NACA TN 2714

TECH LIBRARY KAFB, NM
0065761

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 2714

NORMAL ACCELERATIONS AND OPERATING CONDITIONS ENCOUNTERED BY A HELICOPTER IN AIR-MAIL OPERATIONS

By Almer D. Crim and Marlin E. Hazen

Langley Aeronautical Laboratory
Langley Field, Va.

Washington
June 1952

AFMDC
TECHNICAL LIBRARY
AFL 2811

TECH LIBRARY KAFB, NM
0065761

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 2714

NORMAL ACCELERATIONS AND OPERATING CONDITIONS ENCOUNTERED BY A HELICOPTER IN AIR-MAIL OPERATIONS

By Almer D. Crim and Marlin E. Hazen

SUMMARY

An analysis is presented of the normal accelerations and operating conditions encountered by a single-rotor helicopter engaged in air-mail operations in the vicinity of Los Angeles and its suburbs. Data were obtained for 14 months of operation, from May 1950 through June 1951, and represent 1,691 flights (253 hours of flying time).

The results indicate that, for this type of operation, maneuver loads developed in routine flight are often greater than the largest gust loads. Considering the maximum positive and negative acceleration increments reached in each flight, approximately 54 percent of these maximums were due to maneuvers occurring either at take-off or during the landing descent.

The largest en-route accelerations, due to gusts or maneuvers, are similar in magnitude to the landing-descent maneuver loads. Maximum increments recorded en route were 0.70g and -0.60g, while corresponding values for the descent were 0.60g and -0.55g.

INTRODUCTION

A knowledge of operating loads and corresponding flight conditions is necessary in establishing a more rational basis for helicopter design. The maximum loads likely to be encountered due to gusts or maneuvers must be determined, and it is desirable to know the percentage of time spent in various flight conditions as an aid in estimating the service life of helicopter components. A relatively large amount of such information has been accumulated for airplanes, but very few comparable data are available for helicopters.

With the cooperation of the Civil Aeronautics Administration, the military departments, and various commercial operators, the National

Advisory Committee for Aeronautics is engaged in a survey of operating loads and associated flight conditions for different types of helicopter operations. Some results obtained through the cooperation of Los Angeles Airways, Inc., on a single-rotor helicopter engaged in air-mail operations have been analyzed and are presented in the present paper.

NACA HELICOPTER VGH RECORDER

Data for the present investigation were obtained by means of an NACA helicopter VGH recorder. This instrument, which records normal acceleration, airspeed, and altitude as a function of time, is similar to the NACA VGH recorder described in reference 1 but is lighter and more compact and was specially built with ranges and frequencies suitable for helicopter use.

The instrument (see fig. 1) is $5\frac{3}{4}$ inches wide, $6\frac{1}{2}$ inches high, and 15 inches long and weighs 12 pounds. Two pressure-sensitive elements for measuring airspeed and altitude, an element for measuring normal acceleration, and a timing mechanism are all contained within the instrument. Recording is effected through a system of mirrors, light sources, and a 50-foot roll of $2\frac{3}{8}$-inch photographic film which advances at the rate of approximately 2.5 feet per hour. The recording time for one drum is therefore about 20 hours. Power is supplied from the helicopter 24-28 volt direct-current source, and current drain is approximately 1 ampere.

SCOPE

The present paper is based on data obtained with a helicopter engaged in air-mail operations in the vicinity of Los Angeles and its suburbs. The helicopter used, figure 2, is a single-rotor machine having a rotor diameter of 48 feet and was operated at a gross weight of approximately 5,000 pounds. A total of 1,691 flights representing 253 hours of flying time were recorded. As may be seen in figure 3, records were taken over a period of 14 months, from May 1950 through June 1951. (In this figure, as well as in succeeding figures which are bar graphs, the separate areas comprising any given bar are proportional to their percentage of the total.)

RESULTS

The records were analyzed by reading, for each flight, four values of acceleration: the maximum and minimum peaks occurring while in flight and the maximum and minimum accelerations due to the landing impact (negative values during landing are apparently due to rebound from initial impact). Typical acceleration peaks are shown in the sample time history of figure 4(a), and records taken during various amounts of atmospheric turbulence are illustrated in figures 4(b) to 4(d). The loads occurring at take-off and climb, en route, and during the landing descent are designated as flight loads, while those due to the actual landing impact are classified as landing loads.

In figure 5 the frequency distribution of accelerations produced by flight loads is plotted as a function of the number of flights, while figure 6 shows the average number of flights required to equal or exceed a given value of acceleration increment. Figure 6 was obtained by summing the frequency distribution and then dividing the resulting cumulative distribution into the total number of flights. Figures 7 and 8 show similar results for the landing loads. The number of flights is considered to be more significant than flying hours in the present case, since the average flight was of short duration and a large percentage of the maximum loads was due to maneuvers associated with take-off or landing.

Since the percentage of time spent in an accelerated state is important in determining the service life of helicopter components, the flight records for the present case were examined for accelerations held for appreciable periods of time. Although no large, sustained maneuver loads were noted, the records showed that 34 acceleration increments equal to or greater than 0.15g were held for 7 seconds or longer. However, the total time spent at or above positive increments of this magnitude, tabulated regardless of duration, was found to be only 0.4 percent of the total operating time. Similarly, the total time spent at or below increments of -0.15g was approximately 8 minutes or 0.05 percent.

One record, which covered 110 flights and 16.8 hours of flight time, was examined in considerably more detail than the bulk of the data obtained. For purposes of analysis, each flight of this group was divided into climb, en-route, and descent conditions. For each condition, the magnitude of all acceleration increments Δn above a threshold value of 0.2g was read, along with the corresponding indicated airspeed V_i. Table I gives the percentage of flight time according to airspeed and flight conditions, and table II summarizes, cumulatively, the number and magnitude of acceleration peaks for climb, en route, and descent.

DISCUSSION

Gust and maneuver loads.- Inspection of figure 5 reveals that in a large percentage of flights the greatest loads are due to either take-off or landing-descent maneuvers. It is found that 54 percent of the maximum acceleration increments reached in flight are a result of these two maneuvers, the descent maneuver alone being responsible for about 37 percent of the total. The extreme en-route increments (due to maneuvers and gusts) were found to be 0.70g and -0.60g, while corresponding values for the landing descent were 0.60g and -0.55g. The largest take-off increment was 0.45g.

The acceleration peaks recorded while en route were, in many cases, not sufficiently abrupt in nature to be classified as pure gust loads.

The typical landing, as may be seen in figure 4, consisted of a steep approach and an early flare, followed by a gradual decrease of airspeed and altitude, with the result that normal accelerations just prior to landing were always near 1 g. The indicated airspeed was usually in the range of 0 to 15 miles per hour at the instant of contact. Examination of figures 7 and 8 reveals that the magnitude and distribution of landing loads were similar to those encountered in flight, the maximum incremental values being 0.69g and -0.47g.

In general, it would appear that maneuver loads may be expected to produce greater accelerations, so far as an occasional very high value is concerned, than atmospheric turbulence. Unpublished data indicate that a helicopter in a pull-up can reach loads corresponding approximately to maximum values of lift coefficient on all blade elements. During flight tests of a small, single-rotor helicopter assigned to the Langley Laboratory, accelerations in pull-ups were reached which corresponded approximately to the theoretical maximum load factor and to the design flight load factor of 2.5g. To produce the same acceleration, a gust velocity of about 60 feet per second (with no alleviation) would be required, which contrasts with a value of 30 feet per second specified by regulatory agencies for design purposes.

In view of the limited amount of data available, as well as the uncertainty regarding the origin of many of the acceleration loads, extrapolation of the present results beyond recorded values does not seem advisable. Also, the maximum values obtained thus far are not considered adequate for design purposes, since much higher loads have repeatedly been obtained in pull-up maneuvers.

Operating conditions.- Although no detailed analysis of operating conditions was made for all the data obtained, the values given in table I are believed to be typical of the operations being considered. Analysis of random samples taken from other data gave almost identical results for the percentage of time spent at various airspeeds and flight conditions. The general distribution of acceleration peaks at these different flight conditions, as given in table II, was also corroborated by other data, but the actual number and magnitude of such peaks may not be typical.

Apparently no wide variation of altitude or length of flight occurred. Operational altitudes were almost always below 2,500 feet (pressure altitude), while the duration of any given flight was usually close to the average of approximately 9 minutes. It is also noteworthy that most of the maximum flight loads occurred either while en route or during the transition from cruise to descent, with corresponding airspeeds in the cruising range of 65 to 85 miles per hour. Landings were apparently made at or near zero ground speed, with the indicated airspeed usually in the range of 0 to 15 miles per hour at the instant of contact.

CONCLUDING REMARKS

An analysis has been made of the normal accelerations and operating conditions encountered by a single-rotor helicopter engaged in air-mail operations in the vicinity of Los Angeles and its suburbs. For the helicopter operation covered by the present data, it appears that loads developed in routine take-off and landing-descent maneuvers are often greater than the maximum loads encountered en route. When the maximum positive and negative acceleration increments were read for each flight, 54 percent of these maximums were found to be due to the take-off and landing-descent maneuvers.

The largest en-route accelerations, due to gusts or maneuvers, are similar in magnitude to the landing-descent maneuver loads. Extreme increments recorded en route were 0.70g and -0.60g, while corresponding values for the descent were 0.60g and -0.55g.

More sampling appears to be required to establish the frequency of accelerations of higher magnitudes. The maximum values obtained thus far would seem inadequate for design purposes, since much larger accelerations have been previously obtained in pull-up maneuvers.

Langley Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., March 10, 1952

REFERENCE

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

TABLE I

SUMMARY OF OPERATING CONDITIONS FROM ONE RECORD

[Flight time, 16.8 hr; number of flights, 110; May 1950]

Flight condition	Percent total flight time at V_i				Total
	0 to 20 mph	20 to 65 mph	65 to 85 mph	Over 85 mph	
Climb	1.9	11.2	1.3	0.1	14.5
En route[a]	0	3.9	63.0	6.9	73.8
Descent	3.4	3.6	3.3	1.4	11.7
Total	5.3	18.7	67.6	8.4	

[a]En route considered to begin when rate of climb was below 300 ft/min and to end when rate of descent exceeded 300 ft/min.

TABLE II

DISTRIBUTION OF ACCELERATION PEAKS FROM ONE RECORD

Condition	Magnitude of peak	Number of peaks at V_i				Peaks per mile at V_i			
		0 to 20 mph	20 to 65 mph	65 to 85 mph	Over 85 mph	0 to 20 mph	20 to 65 mph	65 to 85 mph	Over 85 mph
Climb[a]	$\Delta n \geqq 0.2g$	0	15	6	1	0	0.18	0.36	0.95
	$\Delta n \geqq 0.3g$	0	1	2	0	0	.01	.12	0
	$\Delta n \geqq 0.4g$	0	0	0	0	0	0	0	0
En route	$\Delta n \geqq 0.2g$	0	19	235	79	0	.65	.30	.76
	$\Delta n \geqq 0.3g$	0	1	34	16	0	.03	.04	.15
	$\Delta n \geqq 0.4g$	0	0	5	1	0	0	.01	.01
Descent	$\Delta n \geqq 0.2g$	7	19	11	4	1.24	.70	.26	.19
	$\Delta n \geqq 0.3g$	2	3	1	1	.35	.11	.02	.05
	$\Delta n \geqq 0.4g$	0	0	0	0	0	0	0	0

[a]Does not include take-off loads.

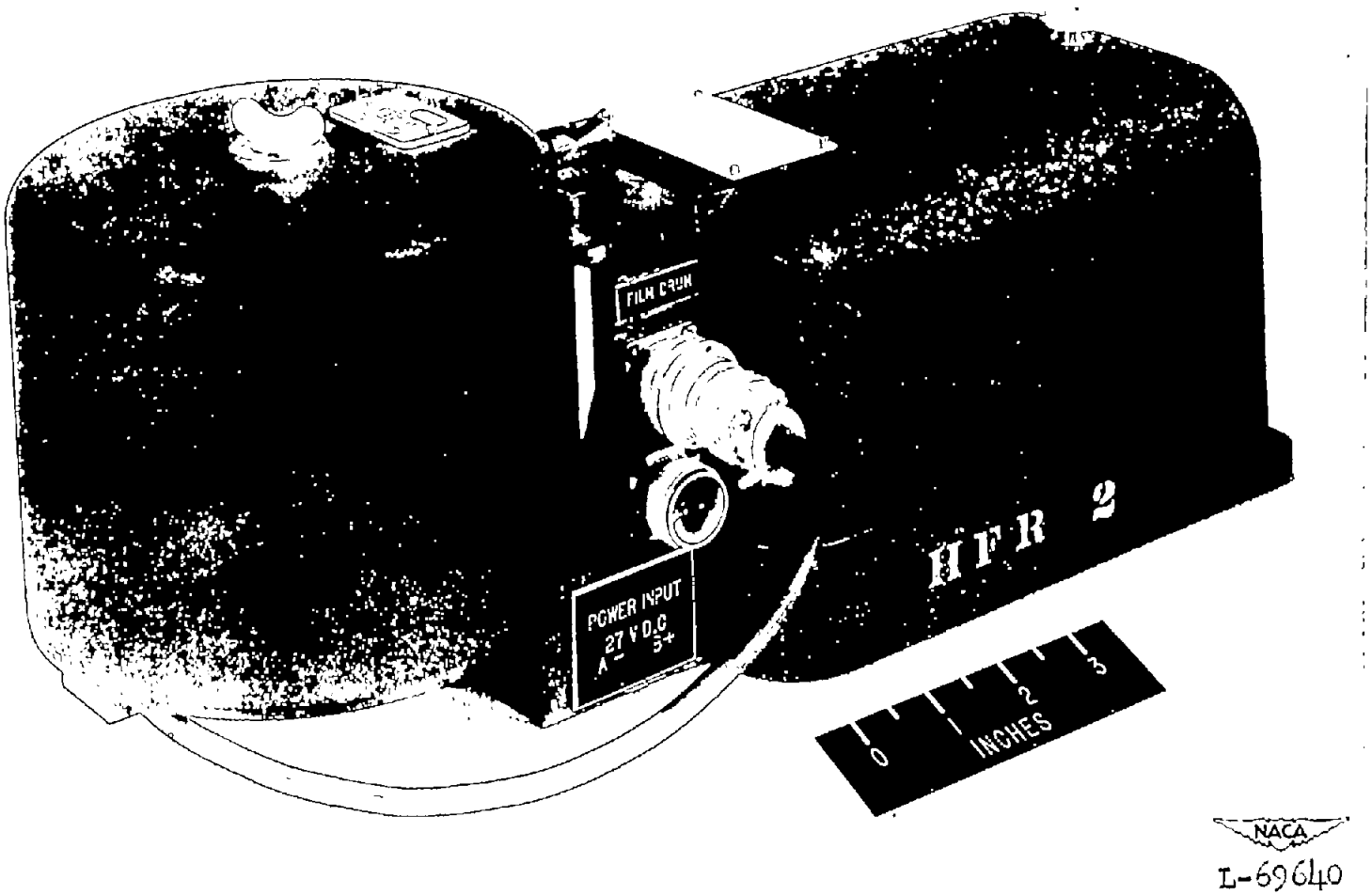


Figure 1.- Special recorder used in investigation.

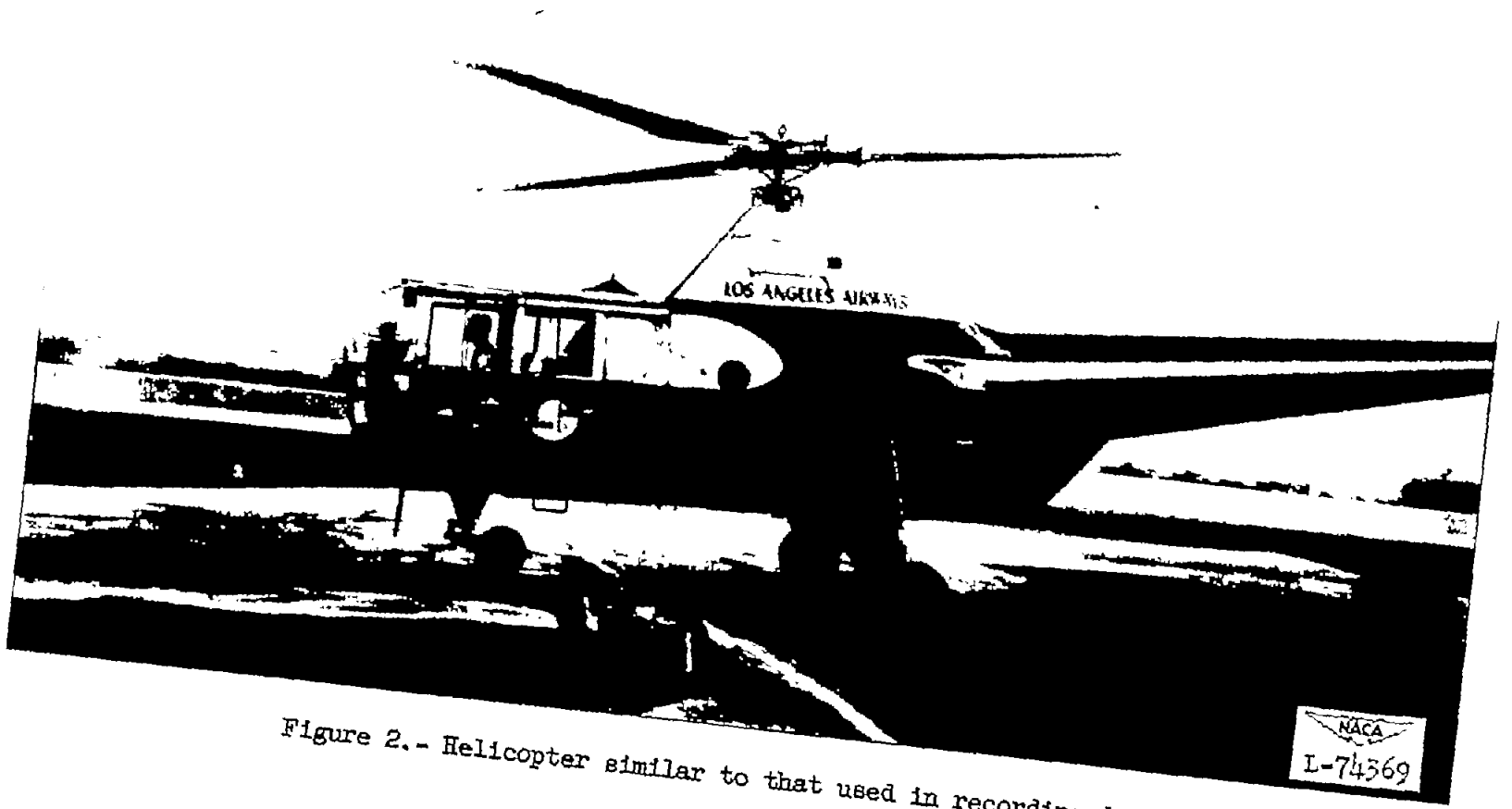


Figure 2.- Helicopter similar to that used in recording data.

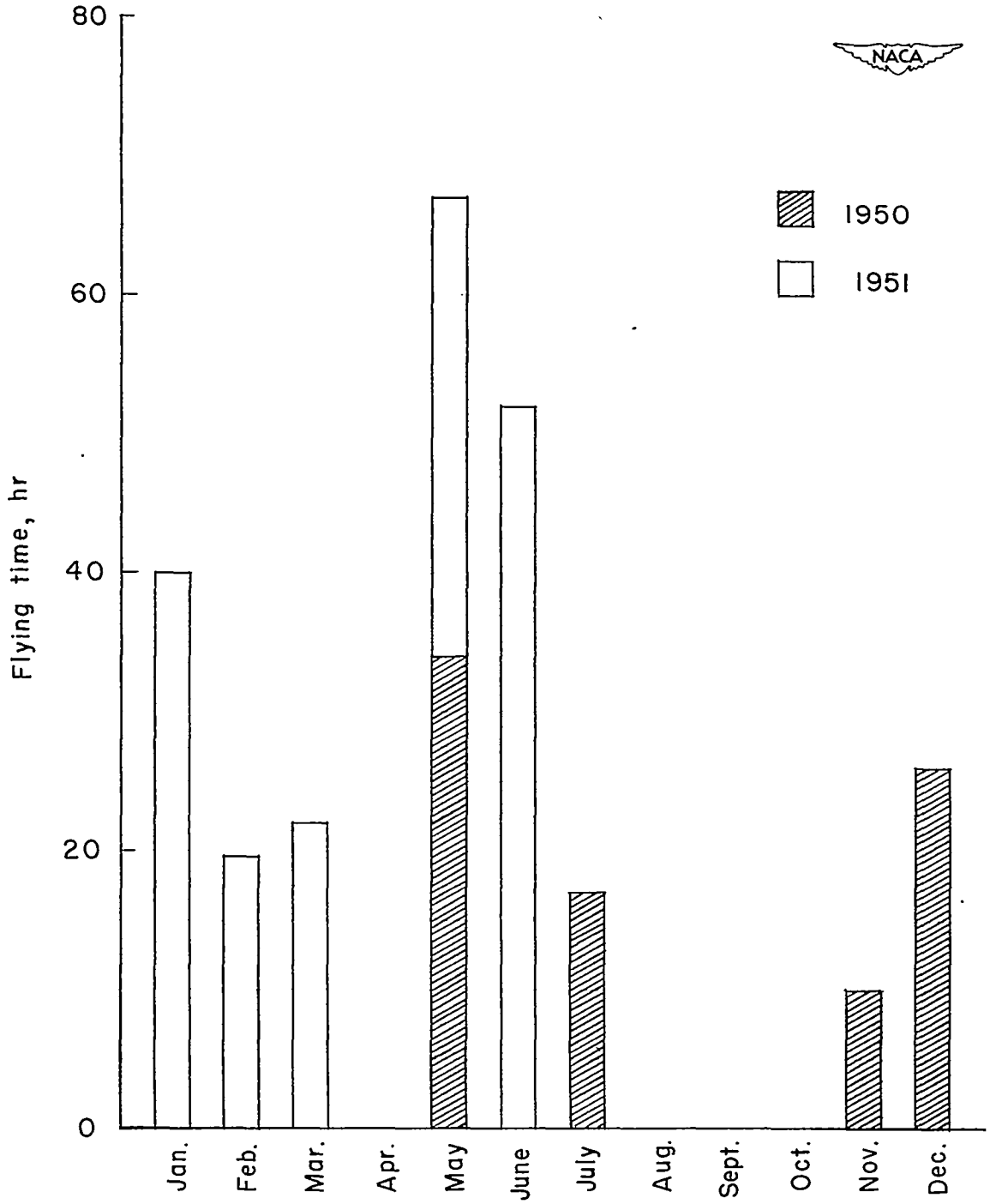
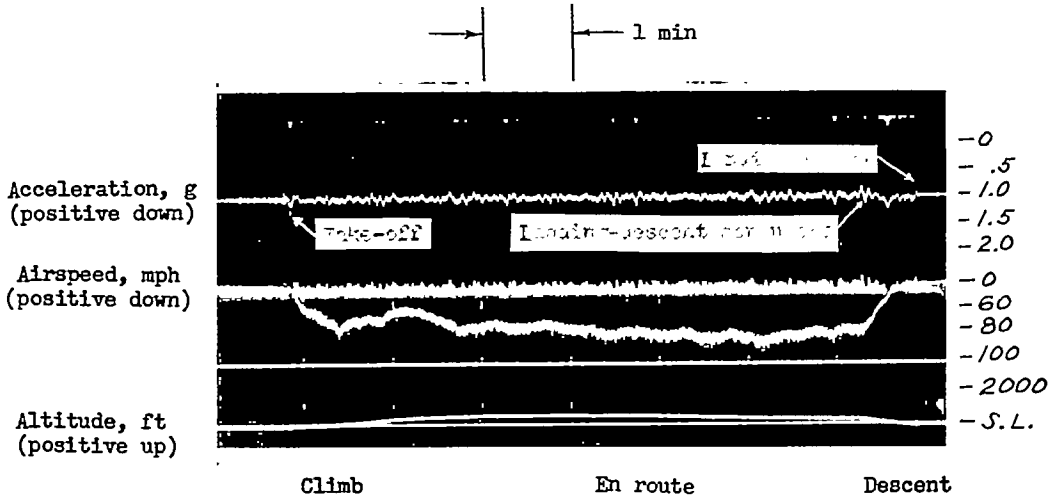
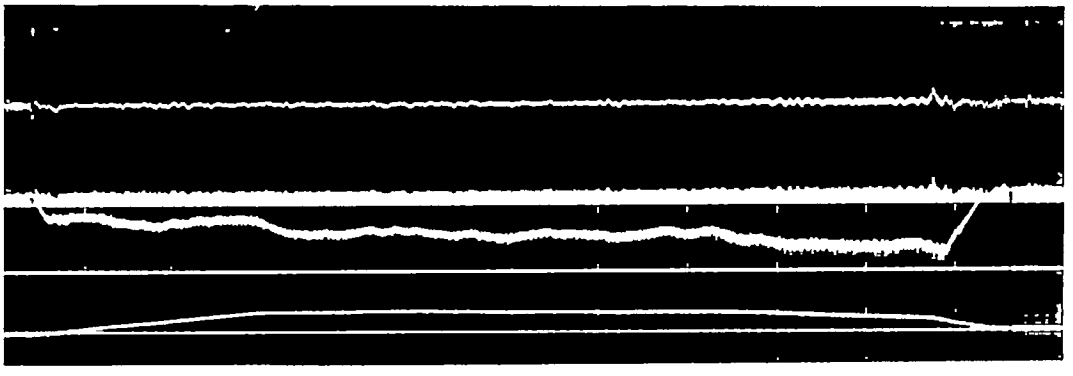


Figure 3.- Distribution of flying time by months.

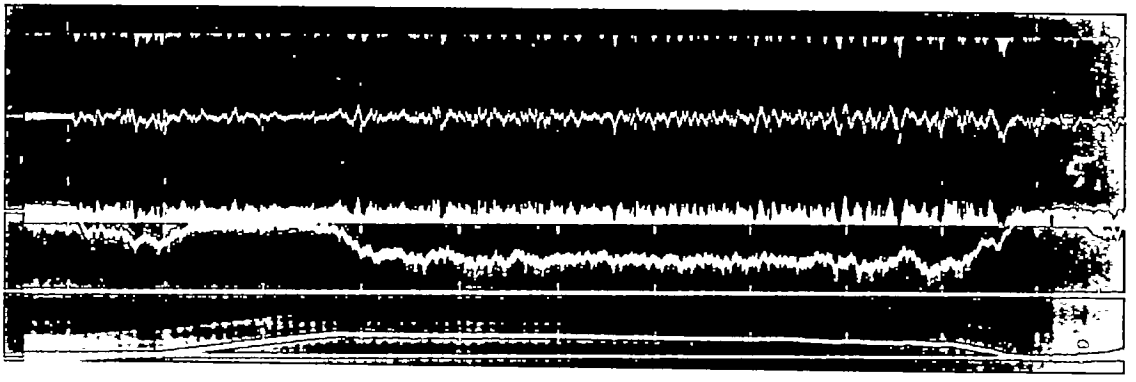


(a) Sample record identifying traces.

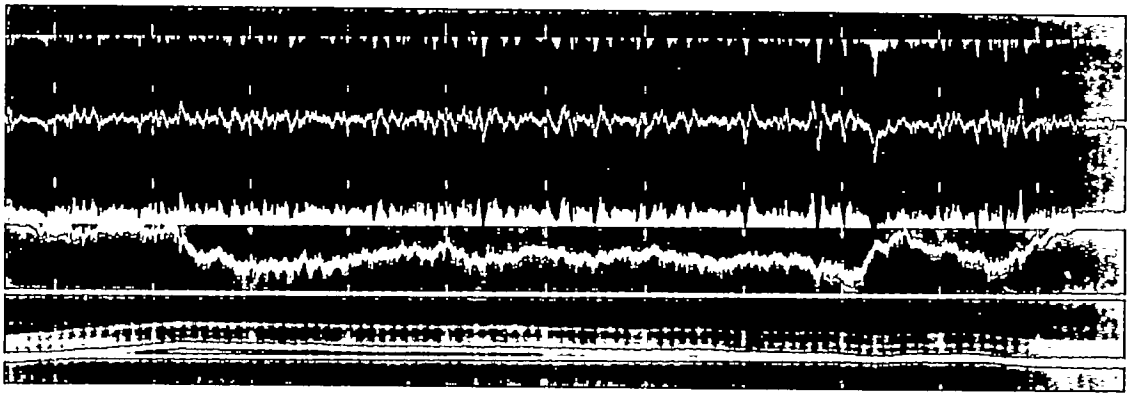


(b) Typical record in smooth air.

Figure 4.- Sample flight records.



(c) Typical record in moderately rough air.



(d) Typical record in rough air.

Figure 4.- Concluded.

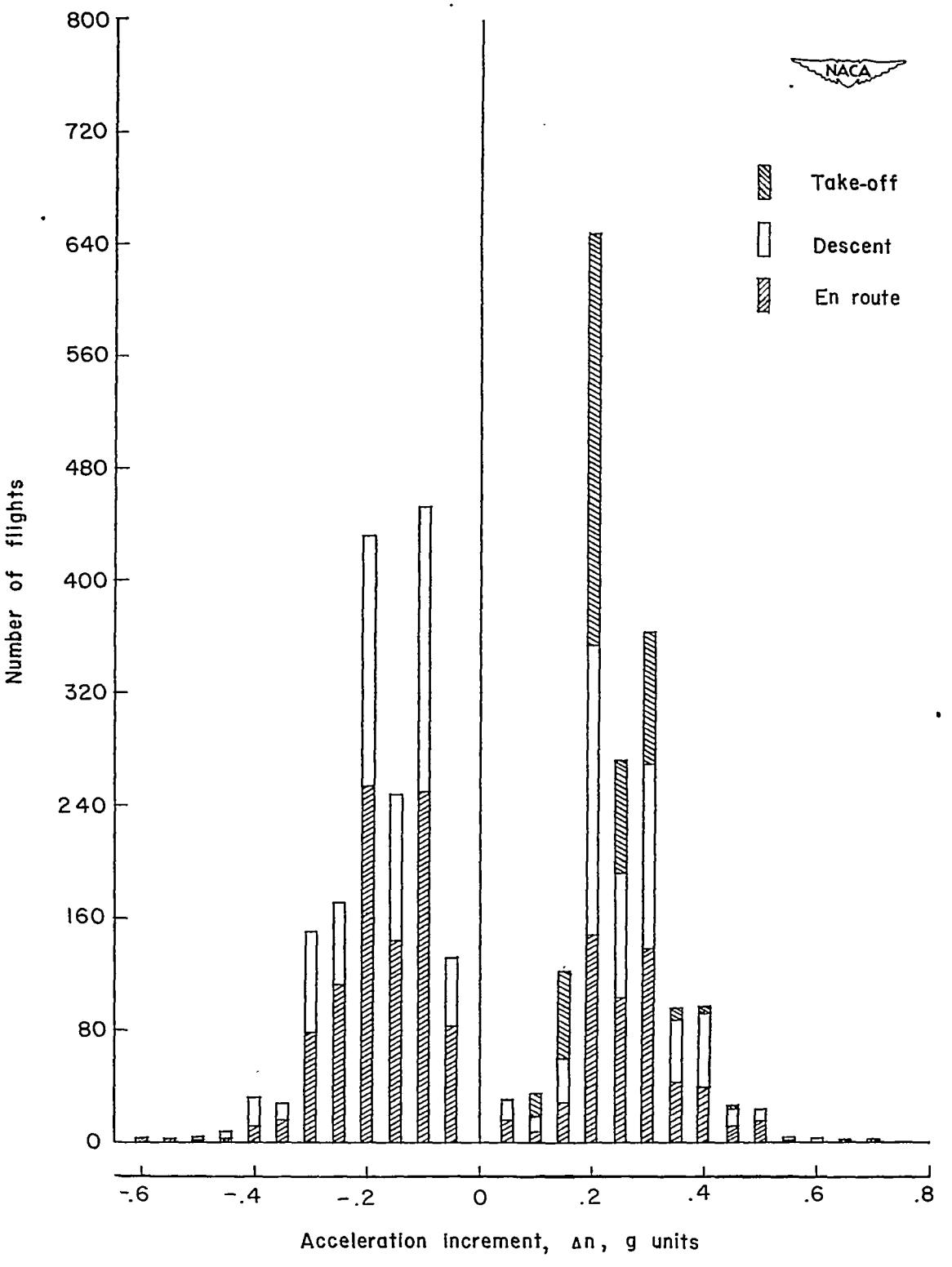


Figure 5.- Total number of flights in which the stated value of acceleration increment was the extreme reached.

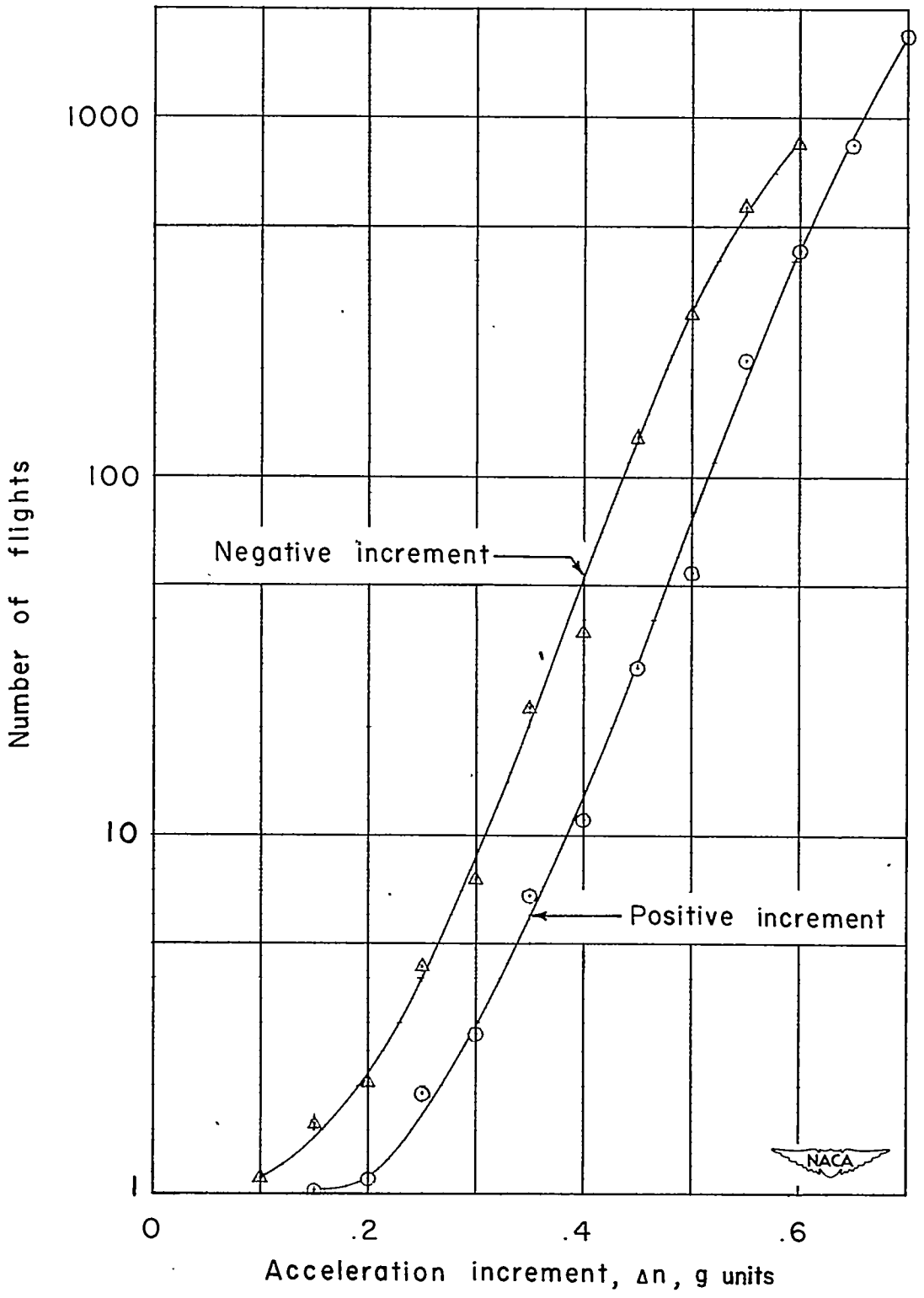


Figure 6.- Average number of flights required to equal or exceed a given value of acceleration increment.

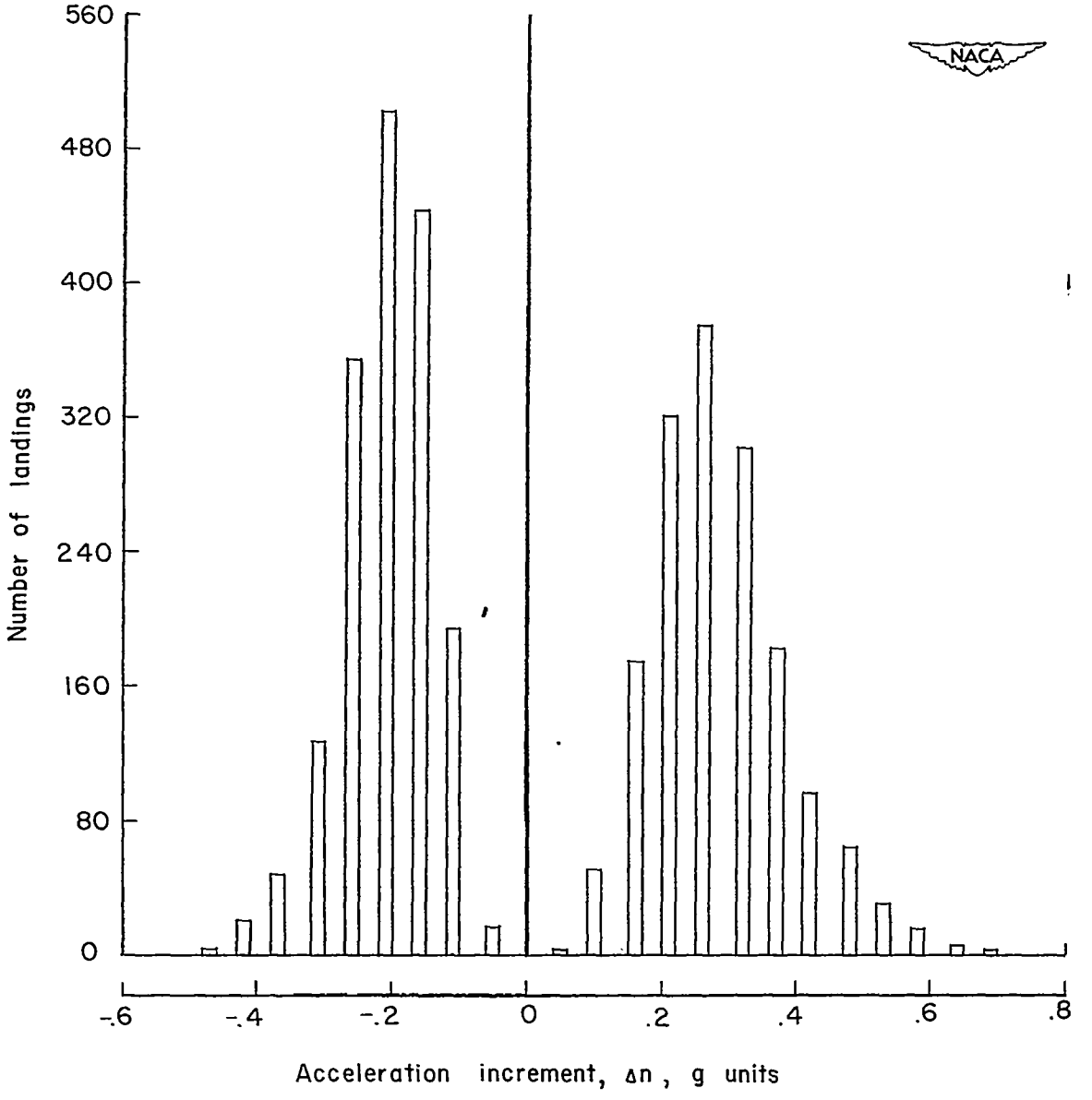


Figure 7.- Total number of landings in which the stated value of acceleration increment was the extreme reached.

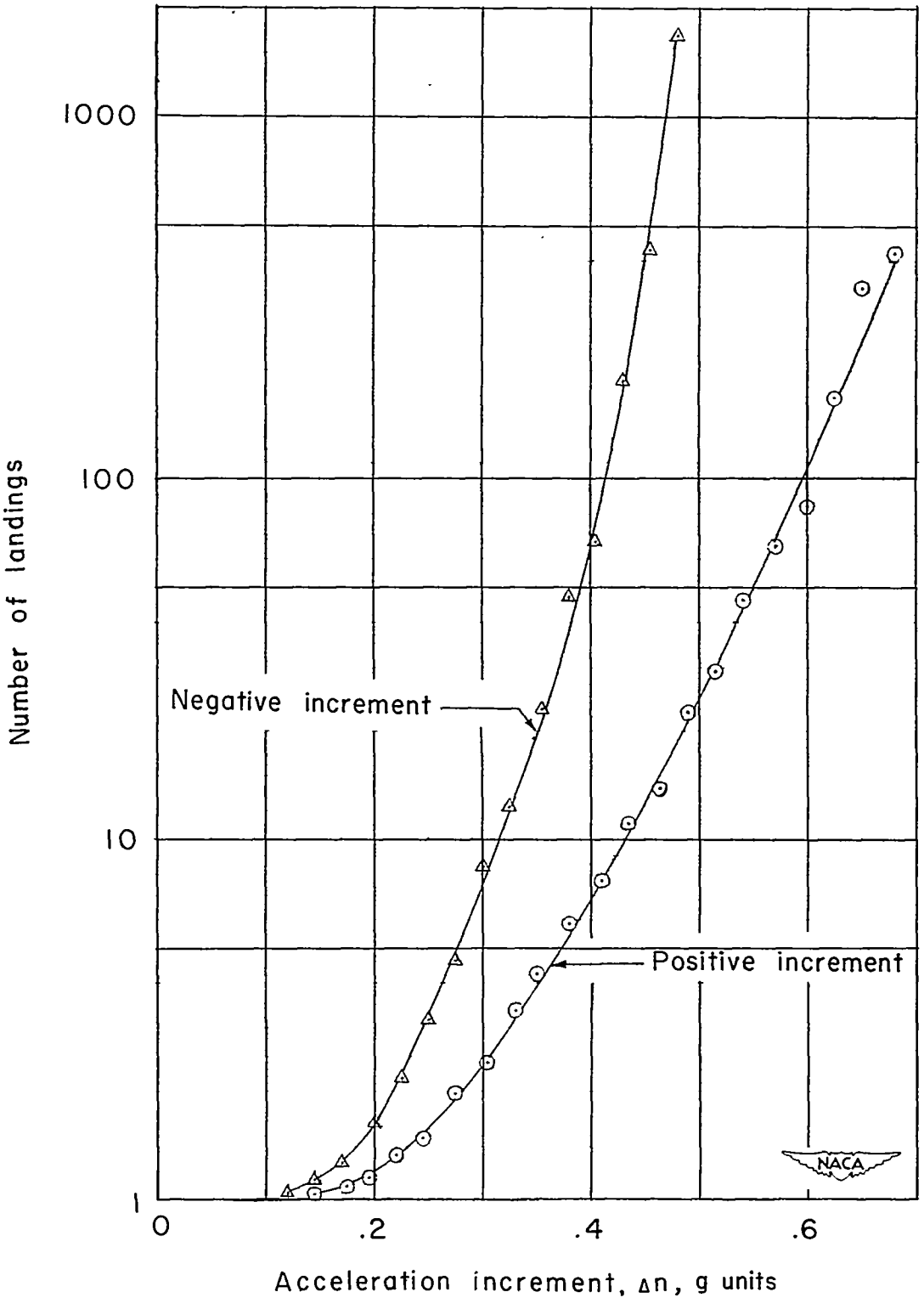


Figure 8.- Average number of landings required to equal or exceed a given value of acceleration increment.

NACA-Langley - 6-23-52 - 1000