NACA TN No. 1733

1181

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE

No. 1733

AN ANALYSIS OF THE AIRSPEEDS AND NORMAL ACCELERATIONS OF SIKORSKY S-42A AIRPLANES IN COMMERCIAL TRANSPORT OPERATION

By Walter G. Walker

Langley Aeronautical Laboratory
Langley Field, Va.

Washington
October 1948

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE NO. 1733

AN ANALYSIS OF THE AIRSPEEDS AND NORMAL ACCELERATIONS OF SIKORSKY S-42A AIRPLANES IN COMMERCIAL TRANSPORT OPERATION

By Walter G. Walker

SUMMARY

Acceleration and airspeed data taken on four Sikorsky S-42A airplanes operated on Caribbean routes and along the east coast of South America have been analyzed and the results indicate that the flight loads seem about average in comparison with the flight loads of other types of airplanes operated on different routes. The limit gust load factor of the S-42A airplanes will be exceeded, on the average, once in about 3×10^7 flight miles. The loads of the Sikorsky S-42A airplanes were less conservative than the loads of the Boeing S-307 airplanes, both of which were operated in the same general region; this difference was attributed to the higher ratio of probable speed of maximum acceleration occurrence to the design maximum level-flight speed V_p/V_L of the S-42A airplanes. Caribbean operations of the S-42A and the S-307 airplanes are in good agreement with respect to route roughness and do not show greater route roughness than most of the other routes compared.

INTRODUCTION

Previous analyses (references 1 to 3) present the results obtained from acceleration and airspeed data taken during commercial transport operation to show the influence of airplane, route, season, and prewar and wartime operations on the flight loads and operating speeds. These papers deal with three different types of airplanes operated on different routes. Insofar as the flight loads of the airplanes are concerned, the results indicate that airplane speed in regions of turbulent air is a significant parameter and that differences are apparent in prewar and wartime operations. Operations of the Douglas DC-3 type airplanes on transcontinental routes of the United States have indicated that variations in the forecasting and dispatching practices of the airlines appear to compensate for differences in route roughness. Trans-Pacific operations of the Martin M-130 airplanes have indicated greater route roughness than did operations over transcontinental routes of the United States or operations over Caribbean routes.

This paper gives the results of an analysis of V-G data taken on four Sikorsky S-42A flying boats operated on Caribbean routes and along the east coast of South America during the period from 1936 to 1939. Investigation has been made of the influence of operating speeds and routes on the flight loads. The available S-42A data are summarized and the flight-load results are compared with the results of analyses made in the past.

SYMBOLS

K	gust-alleviation factor
U_e	effective gust velocity, feet per second
V_L	design maximum level-flight speed, miles per hour
V_{max}	maximum indicated airspeed on V-G record, miles per hour
V_o	indicated airspeed at which maximum positive or negative acceleration increment occurs on V-G record, miles per hour
V_p	probable airspeed at which maximum acceleration will most likely occur on derived flight envelope, miles per hour
Δn_{max}	maximum positive or negative acceleration increment on V-G record, g units
$\overline{V}_{max}$, $\overline{V}_o$, $\overline{\Delta n}_{max}$	average values of distributions of V_{max}, V_o, and Δn_{max}, respectively
σ_v, σ_o, $\sigma_{\Delta n}$	standard deviations of distributions of V_{max}, V_o, and Δn_{max}, respectively
α_v, α_o, $\alpha_{\Delta n}$	coefficients of skewness of distributions of V_{max}, V_o, and Δn_{max}, respectively
P_o	probability that maximum acceleration on a record will occur in a given speed range
T	average flight time per record, hours

SCOPE OF DATA

One-hundred ninety-three V-G records representing 15,902 hours of flight were available for analysis. The records are summarized in table I for the four S-42A flying boats which were operated in scheduled transport operations from Miami, Florida to the West Indies and along the east coast of South America as far south as Buenos Aires, Argentina during the period from April 1936 to December 1939. Information supplied to the National Advisory Committee for Aeronautics with the records included installation and removal dates, routes flown, and the number of flight hours per record. In occasional cases where unusual flight conditions were encountered, supplementary information was given. Actual operating weights were not supplied.

Table I gives a breakdown of the records taken on the four S-42A airplanes. Since the method of analysis requires a reasonably constant number of flight hours per record in a given group, the 117 records, which represent 11,124 flight hours within the range of 70 to 130 hours and which were chosen for analysis herein, conform to the requirements of the method (reference 4). Attempts at breakdowns of the data for given routes yielded no useful results because almost all records included operations both in the Caribbean and to Buenos Aires and the return. Consequently, the data used in the analysis are considered to represent operations over one route. The results obtained in analysis of the individual airplanes shown in table I have been combined since differences were found to be negligible.

The airplane characteristics necessary for the analysis were obtained from the Civil Aeronautics Administration or were computed in accordance with design requirements and are as follows:

Gross weight, pounds	41,000
Wing area, square feet	1,340
Wing span, feet	118.17
Mean aerodynamic chord, feet	12.33
Slope of lift curve, per radian	4.54
Aspect ratio	10.5
Design maximum level-flight speed at sea level, V_L, miles per hour	181
Placard speed, miles per hour	226
Limit gust load factor, g units	2.58
Gust-alleviation factor, K	1.125

The limit gust load factor of 2.58g, which corresponds to an effective gust velocity U_e of 30K feet per second at the maximum speed in level flight V_L, was computed with the gust-load-factor formula of reference 5.

The S-42A airplane was designed before the gust-alleviation factor K was incorporated in the gust-load-factor formula. The factor K is included in the present computations so that the results may be compared with those of references 1 to 3. Because detailed information was lacking, the placard (or never-exceed) speed was computed from information given in reference 6 to be $1.25V_L$ or 226 miles per hour.

The records were evaluated without attempting to distinguish between accelerations caused by gusts and by maneuvers. All large accelerations are assumed to be due to gusts, as experience indicates that most of the large loads imposed during normal transport operation are due to gusts.

ANALYSIS

The method of analysis is given in references 1 to 4. Five values were read from each V-G record: the maximum positive and maximum negative acceleration increments Δn_{max}, the speeds corresponding to maximum-acceleration occurrences V_o, and the maximum speeds flown V_{max}, together with the flight miles per record (obtained by multiplying the average time per record by an assumed average cruising speed of $0.8V_L$). These values constitute the flight load data necessary for the statistical computations. As in references 1 to 3, the distribution of positive and negative accelerations is assumed to be essentially symmetrical about the 1 g line, and therefore the maximum values were sorted and tabulated without regard to sign.

Real differences between probabilities are considered to exist if they differ by more than a ratio of 5:1. The 5:1 ratio for significant differences (references 1 to 3) is used herein as a level of engineering concern in connection with the spread of flight miles required to exceed the limit gust load factor and to exceed fixed effective gust velocity at the probable speed of maximum-acceleration occurrence V_p.

PRECISION

The precision of the V-G recorder and the limitations of the method of analysis employed are discussed in reference 1. The inherent instrument errors are assumed not to exceed ±0.2g for acceleration nor 3 percent of the maximum airspeed range of the instrument.

RESULTS

Table II gives the frequency distributions (reference 4) of V_{max}, Δn_{max}, and V_o of the V-G data used in the analysis. The statistical parameters computed from the three distributions are given at the bottom of the table and are the average value of each distribution indicated by a bar over the symbol, the standard deviation σ, which is a measure of the dispersion of the distribution from the mean, and the coefficient of skewness α, which is a measure of deviation from symmetry of the distribution. These parameters are used to calculate Pearson Type III curves (reference 7) which, as indicated in reference 4, have been assumed to be a reasonable representation of V-G data. The Pearson curves were transformed to curves of average flight miles required to exceed given values of airspeed and acceleration increment by multiplying $1/P_V$ and $1/P_{\Delta n}$ by the factor $0.8V_L\tau$, where $\tau = 95.1$ hours. The transformed curves are presented in figures 1 and 2 together with the cumulative data from V-G records. From these curves and the probability P_o that maximum acceleration on a record will occur in any given speed range, the flight envelopes of figure 3 were derived to show the average flight miles required to exceed stated values of acceleration and speed. The composite of all available V-G records of the S-42A airplane is shown in figure 3 for comparison.

Figure 4 compares the S-42A airplane results at values of the limit gust load factor and fixed effective gust velocity with corresponding results obtained during the prewar period for the airplanes shown in figure 5 of reference 3. Flight miles are plotted in the figure on a logarithmic scale.

DISCUSSION

The average flight miles required to exceed a given value of flight speed of the S-42A airplane, shown in figure 1, indicates that the design level-flight speed V_L will be exceeded, on the average, once in about 1.7×10^5 flight miles, whereas the chance of exceeding the placard speed is decidedly remote. Figure 2, which gives the flight loads of the airplane, indicates that the limit gust load factor will be exceeded, on the average, once in about 3×10^7 flight miles.

Figure 3 indicates that the derived flight envelope and the composite V-G record obtained from all available S-42A V-G records agree reasonably well for corresponding values of flight miles. The increase shown between the two derived envelopes in the figure represents the growth that would be expected of the flight envelope. The probable speed V_p at which the largest accelerations will most likely be experienced appears to be in the neighborhood of 138 miles per hour on the derived envelope.

Consideration of the data in figure 4 indicates that differences exist for the various airplanes in the average flight miles required to exceed the limit gust load factor. These differences range from less than 2-to-1 for the S-42A airplanes compared with the DC-3 airplanes of airline A to about 10-to-1 for the S-42A airplanes compared with the S-307 airplanes. When the whole group is considered, the S-42A flight loads seem about average. The flight loads of the S-42A airplanes are less conservative than those of the S-307, although both airplanes were operated on Caribbean routes. The difference can be attributed to the ratio of probable speed of maximum acceleration occurrence to the design maximum level-flight speed V_p/V_L being lower for the S-307 than for the S-42A or any of the other airplanes compared. The S-42A airplanes were operated at an average speed ratio of 0.76 and the agreement with the other airplanes operated at speed ratios in that neighborhood appears good.

In order to compare operations on the basis of route roughness of the several routes, the flight miles required to exceed the acceleration increment due to an effective gust velocity of 37.5K feet per second encountered at probable speed of gust encounter V_p are given in figure 4. The particular value of gust velocity of 37.5K was chosen because the flight miles required to exceed the resulting accelerations would be roughly comparable to the flight miles required to exceed the limit gust load factor. Since the effect of operating speed is removed, the variation between routes is considerably reduced. Comparison of the 37.5K value for the S-42A airplanes with that for the S-307 airplanes shows good agreement. Since both types were operated on Caribbean routes, agreement might have been expected. No differences greater than about 3-to-1 are apparent between the S-42A and the other airplanes. When judged by the criterion of the 5:1 significance ratio, the differences between the S-42A and other airplanes for the flight miles required to exceed the 37.5K limit are not in excess of 5-to-1, and the conclusion may be drawn that these differences are not of engineering concern. As a consequence, the operations of S-42A airplanes over Caribbean routes do not show greater route roughness than most of the other routes compared.

CONCLUDING REMARKS

The analysis of acceleration and airspeed data taken during the operations of Sikorsky S-42A airplanes on Caribbean routes and along the east coast of South America indicates that the flight loads seem about average in comparison with the flight loads of other types of airplanes flown on different routes. The limit gust load factor of the S-42A airplane will be exceeded, on the average, once in about 3×10^7 flight miles. The loads experienced by the Sikorsky S-42A airplanes were shown to be less conservative than the loads of the Boeing S-307 airplanes, both of which were operated in the same general region; this difference was attributed to the higher ratio of probable speed of maximum acceleration occurrence to the design maximum level-flight speed V_p/V_L of the S-42A airplanes. Caribbean operations of the S-42A and the S-307 airplanes are in good agreement with respect to route roughness and do not show greater route roughness than most of the other routes compared.

Langley Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., July 30, 1948

REFERENCES

1. Peiser, A. M., and Walker, W. G.: An Analysis of the Airspeeds and Normal Accelerations of Boeing S-307 Airplanes in Commercial Transport Operation. NACA TN No. 1141, 1946.

2. Peiser, A. M.: An Analysis of the Airspeeds and Normal Accelerations of Douglas DC-3 Airplanes in Commercial Transport Operation. NACA TN No. 1142, 1946.

3. Walker, Walter G.: An Analysis of the Airpseeds and Normal Accelerations of Martin M-130 Airplanes in Commercial Transport Operation. NACA TN No. 1693, 1948.

4. Peiser, A. M., and Wilkerson, M.: A Method of Analysis of V-G Records from Transport Operations. NACA Rep. No. 807, 1945.

5. Anon.: Airplane Airworthiness. Civil Aero. Manual 04, CAA, U.S. Dept. Commerce, Feb. 1, 1941, sec. 04.2121.

6. Anon.: Airplane Airworthiness - Transport Categories. Pt. 04 Civil Air Regulations, Civil Aero. Board, U.S. Dept. Commerce, Nov. 9, 1945.

7. Kenney, John F.: Mathematics of Statistics. Pt. II. D. Van Nostrand Co., Inc., 1939, pp. 49-51.

TABLE I

SUMMARY OF V-G RECORDS SUPPLIED AND USED IN ANALYSIS

Airplane	Records supplied		Records used in analysis			
	Number of records	Total flight hours	Number of records	Total flight hours	Average flight hours per record	Range of record flight hours
NC-15373	49	4,167	31	2,969	95.7	70 to 130
NC-15374	42	3,126	22	1,975	89.8	70 to 130
NC-15375	65	5,459	41	3,918	95.6	70 to 130
NC-15376	37	3,150	23	2,262	98.4	70 to 130
Total	193	15,902	117	11,124	95.1	70 to 130

NACA

TABLE II

FREQUENCY DISTRIBUTIONS AND STATISTICAL PARAMETERS OF V_{max}, Δn_{max}, AND V_o

V_{max}		Δn_{max}		V_o	
Velocity (mph)	Frequency	Acceleration increment (g units)	Frequency	Velocity (mph)	Frequency
150 to 154	12	0.25 to 0.29	2	105 to 109	1
155 to 159	18	.30 to .34	1	110 to 114	6
160 to 164	22	.35 to .39	10	115 to 119	8
165 to 169	23	.40 to .44	10	120 to 124	20
170 to 174	17	.45 to .49	4	125 to 129	16
175 to 179	16	.50 to .54	10	130 to 134	38
180 to 184	6	.55 to .59	14	135 to 139	38
185 to 189	0	.60 to .64	23	140 to 144	29
190 to 194	1	.65 to .69	34	145 to 149	36
195 to 199	2	.70 to .74	29	150 to 154	21
		.75 to .79	28	155 to 159	9
		.80 to .84	15	160 to 164	6
		.85 to .89	16	165 to 169	2
		.90 to .94	7	170 to 174	3
		.95 to .99	12	175 to 179	0
		1.00 to 1.04	7	180 to 184	0
		1.05 to 1.09	2	185 to 189	0
		1.10 to 1.14	1	190 to 194	0
		1.15 to 1.19	2	195 to 199	1
		1.20 to 1.24	2		
		1.25 to 1.29	2		
		1.30 to 1.34	1		
		1.35 to 1.39	0		
		1.40 to 1.44	1		
		1.45 to 1.49	1		
Total	117	Total	234	Total	234
$\overline{V}_{max}$	167.07	$\overline{\Delta n}_{max}$	0.73	$\overline{V}_o$	139.15
σ_V	9.60	$\sigma_{\Delta n}$	0.20	σ_o	13.00
α_V	0.58	$\alpha_{\Delta n}$	0.58	α_o	0.40

NACA

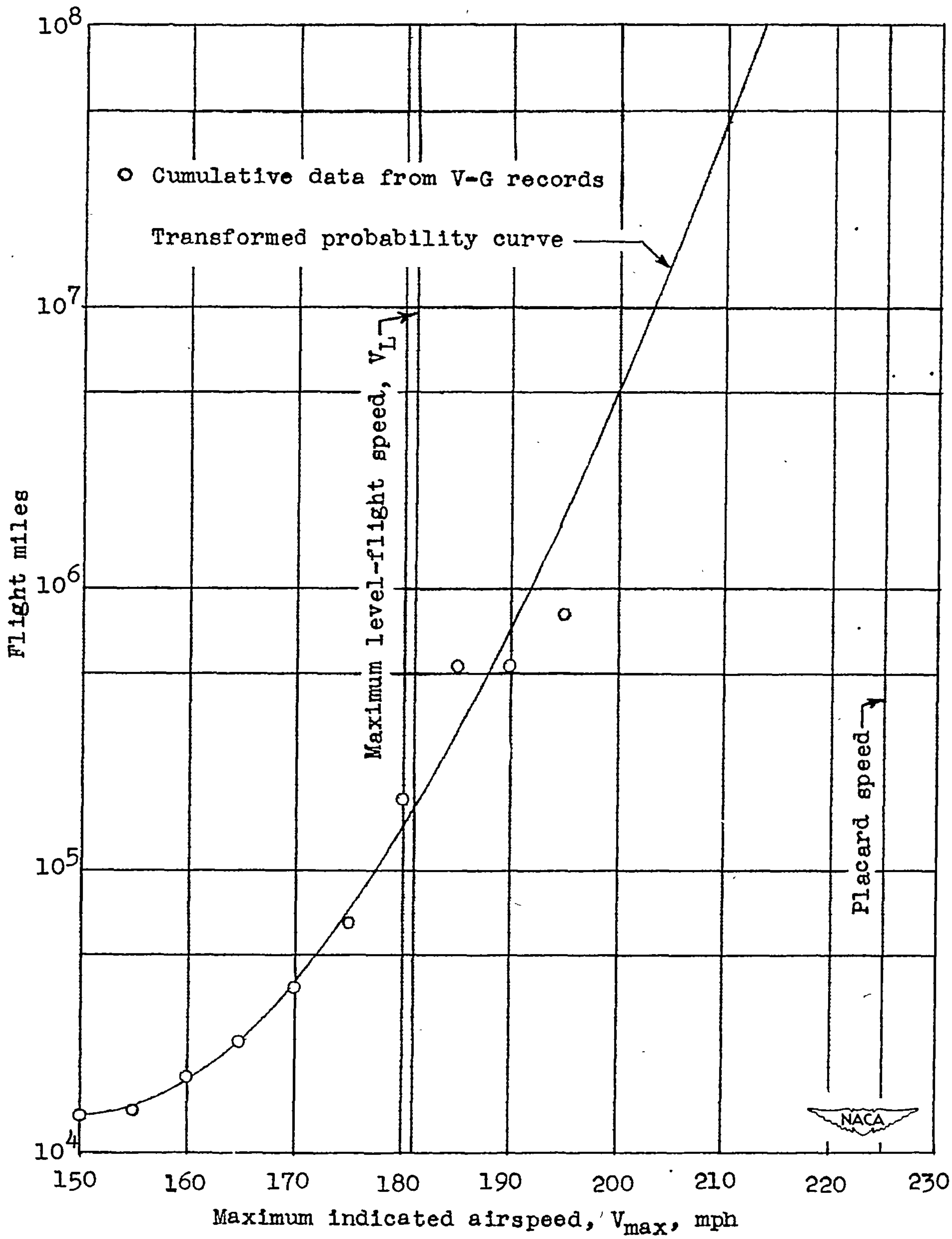

Figure 1.- Average flight miles required to exceed a given value of airspeed.

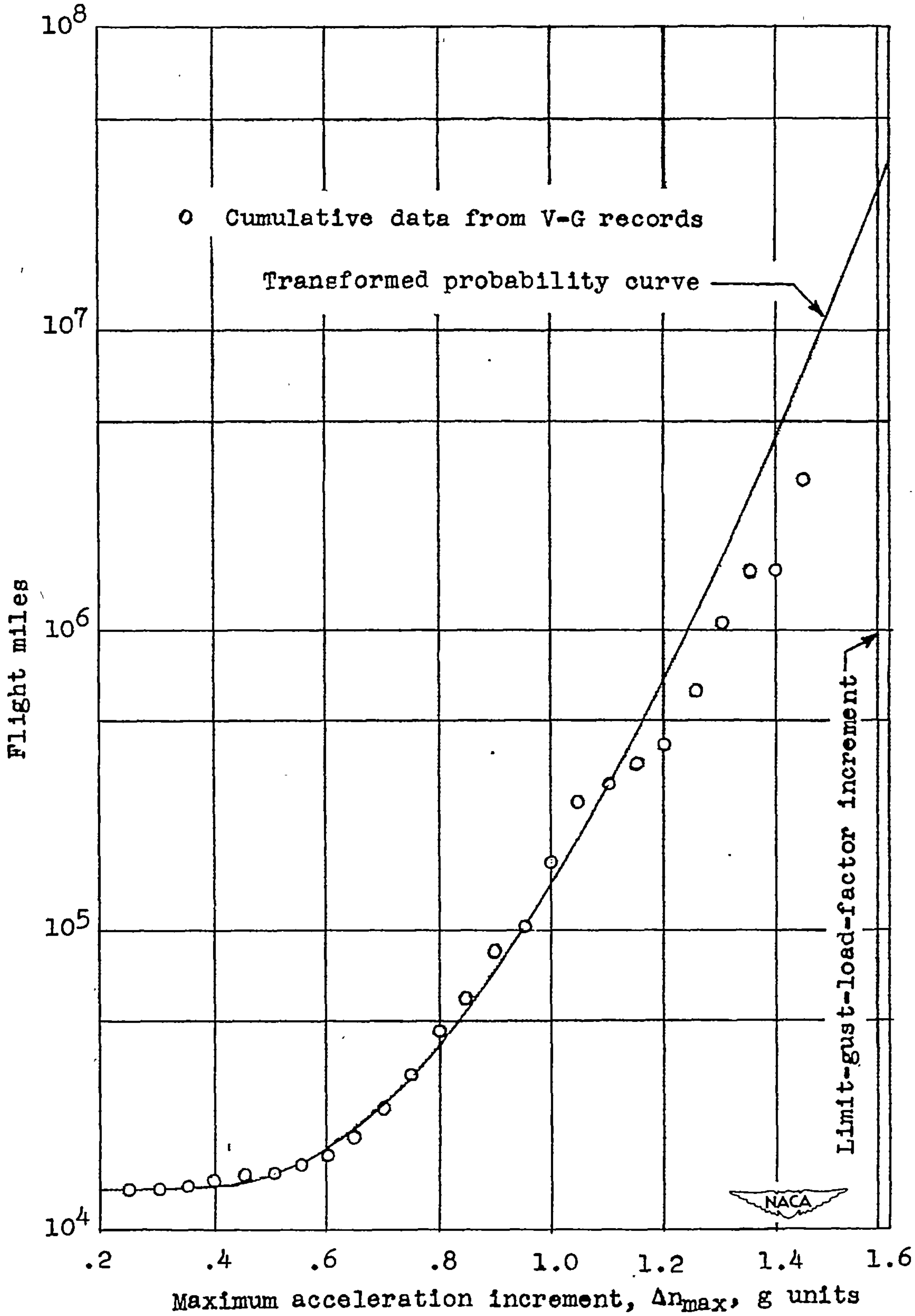

Figure 2.- Average flight miles required to exceed a given acceleration increment.

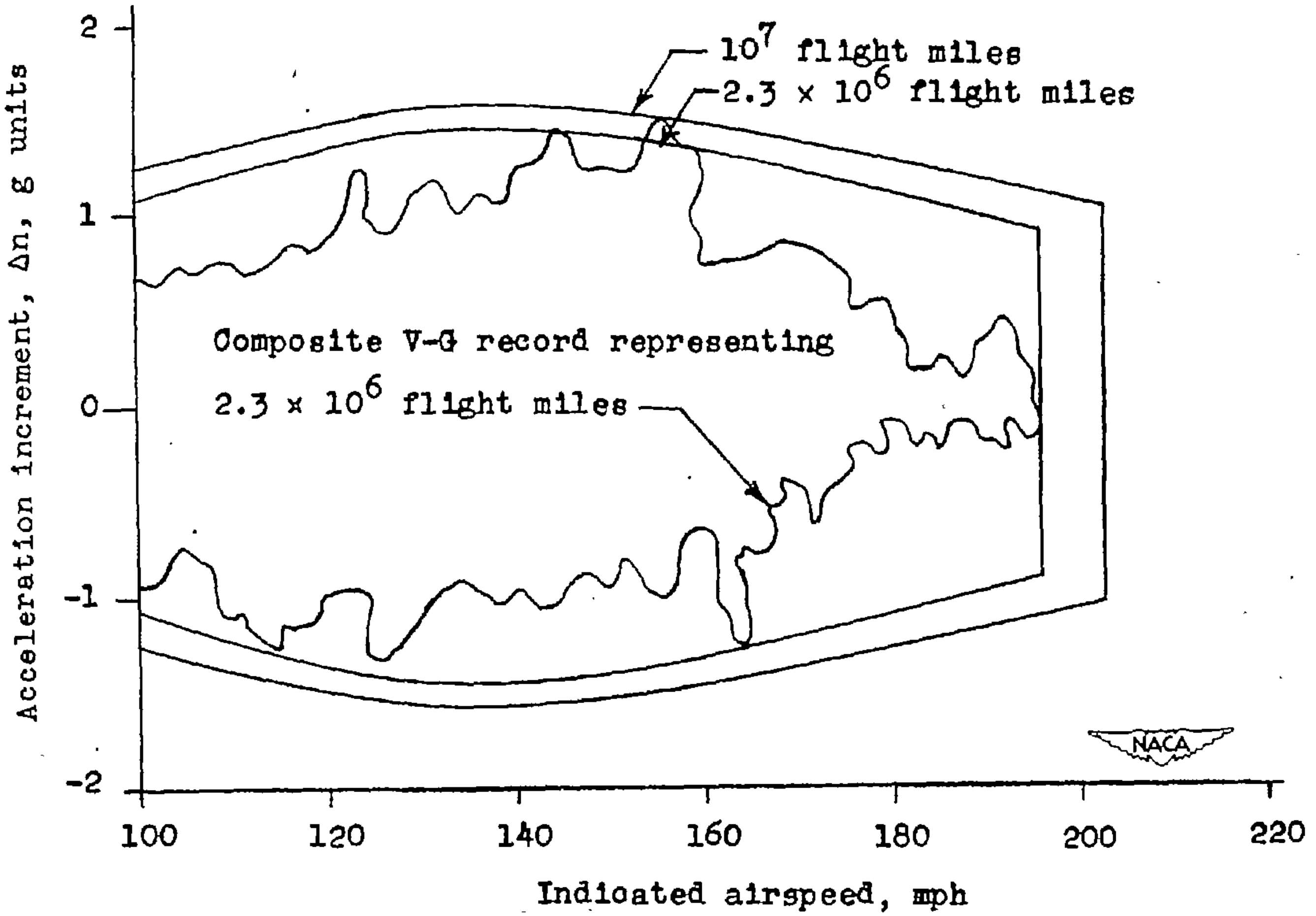

Figure 3.- Comparison of calculated flight envelopes with the composite V-G record of Sikorsky S-42A airplanes.

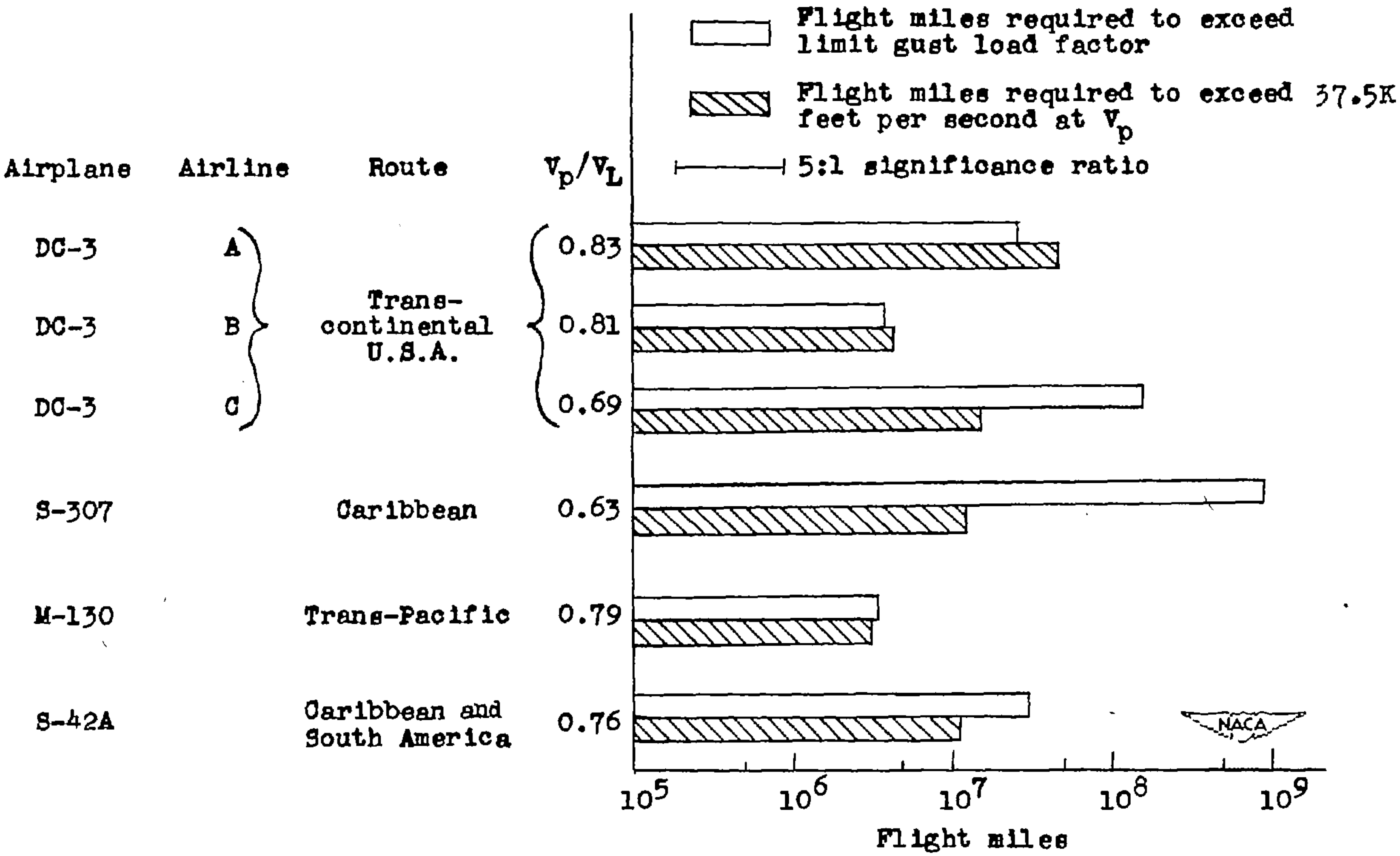

Figure 4.- Comparison of average flight miles required to exceed limit gust load factor and to exceed fixed effective gust velocity at probable speed V_p of gust encounter.