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JET NOISE AND PERFORMANCE COMPARISON STUDY OF A MACH 2.55 SUPERSONIC CRUISE AIRCRAFT

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By
STAFF OF THE LANGLEY RESEARCH CENTER

SUMMARY

A noise and performance comparison study has been conducted on a Lockheed California Company Mach 2.55 supersonic cruise concept based on late 1980 technology and features a variable geometry duct burning engine with a coannular nozzle mounted in an over/under wing arrangement for noise shielding. All input data were provided by the Lockheed California Company. The aircraft has a takeoff gross weight of 3268 kN (734,719 lbf) carrying 290 passengers over a 8890 km (4800 nautical mile) range.

The object of this study was to identify differences in jet noise levels and performance between Lockheed and NASA associated with methodology and ground-rules. In addition, economic and noise information is provided consistent with a previous NASA study on an advanced technology Mach 2.7 configuration, which was reported in reference 1.

The results of the present study indicate that the difference between the NASA and Lockheed performance methodologies are small. NASA computed range is 8843 km (4775 nautical miles). NASA calculates a 32.9 m (108 feet) higher initial climb path, due to differences in takeoff controlling logic. The climb altitude difference has a negligible effect on the noise controlling parameters. NASA has calculated noise levels (no cutback and jet noise only) of 116.6 EPNdB, 112.4 EPNdB, and 100.9 EPNdB, for flyover, sideline, and approach noise respectively, whereas the corresponding Lockheed calculated noise levels (jet noise only) are 114.1 EPNdB, 110,8 EPNdB, and 101.7 EPNdB. NASA does not include any benefits for over/under engine noise shielding. This factor in addition to the differences that result from the use of the ANOPP or the SAE jet noise prediction method, especially on landing approach account for the noise levels differences. Lockheed assumes benefits in flyover and approach noise of 3 db for shielding.

Resizing the Lockheed aircraft to NASA groundrules (Range of 8334 km (4500 nautical mile), payload of 273 passenger, etc.) results in small changes in flyover, sideline and approach noise levels. The resulting noise levels (jet noise only) for the resized aircraft with NASA groundrules for a maximum power takeoff with cutback at the flyover monitor are 110.5 EPNdB, 113.7 EPNdB, and 100.7 EPNdB. The effects of reducing jet velocity by oversizing and power cutback are quite sensitive to the assumptions used in estimating flight effects on noise. In addition to the above minimum weight aircraft, two additional

aircraft have been generated with increased engine size to reduce noise. Since the critical noise monitoring station is at the sideline position for a maximum power takeoff, the large engine sizes increase sideline noise resulting in no reduction in traded noise at the power settings chosen for the study. There may be intermediate power settings that would permit somewhat lower traded noise, but these combinations were not evaluated in the present study. In terms of the summated noise level, the decreases in noise with engine size result in a 10 db reduction for an 8 percent increase in total operating costs. This corresponds to an average reduction of 3.3 EPNdB at the three observer positions.

INTRODUCTION

International studies are underway within the framework of the International Civil Aviation Organization (ICAO) to establish recommended certification noise rules for supersonic cruise aircraft. In support of this effort, the FAA requested NASA to conduct a noise sensitivity study applicable to future supersonic cruise aircraft. Accordingly, Langley Research Center undertook an initial study to determine noise and performance levels for an in-house generated Mach 2.7 study configuration (ref. 1). Results were presented for various engine cycles, provided by industry, consistent with post-1985 technology (CLASS III ICAO definition). The cost/noise sensitivity by engine oversizing was determined for each engine cycle.

Parallel to the Langley study, the U.S. aircraft industry conducted independent studies (refs. 2-6) on their individual study configurations. Direct comparisons of the results of these studies are not possible, since they reflect different philosophies as to timing, cruise speed, and degree of assumed technology. In addition, differences in performance prediction methods, noise prediction methods, and performance groundrules also affect the results. In order to identify the differences in methodology and groundrules, between the various studies, NASA is in the process of calibrating the performance and noise levels of the industry configurations.

The purpose of this report is to provide results of the comparison of the Lockheed California Company noise sensitivity baseline configuration (ref. 2). The configuration is a Mach 2.55 design supersonic cruise vehicle incorporating CLASS III technology (beyond 1985) variable cycle engines. The calibration process is conducted in three steps. First, using all Lockheed configuration characteristics and groundrules, calculating performance and noise levels by both Langley and Lockheed methods will provide the difference due to methodology. Second, resizing to the NASA (ref. 1) design parameters (range of 8334 km (4500 nautical mile), payload of 273 passengers, takeoff field length of 3810 (12500 ft.), etc.,) will provide the difference due to groundrules. Finally, NASA groundrules are used with engine oversizing to determine the cost/noise sensitivity.

METHOD OF ANALYSIS

In order to accomplish the objectives of the study, an interaction between design, performance, economics, and noise prediction was required. Specifically, four computer programs were interfaced. The study approach consists of utilizing individual programs for aircraft sizing and performance, takeoff and landing performance, noise prediction, and economics. A brief description of the essential features of each of these programs follows.

Aircraft Sizing and Performance

The aircraft sizing program (ref. 7) determines the effects of aerodynamics, weights, and propulsion on aircraft range. The baseline aircraft can be resized for changes in thrust/weight, wing loading, number of passenger, or gross weight. New aerodynamics and propulsion effects are computed, weights are generated, and a mission profile is flown to find new range capability. Enroute performance analysis uses a step-wise integration of the equations of motion including minimum fuel climb and acceleration, and supersonic cruise at optimum range factor. Fuel reserves are computed based upon percent trip fuel, missed approach, subsonic cruise to alternate airport, and an altitude hold. The output of the aircraft sizing program is a matrix of airplane thrust/weight ratio (sea level static installed maximum thrust) and wing loading (takeoff gross weight/wing area) combinations which meet the specified range and payload. Design constraints such as fuel volume margins are determined.

Takeoff and Landing Performance

This computer program determines aircraft takeoff performance in accordance with Federal Air Regulation (FAR) Part 25 safety requirements. The program was developed for detailed analysis of specific aircraft designs. Takeoff profiles are generated by stepwise integration of the equations of motion. The method searches for critical engine failure speed and balanced field length. Power cutback and acceleration is available during climbout for noise alleviation. Approach profiles are also generated, with options for two-segment and/or decelerating approaches. Extensive time histories of noise critical parameters are developed for input to the NASA aircraft noise prediction program (ANOPP).

Aircraft Noise Prediction

Noise predictions were made with the Aircraft Noise Prediction Program (ANOPP) (ref. 8). This program utilizes time-dependent trajectory and engine data from the takeoff and landing performance program to predict the time-dependent one-third octave band spectra at a set of observer positions. These spectra are then integrated to obtain perceived noise and effective perceived noise. ANOPP includes noise source prediction modules for jet mixing noise, jet shock cell noise, compressor noise, combustion noise, turbine noise, and airframe noise. In the present studies, only the jet mixing noise module was utilized.

Atmospheric attenuation of the sound was predicted using the proposed American National Standards Institute (ANSI) standard method (ref. 9). Ground effects include reflections and attenuation of sound. ANOPP implements a theory which relates the noise received by a raised microphone (1.20 meters) over a ground surface to the noise that would be present in the free-field. Effects of shielding on sideline or flyover noise have not been included in this study.

Economics Methodology

The Sub-group for Economics to the Working Group E (WG/E) composed of representatives of the United Kingdom, France, the USSR and the USA, agreed to the following definitions and ground rules known as the "ICAO Common Method".

The figure of merit will be Total Operating Cost (TOC) computed to cents/available seat mile (ASM) or cents/kilometer. TOC will include Direct Operating Cost (DOC), Indirect Operating Cost (IOC), plus interest charges of 5 percent of new A/C cost and spares annually (or 10 percent of average value). DOC is based primarily on the Air Transport Association (ATA) method and includes algorithms for computing flight operation costs, maintenance costs, and depreciation costs. Flight operation costs include cockpit crew, fuel, and insurance costs. IOC is based primarily on a Lockheed-Boeing method of coefficients and includes systems costs, local costs, control costs, cabin attendant costs, food expense, passenger handling, cargo handling (baggage), other passenger service costs, and general and administrative costs.

The European members submitted formulas for price and maintenance costs based on the EURAC method. Since their studies encompass CLASS II pre-1985 all aluminum technology and the NASA studies encompass CLASS III post-1985 titanium technology, it was agreed that pricing and maintenance costs would be handled according to the technology of the study aircraft, but allow comparisons to be made between studies. The difference between the methods results in maintenance costs approximately 54 percent greater with the EURAC method and acquisition costs approximately 48 percent greater with the NASA method (ref. 10). The sum of maintenance and depreciation costs, as components of the DOC, with either method results in DOC's within 10 percent of the other, primarily because fuel costs dominate. A substitution to the flight crew cost formula of the Air Transport Association (ATA) method was adopted by the WG/E. It represents the European Aircraft Consortium (EURAC) method and contains a supersonic flight crew bonus of approximately 53 percent.

The assumptions and ground rules adopted were as follows: All cost computations are in constant 1976 U.S. dollars, aircraft economic life is 16 years; A/C utilization is 3600 hr/yr; A/C salvage value is 5 percent of A/C plus spares costs; insurance is 1 percent of average cost (1/2 percent of new cost); interest is 5 percent of A/C new cost (10 percent of average cost); labor rate is \$9/hr; overhead is 2x Labor rate; ground manuever time is 10 min/flight; payload is 60 percent load factor at 209 lb/passenger. Configuration is all tourist, no cargo, no subsonic cruise leg; cabin attendants assigned at 1/35 seats; fuel is \$0.13/liter (\$0.50/gallon) Jet A; airframe spares at 10 percent airframe cost; engine spares at 30 percent total engine cost; non revenue factor at 2 percent on fuel cost and maintenace costs; CLASS III technology costs (including development costs) of \$300/lb airframe weight and \$356/lb engine weight.

AIRPLANE DESCRIPTION

The study reference configuration (ref. 2), designated the baseline CL1611-1, is designed for long-range supersonic cruise at Mach 2.55 on a hot day for a distance of 8890 km (4800 nautical mile). The maximum takeoff gross weight is 3268 kN (743 719 lbf). A one-class, single aisle cabin with six abreast seating accommodates 290 passengers. The airplane features a highly-swept arrow wing planform with over/under nacelles that contain variable cycle powerplants, wing leading and trailing edge high-lift devices combined with aft mounted horizontal tail, and far term technology structural concepts. The general arrangement of the baseline CL1611-1 is presented in figure 1, and a summary of its primary characteristics is shown in table I.

Wing loading and thrust/weight ratio are chosen to produce a configuration that is close to the center of the DOC knothole, based on previous experience. A wing loading of 4217 Pa (88.1 psf) at takeoff results in a wing area of 775.0 m^2 (8340 ft^2) with wing tips folded. Folding wing tips that extend for takeoff and landing to increase span are used in conjunction with trailing edge flaps to provide needed additional lift and improve lift/drag ratio characteristics. Extension of the folding tips increases the wing aspect ratio from 1.72 to 2.07. The wing is highly cambered to provide improved cruise lift/drag ratio by improving the load distribution to minimize drag due-to-lift and trim drag.

Four Pratt and Whitney 516L variable cycle engines are located in an arrangement that uses shielding as a potential means for reducing jet and fan noise. The concept has engines mounted in an arrangement that places two of the engines on top of the wing, positioned above two below-wing mounted engines in an over/under arrangement. Jet noise shielding such as provided by an over/under engine installation has been demonstrated in experimental results from twin jet noise studies to provide a 3 to 5 EPNdB noise reduction beneath the path of the aircraft. Forward radiated fan noise also is shielded by the wing structure providing a potential fan noise relief. The four variable stream control duct burning turbofan engines have an installed thrust of 228.8 kN (51 430 lbf) each, at hot day takeoff conditions, providing an airplane thrust-to-weight (T/W) ratio of 0.302. The airflow at takeoff is 338 kg/s (745 lbm/sec) per engine.

The over/under arrangement has several other benefits. These include reduced engine-out control requirements, a single structural beam for mounting both engines on each side of the airplane, inlet isolation to prevent unstart propagation, and the availability of more trailing edge for flaps to enhance low speed lift.

The aircraft structure employs advanced structures technology. Total airframe weight (including landing gear, control surfaces, etc.) is about 51 percent composite materials, 24 percent titanium alloy 6AL-4V and 25 percent aluminum, steel, and other metals. The basic airframe structure (wing, tail, and fuselage) is about 64 percent composites; 34 percent is for primary structure and 30 percent is for secondary structure.

Graphite-polyimide is employed on the wing secondary structure (leading edge and control surfaces) as well as on the empennage and the strength and stiffness-critical aft and tip box structures. The titanium alloy forward box structure employs the advanced beaded panel concept fabricated by the superplastic formed/diffusion bonded process.

The fuselage shell is a skin-stringer-frame design using advanced composite materials. The floor panels, beams, posts, fairing and other nonprimary structure items are also composites. The main frames are titanium alloy and Lockheed projects the use of precision no-draft forging technology. Metal-matrix, boron-aluminum composite is applied as a reinforcement to the stiffness critical engine support beams and temperature-critical empennage structure.

ANALYSIS OF RESULTS

Calculations of noise are presented herein for the FAR 36 (stage 2) noise locations: centerline 6482 m (3.5 nautical miles) from brake release, sideline at 648 m (0.35 nautical miles) at the point where the noise is the greatest, and in approach at 1852 m (1 nautical mile) from threshold. Results are presented for a V_2 + 5 m/sec climb with cutback over the flyover monitor (V_2 is the speed of aircraft at the 10.7 m (35 ft) obstacle). The takeoff is accomplished within FAR 36 procedures; that is, constant flap and throttle setting during climb prior to cutback over monitor. Thrust cutback occurs at 5950 m (19500 ft) from brake release except where limited by the 216 m (700 ft) altitude restriction.

Effect of Methodology Differences

The configuration described in the previous section and input data provided by Lockheed, have been used exclusively in this study. This data included trimmed drag polars throughout the operating Mach number and altitude range. Variable cycle engine data consists of fuel flow versus thrust as a function of Mach number and altitude. Installed engine performance is based upon a Lockheed axisymmetric, translating centerbody, mixed compression design (NASA P-1 type) having seventy-six percent internal contraction (See ref. 2, p. 3-30). Bleed, spillage and bypass drag were also included.

The input data were used in the aircraft sizing and performance program (ref. 7), and range computed based upon the weight statement provided by Lockheed. The difference in range is 47 km (25 nautical miles) as shown in table II together with a breakdown of fuel burned in each mission segment.

The difference in NASA and Lockheed climb paths for takeoff (without power cutback) are shown in figure 2. The Lockheed climb path involves a gradual acceleration from the obstacle to a point above the noise monitoring position; the NASA procedure employs a more rapid acceleration initially followed by a constant climbout velocity to the monitor station.

The difference in climb paths has a small effect on the noise dominating parameters (jet velocities before and after cutback, altitude over the flyover monitor) as shown in Table III. The first column shows Lockheed quoted results for jet noise only. Flyover and approach noise levels from Lockheed include 3.0 EPNdB benefits due to shielding. The second column shows corresponding NASA results which do not include the 3.0 EPNdB shielding noise benefits. Lockheed employed the SAE method to calculate jet exhaust noise. The resulting noise values for the higher jet velocities associated with the sideline and flyover conditions are quite similar to those resulting from the use of ANOPP, but are about 3 EPNdB higher than ANOPP at the lower jet velocities associated with the landing approach conditions.

Effect of Groundrule Difference

The reference aircraft of 3268 kN (734719 lbf) has been resized to the design groundrules used in the previous NASA study (ref. 1), namely; a range of 8334 km (4500 nautical miles), payload of 273 passengers, and takeoff field length equal to 3810 m (12500 ft.). During the resizing, the following changes were incorporated:

- o Takeoff power changed 93 percent to 100 percent.
- o Cutback thrust determination based on three engine climb gradient of zero.
- o Trip fuel allowance included in aircraft weight during reserve segment.
- o Eliminated 4 minute cruise segment after takeoff, and five minute cruise segment before landing.
- o Approach velocity changed from 79.7 to 77.7 m/sec

The effect of the above changes in groundrules is shown in table IV. The slight increase in sideline noise is a result of increased takeoff thrust (93 percent to 100 percent). The significant reduction in flyover noise (6.1 EPNdB) results from the power cutback operation. Approach noise remains essentially unchanged since angle of attack, engine power setting, and speed remain about the same.

Cost/Noise Sensitivity

Consistent with the approach of reference 1, the effect of engine oversizing to reduce noise was examined. The rationale is to operate the aircraft with oversized engines at maximum power to reduce flyover noise (altitude effect) or to operate with a derated power setting corresponding to an extended takeoff field length to reduce sideline noise (jet velocity effect). Since the aircraft with oversized engines requires higher takeoff weight to perform the same range, economic penalties are associated with this approach. Thus a cost/noise sensitivity is generated.

The aircraft sizing chart for a range of 8334 km (4500 n.mi.) is shown in figure 3. The lowest weight aircraft or global optimum indicated by the lowest blocked-in symbol, corresponds to the aircraft discussed in the previous section. Two additional aircraft with oversized engines were chosen at constant wing loading as indicated by the upper two blocked-in symbols. The aircraft is not constrained by takeoff field length. The requirement for fuel volume margin coincides, with the global optimum. The fuel volume constraint requires that the wing be large enough to house sufficient fuel so that the entire payload could be off-loaded and replaced with fuel. Since the takeoff field length requirement does not constrain the designs, all three aircraft can be flown in either a maximum power or derated mode.

Takeoff performance and noise have been computed only for the maximum power operating procedure with power cutback over the flyover monitor. The noise results, shown in figure 4, indicate a decrease in flyover noise due to increasing altitude over the flyover monitor (563 m to 1082 m., (1847 ft. to 3550 ft.)). Approach noise decreases with engine oversizing due to matching at a lower part power throttle position. Since the noise prediction includes suppressed jet noise only, the low values of approach noise should be viewed with caution, since other sources such as fan, compressor, turbine, core, and airframe noise, may become significant contributors. It should also be pointed out that the effects of reducing jet velocity by oversizing and power cutback is quite sensitive to the assumption used in estimating flight effects on noise.

Since the maximum noise level is at the sideline monitor, possible benefits due to source shielding and exhaust nozzle shaping would show one for one reductions in traded noise.

Economic characteristics have been computed for the three aircraft using ICAO groundrules; i.e. fuel price of 50¢/gallon ($0.13/liter), and load factor at 60 percent. Configuration results are shown in table V which is the ICAO standard result format.

The cost/noise sensitivity is shown in figures 5 and 6. Direct operating costs, relative to the lowest weight aircraft (global optimum) are shown versus traded noise in figure 5 for maximum power takeoff. Since traded noise is 2 db less than the maximum noise value, no noise reductions are shown for large increases in engine size and direct operating costs at the power setting chosen. There may be intermediate power settings other than the maximum throttle used in the present study that would permit somewhat lower traded noise, but these combinations were not generated in the present study.

Another method of presentation, which has been used by ICAO, is shown in figure 6. Total operating cost, again, relative to the global optimum aircraft, is plotted versus summated noise (the sum of the noise at the three monitors). With summated noise as the figure of merit, noise reductions of 10 EPNdB are available for increases in total operating costs of 8 percent. This corresponds to an average reduction of 3.3 EPNdB at each of the three observer positions.

CONCLUSIONS

A noise and performance comparison study has been conducted on a Lockheed California Company Mach 2.55 supersonic cruise concept. The configuration is based upon late 1980's technology and features a variable geometry duct burning engine with a coannular nozzle mounted in an over/under wing arrangement for noise shielding. All input data were provided by the Lockheed California Company. The aircraft has a takeoff gross weight of 3268 kN (743,719 lbf) carrying 290 passengers over a 8890 km (4800 nautical mile) range.

The purpose of this study was to identify differences in jet noise levels and performance between Lockheed and NASA associated with methodology and groundrules. In addition, economic and noise information is provided consistent with a previous NASA study on an advanced technology Mach 2.7 configuration, reported separately.

The results of the present study indicate that the difference between NASA and Lockheed performance methodology is small. NASA computed range is 8843 km (4775 nautical miles). NASA calculates a 32.9 m (108 feet) higher initial climb path, due to differences in takeoff controlling logic. The climb altitude difference has a negligible effect on the noise controlling parameters. NASA calculates noise levels (no cutback and jet noise only) of 116.6 EPNdB, 112.4 EPNdB, and 100.9 EPNdB, for flyover, sideline and approach noise respectively compared to the corresponding Lockheed calculated noise levels (jet only) of 114.1 EPNdB, 110.8 EPNdB, and 101.7 EPNdB. It should be noted that NASA does not include any benefits for the over/under engine noise shielding. This factor account for in addition to the differences that result from the use of the ANOPP or the SAE jet noise prediction method, especially on landing approach account for the noise levels difference. Lockheed assumes benefits in flyover and approach noise of 3 db for shielding.

Resizing the Lockheed aircraft to NASA groundrules (Range of 8334 km (4500 nautical miles), payload = 273 passenger, etc.) results in small changes in flyover, sideline and approach noise levels. The resulting noise levels (jet only) for the resized aircraft with NASA groundrules for a maximum power takeoff with cutback at the flyover monitor are 110.5 EPNdB, 113.7 EPNdB, and 100.7 EPNdB. It should be pointed out that the effects of reducing jet velocity by oversizing and power cutback is quite sensitive to the assumptions used in estimating flight effects on noise. In addition to the above minimum weight aircraft, two additional aircraft have been generated with increased engine size to reduce noise. Since the critical noise monitoring station is at the sideline position for a maximum power takeoff, the large engine sizes increase sideline noise resulting in no reduction in <u>traded</u> noise at the power settings chosen for the study. There are, however, intermediate power settings that would permit somewhat lower traded noise, but these combinations were not evaluated in the present study. In terms of the <u>summated</u> noise level, the decreases in noise with engine size result in a 10 db reduction for an 8 percent increase in total operating cost. This corresponds to an average noise reduction of 3.3 EPNdB at the three observer positions.

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TABLE I. - REFERENCE CONFIGURATION CHARACTERISTICS, BASELINE CL1611-1

Technology level	Late 1980's
Design Mach number	2.55
Design range-km (n.mi.)	8890 (4800)
Structure concept	Far Term
TOGW - kN (lbf)	3268 (734 719)
Op. wt. Empty kN (lbf)	1223 (274 846)
Passengers	290
Wing planform	Arrow
Wing area - m^2 (ft^2)	775 (8340)
Wing span m (ft)	36.5 (119.8)
Takeoff W/S - Pa (psf)	4217 (88.1)
Engine cycle/number	P&WA VSCE 516L/4
Thrust/engine N (lbf)	228 760 (51430)
Takeoff T/W	.302
Takeoff airflow - kg/s (lbm/sec)	338 (745)
Engine location	Over/Under

TABLE II

LOCKHEED - NASA MISSION COMPARISON
TOGW = 3268 kN (734, 719 lbf)

Range, Km(n.mi.)	Lockheed	NASA	Δ
Climb	707 (382)	715 (386)	8 (4)
Cruise	7814 (4219)	7743 (4181)	-71 (-38)
Descent	369 (199)	385 (208)	16 (9)
Total	8890 (4800)	8843 (4775)	-47 (-25)
Fuel, Kg (lb)			
Takeoff Allowance	61 (13660)	61 (13660)	0 (0)
Climb	377 (84787)	370 (83148)	-7 (-1639)
Cruise	1122 (252234)	1114 (250509)	-8 (-1725)
Descent	16.9 (3815)	16.5 (3717)	-0.4 (-98)
Reserves	210 (47208)	(50,835)	16(3627)
Total	1787 (401,704)	1788 (401869)	1 (165)

TABLE III

EFFECT OF METHODOLOGY DIFFERENCES

Mission Parameters	Lockheed	NASA
Range Km (n.mi.)	8890 (4800)	8843 (4775)
Payload, Passengers	290	290
TOGW, kN (lbf)	3268 (734719)	3268 (734,719)
w/s Pa, (lb/ft^2)	4217 (88.1)	4217 (88.1)
T/W	.302	.302
Airflow, kg/sec (lb/sec)	338 (745)	338 (745)
Takeoff and Landing Parameter		
Takeoff Power, %	93	93
Takeoff Field Length, (ft)	3197 (10489)	3200 (10499)
V_{Jet} Climb duct/core, m/sec (ft/sec)	887/521 (2910/1710)	827/517 (2715/1696)
V_{Jet} Flyover duct/core, m/sec (ft/sec)	887/521 (2910/1710)	827/517 (2715/1696)
ALT, Flyover, m (ft)	388 (1272)	421 (1380)
$V_{Approach}$, m/sec	79.7	79.7
V_{Jet} Approach duct/core, m/sec (ft/sec)	386/254 (1265/835)	362/238 (1188/782)
Noise Parameter		
Source	Jet	Jet
Flyover (no cutback), EPNdB	114.1*	116.6
Sideline, EPNdB	110.8	112.4
Approach, EPNdB	101.7*	100.9

*Includes - 3 db Shielding

TABLE IV

EFFECT OF GROUNDRULE DIFFERENCES

Mission Parameters	NASA	NASA (Resized)
Range Km (n.mi.)	8843 (4775)	8334 (4500)
Payload, Passengers	290	273
TOGW, kN (lbf)	3268 (734 719)	2891 (650,000)
w/s Pa, (lbf/ft^2)	4217 (88.1)	3754 (78.4)
T/W	.302	.310
Airflow, kg/sec (lb/sec)	338 (745)	308 (678)
Takeoff and Landing Parameter		
Takeoff Power, %	93	100
Takeoff Field Length, m(ft)	3200 (10499)	2404 (7888)
V_{Jet} Climb duct/core m/sec (ft/sec)	827/517 (2715)/(1696)	885/553 (2903)/(1815)
V_{Jet} Flyover duct/core m/sec (ft/sec)	827/517 (2715)/(1696)	685/427 (2248)/(1400)
ALT Flyover, m (ft)	421 (1380)	563 (1847)
$V_{Approach}$, m/sec,	79.8	77.7
V_{Jet} Approach duct/core, m/sec (ft/sec)	362/238 (1188)/(782)	361/238 (1185)/(781)
Noise Parameter		
Suppression	NONE	NONE
Flyover, EPNdB	116.6*	110.5
Sideline, EPNdB	112.4	113.7
Approach, EPNdB	100.9	100.7

*No Cutback

NASA/LOCKHEED COMPARISON STUDY SUMMARY
MACH 2.55 DESIGN - P&W 516L

Org.	Range/Payload Km (NM)	Pass.	TOGW kN (lbf)	$\frac{W}{S}$ Pa (lb/ft2)	T/W	Takeoff	NOISE (EPNdB) Flyover	Sideline	Approach	ICAO RULES - 60% DOC ¢ Seat-Stmi	TOC Seat-Stmi
Lockheed	8890 (4800)	290	333268 (734719)	4217 (88.1)	.302	93%	114.1*	110.8	101.7		
(NASA/Lockheed	8334 (4500)	273	2891 (650000)	3754 (78.4)	.310	100%	110.5	113.7	100.7	2.202	3.708
(NASA/Lockheed	8334 (4500)	273	3002 (675000)	3754 (78.4)	.36	100%	106.5	114.3	99.1	2.273	3.809
(NASA/Lockheed	8334 (4500)	273	3225 (725000)	3754 (78.4)	.41	100%	104.0	113.9	97.6	2.429	4.018

*No Cutback

NASA-Langley Form 10 (AUG 1969)

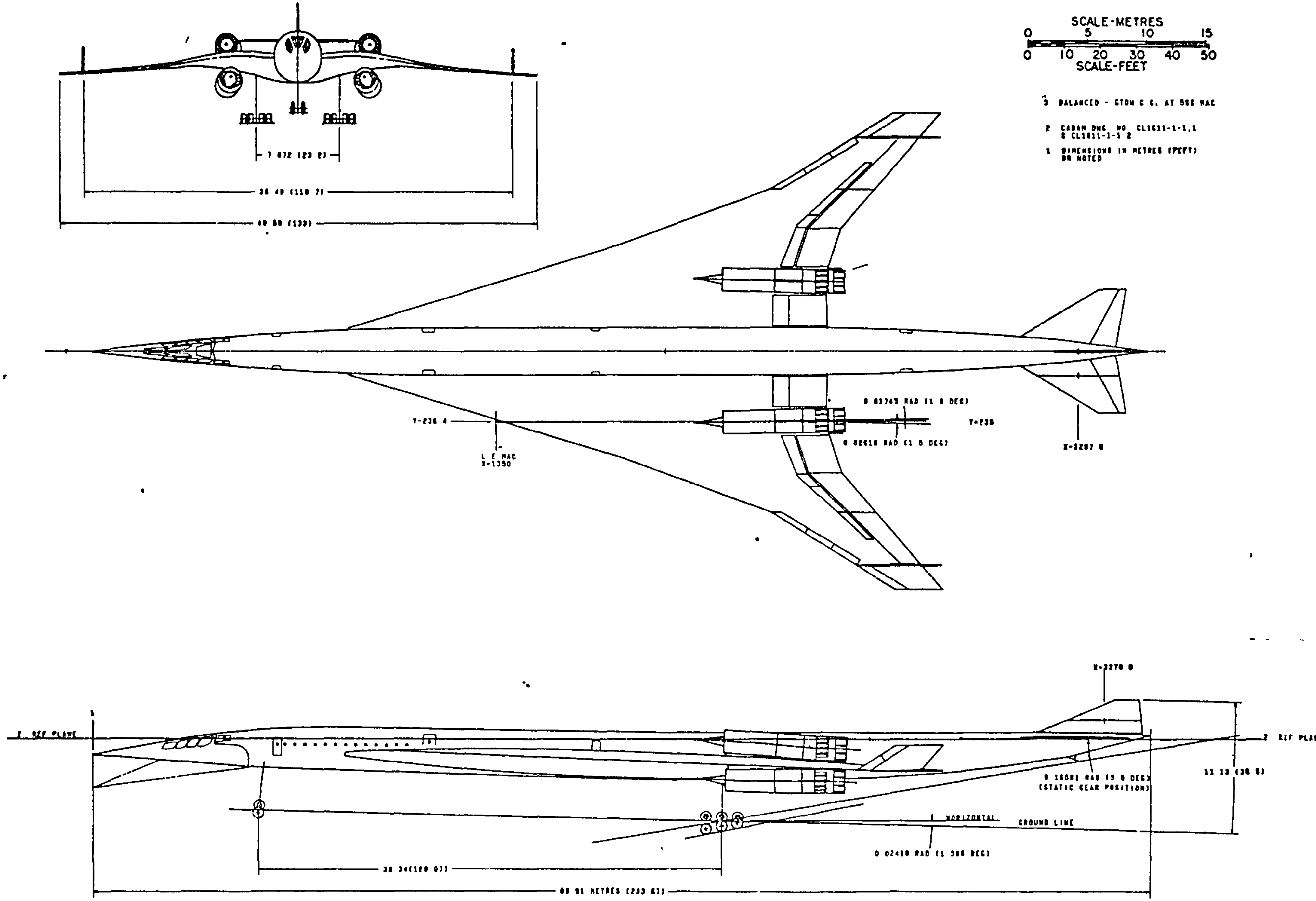

Figure 1 - General arrangement baseline CL1611-1

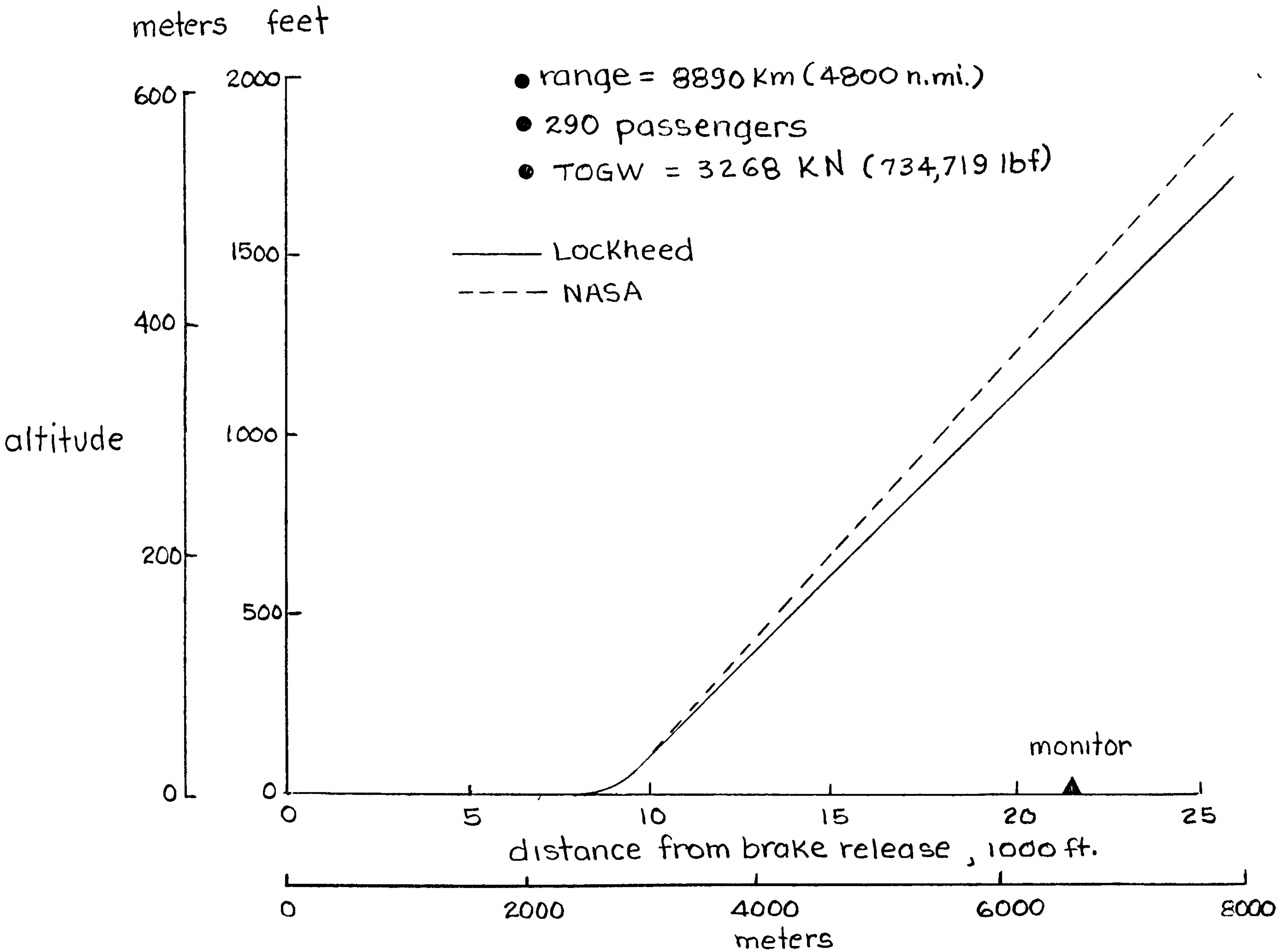

Figure 2 - Climb path comparisons.

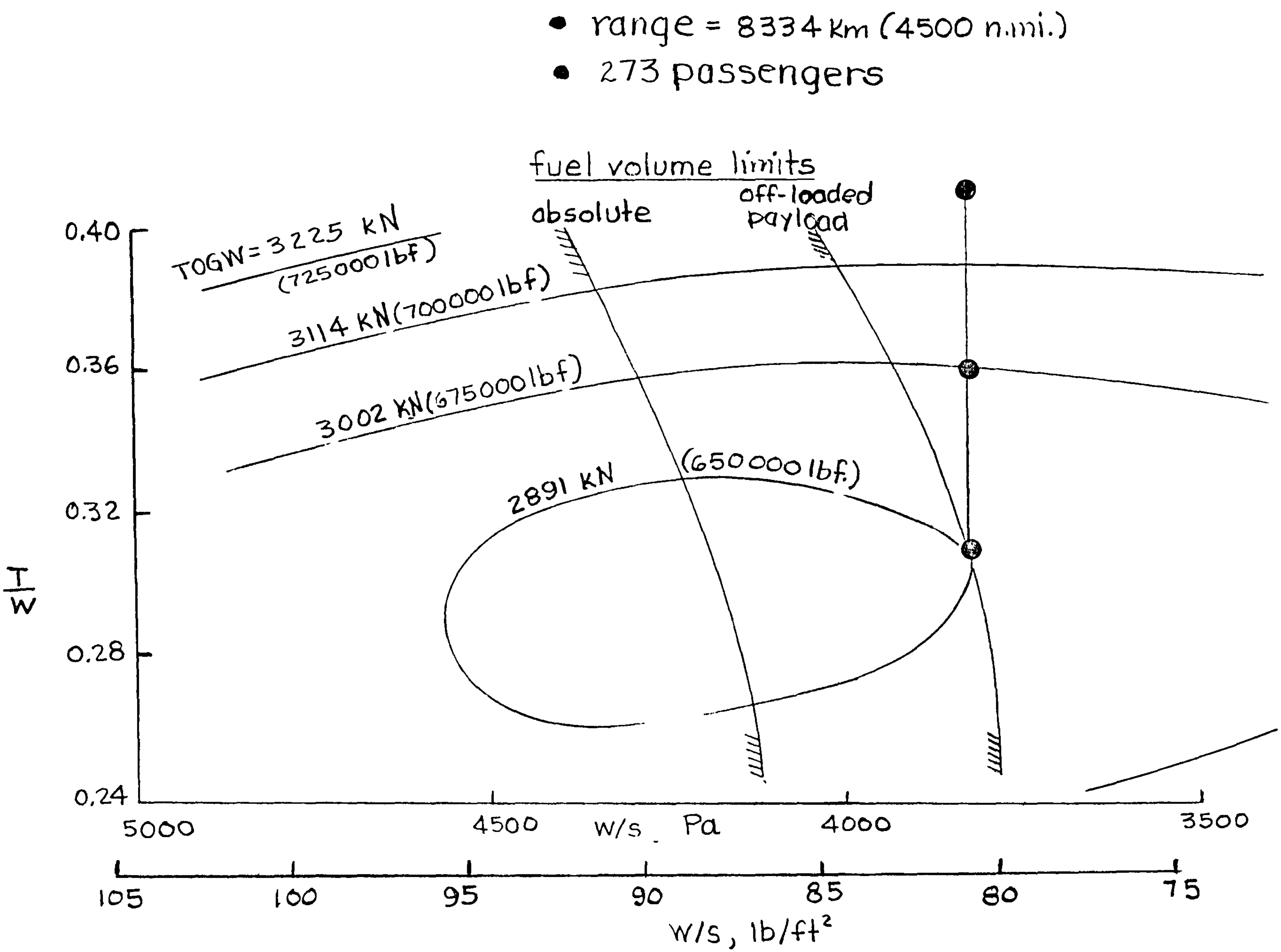

Figure 3. - Aircraft sizing chart for Lockheed Mach 2.55 with P&W 516L VCE.

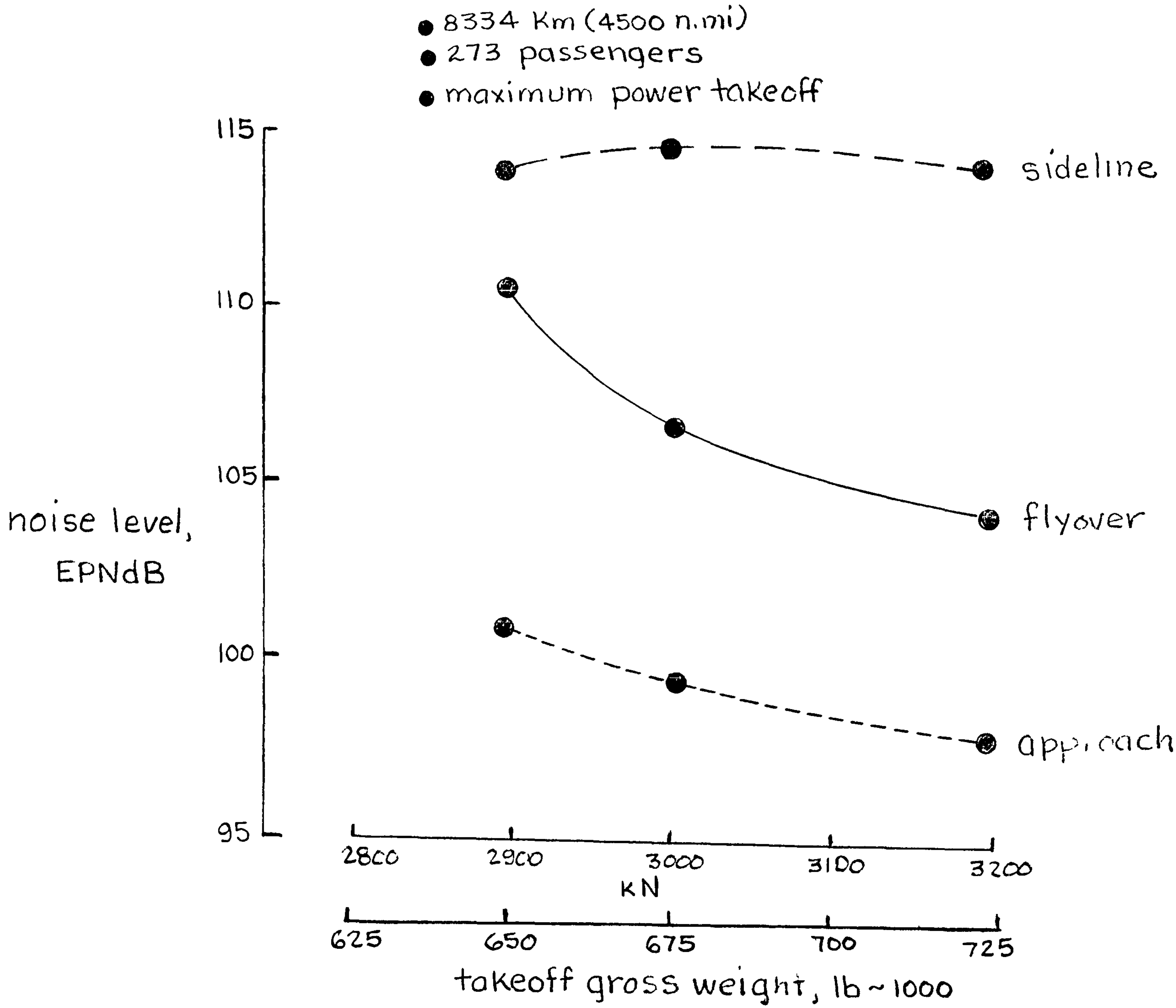

Figure 4.- Effect of engine oversizing on noise - Lockheed Mach 2.55 airplane with P&W 516L VCE.

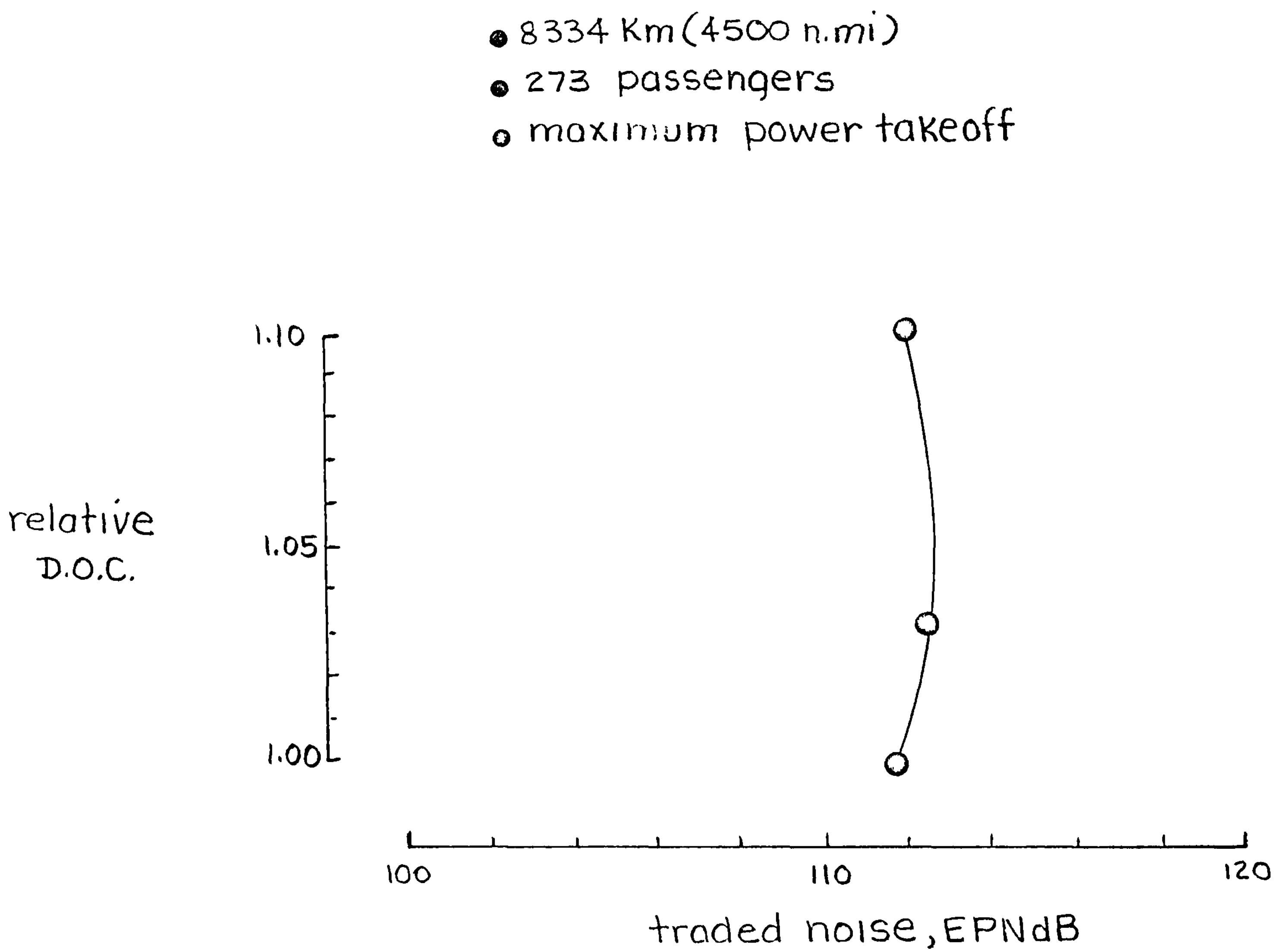

Figure 5.- Effect of traded noise on direct operating cost - Lockheed Mach 2.55 airplane with P&W 516L VCE.

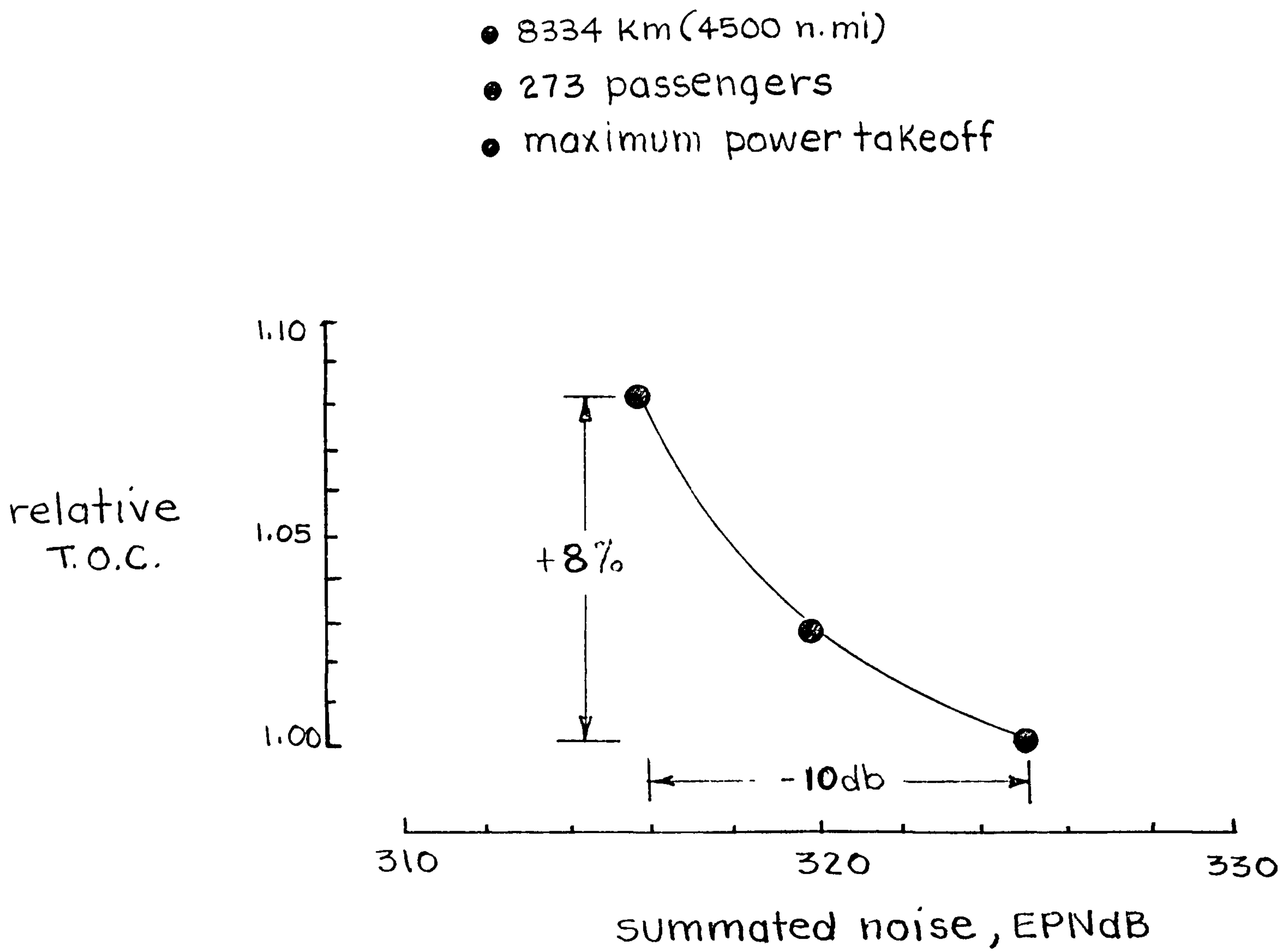

Figure 6.- Effect of summated noise on total operating cost - Lockheed Mach 2.55 airplane with P&W 516 L VCE.

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16 Abstract

A noise and performance comparison study has been conducted on a Lockheed California Company Mach 2.55 supersonic cruise concept employing a post 1985 technology level, variable cycle engine. All input data was provided by Lockheed California Company. The objective of this study was to identify differences in noise levels and performance between Lockheed and NASA associated with methodology and groundrules. In addition, economic and noise information is provided consistent with a previous study based on an advanced technology Mach 2.7 configuration, reported separately.

The results of the present study indicate that the difference between NASA and Lockheed performance methodology is small. Resizing the Lockheed aircraft to NASA groundrules also results in small changes in flyover, sideline and approach noise levels. For the power setting chosen, engine oversizing resulted in no reduction in traded noise. In terms of summated noise level, a 10 EPNdB reduction is realized for an 8 percent increase in total operating costs. This corresponds to an average noise reduction of 3.3 EPNdB at the three observer positions.

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