0.44
70	0.00	0.16	0.20	0.24	0.26	0.26	0.27
80	0.00	0.06	0.08	0.10	0.11	0.12	0.13
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 1250 Hz							
5	0.00	4.10	5.60	6.35	6.81	7.05	7.19
10	0.00	3.12	4.43	5.11	5.48	5.69	5.80
15	0.00	2.35	3.51	4.11	4.36	4.55	4.60
20	0.00	1.77	2.68	3.15	3.39	3.53	3.59
30	0.00	1.01	1.54	1.83	1.98	2.09	2.13
40	0.00	0.60	0.89	1.04	1.13	1.19	1.23
50	0.00	0.41	0.55	0.59	0.66	0.67	0.68
60	0.00	0.25	0.33	0.36	0.37	0.38	0.38
70	0.00	0.15	0.17	0.18	0.19	0.19	0.20
80	0.00	0.05	0.07	0.08	0.09	0.10	0.10
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 1600 Hz							
5	0.00	5.25	6.49	7.23	7.57	7.74	7.85
10	0.00	3.91	5.00	5.64	5.95	6.14	6.18
15	0.00	2.82	3.81	4.32	4.61	4.80	4.87
20	0.00	1.97	2.79	3.22	3.46	3.60	3.66
30	0.00	1.08	1.44	1.64	1.77	1.86	1.89
40	0.00	0.53	0.75	0.90	0.96	0.97	0.99
50	0.00	0.27	0.40	0.47	0.54	0.56	0.60
60	0.00	0.14	0.22	0.30	0.32	0.32	0.33
70	0.00	0.07	0.12	0.16	0.18	0.20	0.21
80	0.00	0.03	0.05	0.06	0.07	0.08	0.08
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 3 (continued)
One-third-octave-band lateral attenuation of sound for airplanes with side-fuselage or center-fuselage-mounted engines

ϕ deg	R,m 0	200	400	600	800	1000	1200
One-third-octave-band center frequency= 2000 Hz							
5	0.00	5.37	6.54	7.17	7.46	7.59	7.61
10	0.00	4.06	5.06	5.68	5.97	6.06	6.10
15	0.00	2.73	3.79	4.31	4.55	4.63	4.72
20	0.00	2.08	[illegible]	[illegible]	3.39	3.51	3.57
30	[illegible]	[illegible]	1.69	1.94	2.09	2.14	2.16
40	[illegible]	[illegible]	1.02	1.16	1.30	1.31	1.32
50	0.00	0.43	0.57	0.67	0.72	0.76	0.76
60	0.00	0.22	0.30	0.34	0.35	0.36	0.36
70	0.00	0.08	0.13	0.15	0.16	0.16	0.17
80	0.00	0.03	0.04	0.05	0.06	0.07	0.07
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 2500 Hz							
5	0.00	4.76	6.20	6.97	7.29	7.43	7.47
10	0.00	3.94	5.09	5.73	6.04	6.15	6.20
15	0.00	3.16	4.07	4.58	4.85	4.99	5.03
20	0.00	2.47	3.19	3.63	3.84	3.97	4.01
30	0.00	1.46	1.89	2.21	2.36	2.46	2.49
40	0.00	0.80	1.09	1.30	1.39	1.49	1.50
50	0.00	0.34	0.51	0.66	0.75	0.77	0.78
60	0.00	0.12	0.21	0.28	0.34	0.34	0.36
70	0.00	0.05	0.09	0.11	0.14	0.15	0.16
80	0.00	0.04	0.06	0.07	0.08	0.08	0.09
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 3150 Hz							
5	0.00	4.75	5.97	6.69	7.12	7.33	7.44
10	0.00	3.79	4.72	5.31	5.68	5.95	6.00
15	0.00	2.94	3.74	4.15	4.42	4.59	4.68
20	0.00	2.25	2.90	3.23	3.42	3.54	3.61
30	0.00	1.39	1.81	2.09	2.22	2.32	2.34
40	0.00	0.84	1.18	1.33	1.42	1.48	1.49
50	0.00	0.53	0.72	0.83	0.94	0.97	0.98
60	0.00	0.32	0.43	0.49	0.53	0.56	0.57
70	0.00	0.17	0.22	0.26	0.28	0.29	0.30
80	0.00	0.04	0.07	0.09	0.11	0.11	0.12
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 4000 Hz							
5	0.00	5.11	6.26	6.92	7.26	7.41	7.48
10	0.00	3.94	4.93	5.53	5.86	5.99	6.06
15	0.00	2.92	3.80	4.27	4.58	4.72	4.77
20	0.00	2.19	2.90	3.34	3.56	3.68	3.76
30	0.00	1.27	1.74	2.04	2.21	2.28	2.29
40	0.00	0.72	1.03	1.25	1.33	1.38	1.40
50	0.00	0.34	0.54	0.65	0.72	0.76	0.78
60	0.00	0.13	0.23	0.30	0.34	0.35	0.36
70	0.00	0.07	0.11	0.15	0.16	0.17	0.18
80	0.00	0.30	0.04	0.05	0.06	0.07	0.07
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 3 (concluded)
One-third-octave-band lateral attenuation of sound for airplanes with side-fuselage or center-fuselage-mounted engines

ϕ deg	R,m 0	200	400	600	800	1000	1200
One-third-octave-band center frequency= 5000 Hz							
5	0.00	5.39	6.48	7.00	7.24	7.36	7.45
10	0.00	4.17	5.06	5.52	5.74	5.88	5.96
15	0.00	3.18	3.94	4.29	4.51	4.63	4.67
20	0.00	2.46	2.96	3.28	3.53	3.64	3.67
30	0.00	1.47	1.76	1.99	2.17	2.25	2.30
40	0.00	0.79	1.05	1.26	1.35	1.46	1.48
50	0.00	0.42	0.55	0.69	0.81	0.87	0.90
60	0.00	0.19	0.30	0.37	0.42	0.46	0.48
70	0.00	0.09	0.16	0.20	0.22	0.23	0.23
80	0.00	0.03	0.05	0.06	0.07	0.08	0.08
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 6300 Hz							
5	0.00	4.10	5.23	5.93	6.30	6.50	6.59
10	0.00	3.21	4.20	4.81	5.10	5.29	5.38
15	0.00	2.49	3.47	3.90	4.16	4.28	4.34
20	0.00	1.93	2.82	3.17	3.36	3.46	3.48
30	0.00	1.17	1.71	2.00	2.19	2.26	2.27
40	0.00	0.69	0.99	1.14	1.30	1.36	1.39
50	0.00	0.34	0.48	0.60	0.69	0.72	0.74
60	0.00	0.16	0.24	0.28	0.31	0.33	0.35
70	0.00	0.07	0.11	0.12	0.13	0.14	0.15
80	0.00	0.03	0.04	0.05	0.05	0.05	0.05
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency= 8000 Hz							
5	0.00	4.54	5.68	6.29	6.55	6.69	6.75
10	0.00	3.66	4.71	5.12	5.32	5.44	5.50
15	0.00	2.93	3.74	4.07	4.25	4.34	4.38
20	0.00	2.35	2.90	3.16	3.34	3.41	3.44
30	0.00	1.25	1.66	1.89	2.00	2.08	2.11
40	0.00	0.65	0.93	1.10	1.18	1.23	1.22
50	0.00	0.31	0.49	0.56	0.62	0.65	0.66
60	0.00	0.17	0.27	0.30	0.31	0.32	0.32
70	0.00	0.07	0.13	0.14	0.15	0.15	0.15
80	0.00	0.03	0.04	0.05	0.05	0.06	0.06
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00
One-third-octave-band center frequency=10000 Hz							
5	0.00	4.19	5.50	6.21	6.51	6.68	6.71
10	0.00	3.42	4.53	5.03	5.28	5.39	5.40
15	0.00	2.67	3.55	3.94	4.17	4.26	4.28
20	0.00	2.04	2.72	3.05	3.21	3.28	3.30
30	0.00	1.14	1.60	1.83	1.96	2.00	2.01
40	0.00	0.48	0.79	0.99	1.13	1.16	1.17
50	0.00	0.23	0.41	0.52	0.58	0.60	0.60
60	0.00	0.13	0.22	0.26	0.27	0.28	0.28
70	0.00	0.07	0.10	0.12	0.12	0.13	0.13
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90	0.01	0.01	0.00	0.00	0.00	0.00	0.00

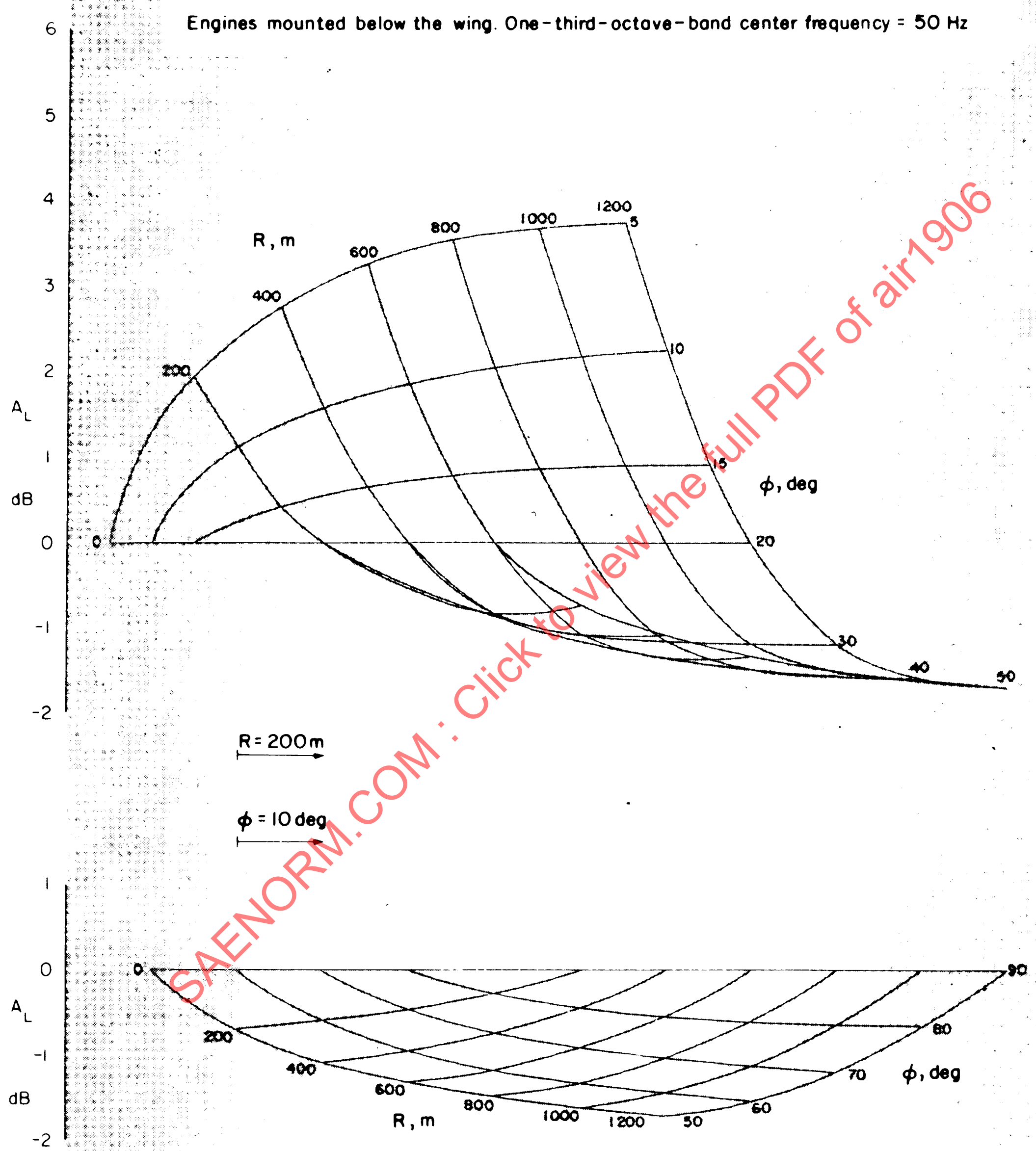

Engines mounted below the wing. One-third-octave-band center frequency = 50 Hz
A_L
dB
R, m
φ, deg
R = 200m
φ = 10 deg

FIGURE 1

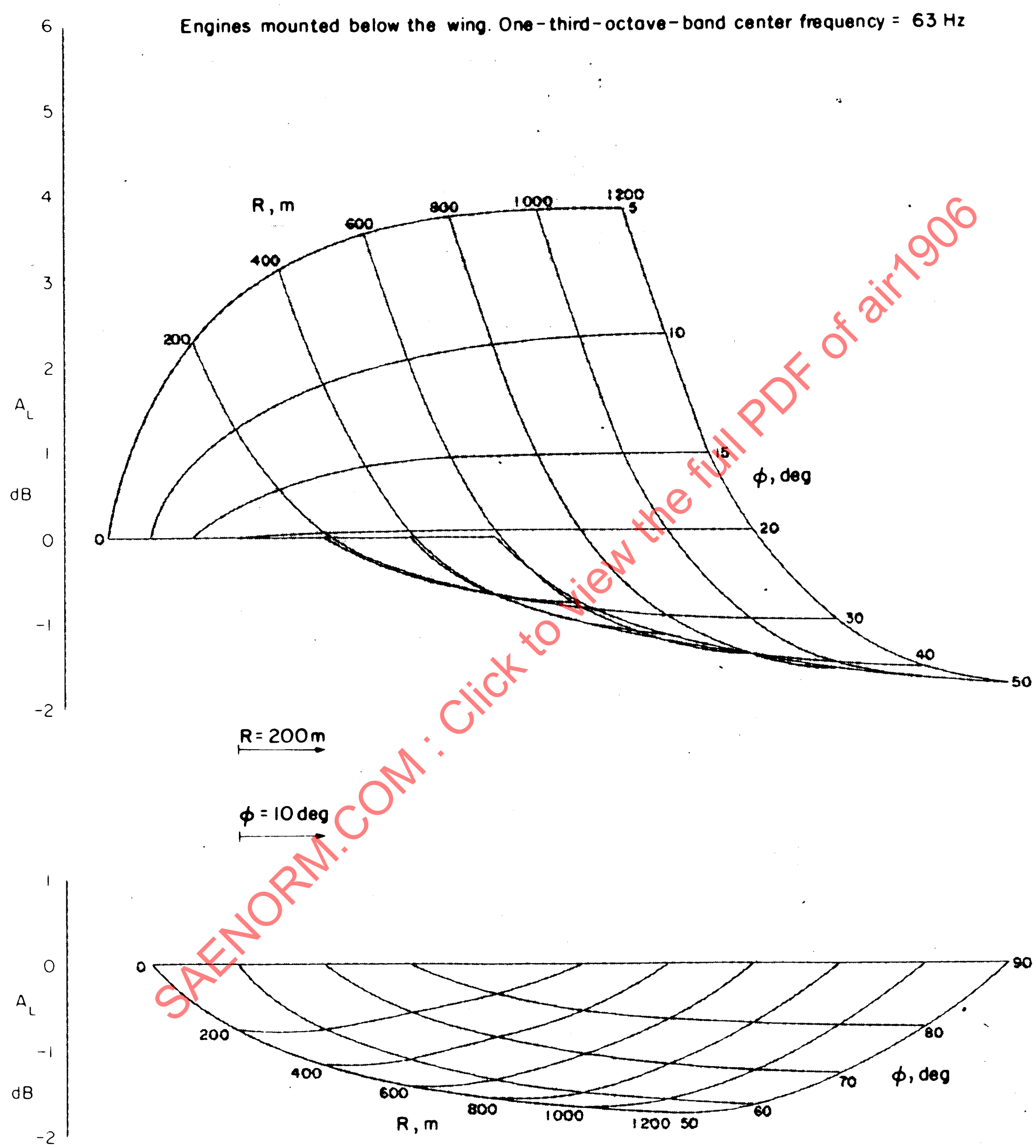

Engines mounted below the wing. One-third-octave-band center frequency = 63 Hz
A_L
dB
R, m
200
400
600
800
1000
1200
φ, deg
5
10
15
20
30
40
50
R = 200m
φ = 10 deg
60
70
80
90

FIGURE 2

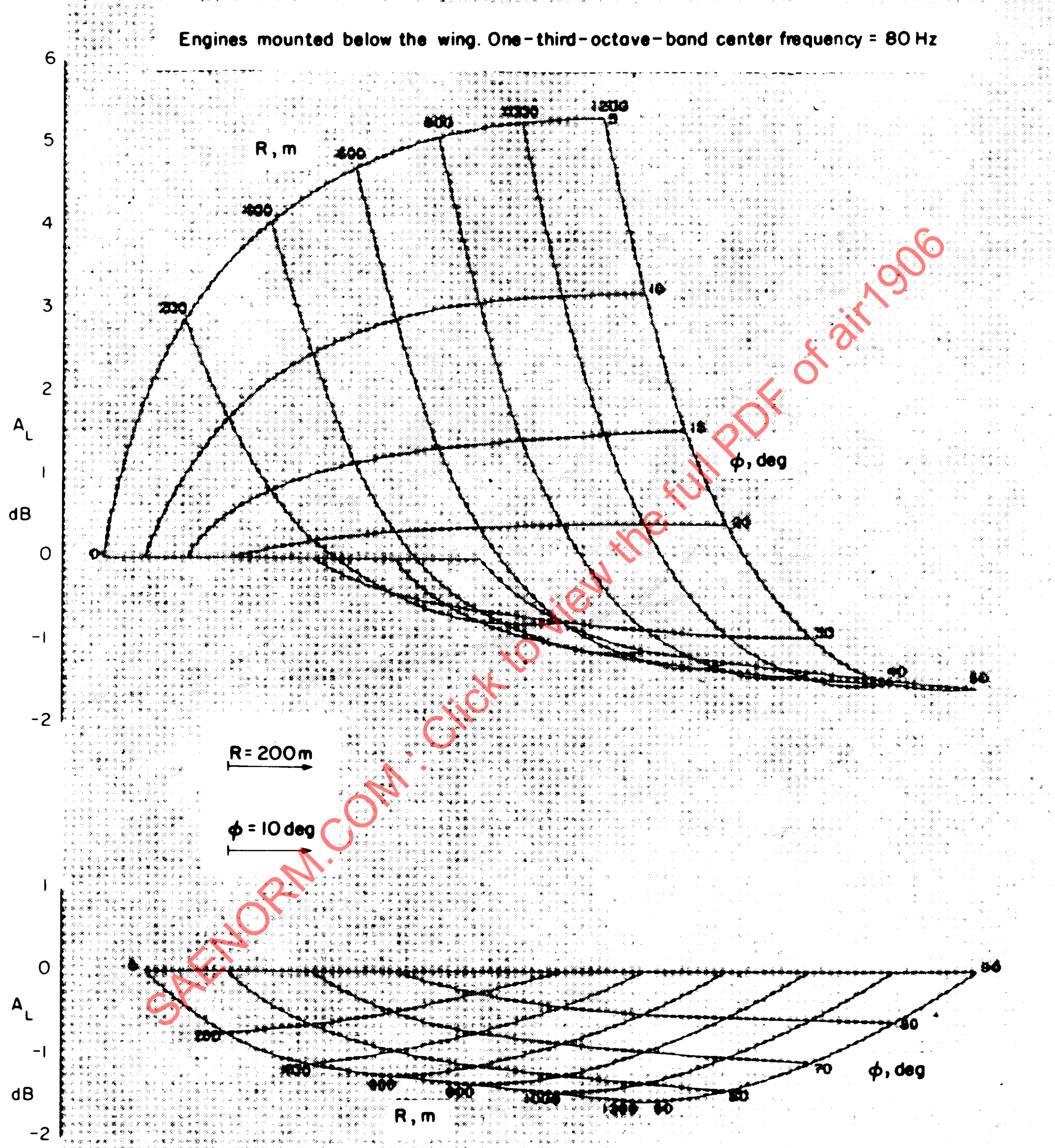

Engines mounted below the wing. One-third-octave-band center frequency = 80 Hz
6
5
4
3
2
1
0
-1
-2
A_L
dB
R, m
200
400
600
800
1000
1200
10
15
20
30
40
60
φ, deg
R = 200m
φ = 10 deg
1
0
-1
-2
A_L
dB
200
400
600
800
1000
1200
80
70
60
50
φ, deg
R, m

FIGURE 3

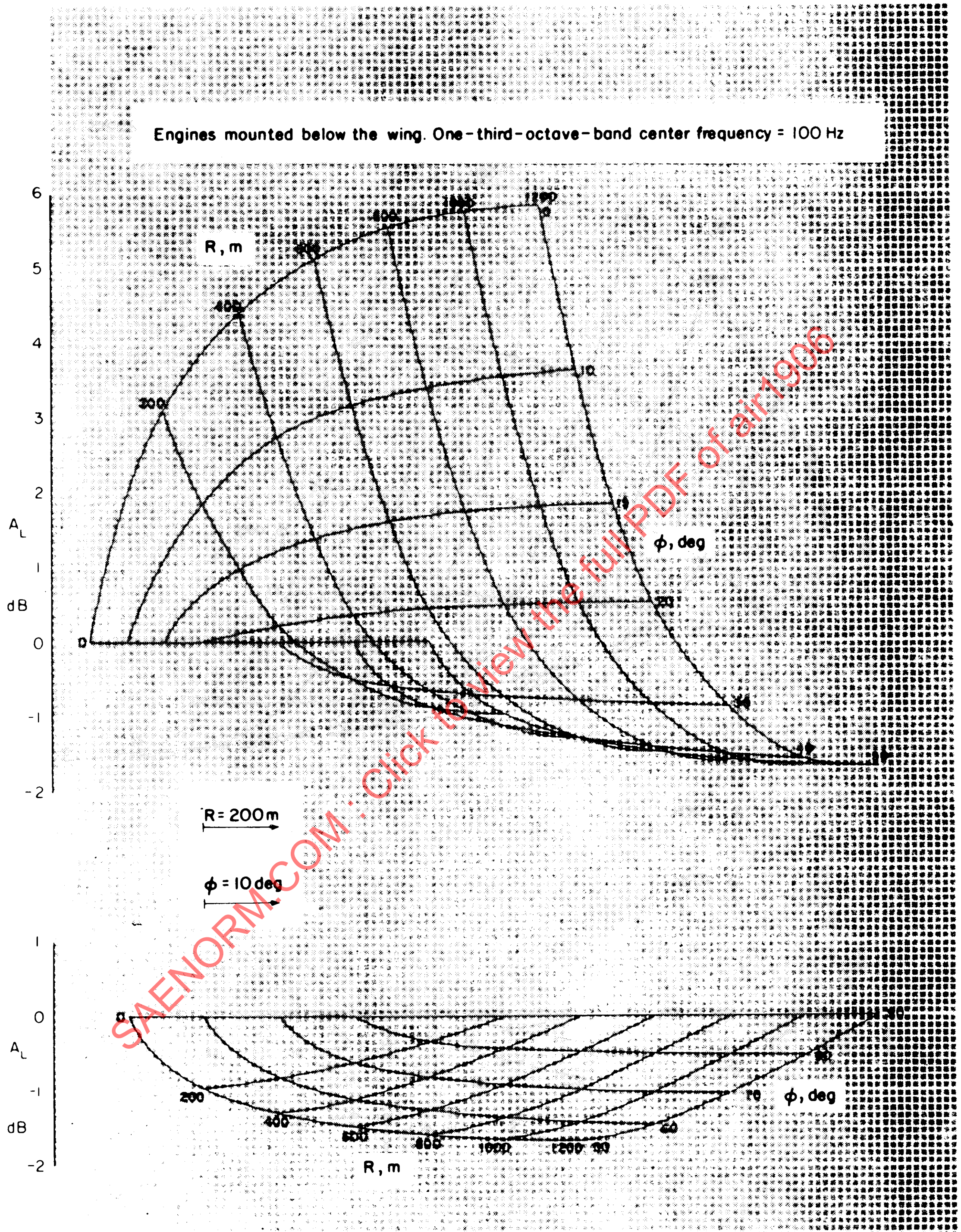

Engines mounted below the wing. One-third-octave-band center frequency = 100 Hz
R, m
φ, deg
A_L dB
R = 200 m
φ = 10 deg
R, m
φ, deg
A_L dB

FIGURE 4

Engines mounted below the wing. One-third-octave-band center frequency = 125 Hz

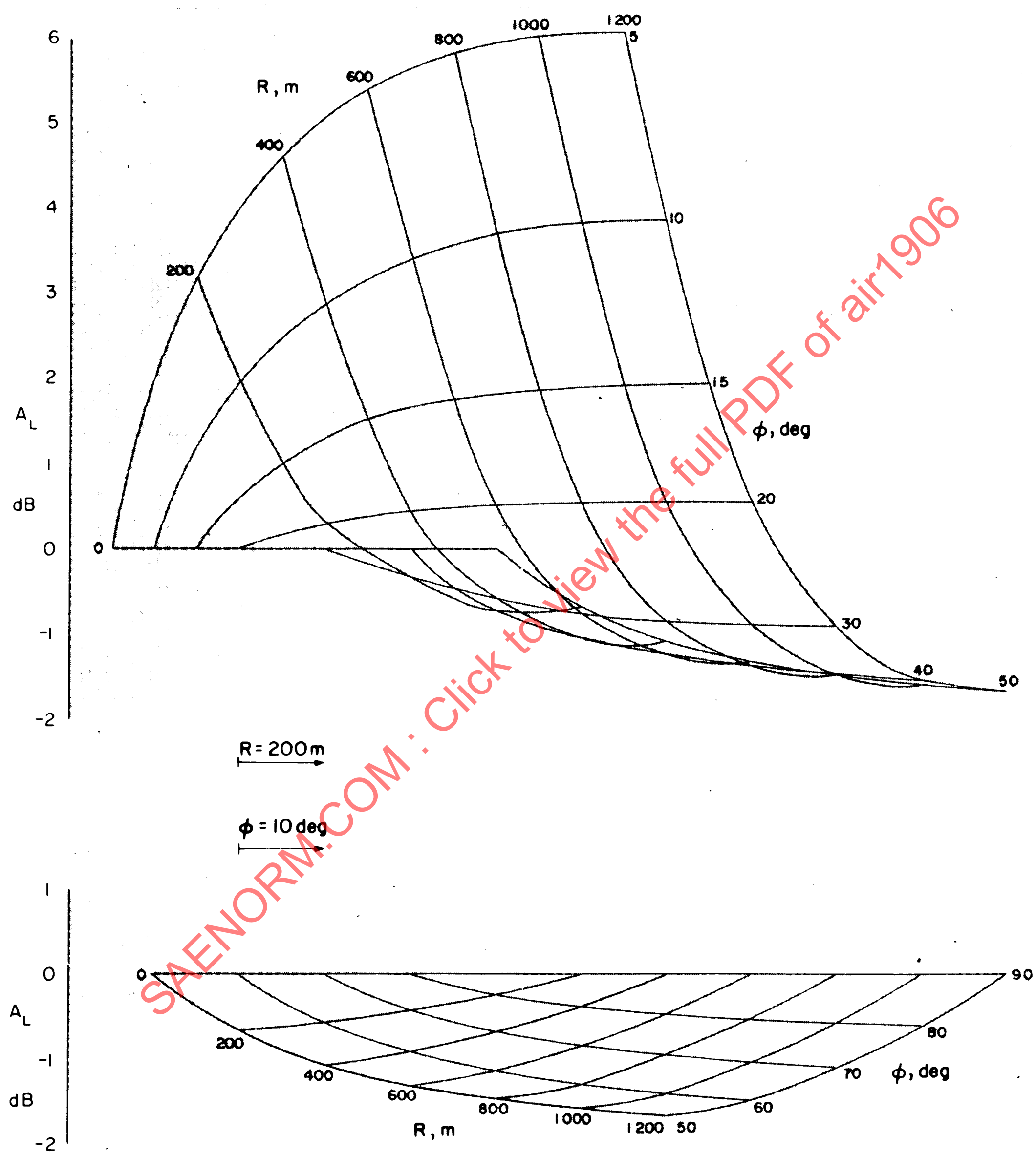


FIGURE 5

Engines mounted below the wing. One-third-octave-band center frequency = 160 Hz

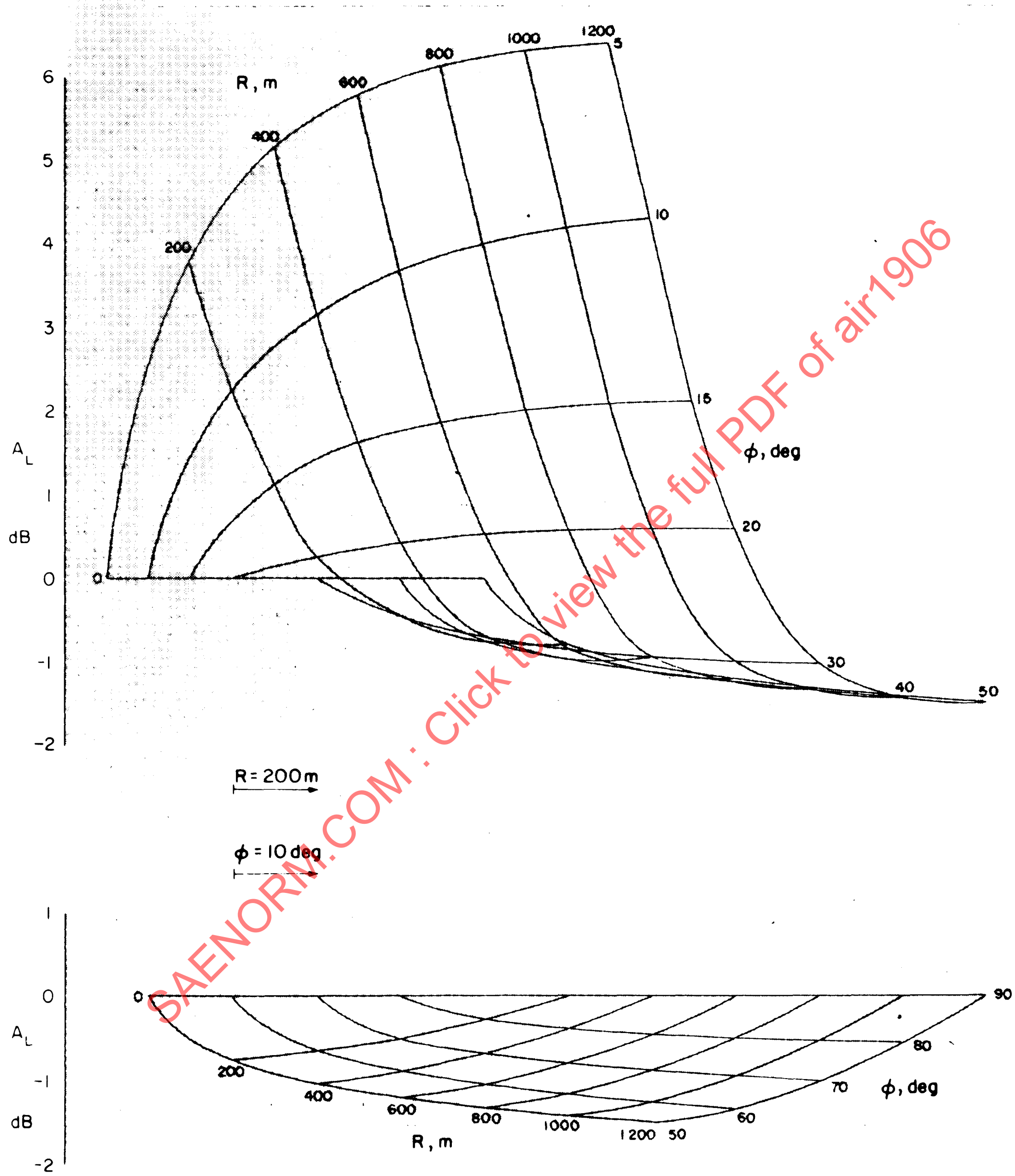


FIGURE 6

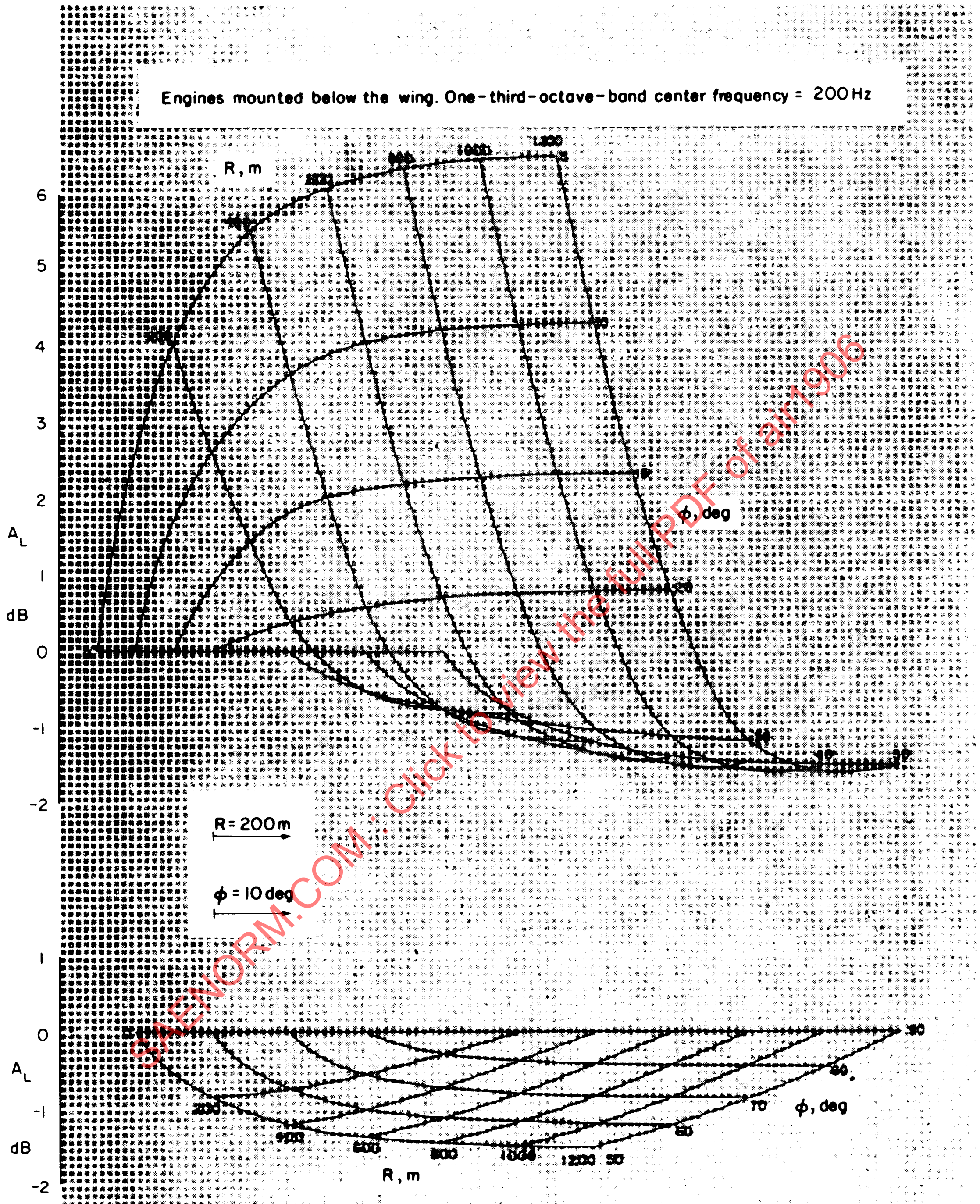

Engines mounted below the wing. One-third-octave-band center frequency = 200 Hz
R, m
φ, deg
A_L
dB
6
5
4
3
2
1
0
-1
-2
R = 200 m
φ = 10 deg
1
0
-1
-2
200
400
600
800
1000
1200
50
60
70
80
90
φ, deg
R, m

FIGURE 7

Engines mounted below the wing. One-third-octave-band center frequency = 250 Hz

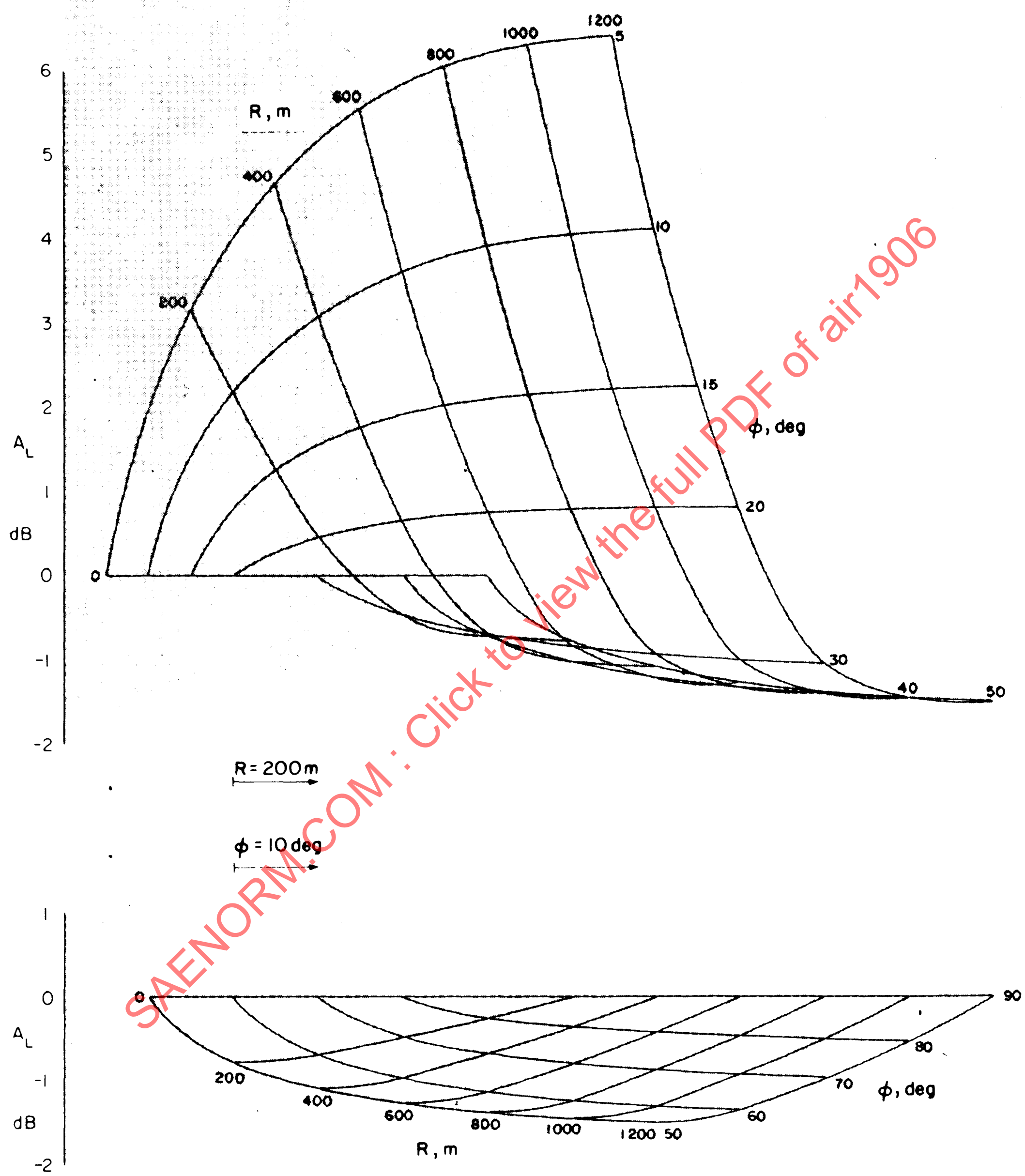


FIGURE 8

Engines mounted below the wing. One-third-octave-band center frequency = 315 Hz

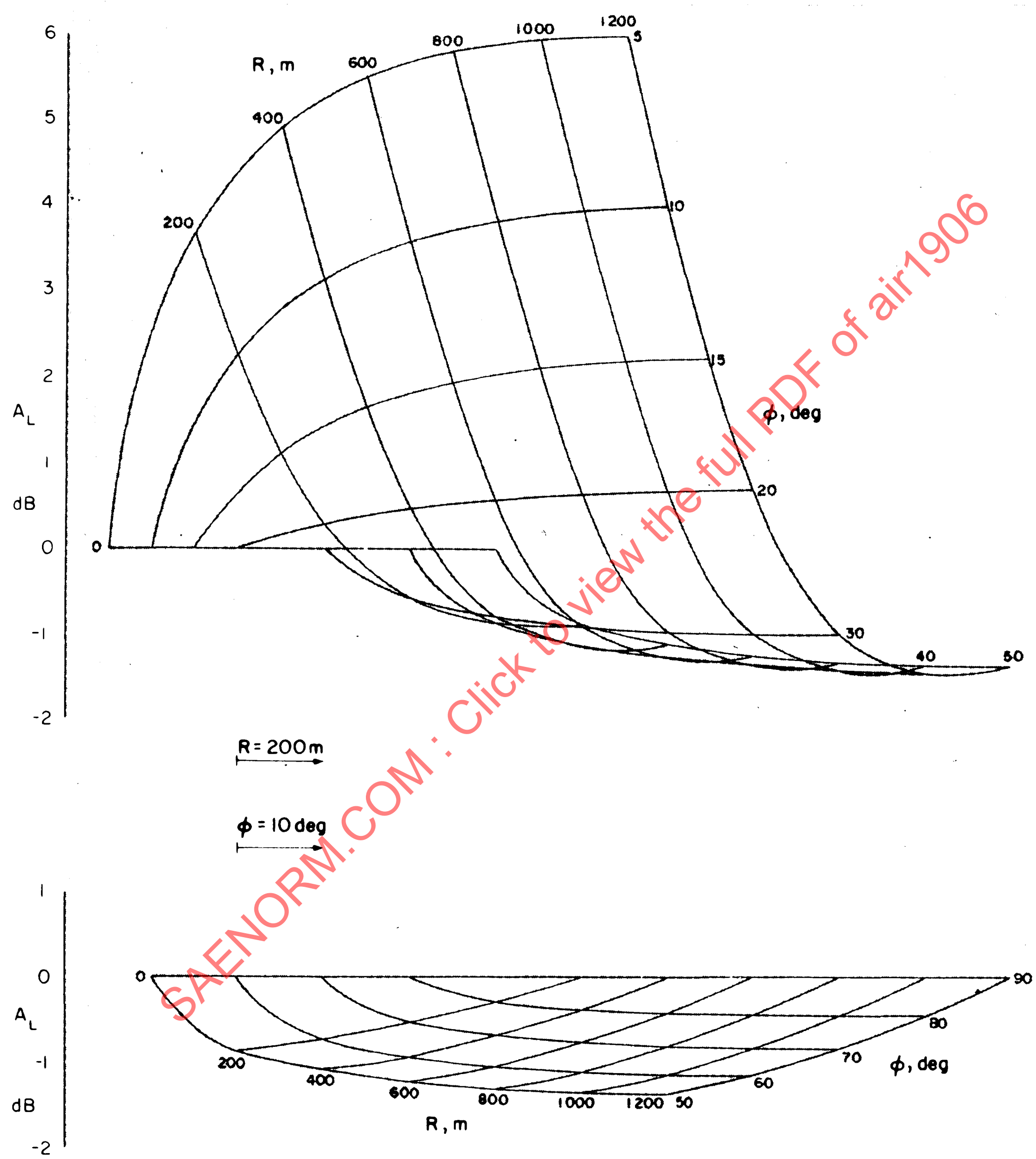


FIGURE 9

Engines mounted below the wing. One-third-octave-band center frequency = 400 Hz

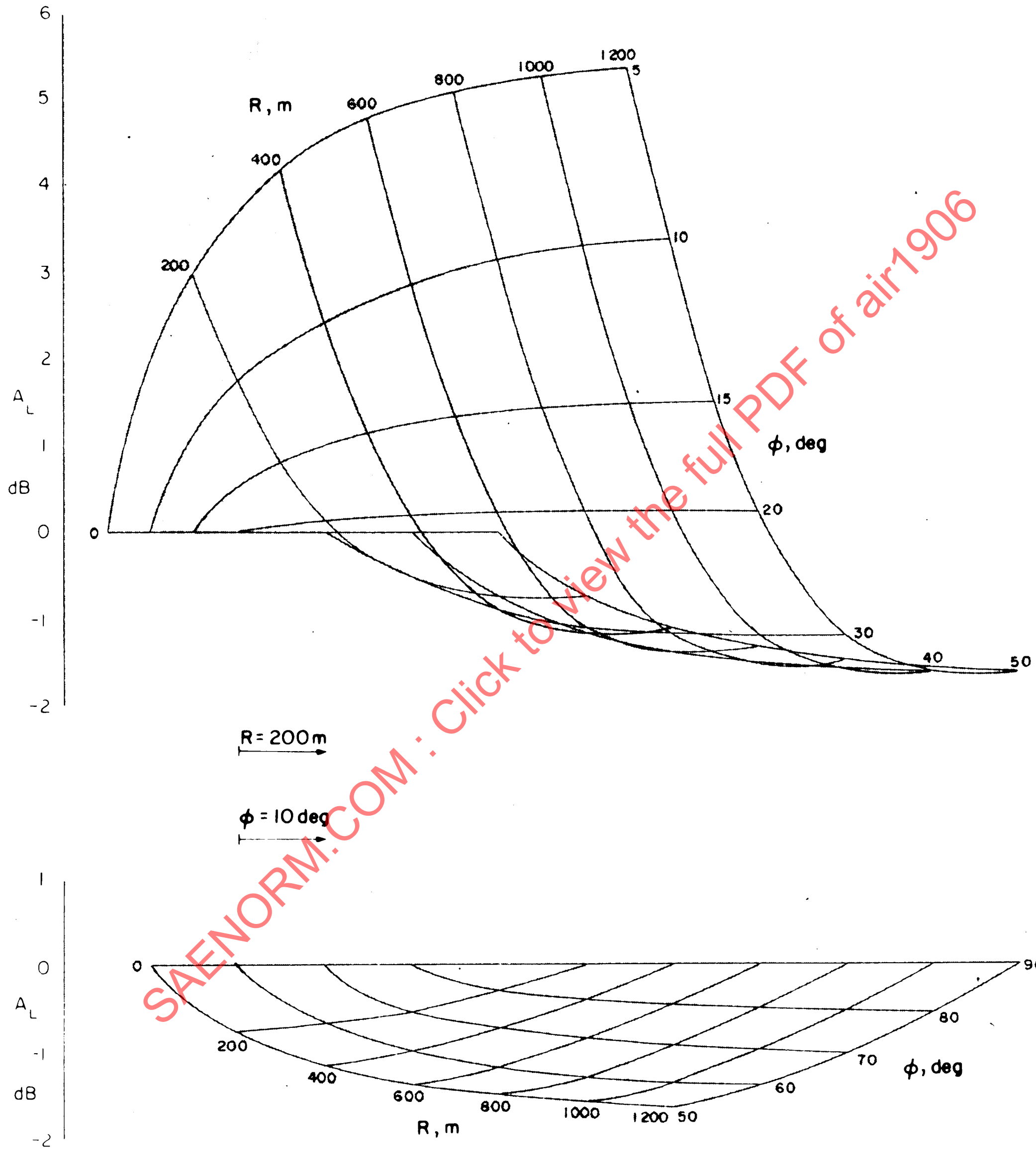


FIGURE 10

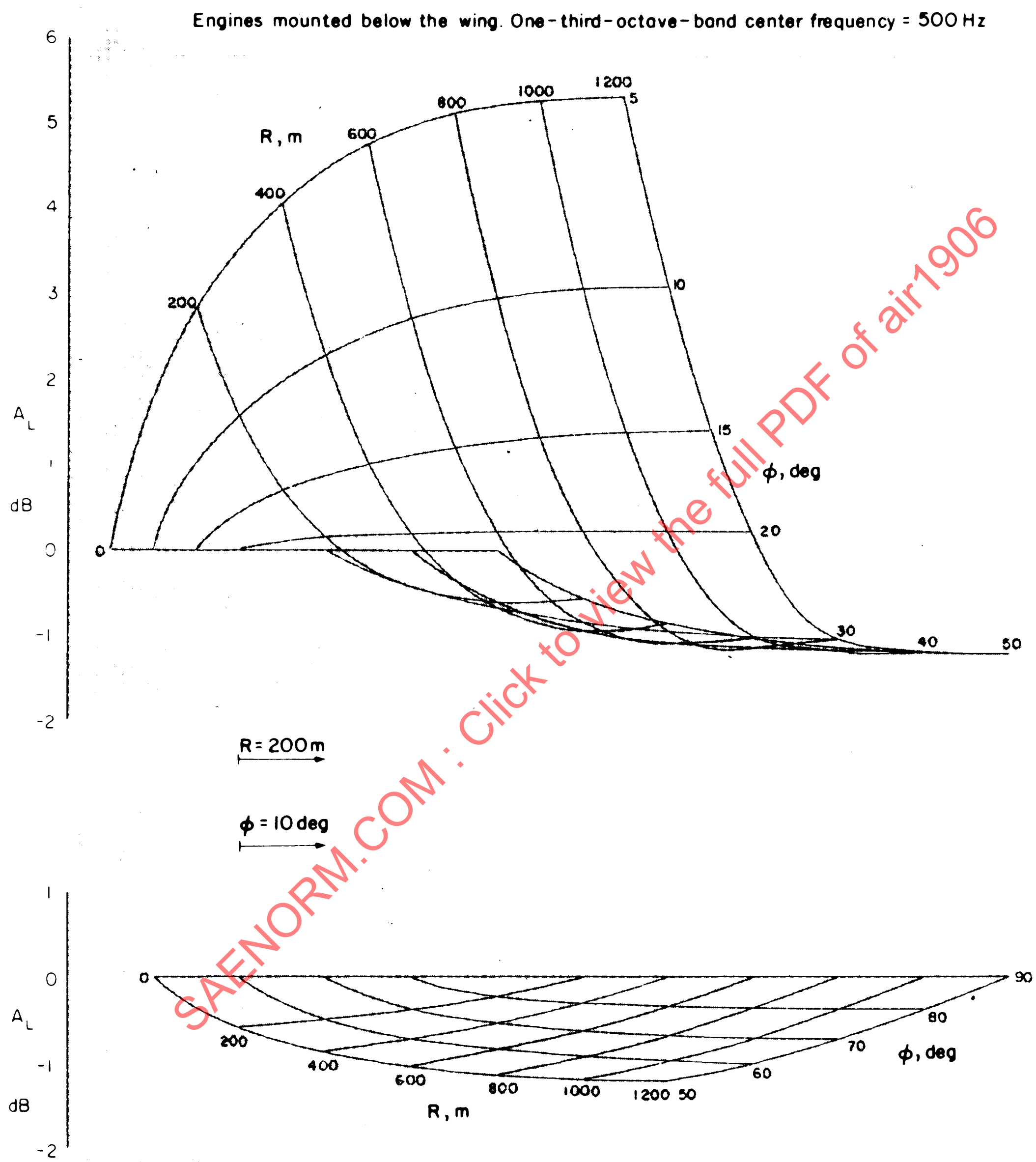

Engines mounted below the wing. One-third-octave-band center frequency = 500 Hz
6
5
4
3
2
1
0
-1
-2
A L
dB
R, m
0
200
400
600
800
1000
1200
5
10
15
20
30
40
50
φ, deg
R = 200 m
φ = 10 deg
1
0
-1
-2
A L
dB
0
200
400
600
800
1000
1200
50
60
70
80
90
φ, deg
R, m

FIGURE 11

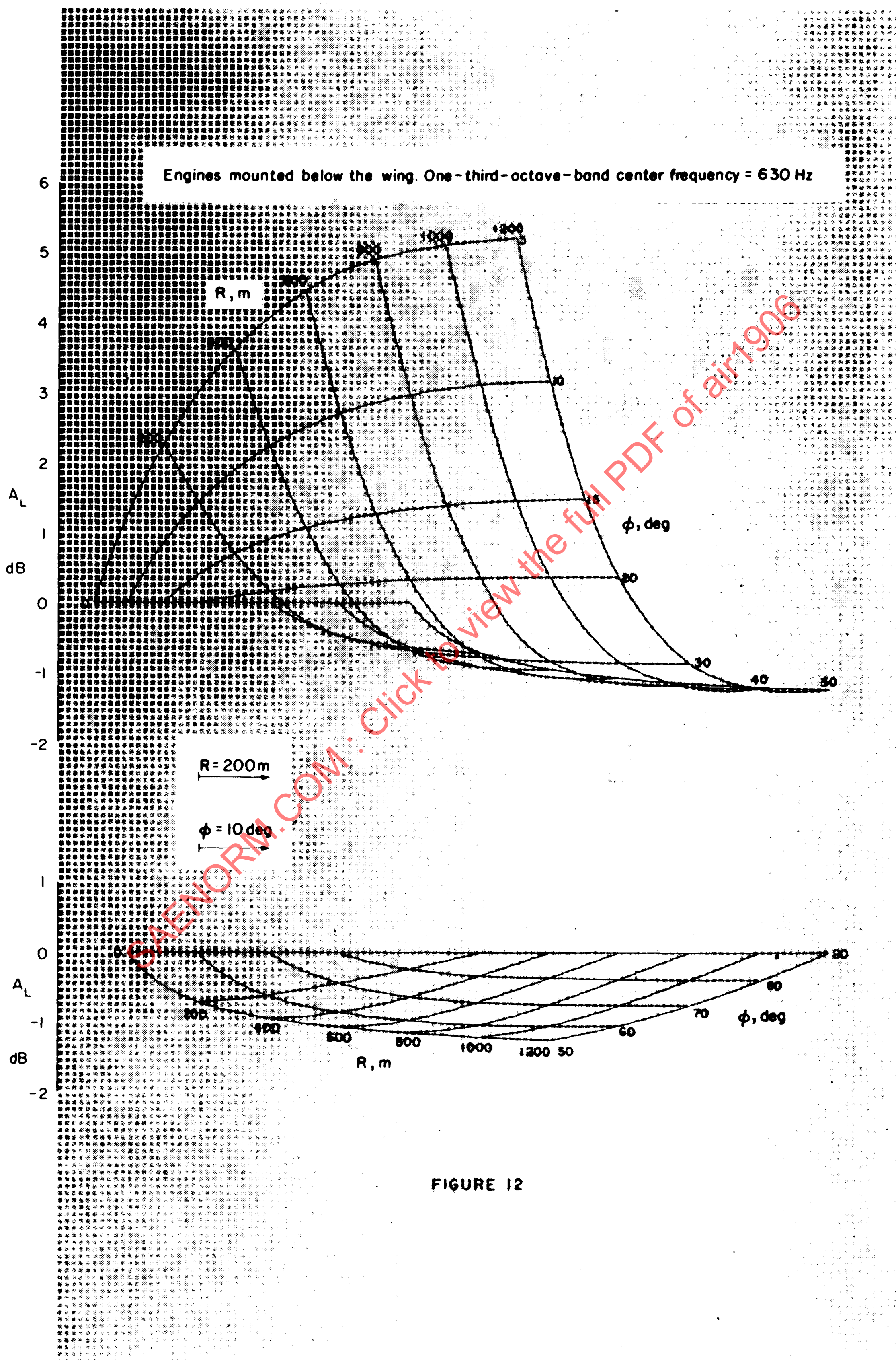

Engines mounted below the wing. One-third-octave-band center frequency = 630 Hz
A_L
dB
R, m
φ, deg
R= 200m
φ = 10 deg
R, m
φ, deg

FIGURE 12

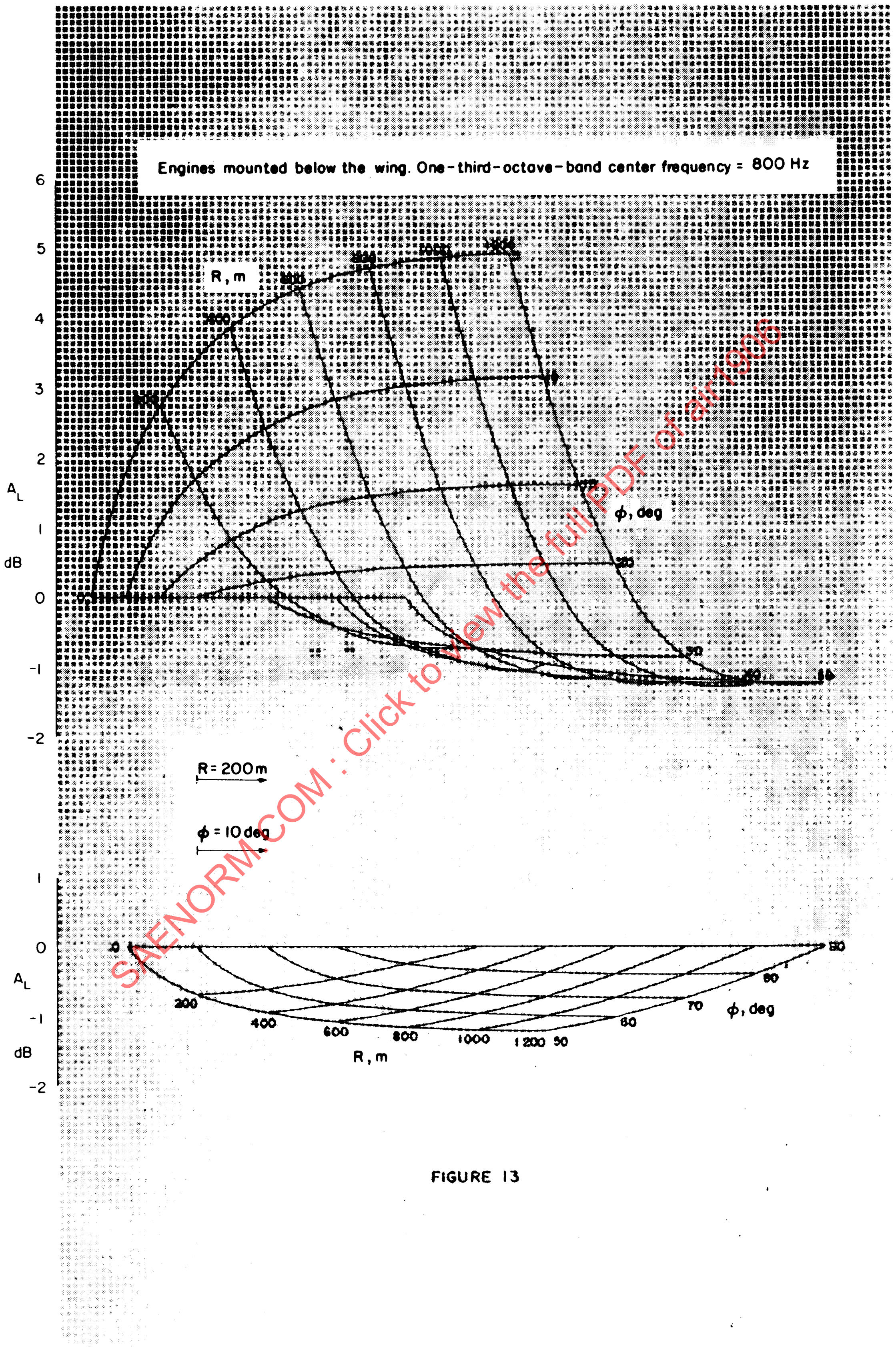
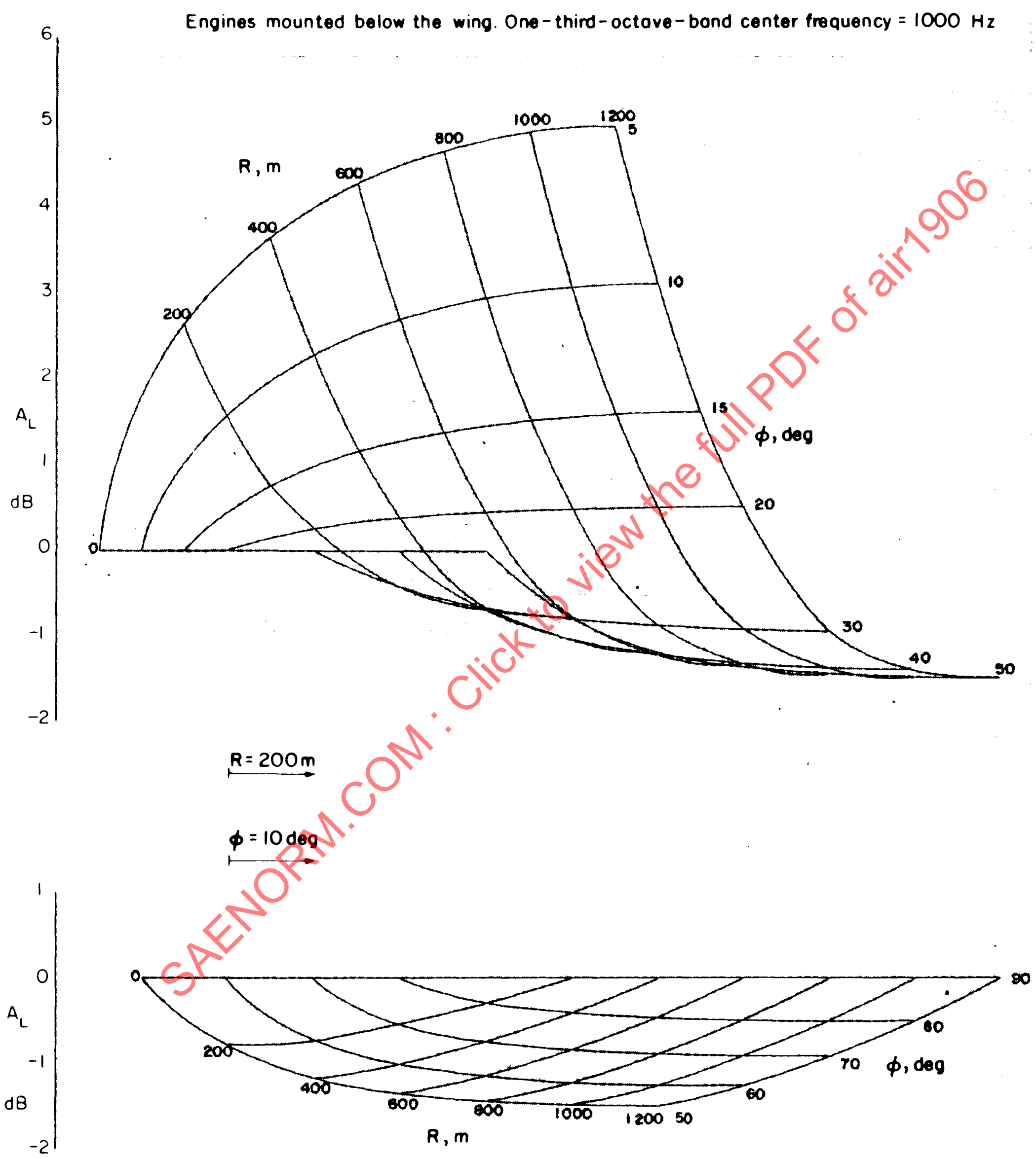

Engines mounted below the wing. One-third-octave-band center frequency = 800 Hz
R, m
φ, deg
A_L
dB
R = 200m
φ = 10 deg
200
400
600
800
1000
1200
50
60
70
80
90

FIGURE 13



Engines mounted below the wing. One-third-octave-band center frequency = 1000 Hz
6
5
4
3
2
1
0
-1
-2
A_L
dB
R, m
0
200
400
600
800
1000
1200
5
10
15
20
30
40
50
φ, deg
R = 200 m
φ = 10 deg
1
0
-1
-2
A_L
dB
0
200
400
600
800
1000
1200
50
60
70
80
90
φ, deg
R, m

FIGURE 14

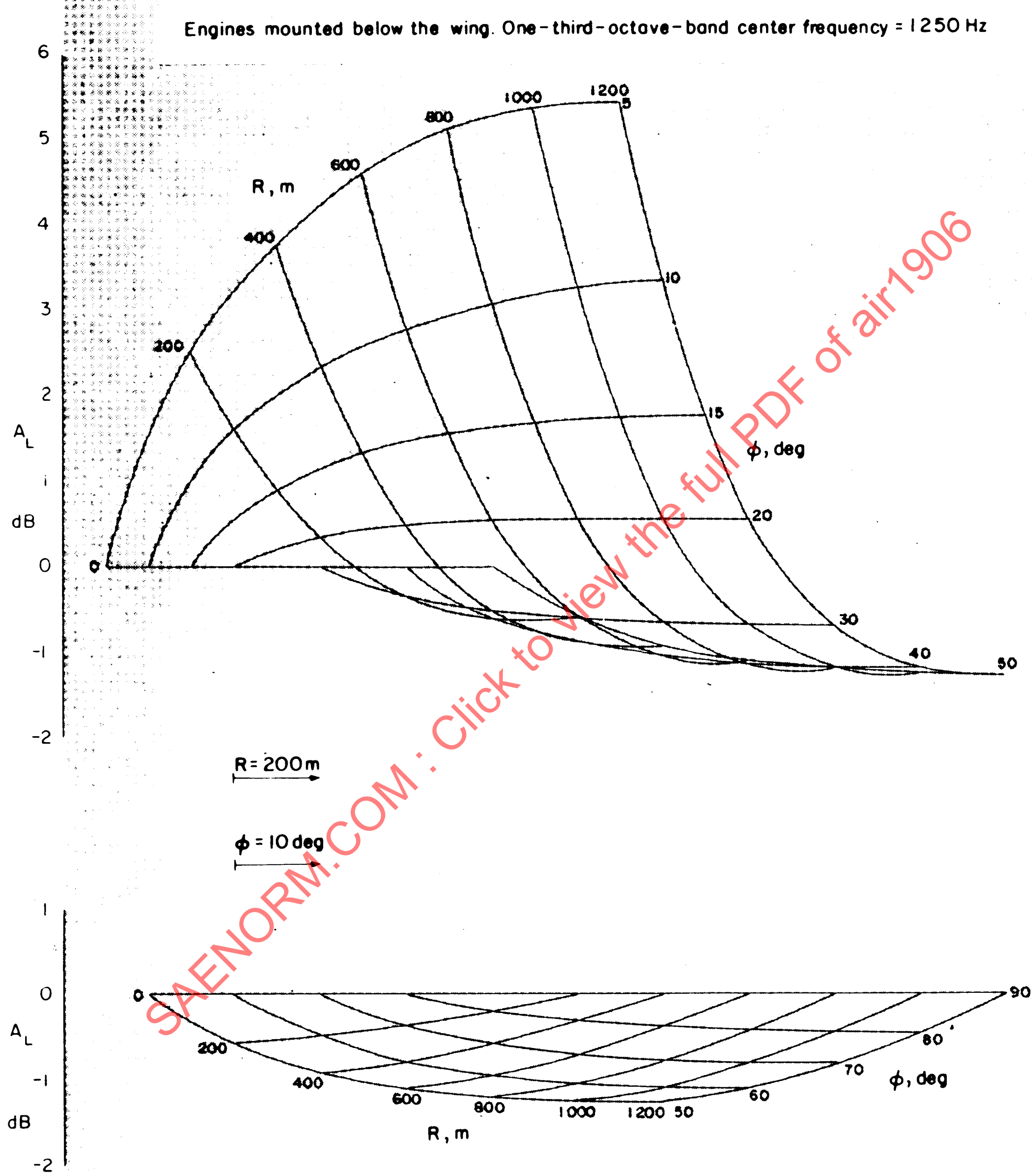

Engines mounted below the wing. One-third-octave-band center frequency = 1250 Hz
6
5
4
3
2
1
0
-1
-2
A
L
dB
R, m
0
200
400
600
800
1000
1200
5
10
15
20
30
40
50
φ, deg
R = 200m
φ = 10 deg
1
0
-1
-2
A
L
dB
0
200
400
600
800
1000
1200
50
60
70
80
90
φ, deg
R, m

FIGURE 15

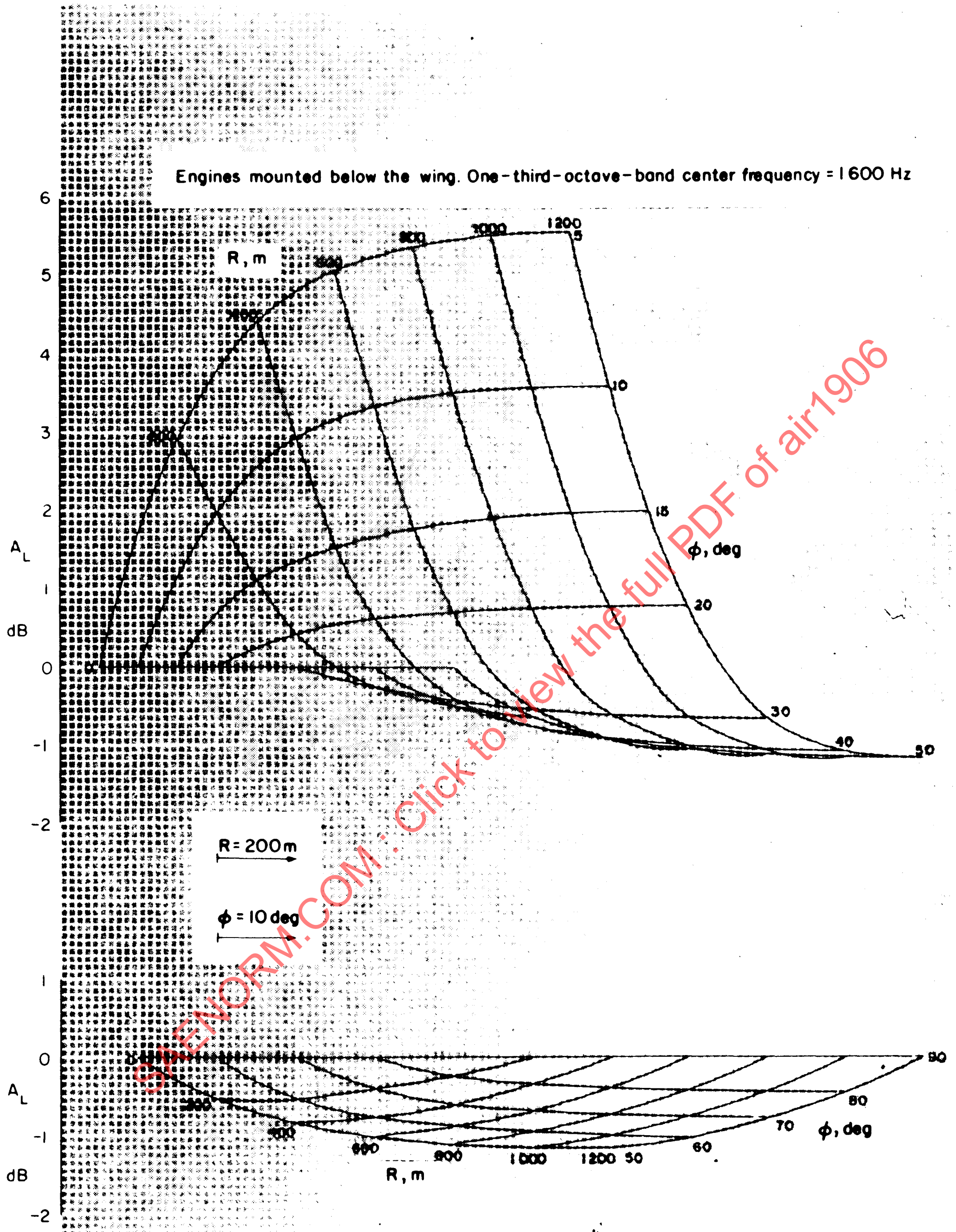

Engines mounted below the wing. One-third-octave-band center frequency = 1600 Hz
R, m
ϕ, deg
A_L
dB
R = 200m
ϕ = 10 deg
R, m
ϕ, deg
A_L
dB

FIGURE 16

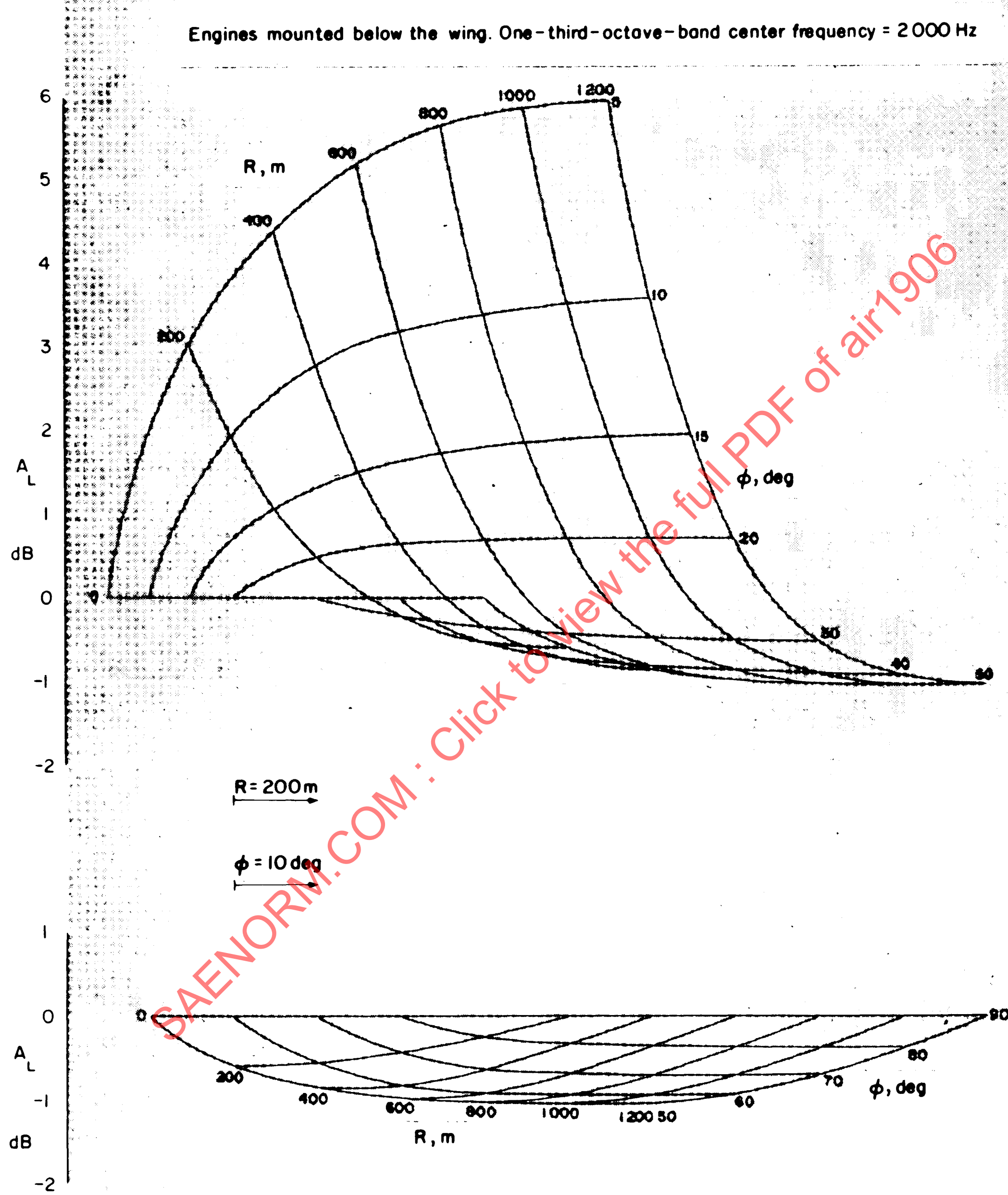

Engines mounted below the wing. One-third-octave-band center frequency = 2000 Hz
6
5
4
3
2
1
0
-1
-2
A
L
dB
R, m
200
400
600
800
1000
1200
5
10
15
20
30
40
60
φ, deg
R = 200m
φ = 10 deg
1
0
-1
-2
A
L
dB
0
200
400
600
800
1000
1200 50
60
70
80
90
φ, deg
R, m

FIGURE 17

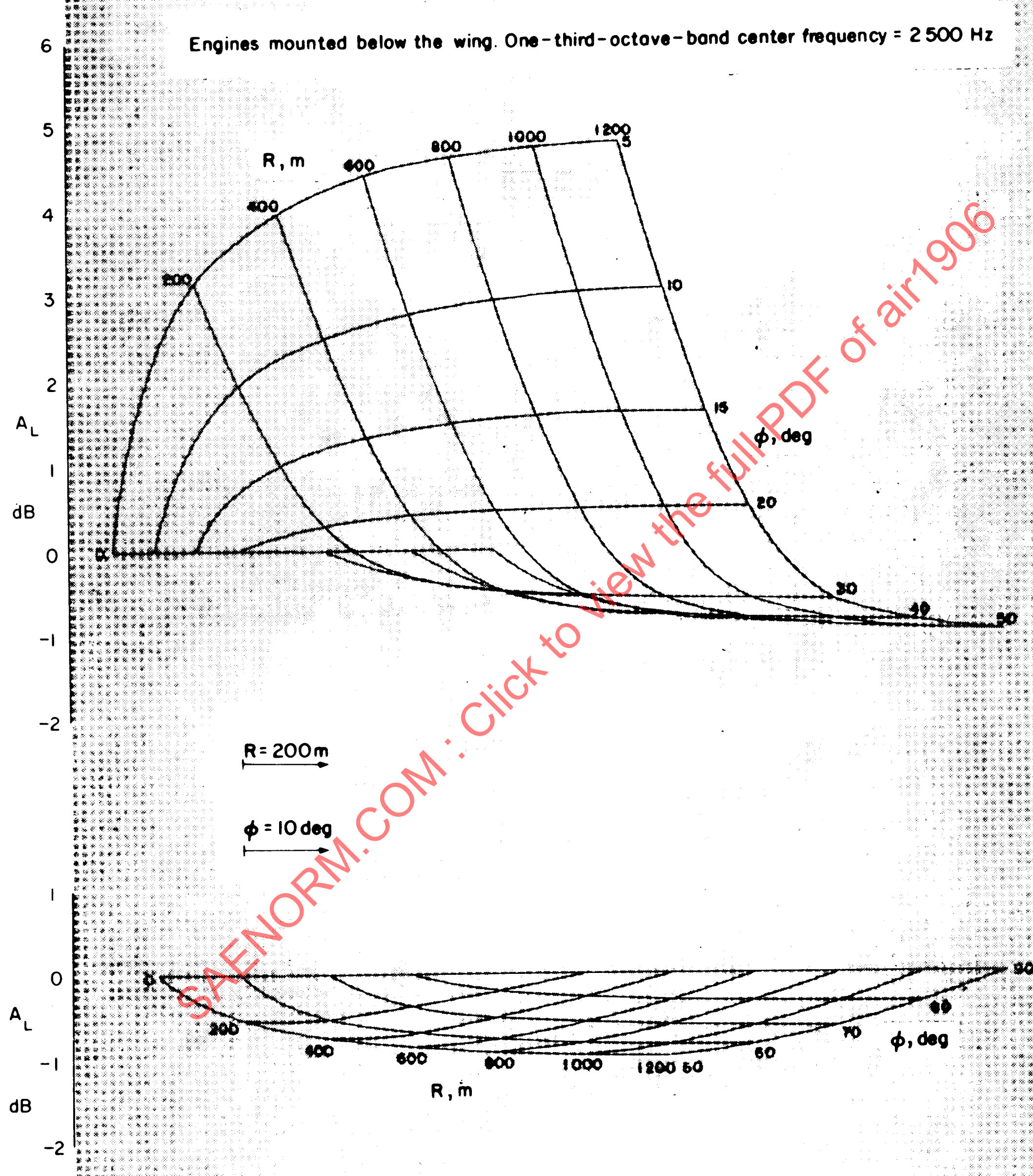
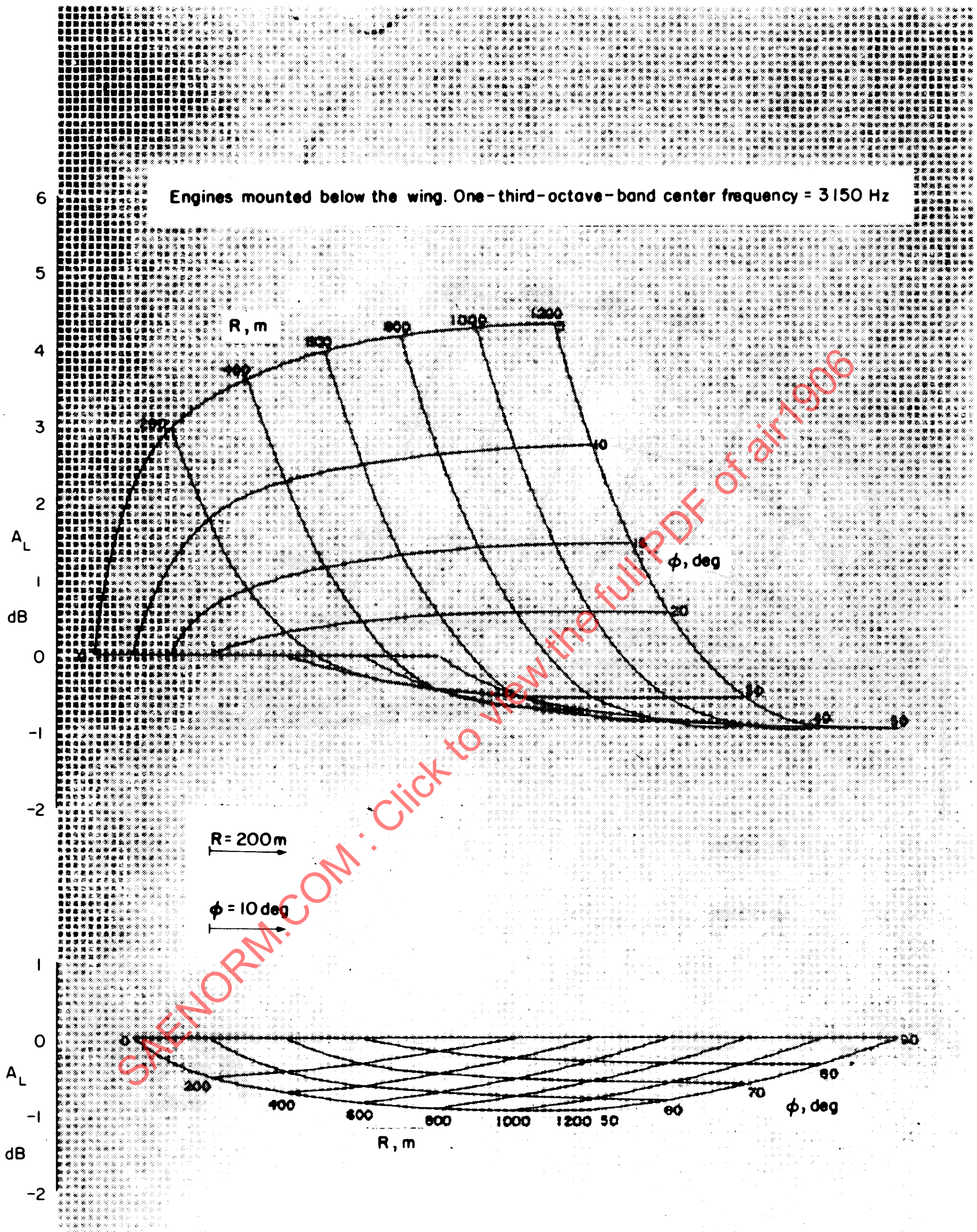

Engines mounted below the wing. One-third-octave-band center frequency = 2 500 Hz
6
5
4
3
2
1
0
-1
-2
A_L
dB
R, m
200
400
600
800
1000
1200
5
10
15
20
30
40
50
φ, deg
R = 200m
φ = 10 deg
1
0
-1
-2
A_L
dB
200
400
600
800
1000
1200 50
60
70
80
90
φ, deg
R, m

FIGURE 18



Engines mounted below the wing. One-third-octave-band center frequency = 3150 Hz
6
5
4
3
2
1
0
-1
-2
A_L
dB
R, m
200
400
600
800
1000
1200
10
15
20
30
40
90
φ, deg
R = 200m
φ = 10 deg
1
0
-1
-2
A_L
dB
0
200
400
600
800
1000
1200
50
60
70
80
90
φ, deg
R, m

FIGURE 19

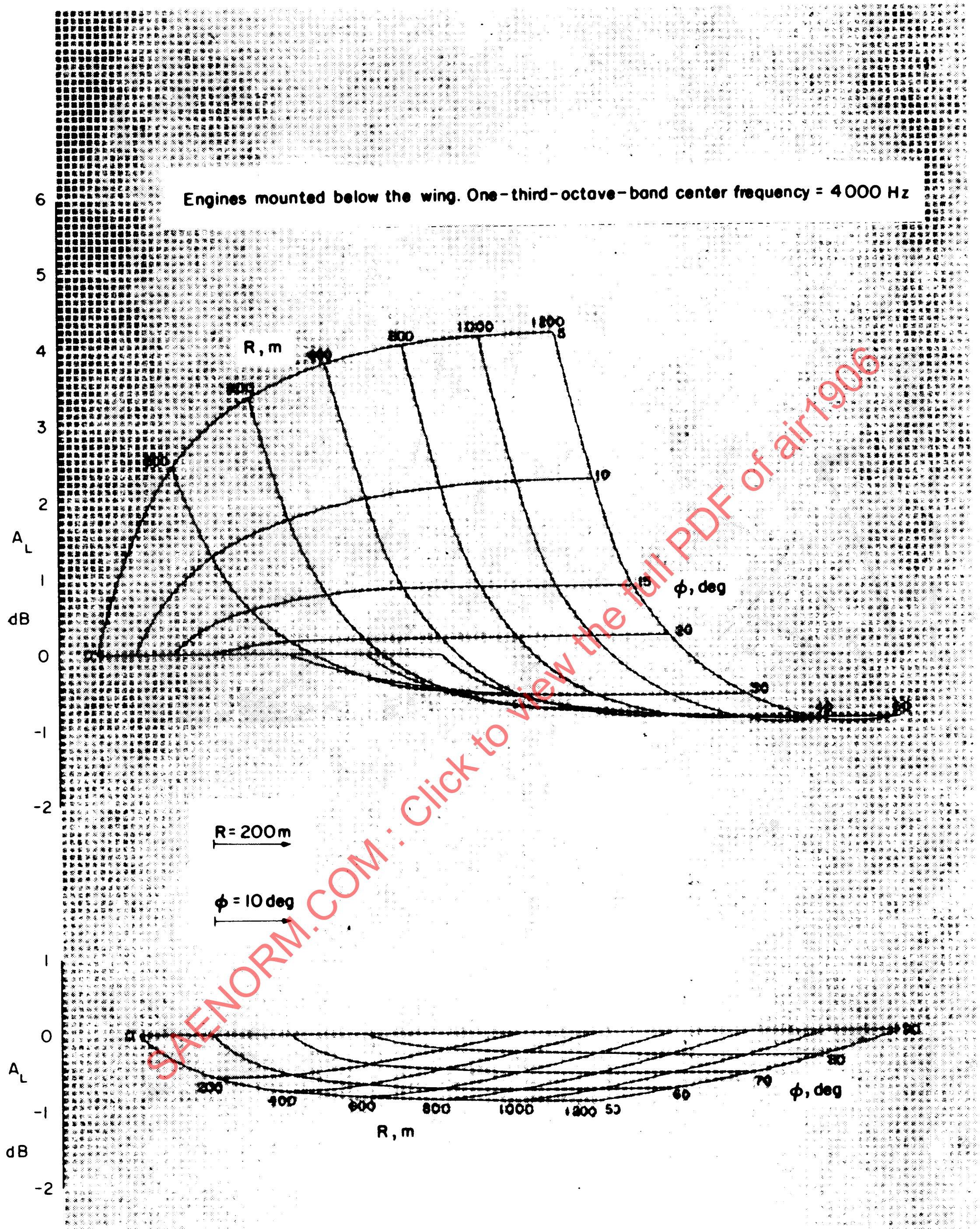
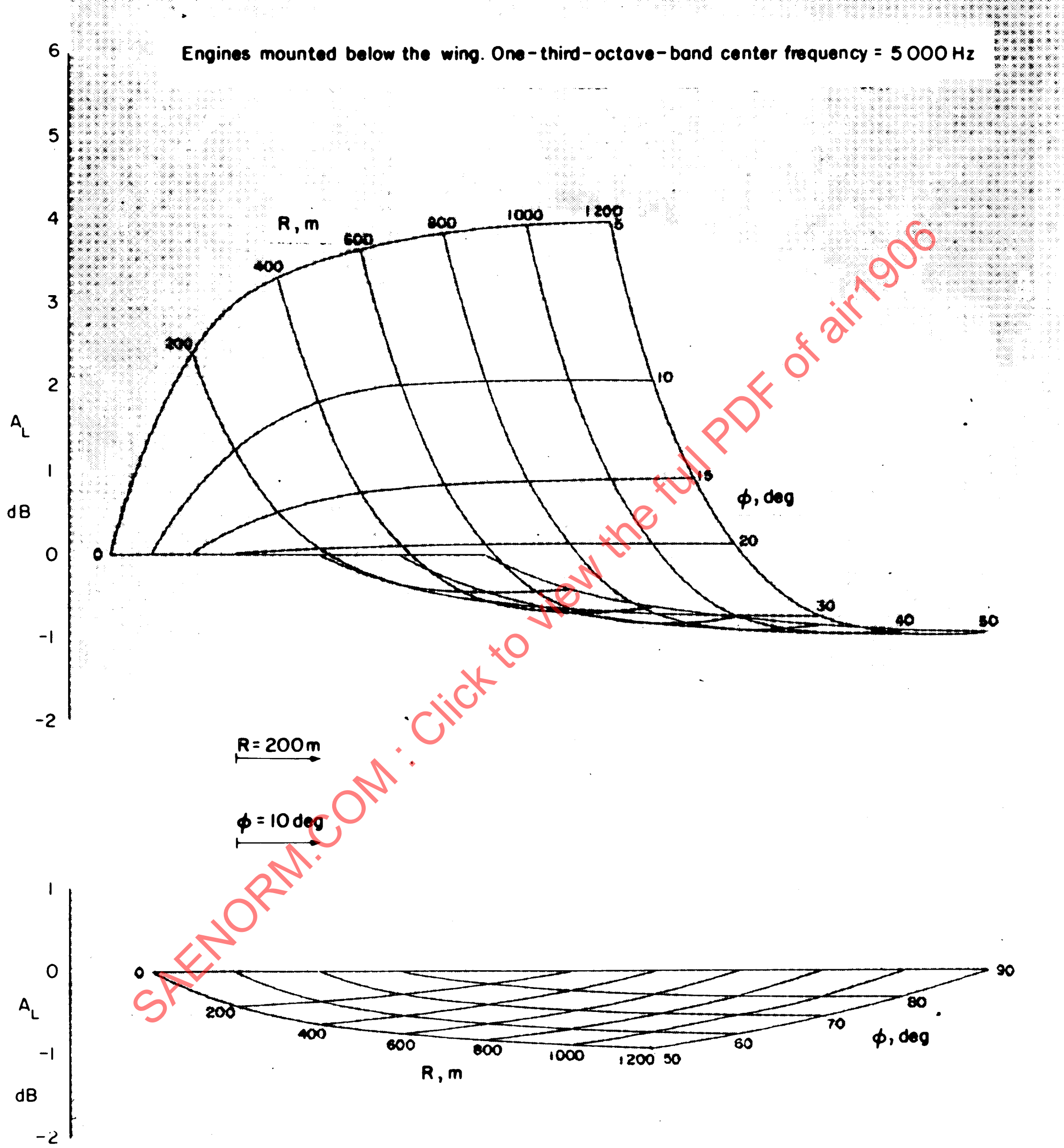
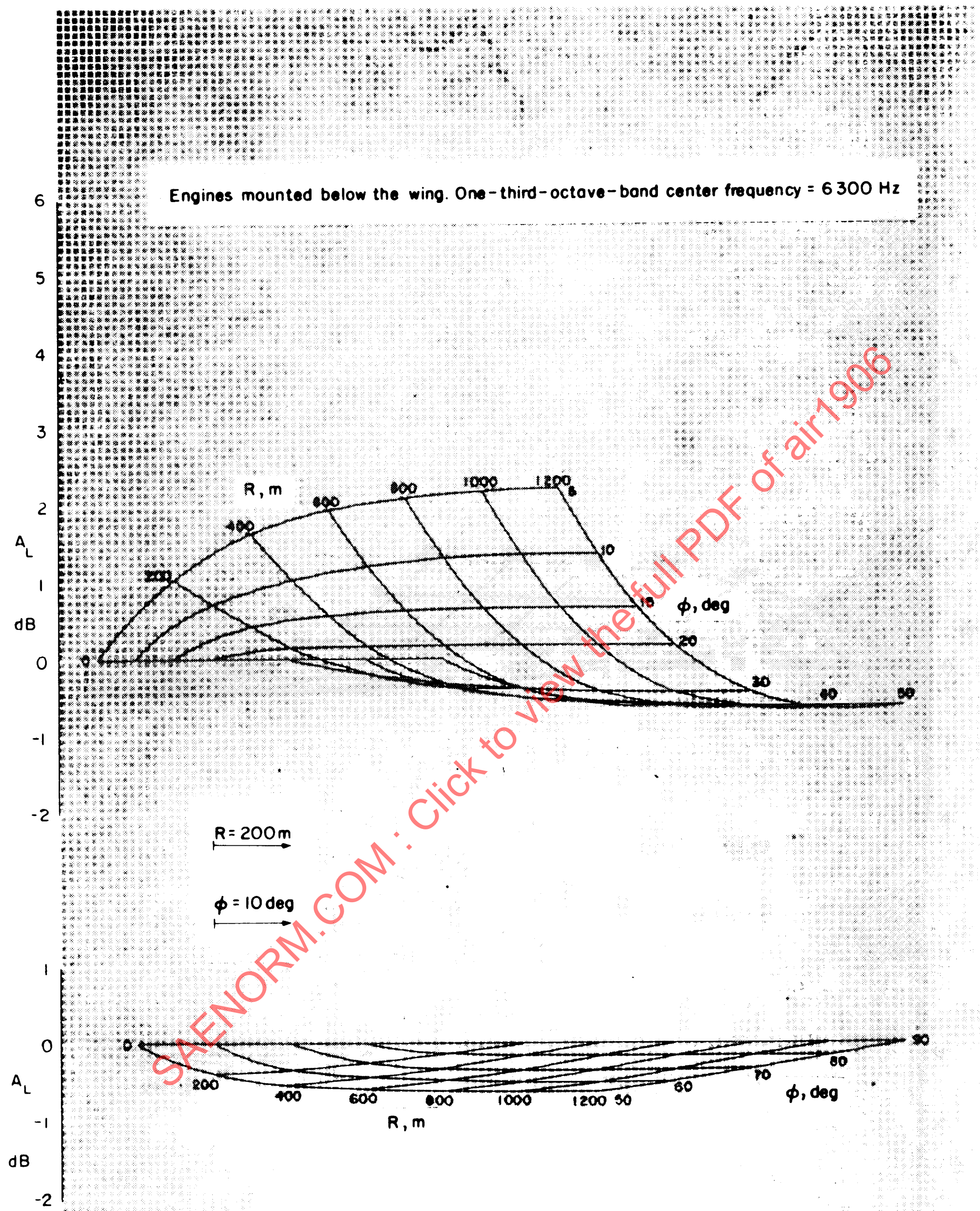

Engines mounted below the wing. One-third-octave-band center frequency = 4000 Hz
6
5
4
3
2
1
0
-1
-2
A_L
dB
R, m
200
400
600
800
1000
1200
5
10
15
20
30
40
50
ϕ, deg
R = 200m
ϕ = 10 deg
1
0
-1
-2
A_L
dB
200
400
600
800
1000
1200
50
60
70
80
90
ϕ, deg
R, m

FIGURE 20



Engines mounted below the wing. One-third-octave-band center frequency = 5 000 Hz
6
5
4
3
2
1
0
-1
-2
A_L
dB
R, m
200
400
600
800
1000
1200
0
5
10
15
20
30
40
50
φ, deg
R= 200m
φ = 10 deg
1
0
-1
-2
A_L
dB
0
200
400
600
800
1000
1200
R, m
50
60
70
80
90
φ, deg

FIGURE 21



Engines mounted below the wing. One-third-octave-band center frequency = 6300 Hz
6
5
4
3
2
1
0
-1
-2
A_L
dB
R, m
200
400
600
800
1000
1200
0
5
10
15
20
30
40
50
ϕ, deg
R = 200m
ϕ = 10deg
1
0
-1
-2
A_L
dB
0
200
400
600
800
1000
1200
50
60
70
80
90
ϕ, deg
R, m

FIGURE 22

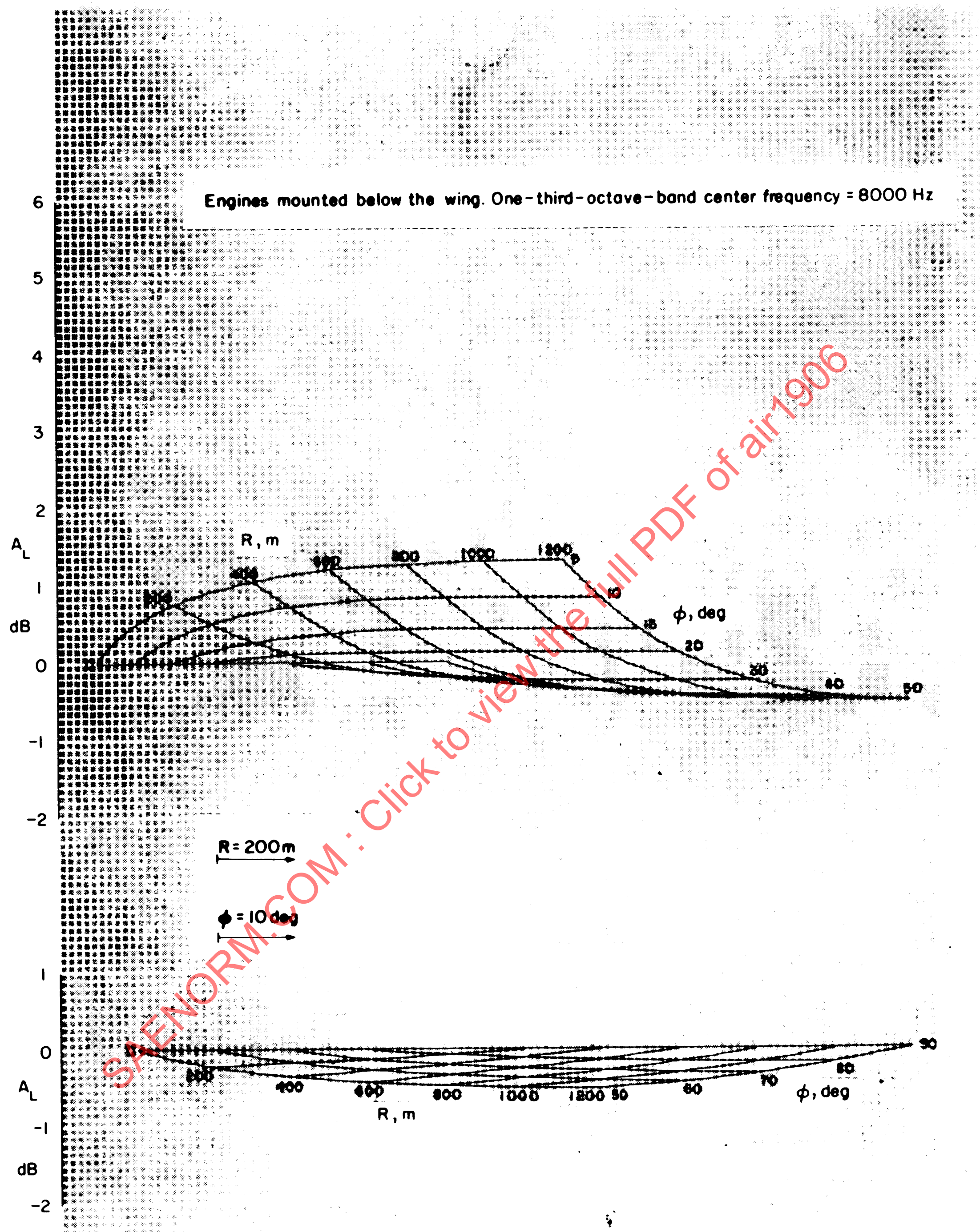

Engines mounted below the wing. One-third-octave-band center frequency = 8000 Hz
6
5
4
3
2
A_L
1
dB
0
-1
-2
R, m
200
400
600
800
1000
1200
10
15
20
30
40
50
90
ϕ, deg
R = 200m
ϕ = 10 deg
1
0
A_L
-1
dB
-2
400
600
800
1000
1200
50
60
70
80
90
ϕ, deg
R, m

FIGURE 23

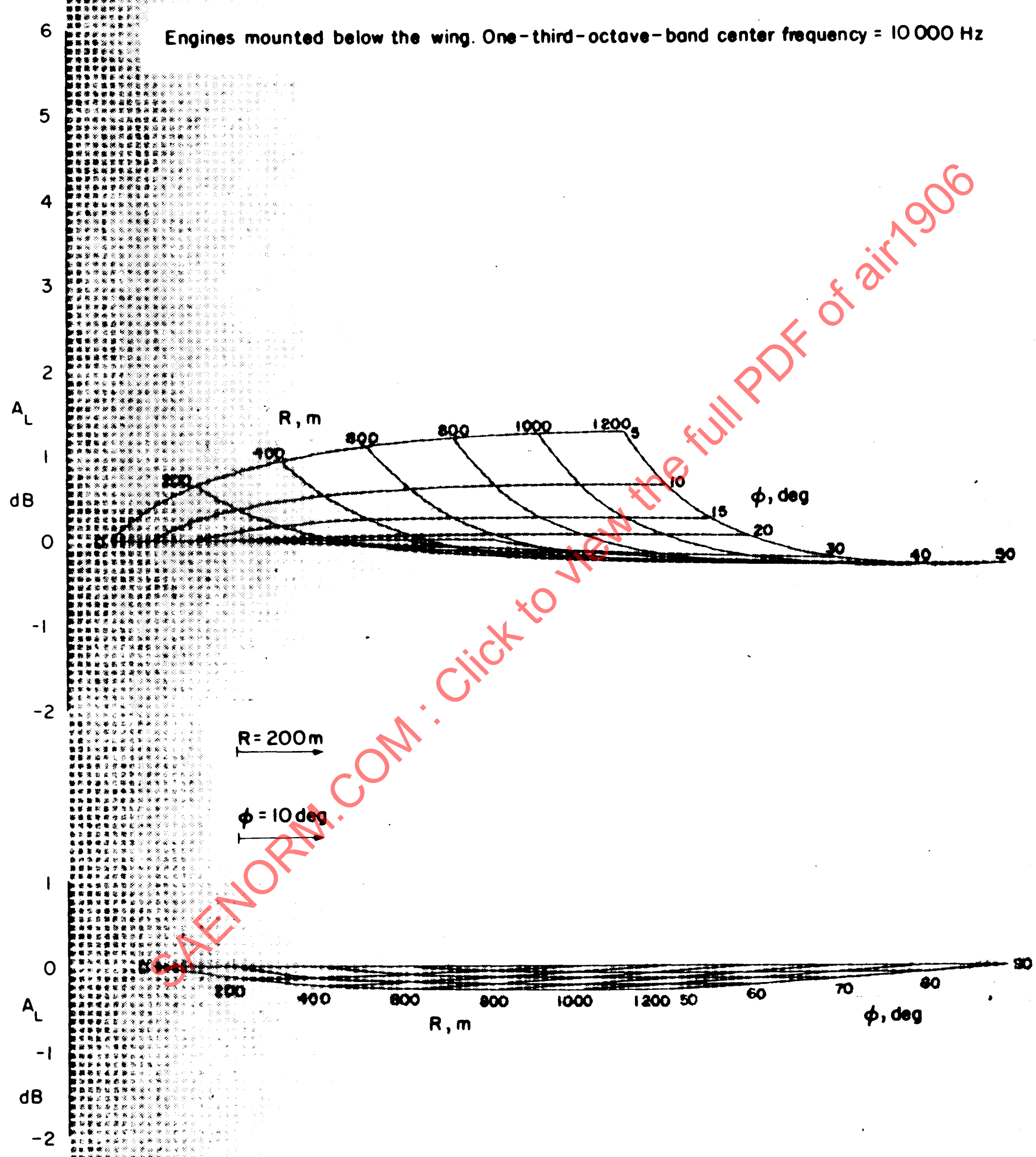
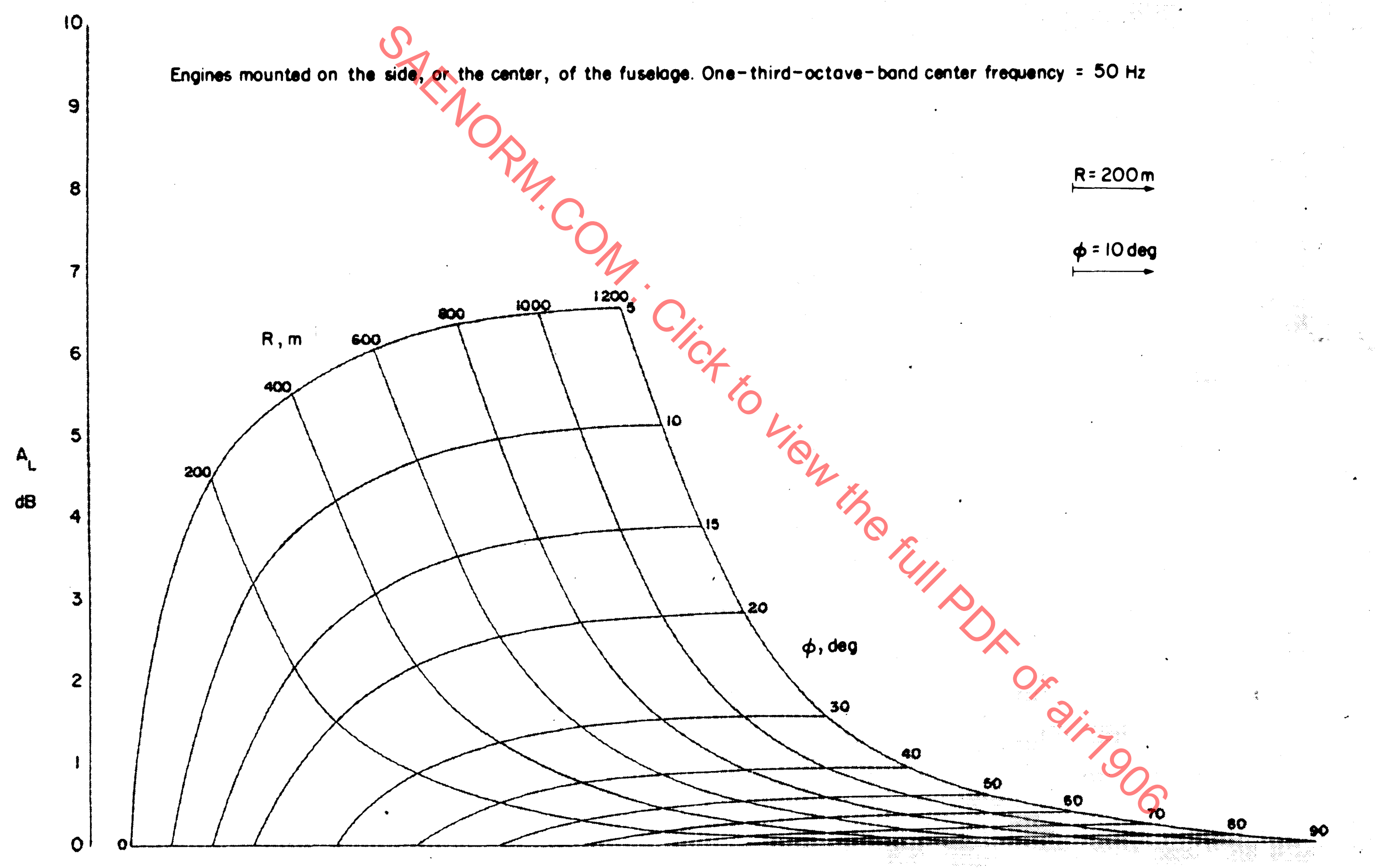

Engines mounted below the wing. One-third-octave-band center frequency = 10 000 Hz
6
5
4
3
2
1
0
-1
-2
A_L
dB
R, m
200
400
600
800
1000
1200
5
10
15
20
30
40
90
ϕ, deg
R = 200 m
ϕ = 10 deg
1
0
-1
-2
A_L
dB
200
400
600
800
1000
1200
50
60
70
80
90
R, m
ϕ, deg

FIGURE 24



Engines mounted on the side, or the center, of the fuselage. One-third-octave-band center frequency = 50 Hz
R = 200 m
ϕ = 10 deg
A_L
dB
0
1
2
3
4
5
6
7
8
9
10
R, m
0
200
400
600
800
1000
1200
ϕ, deg
5
10
15
20
30
40
50
60
70
80
90

FIGURE 25

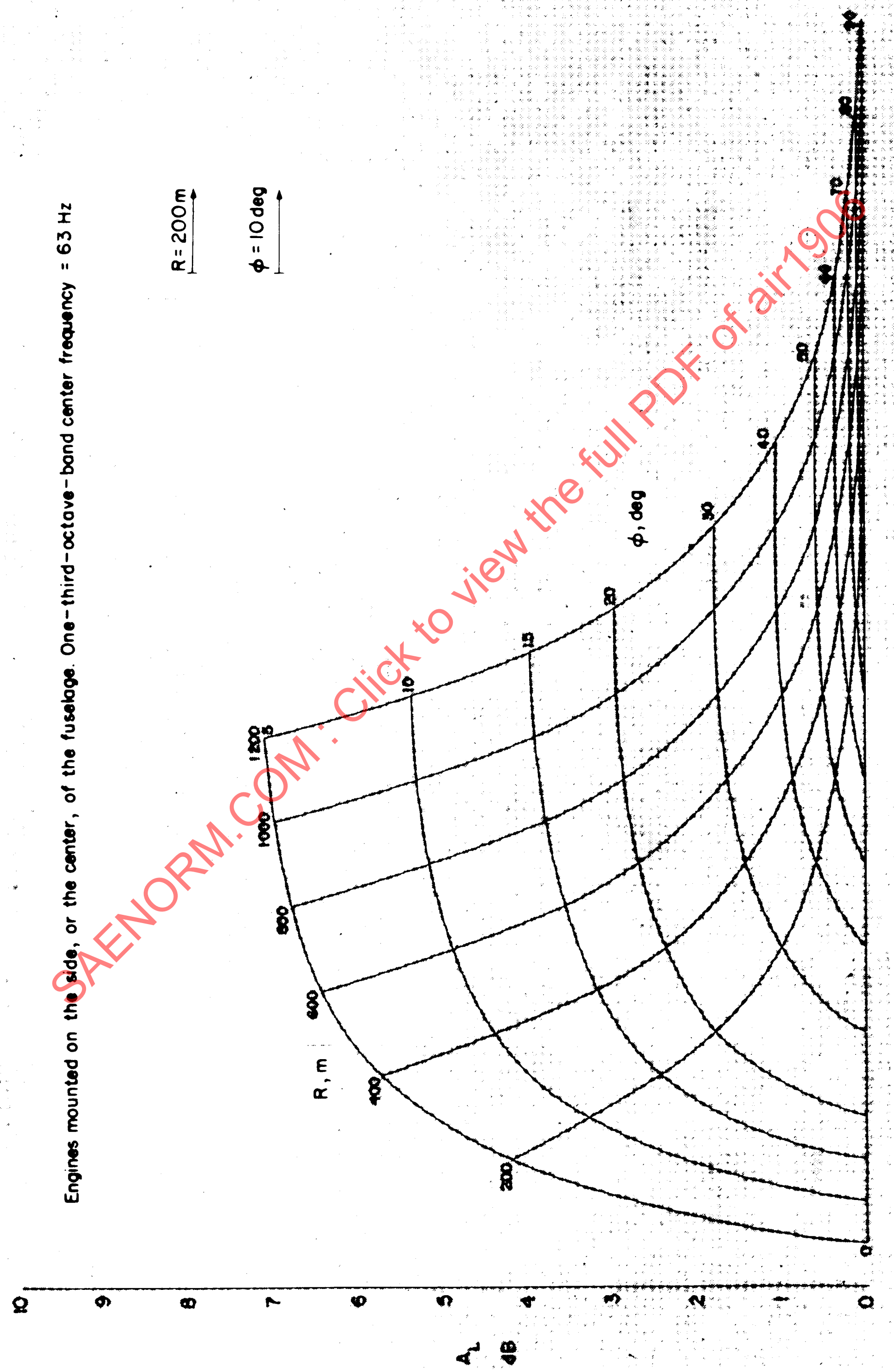

Engines mounted on the side, or the center, of the fuselage. One-third-octave-band center frequency = 63 Hz
R = 200m
φ = 10 deg
R, m
200
400
600
800
1000
1200
φ, deg
5
10
15
20
30
40
50
A_L
dB
0
1
2
3
4
5
6
7
8
9
10

FIGURE 26

Engines mounted on the side, or the center, of the fuselage. One-third-octave-band center frequency = 80 Hz

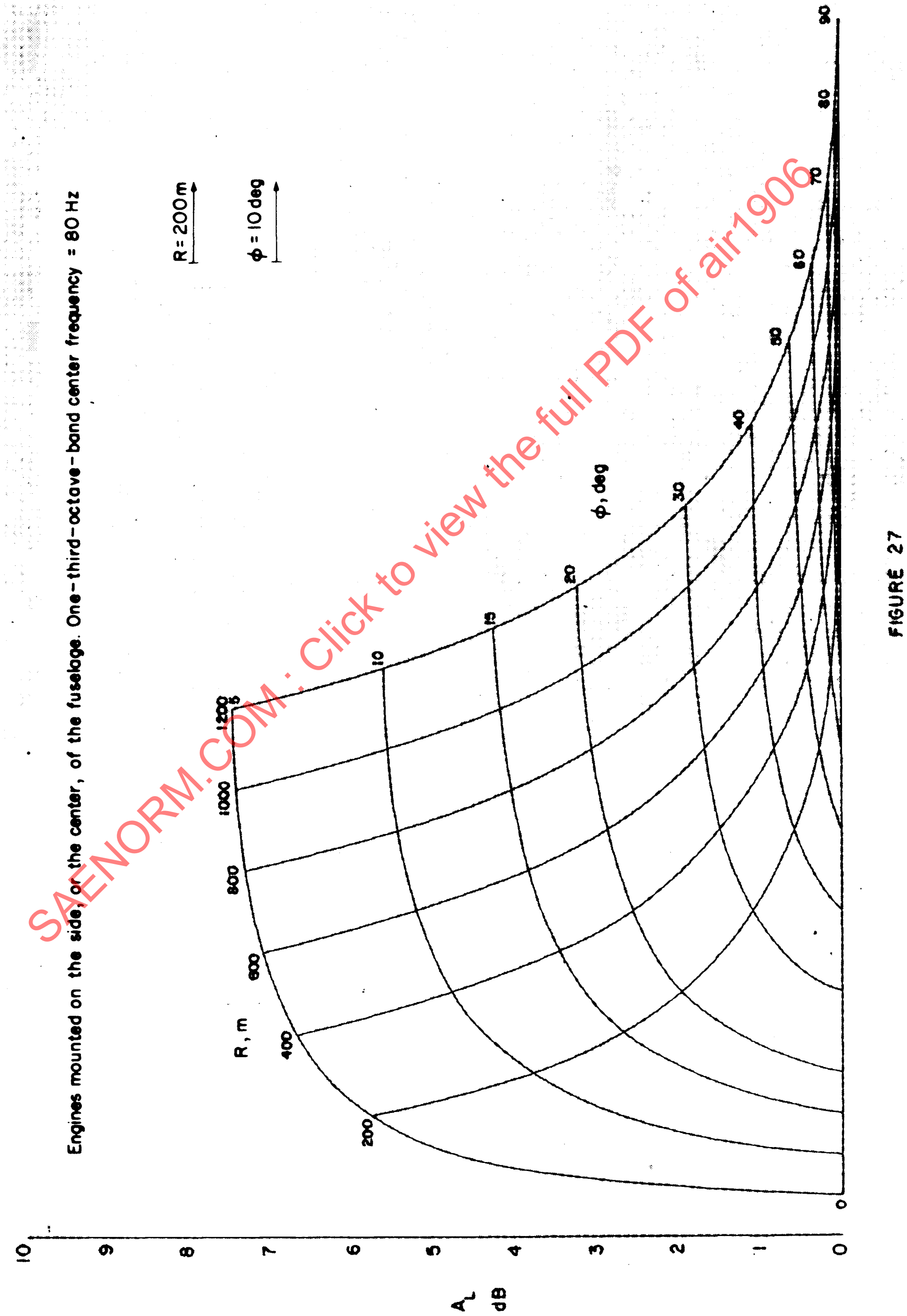


FIGURE 27

Engines mounted on the side, or the center, of the fuselage. One-third-octave-band center frequency = 100 Hz

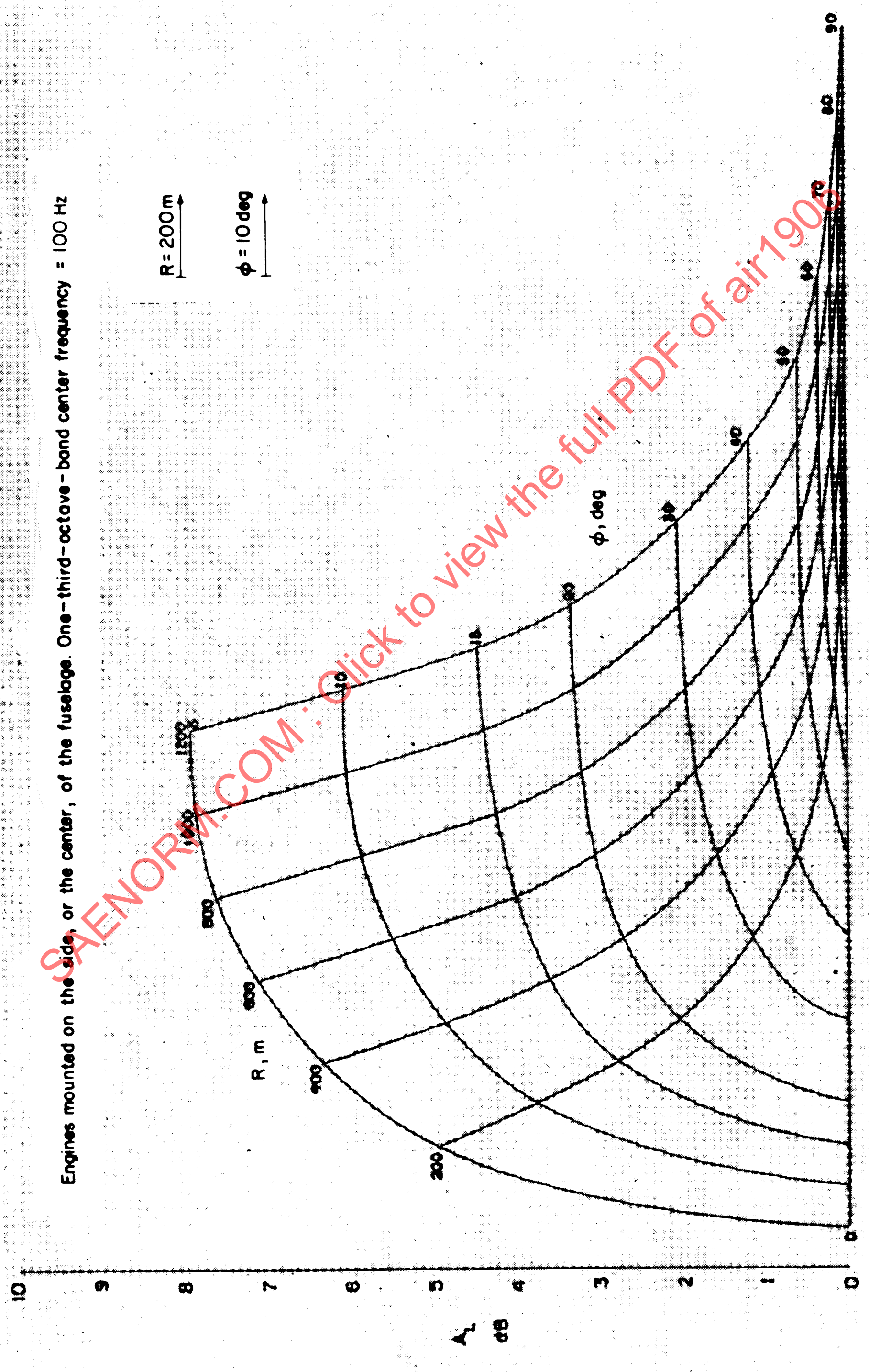


FIGURE 28

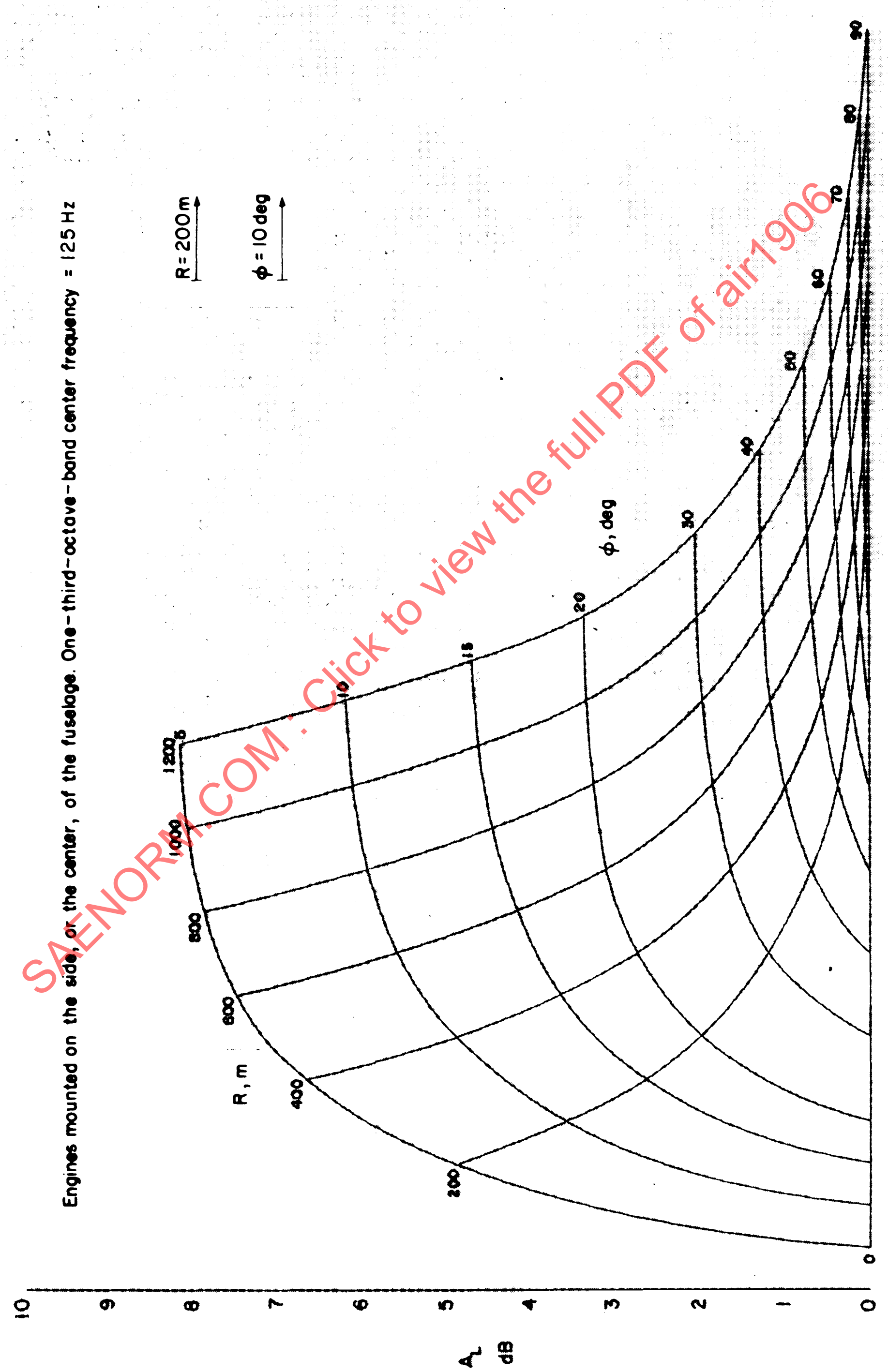

Engines mounted on the side, or the center, of the fuselage. One-third-octave-band center frequency = 125 Hz
R = 200 m
φ = 10 deg
R, m
φ, deg
0
200
400
600
800
1000
1200
5
10
15
20
30
40
50
60
70
80
90
A_L
dB
0
1
2
3
4
5
6
7
8
9
10

FIGURE 29

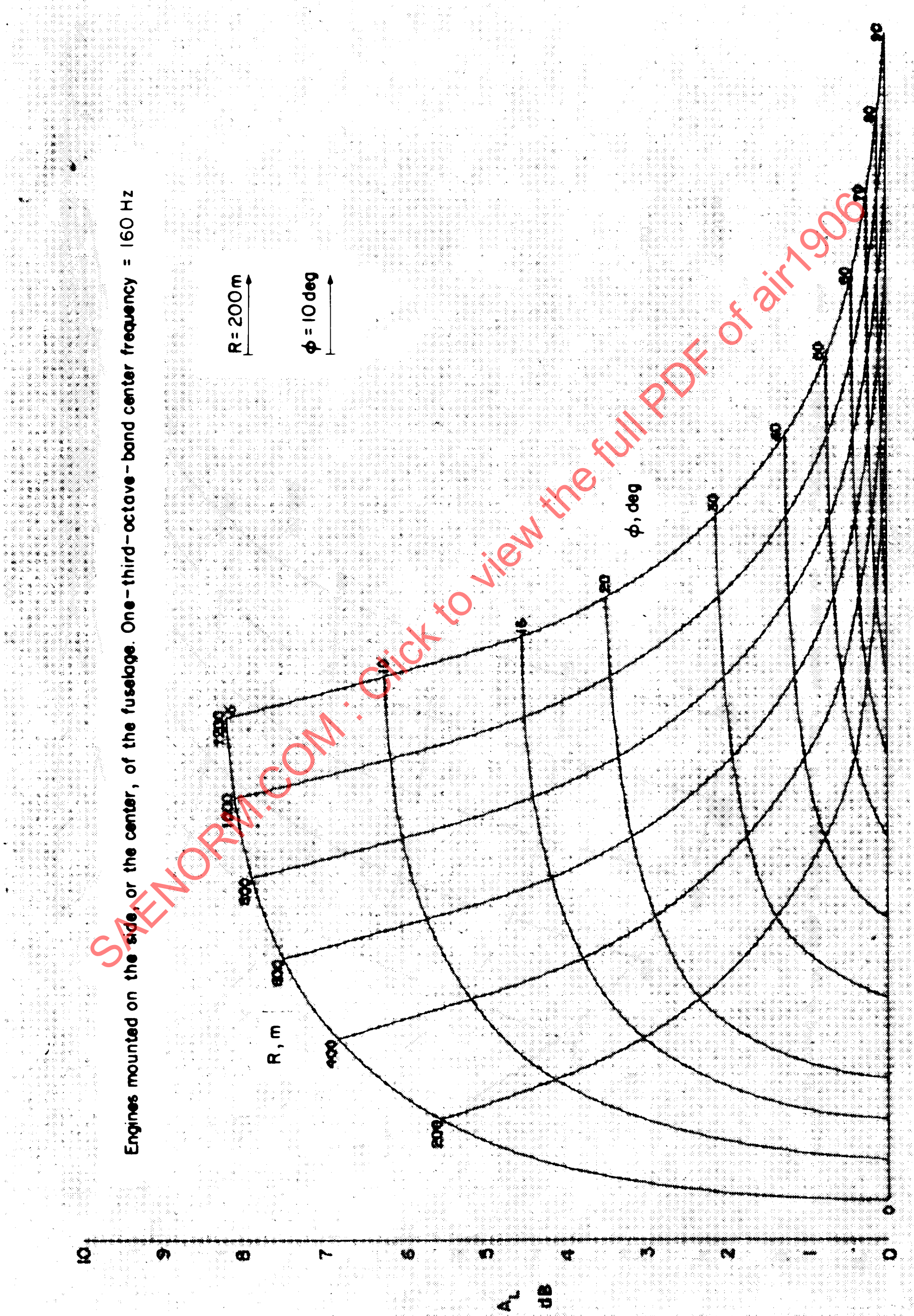

Engines mounted on the side, or the center, of the fuselage. One-third-octave-band center frequency = 160 Hz
R = 200 m
φ = 10 deg
R, m
φ, deg
A_L
dB
0
1
2
3
4
5
6
7
8
9
10
200
400
800
1200
1600
2200
0
10
20
30
40
50
60
70
80
90

FIGURE 30

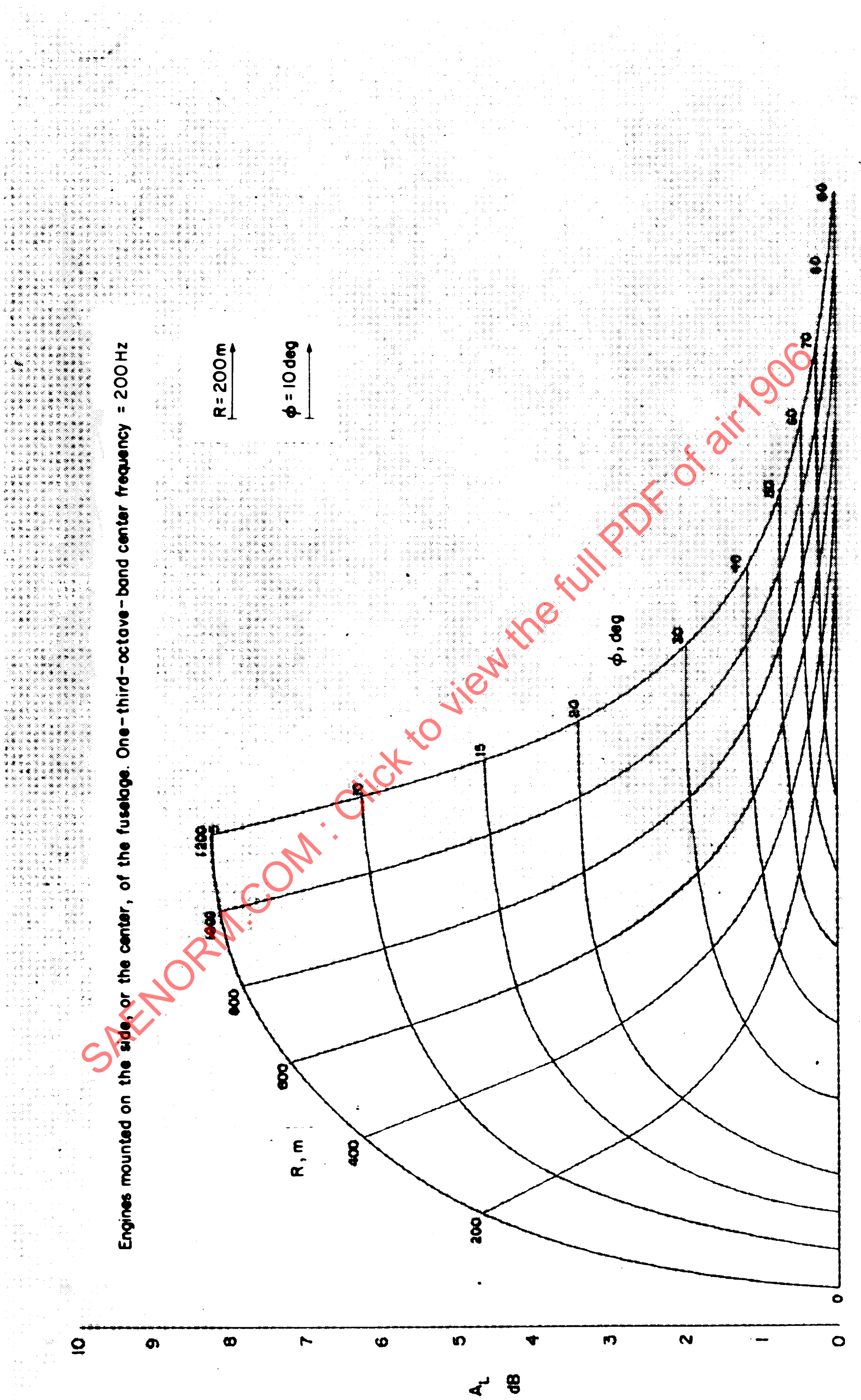

Engines mounted on the side, or the center, of the fuselage. One-third-octave-band center frequency = 200 Hz
R = 200 m
φ = 10 deg
φ, deg
R, m
A_L
dB
0
1
2
3
4
5
6
7
8
9
10
0
200
400
600
800
1000
1200
10
15
20
30
40
50
60
70
80
90

FIGURE 31

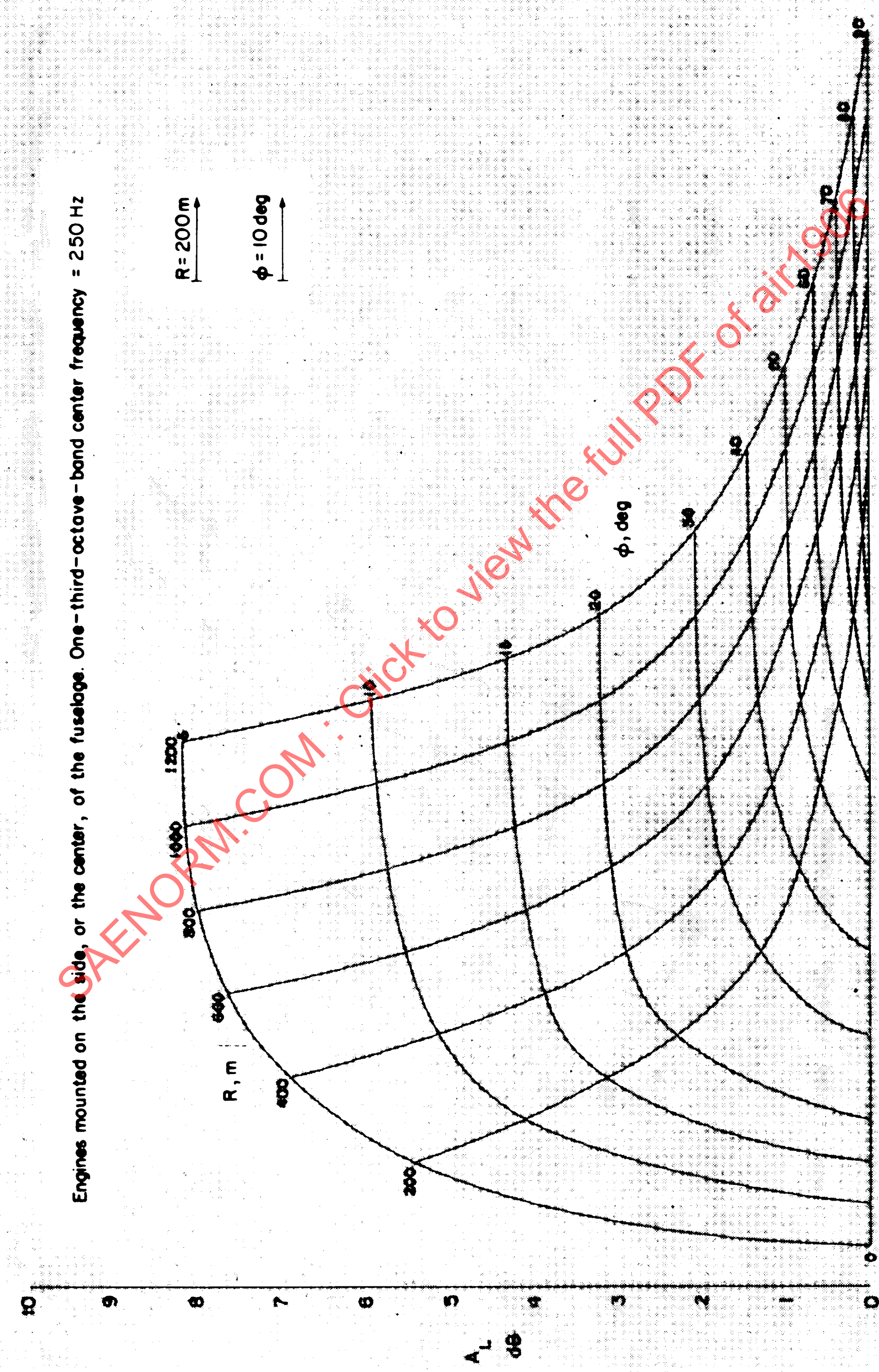

Engines mounted on the side, or the center, of the fuselage. One-third-octave-band center frequency = 250 Hz
R = 200 m
φ = 10 deg
φ, deg
R, m
A_L dB
0
1
2
3
4
5
6
7
8
9
10
200
400
600
800
1000
1200
10
20
30
40
50
60
70
80
90

FIGURE 32

Engines mounted on the side, or the center, of the fuselage. One-third-octave-band center frequency = 315 Hz

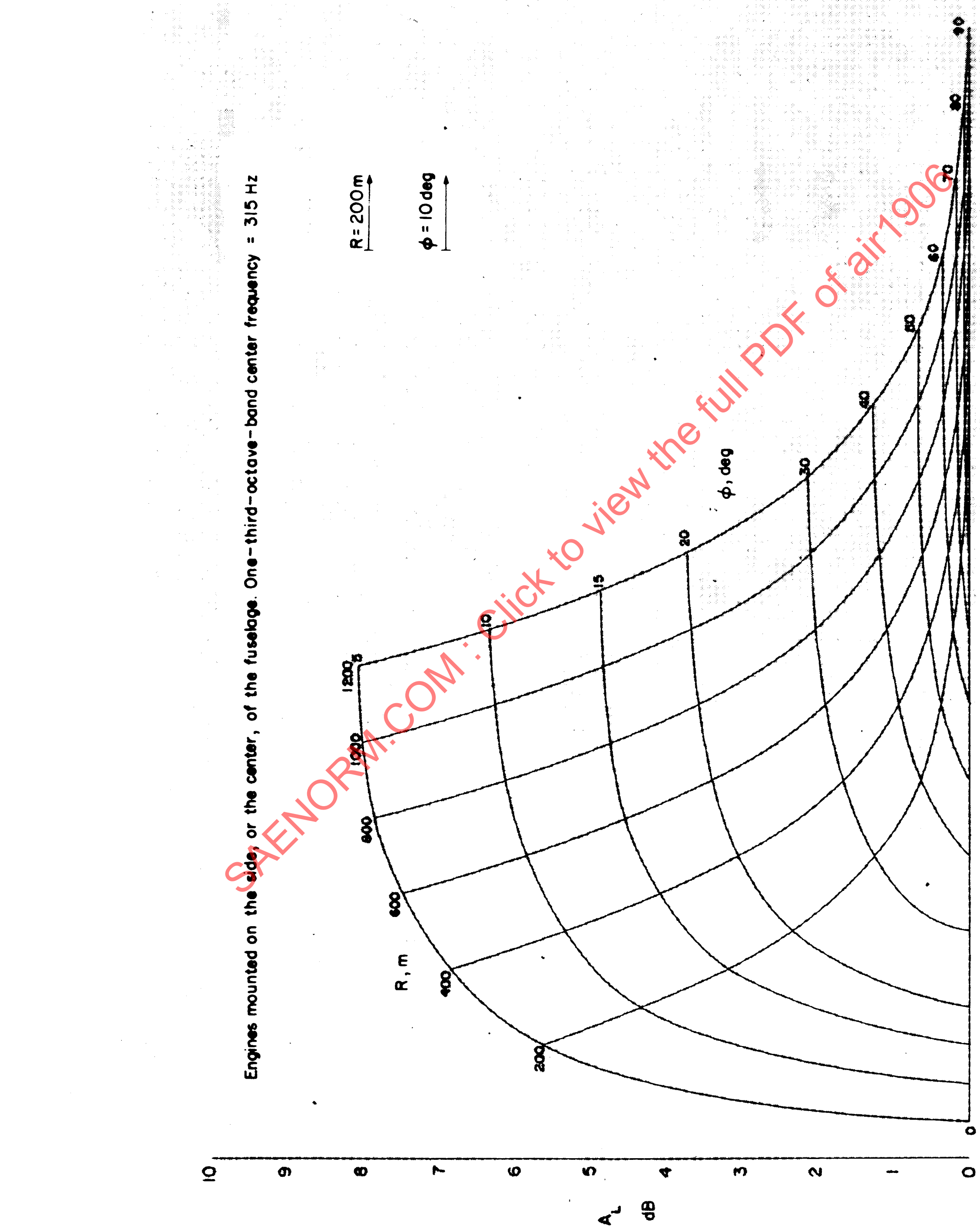


FIGURE 33