NASA TECHNICAL NOTE

NASA TN D-2740

c. 1

NASA TN D-2740

SUMMARY OF V-G DATA OBTAINED FROM TURBINE-POWERED TRANSPORT AIRPLANES FROM 1959 TO 1963

by Walter G. Walker

Langley Research Center
Langley Station, Hampton, Va.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • APRIL 1965

SUMMARY OF V-G DATA OBTAINED FROM TURBINE-POWERED TRANSPORT AIRPLANES FROM 1959 TO 1963

By Walter G. Walker

Langley Research Center
Langley Station, Hampton, Va.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

For sale by the Office of Technical Services, Department of Commerce,
Washington, D.C. 20230 -- Price $1.00

SUMMARY OF V-G DATA OBTAINED FROM TURBINE-POWERED TRANSPORT AIRPLANES FROM 1959 TO 1963

By Walter G. Walker
Langley Research Center

SUMMARY

Normal acceleration and airspeed data obtained with NASA V-G recorders installed on two types of turboprop and three types of turbojet commercial transport airplanes have been analyzed to determine the frequency of occurrence and the severity of the in-flight accelerations experienced. The data cover approximately 176,000 hours of flight on eight different U.S. airlines during operations from 1959 to 1963. The results indicate that the frequencies per flight mile of the occurrence of acceleration increments equaling or exceeding $\pm 1.4g$ ranged from about 1.1×10^{-7} to 3.0×10^{-6} for the four-engine turbine transports. For the operations of a two-engine turboprop transport, the frequency of occurrence was about 7.0×10^{-6}. Such variations in the acceleration experiences are not unusual. From overall considerations, the frequency of occurrence of large accelerations in the turbine transports does not appear to be appreciably different from that observed previously in piston-transport operations. However, the largest accelerations for the turbine transports tend to occur at random throughout the design airspeed range; whereas for piston transports, the largest accelerations were usually experienced at low speeds relative to the design airspeed range.

INTRODUCTION

The National Aeronautics and Space Administration is collecting normal-acceleration, airspeed, and altitude data from different types of turbine-powered, commercial transports operated in long-haul, short-haul, and feeder service. The present program is a continuation of the long-standing NASA effort in collecting operational data on commercial transport airplanes and is providing information on current operations similar to the information summarized in reference 1 for a number of piston-engine transports. The data obtained not only provide a basis for comparing actual airplane operation with the design concepts, but also point out unanticipated operational aspects and provide a background of information applicable to the design of new airplanes.

The data are being obtained with NASA V-G recorders (ref. 2) which provide envelope-type records of indicated airspeed plotted against acceleration and with VGH recorders (ref. 3) which provide time-history records of indicated airspeed, pressure altitude, and normal acceleration. Some of the results that have been obtained from turbine transports are given in references 4 to 7.

This paper summarizes the V-G data collected on turbine-powered transports. The data were obtained from a two-engine turboprop transport operated in feeder service, a four-engine turboprop transport used in short-haul service, and three types of four-engine turbojet transports used in long-haul service. The results are presented as composite envelopes of the acceleration increment plotted against airspeed and as cumulative frequency per flight mile of the maximum acceleration distributions. Comparisons are made between the acceleration experiences of turbine- and piston-engine transports.

SYMBOLS

a_n normal-acceleration increment, g units

$a_{n,max}$ maximum positive and negative normal-acceleration increment from each V-G record, g units

Σf cumulative frequency of occurrence

g acceleration due to gravity, 32.2 ft/sec^2

l flight distance, international nautical miles

V indicated airspeed, knots

V_C design cruising speed, knots

$\bar{V}_T$ average true airspeed, knots

$V_{NE,max}$ maximum value of never-exceed speed, knots

$V_{NO,max}$ maximum value of normal-operating limit speed, knots

The airspeeds used in this paper are indicated airspeeds unless otherwise noted.

INSTRUMENTATION AND SCOPE OF DATA

The data were collected with NASA oil-damped V-G recorders (ref. 2) which provide envelope records of the largest positive and negative acceleration increments from the +1g reference line plotted against the corresponding airspeeds. The recorders were installed on five types of turbine-powered transport airplanes. Some of the basic characteristics of the airplanes are given in table I. The airplanes included three types of four-engine turbojets, one type of four-engine turboprop, and one type of two-engine turboprop. The different types of airplanes are designated by the Roman numerals I to V, and different series of a given type are designated by the letters a to c. As shown in the table, airplane Ia differed from airplane Ic in maximum gross weight, wing area, and wing span, and airplanes IIa, IIb, and IIc differed from each other in maximum gross weight. Airplane IVb differed from airplane IVa primarily because the wing and nacelle structures were modified and strengthened.

The V-G recorder was installed in the two-engine turboprop airplane on the floor under a seat in the passenger cabin within 1 foot of the center of gravity. In the four-engine airplanes, the recorders were installed in the main landing-gear-wheel well within 3 feet of the center of gravity. The pressure and static airspeed lines of the recorder were connected to the copilot's airspeed system, with the exception that in the four-engine turboprop the recorder was connected to an equivalent alternate system having balanced static ports.

The scope of the V-G data samples is summarized in table II according to airline, airplane type, and airplane series. As shown in the table, the data consist of 18 samples of V-G records obtained during operations of the five types of airplanes by eight airlines (designated by the capital letters A to H). These data samples were collected between 1959 and 1963 and range in size from 1,300 flight hours to approximately 23,000 flight hours.

As an overall description of the operations, the estimated average flight time, average pressure altitude, and average true airspeed are shown in table II for each data sample. These values were based on VGH time-history data collected from the same operation as the V-G data or, when such VGH data were not available, were based on VGH data taken on the particular type of airplane flown in a similar operation. For the three types of turbojets (the long-haul operations), the average flight time ranged from 1.54 to 3.75 hours, the average pressure altitude from approximately 24,000 to 30,000 feet, and the average true airspeed from about 425 to 450 knots. For the four-engine turboprop airplanes (the short-haul operations), the average flight time ranged from 0.88 to 1.85 hours, the average altitude from about 11,000 to 15,000 feet, and the average true airspeed from about 250 to 315 knots. The two-engine turboprops (feeder operations) had an average flight time of 0.42 hour, an average altitude of 5,000 feet, and an average true airspeed of 180 knots.

For convenience, particular operations are subsequently identified by a combination of the capital-letter designation of the airline, the Roman-numeral designation of the airplane type, and the lower-case-letter designation of the airplane series. For example, AIa denotes the operation by airline A of airplane type I, series a. (See table II.)

The present samples of data were taken under conditions which are considered to be typical of normal airline operations, with the exceptions noted for operations AIVa and BIVa. (See table II.) As indicated in the table, the maximum permissible placard speeds $V_{NO,max}$ and $V_{NE,max}$ for the type IV airplanes were restricted from March 1960 to February 1961 for airline A and from March 1960 to May 1961 for airline B. In order to distinguish the samples of data taken on the type IV airplanes during speed-restricted operations, such samples are designated as AIVar and BIVar.

EVALUATION OF DATA AND RESULTS

The evaluation of the V-G records consisted of reading from each record the maximum positive and maximum negative in-flight acceleration increments, $a_{n,max}$, regardless of the airspeeds at which they occurred. In addition, the individual records were combined to develop a composite envelope of accelerations and corresponding airspeeds for the period covered by each data sample. Accelerations which occurred at low speeds (below 120 to 180 knots, depending upon the airplane type) were omitted in order to exclude accelerations caused by landing impact.

The composite envelopes of the accelerations and corresponding airspeeds are given in figure 1 for each operation. The values of acceleration increment in g units (a_n) are plotted against indicated airspeed in knots. Several unusual accelerations which involved considerable changes in airspeeds were recorded in the AIVa, AIVar, AIVb, EIIb, and GVa operations and these prominent occurrences are shown as dashed lines on the composites in figure 1. Also shown on each composite are the maximum values of the normal-operating limit speed and of the never-exceed speed $\left(V_{NO,max}\right.$ and $V_{NE,max}$, respectively$\left.\right)$ based on data supplied by the Federal Aviation Agency or the airplane manufacturer. The amounts of data used in preparing the composite plots are listed in figure 1.

In order to compare the turbine-transport composites in figure 1 with similar piston-engine composites, figure 11(b) of reference 5, which represents the V-G records from piston-engine transports, is presented as figure 2. The letter designations used to indicate the types of airplanes in figure 2 are the same as those used in reference 1.

Table III lists, for each operation, the frequency distributions of the values of $a_{n,max}$ read from the V-G records. In each sample the distributions of positive and of negative $a_{n,max}$ were found to be essentially symmetrical and, therefore, were combined. The total flight hours and total nautical flight miles for each sample are also listed in table III. The flight miles given represent the overall climb, cruise, and descent segments and were derived by multiplying the total flight hours of the sample by the average value of true airspeed for the particular operation (table II).

The acceleration distributions of table III are plotted in figure 3 in terms of the cumulative frequency per flight mile with which given values of $a_{n,max}$ were equaled or exceeded. The ordinate values were obtained by progressively summing each distribution of table III (by starting with the frequency for the largest acceleration and then dividing each sum by the number of flight miles represented). The cumulative frequency distributions were fitted with extreme value distribution curves (ref. 8) in order to obtain a mathematical representation of the data. It may be noted that below acceleration values of about 0.8g, the slopes of the distributions in figure 3 decrease. This decrease in slope results from the envelope nature of the V-G record and the attendant method of evaluating only the maximum values of positive and negative normal-acceleration increments from each record. Consequently, the distributions tend to underestimate the frequency of occurrence of all but the largest acceleration - the underestimation being progressively larger as the acceleration level is decreased. In practice, however, the distributions have been found to be an adequate representation of the complete frequency count for accelerations larger than about 1.0g.

To facilitate comparisons of the acceleration experiences for the various operations, the values of the cumulative frequency per mile corresponding to an acceleration increment of ±1.4g were obtained from figure 3 and are plotted in figure 4. The value of ±1.4g was selected as a level for comparison because it is sufficiently large to be of interest for structural considerations, yet is not beyond the limits of the maximum acceleration recorded in most of the data samples. Also shown in figure 4 are the 95-percent confidence bands which are discussed subsequently. In addition, the cumulative frequency distributions from figure 3 are grouped according to airplane type in figure 5. For comparison, the upper and lower limits of corresponding results taken from reference 1 for operations of piston transports are also shown in figure 5. These limit curves were derived on the basis of the combined V-G and VGH acceleration data of reference 1 and are not subject to the underestimation noted previously in the frequency distributions of V-G data at low values of acceleration.

RELIABILITY OF RESULTS

The errors in the V-G recorder are discussed in detail in reference 2. Based on past laboratory calibrations, the maximum instrument errors are estimated to be less than ±0.1g in acceleration and less than ±5 knots in airspeed. The record-reading errors are considered to be random and small enough to be negligible in the overall results. The V-G recorder was installed sufficiently close to the center of gravity of the airplane so that errors due to angular motions were negligible.

Past experience with V-G data has shown that samples of data consisting of about 50 records representing approximately 10,000 or more flight hours from an operation supplying homogeneous data for at least one year will yield results having satisfactory reliability. Inspection of table II shows that 10 of the present 18 samples are of adequate sample size. In order to provide a yardstick for measuring the reliability of the estimated maximum values of acceleration and in order to judge whether differences between samples are real, and not due to sampling variability, the 95-percent confidence bands were calculated from the distributions of table III by the procedures of reference 9. These bands indicate the range within which the true value (value for extended operations) may be expected with a probability of 95 percent. The resulting confidence bands shown in figure 4 for the value of $a_{n,max}$ of ±1.4g indicate that the data for each of the 10 samples in the group representing 10,000 or more flight hours lie within frequency limits of about 5 to 1 and, thus, the statistical reliability is considered to be satisfactory. For the 4,000- to 10,000-hour group, the data for each of the 5 samples lie within limits of about one order of magnitude (a factor of 10 to 1) or less, and the reliability of these samples is considered to be acceptable. The remaining 3 samples have poor reliability as a result of the small number of records and total flight hours represented.

The effect of dynamic structural response on the accelerations measured at the centers of gravity of the airplanes used in the present investigation is unknown and is not accounted for in the results presented. This effect should have no bearing on comparisons between data samples from the same type of airplane. With respect to the overall results, however, dynamic response effect may be important since different types of airplanes are represented in the study.

DISCUSSION

Composite V-G Envelopes

Examination of the composite V-G envelopes in figure 1 shows that the general level of the maximum acceleration increments tends to be roughly the same throughout most of the airspeed range for each operation. The level of acceleration increments for the different airplane types ranges from roughly ±0.75g (airplane type II) to about ±1.25g (airplane types III and V). The largest acceleration increments occurred randomly throughout most of the speed range with peaks as high as ±2.0g evident on some of the composites. The composites indicate that substantial accelerations were experienced at speeds in excess of the maximum normal-operating limit speed $V_{NO,max}$. In some operations, large accelerations occurred even at speeds in excess of the maximum never-exceed speed $V_{NE,max}$.

A qualitative comparison of the composite V-G envelopes from the turbine-airplane operations (fig. 1) with the envelopes for piston-airplane operations (fig. 2) shows that, in general, the characteristic shapes of the envelopes for the two types of transports are different. Whereas the envelopes for the piston airplanes show a marked decrease in acceleration levels at the higher speeds, the drop-off in acceleration for the turbine airplanes is much less pronounced with the result that the envelopes tend to be more or less rectangular. Such differences between the results for the turbine- and piston-engine transports were noted previously in reference 5, which indicated that the turbine transports were operated at a higher percent of the normal-operating limit speed and also that a larger percent of flight time was spent by the turbine transports at speeds in excess of the normal-operating limit speed. As noted in reference 5, the increased accelerations experienced at high speeds for the turbine transports are apparently a consequence of the larger amounts of flight time spent at high speed.

V-G Acceleration Distributions

Comparison of the acceleration distributions for the various operations in figure 3 shows that appreciable differences exist between the frequency of occurrence of the large values of $a_{n,max}$. As summarized in figure 4, the frequency per flight mile with which a value of $a_{n,max}$ of $\pm 1.4g$ was equaled or exceeded, ranged from about 1.1×10^{-7} to 3.0×10^{-6} for the four-engine turbine transports. For the operations of the two-engine turboprop airplane the frequency of occurrence was about 7.0×10^{-6}. Such differences between the acceleration experiences of various airplane types are not considered to be unusual and have been observed previously in results obtained from piston transports (ref. 1). The variations noted in the acceleration histories in figure 3 are due primarily to differences in the airplane wing loading and lift-curve slope, and, to a lesser extent, to differences in the severity of the gusts experienced, the operating airspeeds in rough air, and the maneuvers performed during airplane and pilot check flights.

The frequencies of occurrence of the largest accelerations for all the four-engine turbine transports lie within the upper and lower limits which define the past acceleration experiences of four-engine piston-powered transports. (See fig. 5.) Similarly, the frequency for the two-engine turboprop operation lies within the limits for the two-engine piston transports. Thus, the in-flight accelerations experienced in the turbine-transport operations generally appear to be about the same in order of magnitude and frequency as the accelerations experienced in the past operations of piston-engine transports.

CONCLUDING REMARKS

An analysis of 18 samples of V-G records taken on two types of turboprop transports and three types of turbojet transports during operations by eight airlines has provided information on the large in-flight normal accelerations experienced. The results indicate that, for values of maximum normal-acceleration increments equaling or exceeding $\pm 1.4g$, the frequencies per flight mile ranged from about 1.1×10^{-7} to 3.0×10^{-6} for the four-engine turbine transports. For the operations of a two-engine turboprop transport, the frequency of occurrence was about 7.0×10^{-6}. Such variations in the acceleration experiences are not unusual and have been observed in past operations of piston transports. From overall considerations, the frequency of occurrence of large accelerations for turbine transports does not appear to be appreciably different from that for piston transports. However, the largest accelerations for the turbine transports tend to occur at random throughout the design airspeed range; whereas for piston transports, the largest accelerations were usually experienced at low speeds relative to the design airspeed range.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., January 6, 1965.

REFERENCES

1. Walker, Walter G.; and Copp, Martin R.: Summary of VGH and V-G Data Obtained From Piston-Engine Transport Airplanes From 1947 to 1958. NASA TN D-29, 1959.

2. Taback, Israel: The NACA Oil-Damped V-G Recorder. NACA TN 2194, 1950.

3. Richardson, Norman R.: NACA VGH Recorder. NACA TN 2265, 1951.

4. Copp, Martin R.; and Fetner, Mary W.: Analysis of Acceleration, Airspeed, and Gust-Velocity Data From a Four-Engine Turboprop Transport Operating Over the Eastern United States. NASA TN D-36, 1959.

5. Coleman, Thomas L.; Copp, Martin R.; and Walker, Walter G.: Airspeed Operating Practices of Turbine-Powered Commercial Transport Airplanes. NASA TN D-744, 1961.

6. Staff of Langley Airworthiness Branch: Operational Experiences of Turbine-Powered Commercial Transport Airplanes. NASA TN D-1392, 1962.

7. Hunter, Paul A.; and Walker, Walter G.: An Analysis of VG and VGH Operational Data From a Twin-Engine Turboprop Transport Airplane. NASA TN D-1925, 1963.

8. Press, Harry: The Application of the Statistical Theory of Extreme Values to Gust-Load Problems. NACA Rep. 991, 1950. (Supersedes NACA TN 1926.)

9. Kimball, Bradford F.: An Approximation to the Sampling Variance of an Estimated Maximum Value of Given Frequency Based on Fit of Doubly Exponential Distribution of Maximum Values. Ann. Math. Statist., vol. XX, no. 1, Mar. 1949, pp. 110-113.

TABLE I.- AIRPLANE CHARACTERISTICS

Airplane		Number of engines	Propulsion	Maximum gross weight, lb	Wing area, sq ft	Wing span, ft	Wing loading, lb/sq ft
Type	Series						
I	a	4	Turbojet	245,000	2,433	130.8	100.7
	c	4	Turbojet	311,000	2,892	142.4	107.5
II	a	4	Turbojet	273,000	2,771	142.4	98.4
	b	4	Turbojet	276,000	2,771	142.4	99.5
	c	4	Turbojet	310,000	2,771	142.4	111.7
III	a	4	Turbojet	189,500	2,000	120.0	94.8
IV	a	4	Turboprop	113,000	1,300	99.0	86.9
	*b	4	Turboprop	113,000	1,300	99.0	86.9
V	a	2	Turboprop	35,700	754	95.2	47.4

*In airplane type IV, series b differs from series a primarily because the wing and nacelle structures were modified and strengthened.

TABLE II.- SCOPE OF V-G DATA FROM TURBINE-TRANSPORT OPERATIONS

Airline	Airplane		Dates of operation	Number of -			Average overall flight conditions (*)		
	Type	Series		Airplanes	Records	Flight hours	Flight time, hr	Pressure altitude, ft	$\bar{V}_T$, knots
A	I	a	Aug. 1959 to Apr. 1963	4	75	23,496	2.44	26,000	428
	IV	a	Oct. 1959 to Apr. 1960	4	9	1,996	1.67	14,621	315
		ar	†Mar. 1960 to Feb. 1961	3	18	4,019	1.46	15,103	263
		b	Mar. 1961 to Apr. 1963	4	55	17,056	.88	11,598	287
B	II	b	Mar. 1960 to June 1962	3	41	9,125	2.00	25,310	431
	IV	a	Dec. 1959 to Apr. 1960	3	7	1,602	1.85	13,925	307
		ar	†Mar. 1960 to May 1961	4	41	8,865	1.23	12,702	252
		b	May 1961 to Feb. 1962	4	20	4,600	1.20	13,000	285
C	I	a	Jan. 1959 to June 1961	2	54	11,623	3.35	26,564	428
		c	Jan. 1960 to Mar. 1963	2	47	13,440	3.36	28,036	445
	II	c	June 1960 to Feb. 1963	4	54	13,750	2.75	26,000	438
D	I	a	Nov. 1959 to Mar. 1963	2	47	10,145	2.31	24,419	427
		c	Mar. 1960 to Feb. 1963	1	29	5,890	3.75	30,453	449
E	II	a	Dec. 1959 to Mar. 1963	2	46	13,571	1.91	26,000	435
		b	Jan. 1960 to Mar. 1963	2	54	15,353	3.11	26,000	435
F	III	a	Oct. 1960 to Mar. 1963	4	46	10,103	1.54	24,657	441
G	V	a	Feb. 1959 to Nov. 1961	2	47	10,368	0.42	5,026	180
H	II	c	Jan. 1961 to May 1962	1	6	1,300	2.44	27,597	438

*Based on VGH data from same operation except for operations AIa, BIVb, CIIc, EIIa, and EIIb. For these five operations, values were estimated from VGH data for the same type of airplane in a similar operation.

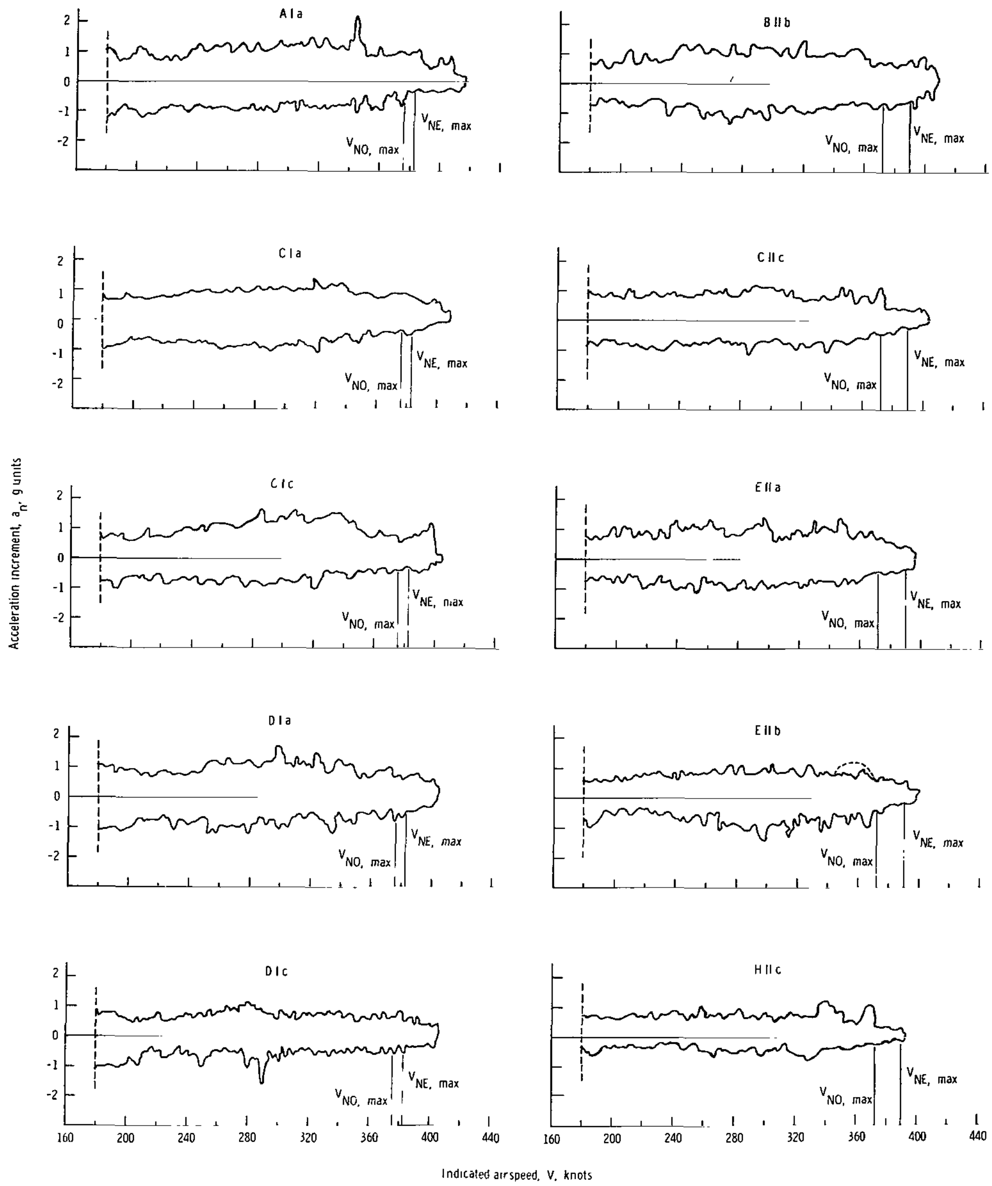
†Speed-restricted period.

TABLE III.- FREQUENCY DISTRIBUTIONS OF IN-FLIGHT MAXIMUM ACCELERATIONS FROM V-G RECORDS

Maximum acceleration increment, $\pm a_{n,max}$, g units	Frequency distribution for operation -																	
	AIa	CIa	CIc	DIa	DIc	BIIb	CIIc	EIIa	EIIb	HIIc	FIIIa	AIVa	AIVar (*)	AIVb	BIVa	BIVar (*)	BIVb	GVa
0.3 to 0.4	6	1	---	2	---	---	1	1	1	---	---	---	---	---	---	2	---	---
0.4 to 0.5	9	1	2	7	5	1	5	7	5	1	---	---	---	1	---	5	---	---
0.5 to 0.6	16	12	13	21	11	2	18	11	14	0	2	1	7	3	---	8	---	---
0.6 to 0.7	23	25	19	14	19	7	19	20	21	3	3	3	8	12	1	10	8	---
0.7 to 0.8	26	30	16	22	7	15	25	12	26	4	5	1	7	24	0	19	5	1
0.8 to 0.9	21	13	11	4	4	10	17	18	18	0	12	3	6	21	2	13	6	4
0.9 to 1.0	14	14	13	10	6	12	9	10	8	1	18	5	2	14	1	10	8	18
1.0 to 1.1	13	8	6	8	4	16	5	8	9	2	13	3	4	16	5	12	5	23
1.1 to 1.2	5	2	4	1	1	9	9	4	2	1	13	0	0	11	3	1	4	16
1.2 to 1.3	8	1	4	3	0	3		0	3		7	2	1	3	1	1	1	10
1.3 to 1.4	6	1	1	0	0	6		1	0		9		0	4	0	0	1	8
1.4 to 1.5	0		2	1	0	1			1		4		0	1	0	1	0	4
1.5 to 1.6	2		1	0	0						2		0		0		0	6
1.6 to 1.7	0		2	0	1						1		0		0		0	0
1.7 to 1.8	0			1							1		1		1		1	3
1.8 to 1.9	0										0						0	0
1.9 to 2.0	0										1						0	0
2.0 to 2.1	0										0						0	1
2.1 to 2.2	0										1						0	
2.2 to 2.3	1																1	
Total	150	108	94	94	58	82	108	92	108	12	92	18	36	110	14	82	40	94
Flight hours . . .	23,496	11,623	13,440	10,145	5,890	9,125	13,750	13,571	15,353	1,300	10,103	1,996	4,019	17,056	1,602	8,865	4,600	10,368
Flight miles . . .	1.0×10^7	5.0×10^6	6.0×10^6	4.3×10^6	2.7×10^6	3.9×10^6	6.0×10^6	5.9×10^6	6.7×10^6	5.7×10^5	4.5×10^6	6.3×10^5	1.1×10^6	4.9×10^6	4.9×10^5	2.2×10^6	1.3×10^6	1.9×10^6

*Operation during speed-restricted period.

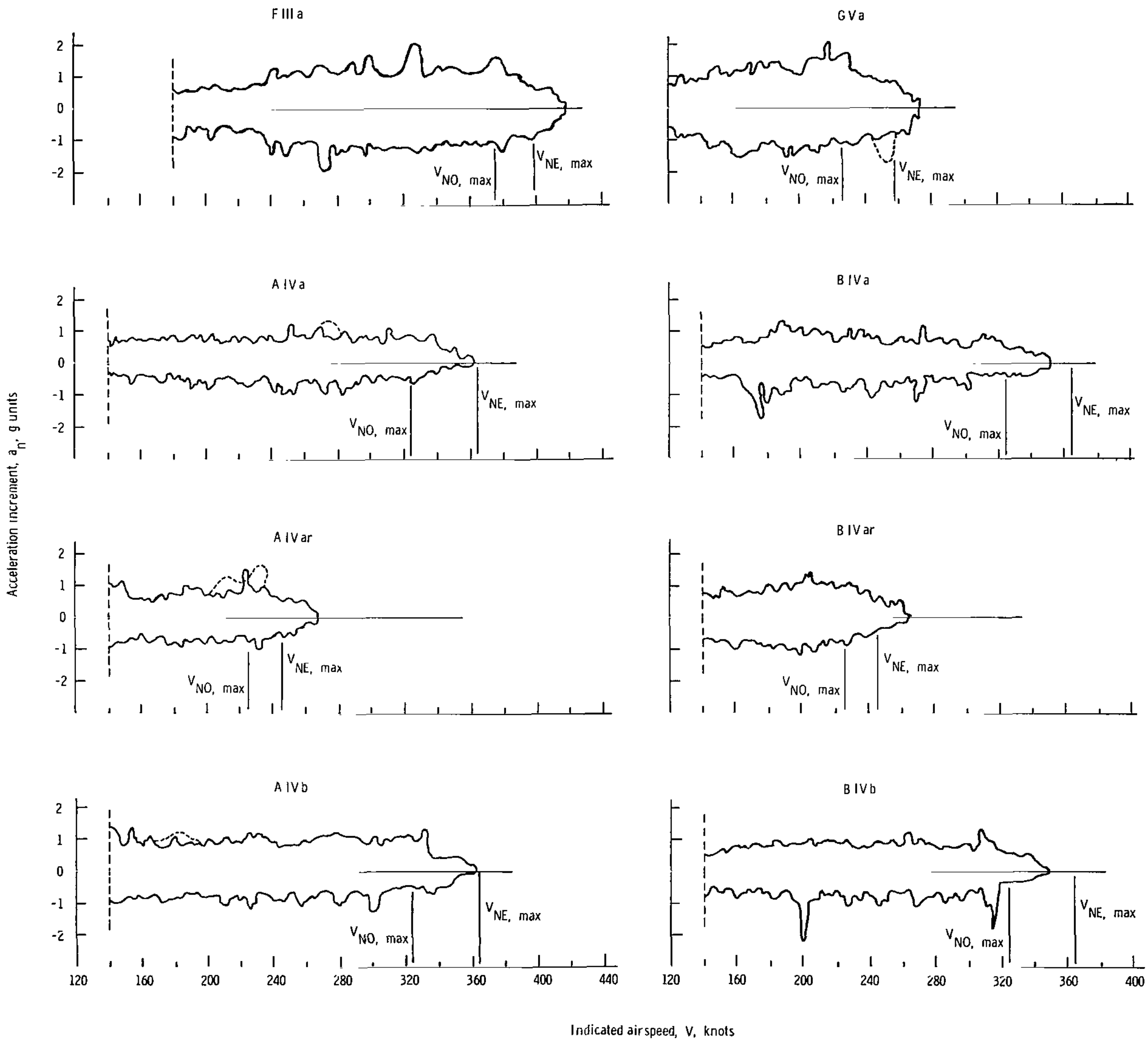
Operation	Number of —		
	Airplanes	Records	Flight hours
A I a	4	75	23,496
C I a	2	54	11,623
C I c	2	47	13,440
D I a	2	47	10,145
D I c	1	29	5,890
B II b	3	41	9,125
C II c	4	54	13,750
E II a	2	46	13,571
E II b	2	54	15,353
H II c	1	6	1,300



(a) Airplane types I and II.

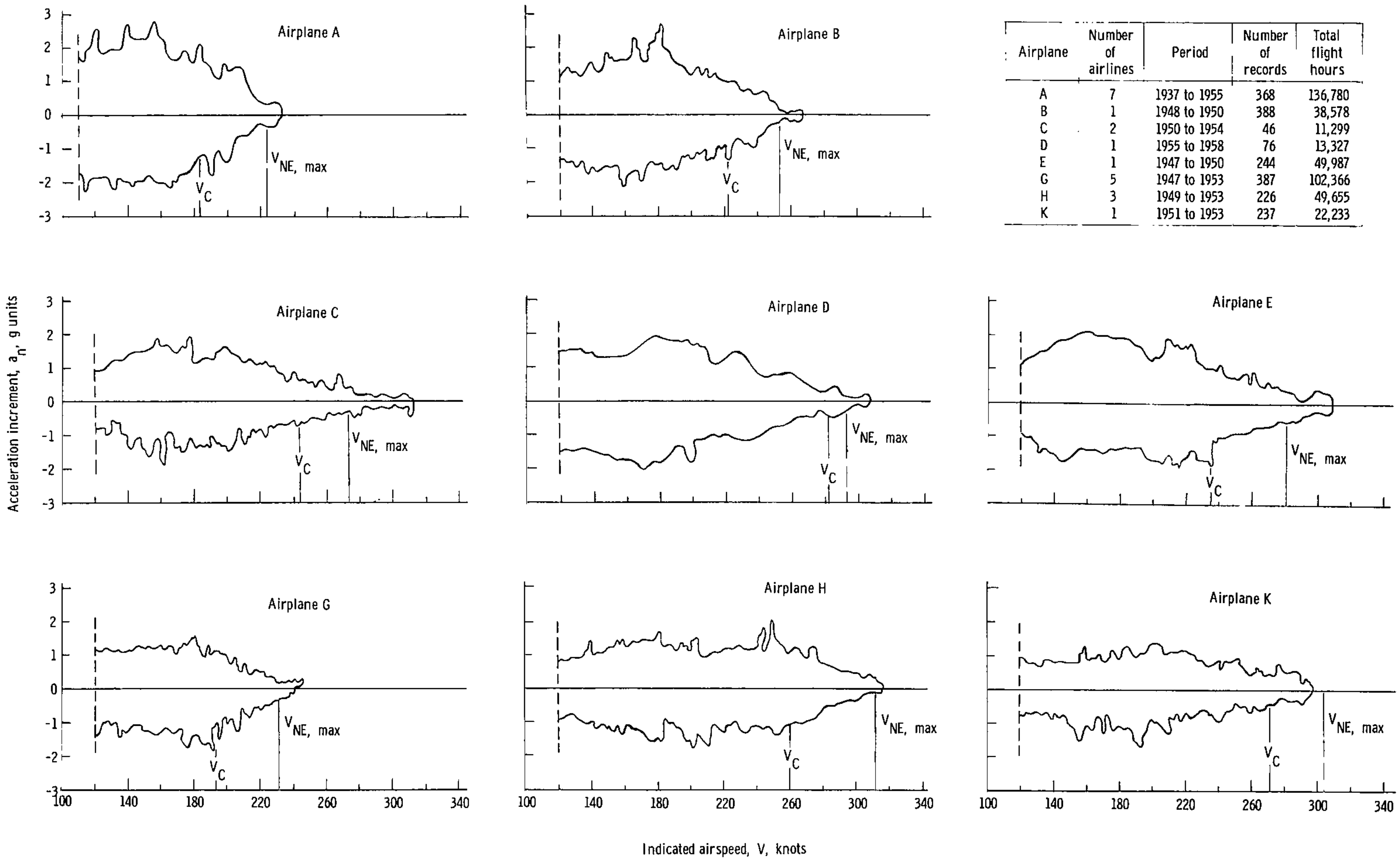
Figure 1.- Composite envelopes from turbine-transport V-G records.

Operation	Number of —		
	Airplanes	Records	Flight hours
F III a	4	46	10,103
A IV a	4	9	1,996
A IV ar	3	18	4,019
A IV b	4	55	17,056
B IV a	3	7	1,602
B IV ar	4	41	8,865
B IV b	4	20	4,600
G V a	2	47	10,368



(b) Airplane types III, IV, and V.

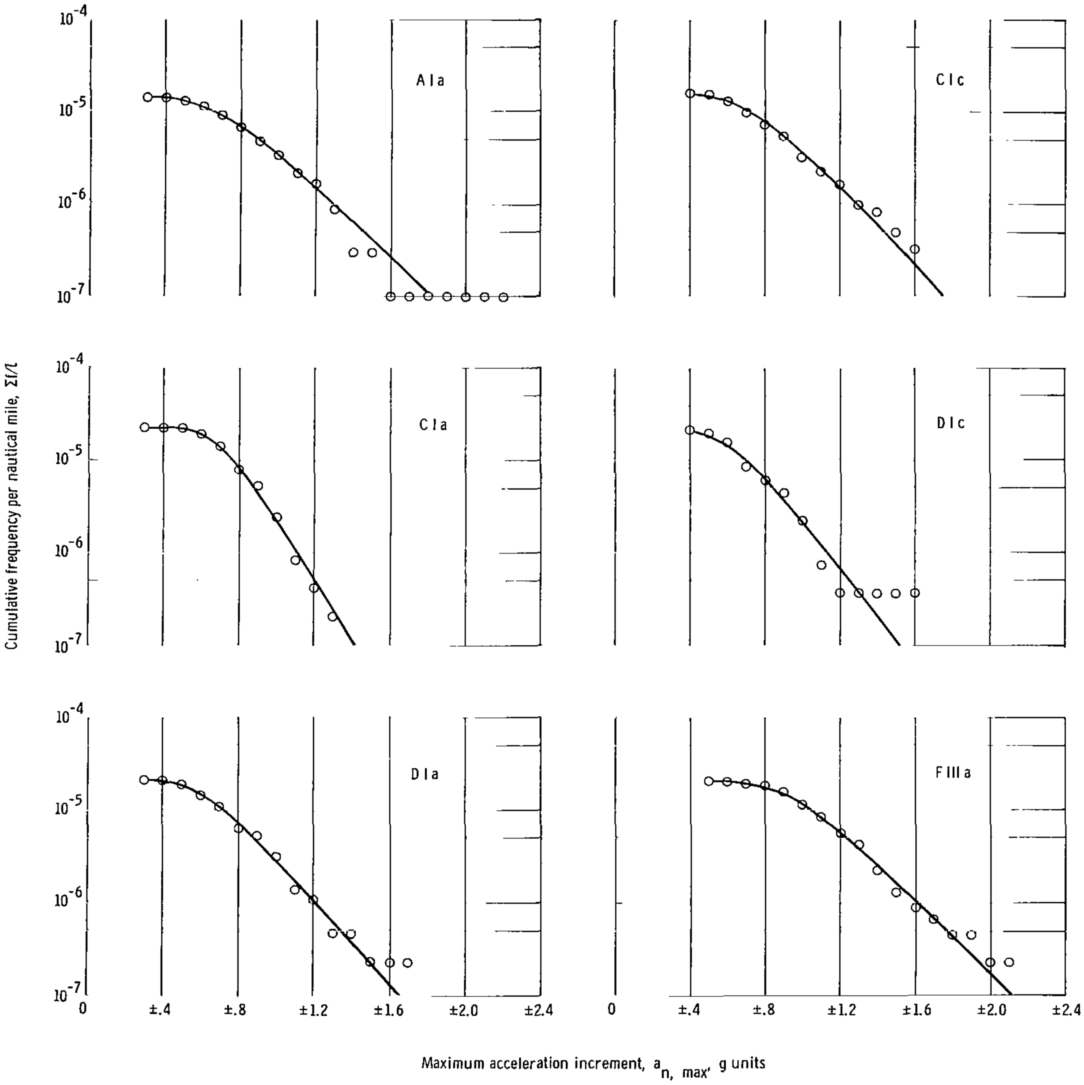
Figure 1.- Concluded.



Airplane	Number of airlines	Period	Number of records	Total flight hours
A	7	1937 to 1955	368	136,780
B	1	1948 to 1950	388	38,578
C	2	1950 to 1954	46	11,299
D	1	1955 to 1958	76	13,327
E	1	1947 to 1950	244	49,987
G	5	1947 to 1953	387	102,366
H	3	1949 to 1953	226	49,655
K	1	1951 to 1953	237	22,233

Figure 2.- Composite envelopes from piston-transport V-G records. (From ref. 5.)

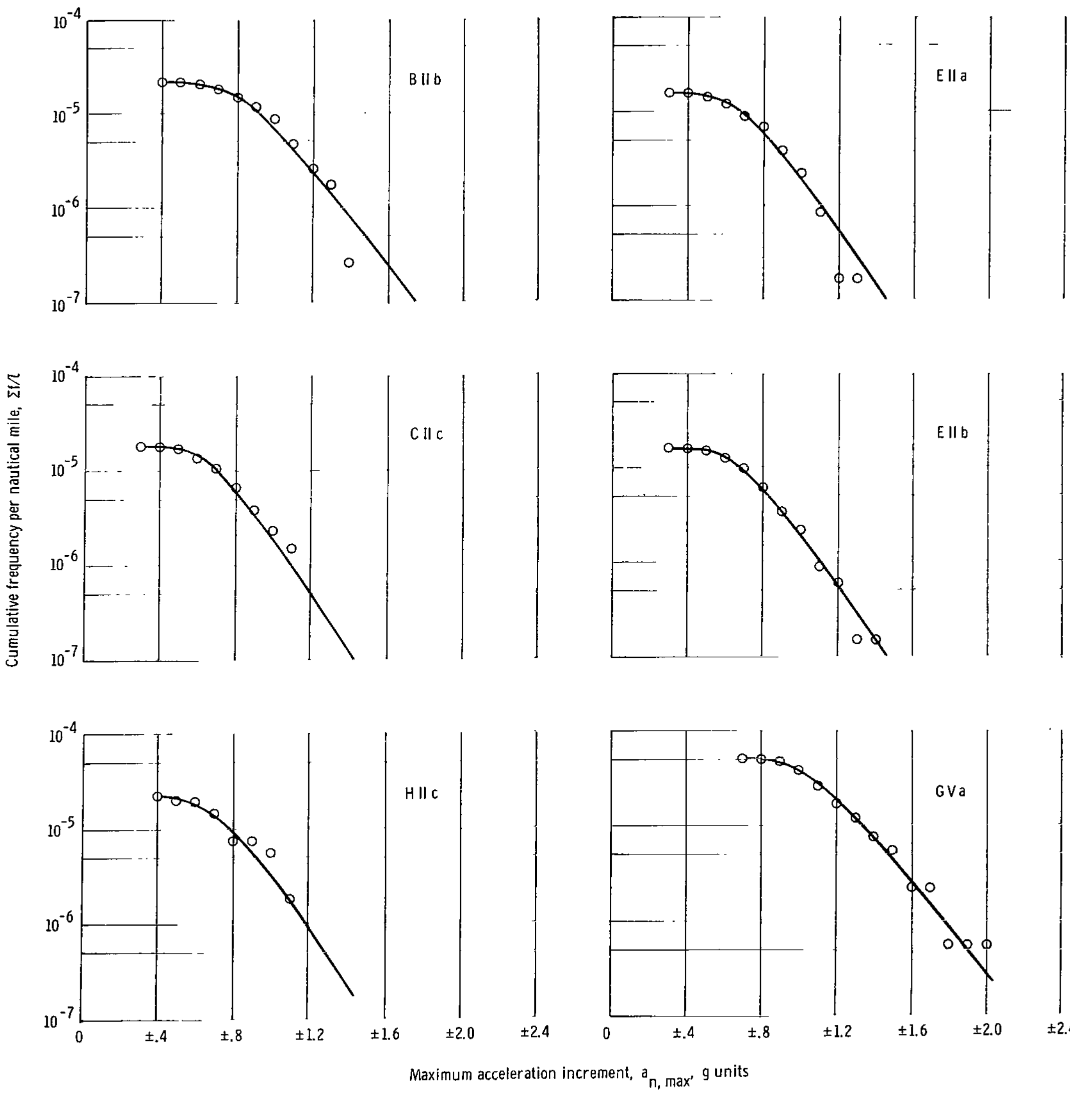
Operation	Airplanes	Records	Flight hours
	Number of —		
A I a	4	75	23,496
C I a	2	54	11,623
C I c	2	47	13,440
D I a	2	47	10,145
D I c	1	29	5,890
F III a	4	46	10,103



(a) Airplane types I and III.

Figure 3.- Frequency per flight mile with which given values of maximum acceleration increment were equaled or exceeded.

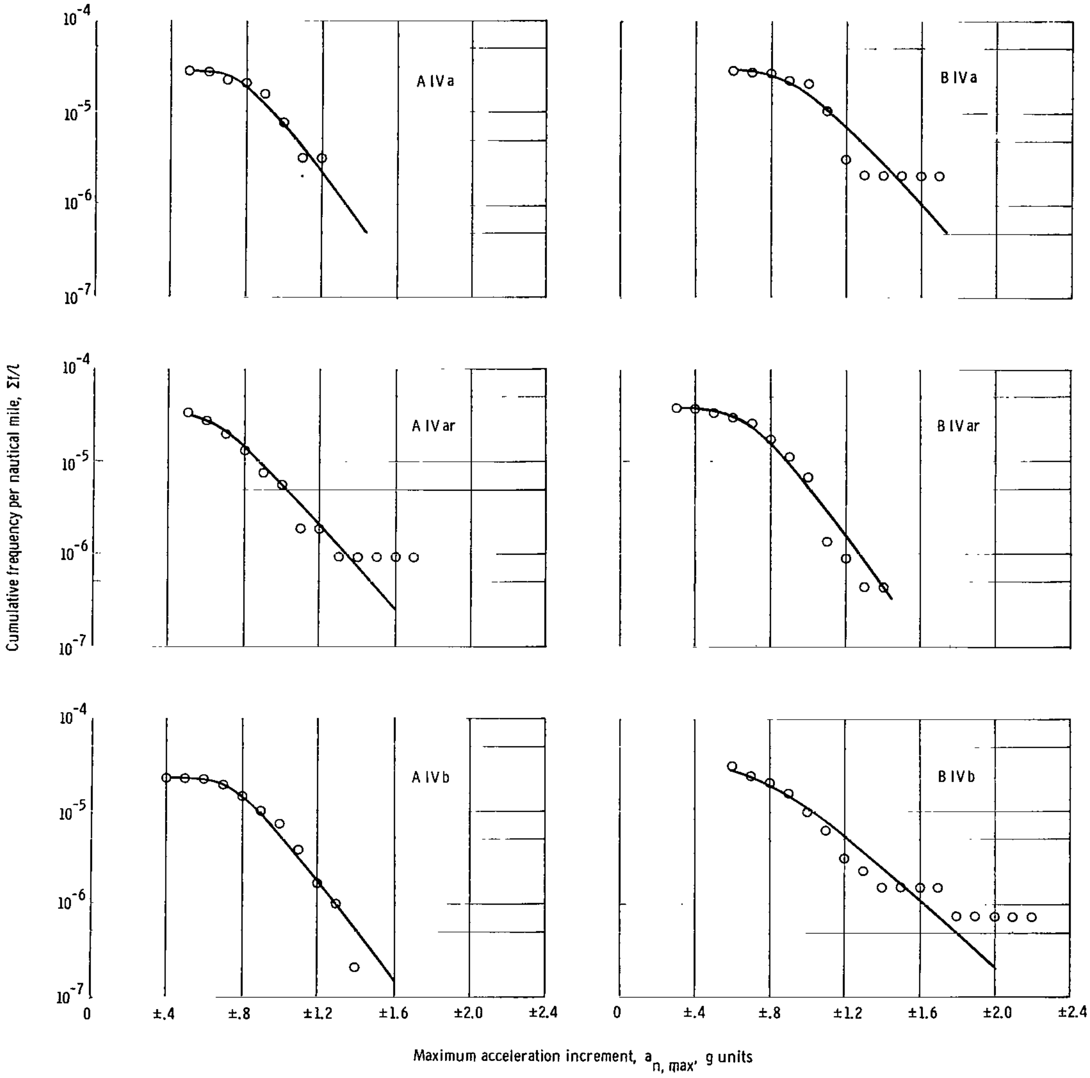
Operation	Number of —		
	Airplanes	Records	Flight hours
B II b	3	41	9,125
C II c	4	54	13,750
E II a	2	46	13,571
E II b	2	54	15,353
H II c	1	6	1,300
G V a	2	47	10,368



(b) Airplane types II and V.

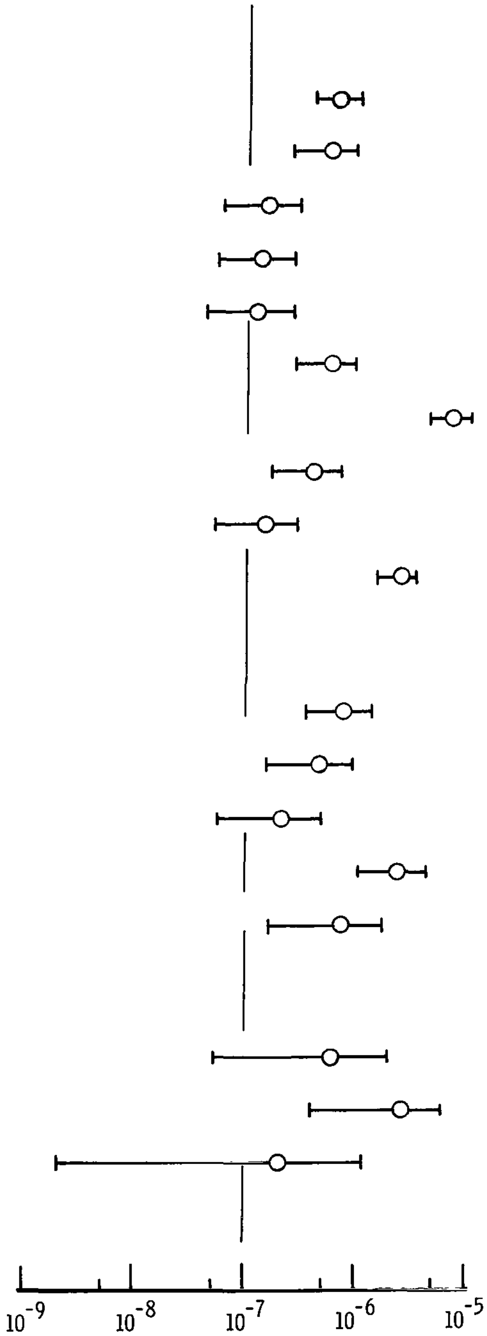
Figure 3.- Continued.

Operation	Number of —		
	Airplanes	Records	Flight hours
A IVa	4	9	1,996
A IVar	3	18	4,019
A IVb	4	55	17,056
B IVa	3	7	1,602
B IVar	4	41	8,865
B IVb	4	20	4,600



(c) Airplane type IV.

Figure 3.- Concluded.



Operation	Number of records	Flight hours
A I a	75	23,496
A IV b	55	17,056
E II b	54	15,353
C II c	54	13,750
C I a	54	11,623
C I c	47	13,440
G V a	47	10,368
D I a	47	10,145
E II a	46	13,571
F III a	46	10,103
B II b	41	9,125
B IV ar	41	8,865
D I c	29	5,890
B IV b	20	4,600
A IV ar	18	4,019
A IV a	9	1,996
B IV a	7	1,602
H II c	6	1,300

Figure 4.- Frequency with which a value of $a_{n,max}$ of ±1.4g was equaled or exceeded and the 95-percent confidence bands.

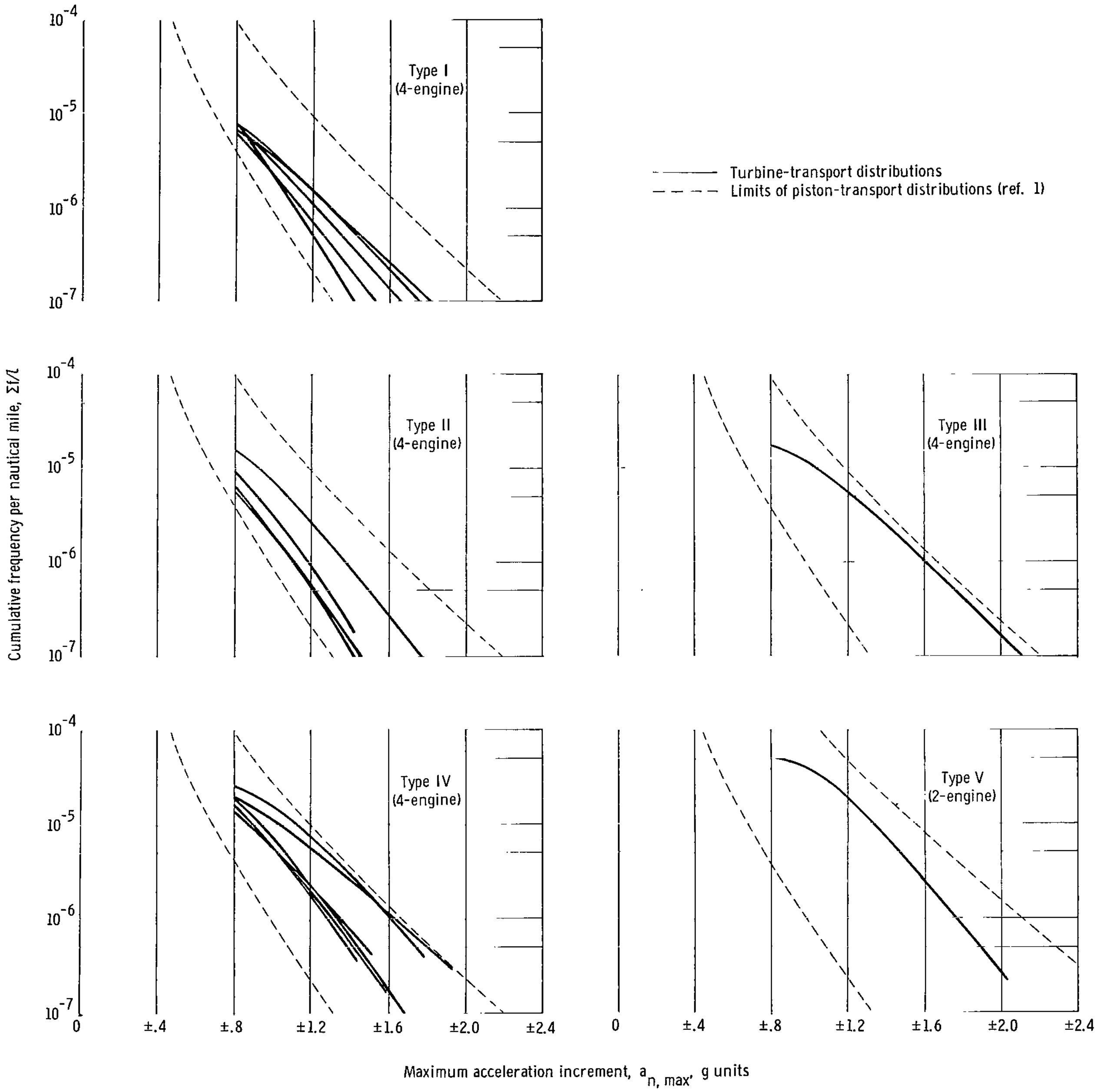


Figure 5.- Comparison of the acceleration distribution curves for two-engine and four-engine turbine-powered and piston-powered transports.

2/22/85

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

NASA SCIENTIFIC AND TECHNICAL PUBLICATIONS

TECHNICAL REPORTS: Scientific and technical information considered important, complete, and a lasting contribution to existing knowledge.

TECHNICAL NOTES: Information less broad in scope but nevertheless of importance as a contribution to existing knowledge.

TECHNICAL MEMORANDUMS: Information receiving limited distribution because of preliminary data, security classification, or other reasons.

CONTRACTOR REPORTS: Technical information generated in connection with a NASA contract or grant and released under NASA auspices.

TECHNICAL TRANSLATIONS: Information published in a foreign language considered to merit NASA distribution in English.

TECHNICAL REPRINTS: Information derived from NASA activities and initially published in the form of journal articles.

SPECIAL PUBLICATIONS: Information derived from or of value to NASA activities but not necessarily reporting the results of individual NASA-programmed scientific efforts. Publications include conference proceedings, monographs, data compilations, handbooks, sourcebooks, and special bibliographies.

Details on the availability of these publications may be obtained from:

SCIENTIFIC AND TECHNICAL INFORMATION DIVISION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Washington, D.C. 20546