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COMMERCIAL AIRCRAFT NOISE DEFINITION - L-1011 TRISTAR. VOLUME I

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Lockheed-California Company

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COMMERCIAL AIRCRAFT NOISE DEFINITION
L-1011 TRISTAR

Volume I-FINAL REPORT

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16. Abstract

Calculation procedures to describe airplane noise during takeoff and approach have been programmed for batch operation on a large digital computer. Three routines are included. The first normalizes far-field noise spectra to reference conditions and then determines spectra at various distances from the airplane, for airport elevations between sea level and 6000 feet and ambient temperatures between 30°F and 100°F. Overall sound pressure levels, A-weighted noise levels, perceived noise levels, and effective perceived noise levels are calculated. The second routine uses aerodynamic and engine thrust data to produce takeoff and approach flight path description. The basic takeoff is at constant equivalent airspeed, with thrust reduction or acceleration option after gear-up. The approach is along any constant glide slope between 3 and 6 degrees at constant airspeed, with a two-segment option. The last routine combines noise propagation and flight path information to produce constant noise contour "footprints." The program has been exercised on Lockheed L-1011-1 Tristar/Rolls-Royce RB.211-22 data, providing results in EPNdB and dBA.

- Volume I contains detailed discussion of the calculation procedures.
- Volume II includes L-1011-1 noise propagation and airplane performance and samples of contours.
- Volume III presents the logic behind the calculations and outlines the computational procedures.
- Volumes IV and V describe the computer program and give instructions for its operation.

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PREFACE

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NOMENCLATURE

SYMBOL		UNITS	DESCRIPTION
Engr.	FORTRAN		
a	ACC	KTAS/SEC	Calculated level-flight acceleration.
a_1	ACCI	KTAS/SEC	Acceleration. An input.
area	AREA	SQ. ST. MI.	Area enclosed by contour (cumulative vs. x).
-	ATMOS	-	An atmosphere subprogram. Entry is with a pressure altitude; HP, HTP, or Have. Returns include the parameters DT, TRAT, DELTA, SRSIG, and C_e.
C	C	METERS/SEC	Speed of sound.
CB_{FAC}	CBFAC	NON-DIM.	Thrust cutback factor. A decimal between 0. and 1.0. An input.
C_{L_α}	CLALF	-	An input array of CL as a function of angle of attack (α) for various flap settings.
C_D	CD	NON-DIM.	Drag coefficient.
$C_{D_{TRIM}}$	CDTRIM	NON-DIM.	Engine-out trim drag coefficient.
Ce	CE	KEAS	Speed of sound.
C_L	CL	NON-DIM.	Lift Coefficient.
-	CLCD	-	An input array of CD as a function of CL for various flap settings.
$C_{L_{lof}}$	CLLOF	NON-DIM.	Lift-off lift coefficient.
$C_{L_{rms}}$	CLRMS	NON-DIM.	A root-mean-square value of lift coefficient. A return from subprogram RMS.
C_{L_S}	CLS	-	An input array of stall lift coefficient as a function of flap setting.
C_N	CN	NON-DIM.	Engine-out moment coefficient.
d	D/ DDTAB(I)	FT.	Flyover distance to which spectra is to be attenuated.
D	DRAG	LB.	Drag.
D_c	DC	PNdB	Duration correction.
D_o	DO	FT.	Distance for input data.
D_{wm}	DWM	LB.	Engine-out windmilling drag.
EGA	EGA	dB	Extra ground attenuation.
EPR	EPRT	NON-DIM.	Engine pressure ratio. An input array.
EPNL	EPNL	EPNdB	Effective perceived noise level.
FF	FF	NON-DIM.	Correction factors for -22C engines.

NOMENCLATURE

SYMBOL		UNITS	DESCRIPTION
Engr.	FORTRAN		
-	FLAPV	DEG.	Flap deflection that reflects flap retraction.
FLAP	FLAP	DEG.	Flap selection for takeoff. An input.
FLATR	FLATR	DEG. C	Engine flat rating. A delta temperature above standard. An input.
FN	FN	LB.	Engine thrust. (per engine)
FN_{EO}	FNEO	LB.	Thrust required for level flight with a wing engine out.
FN_{TAB}	FN	LB.	Thrust required for approach from a Weight-Thrust table.
grad	GRAD	NON-DIM.	Climb gradient after gear up.
H	H	FT.	Geometric height above ground.
$\bar{H}$	Have	FT.	Average pressure altitude.
H_p	HP/H	FT.	Pressure altitude (airport). An input.
HT_{CB}	CBHT	FT.	Engine cutback altitude. An input. A pressure altitude.
HT_G	HTG	FT.	Geometric height or altitude (above sea level).
HT_{GU}	GUHT	FT.	Height or altitude above sea level for gear up.
HT_{GU}	GUHTO	FT.	Height above 35 feet for gear up. A third degree curve fit of flight test data. A function of flight path angle at liftoff (γ_{lof}).
HT_p	HTP	FT.	Pressure height or altitude (above sea level).
i	I	NON-DIM.	1/3 octave band number. i=1 is 50 Hz band.
IEPR	IEPR	NON-DIM.	Engine pressure ratio. Interpolated for in an EPR table as a function of FN/δ and Mach number.
KK	KK	NON-DIM.	An input array of correction factors to allow for a match of flight test noise profiles with the mathematical simulation.
L	-	LB.	Lift.
L_A	L	dB A.	A - sound level.

NOMENCLATURE

SYMBOL Engr.	 FORTRAN	UNITS	DESCRIPTION
L_{ave_i}	L	dB*	Average normalized 1/3 octave band SPL.
L_c	LC	dB	Level on centerline.
L_i	L	dB*	1/3 octave band sound pressure level.
L_s	LS	dB	Level on sideline.
L1	LLL	dB	Level with Extra Ground Attenuation
L_2	LLL	dB	Level without Extra Ground Attenuation.
$L_{200,i}$	L	dB*	1/3 octave band SPL at 200 ft and reference conditions.
M	MACH	NON-DIM.	Mach number.
$\overline{M}$	MAVE	NON-DIM.	Average Mach number. Ratio of Vave to Ce.
M_{lof}	MLOF	NON-DIM.	Mach number at liftoff.
M_{lof1}	MLOF1	NON-DIM.	Mach number at liftoff.
$NE/NE_{in}/NE_{out}$	NE/NENGO/ NENGIN	NON-DIM.	Number of engines.
$\frac{N1}{\sqrt{\theta}}$	XN1	PERCENT	Normalized fan speed. (100% is 3900 RPM)
OASPL	OASPL	dB*	Overall sound pressure level.
OBSPL		dB*	Octave band sound pressure level.
OS	OS	NON-DIM.	Multiplier. Overspeed factor. 1.05 is 5% overspeed, for example.
p	PRESS	INCHES Hg	Ambient pressure.
P		Pascals	Ambient pressure.
PNL	PNL	PNdB	Perceived noise level.
q	Q	LB./FT.^{2}	Dynamic pressure.
-	QXTRP3	-	A trivariate interpolation subprogram. Entry is with a pressure altitude, Mach number, temperature increment, and THRUST array. An interpolated value of thrust (FN) is the return.
R	R	FT.	Slant distance to the flight path.
RAT	RAT	NON-DIM.	Minimum computed thrust cutback factor.
R_v	R	FT.	Distance to flight path with the velocity correction.
R_e			Equivalent earth radius. 6353.5 Km or 20846 ft.

*Reference: 0.0002 microbar

NOMENCLATURE

SYMBOL		UNITS	DESCRIPTION
Engr.	**FORTRAN**		
Relative Humidity	RLTHUM	PERCENT	Relative humidity.
RMS	RMS	-	A subprogram which calculates the root-mean-square value of an initial and final velocity. The rms velocity is used to calculate an associated rms value of lift coefficient, CLrms, which is a return from the subprogram.
R/C or R/D	ROC	FT./SEC.	Rate-of-climb or rate-of-descent. Tapeline.
R_1	R1	FT.	Distance to flight path for a given level without EGA.
R_2	R2	FT.	Distance to flight path for a given level with EGA.
S	S	FT^2	Wing area. ($3456\ FT^2$). An input.
S_a	SA	FT.	Downrange distance during ground acceleration from brake release to rotation.
S_c	SC	FT.	Downrange distance during climb from liftoff to 35 feet.
S_{clmb}	SCLMB	FT.	Incremental downrange distance during gear up climb.
S_{GU}	TSGU	FT.	Downrange distance for the climb segment from 35 ft. to gear up.
S_{TOT}	TDIST	FT.	Total downrange distance.
S_r	SR	FT.	Downrange distance during ground acceleration from rotation to liftoff.
t	TTEMP	DEG. F	Ambient temperature.
T	TN/ -	DEG. K/LB.	Temperature or total thrust.
T_{amb}	TAMB	DEG. F	Ambient temperature at altitude.
T_{amb_i}	TAMBI	DEG. F	Ambient airport temperature. An input.
T_{clmb}	TCLMB	SEC.	Time to climb from liftoff. A third degree curve fit of flight test data. A function of flight path angle at liftoff (γ_{lof}).

NOMENCLATURE

SYMBOL Engr.	FORTRAN	UNITS	DESCRIPTION
T_{Clmb}	TCLMBV	SEC.	Time increment for climb after gear up. A fixed value for all climbs except thrust cutback, wherein a value is calculated.
T_{EX}	TEX	LB.	Excess thrust.
T_{FAC}	TFAC	NON-DIM.	Thrust multiplier. An input.
T_{STD}	TSTD	DEG. K	Standard temperature.
TPNL	TPNL	PNdB	Tone corrected perceived noise level.
T_{RAT}	TRAT	NON-DIM.	Temperature ratio, TAMB/TSTD. Return from ATMOS.
-	THRUST	LB.	Engine thrust. An input array of engine thrust as a function of altitude and Mach number.
-	TRP2	-	A bivariate interpolation subprogram. Entry is with a bivariate array (ESR; CLCD; CLALF) and two independent variables (FN/DELTA, Mach number; CL, Flap setting). An interpolated value of a dependent variable (ESFN, CD, ALPHA) is the return.
$(T/W)_{lof}$	TWLOF	NON-DIM.	Thrust to weight ratio at liftoff.
$\bar{V}$	VAVE	KEAS	Average velocity.
V_e	VE	KEAS	Equivalent airspeed.
V_{init}	VINIT	KTAS	Initial velocity.
V_{lof}	VLOF	KEAS	Liftoff speed.
V_{lof}	VVLOF	KTAS	Liftoff speed.
V_R	VR	KEAS	Velocity at rotation.
V_S	VS	KEAS	Stall speed.
V_a	V	KTAS	Velocity for input data of approach.
V_T	TAS	KTAS	True airspeed.
$V_2(2)$	V2(2)	KTAS	Airspeed at 35 feet after engine failure.
$V_2(2)+10$	V2(2)+10	KEAS	Climb airspeed after gear up.
V_2ten	V2TEN	KTAS	V2 speed plus 10 KTAS.
$V_2(3)$	V3	KTAS	Three engine true airspeed at the 35 foot point.

NOMENCLATURE

SYMBOL		UNITS	DESCRIPTION
Engr.	FORTRAN		
V_w	VW	KTAS	Adjusted wind velocity.
V_{w_i}	VWI	KTAS	Wind velocity. Input. - = tail wind. + = head wind.
W	W	LB.	Airplane takeoff weight. An input.
W_{a_i}		dB.	A-weighting.
W/W_{CORR}	W/WCORR	LB.	Uncorrected (W) or energy corrected weight (WCORR).
X	X/XX	FT.	X distance along flight path projected to the ground.
X'	XPJ	FT.	X intercept of noise level on the ground on the extended runway centerline.
X''	XPPJ	FT.	X intercept of noise level on the ground on the sideline.
Z_p	ZP	KM.	Pressure altitude.
α	ALPHA	DEG.	Angle of attack.
α_i	ALPHA	dB/1000 FT.	1/3 octave band absorption coefficient for the input conditions. Calculated by ARP 866.
α_{o_i}	ALPHAO	dB/1000 FT.	1/3 octave band absorption coefficient for the FAR day conditions.
α_{r_i}	ALPHAR	dB/1000 FT.	1/3 octave band absorption coefficients for the reference day conditions.
β	–	DEG.	Angle of elevation to aircraft along cone of max. radiation.
γ_{lof}	GAMLOF	DEG.	Flight path angle at liftoff.
δ	DELTA	NON-DIM.	Ambient to sea level pressure ratio, $Pamb/P_o$.
$\Delta FN_{\Delta V}$	DVCORR	LB.	Incremental thrust due to incremental approach speed.
ΔFN_{V_W}	B*VW	LB.	Incremental thrust due to wind.
ΔH	DELH	FT.	Altitude or height increment. Set at an initial value of 63 ft. in the climb from 35 ft. to gear up climb segment.

NOMENCLATURE

SYMBOL		UNITS	DESCRIPTION
Engr.	FORTRAN		
ΔH	DELHV	FT.	An altitude increment for gear up climb.
ΔHT_{GU}	HTGU	FT.	Calculated delta height from 35 feet to gear up. This accounts for an increase in true airspeed in this segment.
$\Delta(N_1/\sqrt{\theta})$	DNA DNE	PERCENT	Increment to $N_1/\sqrt{\theta}$. subscripts alt - due to aircraft pressure alt. EPR - due to engine pressure ratio.
ΔT	DT	DEG. C	Temperature increment. Difference between current and standard-day temperature at altitude. A return from ATMOS.
Δt	DTIME	SEC.	Incremental time to climb.
ΔV	DELV	KTAS	Incremental approach speed above 1.3 V_S.
θ	PITCH	DEG.	Vehicle pitch angle with respect to the ground.
θ	THETA	DEG.	Assumed angle of radiation measured from inlet.
μ_r	MUR	NON-DIM.	Coefficient of rolling friction. Set at 0.015.
ρ	RHO	KG/M^3	Atmospheric density.
ρc	RHOC	MKS rayles	Characteristic impedence.
$\sqrt{\sigma}$	SRSIG	NON-DIM.	The square root of density ratio. A return from subprogram ATMOS. Establishes an equivalence between true airspeed and equivalent airspeed.
ϕ	SLOPE	RADIANS	Airport runway slope. -Down, + Up. An input.

Abbreviations

BR	Brake release
ROT	Rotation
LOF or lof	Liftoff
35	35 foot point
GU	Gear up

SECTION 1

INTRODUCTION

The need to provide adequate air transportation service results in the growth of aircraft size and of air traffic. This growth tends to aggravate the noise intrusion into the communities in the vicinity of airports unless an effort is made to halt or modify the growth of noise. As part of this effort, the Federal Aviation Administration has established the aircraft noise limits of FAR Part 36 (Reference 1), and the demonstrated noise levels, at FAR Part 36 conditions, of new airplane types are included in the airplane flight manual. For more detailed descriptions of airplane noise over a range of operating conditions and procedures and for general analyses of the totality of noise exposure due to all airplane operations at a given airport, extensive information on the acoustical and performance characteristics of airplanes is required.

The study of commercial aircraft noise definition reported here has involved the organization of the calculation procedures for developing the data needed to describe in detail the airplane noise patterns during takeoff and approach operations in the vicinity of an airport. The calculations have been programmed for batch operations on a large digital computer and the program has been exercised to produce performance and noise data for the Lockheed L-1011-1 Tristar, and to compute and plot constant noise contours, "noise footprints," for a sampling of airplane operations. The output data have been presented in the form of graphs and nomographs which may be used for L-1011 noise analyses, where the detail and precision of a computer run is not needed. The computer program can be adapted to determine flyover noise characteristics of any airplane when appropriate noise, power-plant, and aerodynamic noise data are available.

The aircraft noise definition procedure is divided into several calculation routines:

- Noise Propagation - Measured or predicted far-field noise spectra are normalized to a reference distance on a FAR Part 36 reference day of sea level, 77° F, 70% relative humidity. By applying proper attenuation and correction factors to the normalized spectra, noise spectra at other distances, airport elevations and atmospheric conditions are determined. From the spectra at each set of distances and conditions, calculations produce the overall sound pressure levels, A-weighted noise levels, perceived noise levels, and effective perceived noise levels.

- Airplane Performance - FAA approved L-1011 aerodyanmic data, speed relationships, and engine thrust characteristics are used in conjunction with performance equations to generate takeoff and approach flight path information. The primary takeoff flight path involves a three-engine takeoff and a climbout at constant equivalent airspeed; the two takeoff options provide for a thrust reduction or an acceleration after gear-up. The approach flight path may be along any constant glide slope between 3° and 6° at constant calibrated airspeed, with a two segment option allowed.
- Noise Footprints - Acoustical data in the form of noise versus distance and flight path information from the performance calculation above, or from some other source, are utilized to calculate noise under the flight path, noise along a sideline parallel to flight path projection on the ground, and the coordinates of points of any specified noise level. Points of equal noise level determine constant noise contour footprints which may be plotted by hand or by means of a machine plotting routine.

L-1011-1 data computed by the above procedures are included in Volume II of this report. The computation utilizes the results of the acoustical and performance measurements conducted during the airplane flight test program and the FAA certification demonstrations. These reported data are for operations at elevations between sea level and 6000 feet and at ambient temperatures between 30° F and 100° F. The noise propagation data are in the form of noise versus distance curves for effective perceived noise level and A-noise level. The performance section includes takeoff and approach nomographs which may be used to obtain approximate noise levels under the flight path for a range of temperatures, airport elevations and operational parameters. No takeoff thrust cutback data are shown, but, as noted above, the computer program does include a cutback capability. A number of footprint plots illustrate the effect of operational parameters on areas exposed to noise.

Volume III, "Model User's Manual," presents the logic behind the noise and performance calculation routines and outlines the computation procedures. Volumes IV and V, "Program Design Specification" and "Computer Programmer's Manual" respectively, document the computer program developed to perform the noise definition calculations.

SECTION 2

TAKEOFF AND APPROACH NOISE

The noise heard on the ground during takeoff or approach operations of an airplane is a function of the airplane performance and of the noise generated at the airplane. The airplane performance determines the engine thrust required for the operation and the propagation distance of the sound. Although there is indication that aerodynamic noise generated by the airframe motion through the air contributes to the total noise at low-thrust approach operations of the new relatively quiet wide-bodied jet transports (Reference 2), the power plant's acoustic output is generally the major source of airplane flyover noise.

For the airplane noise definition study of this report the physical noise characteristics are described, as is common, in terms of one-third octave-band sound pressure levels in decibels (dB) re 0.0002 microbar. Subjective noise characteristics are reported as effective perceived noise level (EPNL) in EPNdB and A-noise level (L_A) in dBA. EPNL is the prescribed noise measure for the transport aircraft noise certification of FAR Part 36 (Reference 1), while L_A is the common measure for industrial and highway noise description and regulation and is often used for airport noise monitoring. Noise calculations are performed with sound pressure level spectra, and then the associated subjective levels are determined. Effective perceived noise level is determined by the procedures of FAR Part 36 and A-noise level is determined by the spectrum weighting of IEC 179 (Reference 3). To ensure far field conditions, airplane noise is considered only at distances of 200 feet and greater.

2.1 AIRPLANE NOISE CHARACTERISTICS

Aircraft noise analysis requires information on noise at various engine operational thrust settings and at various distances from the aircraft. Noise versus distance data are designated here as noise propagation characteristics. Since noise information, either predicted or measured, is usually available, initially, for very limited conditions and distances, the calculation procedure developed, and programmed for a digital computer, first normalizes the available spectral noise information to reference conditions and a reference distance. The normalized data are called the airplane noise signature and are the starting point for the propagation calculations.

2.1.1 Noise Signatures

An aircraft noise signature is defined here as the one-third octave-band spectrum for the maximum noise at any engine power setting at a distance of 200 foot linear (the maximum noise anywhere on a line 200 feet from the aircraft) for the FAR Part 36 reference conditions of sea level, ambient temperature of 77° F, and relative humidity of 70 percent. Spectral noise data at other distances and other conditions are normalized to noise signatures. The normalization to 200 feet includes the effects of spherical spreading (inverse square law), extra air attenuation (References 4 and 5), characteristic impedance (Reference 6), and any change in number of engines between the input and the normalized data. The extra air attenuation correction from the temperature and humidity for the input data to the reference day conditions is performed as in Appendix A of FAR Part 36, neglecting elevation effects (Reference 7). If radial distance from the airplane is given, then linear distance for the atmospheric attenuation correction is obtained by multiplying the radial distance by the sine of the noise radiation angel with respect to the flight path. The characteristic impedance (pc) adjustment, in dB, is 10 log $\frac{410}{pc}$, where 410 MKS rayls is the characteristic impedance of air at 77° F at sea level and pc is the characteristic impedance for the input noise data conditions. This correction is small for the usual temperature range at a given elevation, but somewhat larger for the range of elevations considered. The complete calculation for a one-third octave-band sound pressure level, L_i, is represented by:

$$\begin{aligned} L_i\ (\text{normalized}) = {} & L_i\ (\text{input}) \quad \text{dB} && (2.1\text{-}1) \\ & + 20 \log_{10} \frac{D_o}{200} && \text{inverse square} \\ & + \alpha_i\ (D_o - 200)/1000 \sin\theta && \\ & && \text{extra air attenuation} \\ & + (200/1000 \sin\theta)\ (\alpha_i - \alpha_{o_i}) && \\ & + 10 \log_{10} \frac{410}{\rho c} && \text{impedance} \\ & + 10 \log_{10} (NE_{out}/NE_{in}) && \text{number of engines} \end{aligned}$$

When more than one spectrum is available for any given engine setting, then the normalized spectra are averaged by

$$L_i\ (\text{ave}) = 10 \log_{10} \frac{1}{n} \sum_{k=1}^{n} 10^{(L_{i,k}/10)} \quad \text{dB} \qquad (2.1\text{-}2)$$

where i is the band number, k the spectrum number, and n is the total number of spectra to be averaged.

Duration corrections for effective perceived noise level computation (EPNL - $PNLT_{max}$) are normalized to 160 knots true airspeed on the basis of ten times the logarithm of the velocity ratios and are normalized to 200 foot linear on the basis of ten times the logarithm of the distance ratios. Combining the two normalization terms gives the expression

$$10 \log_{10} 1.25 \frac{V}{D_o} \quad \text{dB} \qquad (2.1\text{-}3)$$

If a number of duration correction values result from the input data, then the normalized values are averaged arithmetically.

From the normalized spectra, calculations may be made of any type of weighted level desired. The computer program developed under the noise definition study determines overall and octave-band sound pressure levels in dB re 0.0002 microbar; perceived noise level and tone-corrected perceived noise level in PNdB; effective perceived noise level, in EPNdB, using the normalized duration corrections; and A weighted noise levels in dBA, which will be referred to subsequently as A-noise levels.

If normalized levels at a sufficient number of engine thrust settings are available, then noise versus thrust setting curves or relationships may be determined, as illustrated in Figure 2.1-1. However, no curve fitting procedure to do this has been included in the computer program. The normalized spectra and time durations are projected to other distances to generate the noise versus distance propagation characteristics.

2.1.2 Noise Propagation

Noise calculations may be made for noise propagation from the airplane to the ground, assuming only air absorption, and for noise propagation along the ground, introducing extra ground attenuation. The latter is needed to determine the noise at large distances to the side of the airplane's flight path.

2.1.2.1 Air to Ground Propagation

The normalized one-third octave-band sound pressure levels are adjusted to other distances, and to other atmospheric conditions and elevations, in the same manner that input noise data were normalized, above. The propagated sound pressure level, L_i, is calculated by

$$\begin{aligned} L_i = L_i \text{ (normalized)} \quad & \text{dB} & (2.1\text{-}4) \\ -20 \log_{10} \frac{d}{200} \quad & \text{inverse square} & \\ -\alpha_{r_i} (d-200)/1000 \sin\theta \quad & \text{extra air attenuation} & \\ +(200/1000 \sin\theta)(\alpha_{o_i} - \alpha_{r_i}) \quad & & \\ +10 \log_{10} \frac{\rho c}{410} \quad & \text{impedance} & \end{aligned}$$

At each distance for which a spectrum is determined, the spectral values are used to calculate the overall and octave-band sound pressure levels, maximum perceived noise level, effective perceived noise level, and A-noise level. To get the duration correction for effective perceived noise level, the normalized duration correction is adjusted to the appropriate distance and velocity as in 2.1.1 above on the basis of ten times the logarithm of the distance ratio and of the velocity ratio.

Noise versus distance propagations curves may be plotted for any one of the levels calculated. An example of EPNL versus distance propagation curves at a number of corrected fan speeds for the L-1011-1 with three RB.211-22B engines is shown as Figure 2.1-2. To produce such curves it has been found convenient to calculate noise levels at 200, 370, 800, 1600, 3200, . . . etc. feet.

2.1.2.2 Ground to Ground Propagation

The extra ground attenuation is derived from SAE AIR 923 (Reference 8). This document assumes a 10 knot headwind and a ground roughness parameter corresponding to a one-foot high grass ground cover. Although the applicability of the assumptions and data to typical airport communities has not been verified, this AIR provides the most complete procedure for estimating ground attenuation. For introduction into the computer program, extra ground attenuation (EGA) is calculated by means of a mathematical model of the zero degree angle of elevation condition of Figure 4 of AIR 923. The extra ground attenuation is a function of the two variables, frequency and propagation distance. The variation with frequency is taken as linear with the logarithm of the frequency with the slope of the relationship dependent on the distance from the source.

As with air absorption, use of extra ground attenuation requires a sound pressure level spectrum of the noise. When only effective perceived noise level or A-noise level versus distance, for air to ground propagation, is known and no spectrum is available, then approximate corrections for ground attenuation may be made from the curves of Figure 2.1-3. The high-bypass engine curves are based on L-1011 data, reported in Volume II. The current 4 engine and 3/2 engine low-bypass engine curves are based on information in Reference 9.

For over-the-ground propagation, the noise from the far-side engines is likely to be shielded by the airplane and by the turbulent exhaust from the nearer engines. The shielding adjustment of 5 $\log_{10}$ (number of engines) from Reference 10 is applied in the calculation of ground-to-ground propagation. The complete calculation from the air-to-ground levels calculated first is

$$L_i \text{ (ground)} = L_i \text{ (air)} - EGA_i - 5 \log_{10} (NE_{out}) \quad \text{dB} \qquad (2.1\text{-}5)$$

2.1.3 L-1011-1 Noise Characteristics

The calculation procedures described above have been applied to L-1011-1/RB.211-22B measured noise data and the resultant noise propagation curves are shown, in detail, in Volume II.

The basic data for this noise analysis are from the acoustical measurements of the FAR Part 36 certification program (Reference 10) conducted by the Lockheed-California Company Commercial Engineering Flight Test organization. Twenty-three flights were recorded, fifteen approach and eight takeoff flights. The instrumentation and the measurement and data reduction procedures complied with the requirements of FAR Part 36. Two microphones were used at the takeoff point and four at the approach point. The takeoff measurements were made at 3.5 nautical miles from brake release. A range of airplane takeoff weights provided a range of noise path distances of about 1200 to 1800 feet. The approach measurements were made at 1 nautical mile from the threshold, resulting in a flyover height of about 350 feet. A range of landing weights provided a range of engine thrust settings. Experience with both test stand and flight noise measurements had showed that the fan was the major contributor to the total noise. Consequently, fan speed was the most appropriate parameter against which to correlate noise. Corrected fan speed, $N_1/\sqrt{\theta}$, expressed as a percentage of maximum design speed, was selected as correlating parameter. The takeoff measurements, at maximum takeoff thrust, were in the range of 90 to 95 percent $N_1/\sqrt{\theta}$; the approach measurements spanned a range of about 70 percent to 55 percent.

The one-third octave-band sound pressure levels, the angles of noise radiation, and the noise durations between the 10 dB down points of the tone-corrected perceived noise level time histories, for each measurement condition and each microphone, were normalized as described in 2.1.1 above. All normalized spectra at a given fan speed were averaged. The radiation angles at takeoff and at approach conditions were averaged separately; the approach average was then used for the propagation calculations at fan speeds up to 75% $N_1/\sqrt{\theta}$, and the takeoff average at higher fan speeds. The difference in noise resulting from the angle difference was not considered sufficiently great to warrant varying the angle at intermediate fan speeds. The averaged normalized duration corrections were essentially constant for the approach conditions but about 2 dB higher for takeoff conditions. A linear increase in duration correction above 70% $N_1/\sqrt{\theta}$ was used.

The effective perceived noise levels and the A-noise levels, at normalized conditions, were also averaged at the various corrected fan speeds for which data existed. Curves of noise level versus $N_1/\sqrt{\theta}$ were then fitted to this 200 foot distance, reference day, data, as shown on Figure 2-1. Similarly curves were fitted to the data points for each of the one-third octave-band sound pressure levels, and interpolated spectra were determined at steps of 5 percent in $N_1/\sqrt{\theta}$ between 55 and 95 percent. In addition a spectrum was interpolated at 67.4 percent, the corrected fan speed for L-1011-1 maximum design landing weight operation at sea level on a FAR Part 36 reference day. These interpolated <u>noise</u> <u>signature</u> spectra are tabulated on Table 2-I.

These noise signature spectra were then adjusted to other distances and conditions as described in 2.1.2 above, to provide L-1011-1 noise propagation characteristics in the form of noise level versus distance. When only the distances and air-to-ground propagation are involved and the sea-level 77° F/70% relative humidity conditions maintained, the results are reference-day noise propagation and are illustrated, for effective perceived noise level, on Figure 2-2. An extensive set of air-to-ground propagation plots are included in Volume II. In the calculation process, distances of less than 200 feet were avoided, as the far-field assumptions of the calculation procedure might not hold. Propagation calculations were carried out to 12800 feet, although it is generally recognized that for "real" atmospheres, the atmospheric absorption values at ambient airport conditions cannot be expected to give reasonably accurate results beyond two- to three-thousand feet. For use in the more detailed noise exposure analysis to be described in a later section, noise propagation calculations were also conducted with extra ground attenuation added.

From the L-1011-1 propagation data "correction" curves have been developed to permit conversion of effective perceived noise levels and A-noise levels at reference conditions to other temperature and elevation conditions without the more detailed and more accurate use of spectra. These curves are shown as Figures 2-17 through 2-23 in Volume II "L-1011-1 Data."

TABLE 2-I L-1011/RB.211-22B NOISE SPECTRA AT 200 FEET
SEA LEVEL, 77° F, 70% RELATIVE HUMIDITY

$V_J/\sqrt{\theta}$, %	55	60	65	67.4	70	75	80	85	90	95
1/3 Octave Band Center Frequencies, Hz	Sound Pressure Levels, dB re 0.0002 microbar									
50	84.44	85.69	86.90	87.47	88.08	89.23	90.33	91.40	92.43	92.43
63	79.32	80.25	81.21	81.68	82.21	83.25	84.32	85.44	86.59	86.59
80	76.00	77.32	78.85	79.66	80.60	82.55	84.71	87.09	89.67	89.67
100	86.05	86.74	87.77	88.39	89.15	90.88	92.96	95.39	98.16	98.16
125	88.81	90.94	92.93	93.84	94.80	96.52	98.12	99.58	100.90	100.90
160	88.56	92.19	95.22	96.46	97.65	99.48	100.72	101.36	101.40	101.40
200	84.63	86.32	88.00	88.79	89.65	91.29	92.90	94.50	96.07	96.07
250	85.39	87.36	89.38	90.36	91.45	93.57	95.74	97.97	100.25	100.25
315	87.80	89.05	90.51	91.28	92.17	94.03	96.09	98.35	100.82	100.82
400	87.77	88.56	89.63	90.25	90.98	92.60	94.50	96.68	99.13	99.13
500	88.27	88.82	89.57	90.01	90.55	91.73	93.13	94.74	96.56	96.56
630	87.39	88.36	89.47	90.06	90.72	92.11	93.64	95.31	97.12	99.07
800	86.19	86.70	87.50	87.99	88.60	89.98	91.66	93.63	95.88	95.88
1000	86.00	86.19	86.76	87.16	87.71	89.03	90.74	92.83	95.30	95.30
1250	85.50	86.90	88.17	88.85	89.61	91.12	92.71	94.37	96.09	96.09
1600	83.89	85.49	87.11	87.89	88.74	90.37	92.02	93.67	95.34	97.02
2000	84.53	85.73	87.14	87.89	88.75	90.56	92.57	94.78	97.20	98.95
2500	85.15	87.25	89.13	89.95	90.78	92.20	93.39	94.36	95.10	95.61
3150	83.72	86.55	82.93	89.91	90.86	92.35	93.40	94.01	94.17	94.17
4000	82.76	85.22	87.31	88.18	89.03	90.38	91.35	91.96	92.20	92.20
5000	81.06	84.07	86.20	86.91	87.45	87.83	87.33	85.95	83.69	83.69
6300	78.66	81.93	84.10	84.75	85.17	85.13	83.99	81.75	78.41	78.41
8000	77.98	80.68	82.31	82.71	82.66	82.32	80.70	78.00	74.22	74.22
10000	72.49	76.39	78.82	79.47	79.80	79.31	77.36	73.95	69.07	69.07
	Radiation Angles, degrees									
	65.46	65.46	65.46	65.46	65.46	65.46	82.41	82.41	82.41	82.41
	Duration Corrections Normalized to 160 Knots, dB									
	-8.367	-8.367	-8.367	-8.367	-8.367	-8.872	-9.387	-9.902	-10.430	-10.943

2.1.4 Data Accuracy

Appendix A of FAR Part 36 (Reference 1) requires that for noise certification data one must "establish statistically . . . a 90% confidence limit not exceeding ± 1.5 EPNdB." This same requirement has been applied to the noise definition study and a statistical analysis has been conducted to verify the accuracy of the L-1011-1 noise data submitted with this report. This analysis is an extension of that performed for the L-1011-1 noise certification results (Reference 11).

The 90% confidence limits have been calculated for polynomial fits to the EPNL and L_A versus $N_1/\sqrt{\theta}$ data calculated from the measured noise certification spectra by the procedures of Section 2.1.2. Polynomial curves were fitted to the data by the method of least squares at each of the distances 200, 300, 800, 1600, 3200, 6400, and 12800 feet. The standard error of estimate (Reference 12) is found by

$$S_{L|N_1/\sqrt{\theta}} = \frac{\sum_{i=1}^{n} (L_i - L'_i)^2}{N - k - 1} \qquad (2.1\text{-}6)$$

where $S_{L|N_1/\sqrt{\theta}}$ is the standard error of estimate of

L on $N_1/\sqrt{\theta}$

L_i is the level of noise input to curve fit,

L'_i is the fitted level,

N is the number of inputted points to the curve fit,

k is the order of the fit.

The upper 90% confidence limit for the true mean of L is

$$L' + t_{\alpha', N-k-1} S_{y|1,2,\ldots k} \sqrt{1/N} \qquad (2.1\text{-}7)$$

where $t_{\alpha', N-k-1}$ is obtained from a table of Student t distribution for 100 (1-α) percent and N-k-1 degrees of freedom

$S_{y|1,2,\ldots k}$ is the standard error of estimate.

For $N = 23$ points (the number of L-1011-1 noise certification flights) and k = 2nd order fit, $t = 1.325$ and $t/\sqrt{N} = 0.2762$. Using these values Table 2-II results.

TABLE 2-II

90% Confidence Limits of L-1011-1 Noise Data from Curve Fits to EPNL and L_A Values

Distance Feet	EPNL ~ EPNdB $S_{y\|1,2}$	 90% C.L.	L_A ~ dBA $S_{y\|1,2}$	 90% C.L.
200	.4329	.120	.8048	.222
370	.4426	.122	.8521	.235
800	.4908	.136	.9424	.260
1600	.5393	.149	1.03468	.286
3200	.7798	.215	1.0972	.303
6400	.8961	.248	1.1227	.280
12800	1.0677	.295	1.16851	.323

Since it was convenient to use spectra at given values of $N_1/\sqrt{\theta}$, second order polynomial curves were fitted to the spectral band levels versus $N_1/\sqrt{\theta}$. The resulting spectra are shown on Table 2-I. The 90% confidence limits for each band were then determined and the EPNL's and L_A's found for the fitted spectra and for spectra with the 90% confidence limits added to each level. Taking the differences between these pairs of EPNL's and of L_A's, gives the 90% confidence limits versus distance of Table 2-II.

TABLE 2-III

90% Confidence Limits of L-1011-1 Noise Data from Curve Fits to One-Third Octave-Band Spectra

	90% C.L.	
Distance Feet	EPNL ~ EPNdB	L_A dBA
200	0.31	0.30
370	0.32	0.30
800	0.32	0.31
1600	0.32	0.33
3200	0.36	0.35
6300	0.38	0.37
12800	0.39	0.38

Considering both of these statistical analyses, the fit of the acoustical data is seen to be good for the measurement range, showing a 90% confidence limit less than ±0.5 EPNdB or dBA. This, of course, is only a test of the measured data and of the calculation procedure, because no statistical analysis is performed on the atmospheric absorption values which are fundamental to the propagation calculations.

Further flight noise measurements to improve the accuracy of the acoustical data over the range of conditions already demonstrated cannot be justified. Measurements at much larger distances would be valuable. However, flight test experience (Reference 11) has shown that even at distances of 1000 to 2000 feet, the dynamic range and background noise of the best available instrumentation is not adequate to measure the very low L-1011-1 noise levels at higher frequencies. At greater distances, this problem would be aggravated, eliminating even greater portions of the spectrum, and making EPNL and L_A calculation less accurate. Attempts to improve the accuracy of the atmospheric absorption data of ARP 866 (References 4 and 5) have encountered similar dynamic range and instrumentation background noise problems (Reference 13). The only additional data acquisition that might be warranted would be that aimed at filling in the gap in flyover noise measurements between 70% and 90% $N_1/\sqrt{\theta}$. Previous experience with static test stand and flight noise measurements of earlier versions of the RB.211-22B engines powering the L-1011 would indicate, however, that no appreciable change in the shape of the noise versus fan-speed curve is likely from additional data.

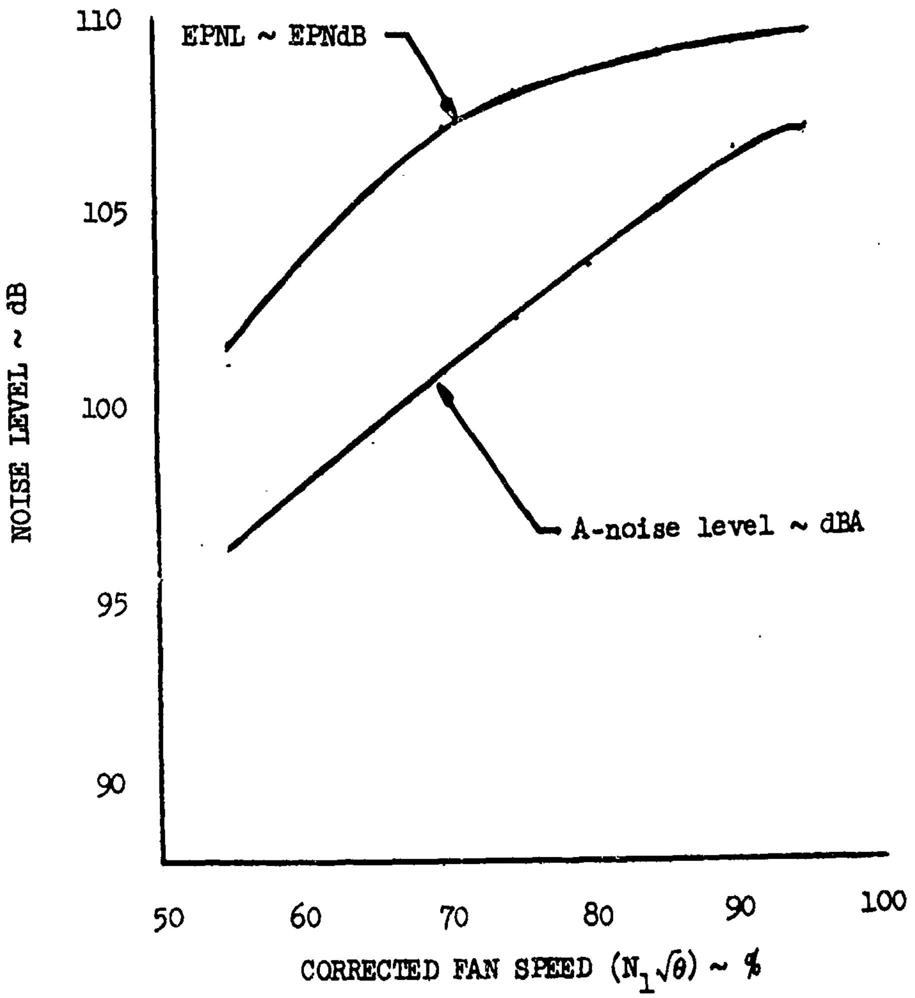


FIGURE 2.1-1 L-1011-1/RB211-22B NORMALIZED THREE ENGINE NOISE LEVELS ON 200 FT. SIDE LINE FOR S.L., 77°F, 70% RELATIVE HUMIDITY

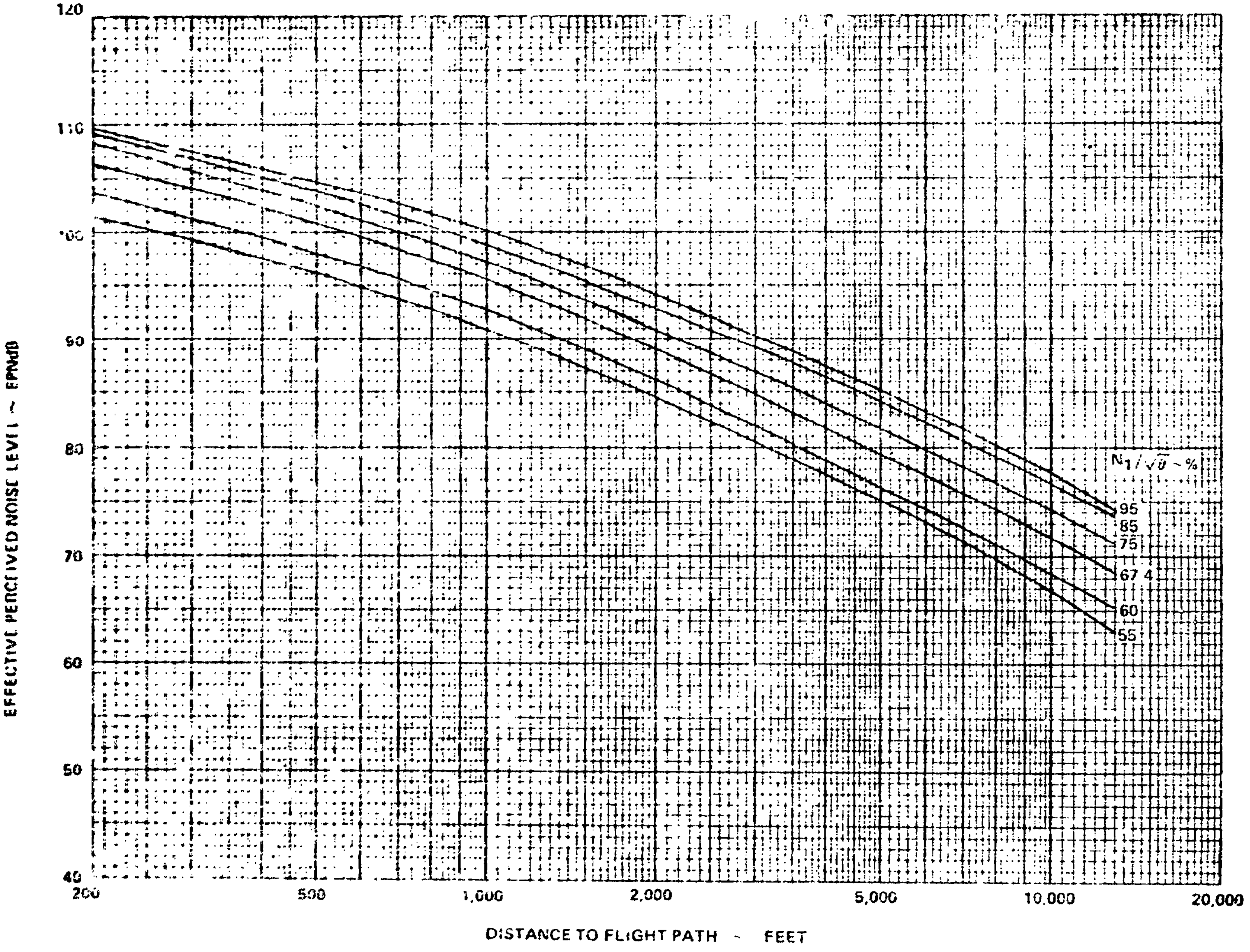


FIGURE 2.1-2 L 1011-1/RB.211-22B NOISE PROPAGATION
EFFECTIVE PERCEIVED NOISE LEVEL AT 160 KTS
SEA LEVEL 77°F 70% RELATIVE HUMIDITY

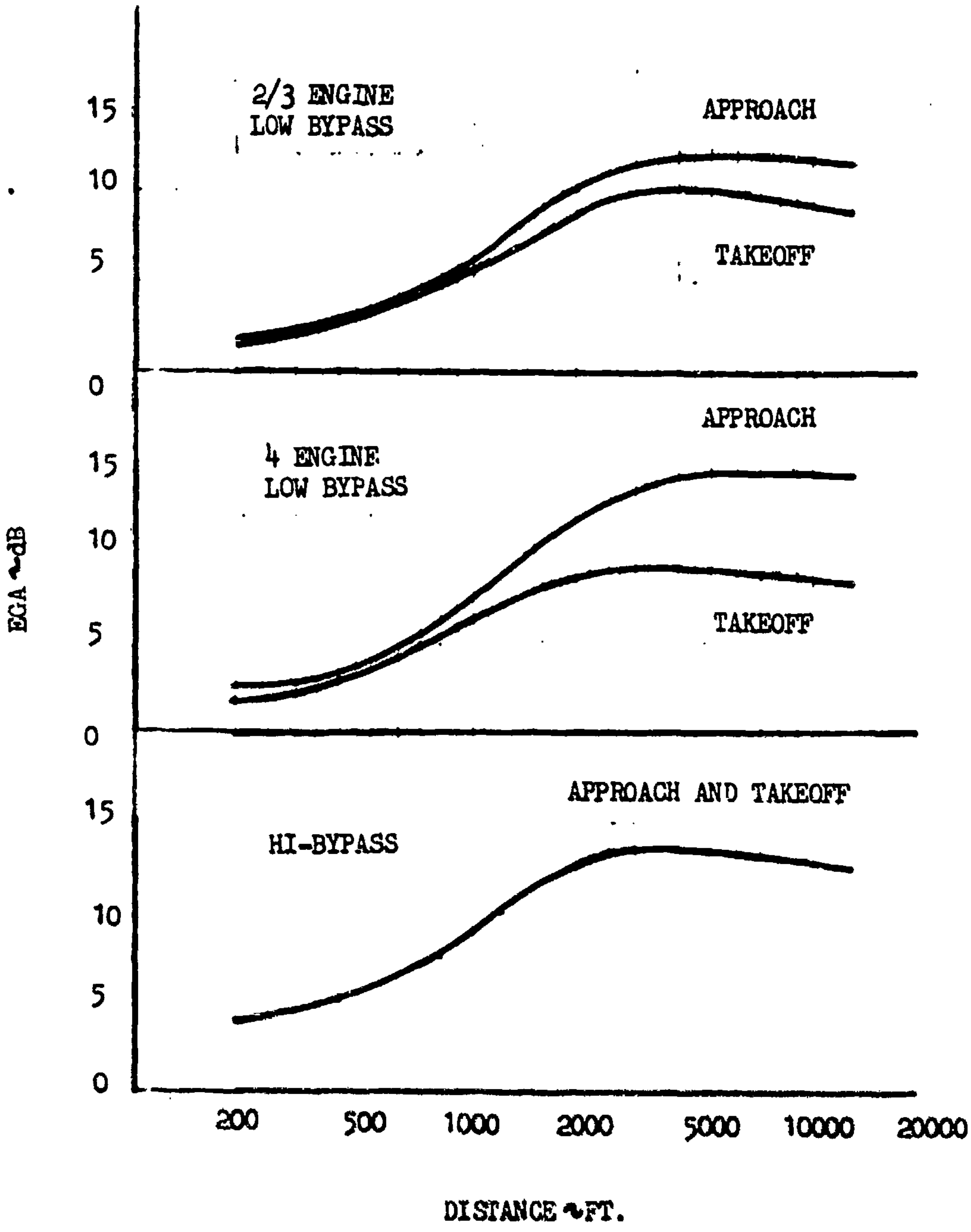


FIGURE 2.1-3 NOMINAL EXTRA GROUND ATTENUATION CORRECTIONS

2.2 AIRPLANE PERFORMANCE

Section 2.2 presents a technical discussion of airplane performance in terms of takeoff and approach. It is necessary to calculate takeoff and approach trajectories or flight paths to facilitate the calculation of noise beneath these paths. Figure 2.2-1 presents a general schematic or flow diagram of the noise definition program. It is the mathematics of the two parallel branches, takeoff and approach, which is discussed here. The end result is the calculation of takeoff trajectories, such as the sample of Figure 2.2-2, and/or approach trajectories, similar to the sample of Figure 2.2-3. The parameters $N_1/\sqrt{\theta}$, altitude, Mach number, and downrange distance, at appropriate points in the trajectory, are saved and transferred to the noise footprint subroutine of the program.

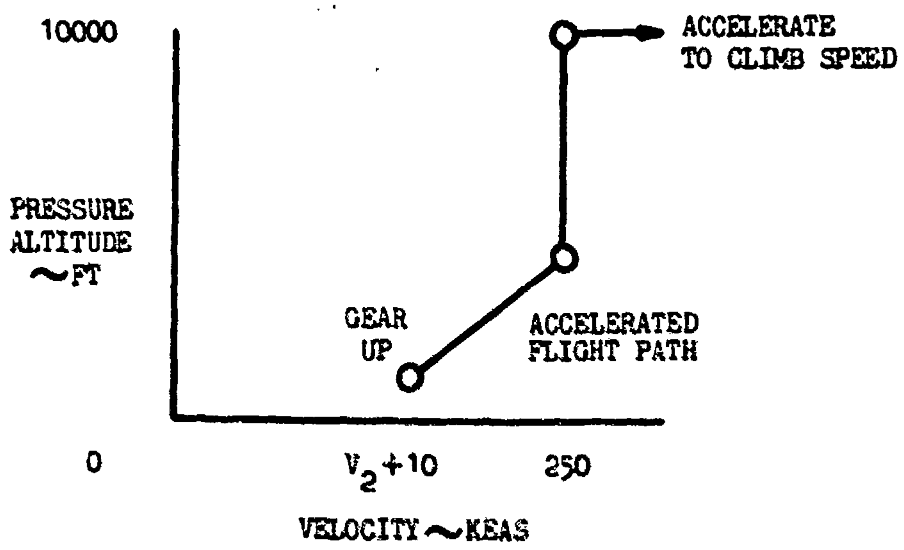
2.2.1 Takeoff

This section describes the subroutine which calculates the takeoff flight path from brake release (BR) to about 9500 feet above sea level (ASL) for three different flight paths. All flight paths reflect all engine operation and FAA approved aerodynamic data, thrust characteristics and speed relationships. The all engine distance to 35 feet is actual and does not include the 15 percent factor associated with FAR field lengths.

The primary flight path is a 3 engine takeoff and climbout at constant equivalent airspeed after gear up. Another path is a 3 engine takeoff and climbout to gear up with the option of a thrust reduction at any point after gear up. During accelerated flight after gear up, normal cleanup procedures (flap retraction) are followed.

The 1962 Standard Atmosphere (Reference 14) is used throughout for all calculations.

The program uses equations and methods developed by Flight Test (Reference 11) that describe a takeoff and climbout from brake release to a point where the aircraft is at about 9500 feet above sea level (Figure 2.2-4). Using FAA approved thrust, drag, and speed relationships, the aircraft is accelerated from BR to rotation (ROT), ROT to liftoff (LOF) and LOF to a point where the aircraft is at 35 feet (AGL). Then the aircraft is accelerated from the velocity at the 35 foot point (V_2 (3 engine)) to a speed equivalent to the engine out speed (V_2 (2 engine)) plus 10 knots at gear up. After gear up this speed is maintained to about 9500 feet (ASL) with the flap setting used for takeoff. At gear up, any flight acceleration between that corresponding to maximum climb gradient to the maximum acceleration corresponding to level flight may be selected (Figure 2.2-5). Use of the accelerated flight path requires an explanation of the speed schedule after gear up. The sketch below shows the speed-altitude relationship required to meet FAR Part 25 (Reference 14), which limits airspeed below 10000 feet to 250 knots.



Also, if climb speed is allowed to increase, normal cleanup procedure (flap retraction) is followed. Successive incremental retraction of the flaps will take place at the airplane speeds specified in the FAA Approved Flight Manual (Reference 16). The stepwise retraction is instantaneous, although the acceleration will be continuous during the cleanup.

After gear up any cutback thrust level may be chosen between full thrust and that corresponding to the thrust required for level flight with a wing engine inoperative (Figure 2.2-6). After gear up, the aircraft is climbed at constant equivalent airspeed, corresponding to V_2 + 10 KEAS, to the predetermined cutback altitude. At this altitude, the throttles are set to an EPR (Engine Pressure Ratio) corresponding to a percent of maximum takeoff thrust and a new climb gradient is established. The climb is continued at constant speed to about 9500 feet (ASL).

Head and tailwinds and the possibility of positive or negative runway slope are accounted for in the mathematical model.

2.2.1.1 Input Variables and Preliminary Calculations

The takeoff subroutine is a self contained program which means that, among other things, except for input variables, the program contains all of the FAA approved aerodynamic and propulsion data necessary to run takeoff and climbout paths within the physical limits of L-1011-1 Tri-Star and the contract requirements described in Reference 16. This section lists and describes the stored aerodynamic and propulsion data. In addition, input variables are noted, and selected preliminary-type calculations are explained. The program is then in a state to calculate a takeoff trajectory from brake release through termination (about 9500 ft. (AGL)).

Internally Stored Data

Internally stored L-1011-1 aerodynamic and propulsion data includes:

- Propulsion Data

  RB211-22C ECS Bleed On Flatrated to STD +3.8°C
  RB211-22C ECS Bleed Off Flatrated to STD +3.8°C
  RB211-22B ECS Bleed On Flatrated to STD +13.9°C
  RB211-22B ECS Bleed Off Flatrated to STD +13.9°C

  F_N vs. Mach No. from SL to 10000 (Press) ft.
  Temperature range 0°F to 110°F

- Engine Rating (FLATR)
  The first value in Thrust Table

- Drag Polars

  C_L vs. C_D for flap settings 4, 10, 18, 22, and 27 degrees

- C_L vs. α

  C_{L_α} @ CG=17° Mac. Power On

  C_{L_α} for Flap Settings 0, 4, 10, 18, 22, 27, 33* and 42* degrees
  *Approach Flap Settings

- RB211 EPR Map (58014)

  EPR vs. F_N/δ for Mach No. .1, .2, .3, .4, and .5

- $C_{L_s} \sim$ Stall C_L

  C_{L_s} vs. Flap Settings 4, 10, 18, 22, and 27 Degrees

- "K" Factor's For Use In Ground Run Distance Equations

- L-1011-1 Wing Area

  $S = 3456 \text{ ft}^2$

- Rolling Coefficient

  $\mu_R = .015$

- Takeoff Speed Ratios

  V_2/V_s, V_{LOF}/V_s, and V_R/V_s for $(T/W)_{LOF}$ from .14 to .31 (covers all engine and engine out operation)

- Windmilling Drag

  Occurs in the program in the form of a third order curve fit of DWM/δ vs. Mach number (M).

- Time to Climb from Liftoff to 35 ft.

  Occurs in the program in the form of a third order curve fit of T_{CLMB} vs. $\left(\frac{T}{W} - \frac{D}{L}\right)_{LOF}$

- Gear Up Height

  Occurs in the program in the form of a third order curve fit of HT_{GU} vs. $\left(\frac{T}{W} - \frac{D}{L}\right)_{LOF}$

User Supplied Input Data

The input variables that the program needs in order to calculate various take-off and climbout trajectories, plus their normal operational limits, include:

- **(OS) Overspeed Factor**

  A multiplier on V_R, V_{LOF}, and V_2

OS	Remarks
1.0	Zero Overspeed
1.025	2½% Overspeed
1.05	5% Overspeed

- **(V_{w_i}) Airport Wind Velocity**

  V_{w_i} is the airport reported wind at 50 feet above the runway

- (T_{amb_i}) Airport Ambient Temperatures in Degrees F

- **(TFAC) Thrust Factor**

  TFAC = 1 This factor can be used to run degraded engine data for -22B-10% (TFAC - 0.9)

- **(a_1) Acceleration**

  Desired acceleration along the flight path (KTAS/SEC) above gear up.

a_1	Remarks
0	Zero Acceleration
1	1 KT/SEC
3	3 KT/SEC

- **(HT_{CB}) Cutback Height**

  Predetermined pressure altitude (ft) where cutback will occur

- **(CB_{FAC}) Cutback Factor**

  Predetermined percent of takeoff power

CB_{FAC}	Remarks
1.0	Full Takeoff Power
0.9	90% of Takeoff Power
0.5	50% of Takeoff Power

- **(FLAP) Takeoff Flap Settings**

Takeoff (-22C) 4, 10, 18, 22°
(-22B) 4, 10, 18, 22, 27°

Approach 33, 45°

- **(ϕ) Runway Slope**

Slope of the runway in percent (decimal)

Slope	Remarks
-.02	2% Down Slope
0	No Slope
+.02	2% Up Slope

- **(H_p) Airport Pressure Altitude**

Airport Pressure Altitude (ft)

H_p	Remarks
0	Sea Level
2000	2000 Pressure Alt. (ft)
6000	6000 Pressure Alt. (ft)

6000 feet is the upper limit for the program. Higher altitudes can be run, but extrapolation of propulsion data would result.

And finally,

- **(W) Takeoff Gross Weight**

Takeoff gross weight is the weight at brake release. The normal range of takeoff weights for use with the program are:

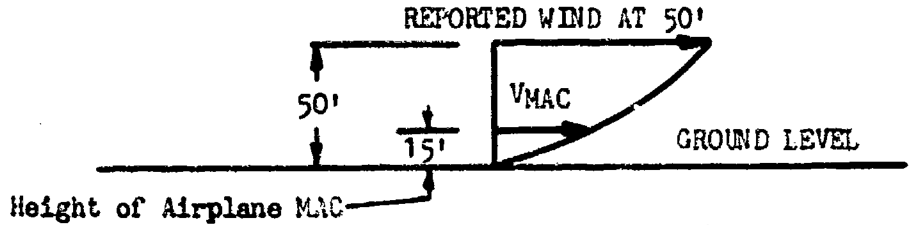
(Lower)	280,000 lb.
(Upper)	430,000 lb.

The use of winds in the program needs further explanation. As per FAR regulations, wind used in takeoff calculations must be 50% of the reported headwind and 150% of the reported tailwind. Therefore, the actual wind velocity used in all distance calculations must be factored in the following manner:

Headwind $0.5 \times V_{w_i}$

Tailwind $1.5 \times V_{w_i}$

In addition, the reported wind at a height of 50 feet must be corrected to the height of the airplane MAC for calculations from brake release (BR) to rotation (ROT). The wind shear correction is described below.



$$\text{Wind Shear Correction} = \left(\frac{V_{MAC}}{V_w}\right)^{\frac{1}{7}}$$

$$= \left(\frac{15}{50}\right)^{\frac{1}{7}}$$

$$= .842 \qquad \text{NON-DIM.} \quad (2.2\text{-}1)$$

Therefore, for all distance calculations up to and including rotation the following wind factors apply.

V_{w_i} = Reported Wind at 50 feet

V_w = Adjusted Wind Velocity

$$V_w = (.842)\,(1.5)\,V_{w_i} \qquad \text{KTAS} \qquad (2.2\text{-}2)$$

$$\underline{V_w = 1.263\,V_{w_i} \text{ (Tailwind)}}$$

and

$$V_w = (.842)\,(.5)\,V_{w_i}$$

$$\underline{V_w = .421\,V_{w_i} \text{ (Headwind)}}$$

All engine and engine out speed at the 35 foot point, called $V_2(3)$ and $V_2(2)$, are required. Such information is provided by flight test and is presented in Figure 2.2-9. The variation of V_2/V_S with thrust to weight et liftoff is linear.

2.2.1.2 Brake Release to Rotation

The pertinent equations and data used in calculating ground roll performance from brake release to rotation are presented here. Figure 2.2-4 shows a general schematic of a nominal (normal) 3 engine climb to altitude, including, of course, the ground roll as defined here. Values of normalized rotation speed (V_R/V_S) as a function of thrust to weight at liftoff have been determined from measured flight test data and are shown in Figure 2.2-9. These data apply at all flap settings. A first degree or linear curve fit of this data yields an expression of the form

$$\frac{V_R}{V_S} = 1.282-0.45 \left.\frac{T}{W}\right)_{lof} \qquad \text{NON-DIM.} \qquad (2.2\text{-}3)$$

Stall speed is determined from

$$V_S = \sqrt{\frac{295.37\ W}{C_{L_S}\ S}} \qquad \text{KEAS} \qquad (2.2\text{-}4)$$

The incremental ground distance covered from BR to ROT is

$$S_a = \frac{.04427\ (V_R^{\ 2}-V_w^{\ 2})}{T/W - \mu_r - \phi - \dfrac{KK}{C_{L_{rms}}}} \qquad \text{FT.} \qquad (2.2\text{-}5)$$

Equation 2.2-5 is derived from the application of an elementary force balance wherein runway slope and winds are accounted for in addition to the customary aerodynamic and ground roll forces. Section 9.3 of Reference 17 provides a detailed development of this and other distance equations. It should be noted that all velocities used in this and subsequent distance equations are equivalent airspeeds. The equivalence between true and equivalent airspeed is the standard relationship:

$$V_T = \frac{V_E}{\sqrt{\sigma}} \qquad \text{KEAS} \qquad (2.2\text{-}6)$$

Geometric altitude (HT_G) at the end of the segment (rotation) is calculated in a manner which reflects runway slope, and indirectly, winds. Thus,

$$HT_G = H_p \times T_{RAT} + \phi \times S_a \quad \text{FT.} \qquad (2.2\text{-}7)$$

Incremental time (Δt) from BR to ROT is calculated from

$$\Delta t = \frac{S_a}{\left[\frac{V_R}{2\sqrt{\sigma}} - V_w\right] 1.6878} \quad \text{SEC.} \qquad (2.2\text{-}8)$$

Equation 2.2-8 is essentially the ratio of distance covered to average velocity, with due regard for wind and units.

At segment end, rotation, an interpolation is made for $N_1/\sqrt{\theta}$ using appropriate calculated values of EPR, Mach number, and pressure altitude. These parameters, plus downrange distance, are passed to the footprint routine for use in calculating noise along the flight path.

2.2.1.3 Rotation to Liftoff

The performance from rotation to liftoff is described in the same manner as for the previous segment. The liftoff speed is obtained from Figure 2.2-9 An acceleration from V_R to V_{LOF} is made. The incremental distance covered is .

$$S_r = \frac{.04427 \left[(V_{\ell of} - V_w)^2 - (V_R - V_w)^2\right]}{T/W - \mu_r - \phi - \dfrac{KK}{C_{L_{rms}}}} \quad \text{FT.} \qquad (2.2\text{-}9)$$

Equation (2.2-9) is the generalized ground roll equation which is derived using simple force balance mathematics. A detailed derivation is given in Reference 17, Section 9.3 (Takeoff Distances).

Geometric altitude (HT_G) at the segment end point (liftoff) is given by the expression

$$HT_G = H_p x T_{RAT} + \phi \times S_{TOT\,(BR\ to\ ROT)} \quad \text{FT.} \qquad (2.2\text{-}10)$$

where runway slope is accounted for by the $\phi \times S_{TOT}$ term.

Incremental time (Δt) from rotation to liftoff is calculated from

$$\Delta t = \frac{S_r}{\left[\dfrac{(V_{\ell of} + V_R)}{2\sqrt{\sigma}} - V_w\right] 1.6878} \quad \text{SEC.} \qquad (2.2\text{-}11)$$

which is essentially a distance divided by an average velocity with due regard for wind and units.

At segment end point (liftoff) an interpolation is made for $N_1/\sqrt{\theta}$ using appropriate values of EPR, Mach number, and pressure altitude. These parameters, plus downrange distance, are passed to the footprint routine for use in calculating noise along the flight path.

2.2.1.4 Liftoff to 35 Feet

This segment begins at liftoff and covers the distance traveled during transition from ground run to a point where the aircraft has climbed to a height of 35 feet (AGL). The time for this transition (T_{clmb}) is described as a function of gradient at liftoff (γ_{lof}) as shown in Figure 2.2-7. This curve results from measured flight test data and is supplied by the Lockheed Flight Test organization. A third degree curve fit of this data yields a time equation of the form

$$T_{clmb} = 8.77 - 49.5\,\gamma_{lof} + 107.8\,\gamma_{lof}^{2} + 54.4\,\gamma_{lof}^{3} \quad \text{SEC.} \qquad (2.2\text{-}12)$$

Ground distance covered during the climb (S_c) is derived from the elementary equation

$$S = \bar{V}\,\Delta t \quad \text{FT.} \qquad (2.2\text{-}13)$$

Therefore,

$$S_c = \left[\left(\frac{V_2(3) + V_{lof}}{2\sqrt{\sigma}}\right) - V_w\right] 1.6878\,T_{clmb} \quad \text{FT.} \qquad (2.2\text{-}14)$$

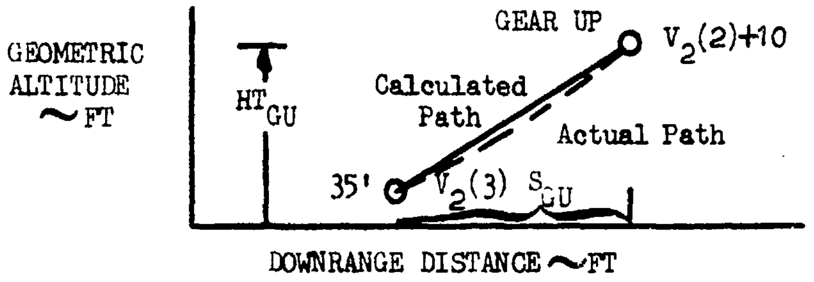
The incremental altitude is set to 35 feet. Geometric altitude (HT_G) at the end of the segment is calculated in a manner which reflects runway slope. Accordingly,

$$HT_G = H_p \times T_{RAT} + \phi\left(S_a + S_r + S_c\right) + 35 \quad \text{FT.} \qquad (2.2\text{-}15)$$

At segment end, the nominal 35 foot point, an interpolation is made for $N_1/\sqrt{\theta}$ using appropriate calculated values of EPR, Mach number, and pressure altitude. These parameters, plus downrange distance, are passed to the footprint routine for use in calculating noise along the flight path.

2.2.1.5 Climb from 35 Feet to Gear Up

This segment describes the airplane flight path from a point where the airplane is 35 feet above ground level (AGL) to a point where the landing gear is fully retracted. It should be noted that the calculated path is linear, whereas the actual path has curvature.



Along the flight path the airplane is accelerated from the velocity at the 35 foot point (V_2 (3 engine)) to a speed at gear up equivalent to the engine out speed (V_2 (2 engine)) plus 10 knots.

Incremental distance to gear up is

$$S_{GU} = 1.6878\ \Delta t_{35' \text{ to } GU}\left[\frac{(V_2(2)+10) + V_2(3)}{2} - V_w\right] \quad \text{FT.} \qquad (2.2\text{-}16)$$

Total time from liftoff to gear retraction is fixed at 17.5 sec (14.5 + 3) (Reference 10). Time from LOF to 35 feet is a function of $\left(\frac{T}{W} - \frac{D}{L}\right)_{LOF}$ as shown in Figure 2.2-7. The data of Figure 2.2-7 evolves from measured flight test data and is provided by the Lockheed Flight Test organization. Delta time from 35 feet to gear up is given by the equation

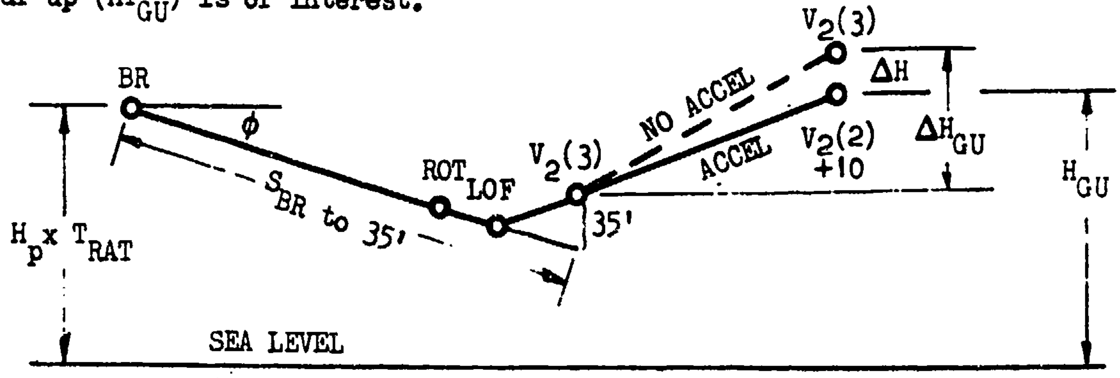
$$\Delta t_{35' \text{ to } GU} = 17.5 - T_{clmb_{LOF \text{ to } 35'}} \quad \text{SEC.} \qquad (2.2\text{-}17)$$

Therefore,

$$S_{GU} = 1.6878\left[\frac{(V_2(2) + 10) + (V_2(3))}{2} - V_w\right]\left(17.5 - T_{clmb_{LOF \text{ to } 35'}}\right) \quad \text{FT.} \qquad (2.2\text{-}18)$$

The effect of wind on ground distance is accounted for in equation 2.2-18 by use of a modified wind velocity (V_w ~ KTAS). For mathematical simulation, the measured (fixed) head or tailwind (which is input) is decreased (headwind) or increased (tailwind) by 50 % to yield an appropriate valve of modified wind velocity. This particular simulation is valid for flight above the 35 foot point and is further justified in Section 2.2.1.1.

Since the program accounts for runway slope, the determination of altitude at gear up (HT_{GU}) is of interest.



$$HT_{GU} = H_p \times T_{RAT} + \phi \times S_{BR\ to\ 35'} + 35 + \Delta H_{GU} - \Delta H \qquad \text{FT.} \qquad (2.2\text{-}19)$$

The height at gear up (ΔH_{GU}) as shown in Figure 2.2-8 has been described by Lockheed Flight Test as a function of gradient at liftoff. This height does not account for the increase in airspeed when accelerating from $V_2(3)$ to $V_2(2)$ + 10 KEAS. Accordingly, an incremental correction altitude, called ΔH, is introduced.

The terms ΔH_{GU} and ΔH of equation 2.2-19 are calculated as follows:

$\Delta H_{GU} = (\Delta H_{GU})_{NO\ ACCEL}$ = Unaccelerated climb to gear up is a function of $\left(\frac{T}{W} - \frac{D}{L}\right)_{LOF}$. (See Figure 2.2-8).

ΔH = The incremental altitude difference between an unaccelerated climb from liftoff to gear up and a climb that accounts for an acceleration from $V_2(3)$, the 3 engine speed at 35 feet, to $V_2(2)$ + 10, which is the 2 engine speed at 35 feet plus 10 knots.

$$(\Delta H_{GU})_{ACCEL} = (\Delta H_{GU})_{NO\ ACCEL} - \Delta H \qquad \text{FT.} \qquad (2.2\text{-}20)$$

$$\Delta H = (\Delta H_{GU})_{ACCEL} - (\Delta H_{GU})_{NO\ ACCEL} \qquad \text{FT.} \qquad (2.2\text{-}21)$$

Since $\frac{dh}{dt}$ = tapeline rate of climb (ft/sec)

and
$$\left.\frac{dh}{dt}\right)_{ACCEL} = 1.6878\, V_T \left[(T/W - D/L) - \frac{1.6878}{g} \frac{dV_T}{dt} \right] \qquad \text{FT./SEC.} \qquad (2.2\text{-}22)$$

so
$$\left.\frac{dh}{dt}\right)_{ACCEL} = \left.\frac{dh}{dt}\right)_{NO\ ACCEL} - \frac{(1.6878)^2}{g} V_T \frac{dV_T}{dt} \qquad \text{FT./SEC.} \qquad (2.2\text{-}23)$$

Substituting and approximating,

$$\left.\frac{\Delta H_{GU}}{\Delta t}\right)_{ACCEL} = \left.\frac{\Delta H_{GU}}{\Delta t}\right)_{NO\ ACCEL} - \frac{(1.6878)^2}{g} V_T \frac{\Delta V_T}{\Delta t} \qquad \text{FT./SEC.} \qquad (2.2\text{-}24)$$

or
$$\Delta H_{GU}\Big)_{ACCEL} = \Delta H_{GU}\Big)_{NO\ ACCEL} - \frac{(1.6878)^2}{g} V_T \Delta V_T \qquad \text{FT.} \qquad (2.2\text{-}25)$$

so
$$\Delta H_{GU}\Big)_{ACCEL} = \Delta H_{GU}\Big)_{NO\ ACCEL} - \frac{(1.6878)^2}{g} \left[\frac{(V_2(2) + 10) + V_2(3)}{2} \right] \times \left[(V_2(2) + 10) - V_2(3) \right] \qquad \text{FT.} \qquad (2.2\text{-}26)$$

Finally,
$$\Delta H_{GU}\Big)_{ACCEL} = \Delta H_{GU}\Big)_{NO\ ACCEL} - .04427 \left[(V_2(2) + 10)^2 - V_2(3)^2 \right] \qquad \text{FT.} \qquad (2.2\text{-}27)$$

where
$$\Delta H = .04427 \left[(V_2(2) + 10)^2 - V_2(3)^2 \right] \qquad \text{FT.} \qquad (2.2\text{-}28)$$

The program has an iterative routine which will determine ΔH by making an initial guess and then calculating a value using equation 2.2-28 until such time as the guess and the calculation are sufficiently close.

At gear up an interpolation is made for $N_1/\sqrt{\theta}$ using appropriately calculated values of EPR, Mach number, and pressure altitude. These parameters, plus downrange distance, are passed to the footprint routine for use in calculating noise along the flight path.

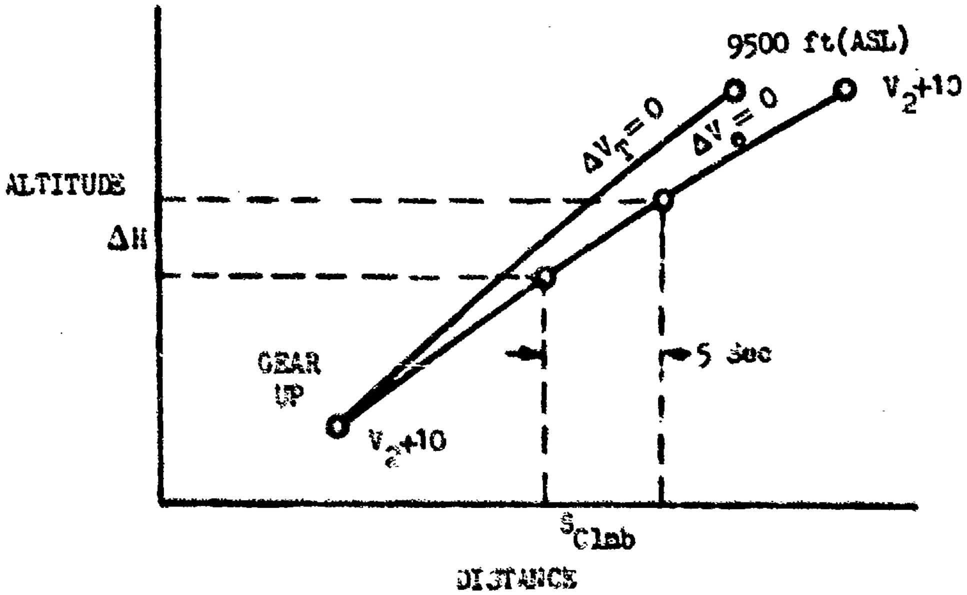
2.2.1.6 3 Engine Climb After Gear Up

The 3 climb options after gear up include: a constant velocity climb ($V_2(2) + 10$) with flaps extended (Figure 2.2-4); an accelerated climb after gear up with normal flap cleanup procedures followed (Figure 2.2-5); and a constant velocity climb with the option of a thrust cut back after gear up (Figure 2.2-6).

2.2.1.6.1 Constant $V_2(2) + 10$ KEAS Climb After Gear Up

For noise analysis a constant equivalent airspeed (EAS) climb is considered the normal climb option after gear up since it results in the highest altitude at any given downrange point. Climb is established at a constant EAS ($V_2(2) + 10$ KEAS) and continued, at the flap setting for takeoff, to about 9500 feet above sea level (ASL).

To establish the method for calculating incremental distance and height after gear up, time increment is fixed at 5 seconds and a graphical type integration is established. The incremental heights over 5 second intervals are summed until the pressure altitude exceeds 9500 feet (ASL).



For climb at a constant equivalent airspeed, true airspeed increases because of the altitude dependence of density ratio (σ) where by definition

$$V_e = V_T \times \sqrt{\sigma} \quad \text{KEAS}$$

This means, of course, that acceleration as used in the program is not equal to zero for a constant EAS climb. The increase in true airspeed is accounted for in the Rate-of-Climb (R/C) equation in the following manner:

Since

$$\mathrm{GRAD}_{\mathrm{NO\ ACC}} = \frac{T}{W} - \frac{D}{L} \qquad \text{NON-DIM.} \qquad (2.2\text{-}29)$$

$$(\Delta V_T = 0)\ R/C_{\mathrm{NO\ ACC}} = 1.6878\,\frac{(T - D)\,V_T}{W} \qquad \text{FT./SEC.} \qquad (2.2\text{-}30)$$

$$(\Delta V_T \neq 0)\ R/C_{\mathrm{ACC}} = 1.6878\,\frac{(T - D)\,V_T}{W\,(1 + \frac{V}{g}\frac{dV}{dh})} \qquad \text{FT./SEC.} \qquad (2.2\text{-}31)$$

For a constant equivalent climb

$$1 + \frac{V}{g}\frac{dV}{dh} = 1 + .567\,M^2$$

Therefore

$$R/C_{\substack{\mathrm{EAS}\\ \mathrm{CLIMB}}} = 1.6878\,\frac{(T - D)\,V_T}{W\,(1 + .567\,M^2)} \qquad \text{FT./SEC.} \qquad (2.2\text{-}32)$$

Or

$$R/C_{\substack{\mathrm{EAS}\\ \mathrm{CLIMB}}} = \frac{1.6878\,V_T}{(1 + .567\,M^2)}\left(\frac{T - D}{W}\right) \qquad \text{FT./SEC.} \qquad (2.2\text{-}33)$$

For "1" g flight L = W

Then

$$R/C_{\substack{\mathrm{EAS}\\ \mathrm{CLIMB}}} = \frac{1.6878\,V_T}{(1 + .567\,M^2)}\left(\frac{T}{W} - \frac{D}{L}\right) \qquad \text{FT./SEC.} \qquad (2.2\text{-}34)$$

$$R/C_{\substack{\mathrm{EAS}\\ \mathrm{CLIMB}}} = \frac{1.6878\,V_T\,(\mathrm{GRAD})_{\mathrm{NO\ ACC}}}{(1 + .567\,M^2)} \qquad \text{FT./SEC.} \qquad (2.2\text{-}35)$$

Equation 2.2-35 accounts for the increase in true airspeed during a constant equivalent airspeed climb. The equation does not account for acceleration along the flight path due to a change in flight path angle. A discussion of the equations for acceleration along the flight path appears in Section 2.2.1.6.2 herein.

Using Equation 2.2-35, the incremental height is a function of the instantaneous rate of climb

$$\Delta H = 5\ (R/C)_{\substack{EAS \\ CLIMB}} \quad FT. \tag{2.2-36}$$

The incremental ground distance travelled during each 5 second interval is a function of the average velocity

$$S_{Climb} = 1.6878\ T_{Climb}\ \bar{V}_T \quad FT. \tag{2.2-37}$$

Since

$$T_{Climb} = 5\ SEC. \tag{2.2-38}$$

Then

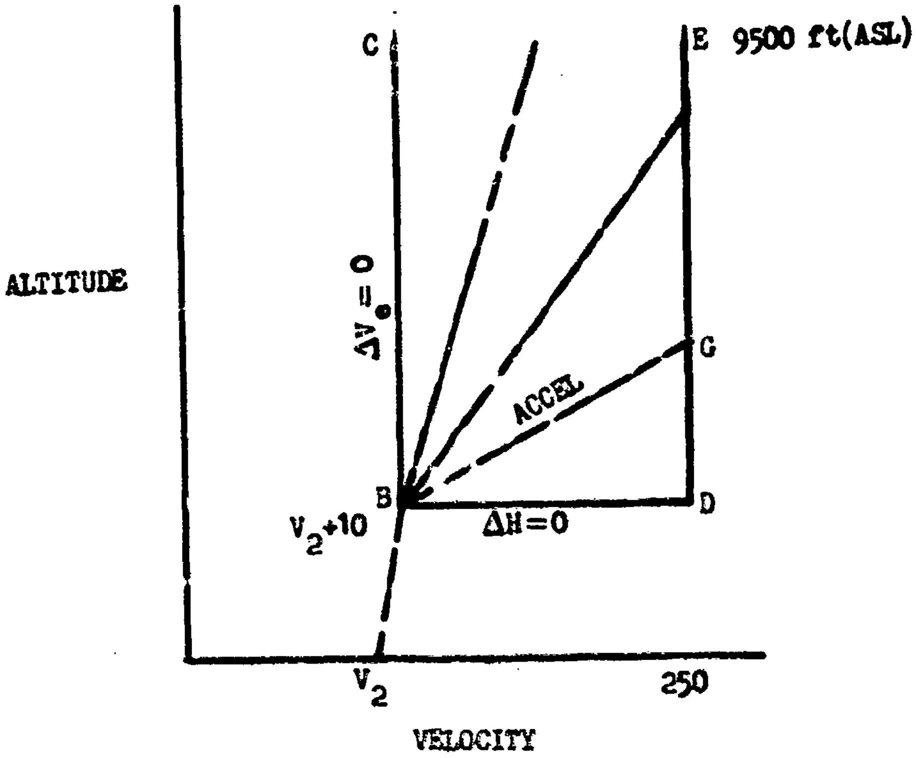
$$S_{Climb} = 8.439\ \bar{V}_T \quad FT. \tag{2.2-39}$$

Equations 2.2-24, 2.2-35, 2.2-36, and 2.2-39 are the basic equations used in each 5 second integration interval to calculate EAS climb performance.

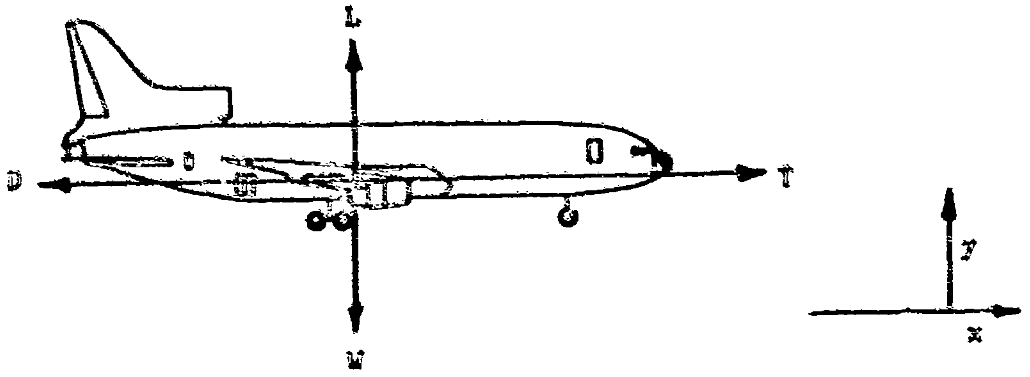
At each calculated end point in the climb an interpolation is made for N_1 using appropriately calculated values of EPR, Mach number, and pressure altitude. These parameters, plus downrange distance, are passed to the footprint routine for use in calculating noise along the flight path.

2.2.1.6.2 Accelerated Climb After Gear Up

The accelerated climb path option starts at gear up, and continues until either a 9500 foot pressure altitude is reached or airspeed reaches 250 KEAS. If 250 KEAS is reached before 9500 feet (ASL), the climb is continued at that speed to 9500 feet (ASL). The sketch at the top of the following page illustrates the boundaries for accelerating to altitude.



Path BC is a constant V_e (EAS) climb from gear up. Path BDE is a level flight acceleration to 250 KEAS followed by a constant 250 KEAS climb. Path BGE represents an intermediate climb where total thrust available is divided between climb and acceleration. The basic logic for the acceleration option assumes that the total thrust after gear up can be divided between climb and acceleration. This is accomplished in the following manner.



A simple force balance yields, for level flight,

$$\Sigma\ F_x = Ma = \frac{W}{g}\,a \qquad (2.2\text{-}40)$$

$$T - D = \frac{W}{g}\,a \qquad (2.2\text{-}41)$$

$$\frac{a}{g} = \frac{T - D}{W} \qquad (2.2\text{-}42)$$

For "1" g flight L = W

So

$$\frac{a}{g} = \left(\frac{T}{W} - \frac{D}{L}\right)_{ACC.} \qquad (2.2\text{-}43)$$

An equation similar to 2.2-43 has already been defined as a gradient term (see Equation 2.2-29, a zero acceleration climb gradient).

Let

$\frac{a}{g}$ = acceleration gradient for level flight (zero climb)

Now that a (zero climb) acceleration gradient and (zero acceleration) climb gradient are defined, the total gradient available is assumed by definition to be the sum of the two gradients

$$\left(\frac{T}{W} - \frac{D}{L}\right)_{AVAIL.} = \left(\frac{T}{W} - \frac{D}{L}\right)_{CLIMB} + \left(\frac{T}{W} - \frac{D}{L}\right)_{ACC.} \qquad (2.2\text{-}44)$$

$$\left(\frac{T}{W} - \frac{D}{L}\right)_{AVAIL.} = \left(\frac{T}{W} - \frac{D}{L}\right)_{CLIMB} + \frac{a}{g} \qquad (2.2\text{-}45)$$

Then

$$\left(\frac{T}{W} - \frac{D}{L}\right)_{CLIMB} = \left(\frac{T}{W} - \frac{D}{L}\right)_{AVAIL.} - \frac{a}{g} \qquad (2.2\text{-}46)$$

Since

$$R/C = \frac{1.6878\ (T - D)\ V_T}{W}$$

$$= 1.6878\ V_T \left(\frac{T}{W} - \frac{D}{L}\right)_{CLMB} \quad \text{FT./SEC.} \qquad (2.2\text{-}47)$$

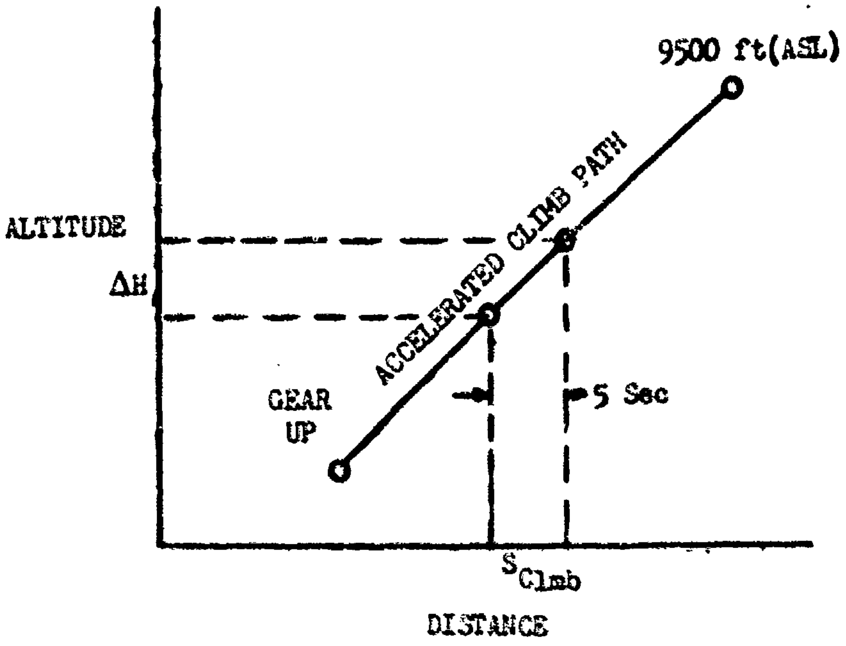
Or

$$R/C_{ACC} = 1.6878\ V_T \left[\left(\frac{T}{W} - \frac{D}{L}\right)_{AVAIL.} - \frac{a}{g}\right] \quad \text{FT./SEC.} \qquad (2.2\text{-}48)$$

So

$$R/C_{ACC} = 1.6878\ V_T\ (GRAD_{AVAIL} - \frac{1.6878\ a}{32.2})\quad FT./SEC.\qquad (2.2\text{-}49)$$

where the input acceleration, a_i, is in KTAS/SEC.



Incremental height and ground distance covered during each 5 second integration interval are

$$\Delta H = 5 \times R/C_{ACC}\qquad FT.\qquad (2.2\text{-}50)$$

V_T = the average velocity over each 5 second interval

$$S_{Climb} = 1.6878\ T_{Climb}\ \overline{V}_T\qquad FT.\qquad (2.2\text{-}51)$$

Or

$$S_{Climb} = 8.439\ \overline{V}_T\qquad FT.\qquad (2.2\text{-}52)$$

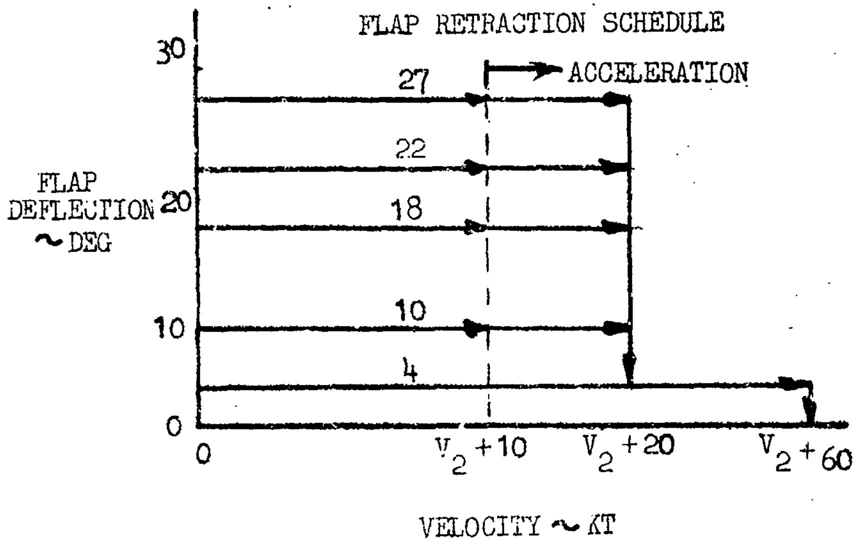
Equations 2.2-49 thru 2.2-51 are the basic equations used in each 5 second integration interval to calculate accelerated climb performance.

At each calculated end point in the climb an interpolation is made for N_1 using appropriately calculated values of EPR, Mach number, and pressure altitude. These parameters, plus downrange distance, are passed to the footprint routine for use in calculating noise along the flight path.

During the acceleration, successive incremental retraction of the flaps will occur at the following minimum flap retraction speeds:

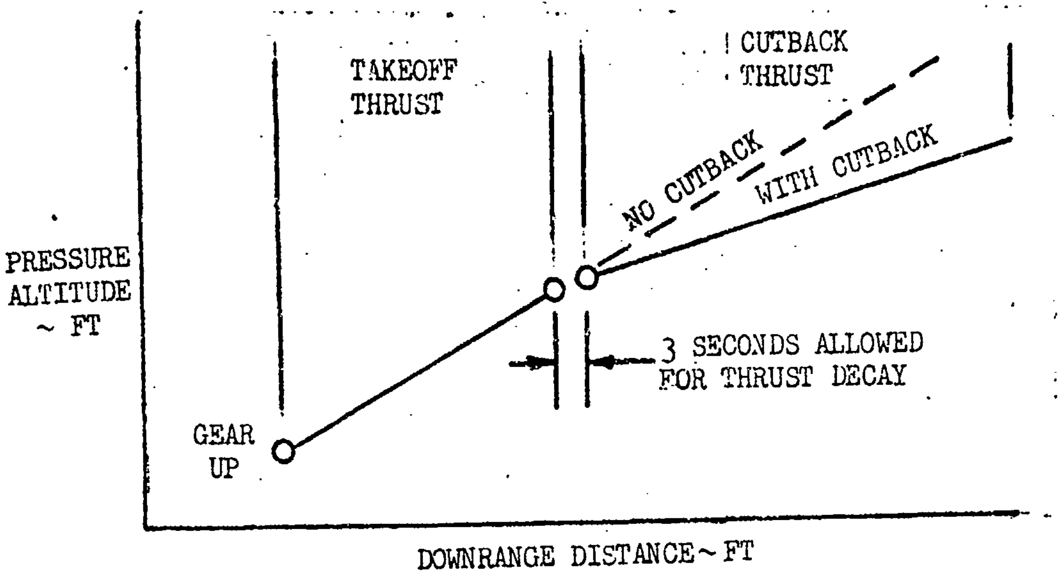
FLAP	MINIMUM FLAP RETRACTION SPEED
27	V_2 + 10
22	V_2 + 10
18	V_2 + 10
10	V_2 + 10
4	V_2 + 20
0	V_2 + 60 (CLEAN)

The stepwise retraction is instantaneous, although the acceleration will be continuous.


FLAP RETRACTION SCHEDULE

2.2.1.6.3 Thrust Cutback After Gear Up

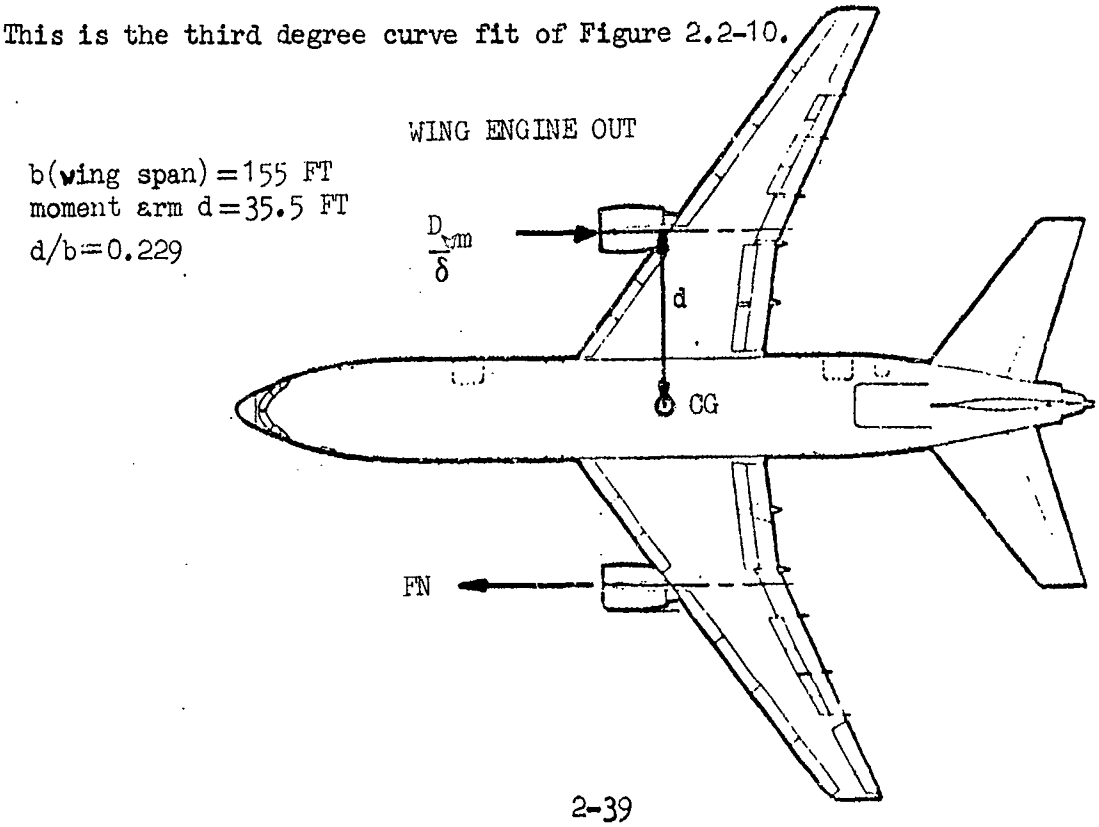
After gear up, any cutback thrust level may be chosen between full takeoff thrust and that corresponding to the thrust required (DRAG) for level flight with a wing engine inoperative (Figure 2.2-6). After gear up, the aircraft is climbed at constant equivalent airspeed, corresponding to V_2 + 10 KEAS, to the predetermined (input) cut back altitude. At this altitude, the throttles are set to an EPR (Engine Pressure Ratio) corresponding to a percent of maximum takeoff thrust and a new climb gradient established. The climb is continued at constant speed to about 9500 feet (ASL).



Thrust cutback can be initiated at any point after gear up by inputting a cutback altitude (HT_{CB}) and a percent of thrust available (CB_{FAC}). At HT_{CB}, the thrust required for level flight with a wing engine out is calculated using the following equations:

$$\text{(Windmilling Drag)}\ D_{wm}/\delta = .57 + 1038\ M + 8571\ M^2 + 3333\ M^3 \quad \text{LB} \qquad (2.2\text{-}53)$$

This is the third degree curve fit of Figure 2.2-10.



Flight Test (Reference 18) describes the out of trim moment coefficient as

$$C_N = .229 \left(F_N + \frac{D_{wm}}{\delta}\right) \qquad \text{NON-DIM.} \qquad (2.2\text{-}54)$$

and the engine out trim drag as

$$CD_{TRIM} = -.00013 + .0226\ C_N + 4.197\ C_N^{\ 2} \qquad (2.2\text{-}55)$$

(2nd degree fit of Figure 2.2-11).

With FN_{Eo} = thrust required with a wing engine inoperative

$$FN_{E_O} = (CD + CD_{TRIM})\ (QS) + \frac{D_{wm}}{\delta}\ (S) \qquad (2.2\text{-}56)$$

When CB_{FAC} is less than FN_{Eo}, CB_{FAC} is set equal to FN_{Eo}.

The integration interval here is altitude based. The basic equations used to calculate climb at each altitude increment include

$$R/C = \frac{1.6878\ (T - D)\ V_T}{W\ (1 + .567\ M^2)} \qquad \text{FT./SEC.} \qquad (2.2\text{-}57)$$

Where

$$T = T\ (CB_{FAC}) \qquad \text{LB.} \qquad (2.2\text{-}58)$$

$$V_T = (V_2 + 10)\ /\sqrt{\sigma} \qquad \text{FT./SEC.} \qquad (2.2\text{-}59)$$

$$T_{Climb} = 200/(R/C) \qquad \text{SEC.} \qquad (2.2\text{-}60)$$

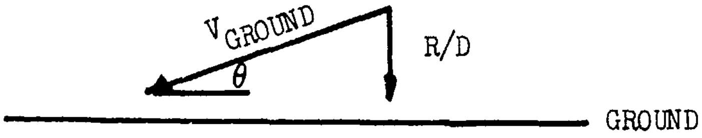
$$S_{Climb} = 1.6878\ V_T\ T_{Climb} \qquad \text{FT.} \qquad (2.2\text{-}61)$$

At each calculated end point in the climb an interpolation is made for $N_1/\sqrt{\theta}$ using appropriately calculated values of EPR, Mach number, and pressure altitude. These parameters, plus downrange distance, are passed to the footprint routine for use in calculating noise along the flight path.

2.2.2 Approach

This section describes in technical detail the equations that are used to calculate the basic engine thrust requirements that are the aerodynamic input necessary for the approach noise program. The basic aerodynamic data such as the airplane drag polars (C_L, C_D), Direct Lift Control drag increment, and stall characteristics of the airplane are all based on FAA approved results such as those published in the FAA Type Certification Report (Reference 18) and the Airplane FAA Approved Flight Manual (Reference 16). The effect of Direct Lift Control on drag and speed is assumed to be the same for the 33 degree flap as for the 42 degree flap configuration. The 33 degree flap drag polar is also based on FAA approved results.

The basic aerodynamic and performance equations used to generate engine thrust required for constant glide slope and constant calibrated airspeed are as follows:



For a constant calibrated airspeed approach with flaps and gear down, the following trigonometric relationship relative to ground reference can be shown:

$$-\sin\theta = -\text{grad} = \frac{R/D}{V_{GROUND}} \qquad \text{NON-DIM.} \qquad (2.2\text{-}62)$$

The rate of descent (R/D) can be derived from the total energy concept of the airplane in 1 'g' flight:

Total Energy = Potential Energy + Kinetic Energy

$$E = PE + KE \qquad \text{FT.-LB.}$$

Potential Energy = Weight x height = Wh

$$\text{Kinetic Energy} = \tfrac{1}{2}m\,V_T^{\,2} = \tfrac{1}{2}\frac{W}{g}\,V_T^{\,2} \times 2.856$$

where 2.856 = conversion factor, knots^2 to feet per second squared.

Total energy is expressed in foot-pounds.

Therefore, the equation:

$$E = Wh + 2.856 \frac{W}{g} \frac{V_T^2}{2} \qquad \text{FT.-LB.}$$

The rate of change of total energy per pound of airplane weight is:

$$\frac{d\,(E/W)}{dt} = \frac{dh}{dt} + 2.856 \frac{V_T}{g} \frac{dV_T}{dt} \qquad \text{FT./SEC.}$$

The acceleration term of $\frac{dV_T}{dt}$ may be written as

$$\frac{dV_T}{dt} = \frac{dV_T}{dh} \times \frac{dh}{dt}$$

and from substitution

$$\frac{d\,(E/W)}{dt} = \frac{dh}{dt} + .0886\, V_T \frac{dV_T}{dh} \frac{dh}{dt}$$

$$= \frac{dh}{dt}\left(1 + .0886\, V_T \frac{dV_T}{dh}\right) \qquad \text{FT./SEC.}$$

The total energy can change only as the result of the net increment between FN and drag vectors acting on the airplane and is expressed by the following:

Energy = Force x Distance = (FN-D) x Distance

The rate of change of total energy per pound of airplane weight is:

$$\frac{d\,(E/W)}{dt} = \frac{(FN-D)}{W} \times \frac{\text{Distance} \times 1.69}{dt} \qquad \text{FT./SEC.}$$

where $\frac{\text{Distance}}{dt}$ = true velocity

1.69 = conversion factor knots to feet per second

Setting this equal to the first equation of $\frac{d(E/W)}{dt}$,

$$1.69 \frac{(FN-D)}{W} V_T = \frac{dh}{dt}\left(1 + .0886\, V_T \frac{dV_T}{dh}\right)$$

and if $\frac{dh}{dt} = R/D$

then

$$R/D \text{ in feet per minute} = \frac{101.3\ (FN-D)\ V_T}{W\left(1 + .0886\ V_T \frac{d\ V_T}{dh}\right)} \qquad \text{FT./MIN.} \qquad (2.2\text{-}63)$$

Substituting this in the gradient equation,

$$-\ \text{grad} = \frac{(FN-D)\ V_T}{W\left(1 + .0886\ V_T \frac{d V_T}{dh}\right)\ V_{GROUND}} \qquad \text{NON-DIM.} \qquad (2.2\text{-}64)$$

For zero wind condition, $V_T = V_{GROUND}$

$$-\ \text{grad} = \frac{(FN-D)}{W\left(1 + .0886\ V_T \frac{d\ V_T}{dh}\right)} \qquad \text{NON-DIM.} \qquad (2.2\text{-}65)$$

In case of head or tail winds, $V_T \neq V_{GROUND}$

$$-\ \text{grad} = \frac{(FN-D)\ V_T}{W\left(1 + .0886\ V_T \frac{DV_t}{dh}\right)\ V_{GROUND}} \qquad \text{NON-DIM.} \qquad (2.2\text{-}66)$$

In determining the engine thrust required for a predetermined gradient, airplane weight and approach speed, it can be seen that the airplane drag must be calculated. The aircraft is assumed to be approaching at a constant calibrated airspeed which for altitudes near sea level is practically identical to equivalent airspeed. With the assumption that calibrated is equivalent airspeed, the drag of the airplane can be calculated as follows:

$$C_L = \frac{W}{q\ S} \qquad \text{NON-DIM.}$$

$$D = C_D\ q\ S \qquad \text{LB.}$$

where q = dynamic pressure = $\frac{V_e^2}{295}$ LB./FT.^{2}

S = wing area = 3456 sq. ft.

Since V_e is constant and independent of altitude, the airplane drag is independent of altitude. The kinetic energy term $\left(1 + .0886\ V_T \frac{dV_T}{dh}\right)$ is dependent on altitude, but by investigation, considering the range of altitude of this analysis, this factor will vary by less than 1 tenth of 1 percent. This factor is generally of the magnitude of 1.03.

By solving the gradient equation for FN, knowing the speed and configuration, the performance input for thrust required is determined for the footprint subroutine of the noise definition program.

A single segment or a two-segment approach may be calculated. Glide slope angle for a single-segment approach may be any value between 3 and 6 degrees, inclusive. If a second segment is added, its glide slope is fixed at 3 degrees. Input required to compute approach includes glide slopes, transition height, direct lift control flag, weight, plus thrust and drag in tabular form. Threshold altitude is fixed at 50 feet. Winds may be accounted for.

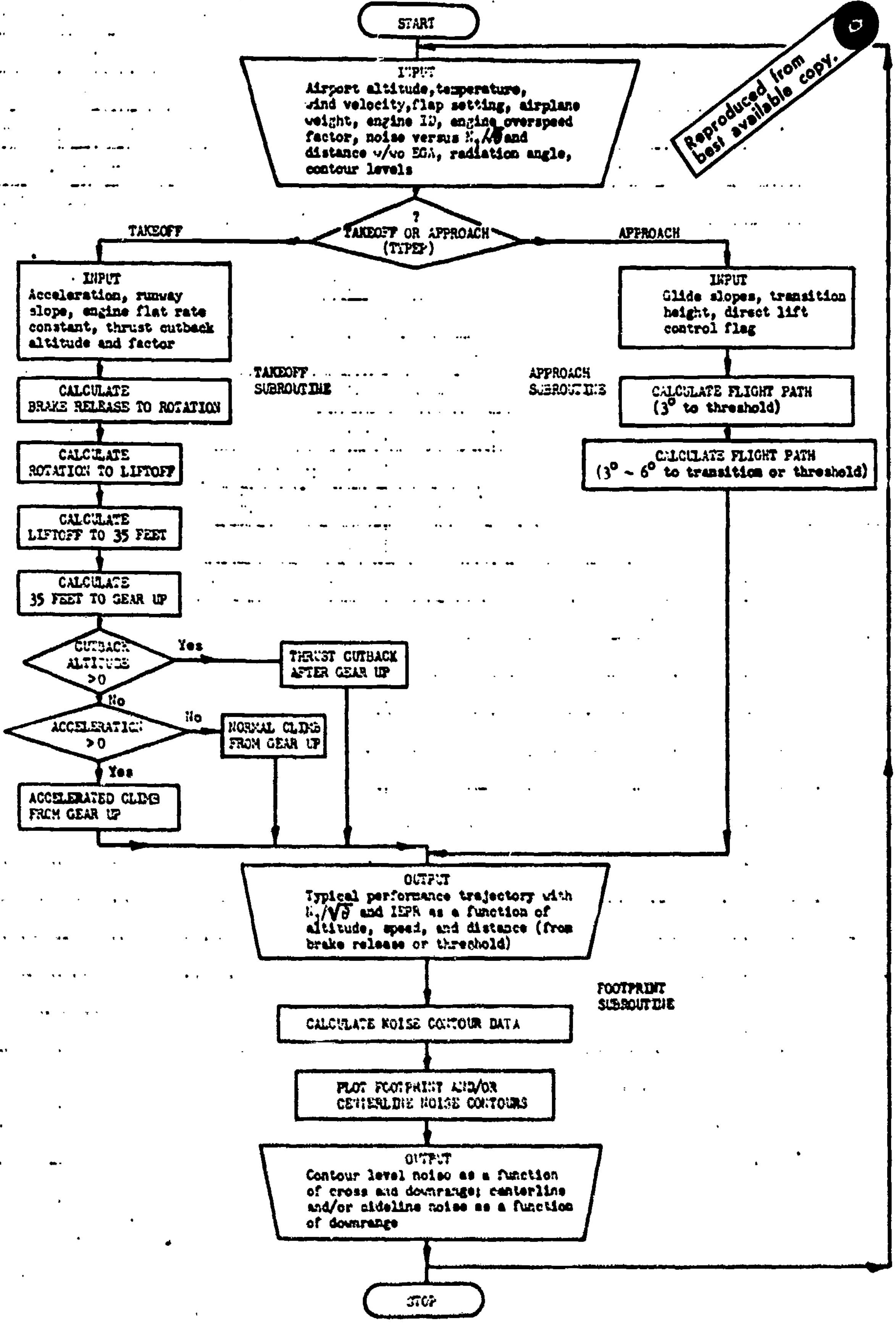


FIGURE 2.2-1 FLOW DIAGRAM OF THE NOISE DEFINITION PROGRAM

```
MAXIMUM TAKEOFF WEIGHT (430,000LB.). 10 DEG. FLAPS, TAKEOFF THRUST       08-10-74           PAGE   6

FLAP=10. DEG   TEMP= 77.0 DEG F  WIND=  0.0 KT  SLOPE=0.0    ACCT = 0.0  KT/SEC

                                                                                                          N1/
          PRESSURE GEOMETRIC   TOTAL    TOTAL                                                       IEPR SQRT(THETA) ROC      FLAP
 SEGMENT  ALTITUDE  ALTITUDE DISTANCE   TIME   THRUST  SPEED   MACH  ALPHA   PITCH   GRAD    TEMP           (PCT)   (FPM)    (DEG)
            (FT)      (FT)     (FT)    (SEC)    (LB)  (KTAS)         (DEG)   (DEG)         (DEG F)

HP=         0.  WEIGHT=   410000.  ICPR=    1.533  ISA+  10.0 DEG C.      RB.211-22B  BLEED OFF
BR-ROT       0.         0.     5519.   43.1  32076.  156.7  .233   ****    ****    ****    77.0   1.521    92.41    *****    10.
ROT-LOF      0.         0.     6579.   47.0  31643.  167.1  .248   ****    ****    ****    77.0   1.519    92.41    *****    10.
LOF-35FT    34.        35.     7810.   51.5  31333.  174.1  .259   ****    ****    ****    76.9   1.519    92.43    *****    10.
35F-GU     332.       344.    11739.   64.5  31008.  177.9  .265   ****    ****    ****    75.8   1.520    92.66    *****    10.
GU+XXXX    682.       705.    14751.   74.5  30767.  178.9  .266   11.6    18.3    .116    74.6   1.523    92.94    2095.    10.
GU+XXXX   1029.      1065.    17777.   84.5  30531.  179.8  .268   11.6    19.2    .114    73.3   1.526    93.21    2075.    10.
GU+XXXX   1372.      1423.    20[illegible].   94.5  30292.  180.7  .270   11.6    18.1    .112    72.1   1.529    93.48    2056.    10.
GU+XXXX   1713.      1773.    23877.  104.5  30054.  181.6  .271   11.6    18.0    .111    70.9   1.532    93.75    2036.    10.
GU+XXXX   2049.      2121.    26950.  114.5  29814.  182.5  .273   11.6    17.9    .109    69.7   1.534    94.01    2016.    10.
GU+XXXX   2393.      2467.    30039.  124.5  29565.  183.5  .275   11.6    17.8    .107    68.5   1.537    94.25    1994.    10.
GU+XXXX   2712.      2808.    33141.  134.5  29319.  184.4  .277   11.6    17.7    .106    67.3   1.539    94.49    1972.    10.
GU+XXXX   3038.      3146.    36263.  144.5  29077.  185.3  .278   11.6    17.6    .104    66.2   1.542    94.74    1950.    10.
GU+XXXX   3361.      3480.    39357.  154.5  28839.  186.2  .280   11.6    17.5    .102    65.0   1.544    94.99    1929.    10.
GU+XXXX   3675.      3813.    42547.  164.5  28604.  187.1  .281   11.6    17.4    .101    63.9   1.547    95.24    1907.    10.
GU+XXXX   3995.      4137.    45712.  174.5  28372.  188.0  .283   11.6    17.3    .099    62.8   1.549    95.50    1886.    10.
GU+XXXX   4316.      4460.    48924.  184.5  28142.  188.9  .285   11.6    17.2    .098    61.6   1.551    95.74    1865.    10.
GU+XXXX   4614.      4783.    52087.  194.5  27915.  189.7  .286   11.6    17.1    .096    60.5   1.554    95.99    1843.    10.
GU+XXXX   4919.      5096.    55297.  204.5  27692.  190.6  .288   11.6    17.1    .095    59.5   1.556    96.24    1822.    10.
GU+XXXX   5220.      5408.    58522.  214.5  27472.  191.5  .290   11.6    17.0    .093    58.4   1.558    96.49    1801.    10.
GU+XXXX   5518.      5717.    61761.  224.5  27256.  192.4  .291   11.6    16.9    .091    57.3   1.561    96.74    1781.    10.
GU+XXXX   5812.      6022.    65018.  234.5  27043.  193.3  .293   11.6    16.8    .090    56.3   1.563    96.99    1760.    10.
GU+XXXX   6103.      6324.    68235.  244.5  26831.  194.1  .295   11.6    16.7    .089    55.2   1.565    97.24    1739.    10.
GU+XXXX   6390.      6622.    71568.  254.5  26619.  195.0  .296   11.6    16.6    .087    54.2   1.567    97.49    1718.    10.
GU+XXXX   6674.      6916.    74866.  264.5  26412.  195.8  .298   11.6    16.6    .086    53.2   1.569    97.74    1698.    10.
GU+XXXX   6954.      7207.    78175.  274.5  26212.  196.7  .299   11.6    16.5    .084    52.2   1.571    97.99    1677.    10.
GU+XXXX   7231.      7495.    81505.  284.5  26016.  197.5  .301   11.6    16.4    .083    51.2   1.573    98.24    1658.    10.
GU+XXXX   7505.      7780.    84846.  294.5  25826.  198.4  .302   11.6    16.3    .082    50.2   1.576    98.48    1638.    10.
GU+XXXX   7776.      8061.    88231.  304.5  25641.  199.2  .304   11.6    16.2    .080    49.3   1.578    98.72    1620.    10.
GU+XXXX   8043.      8339.    91570.  314.5  25461.  200.0  .306   11.6    16.2    .079    48.3   1.580    98.97    1601.    10.
GU+XXXX   8303.      8614.    94954.  324.5  25286.  200.9  .307   11.6    16.1    .078    47.4   1.582    99.21    1583.    10.
GU+XXXX   8570.      8886.    98351.  334.5  25115.  201.7  .309   11.6    16.0    .077    46.5   1.584    99.45    1566.    10.
GU+XXXX   8828.      9155.   101762.  344.5  24949.  202.5  .310   11.6    16.0    .076    45.5   1.586    99.70    1549.    10.
GU+XXXX   9084.      9421.   105187.  354.5  24788.  203.3  .312   11.6    15.9    .074    44.6   1.589    99.95    1532.    10.
GU+XXXX   9338.      9685.   108626.  364.5  24631.  204.1  .313   11.6    15.8    .073    43.7   1.591   100.19    1516.    10.
GU+XXXX   9588.      9945.   112070.  374.5  24478.  205.0  .315   11.6    15.8    .072    42.8   1.593   100.44    1500.    10.
ACC = 0.0  KT/SEC    CBFAC USED = 0.0
```

FIGURE 2.2-2 TYPICAL TAKEOFF TRAJECTORY (CONSTANT EAS CLIMB AFTER GEAR UP)

```
                                                                           08-10-74          PAGE  14
MAXIMUM LANDING WEIGHT (358,000LB.), 42DEG. FLAPS, OLC, 3DEG GLIDE SLOPE

                                                                                            N1/
  H(FT)  PRESSURE  GEOMETRIC    TOTAL                                                EPR SQRT(THETA)  FLAP
         ALTITUDE   ALTITUDE  DISTANCE   THRUST    SPEED   MACH    TEMP                   (PCT)      (DEG)
           (FT)       (FT)      (FT)      (LB)     (KTAS)        (DEG F)
    40.       47.        50.        0.   12292.    152.3   .226    76.8          1.203    66.27       42.
   370.      358.       373.     6010.   12292.    153.0   .228    75.7          1.205    66.61       42.
  1417.     1395.      1457.    26000.   12292.    155.3   .232    72.1          1.213    67.69       42.
  2484.     2380.      2474.    46000.   12292.    157.7   .236    68.5          1.222    68.73       42.
  3515.     3364.      3515.    66013.   12292.    160.1   .241    64.9          1.231    69.78       42.
```

FIGURE 2.2-3 TYPICAL APPROACH TRAJECTORY (SINGLE SEGMENT ~ 3° GLIDE SLOPE

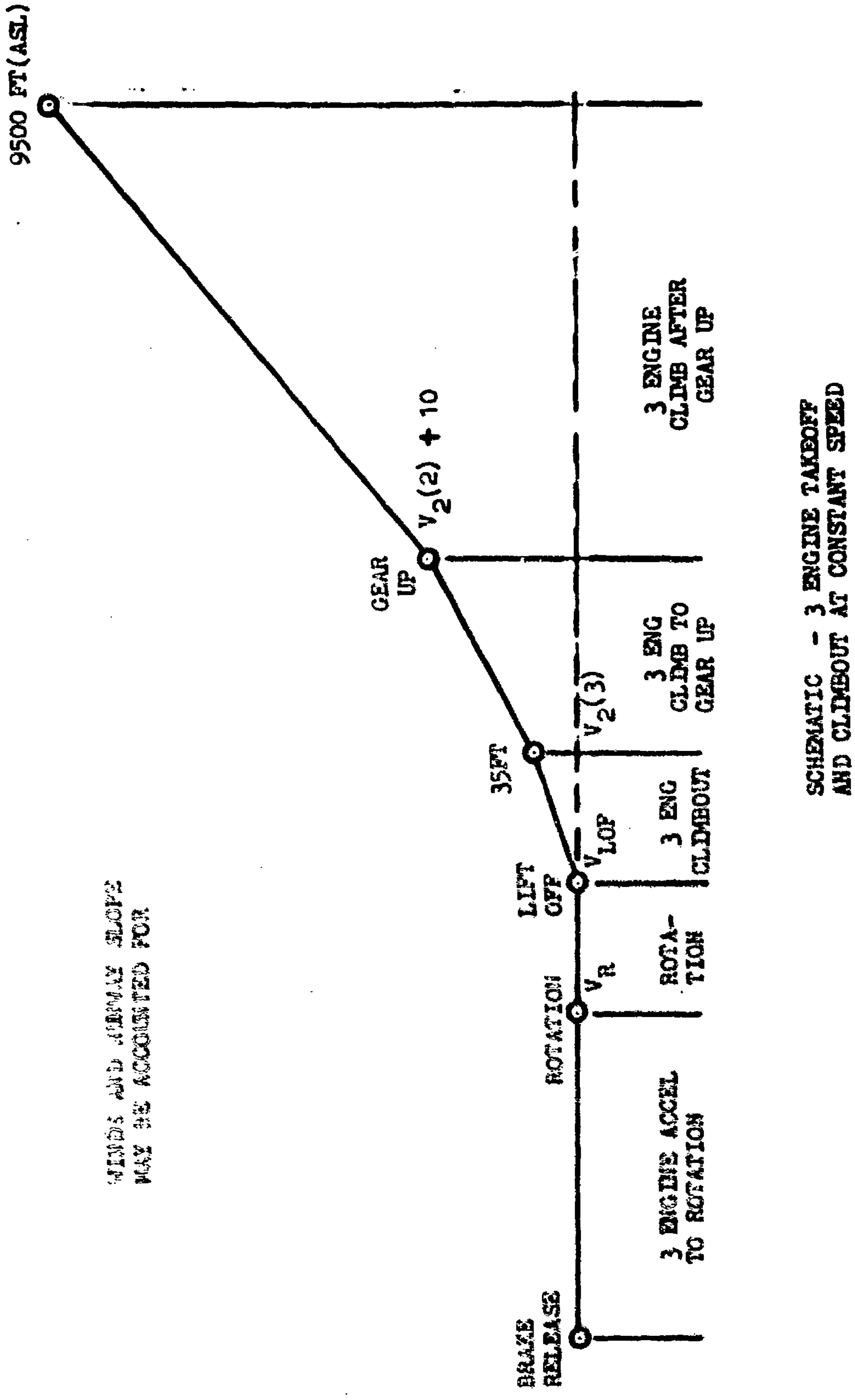
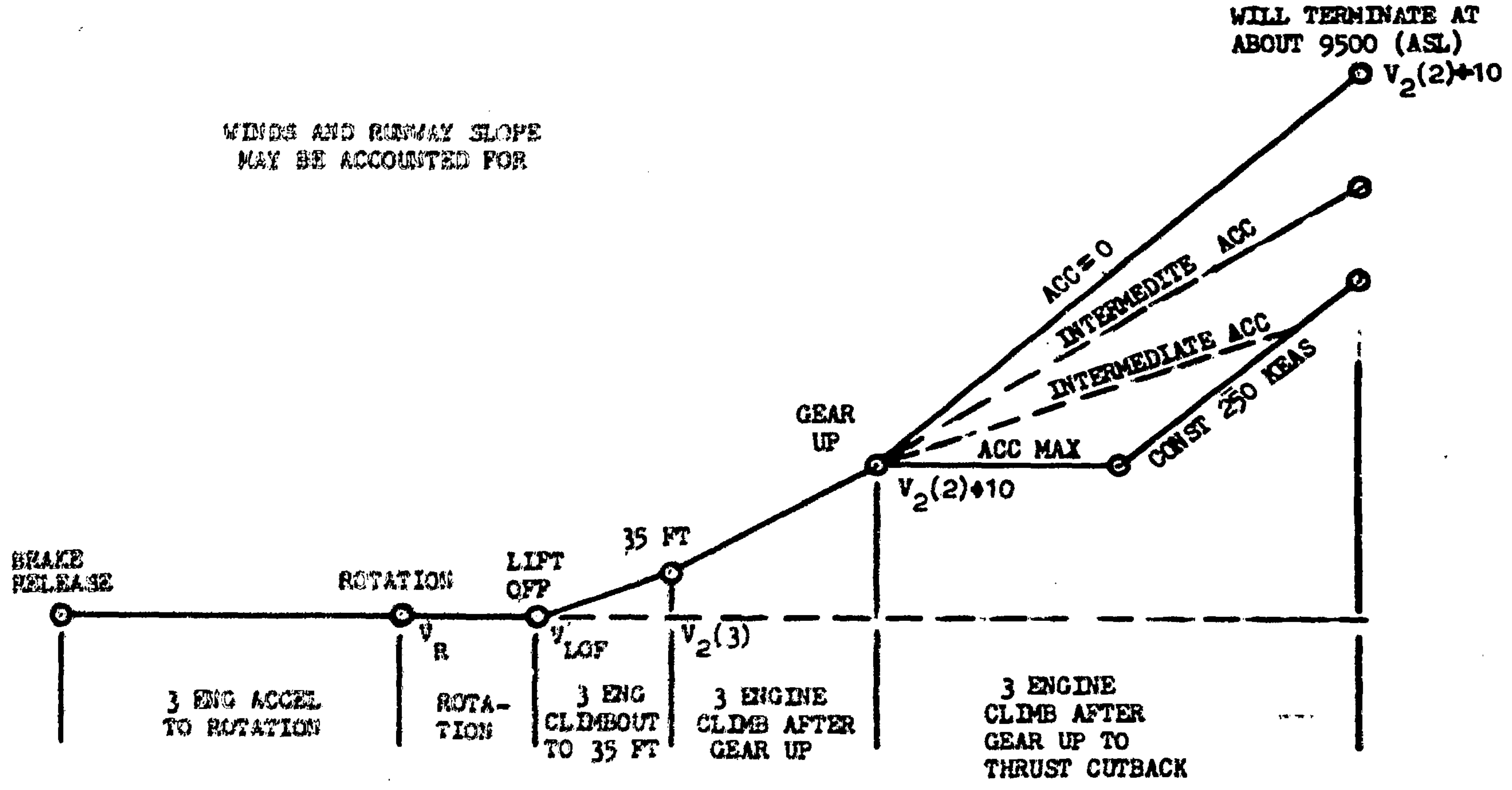


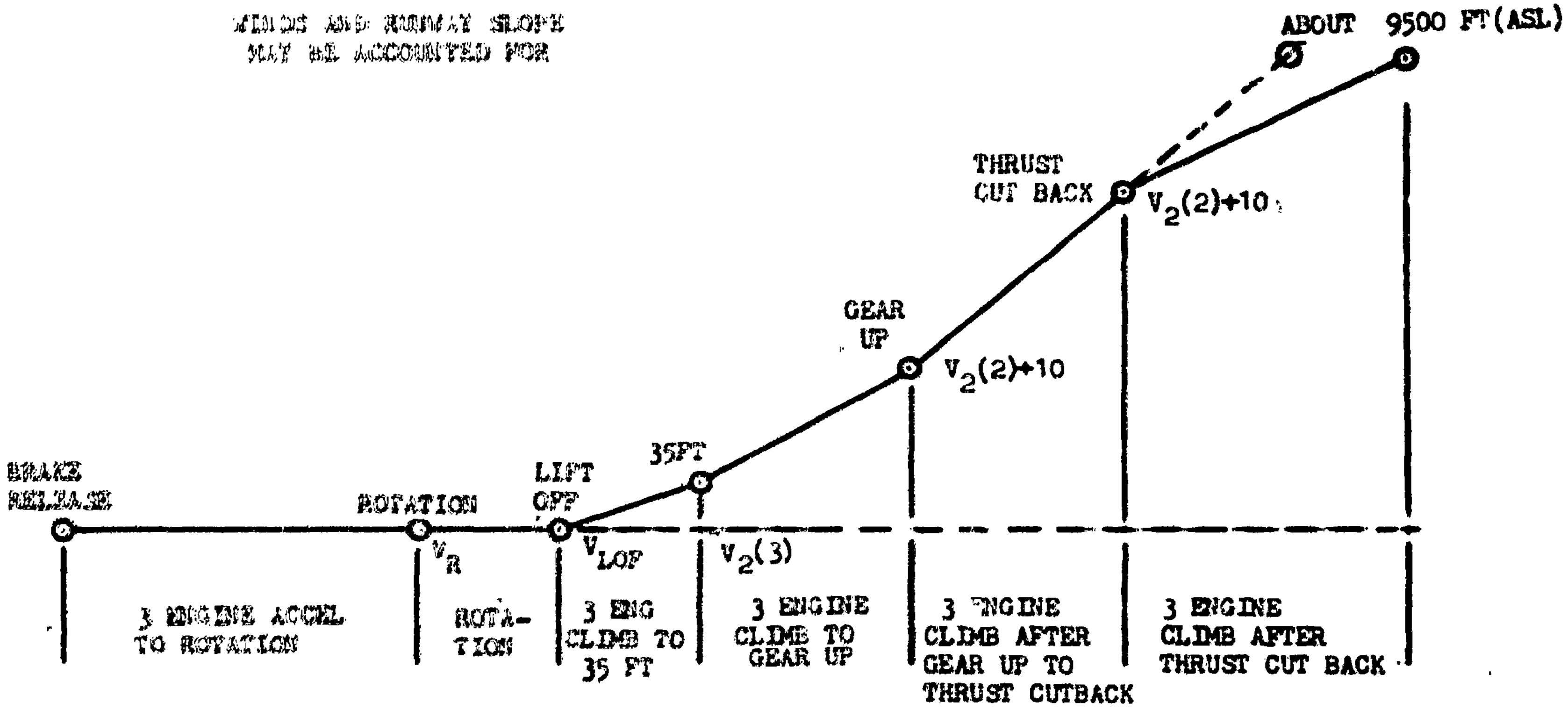
FIGURE 2.2-4 SCHEMATIC - 3 ENGINE TAKEOFF AND CLIMBOUT AT CONSTANT SPEED



WINDS AND RUNWAY SLOPE
MAY BE ACCOUNTED FOR

SCHEMATIC - 3 ENGINE TAKEOFF AND
ACCELERATED CLIMB AFTER GEAR UP

FIGURE 2.2-5 SCHEMATIC - 3 ENGINE TAKEOFF AND
ACCELERATED CLIMB AFTER GEAR UP



SCHEMATIC - 3 ENGINE TAKEOFF AND
CLIMBOUT AT CONSTANT SPEED WITH
THRUST CUTBACK AFTER GEAR UP

FIGURE 2.2-6 SCHEMATIC - 3 ENGINE TAKEOFF AND CLIMBOUT AT CONSTANT SPEED WITH THRUST CUTBACK AFTER GEAR UP

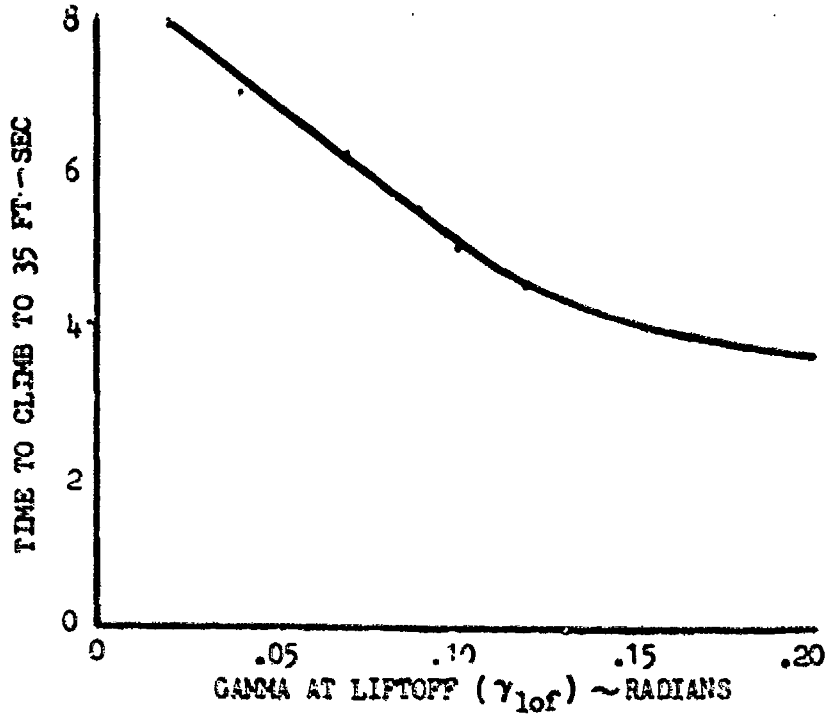


FIGURE 2.2-7 FLIGHT TEST TIME TO CLIMB FROM LIFTOFF TO 35 FEET

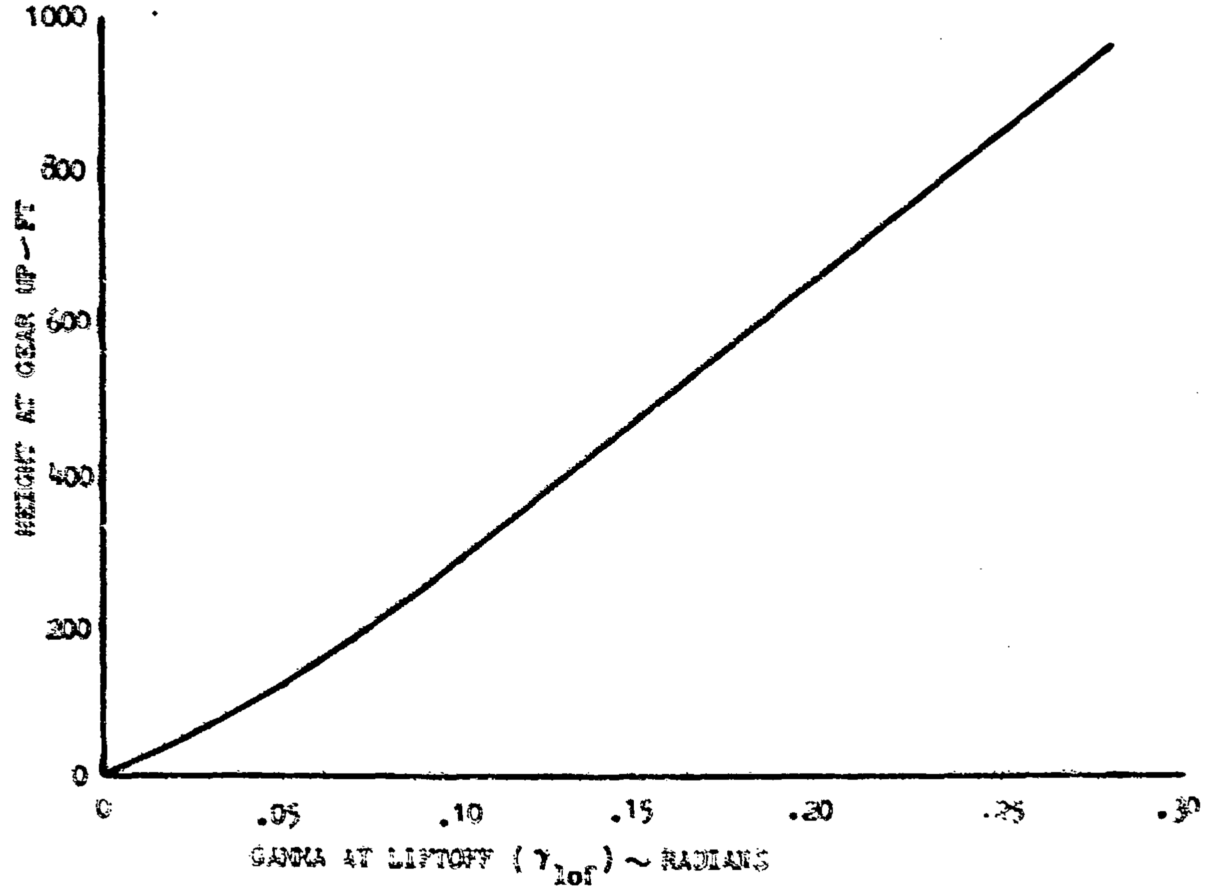


FIGURE 2.2-8 FLIGHT TEST GEAR UP HEIGHT

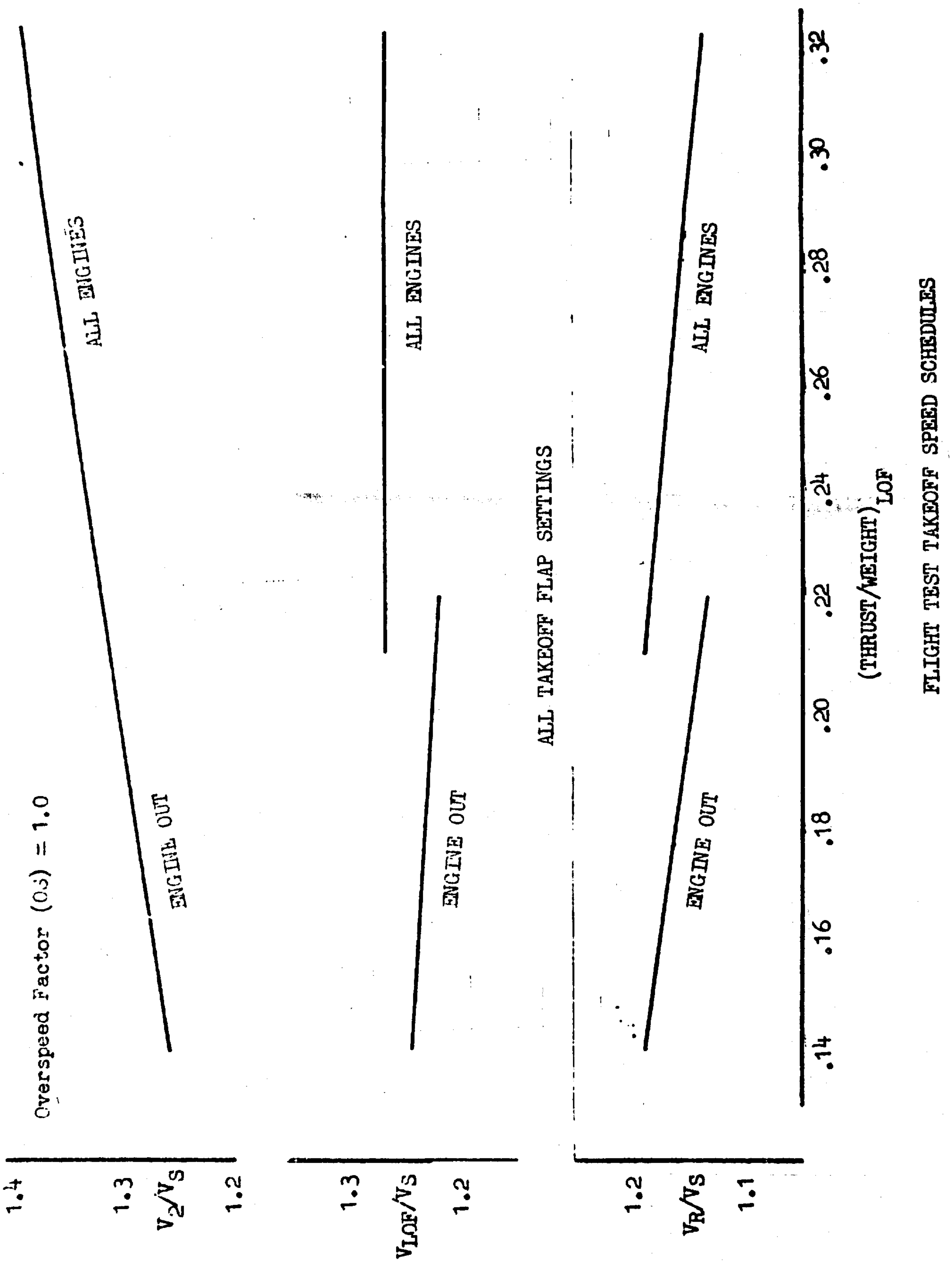


FIGURE 2.2-9 FLIGHT TEST TAKEOFF SPEED SCHEDULES

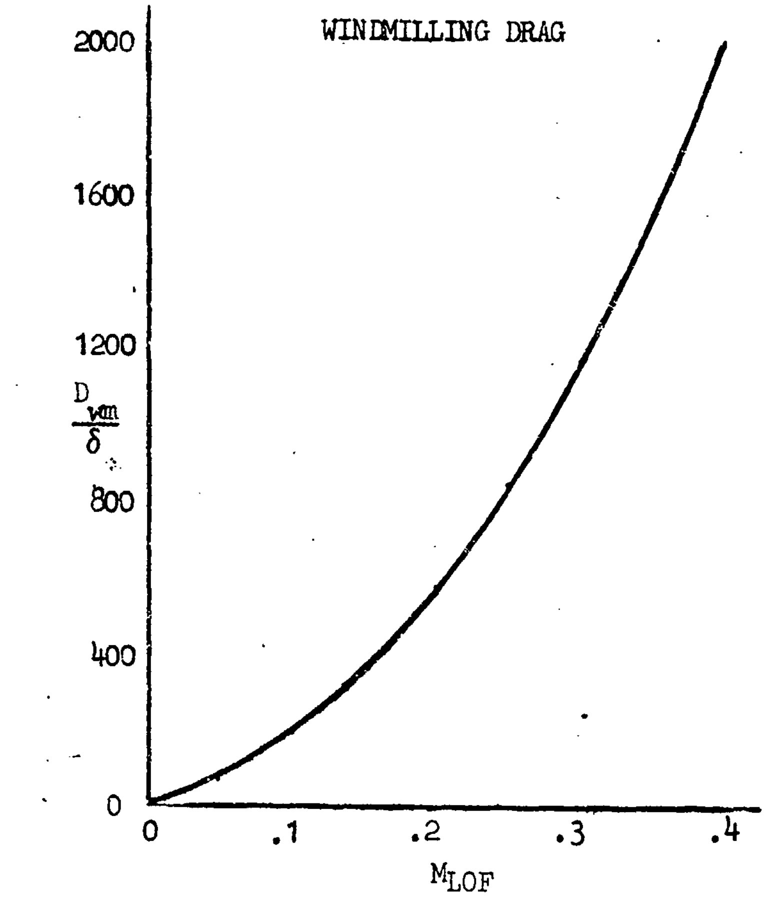


FIGURE 2.2-10 WINDMILLING DRAG

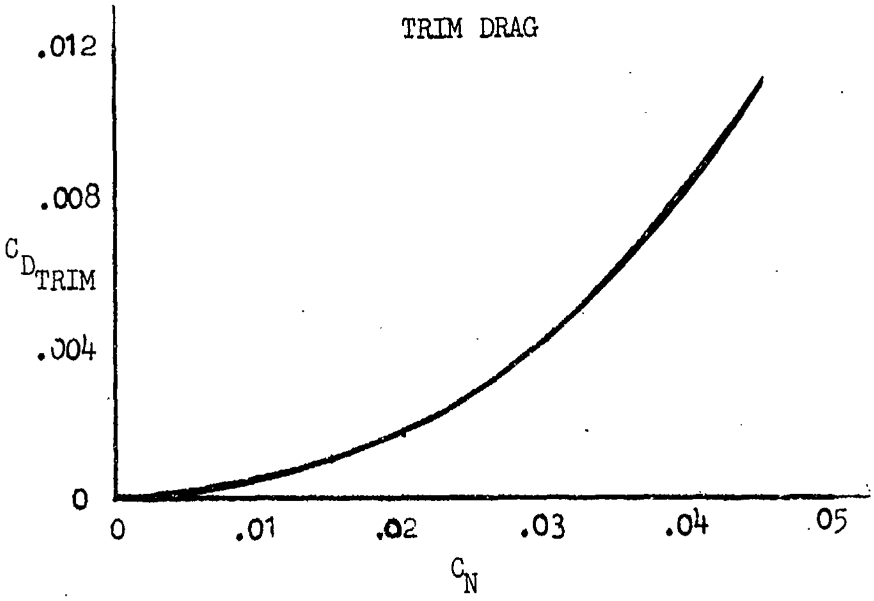


FIGURE 2.2-11 ENGINE OUT TRIM DRAG

2.2.3 The Atmosphere

Several acoustic and performance parameters are derived from atmospheric parameters. These are obtained from a mathematical model of the atmosphere. The information presented on the following pages explains this model in terms of what it is, where it comes from, and how it is used in the two noise programs.

2.2.3.1 Derivation

The atmosphere employed in the noise definition program and the noise propagation program was constructed by using appropriate equations from the 1962 U. S. Standard Atmosphere (Reference 13). Normally, pressure altitude is given and other conventional atmospheric quantities are required.

First, pressure altitude is converted to geopotential pressure altitude.

$$H_p = Z_p \times R_e/(Z_p + R_e). \qquad (2.2\text{-}67)$$

where H_p is the geopotential pressure altitude.
Z_p is the pressure altitude.
R_e is the equivalent earth radius. (6353.5 KM or 20,844,820 FT.)

If pressure altitude (H) is given in feet, it is converted to KM. by

$$Z_p\ (\text{KM.}) = .0003048\ H\ (\text{FT.}) \qquad (2.2\text{-}68)$$

with

$$H_p = 6353.5\ Z_p/\ (Z_p + 6353.5) \quad \text{KM} \qquad (2.2\text{-}69)$$

Combining these equations,

$$H_p\ (\text{KM.}) = .0003048\ \left[20884820\ H\ (\text{FT.})/(H(\text{FT}) + 20844820)\right] \qquad (2.2\text{-}70)$$

Next the standard temperature can be found from

$$T_{std}\ (^{\circ}\text{K}) = 288.15 - 6.5\ H_p(\text{KM.}) \qquad (2.2\text{-}71)$$

where T_{std} is the standard temperature in degrees Kelvin. $-6.5\,^{\circ}$K/KM is the first-layer standard lapse rate.
288.15 °K is the S.L. standard temperature.

If the atmospheric temperature (t) is given in degrees Fahrenheit, it can be converted to degrees Kelvin by the equation

$$T\ (^{o}K) = (t\ (^{o}F) - 32)/1.8 + 273.15 \qquad (2.2\text{-}72)$$

or

$$T\ (^{o}K) = (t\ (^{o}F) + 459.67)/1.8 \qquad (2.2\text{-}73)$$

The temperature increment from standard is given by

$$\Delta T = T - T_{std} \qquad (2.2\text{-}74)$$

If the atmospheric temperature is given as the increment ΔT in degrees Celsius (or ^{o}K)

$$T\ (^{o}K) = T(^{o}K)_{std} + \Delta T \qquad (2.2\text{-}75)$$

and

$$t\ (^{o}F) = 1.8\ T(^{o}K) - 459.67 \qquad (2.2\text{-}76)$$

Knowing the ambient temperature $T(^{o}K)$ the pressure ratio $\delta = P/P_o$ can be calculated, where P_o with sea level standard pressure of 101325 Pascals (Newtons/meter^2), 2116 LB/FT^2 or 29.92 inches of mercury. The equation for δ is

$$\delta = (T_o/T_{std})^{(G_o\ M_o/-6.5\ R_g)} \qquad \text{NON-DIM.} \qquad (2.2\text{-}77)$$

where G_o is the sea level acceleration of gravity (9.80665 m/sec^2).

M_o is the sea level molecular weight of air (28.9644 gm/mole).

R_g is the Universal Gas Constant (8.31432 joules/ ^{o}K-mole).

T_o is sea level standard temperature (288.15 ^{o}K)

Substituting gives

$$\delta = (288.15/T_{std})^{-5.25588} \qquad (2.2\text{-}78)$$

The pressure is found from the relationship

$$P = \delta P_o \qquad (2.2\text{-}79)$$

Knowing the ambient temperature (T) and the pressure ratio δ we can find the σ, where σ is the density ratio ρ/ρ_o. Or knowing the pressure P, we can find the density ρ.

$$\sigma = \sqrt{288.15\ \delta/T} \qquad (2.2\text{-}80)$$

Also, $\rho = M_o\ P/1000\ R_g T = P/287.053\ T$ KG/METER^3 (2.2-81)

The speed of sound is needed to calculate the characteristic impedance (ρc) of the air or the Mach number of the aircraft. The speed of sound is found from the equation

$$c = \sqrt{\frac{1000\ \gamma\ R_g\ T}{M_o}} \text{ in METERS/SEC} \qquad (2.2\text{-}82)$$

where γ is the ratio of specific heats (1.4 for air).

Substituting for the constants

$$c = \sqrt{401.874\ T} \text{ METERS/SEC} \qquad (2.2\text{-}83)$$

For convenience in calculating the Mach number we use the equivalent speed of sound in knots.

$$C_e = 29.04493\sqrt{1.8\ T\ \sigma} \text{ KNOTS} \qquad (2.2\text{-}84)$$

To convert from pressure altitude H to geometric altitude H_g, the following approximation is used:

$$H_g = H\ T_{RAT} \qquad (2.2\text{-}85)$$

where $T_{RAT} = T/T_{std}$

The temperature ratio (T_{RAT}) is assumed independent of altitude. In addition, the ratio

$$\frac{R_e + H_g}{R_e + H} \cong 1.000$$

is assumed sufficiently close to 1.000. These assumptions are good engineering approximations for low altitudes, say less than 10000 ft., with modest temperature excursions from standard day, say STD ± 40 °F.

2.2.3.2 Application

The relationships shown were used in different ways in the performance routines and the noise propagation program.

For the performance routine,

(1) $H_p = .0003048 \left[20884820\ H/(H + 20844820)\right]$ (2.2-86)

(2) $T_{std} = 288.15 - 6.5\ H_p$ (2.2-87)

If the altitude H is the airport elevation

(3) $T = (t - 32)/1.8 + 273.15$ (2.2-88)

and (4) $\Delta T = T - T_{std}$ (2.2-89)

(5) $T_{RAT} = T/T_{std}$ (2.2-90)

(6) $\delta = (T_{std}/T_o)^{5.25588}$ (2.2-91)

(7) $\sqrt{\sigma} = \sqrt{288.15\ \delta/T}$ (2.2-92)

(8) $C_e = 29.04493 \sqrt{1.8\ T\ \sigma}$ (2.2-93)

(9) $t = 1.8\ T - 459.67$ (2.2-94)

If the altitude is other than the airport elevation set (3) $T = T_{std} + \Delta T$, then do (5) through (9).

The atmosphere subroutine in the noise propagation program is used to calculate the characteristic impedance (ρc) and the temperature (t). If pressure altitude (H) and the incremental temperature (ΔT) are known:

(1) $Z_p = .0003048\ H$ (2.2-95)

(2) $H_p = 6353.5\ Z_p/(Z_p + 6353.5)$ (2.2-96)

(3) $T_{std} = 288.15 - 6.5\ H_p$ (2.2-97)

(4) $T = T_{std} + \Delta T$ (2.2-98)

(5) $t = 1.8\ T - 459.67$ (2.2-99)

(6) $P = 101325\ (288.15/T_{std})^{-5.25588}$ (2.2-100)

(7) $\rho = P\ /287.053\ T$ KG/M^3 (2.2-101)

(8) $c = \sqrt{401.874\ T}$ METERS/SEC (2.2-102)

If the temperature (t) and the pressure (p) in inches of mercury are known:

(1) $T = t + 459.67/1.8$ (2.2-102)

(2) $P = 3386.39\ p$ (2.2-103)

(3) $\rho = P/287.053\ T$ KG/M^3 (2.2-104)

(4) $c = \sqrt{401.874\ T}$ METERS/SEC (2.2-105)

SECTION 3

COMMUNITY NOISE CONTOURS

For aircraft noise certification FAR Part 36 (Reference 1) requires the determination of noise at three points - 3.5 nautical miles from brake release and the maximum noise point along an 0.25 or 0.35 nautical mile sideline for takeoff, and 1.0 nautical miles from threshold for approach. The L-1011-1 measured noise data used in Section 2.1.3 above were accumulated primarily to demonstrate the noise levels at the three certification points. The more general airplane noise characteristics as developed by the calculation procedures of Section 2.1 may be used for more detailed analysis of noise exposure during takeoff and landing approach operations. Constant noise contours--often referred to as noise "footprints" because of their shape--provide such noise exposure information in a convenient form.

3.1 FOOTPRINT CALCULATIONS

The airplane performance results and the airplane noise characteristics of Section 2 provide the information that, with appropriate geometrical relations, determine the noise at any point on the ground during takeoff and approach maneuvers. The calculation, which has been programmed for the computer, provides noise under the flight path and along a quarter nautical mile sideline and the coordinates of points where any specified maximum noise level is reached. Through these points constant maximum-noise contours may be drawn by hand or by means of a computer plotting routine.

The airplane performance information may be obtained directly from the performance subroutine or may be inputted from other tabulated performance data. The performance data are in the form of airplane height above the ground along the takeoff or approach path, airplane speed, and corrected fan speed ($N_1/\sqrt{\theta}$) for the engine thrust setting in use. These data are at distances, from brake release or from threshold, determined at equal time intervals of 10 seconds. To obtain the resolution needed for contour plotting, the flight profile height versus distance data from the performance subroutine must be augmented with additional points, by interpolating linearly between the provided profile points.

The airplane noise characteristics are entered in tabular form as noise level at various distances for a number of corrected fan speeds bracketing takeoff and approach engine thrust settings. One set of noise levels is for air-to-ground propagation and the second set is for ground-to-ground propagation, including the extra ground attenuation of Reference 8. A typical input noise tabulation is shown as Table 3-1. A separate noise table must be prepared for each combination of airport elevation, temperature, and relative humidity to be considered. The tabulated airplane noise characteristics may be obtained from the results of a calculation as described in Section 2.1.2 or from any other appropriate source of measured or predicted noise characteristics and may be in terms of any physical or subjective noise level desired.

The detailed calculation procedure is outlined in Volume III "Model User's Manual" of this report. In general the procedure involves determining, geometrically, the maximum noise intercept on the projection of the flight path and on the sideline for each selected airplane position. The distances to the positions on the ground for a specific maximum noise level are obtained by logarithmic interpolation in the tables of noise level versus distance, without extra ground attenuation and with extra ground attenuation. To take into account the dependence of extra ground attenuation on the angle of the noise path with the ground, the distance is modified by the exponential factor $e^{-\sqrt{\tan 3\beta}}$ from Reference 9. β is the angle of elevation of the noise path.

When effective perceived noise level is the measure for which footprints are to be obtained, then a velocity correction must be applied to account for the difference between the airplane's actual velocity and the normalized 160 knot velocity of the input tables.

Since the community area exposed to some given noise level may be of interest, the areas enclosed by the contours are calculated, using trapezoidal rule quadrature. The computer determines accumulated area in square miles enclosed by the contour up to each individual coordinate point. When the contour closes the total area is provided.

TABLE 3-1 L-1011-1/RB.211-22B EFFECTIVE PERCEIVED NOISE LEVEL PROPAGATION
SEA LEVEL, 77° F, 70% RELATIVE HUMIDITY

$N_1/\sqrt{\theta}$,%	55	60	67.4	75	85	95
Distance, Feet			EPNL, EPNdB, with Extra Ground Attenuation			
200	97.5	99.5	102.3	104.0	105.1	105.7
370	93.0	95.0	97.7	99.4	100.8	101.5
800	84.9	86.8	89.3	91.2	93.2	94.3
1600	74.3	75.8	79.0	81.2	83.7	84.3
3200	65.8	67.3	70.6	72.9	75.2	75.9
6400	58.6	60.4	63.8	66.2	68.6	69.2
12800	50.1	[illegible]	56.1	58.6	61.2	61.3
			EPNL, EPNdB, without Extra Ground Attenuation			
200	101.6	103.6	106.4	108.1	109.1	109.6
370	98.1	100.0	102.8	104.5	105.7	106.4
800	92.8	94.7	97.3	99.0	100.6	101.6
1600	86.8	88.4	90.9	92.7	94.8	96.2
3200	79.9	81.2	84.0	86.3	88.6	89.6
6400	72.3	73.6	76.8	79.2	81.7	82.6
12800	63.2	65.2	68.7	71.2	73.8	74.3

3.2 L-1011-1 FOOTPRINTS

The computational procedure for constant maximum-noise contour generation has been exercised on the L-1011-1/RB.211-22B performance and noise of Sections 2.1 and 2.2 above. Effective perceived noise level and A-noise level contour plots, included in Volume II of this report, have been prepared for the following reference-condition cases:

Takeoff	Maximum takeoff gross weight (430,000 lb.), 10° flaps, takeoff thrust
	Reduced takeoff gross weight (350,000 lb.), 10° flaps, takeoff thrust
	Maximum takeoff gross weight (430,000 lb.), 22° flaps, takeoff thrust
	Maximum takeoff gross weight (430,000 lb.), 10° flaps, FAR Part 36 thrust cutback at 3.5 nautical miles
Approach	Maximum landing weight (358,000 lb.), 42° flaps, 3° glide slope
	Reduced landing weight (300,000 lb.), 42° flaps, 3° glide slope
	Maximum landing weight (358,000 lb.), 33° flaps, 3° glide slope
	Maximum landing weight (358,000 lb.), 42° flaps, $6^{\circ}/3^{\circ}$ two segment glide slope with transition at 1000 ft. altitude

Note: All approaches with DLC (direct lift control).

An example of contour plots is shown as Figure 3.2-1. Contours are drawn for 80, 90, 100, 110, and 120 EPNdB. A corresponding A-noise level set would normally include 70, 80, 90, 100, and 110 dBA contours. The set of contour plots produced is by no means a complete coverage of airplane operational variations. However, it serves to illustrate some of the effects of operational parameters.

There is, for instance, only little effect close to the airport for a change in takeoff flaps but the higher flap setting does extend the noise exposure farther. Where takeoff field length is not restricting, the lower flaps should be considered for noise exposure reduction. The takeoff thrust-cutback procedure reduces noise close to the airport, as may be seen from a 90 EPNdB contour, but increases the exposure area to an 80 EPNdB contour.

For approach, reduced flaps are seen to be effective in reducing noise exposure and should be considered for noise abatement when available runway lengths permit. The dramatic impact of a two-segment approach may be seen clearly from the greatly reduced noise contour areas. The desirability of developing operational safeguards to permit two-segment approach maneuvers is obvious.

Similar analyses of operational variables may be made for any aircraft by using its performance and noise characteristics in the footprint calculation and plotting routine.

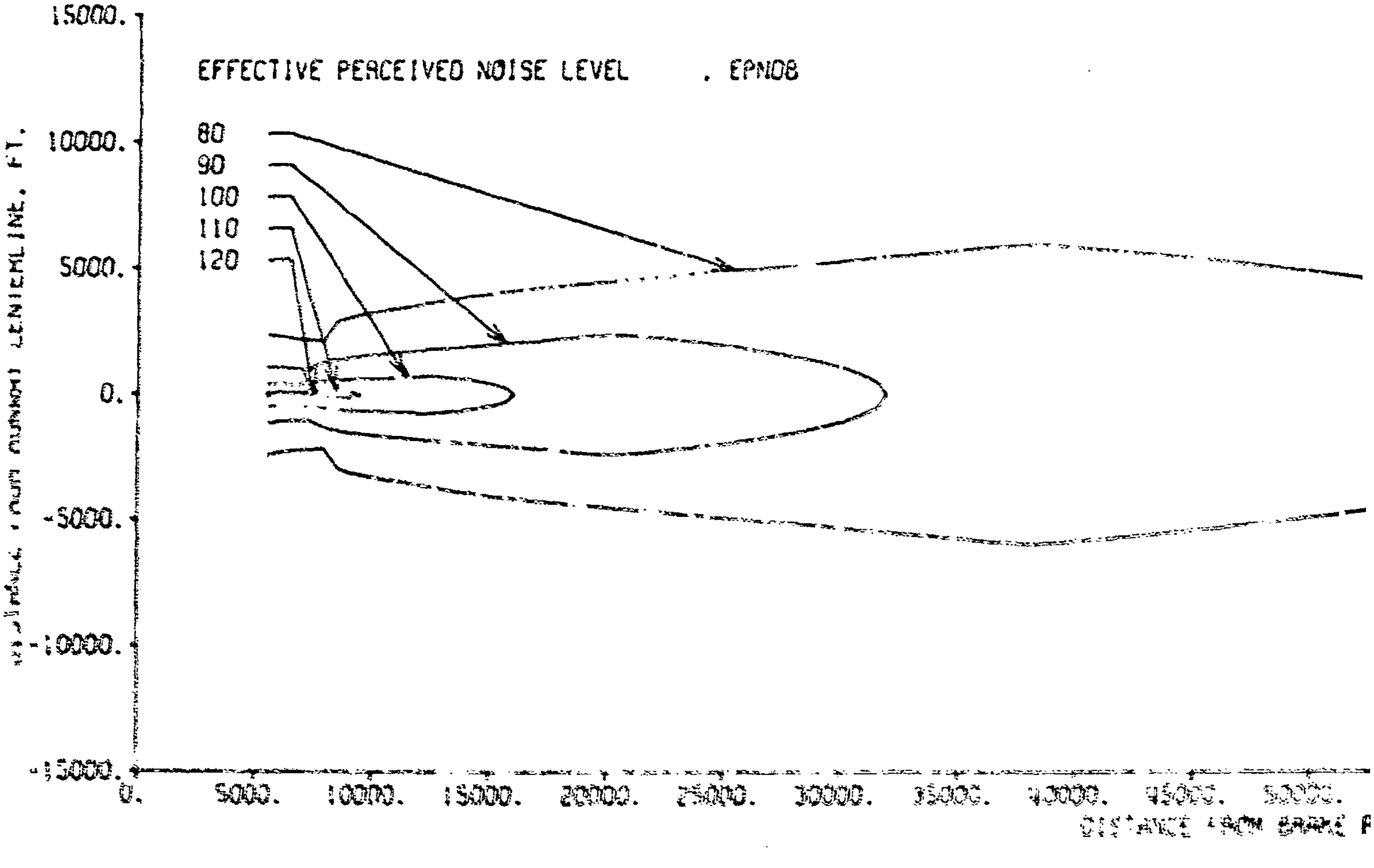
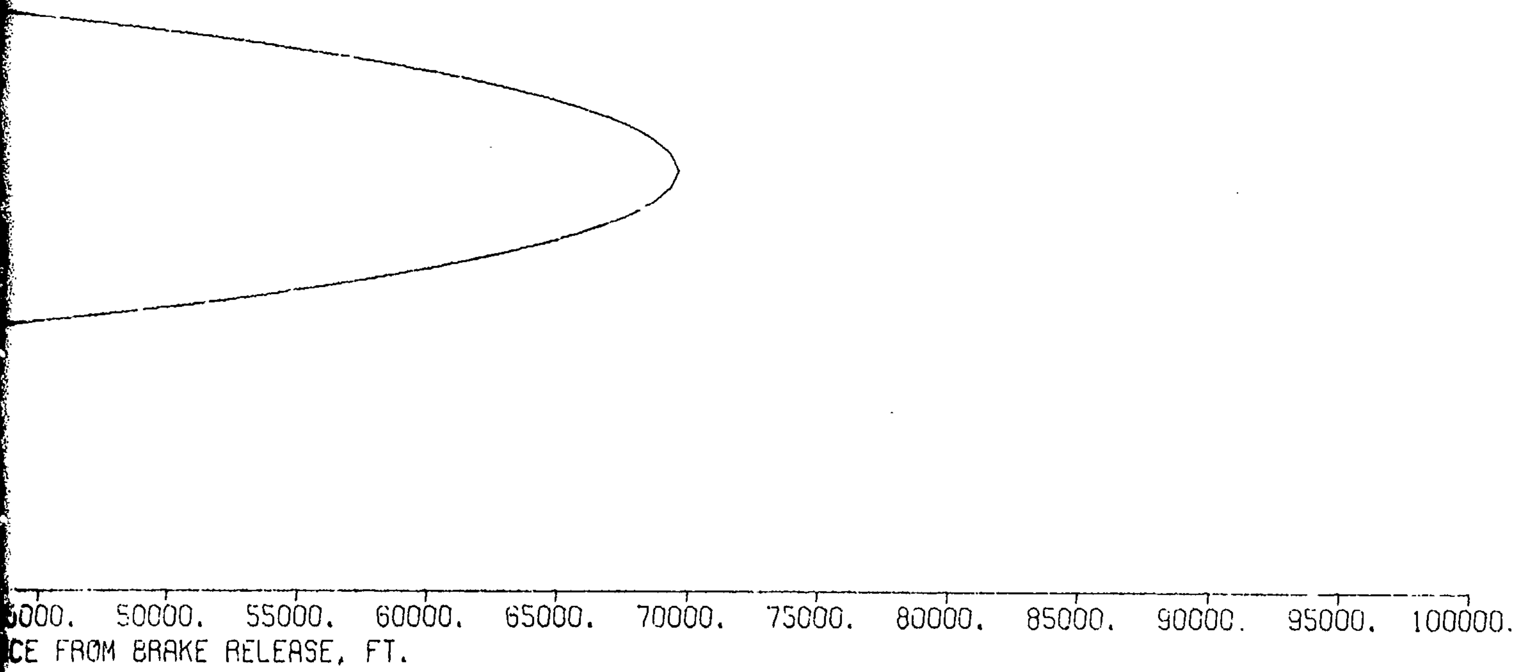


FIGURE 2.2 1 CONTOUR PLOTS
L-1011-1 / RB211-22B EFFECTIVE PERCEIVED NOISE LEVEL
SEA LEVEL, 77 DEG. F., 70% RELATIVE HUMIDITY
MAXIMUM TAKEOFF WEIGHT (430,000LB.), 10 DEG. FLAPS, TAKEOFF THRUST

A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THRUST

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SECTION 4

SUMMARY

The Commercial Aircraft Noise Definition for the Lockheed L-1011-1 Tristar, conducted for the Federal Aviation Administration in compliance with Contract DOT-FA/73WA-3300 dated June 6, 1973, is documented in the five volumes of this report. This volume, I, presents a technical discussion of the calculation procedures developed, and programmed for batch operation on a digital computer, to determine an airplane's performance and noise characteristics during take-off and approach operations and to produce constant maximum-noise contour footprints for noise exposure analyses. The programmed procedures have been applied to L-1011-1 flight data and the results are contained in Volume II, titled "L-1011-1 Data." The logic behind the calculation procedure and the capabilities and limitations of the procedure are reviewed in the "Model User's Manual" of Volume III. The detailed information required for operation of the computer program is presented in Volumes IV and V.

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