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# ANALYSIS OF V-G RECORDS FROM THE SNB-1 AIRPLANE

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MEMORANDUM REPORT

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## SUMMARY

Acceleration and airspeed data in the form of V-G records obtained on an SNB-1 trainer airplane were analyzed to determine the loads and speeds experienced during certain training operations. By utilizing a method of analysis previously developed, results were determined in the form of "flight envelopes" which predict the occurrences of large values of airspeed and acceleration.

As a matter of incidental interest, the results were compared with results previously reported for another scout-trainer airplane - the SNJ-4. The comparison shows large differences in the frequency of occurrence of large values of acceleration and airspeed. This result is probably attributable to the fact that the two airplanes are actually of quite different types, notwithstanding their design to the same load and speed requirements.

## INTRODUCTION

Several sets of acceleration and airspeed data in the form of V-G records were obtained on Navy airplanes and transmitted to the NACA for analysis of applied load factors and speeds. Two sets of such data, together with supplementary information were supplied for two trainer class airplanes, the SNB-1 and the SNJ-4, in large enough quantities to be analyzed by a statistical method. The SNJ-4 data obtained during training operations were analyzed by the method of reference 1, and the results of the analysis were presented in reference 2. The V-G records taken on the SNB-1 airplane type during training operations have been similarly analyzed and the results are presented herein.

Both the SNB-1 and SNJ-4 airplanes are classed as scout trainers, and they were designed to meet the same load-factor requirements. The SNB-1 airplane, however, is a twin-engine six-place cabin airplane, whereas the SNJ-4 is a two-place airplane of substantially smaller size and greater maneuverability.

Because of these considerable dissimilarities in airplane characteristics and in the implied manner of operation, it might be expected that substantially different applied loads and speeds would be imposed in the two cases, notwithstanding the similarity in type designation and design requirements. The results of the analysis of the SNB-1 data were, therefore, compared with the results previously obtained for the SNJ-4 in order to disclose any differences in the applied loads and speeds. The comparison shows that the SNB-1 airplane was subjected to substantially less severe loads and speeds than the SNJ-4.

The SNB-1 data were supplied by the Navy under authority of the Bureau of Aeronautics letter, file Aer-E-2411-JK, serial no. 64187, dated 18 April 1945, and the SNJ-4 data were supplied under authority of the Bureau of Aeronautics letter, file Aer-E-2411-JK, dated 16 January 1945.

## SCOPE OF DATA

Thirty-three V-G records having a total flight time of 561 hours were available for the SNB-1 analysis. Fairly complete supplementary information giving the type of mission flown, operating weights, number of pilots per record, operating altitude, etc., was also available. Since the method of analysis used (reference 1) required a reasonably uniform flight time per record, the 32 records in the range 15 to 24 hours with total flight time of 526 hours were used for the analysis.

Only 40 of the 78 available records for the SNJ-4 were analyzed in reference 2 to meet the requirement of reasonably uniform flight time per record.

The characteristics of the SNB-1 and SNJ-4 types, together with the sources from which these data were obtained, are given in tables I and II.

Table III gives a breakdown of the data to show the percent of total flight time spent on comparable missions for the SNB-1 and the SNJ-4.

## METHOD AND RESULTS

The method used to evaluate the data of this report is described in references 1 and 2. The frequency distributions shown in table IV for the SNB-1 airplanes were used to prepare the probability curves of the maximum indicated airspeed $V_{max}$, the maximum positive or negative acceleration increment $\Delta n_{max}$, and the indicated airspeed $V_o$, at which the maximum positive or negative acceleration increment is experienced. The average values of the distributions $\overline{V}_{max}$, $\overline{\Delta n}_{max}$, and $\overline{V}_o$ are given at the bottom of table IV together with the standard deviations of the distributions $\sigma_V$, $\sigma_{\Delta n}$, and $\sigma_o$, respectively, and the coefficients of skewness of the distributions $\alpha_V$, $\alpha_{\Delta n}$, and $\alpha_o$, respectively, as computed by the method of reference 1. The term "probability," in the sense used herein, may be interpreted as the ratio of the number of records in which a given event occurs to the total number of records used.

Figures 1, 2, and 3 show the probabilities $P_V$, $P_{\Delta n}$, and $\Sigma P_o$, of exceeding given values of $V_{max}$, $\Delta n_{max}$, and $V_o$, respectively, for the SNB-1 airplane. In figure 1, for example, the probability of exceeding a maximum indicated airspeed of 250 miles per hour is 0.025 or, in terms of records, this value of airspeed will be exceeded, on the average, on one record in 40 records. Figures 2 and 3 may be interpreted in a similar manner. Also shown in these figures are the cumulative frequency distribution points obtained from the relative frequencies of table IV to illustrate the agreement of the basic data with the probability curves. The necessary extrapolations of the curves of figure 3 were made by the "straight-line" method developed in reference 2. The extrapolation of the $V_o$ curve for positive accelerations starts at 215 miles per hour, the maximum level-flight speed of the airplane, and the extrapolation of the negative $V_o$ curve starts at 180 miles per hour, the normal cruising speed.

The values of $P_V$, $P_{\Delta n}$, and $\Sigma P_o$ of figures 1, 2, and 3 were used to derive flight envelopes. These envelopes are such that, on the average, in a stated number of flight hours, the envelope will be exceeded by one positive and one negative acceleration increment, and by one maximum airspeed. Figure 4 shows the flight envelopes derived for the SNB-1 airplanes for 250, 500, and 3,000 hours of operation and the composite V-G record for 561 flight hours.

Figure 5 shows the results for the SNJ-4 airplane obtained in the same manner as for the SNB-1 from the data of reference 2. It is to be noted in figure 5 that the flight envelopes predict accelerations considerably greater than those corresponding to $C_{N_{max}}$ and $C_{N_{min}}$. This result was obtained since derivation of the flight envelopes is essentially an extrapolation process that breaks down at regions of discontinuity in physical phenomena. Considering this fact, no reliance should be placed in the envelope where it exceeds the $C_{N_{max}}$ and $C_{N_{min}}$ curves.

The design V-n diagrams presented in figures 4 and 5 for comparison with the flight envelopes of the SNB-1 and SNJ-4 airplanes were developed in accordance with the specifications of reference 3. Since no data were given on the maximum normal-force coefficients and because values were needed to complete the design diagrams, the values of $C_{N_{max}} = 2.0$ and $C_{N_{min}} = -1.0$ were arbitrarily chosen.

In order to have a direct comparison of the average time to exceed given values of accelerations and speeds, figures 6 and 7 were prepared. The curves shown in these figures were plotted from figures 1 and 2 for the SNB-1 and from the corresponding figures of reference 2 for the SNJ-4, by introducing the flight time factor as explained in reference 1.

## DISCUSSION

The flight envelopes developed are in reasonable agreement with the composite flight envelopes of the available V-G records. Figure 4, for example, shows that the 500-hour envelope compares well with the 561-hour composite. Two positive and two negative accelerations of the SNB-1 composite exceed the flight envelope while only one negative acceleration of the SNJ-4 composite (fig. 5) exceeds the flight envelope, instead of one positive and one negative occurrence which was predicted (reference 1). This is considered good agreement in view of the limited amounts of data available for analysis. Close agreement of the basic data with the probability predictions can be expected when large masses of data are analyzed.

Comparison of the flight envelopes of the SNB-1 and the SNJ-4 types shown in figures 4 and 5, respectively, indicates large difference in the predicted flight envelopes of the two types. It is seen in figure 4 that the 500- and 3000-hour flight envelopes of the SNB-1 do not exceed the design-limit load factors at any point of the diagram and the 3000-hour envelope exceeds the restricted speed by only a small margin. On the other hand, figure 5 shows that the SNJ-4 flight envelopes for 500 and 3000 hours exceed the design-limit load factors over a considerable range of speed and the restricted speed is exceeded by a large amount. Average conditions for the sets of data used, as shown in figures 6 and 7, indicate that the SNJ-4 airplane loads can be expected to reach the design-positive-limit load factor about once in 200 flight hours and the design negative limit about once in 2000 flight hours, while the restricted speed will be exceeded approximately once in every 6 flight hours. Inspection also shows that the SNB-1 type would not be expected to exceed the design-limit-load factors in either the positive or negative direction in less than $(10)^7$ flight hours and the restricted speed only about once in 1000 flight hours.

Inspection of supplementary data forwarded with the V-G records indicated that direct comparison on the basis of particular mission was not possible although both airplane types were flown on comparable missions part of the time. Therefore, an analysis of the data for both types was made on the basis of classifying the missions in four general categories as shown in table III. Sufficient data on both types for comparison existed only in the ground-attack category. Detailed inspection showed the SNB-1 was used only for strafing while the SNJ-4 was utilized for diving and bombing under the ground-attack category. It is seen in this table that the percent of time spent in maneuvers that would be expected to produce high values of acceleration and airspeed is much greater for the SNJ-4 than the SNB-1 type. When the SNJ-4 records covering only one mission per record were examined for the effect of mission on the load factors and airspeeds experienced, it was found that the acrobatic category did show higher average values of loads and speeds than the attack and straight-flying categories.

Other possible reasons may be advanced to explain the more conservative operations of the SNB-1 than the SNJ-4 airplanes, although no proof exists to support such contentions in connection with the data used herein. The amount of experience of the group of pilots that flew each type may not have been the same and one group might have exercised more caution in flight than the other group. Also, it would be expected that the twin-engine SNB-1 would be handled by the pilot with more care than the single-engine SNJ-4 type in view of the fact that in most flights the SNB-1 carried a six-man crew, while nearly all the flights of the SNJ-4 were solo. In addition, since it is a larger and heavier type, the SNB-1 is less maneuverable than the SNJ-4.

## CONCLUSIONS

The available data obtained on SNB-1 trainer-class airplanes were analyzed and the results are presented as "flight envelopes" which predict the occurrences of large values of airspeed and acceleration. Comparison is made with SNJ-4 trainer-class airplane data analyzed by the same method. While the two types are designed to the same strength factors, they differ considerably in configurations and the data are not strictly comparable because utilization of each type in trainer operations was different. However, the following conclusions can be drawn:

1. The flight envelopes developed by the method of analysis used represent the data in a satisfactory manner.

2. Comparison of the results of each type shows large differences in the flight loads and speeds experienced.

3. On the basis of the method used and considering the limited amounts of data available for analysis, the SNB-1 will seldom, if ever, exceed the design-limit load factor and the restricted speed will be exceeded very seldom during the airplane lifetime, while the SNJ-4 airplane can be expected to exceed the design-limit load factor and restricted speed in a very small number of flight hours.

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## REFERENCES

1. Peiser, A. M., and Wilkerson, M.: A Method of Analysis of V-G Records from Transport Operations. NACA ARR No. L5J04, 1945.

2. Wilkerson, M., and Bennett, S. A.: Analysis of V-G Records from the SNJ-4 Airplane. NACA MR No. L5L06, 1945.

3. Anon.: Specification for Flight Loading Conditions for the Structural Design of Naval Airplanes. NAVAER SS-1A, Bur. Aero., Dec. 7, 1942.

TABLE I

CHARACTERISTICS OF NAVY SNB-1 (ARMY AT-11) AIRPLANE

| | |
|---|---|
| Maximum design gross weight (recommended), lb | 9300 |
| Gross weight at take-off (as flown, V-G records), lb | 8200 |
| Wing area, sq ft | 349 |
| W/S, lb/sq ft | 23.5 |
| Wing span, ft | 47.7 |
| Mean aerodynamic chord, in. | 96.6 |
| Aspect ratio | 6.5 |
| Normal cruising speed, mph | 180 |
| Maximum speed in level flight (7850 lb at 5000 ft) mph | 215 |
| Maximum restricted speed (IAS), mph | 253 |
| Center-of-gravity range, percent M.A.C. | 16 to 30 |
| Design applied load factors, g units | 6 to -3 |
| Service ceiling (7850 lb), ft | 22,400 |
| Number of engines | 2 |

Note: The above table was prepared from:

AAF Tech. Order. AN-01-90KA-2
AAF Tech. Order. AN-01-90K-5

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# TABLE II

## CHARACTERISTICS OF NAVY SNJ-4 (ARMY AT-6D) AIRPLANE

| | |
|---|---|
| Maximum design gross weight (recommended), lb | 5300 |
| Gross weight at take-off (as flown, V-G records), lb | 5043 |
| Wing area, sq ft | 253.7 |
| W/S, lb/sq ft | 19.9 |
| Wing span, ft | 42.1 |
| Mean aerodynamic chord, in. | 76.0 |
| Aspect ratio | 7.0 |
| Normal cruising speed, mph | 170 |
| Maximum speed in level flight, mph | 205 |
| Maximum restricted speed (IAS), mph | 240 |
| Center-of-gravity range, percent M.A.C. | 22.5 to 25.6 |
| Design applied load factors, g units | 6 to -3 |
| Service ceiling, ft | 21,500 |
| Number of engines | 1 |

Note: The above table was prepared from:

Navy Tech. Order. AN01-60F-2
Navy Tech. Order. AN01-60FE-1, revised 15 Feb. 1945.

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TABLE III

OPERATING CONDITIONS UNDER WHICH V-G RECORDS WERE TAKEN

ON THE SNB-1 AND SNJ-4 AIRPLANES

| Type of mission | Percent of time per mission | |
|---|---|---|
| | SNB-1 | SNJ-4 |
| Combat acrobatics | 0 | 48.8 |
| Air attack | 32.5 | 1.6 |
| Ground attack | 42.4 | 35.2 |
| Straight flying | 25.1 | 14.4 |
| Total | 100.0 | 100.0 |

Note: The values given above are based on 33 SNB-1 records for 561 flight hours and on 78 SNJ-4 records for 275 flight hours.

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# TABLE IV

## FREQUENCY DISTRIBUTIONS AND PARAMETER VALUES FROM SNB-1 V-G RECORDS

| $V_{max}$ distribution | | Positive accelerations | | | | Negative accelerations | | | |
|---|---|---|---|---|---|---|---|---|---|
| $V_{max}$ (mph) | Frequency | $\Delta n_{max}$ (g units) | Frequency | $V_o$ (mph) | Frequency | $\Delta n_{max}$ (g units) | Frequency | $V_o$ (mph) | Frequency |
| 200 - 204 | 1 | 0.70 - 0.79 | 3 | 130 - 139 | 1 | 0.20 - 0.29 | 2 | 120 - 129 | 2 |
| 205 - 209 | 2 | 0.80 - 0.89 | 2 | 140 - 149 | 1 | 0.30 - 0.39 | 0 | 130 - 139 | 3 |
| 210 - 214 | 3 | 0.90 - 0.99 | 7 | 150 - 159 | 6 | 0.40 - 0.49 | 3 | 140 - 149 | 4 |
| 215 - 219 | 5 | 1.00 - 1.09 | 4 | 160 - 169 | 7 | 0.50 - 0.59 | 4 | 150 - 159 | 5 |
| 220 - 224 | 4 | 1.10 - 1.19 | 1 | 170 - 179 | 4 | 0.60 - 0.69 | 5 | 160 - 169 | 7 |
| 225 - 229 | 7 | 1.20 - 1.29 | 6 | 180 - 189 | 6 | 0.70 - 0.79 | 7 | 170 - 179 | 5 |
| 230 - 234 | 3 | 1.30 - 1.39 | 3 | 190 - 199 | 3 | 0.80 - 0.89 | 6 | 180 - 189 | 4 |
| 235 - 239 | 2 | 1.40 - 1.49 | 1 | 200 - 209 | 1 | 0.90 - 0.99 | 2 | 190 - 199 | 1 |
| 240 - 244 | 2 | 1.50 - 1.59 | 1 | 210 - 219 | 0 | 1.00 - 1.09 | 1 | 200 - 209 | 1 |
| 245 - 249 | 3 | 1.60 - 1.69 | 2 | 220 - 229 | 0 | 1.10 - 1.19 | 0 | | |
| | | 1.70 - 1.79 | 1 | 230 - 239 | 2 | 1.20 - 1.29 | 2 | | |
| | | 1.80 - 1.89 | 0 | 240 - 249 | 1 | | | | |
| | | 1.90 - 1.99 | 1 | | | | | | |

| $V_{max}$ distribution | Positive accelerations ($\Delta n_{max}$) | Positive accelerations ($V_o$) | Negative accelerations ($\Delta n_{max}$) | Negative accelerations ($V_o$) |
|---|---|---|---|---|
| $\bar{V}_{max} = 225.78$ | $\overline{\Delta n}_{max} = 1.17$ | $\bar{V}_o = 177.50$ | $\overline{\Delta n}_{max} = 0.72$ | $\bar{V}_o = 161.88$ |
| $\sigma_V = 11.90$ | $\sigma_{\Delta n} = 0.30$ | $\sigma_o = 25.13$ | $\sigma_{\Delta n} = 0.23$ | $\sigma_o = 19.60$ |
| $\alpha_V = 0.17$ | $\alpha_{\Delta n} = 0.69$ | $\alpha_o = 1.05$ | $\alpha_{\Delta n} = 0.19$ | $\alpha_o = -0.01$ |

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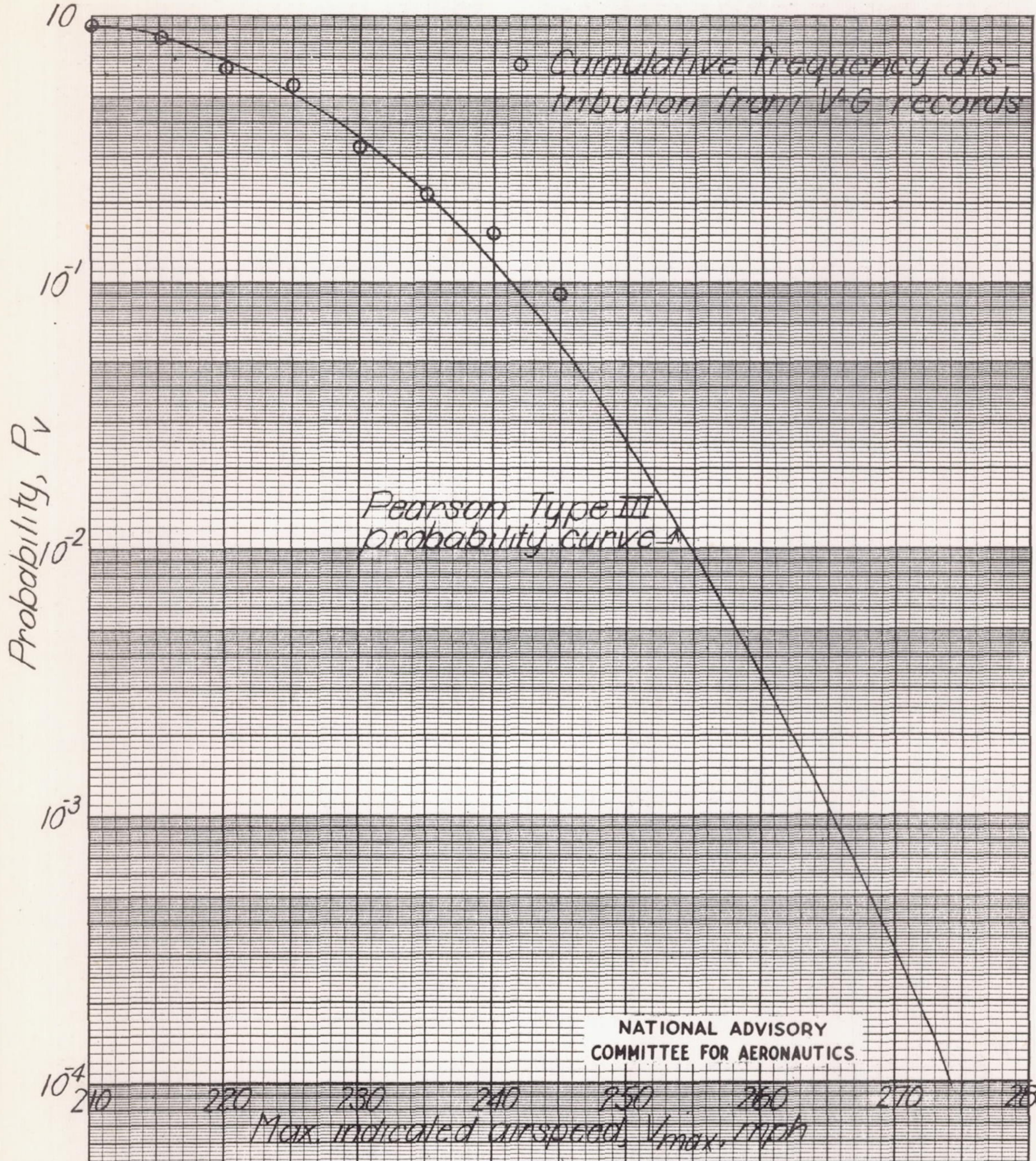


Figure 1.- Probability that maximum indicated airspeed on an SNB-1 airplane V-G record will exceed a given value.

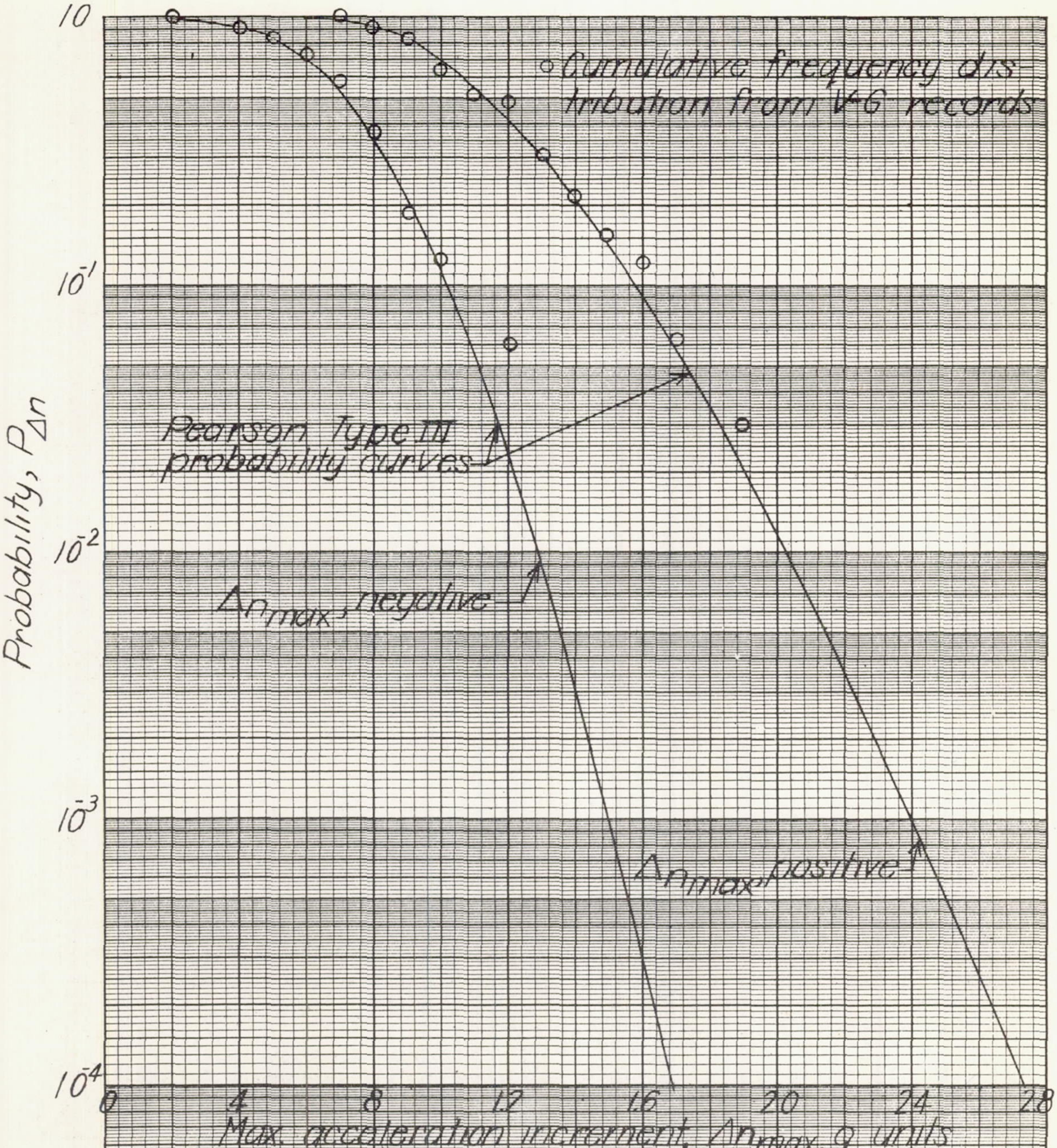


Figure 2.- Probability that maximum acceleration increment on an SNB-1 airplane V-G record will exceed a given value.

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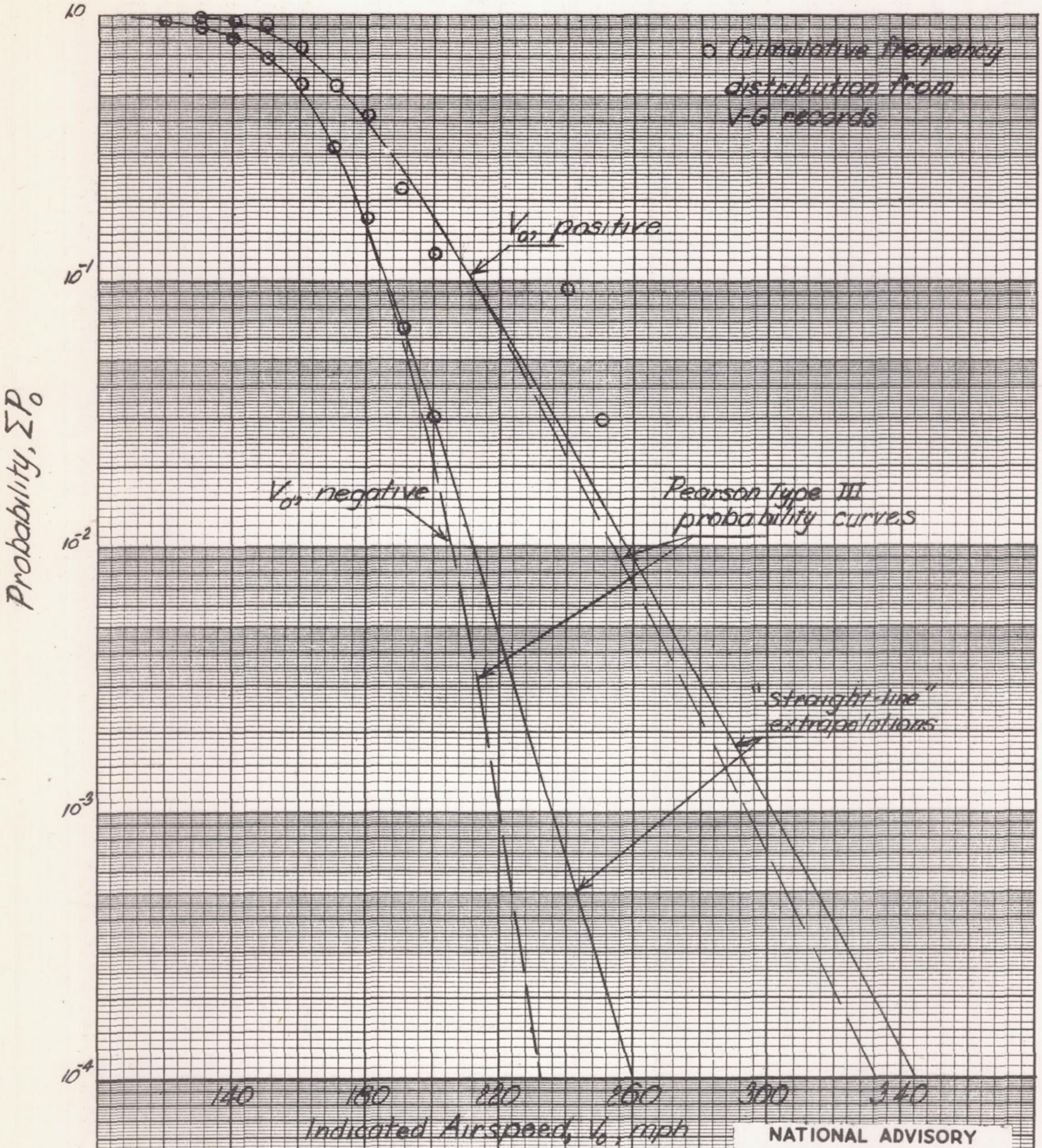


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Figure 3.- Probability that the airspeeds at which the maximum acceleration increments are experienced on an SNB-1 airplane V-G record will exceed given values.

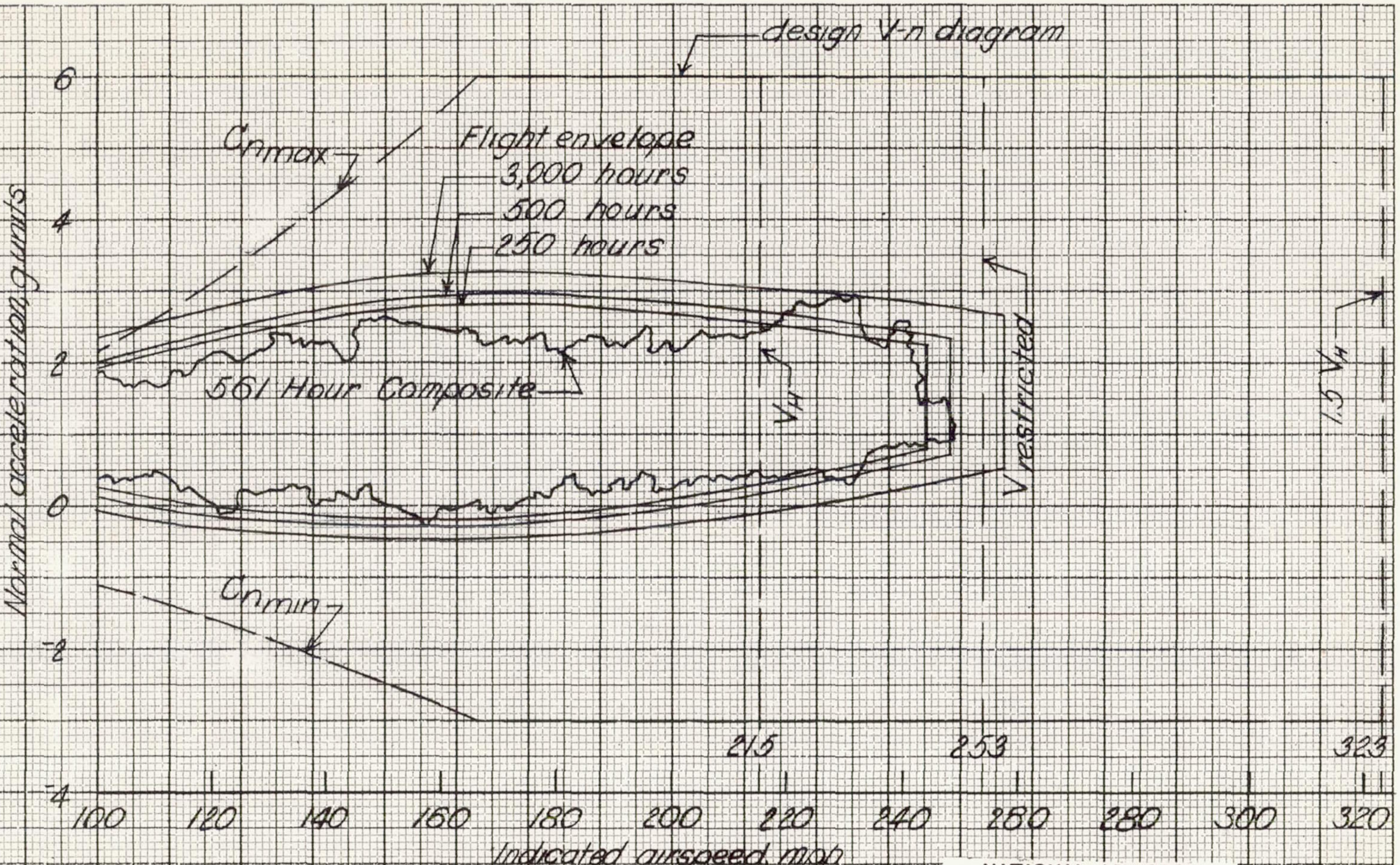


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Figure 4.- Comparison of 250, 500, and 3,000 hour flight envelopes for the SNB-1 airplane with the 561 hour V-G record composite and the design V-n diagram.

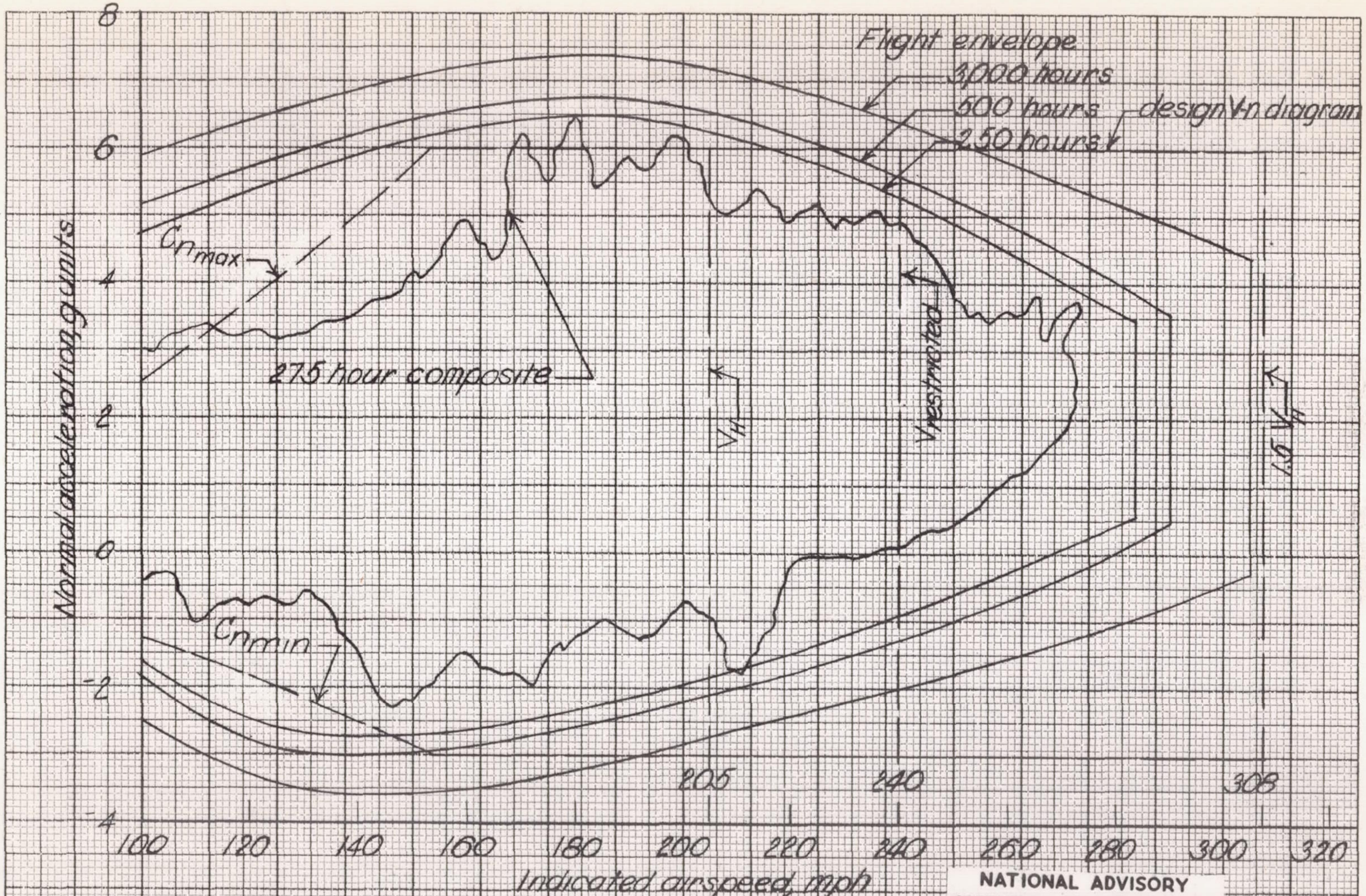


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Figure 5.- Comparison of 250, 500, and 3,000 hour flight envelopes for the SNJ-4 airplane with the 275 hour V-G record composite and the design V-n diagram.

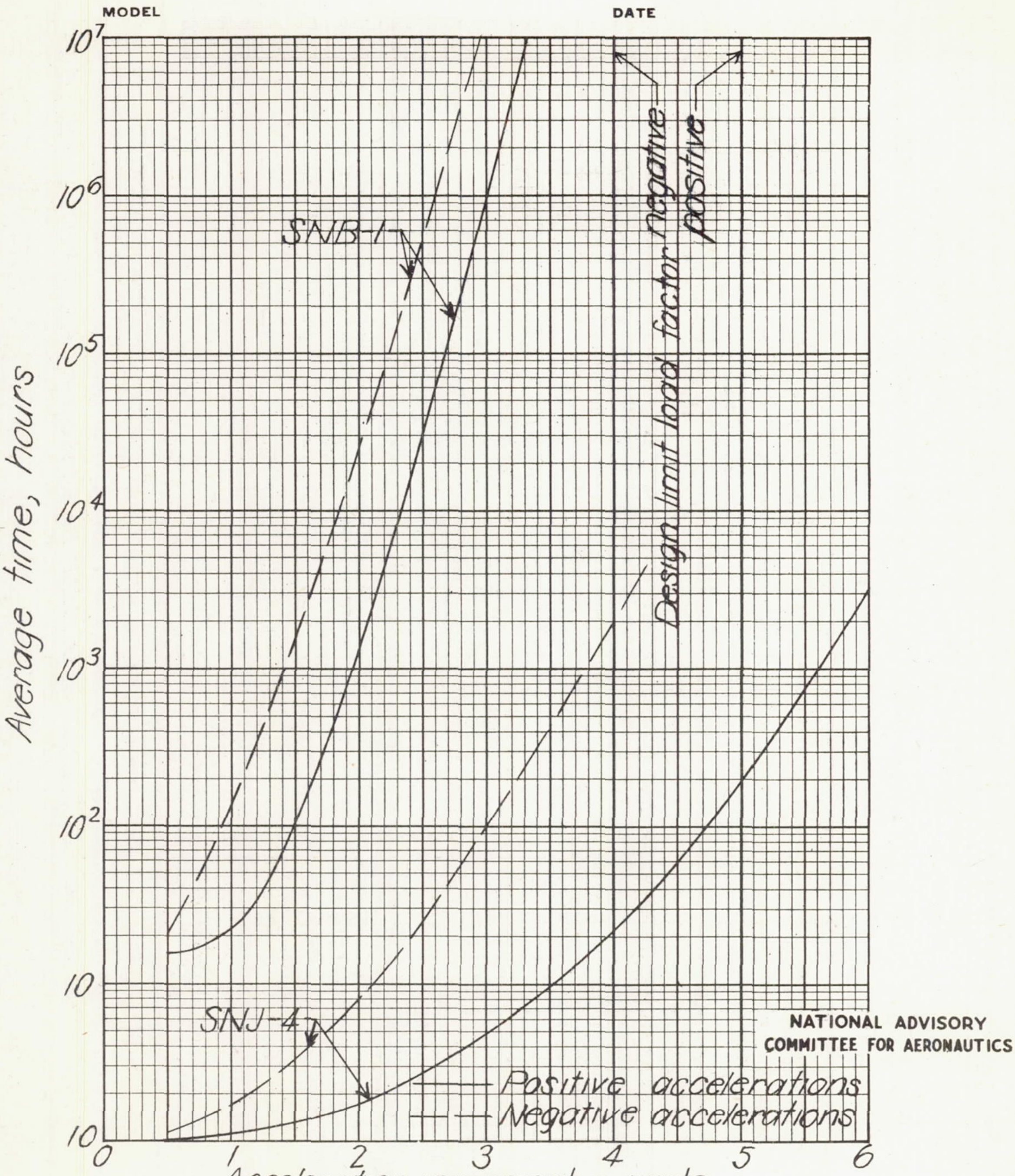


Figure 6.-Comparison of average time required to exceed given values of acceleration.

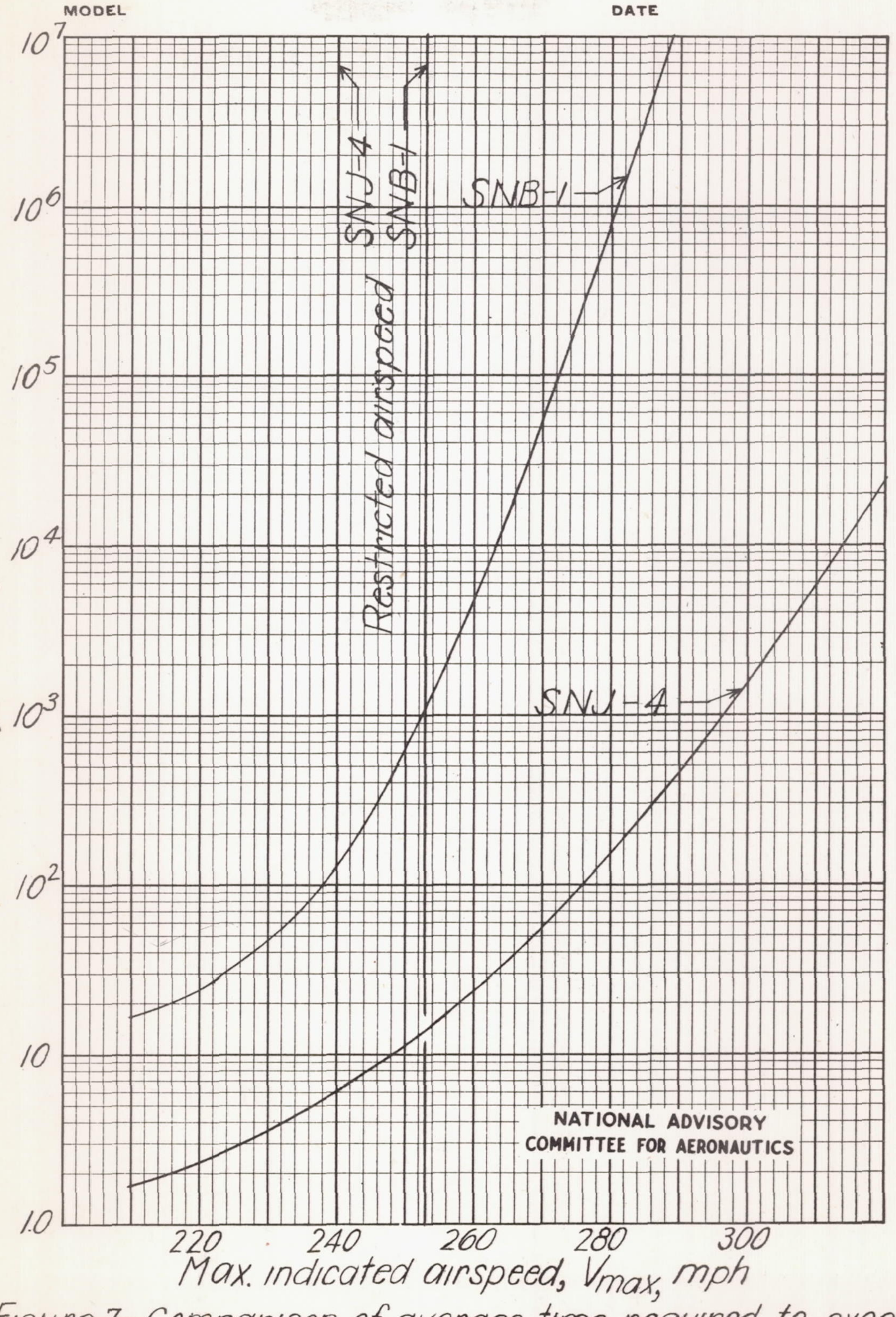


Figure 7.- Comparison of average time required to exceed given values of maximum indicated airspeed