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Gust Loads Section.

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NOTES ON UNUSUAL V-G RECORDS FROM

TRANSPORT AIRPLANES

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RESTRICTED BULLETIN

NOTES ON UNUSUAL V-G RECORDS FROM

TRANSPORT AIRPLANES

By Walter G. Walker

SUMMARY

Unusual V-G records obtained on transport airplanes, which are defined in this report as records of accelerations experienced in flight that resulted from causes other than atmospheric gusts, have been studied and the basis of interpretation of these records is explained. The results of the study of the velocity-acceleration data of this class of unusual records are compared with the results of a study of gust-loads data made in 1942. It is shown that the 1942 results are not changed by the results of this report. Atmospheric-gust data and the data of unusual V-G records that result from maneuvers and from combinations of gusts and maneuvers should be studied separately so that they may be subsequently compared to determine the respective load effects of gusts and maneuvers on the airplane structure. Supplementary information to permit the proper analysis of the data is very important.

INTRODUCTION

The analysis of velocity-acceleration data obtained on transport airplanes depends upon a knowledge of the conditions prevailing when the records were taken. Although the loads that result from any given acceleration will be the same, for all practical purposes, whether induced by an atmospheric gust, a maneuver, or a combination of gust and maneuver, it is desirable to know the specific causes of the larger loads in order that design load factors can be maintained on a rational basis. The accelerations that result from maneuvers can be controlled, whereas those that result from atmospheric gusts cannot; the two conditions should be separated, therefore, when a study of the data is made.

A study of unusual V-G records has been made in order to determine, whenever possible, the accelerations that occurred as a result of gusts, of maneuvers induced by gusts, or of maneuvers alone. The unusual records are defined herein as those V-G records showing large accelerations that may have resulted from conditions in flight other than atmospheric gusts. The present report has been prepared as a supplement to reference 1, in which an analysis of accelerations produced by gusts is given.

EVALUATION OF RECORDS

The data from which the present study has been made were obtained from NACA V-G recorders (see reference 2) installed in transport airplanes. More than 1200 V-G records representing over 170,000 flying hours in airline operations during the past 10 years were examined. All records that showed increments of acceleration larger than $\pm 1.5g$ from the $1g$ datum line and records not included in reference 1 because they resulted from causes other than gusts were separated from the rest for analysis. These V-G records were studied, together with all available information regarding the records, in order to determine as nearly as possible the conditions that existed at the time of the acceleration. It was hoped that the different causes could be reasonably established and the individual records placed in one of several classifications; namely, records produced by gust accelerations, maneuver accelerations, gust-maneuver accelerations, or landing accelerations, and records marred by handling or malfunctioning of the NACA V-G recorder.

The results of the study are summarized in tables I and II. The unusual V-G records have been evaluated and are presented in figures 1 to 10. Figure 11 presents a typical record that is a sample of unsatisfactory instrument operation. Table I shows that about 5 percent of the total number of records examined were classified as unusual. The records tentatively classified as unusual were reexamined and approximately 90 percent of these were determined to be of no value because they had been marred in handling or spoiled by excessive vibration of the NACA V-G recorder. All faulty records had been discarded in previous studies of the data but are classified in the present study to show the cause of the trouble.

ANALYSIS OF RESULTS

Characteristics of records.- In order to determine the proper classification of each unusual record, it has been necessary to deduce what happened to cause the record to exhibit the characteristics shown.

In general, gust-acceleration records have characteristics that indicate their classification; for example, gust accelerations occur with about equal frequency and magnitude in both positive and negative directions, whereas in maneuvers positive accelerations predominate. The change in airspeed during the individual gust acceleration is usually small so that the V-G record produced during a gust is ordinarily a line or a narrow vertical loop. Occasionally substantial airspeed changes occur during the course of a change in normal acceleration in a gust; in such cases, the fact that the V-G record results from a gust may be deduced from the irregularity of the loop as contrasted with the smooth regular loops resulting solely from maneuvers.

Records that result from maneuvers normally show greater variation than records that result from gusts. It is generally true that maneuver accelerations occur in one direction; the direction is positive in records obtained from transport operations except under very unusual conditions. A maneuver such as a banked turn together with a change in airspeed will result in a record that shows an acceleration loop in the positive direction. The shape of the loop will depend upon the magnitude of the acceleration imposed in the banked turn and upon the amount of change in the airspeed. In most cases the loop obtained from a maneuver acceleration is not so sharply defined as the loop obtained from a gust acceleration; the maneuver records show smoothly rounded shapes in many cases.

Occasionally, records may be of such character that they are placed in different classifications when interpreted by different personnel. It is not possible in all cases to declare definitely that a record should or should not be placed in a certain class. When no information exists to help place such records in a definite category, the classification depends on the knowledge and experience of the personnel classifying the records.

A gust-maneuver record can be expected to exhibit characteristics that are a combination of the characteristics of the two types of record described.

The V-G records that have been marred in handling are easily identified when these records contain many extraneous scratches, which vary in direction and obviously have no significance in connection with the correct recording. A few cases have been noted in which identification of these records is rather difficult. The criterion is usually the angle made by the individual mark to the record area. Other peculiar characteristics may exist on individual records that will aid in identification. If scratches occurred after application of the lacquer film, it is usually fairly easy to identify them.

Interpretation of individual records.- The V-G records included in this report have been classified on the basis of the characteristics described. The record shown in figure 1, for example, has been placed in the gust classification because positive and negative accelerations of about equal value are shown and the airspeed change for each acceleration loop is small.

The records in figures 2 and 3 have been classified as maneuver records on the basis of the appreciable airspeed change, the smoothly rounded acceleration loops, and the predominance of positive accelerations. Records similar to these are obtained when the airplane is flown in a banked turn or pull-up.

The record in figure 4 is difficult to interpret because it shows unusual characteristics that resulted from either gusts or maneuvers. The fact that the record contains negative accelerations, which apparently were not the result of maneuvers, offers sufficient justification for placing this record in the gust classification. The accelerations occurring in both directions in the airspeed range of 160 to 170 miles per hour appear to have resulted from gusts. Since this interpretation has been made for this part of the record, it is logical to assume that the acceleration loops occurring at 140 and at 190 miles per hour also resulted from gusts.

The V-G records shown in figures 5 and 6 appear to have been scratched after removal from the NACA V-G recorder, and these records are therefore of doubtful

value. It was discovered by inspection of the original glass plate that the mark at 180 miles per hour on the record shown in figure 5 was an extraneous scratch, although this fact is not evident from inspection of the plot. In figure 6 the positive and negative accelerations recorded at 120 to 130 miles per hour are the result of gusts or extraneous scratches. Since the record was obviously marred, as is shown at 145 miles per hour, the marks at 120 to 130 miles per hour were considered questionable; however, the positive accelerations appearing at 170 miles per hour and in the range from 100 to 120 miles per hour appear to have resulted from maneuvers. It seems illogical to assume that a pilot would maneuver a transport airplane to obtain the acceleration magnitude shown by this record at the airspeed of 120 miles per hour; nevertheless, the record is not of such a character as to indicate that it resulted from gusts. It would be equally illogical to assume that these high accelerations resulted from a landing at that airspeed since most pilots avoid high-speed landings. Finally, the possibility exists that ground shocks during take-off caused this portion of the record.

Figures 7 to 9 have been classified as gust-maneuver records because the normal flight procedure was disturbed and control movement was apparently necessary to restore the airplane to normal flight.

Figure 10 is an unusual record that may be classed either as a gust record or as a gust-maneuver record. This record has been placed in the former classification in table II. Additional information is required, however, for the proper interpretation of such a record.

Records similar to figure 11 have been excluded as of no value in the analysis of the data. The vibration amplitude, as it affected this record, was larger than any flight accelerations.

DISCUSSION

The analysis of V-G records that show large acceleration increments in the flight range depends upon having supplementary information in regard to unusual conditions existing at the time the records are taken.

In the past, some airline operators have been more cooperative than others in supplying the NACA with information pertaining to the records. When this information has been supplied, it has proved very helpful in the study of the data. As an example, if the statement were made that a certain record included test flights, this information could be taken to indicate that the relatively large accelerations recorded resulted from maneuvers in test flights and not from gusts. When such information is not supplied, it becomes practically impossible to determine definitely from examination of the record alone whether the recorded acceleration resulted from a maneuver or a gust.

The V-G record shown in figure 1 was accompanied by information from the airline operator regarding unusual conditions. The following statement was received with the record: "Heavy rain was encountered in the Eastern Division and ice formed in the airspeed lines. In attempting to remove the ice and water the V-G diaphragm was sprung." The proper interpretation of this record depended upon this information because, although the airspeed evaluation as shown may be incorrect, the accelerations appear to have resulted from gusts. The NACA V-G recorder from which this record was obtained was subsequently returned to the NACA and examination of the instrument verified the statement of damage.

The records presented in figures 2 to 11 were received with no information other than that given on each figure. These are typical records that have been classified in table II on the basis of past experience with NACA V-G recorders and in accordance with the principles previously explained.

If the unusual V-G records discussed herein were combined with the composite outlines shown in reference 1 for corresponding airplane types, the resulting composite outlines would be slightly different from the original outlines for the Douglas DC-2 and DC-3 airplanes and changed considerably for the Boeing S-307 airplane. The record of figure 9 for the Boeing S-307 airplane, which differs greatly from the S-307 composite outline of reference 1, was not a part of the data examined during the preparation of that report because this record was not received until the year after reference 1 was prepared. The record of figure 9 is undoubtedly due to

a combination of a gust and a maneuver and would not have been included had it been available at that time, since reference 1 was confined to the presentation of gust data.

CONCLUSIONS

1. Conclusions previously reached concerning V-G data, which included only those accelerations resulting from atmospheric gusts and excluded maneuver and gust-maneuver accelerations, are not changed by the results of this report.

2. Atmospheric-gust data and the resulting loads acting on the aircraft structure should be studied separately from the loads imposed on the aircraft by gust-maneuvers, maneuvers, and other causes.

3. Information in addition to the routine information supplied by the airline operators is required to analyze properly unusual V-G records.

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REFERENCES

1. Walker, Walter G.: Gust Loads on Transport Airplanes. NACA RB, July 1942.
2. Rhode, Richard V.: Gust Loads on Airplanes. SAE Jour. vol. 40, no. 3, March 1937, pp. 81-88.

TABLE I
SUMMARY OF V-G RECORDS EXAMINED FOR CLASSIFICATION

Airplane	Number of records examined	Number of records classed as unusual	Total flying time (hr)	Period	
				From	To
Boeing S-307	258	10	15,326	April 1940	Dec. 1943
Douglas DC-3	120	10	47,321	Feb. 1937	Feb. 1944
Douglas DC-2	67	7	13,702	July 1935	Dec. 1940
Boeing B-247	} 50	None	14,425	July 1933	Oct. 1938
Boeing B-247-D					
Martin 130	186	1	20,801	Feb. 1936	Oct. 1943
Boeing B-314	281	37	37,579	March 1939	Dec. 1943
Sikorsky S-42	} 202	None	16,392	Sept. 1935	Nov. 1939
Sikorsky S-42A					
Sikorsky S-42B	64	1	5,391	June 1937	March 1940
Total	1228	66	170,937		

TABLE II

UNUSUAL V-G RECORDS NOT INCLUDED IN REFERENCE 1

Airplane	Figure	Period		Total flying time (hr)	Maximum positive acceleration (g)	Indicated airspeed (for max. g) (mph)	Maximum negative acceleration (g)	Indicated airspeed (for max.-g) (mph)	Classification of records
		From	To						
DC-2	1	Jan. 30, 1938	Feb. 4, 1938	12	2.7	163	-0.8	188	Gust ^a
	2	May 11, 1938	June 22, 1938	400	3.0	153	----	---	Maneuver
	5	March 6, 1939	April 10, 1939	294	2.8	175	-.4	162	Marred
	7	Oct. 30, 1939	Dec. 30, 1939	520	2.7	154	-.5	170	Gust-maneuver
DC-3	10	April 16, 1938	Aug. 20, 1938	720	2.8	185	-.8	189	Gust
	8	Nov. 8, 1938	Jan. 2, 1939	492	2.4	229	----	---	Gust-maneuver
	6	Aug. 14, 1939	Sept. 21, 1939	252	3.3	142	-.9	120	Marred
	3	Jan. 29, 1939	March 8, 1939	245	2.4	140	----	---	Maneuver
S-307	4	April 21, 1941	April 29, 1941	63	2.1	160	0	160	Gust
	9	March 6, 1943	March 21, 1943	95	3.3	205	-1.1	140	Gust-maneuver
B-314	11	Dec. 25, 1941	Jan. 27, 1942	220	3.9	177	-1.7	120	Vibration ^b

^aAdditional information received only with this record.^bThe V-G recorder experienced excessive vibration which obliterated the flight accelerations.NATIONAL ADVISORY
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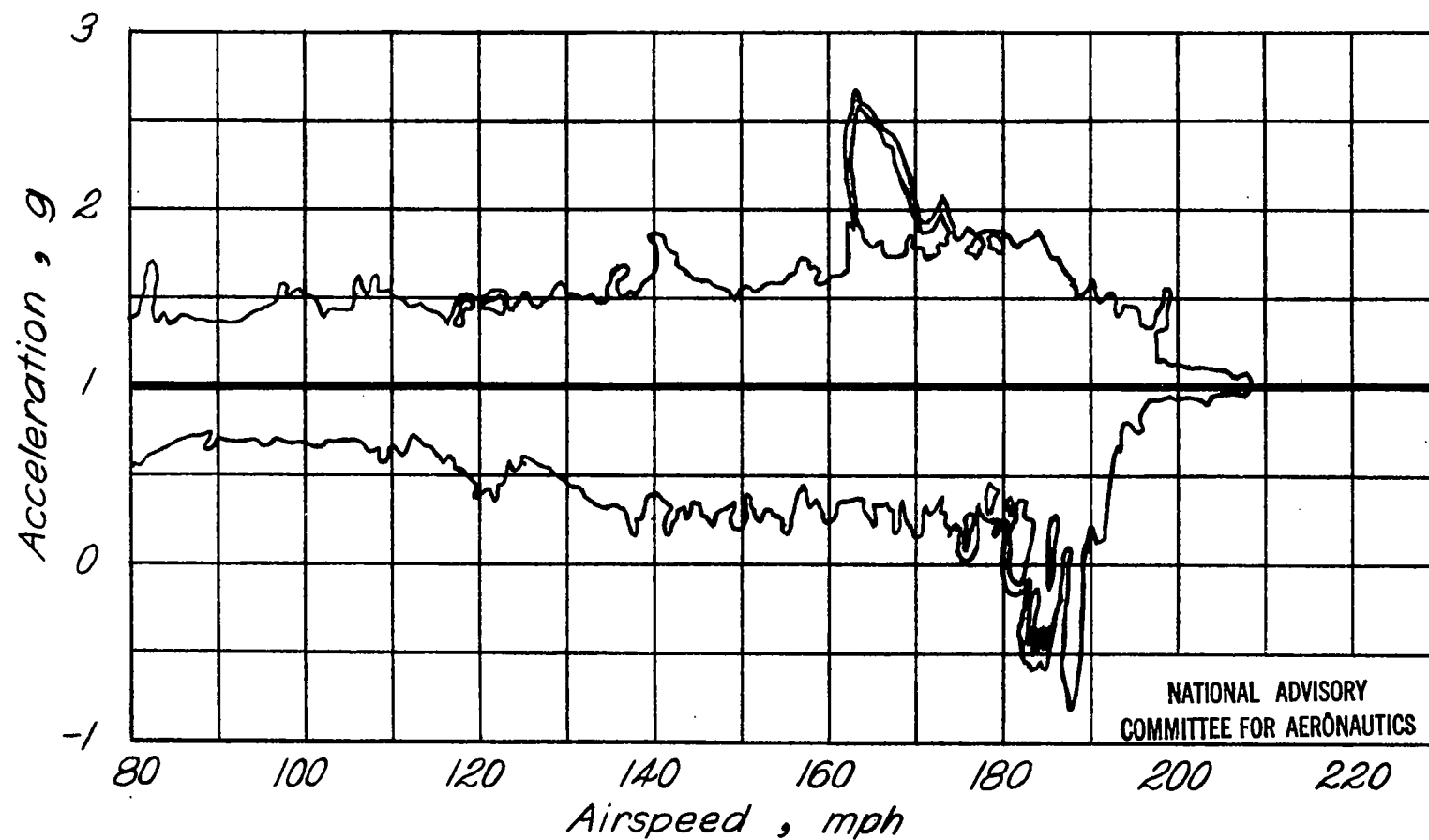


Figure 1.- V-G record obtained on DC-2 airplane in flight from Newark to Los Angeles, January 30 to February 4, 1938. Flying time, 12 hours.

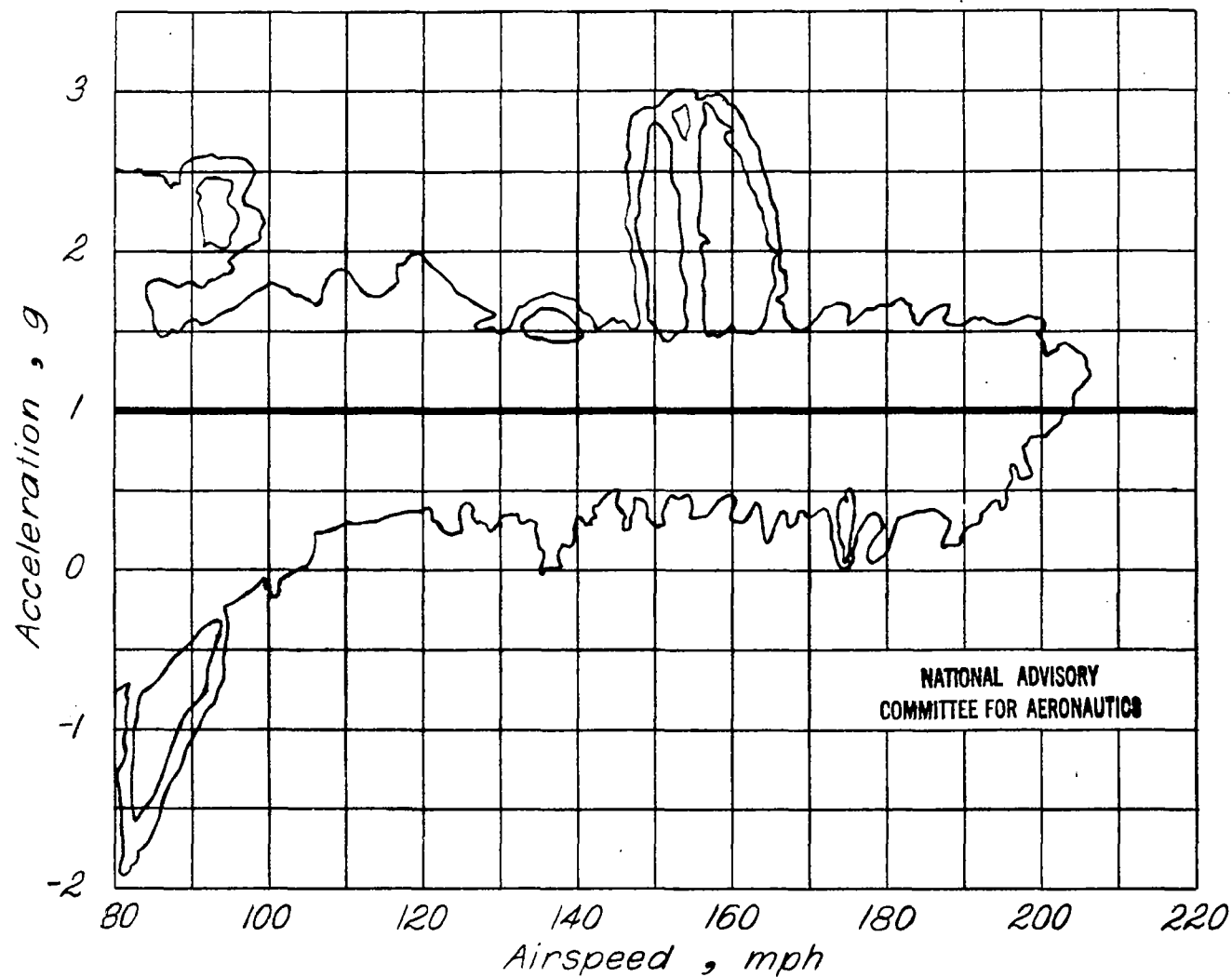


Figure 2.- V-G record obtained on DC-2 airplane in flights from Miami to Newark to Boston, May 11 to June 22, 1938. Flying time, 400 hours.

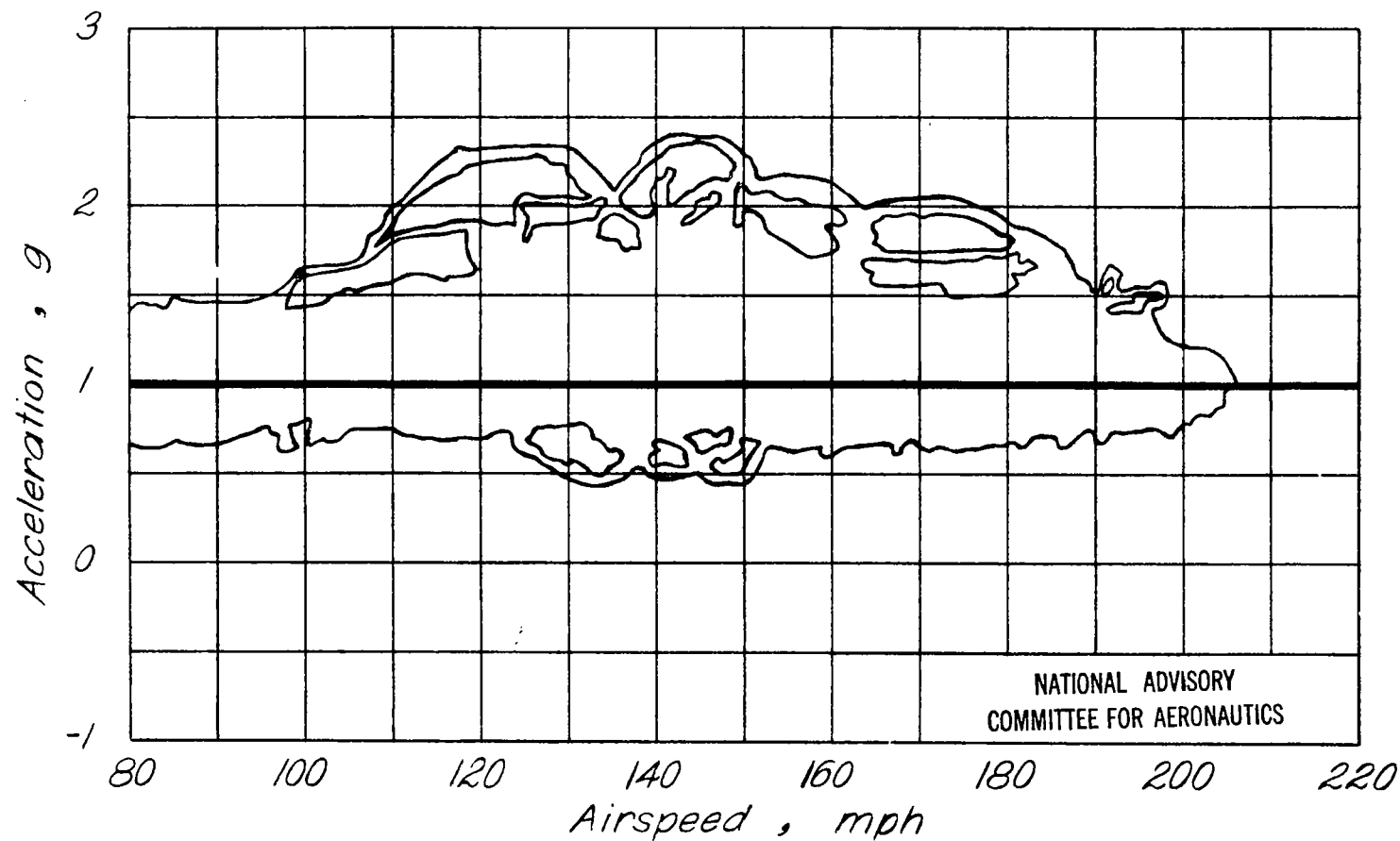


Figure 3.- V-G record obtained on DC-3 airplane in flights from Newark to Los Angeles, January 29 to March 8, 1939. Flying time, 245 hours.

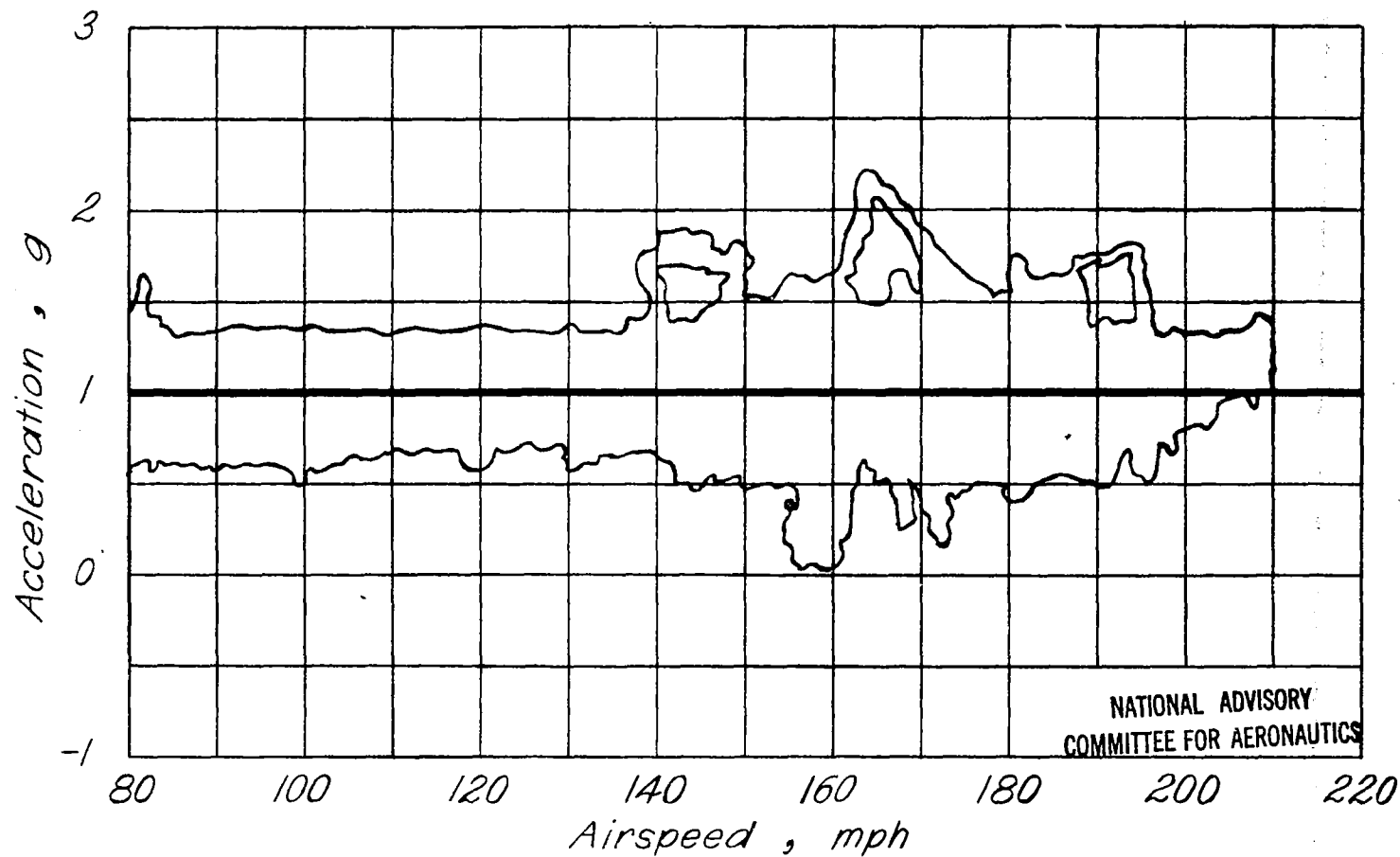


Figure 4.- V-G record obtained on S-307 airplane in flight from Miami to Balboa to Belém to Miami, April 21 to April 29, 1941. Flying time, 63 hours.

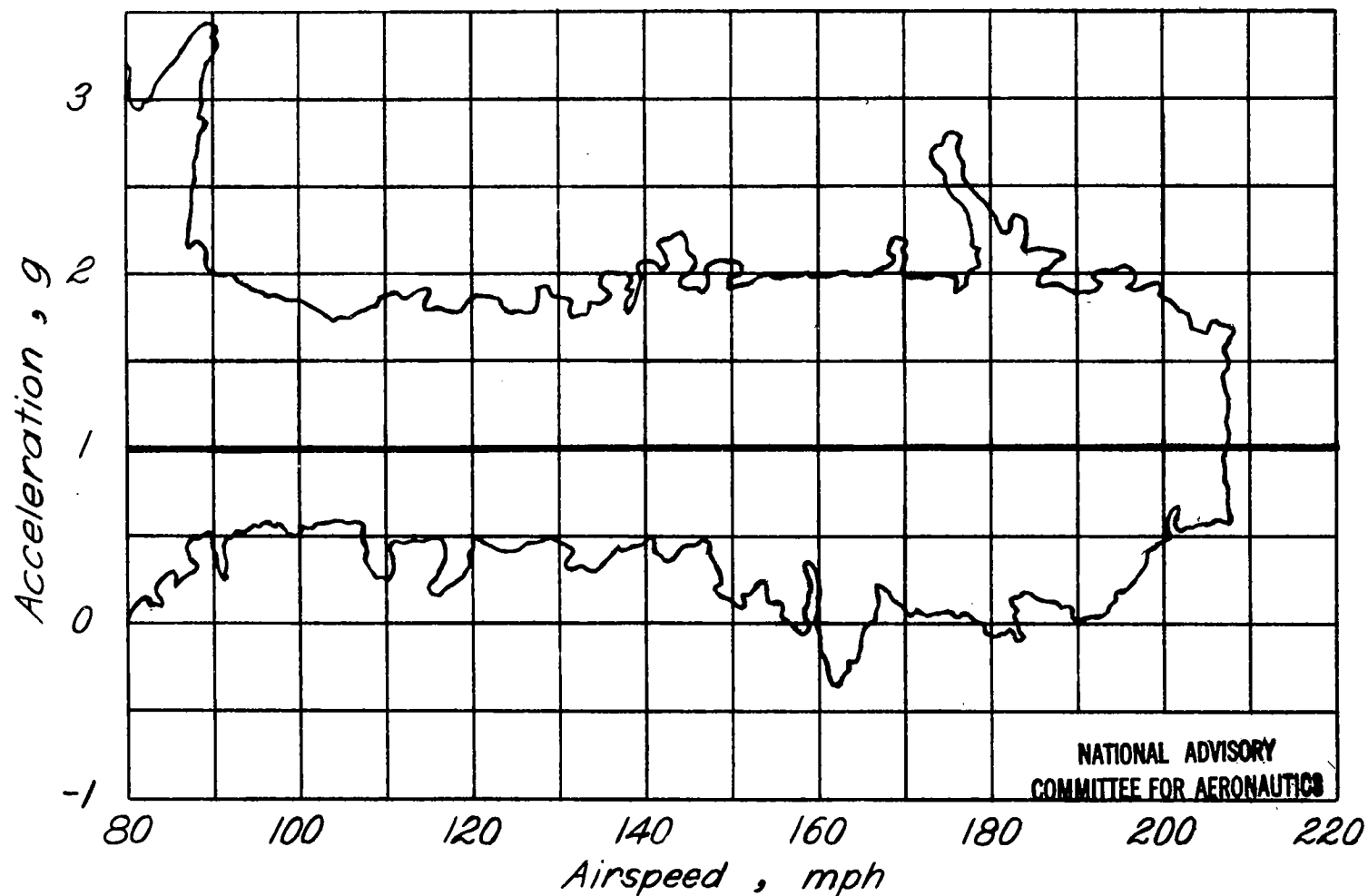


Figure 5.- V-G record obtained on DC-2 airplane in flights from Miami to Newark to Boston, March 6 to April 10, 1939. Flying time, 294 hours.

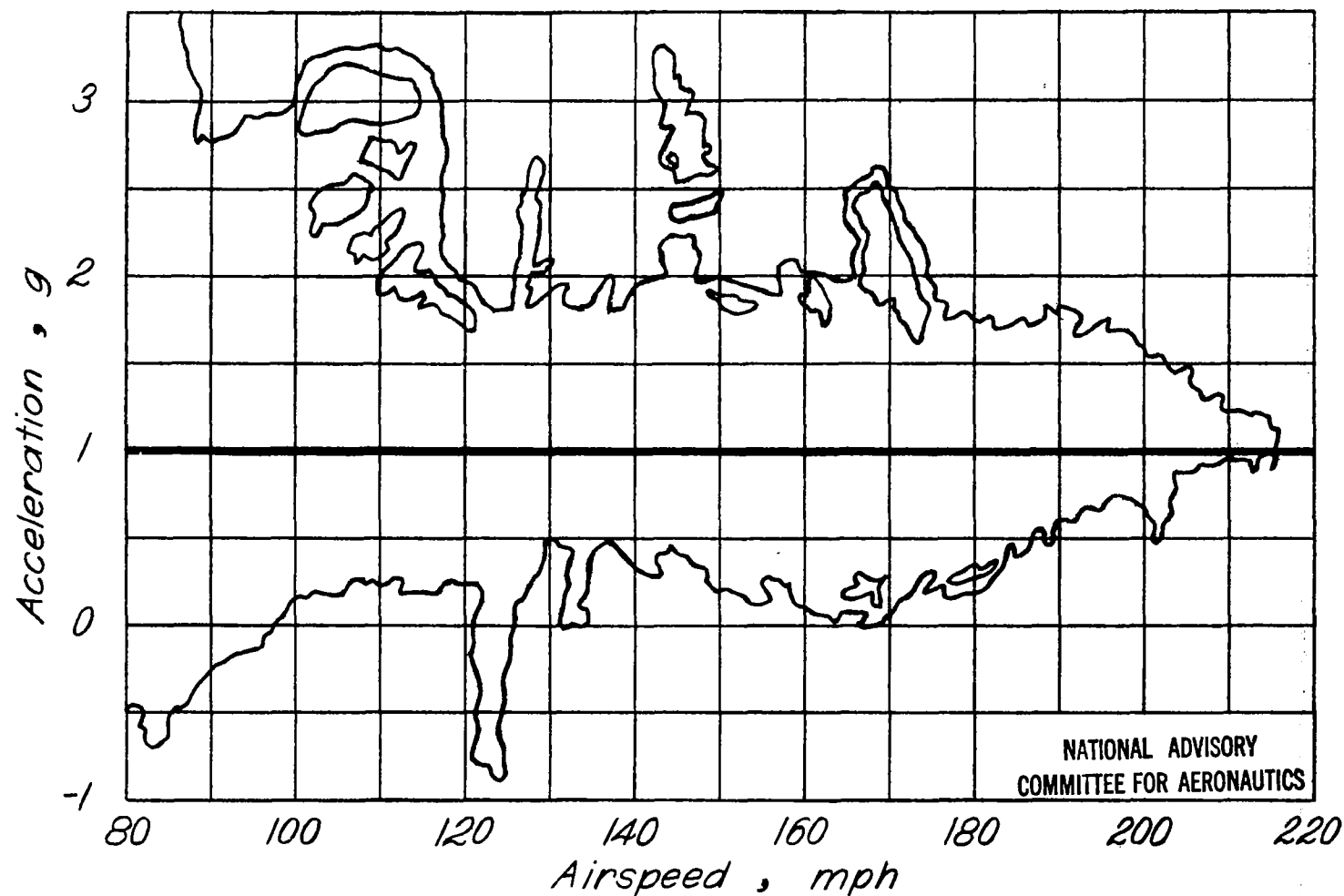


Figure 6.- V-G record obtained on DC-3 airplane in flights from Chicago to Boston to Newark to Fort Worth, August 14 to September 21, 1939. Flying time, 252 hours.

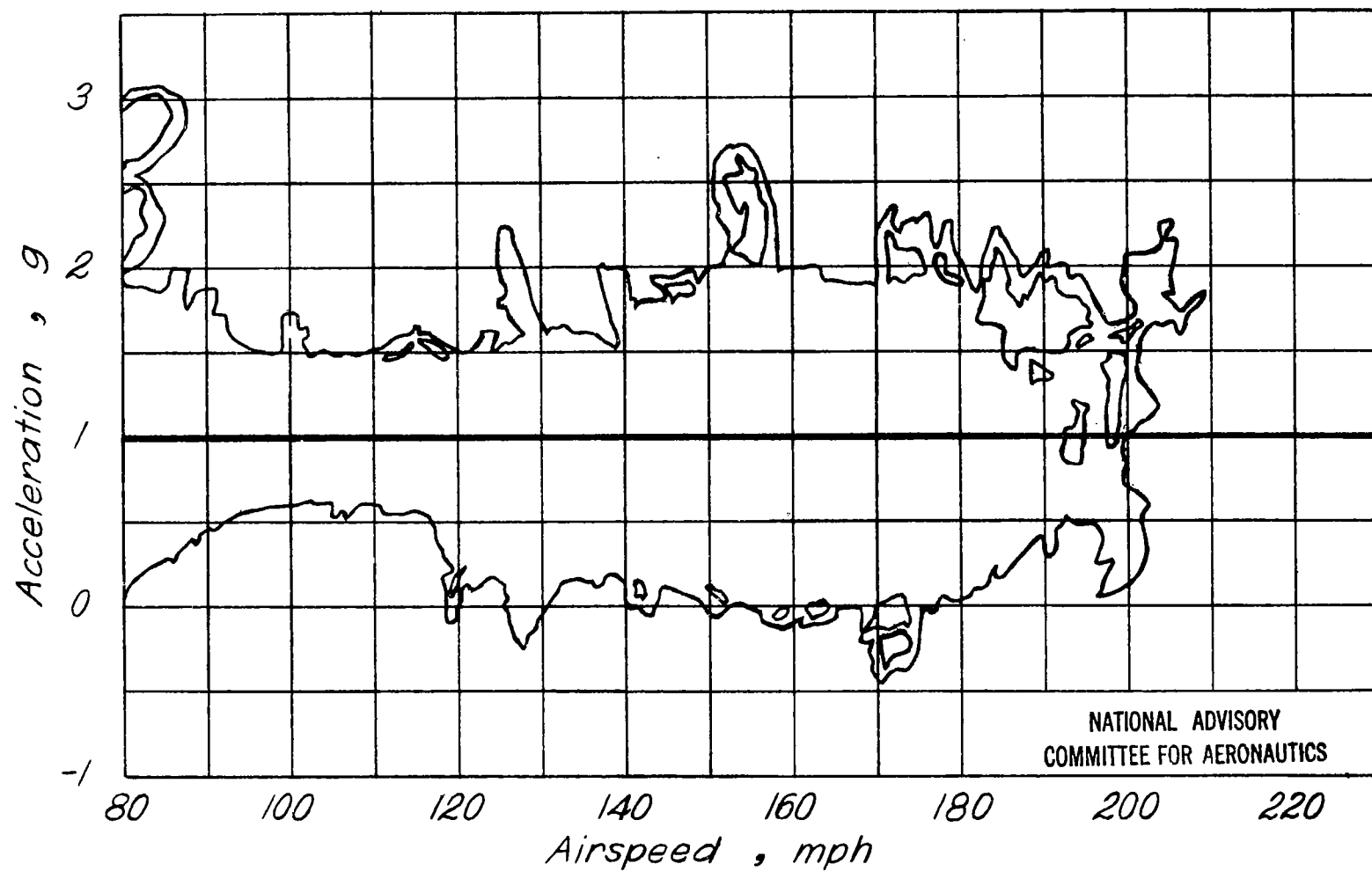


Figure 7.- V-G record obtained on DC-2 airplane in flights from Miami to Newark to Boston, October 30 to December 30, 1939. Flying time, 520 hours.

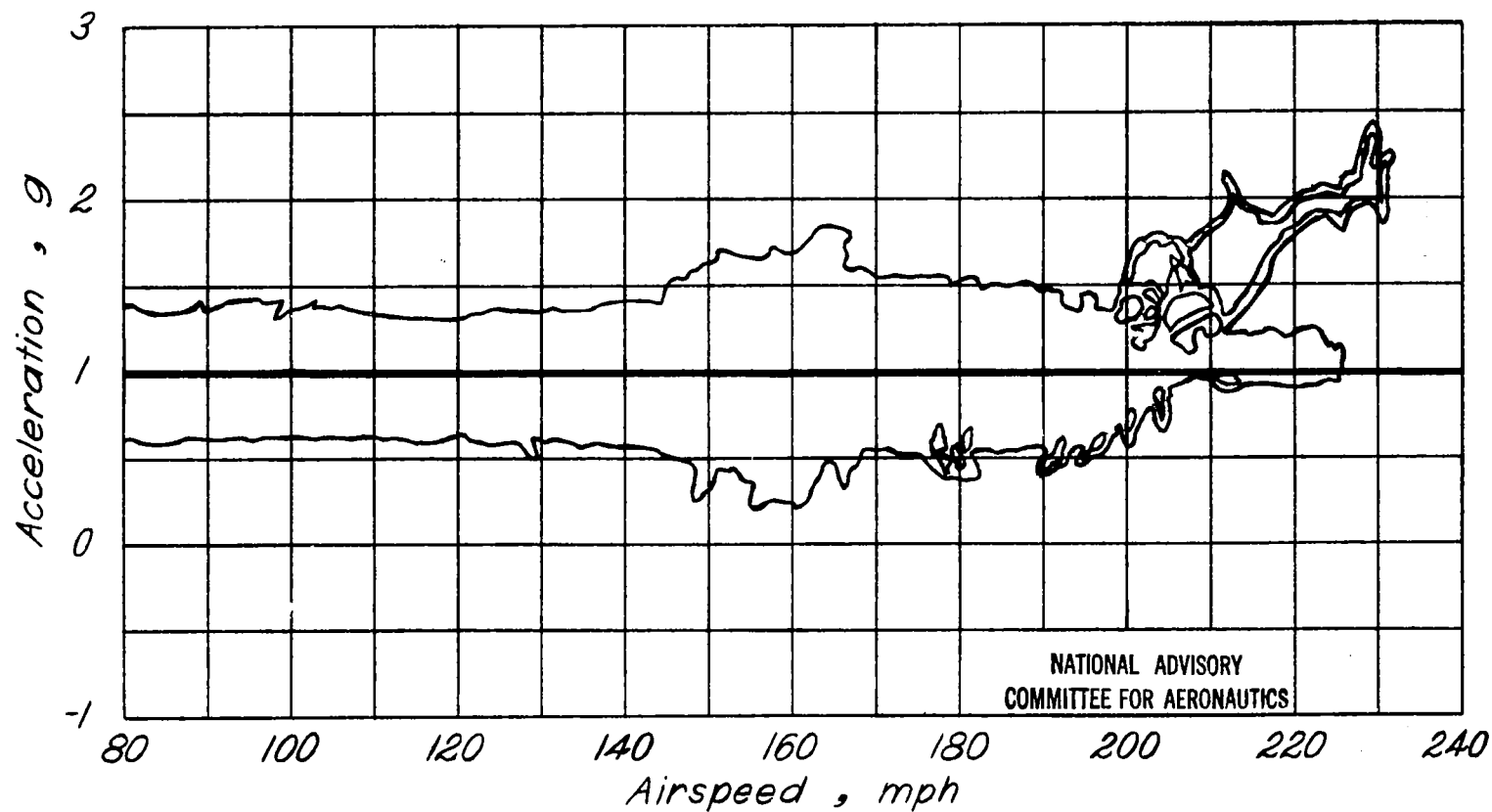


Figure 8.- V-G record obtained on DC-3 airplane in flights from Boston to Newark to Los Angeles, November 8, 1938, to January 2, 1939. Flying time, 492 hours.

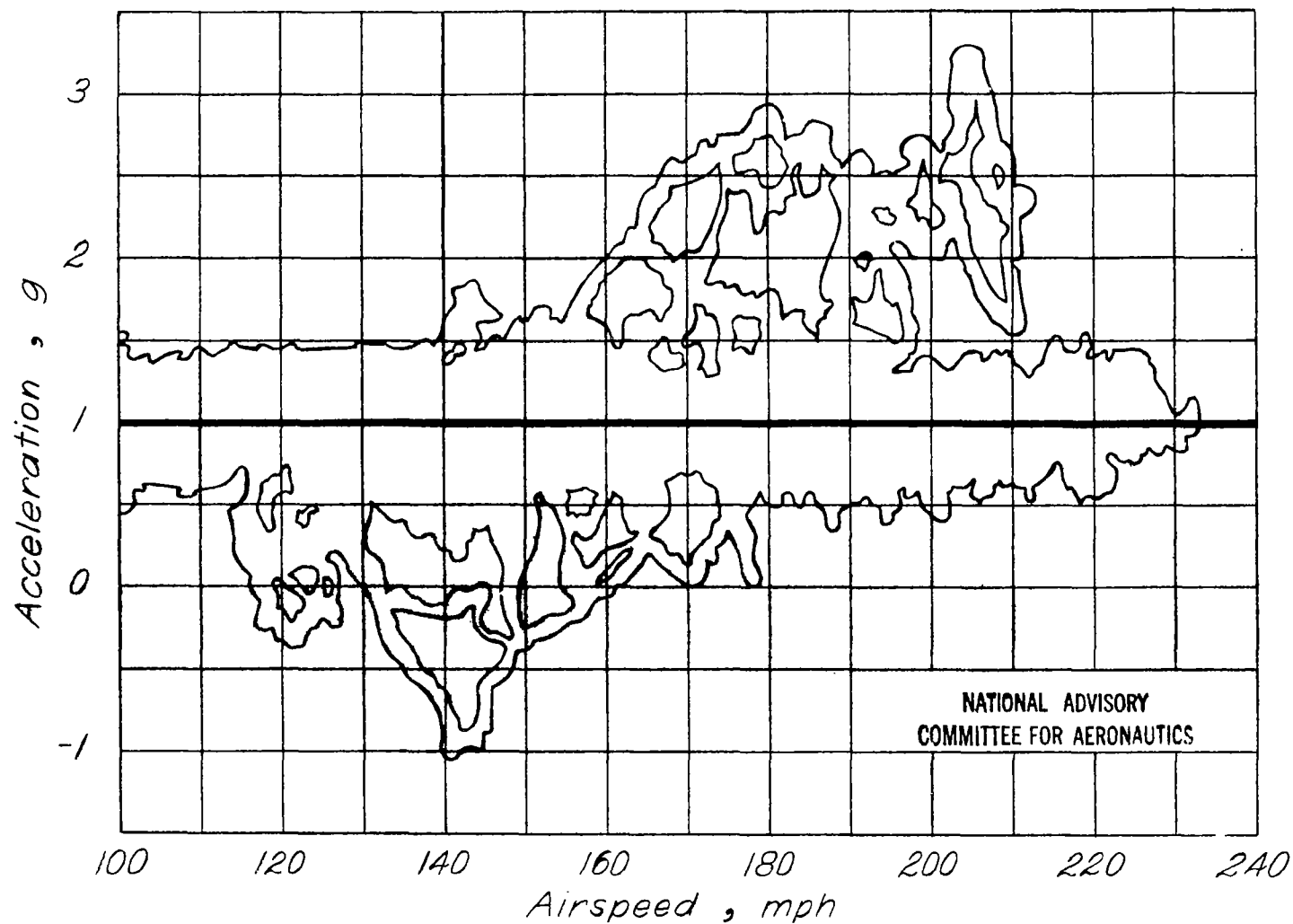


Figure 9.- V-G record obtained on S-307 airplane in flights from Miami to Balboa to Miami, March 6 to March 21, 1943. Flying time, 95 hours.

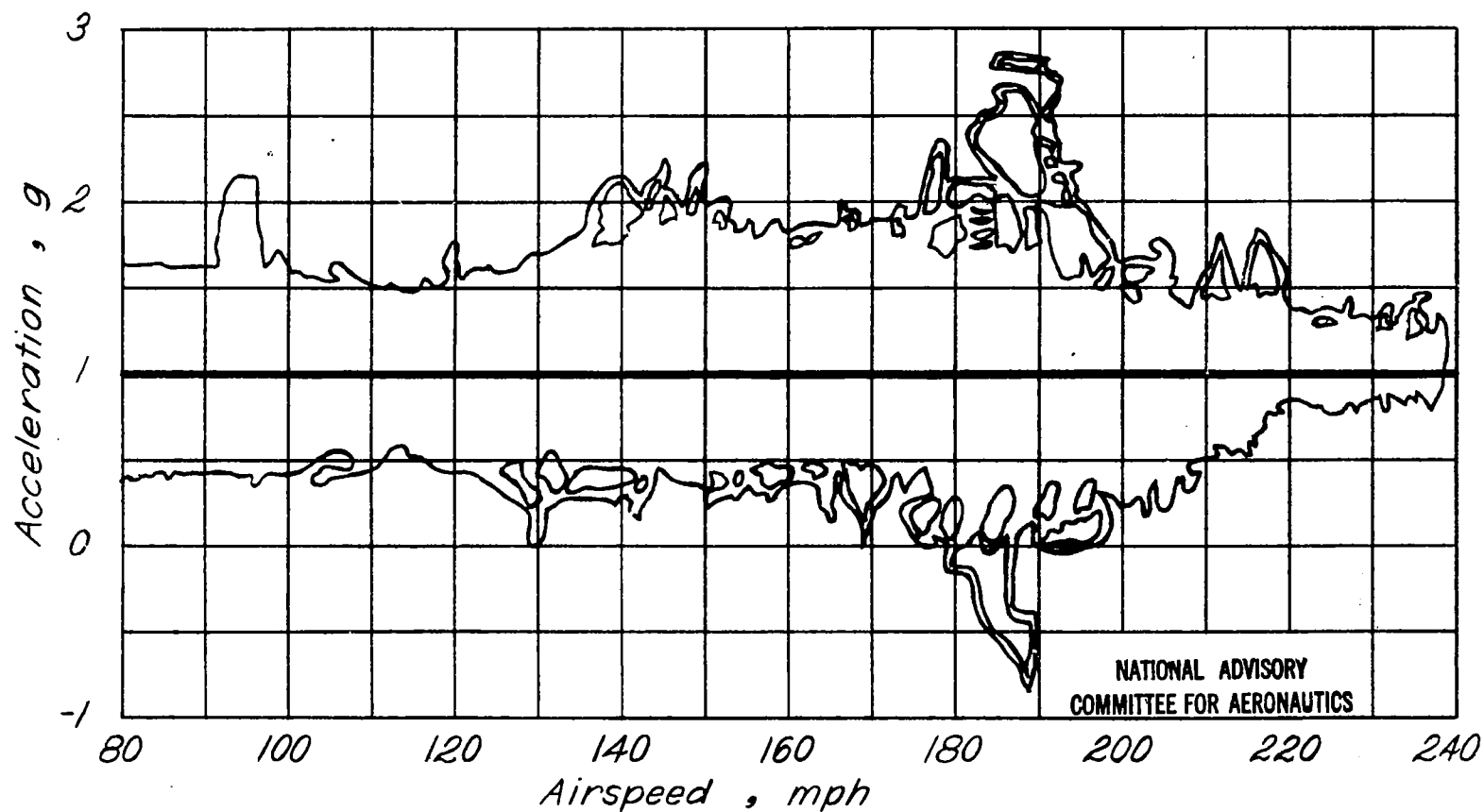


Figure 10.- V-G record obtained on DC-3 airplane in flights from Boston to Newark to Los Angeles, April 16 to August 20, 1938. Flying time, 720 hours.

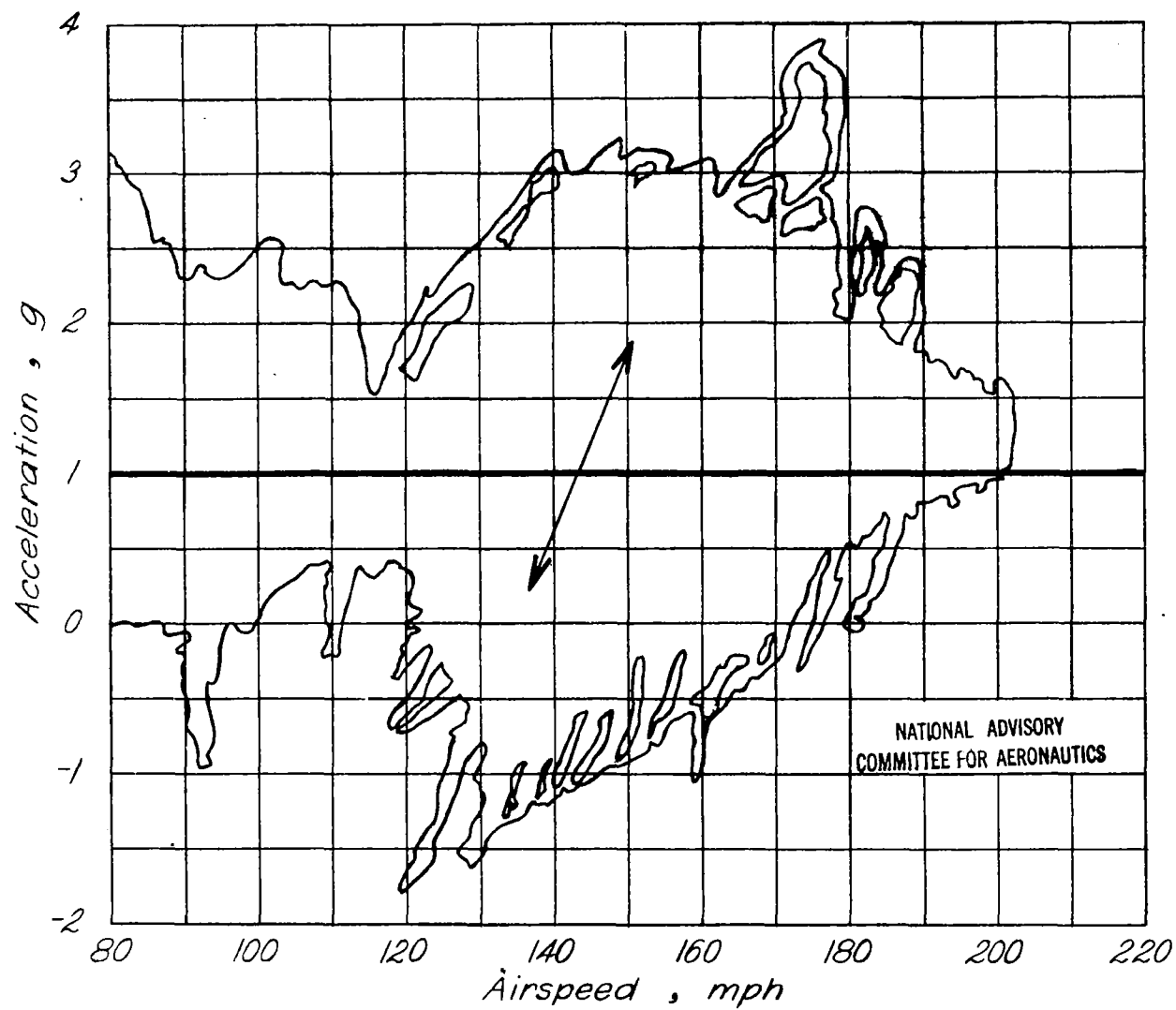


Figure 11.-- V-G record obtained on B-314 airplane in flights from New York to Europe to New York, December 25, 1941, to January 27, 1942. Flying time, 220 hours.

Welker, W. G.

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ABSTRACT

Records of accelerations experienced in flight that resulted from causes other than atmospheric gusts have been studied and the basis of interpretation of these records is explained. Results of this velocity-distribution study are compared with data obtained in a previous gust-load investigation. Gust data and data resulting from maneuvers should be investigated separately to determine respective load effect of these factors upon the airplane structure. Results are presented graphically.

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