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NOISE AND PERFORMANCE CALIBRATION STUDY OF A MACH 2.2 SUPERSONIC CRUISE AIRCRAFT

STAFF OF THE LANGLEY RESEARCH CENTER

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16 Abstract

A noise and performance calibration study has been conducted on a McDonnell-Douglas Corporation Mach 2.2 supersonic cruise concept employing a 1980 - 1985 technology level, dry turbojet, mechanically suppressed engine. All input data was provided by McDonnell Douglas Corporation. The objective of this study was to identify differences in noise levels and performance between Douglas 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 Douglas performance methodology is small. Resizing the Douglas aircraft to NASA groundrules results in negligible changes in takeoff noise levels (less than 1 EPNdB) but approach noise is reduced by 5.3 EPNdB as a result of increasing approach speed. For the power setting chosen, engine oversizing resulted in no reduction in traded noise. In terms of summated noise level, a 6 EPNdB reduction is realized for a 5% increase in total operating costs.

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TABLE OF CONTENTS

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EXECUTIVE SUMMARY

A noise and performance calibration study has been conducted on a McDonnell-Douglas Corporation Mach 2.2 supersonic cruise concept employing a 1980-1985 technology level, dry turbojet, mechanically suppressed engine. All input data was provided by McDonnell-Douglas Corporation. As a design constraint, Douglas quoted nominal noise levels of 108 EPNdB, 106 EPNdB, and 108 EPNdB, at the flyover, sideline, and approach measuring stations, respectively. The aircraft has a takeoff gross weight of 323,000 kg (712,000 lbs) carrying 250 passengers over a 7408 km (4000 n.mi.) range. The predicted noise levels were considered optimistic by Douglas since no tolerance on design margins were included.

The object of this study was to identify differences in noise levels and performance between Douglas and NASA associated with methodology and groundrules. In addition, economic and noise information is provided consistant 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 Douglas performance methodology is small. NASA computed range is 7402 km (3997 n.mi.). NASA calculates a 30.5 m (100 feet) higher initial climb path, due to differences in takeoff controlling logic. The climb altitude differences has a negligible effect on the noise controlling parameters. Using the Douglas Mechanical suppressor attenuation, NASA calculates noise levels of 109.5 EPNdB, 112 EPNdB, 107.9 EPNdB, for flyover, sideline and approach noise respectively compared to the corresponding Douglas calculated noise levels of 108 EPNdB, 106 EPNdB, and 108 EPNdB. It should be noted that NASA does not include any benefits for lateral noise attenuation (LNA) and exhaust shaping, both of which may account for the difference in sideline noise. LNA includes extra ground attenuation and shielding. In a second evaluation; which used the mechanical suppressor attenuations of a previous NASA study rather than the Douglas valves, the noise levels in flyover and sideline increase by 2.1 db and 3.8 db respectively to 111.6 EPNdB and 115.8 EPNdB.

Resizing the Douglas aircraft to NASA groundrules (Range = 8334 km (4500 n.mi.), payload = 273 passenger, etc.) results in negligible changes in takeoff

noise level (less than 1 EPNdB). Approach noise is reduced by 5.3 db as a result of increasing approach speed from 141 knots to 155 knots. The resulting noise levels for the resized aircraft with NASA groundrules for a maximum power takeoff with cutback at the flyover monitor are 110.7 EPNdB, 115.8 EPNdB, and 102.6 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 larger engine sizes increase sideline noise resulting in no reduction in traded noise at the power settings chosen for this study. There are, however, intermediate power settings that would permit somewhat lower traded noise but these combinations were not generated in the present study. In terms of summated noise level, the decreases in flyover and approach noise with engine size result in a 6 db reduction for a 5 percent increase in total operating costs.

INTRODUCTION

International studies are underway within the framework of the International Civil Aviation Organization (ICAO) to establish certification noise rules for supersonic cruise aircraft. In support of this effort, the FAA, Office of Environmental Quality, which heads the U.S. delegation with the ICAO Committee on Aircraft Noise, requested NASA, early in 1977, to conduct a noise sensitivity study applicable to future supersonic cruise aircraft. Accordingly, NASA, through its 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 consistant 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, industry conducted independent studies (refs. 2-6) on their individual study configurations which have been generated as a result of NASA's Supersonic Cruise Research Program (SCR). Comparisons of the results of 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 calibration of the McDonnell Douglas Corporation baseline configuration (ref. 5). The configuration is a Mach 2.2 design supersonic cruise vehicle incorporating CLASS II (1980-1985 technology) dry turbojet engines with mechanical suppressors. The calibration process is conducted in three steps. First, using all Douglas configuration characteristics and groundrules, calculating performance and noise levels by both Langley and Douglas methods will provide the difference due to methodology. Second, resizing to the NASA (ref. 1) design parameters - range = 8334 km (4500 n.mi.), payload - 273 passengers -takeoff field length = 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 manually 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 Program

The aircraft sizing program (ref. 7) determines the effects of aerodynamics, weight, 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 standard day 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 FAR Part 25 safety requirements. The program was developed for detailed analysis of specific aircraft designs. Takeoff profiles are generated by step-wise 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 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. In the present studies, only the jet mixing noise module was utilized.

Atmospheric attenuation of the sound was predicted using the proposed 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. Sideline engine noise shielding is not included in the case reported here, because with the configurations engine arrangement, ANOPP assumes that engine noise shielding would occur in a narrow shadow zone (from 0° to about 11° from the wing plane), based on simple geometry, and the maximum sideline perceived noise typically occurs in the range of 10° to 30° from the wing plane.

Economics Methodology

The Sub-group for Economics to the 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 Operation Cost (TOC) computed in 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 operations 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 SCR 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 ATA method was adopted by the WG/E. It represents the EURAC method and contains a supersonic factor 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% of A/C plus spares cost; Insurance is 1 percent of average cost (1/2 percent of new cost); Interest is 5 percent a/c new cost (10 percent of average cost); Labor rate is $9/hr; Overhead is 2 times Labor rate; Ground maneuver time is 10 min/flight; Payload is 60 percent load factor at 209 #/passenger. Configuration is all tourist, no cargo, no subsonic cruise leg; cabin attendants assigned at 1/35 seats; Fuel is $0.50 U. S. gallon (6.7 lb) 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 maintenance 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. 5), designated the baseline D3230-2.2-5S, is designed for long-range supersonic cruise at Mach 2.2 on a standard day for a distance of 7408 km (4000 n.mi.). The maximum takeoff gross weight is 323,000 kg (712,100 lbm). A two class (1/3 first class, 2/3 economy), single aisle cabin with four and five abreast seating accommodates 250 passengers. The airplane features a highly-swept modified arrow wing planform with under wing nacelles that contain dry turbojet powerplants with mechanical suppressors, wing leading and trailing edge high-lift devices combined with aft mounted horizontal tail, and near term technology structural concepts. The general arrangement of the baseline D3230-2.2-5S is presented in figure 1, and a summary of its primary characteristics is shown is table I.

Wing loading and thrust/weight ratio are chosen to produce a configuration of minimum weight to meet the FAR 36 (Stage 2), noise constraints. A wing loading of 3409 N/M^2 (71.2 psf) at takeoff results in a wing area of 929 m^2 (10000 ft^2). Wing aspect ratio is 1.84. The wing is cambered to provide improved cruise lift/drag ratio by improving the load distribution to minimize drag due to lift and trim drag.

Four McDonnell-Douglas defined dry turbojet engines, based on the GE4 cycle of the 1971 U.S. SST, are located in an under the wing in single nacelles. The GE4 engine was designed and tested during the former U.S. SST program. The engine weights and performance are updated to reflect the propulsion technology predicted to be available for a 1980-1985 technology readiness date. Each engine incorporates an axisymmetric mixed compression inlet and a mechanical exhaust suppressor/ejector. The four dry turbojet engines have a nominal uninstalled sea level static thrust of 285.9 kN (64,280 lb.) each, at standard day takeoff conditions. The airflow at takeoff is 318 kg/sec (700 lbm/sec).

The airframe structure is of all metal construction based on optimized structural parameters (strength, fatigue, fail-safe, aeroelastics, and flutter) consisting of 64 percent titanium, 27 percent aluminum and 9 percent steel (landing gear and propulsion system). The fuselage is assumed to be titanium and of conventional skin and stringer construction.

The wing structure is a multispar construction and consists of a main torque box and forward box separated by the main landing gear bays. Wing skins are of titanium sandwich construction, providing high structural efficiency and fuel tank insulation properties. The major wing structure is aluminum brazed titanium honeycomb panels over titanium spars and ribs. Wing leading and trailing edges are of aluminum.

The fuselage is assumed to be titanium and of conventional skin and stringer contruction. It also contains aluminum for the low temperature lightly loaded inner frames and/or other secondary structure such as floor beams. Engine/airframe integration is achieved by the use of a structural nacelle concept, the upper segment composed of semi-hoop frames skinned with titanium/honeycomb panels.

ANALYSIS OF RESULTS

Calculations of noise are presented herein for the FAR 36 (stage 2) noise certification locations: centerline at 6482 m (3.5 n.mi.) from brake release, sideline at 648 m (0.35 n.mi.) at the point where the noise is the greatest, and in approach at 1852 m (1 n.mi.) from touchdown. Results are presented for a V_2 + 10 knots 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 5944 m (19500 ft) from brake release except where limited by the 213 m (700 ft) altitude restriction.

Effect of Methodology Differences

The configuration described in the previous section and input data provided by Douglas, have been used exclusively in this study. This data included trimmed drag polars throughout the operating Mach number and altitude range. Dry turbojet engine data consists of fuel flow versus thrust as a function of Mach number and altitude. Installed engine performance is based upon a Douglas mixed compression inlet with bleed, spillage and bypass drag included.

The input data was used in the aircraft sizing and performance program (ref. 7) and range computed based upon the weight statement provided by Douglas. The difference in range is 5.6 km (3 n.mi.) as shown in Table II together with a breakdown of fuel burned in each mission segment.

The difference in NASA and Douglas climb paths for takeoff are shown in figure 2. The difference in initial climb is due to different controlling logic. Douglas climb path is controlled by a constant tangential acceleration rate. The NASA climb path is controlled by maintaining floor angle constant.

The difference in climb paths have 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 Douglas quoted results. Sideline noise levels from Douglas include allowances for lateral noise atte-

Effect of Groundrule Difference

The reference aircraft 323000 kg (712000 lbs) has been resized to the design groundrules used in the previous NASA study (ref. 1), namely; range = 8334 km (4500 n.mi.), payload = 273 passengers, takeoff field length not to exceed 3810 m (12500 ft). During the resizing, the following changes, including those recommended by the McDonnell Douglas Corporation, were incorporated:

- o No thrust losses due to the acoustic lining in the ejector were included
- o Reduced operating empty weights (controlled by contractor scaling equation) to reflect the use of composites in the secondary structure
- o Takeoff power changed from 98 percent to 100 percent
- o Cutback thrust determination change from four engine gradient of .04 to 3 engine gradient of 0.0
- o Corrected for altitude effects on skin friction during cruise and descent
- o Reserve trip fuel allowance changed from 7 percent to 5 percent
- o Alternate airport distance changed from 371 km (200 n.mi.) to 463 km (250 n.mi.)
- o Approach velocity changed from 141 knots to 155 knots.

The effect of the above changes in groundrules is shown in Table IV. Note that the increased range and passenger load results in a relatively small increase in aircraft gross weight. This is due to the first two of the above recommended changes.

The difference in takeoff noise levels are small reflecting slight changes in flight parameters. However, the approach noise is reduced by 5.3 EPNdB. The lower jet velocity in approach results from the groundrule increase in approach speed to 155 knots. Since both aircraft have approximately the same approach wing loading, the decreased lift coefficients results in a higher lift-drag ratio and a reduced power setting.

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 require 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 range = 8334 km (4500 n.mi.) is shown in figure 3. The lowest weight aircraft or global optimum indicated by the lowest blocked-in circle 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 in this case requires that the wing be large enough to house sufficient fuel so that the entire payload could be off-loaded and replaced with fuel. The absolute limit line on figure 3 relates to the condition where the aircraft is provided with only enough volume to carry the full payload to the design range (i.e. payload cannot 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 for the two operating procedures. The results are shown in figures 4 and 5 for maximum power and derated power takeoffs, respectively. In figure 4, the decrease in flyover noise is due to increasing altitude over the flyover monitor (588 m to 957 m., 1929 ft to 3141 ft.). The high levels of mechanically suppressed sideline noise are due to the high jet velocities prior to cutback (937 m/sec - 940 m/sec, 3075 ft/sec - 3086 ft/sec.). Approach noise decreases with engine oversizing due to matching at a lower part power throttle position. Since the noise prediction includes jet mixing noise only, the low values of approach noise should be viewed with caution, since other sources such as core, turbine, compresor and airframe noise, may become significant contributors.

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.

Operating the airplanes at derated throttle conditions (fig. 5), show that the flyover and sideline noise levels reverse. Sideline noise is reduced due to lower jet velocities in climb of 796 m/sec - 727 m/sec (2613 -2386 ft/sec.). However, altitudes over the flyover monitor are approximately 213 m (700 feet) (which indicates that the thrust was derated too much), providing small noise reduction due to power cutback, since the aircraft are at or beyond the monitor at cutback. It should be pointed out that the effect of reducing jet velocity by oversizing and cutback is quite sensitive to the assumptions employed in estimating flight effects on noise.

Economic characteristics have been computed for the three aircraft using ICAO groundrules; i.e. fuel price = 50¢/gal, load factor = 60 percent. Configuration results are shown in Table V which is the ICAO standard results format. The cost/noise sensitivity is shown in figure 6 and 7. Relative Direct Operating Costs are shown versus traded noise in figure 6 for both maximum power takeoff and derated 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 settings chosen. There are, however, intermediate power settings between the maximum and minimum 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 7. Relative total operating cost 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 6 db are available for increases in total operating costs of 5%.

CONCLUSIONS

A noise and performance calibration study has been conducted on a McDonnell-Douglas Corporation Mach 2.2 supersonic cruise concept employing a 1980-1985 technology level, dry turbojet, mechanically suppressed engine. All input data was provided by McDonnell-Douglas Corporation. As a design constraint, Douglas quoted nominal noise levels of 108 EPNdB, 106 EPNdB, and 108 EPNdB, at the flyover, sideline, and approach measuring stations, respectively. The aircraft has a takeoff gross weight of 323000 kg (712,000 lbs) carrying 250 passengers over a 7408 km (4000 n.mi.) range. The predicted noise levels were considered optimistic by Douglas since no tolerance on design margins were included.

The object of this study was to identify differences in noise levels and performance between Douglas and NASA associated with methodology and groundrules. In addition, economic and noise information is provided consistant 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 Douglas performance methodology is small. NASA computed range is 7402 km (3997 n.mi.). NASA calculates a 30.5 m (100 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. Using the Douglas mechanical suppressor attenuation, NASA calculates noise levels of 109.5, 112, 107.9, for flyover, sideline and approach noise respectively compared to the corresponding Douglas calculated noise levels of 108 EPNdb, 106 EPNdB, and 108 EPNdB. Douglas includes allowances in sideline noise for lateral noise attenuation (LNA) and exhaust jet shaping, which may account for the difference sideline noise. Using the mechanical suppressor attenuation of the previous NASA study, the noise levels in flyover and sideline increase by 2.1 db and 3.8 db respectively.

Resizing the Douglas aircraft to NASA groundrules (Range = 8344 km (4500 n.mi.), payload - 273 passenger, etc.) results in negligible changes in takeoff noise level (less than 1 EPNdB). Approach noise is reduced by 5.3 EPNdB as a result of increasing approach speed from 141 knots to 155 knots. The resulting noise levels for the resized aircraft with NASA groundrules for a maximum power takeoff with cutback at the flyover monitor are 110.7, 115.8, and 102.6. 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.

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TABLE I. - REFERENCE CONFIGURATION CHARACTERISTICS, BASELINE D3230-2.2-5S

Technology level	Early 1980's
Design Mach number	2.2
Design range - Km (n.mi.)	7408 (4000)
Structural concept	Near term
TOGW - Kg (lbm)	323,000 (712,100)
Op. wt. empty - Kg (lbm)	136,218 (300,304)
Passengers	250
Wing planform	Modified arrow
Wing area -m^2 (ft^2)	929 (10,000)
Wing span - m (ft)	41.3 (135.5)
Takeoff W/S - N/M^2 (psf)	3409 (71.2)
Engine cycle/number	MDC modified GE4 dry turbojet/4
Thrust/engine - N (lbf)	285,917 (64,280)
Takeoff T/W	0.340
Takeoff airflow - Kg/s (lbm/sec)	318 (700)
Engine location	Under wing

TABLE II

DOUGLAS - NASA MISSION COMPARISON

TOGW = 323,000 KG (712000 LBS.)

	DOUGLAS	NASA	Δ
RANGE, KM (N.MI.)			
CLIMB	923 (498)	917 (495)	-5.6 (-3)
CRUISE	6104 (3294)	6081 (3282)	-22.2 (-12)
DESCENT	385 (208)	408 (220)	22.2 (12)
TOTAL	7412 (4000)	7406 (3997)	-5.6 (-3)
FUEL, KG (LB.)			
TAKEOFF ALLOWANCE	2722 (6,000)	2722 (6,000)	0 (0)
CLIMB	38341 (84,514)	38517 (84,904)	176.9 (390)
CRUISE	89503 (197,291)	88983 (196,145)	-519.9 (-1,146)
DESCENT	3320 (7,318)	3359 (7,404)	39.0 (86)
RESERVES	28866 (63,630)	29170 (64,299)	303.5 (669)
TOTAL	162752 (358,753)	162751 (358752)	-.5 (-1)

EFFECT OF METHODOLOGY DIFFERENCES

MISSION PARAMETERS	DOUGLAS	NASA
RANGE Km (n.mi.)	7412 (4000)	7406 (3997)
PAYLOAD, PASSENGERS	250	250
TOGW, Kg (lbs.)	323,000 (712000)	323,000 (712000)
w/s N/m^2, (lb/ft^2)	3437 (71.8)	3437 (71.8)
T/W	.315	.315
AIRFLOW, kg/sec (lb/sec.)	317.5 (700)	317.5 (700)
TAKEOFF AND LANDING PARAMETER		
TAKEOFF POWER, %	98	98
TAKEOFF FIELD LENGTH, (FT.)	2306 (7567)	2248 (7375)
V_{JET} CLIMB, m/sec. (ft/sec)	919 (3017)	922 (3024)
V_{JET} FLYOVER, m/sec (ft/sec)	756 (2480)	755 (2478)
ALT. FLYOVER, m (ft.)	602 (1974)	604 (1982)
$V_{APPROACH}$, KNOTS	141	141
V_{JET} APPROACH, m/sec (ft/sec)	N.A.	375 (1231)

NOISE PARAMETER

SUPPRESSION	DOUGLAS	DOUGLAS	NASA/DOUGLAS
FLYOVER, EDNdB	108	109.5	111.6
SIDELINE, EPNdB	106*	112.0	115.8
APPROACH, EPNdB	108	107.9	107.9

* INCLUDES LATERAL NOISE ATTENUATION AND EXHAUST SHAPING

EFFECT OF GROUNDRULE DIFFERENCES

MISSION PARAMETERS	NASA	NASA (RESIZED)
RANGE Km (n.mi.)	7406 (3997)	8334 (4500)
PAYLOAD, PASSENGERS	250	273
TOGW, Kg (lbs.)	323,000 (712000)	338230 (745570)
w/s N/m^2, (lb/ft^2)	3437 (71.8)	3437 (71.8)
T/W	.315	.310
AIRFLOW, kg/sec (lb/sec.)	317.5 (700)	321.6 (709)
TAKEOFF AND LANDING PARAMETER		
TAKEOFF POWER, %	98	100
TAKEOFF FIELD LENGTH, m (ft.)	2248 (7375)	2650 (8693)
V_{JET} CLIMB, m/sec. (ft/sec)	922 (3024)	937 (3075)
V_{JET} FLYOVER, m/sec (ft/sec)	755 (2478)	748 (2454)
ALT. FLYOVER, m (ft.)	604 (1982)	616.6 (2023)
$V_{APPROACH}$, KNOTS	141	155
V_{JET} APPROACH, m/sec (ft/sec)	375 (1231)	331 (1087)
NOISE PARAMETER		
SUPPRESSION	NASA/DOUGLAS	NASA/DOUGLAS
FLYOVER, EPNdB	111.6	110.9
SIDELINE, EPNdB	115.8	115.8
APPROACH, EPNdB	107.9	102.6

MACH 2.2 DESIGN - DOUGLAS/GE4 TURBOJET

DOUGLAS MECHANICAL SUPPRESSOR

Org.	Range/Payload Km (NM_F)/Pass.	TOGW Kg (lbn)	$\frac{W}{S}$ N/M^2 (lb/ft^2) T/W	Takeoff Thrust,%	NOISE (EPNdB) Flyover	Sideline	Approach	ICAO RULES DOC ¢ Seat-Stmi	TOC Seat-Stmi
DOUGLAS	7412 (4000)/250	323,000 (712 000)	3437 (71.8) .315	98%	108	106	108	2.895*	4.739*
NASA/DOUGLAS	8334 (4500)/273	338,230 (745 570	3437 (71.8) .310	100%	110.9	115.8	102.6	2.591	4.276
				72%	118.7	110.6	102.6		
NASA/DOUDLAS	8334 (4500)/273	344,980 (760,452	3437 (71.8) .346	100%	108.4	116.6	100.9	2.628	4.337
				65%	118.0	109.7	100.9		
NASA/DOUGLAS	8334 (4500)/273	360,500 (794,664)	3437 (71.8) .380	100%	107.2	116.9	99.1	2.744	4.497
				59%	118.8	109.8	99.1		

* NASA CALCULATIONS

NASA-Langley Form 10 (AUG 1969)

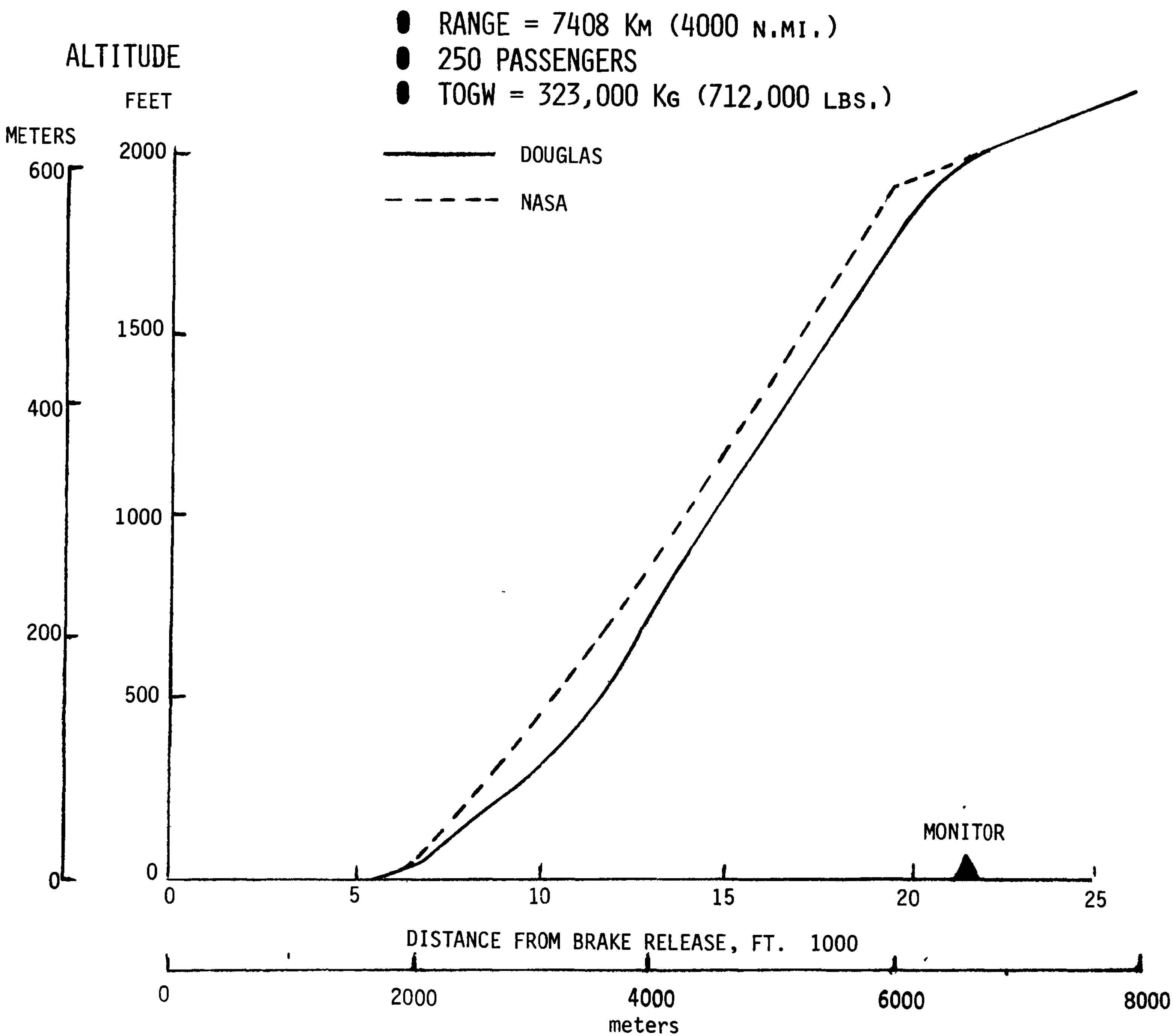

Figure 2. - Climb Path Comparison

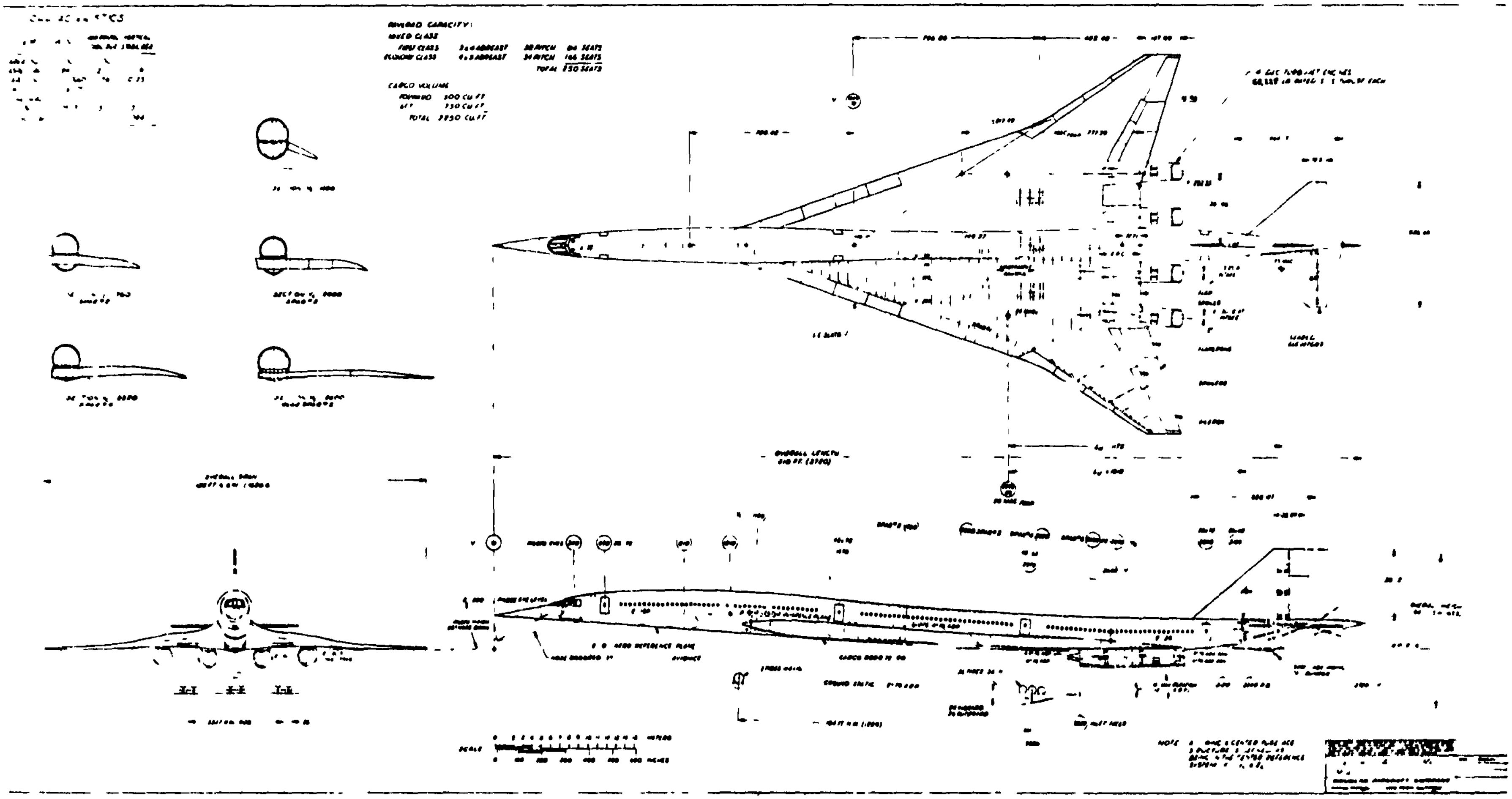

FIGURE 1 GENERAL ARRANGEMENT

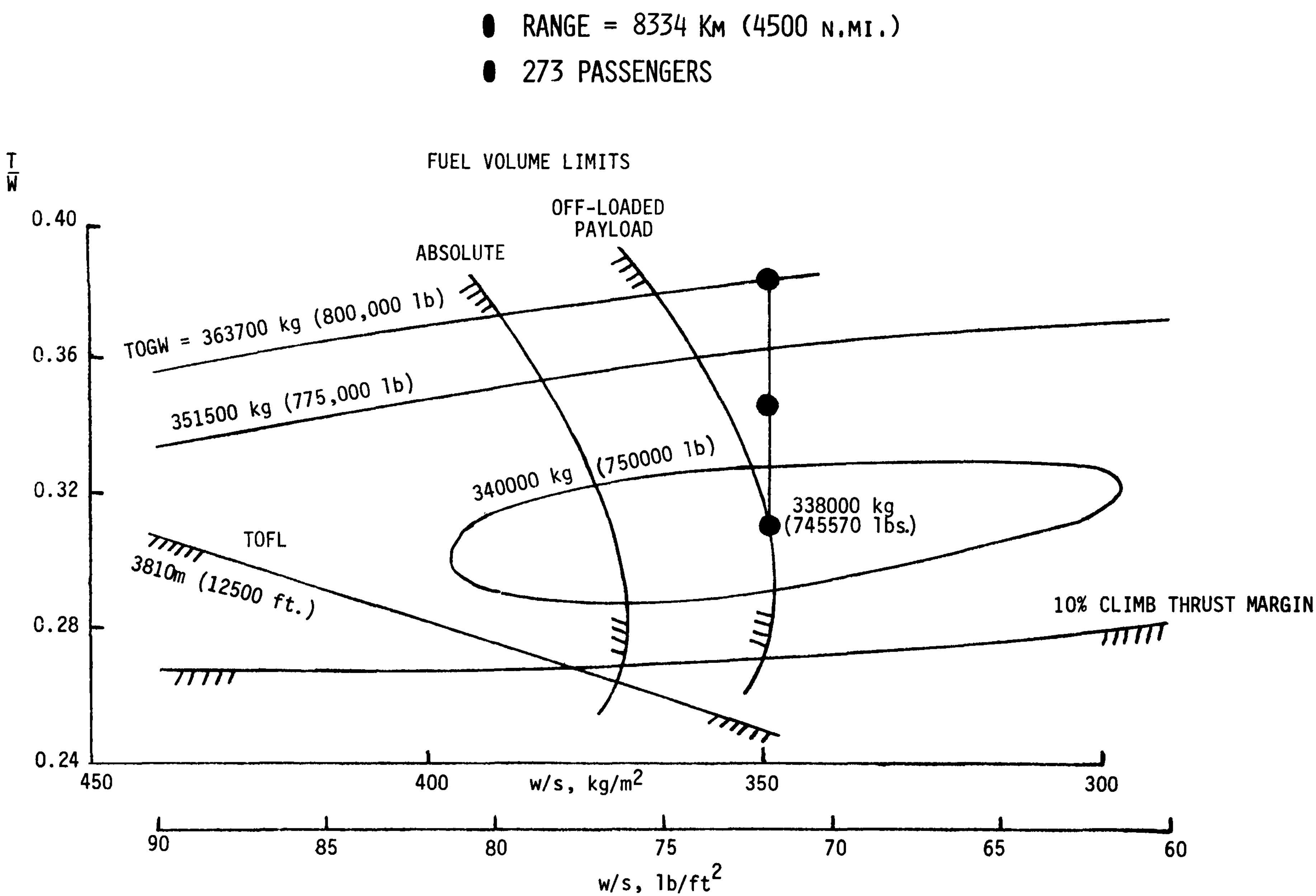

Figure 3. - Aircraft sizing chart for Douglas Mach 2.2 mechanically suppressed turbojet engine

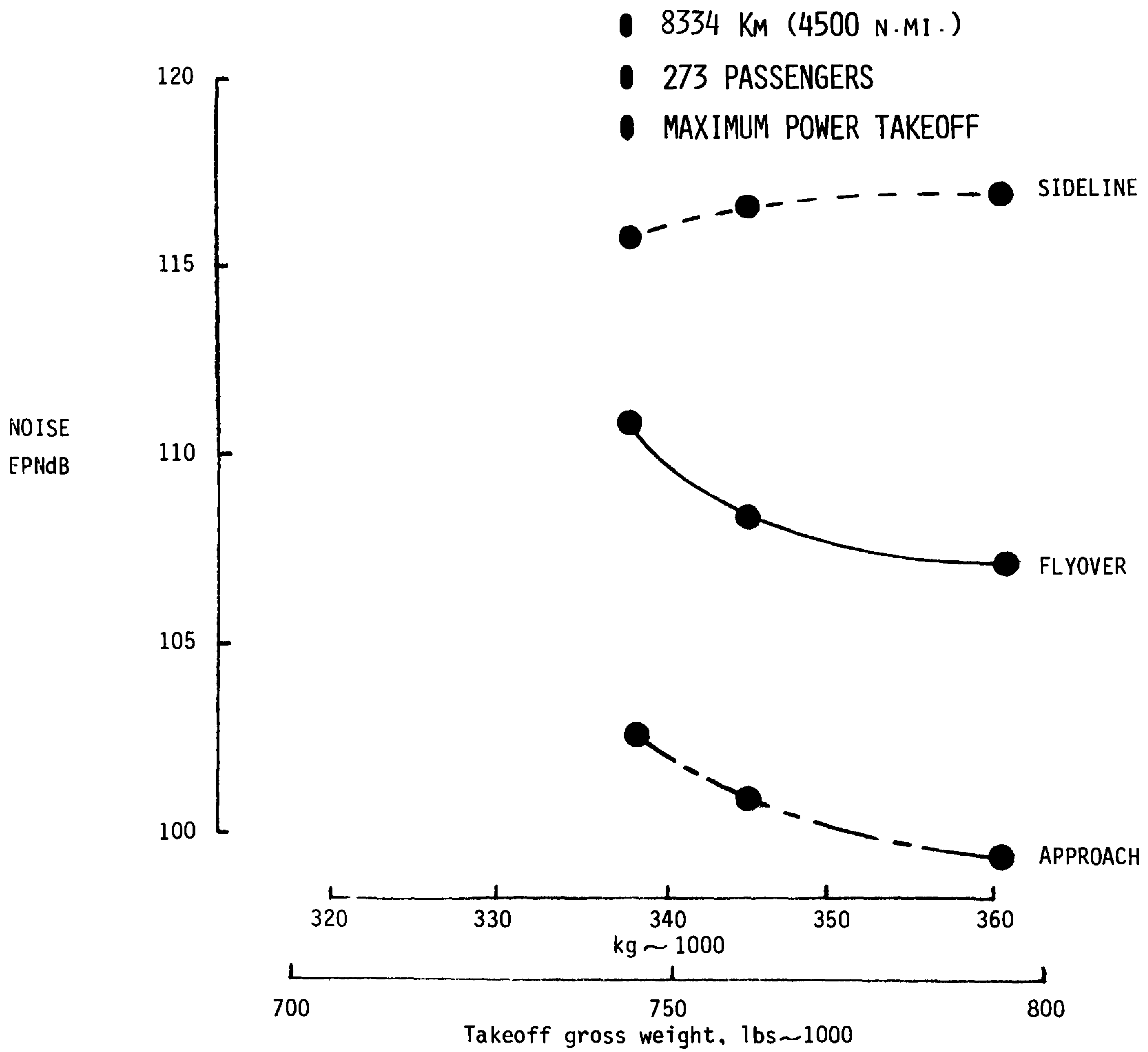

Figure 4. - Effect of engine oversizing on noise - Douglas Mach 2.2 mechanically suppressed turbojet engine.

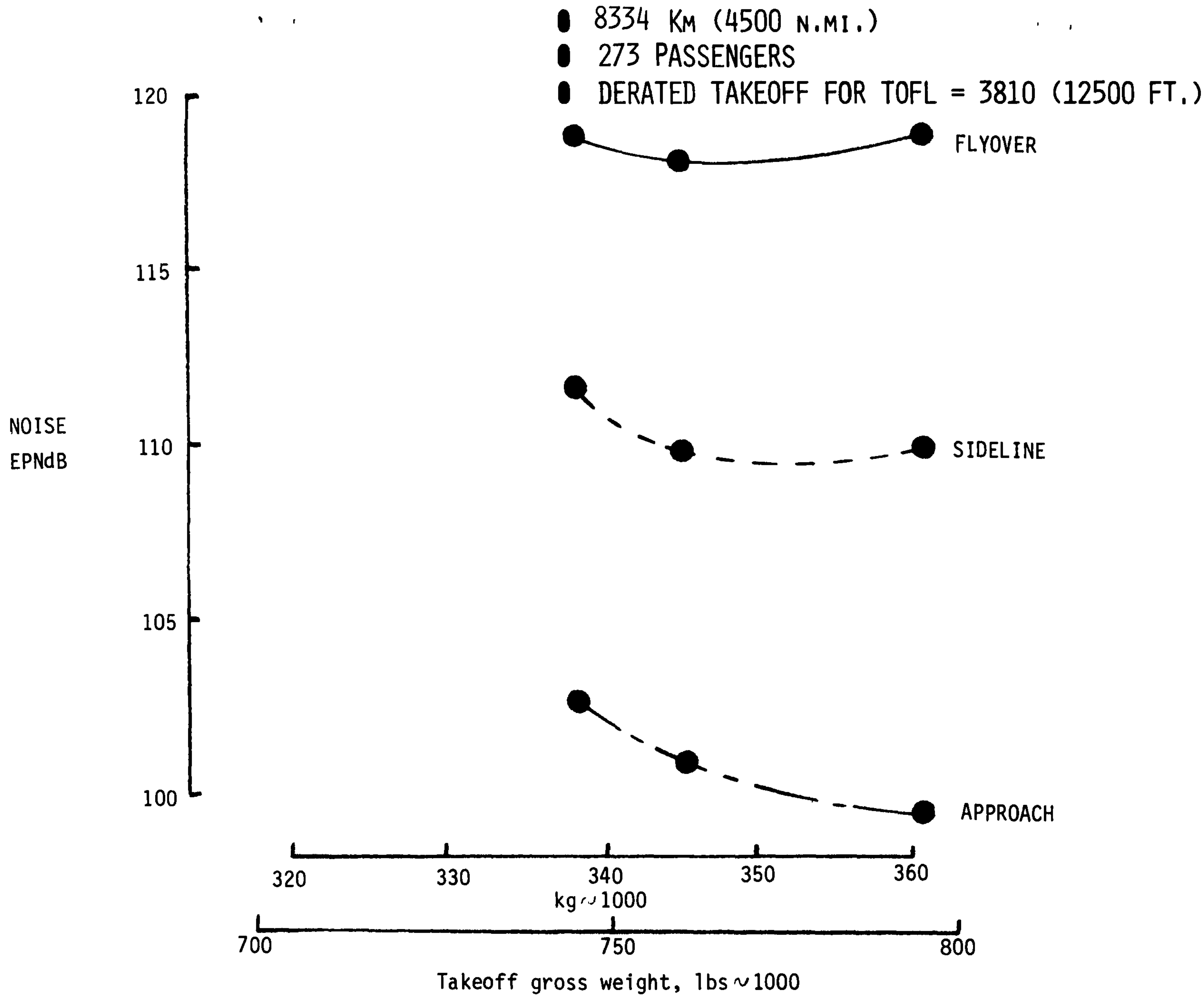

Figure 5. - Effect of engine oversizing on noise - Douglas Mach 2.2 mechanically suppressed turbojet engine.

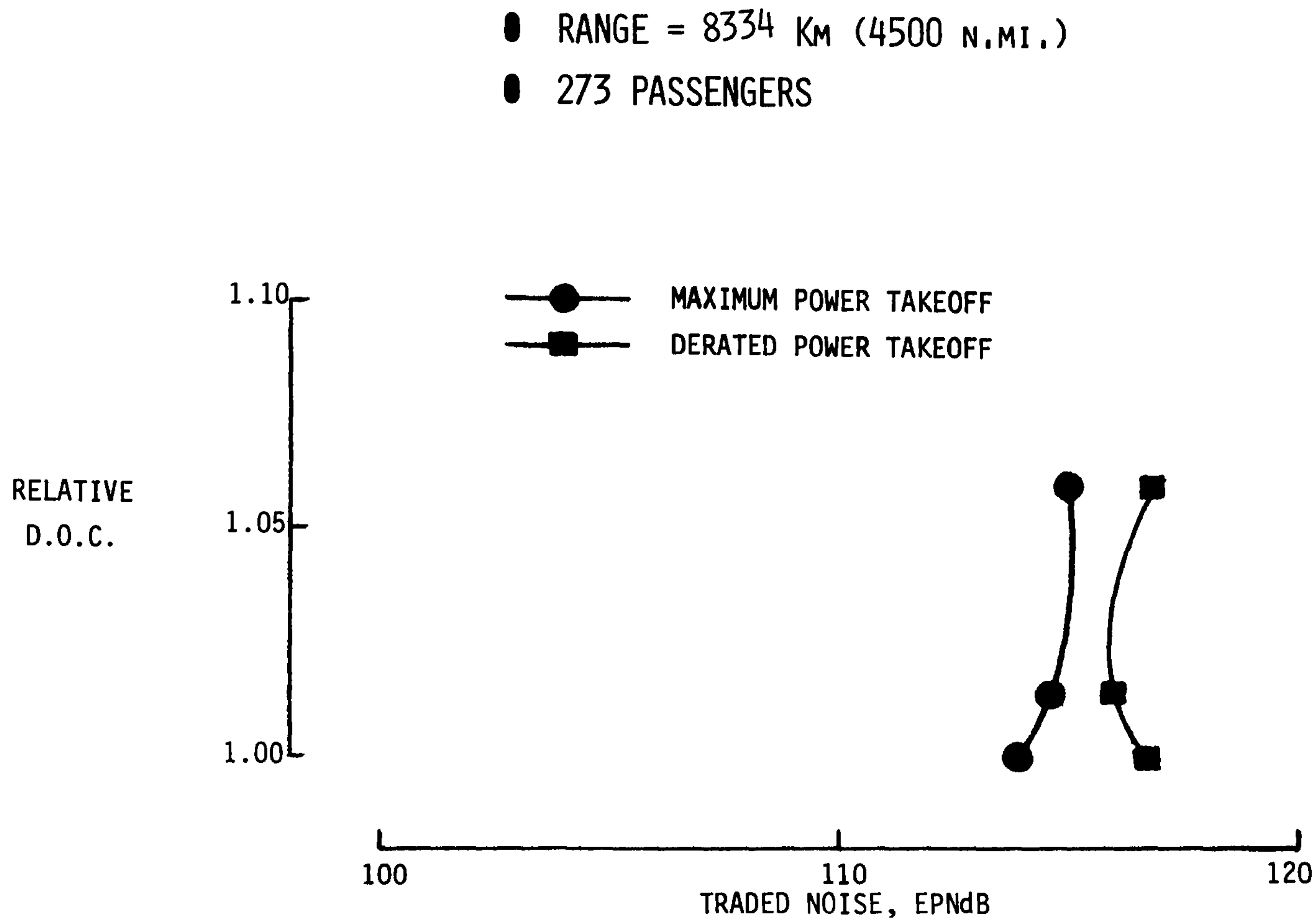

Figure 6. - Effect of traded noise on Direct Operating Cost - Douglas Mach 2.2 mechanically suppressed turbojet engine.

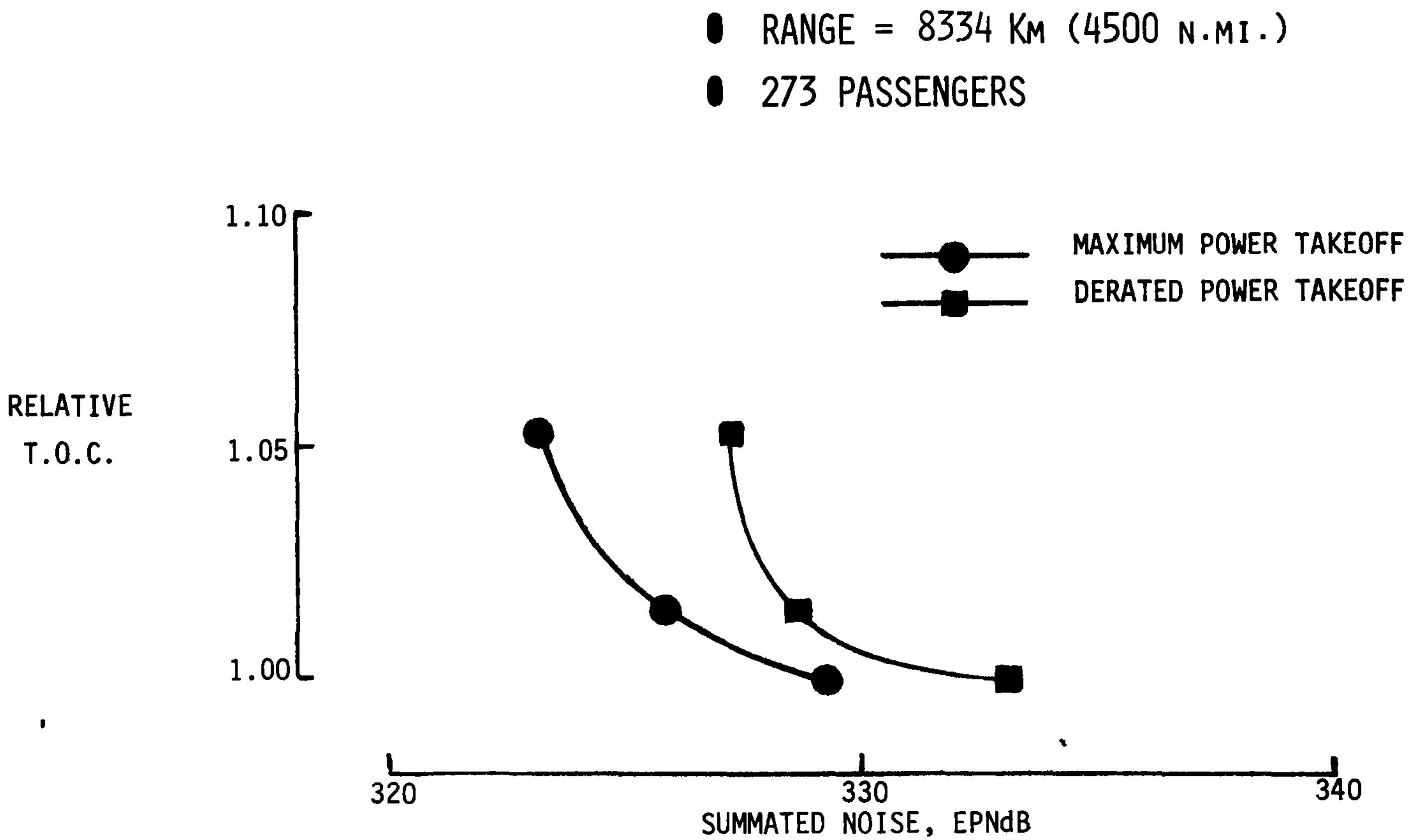

Figure 7. - Effect of summated noise on Total Operating Costs - Douglas Mach 2.2 mechanically suppressed turbojet.

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