INITIAL REPORT ON OPERATIONAL EXPERIENCES OF GENERAL AVIATION AIRCRAFT

By Joseph W. Jewel, Jr.

NASA-Langley Research Center
Langley Station, Hampton, Va.

Presented at the SAE National Business Aircraft Meeting

Wichita, Kansas
April 3-5, 1968

INITIAL REPORT ON OPERATIONAL EXPERIENCES OF GENERAL AVIATION AIRCRAFT

By

Joseph W. Jewel, Jr.

ABSTRACT

An analysis has been made of 27,000 hours of VG and VGH data obtained from 62 general aviation aircraft based throughout the United States. Comparisons are made between the actual flight loads experienced by aircraft engaged in five types of operations and the design flight envelopes for these aircraft. Gust and maneuver acceleration fractions, relating actual load factors to design load factors, are indicated. Airspeed and altitude operating practices are shown for the various aircraft. Landing impact acceleration distributions and a limited sample of accelerations measured during individual, practice, and competitive aerobatics are presented.

INITIAL REPORT ON OPERATIONAL EXPERIENCES OF GENERAL AVIATION AIRCRAFT

By

Joseph W. Jewel, Jr.

INTRODUCTION

About six years ago the National Aeronautics and Space Administration, at the request of the Federal Aviation Administration and upon recommendation of the NASA Committee on Aircraft Operating Problems, commenced a data collection program on aircraft in the general aviation category. The purpose of the program was to update and reassess data on the flight loads and operating practices of light aircraft during their normal usage, since little or no data of this type have been obtained over the past thirty years.

The program has now progressed to the point where preliminary results are available. In this paper, the scope of the program will be indicated; and the results obtained to date will be discussed.

INSTRUMENTATION

The data presented were obtained by NASA VG and VGH recorders which are described in detail in references (1)* and (2), respectively. A brief description of the recorders and the types of record obtained is given in the following paragraphs.

VGH RECORDER - A photograph of the VGH recorder is shown in figure 1. The recorder has three major components: the recorder base, an attached

---

*Numbers in parentheses designate References at end of paper.

film recording drum, and the acceleration transmitter. The transmitter is installed near the center of gravity of the airplane (usually within 2 feet), whereas the recorder base may be mounted at any convenient location within the airplane. The installed weight of the recorder, drum, and acceleration transmitter is 20 to 25 pounds.

An illustrative VGH record is shown in figure 2. The record gives a time-history trace of the aircraft's indicated airspeed, pressure altitude,** and normal acceleration. From the record, detailed counts may be made of the gust, maneuver, and landing impact accelerations and their associated airspeeds and altitudes.

VG RECORDER - A photograph of the VG recorder is shown in figure 3. This recorder weighs less than 5 pounds installed and is usually mounted within 2 feet of the aircraft's center of gravity.

An illustrative VG record is shown in figure 4. This record gives an envelope of the maximum positive and negative accelerations experienced throughout the airspeed range during the period covered by the record. The records were usually removed monthly and each represented from 10 to 60 hours of flight time.

SYMBOLS

a_n	incremental normal acceleration, g units
$a_{n_{LLF}}$	incremental normal acceleration corresponding to the gust or maneuver limit load factor, g units
f	frequency of occurrence
FM	nautical flight miles
K_g	gust factor, $\frac{0.88\mu_g}{5.3 + \mu_g}$

**Based on standard sea level pressure of 29.92 inches Hg.

m	slope of lift curve per radian
ρ_o	air density at sea level, slugs/cu ft
S	wing area, sq ft
U_{de}	derived gust velocity, ft/sec, $\frac{2W\,a_n}{K_g\,\rho_o\,V_e\,m\,S}$
μ_g	airplane mass ratio
V_C	design cruise speed, knots
V_D	design dive speed, knots
V_e	equivalent airspeed, fps
V_{MAX}	maximum indicated airspeed, knots
W	airplane weight, lbs

PROGRAM DESCRIPTION

In order that a representative sample of general aviation operations could be obtained, five types of operations were selected to be covered in the data collection program. These five operations are: twin-engine executive, single-engine executive, personal, instructional, and commercial survey. Typical missions flown in each of the operations are as follows:

Twin-engine executive:
- Charter flight - cargo and personnel
- Business flight - company and individual
- Instrument check flight - training for instrument card
- Instructional - check-out for multiengine

Single-engine executive:
- Charter flight - cargo and personnel
- Business flight - company and individual
- Instrument check flight - training for instrument card
- Instructional - check-out for heavier airplane

Personal:
- Flying club - airplane flown by from 3 to 21 members. Used for pleasure flying, instruction, or business

Individual - used for pleasure and business
Company owned - airplane rented to individual for business or pleasure flying, also aircraft used as check-out for heavier airplane

Instructional:
Training - all instrumented airplanes owned by flying schools. Used as basic trainers for private license. Also used by student after solo for cross country

Commercial survey:
Pipeline patrol - patrols flown from 250 to 300 feet above ground to check for leaks or breaks in the pipeline
Forest patrol - patrols flown 1500 feet above terrain for fire spotting. When fire is spotted, descents are made to 200 to 300 feet to check condition of terrain around fire
Fish spotting - patrols flown 1500 to 2000 feet above water. Occasional descents are made to 300 to 500 feet

Generally, three VGH recorders and nine VG recorders are assigned to aircraft in each operation. The location of the instrumented aircraft in the program is shown on figure 5. Aircraft selected for the program were based throughout the continential United States to avoid biasing the data as coming from any one geographical area.

The basic characteristics of the instrumented aircraft are listed on table I. Aircraft chosen for the program range in size from small, light training planes weighing less than 1600 pounds to twin-engine, jet-powered executive transports weighing 12,500 pounds. Owners of the aircraft were personally contacted, briefed on the purpose and aims of the program, and asked to participate in the program until 1000 or more hours of flight data were obtained over a period covering at least the four seasons.

Figure 6 shows the status of the general aviation program in terms of the number of aircraft instrumented, the hours recorded, and the average number of hours recorded per aircraft per year for each year the program has been in existence. Data obtained in 1967 are presented as half bars, since these data are for a 7-, rather than a 12-, month period. The progressive growth of the program is readily apparent from the figure.

SCOPE OF DATA

The data analyzed and discussed in the following sections represent about 0.05 percent of all the general aviation flying that was done in the period during which the data sample was taken and about 60 percent of the total data collected to date. The largest sample - about 24,000 hours - was obtained from VG recorders. Data from VGH recorders were about one-sixth this size, totaling slightly more than 4000 hours. Sixty-two aircraft, representing 15 different types of airplanes, were involved in the data sample presented.

RESULTS AND DISCUSSION

GENERAL - The operating characteristics of the instrumented airplanes are indicated on figure 7. This figure shows the average pressure altitudes, indicated airspeeds, and flight lengths recorded by aircraft in the five different operations. Turbine-powered aircraft, types 1 and 2, in the twin-engine executive operations, were, as would be expected, flown at the highest average operating altitudes and airspeeds. The lowest average operating altitudes and airspeeds were recorded by aircraft used for instructional operations. The relatively high average operating altitudes exhibited by aircraft type 13 in instructional operations and type 8 in the single-engine executive and survey operations occurred because the aircraft were based at fields having elevations of from four to five thousand feet. The average flight lengths of aircraft in all operations, with the exception of survey, were about one hour or less. Average flight lengths in survey operations ranged from slightly more than two hours for forest patrol work to about four and a half hours for commercial fish spotting.

OVERALL INFLIGHT LOADS - Composite VG records - that is, a series of VG records from one type of aircraft that have been superimposed, one on the other, so that the 1.0g level flight lines and zero airspeed positions coincide - and design flight envelopes for aircraft in the five types of operations are shown on figure 8. The solid and dashed outlines about the VG signatures represent the design flight envelopes based on the aircraft's maximum gross weight and minimum design weight, respectively.

The portions of the VG signatures that exceed the design flight envelope in the low-speed regime of the record are not considered significant since the exceedances were most probably caused by landing shocks. In general, the maximum load factors were about +3.0 and -1.0 and were contained within the design flight envelopes. However, there are two notable exceptions. The first, and probably most noticeable, was recorded by airplane type 14 in instructional operations. In addition to exceeding the design dive speed, this particular aircraft also exceeded the positive and negative limit load factors at the design dive speed. Inspection of the aircraft failed to reveal any structural damage. It appears, then, that although the design limit loads were exceeded, the factor of safety used in the design of the aircraft prevented a structural failure.

The second notable exceedance of the design flight envelope was recorded by airplane type 3 flown in twin-engine executive operations. An inspection of the aircraft by the owner after being notified of the exceedance indicated that no structural damage had occurred. Discussions with the operator revealed that the exceedance was gust induced when the aircraft was flown over the lee side of a mountain range.

From the foregoing discussion, it is evident that atmospheric-induced, as well as pilot-induced, loads in excess of the design flight envelope may be encountered during normal operations of the general aviation fleet. It is also apparent from the data that all aircraft types in the five operations were flown above the design cruising speed.

DESIGN SPEED EXCEEDANCES - Figure 9 indicates the percent time specific aircraft types in a given operation were flown above the design cruising speed. These data were taken from VGH records and were obtained by ratioing the time flown above the design cruise speed to the total time of the data sample.

The results show that the percent time flown above V_C ranged from 1 to 21 percent of the flight time. Airplane type 14 in instructional operations was flown above the design cruise speed 21 percent of the time; airplane type 8 in single-engine executive operations, 16 percent of the time; and airplane type 4 in twin-engine executive operations, 9 percent of the time. An examination of the VGH records indicated that V_C exceedances were most prevalent in the following regimes of flight:

Type 14 – Beginning of cruise. In level flight after descent. In downwind position of traffic pattern during touch and go landing.

Type 8 – During descent shortly after pushover.

Type 4 – During cruise and also in descent. The airplane apparently had sufficient power and was clean enough to exceed V_C during cruise. Most V_C exceedances in descent occurred when descent was steepened.

While VGH data from aircraft types 10 and 11 in personal operations have not been evaluated, a visual check of VGH records from these aircraft indicate that type 11 probably has a higher percentage of time flown above V_C than either of the other two aircraft in this operation. Many excursions above V_C were noted on VGH records from this airplane during cruise and descent. It appears that the ability of the aircraft to cruise at or above V_C in level flight was a contributing factor.

Aircraft in commercial survey operations showed the lowest percent of time flown above V_C of the five operations considered.

The data on figure 10 also relate to design cruise speed exceedances. These data were obtained from VG recorders and represent a much larger data sample than that from the VGH recorders. Because the design cruise and design dive speeds differ between aircraft in a given operation, it was necessary to nondimensionalize the airspeed data in order to compare the speed practices of the various aircraft. This was done by ratioing the difference between the maximum recorded airspeed and the design cruise speed to the difference between the design dive speed and the design cruise speed. The ratio, hereafter referred to as the speed ratio, therefore, indicates the extent that the speed regime between V_C and V_D was penetrated by the instrumented airplane. For example, a speed ratio of 1.0 indicates V_{MAX} equaled V_D. The speed ratio is shown along the abscissa of the figures, and the probability per flight hour of the aircraft type reaching a given ratio is indicated along the ordinate.

The results in figure 10 show that all the aircraft were flown in the speed regime between V_C and V_D and that the probability of exceeding given values of the speed ratio varies significantly between different aircraft within a given operation. Aircraft in instructional and personal operations appear to be flown above V_C more frequently than aircraft in the other operations. This is not unexpected since pilots in these two operations probably have the least flight experience of all the operations sampled.

The overspeed results based on the large samples of VG data shown in figure 10 are, in general, consistent with the results obtained from the smaller sample of VGH data shown in figure 9. For example, the aircraft types showing the highest rate of V_C exceedance are also the same types the VGH records showed as flying the largest percent of time above the design cruise speed.

ROUGH AIR - In order to compare the relative turbulence environment of aircraft in different operations, the percent time aircraft in the five operations were flown in rough air is shown in figure 11. The data were obtained from VGH records and rough air is defined as turbulence containing derived gust velocities larger than 2 fps.

The results show that the percent time spent in rough air varied from 21 percent for a jet-powered twin-engine executive airplane to 97 percent for an aircraft flown on pipeline patrol in commercial survey operations. Single-engine executive, personal, and instructional aircraft operations experienced rough air from about 50 to 80 percent of the flight time. As a general comparison, commercial turbojet-powered transports experience rough air from about 3 to 12 percent of their flight time.

GUST ACCELERATION FRACTION - Figure 12 presents gust acceleration fraction data for representative data samples from aircraft flown in the five types of operations. The gust acceleration fractions - obtained by dividing the incremental (from 1.0g) gust accelerations by the incremental (from 1.0) gust limit load factor at V_C - are indicated along the abscissa. The cumulative frequency per mile of the gust acceleration fractions are shown along the ordinate of the figure. Bands, indicated in the figures by hatched areas, defining boundaries of gust acceleration fractions experienced by three types of short-to-medium haul jet transports are also included in the figures for comparative purposes.

Inspection of the data show, with the exception of airplane type 1, a twin jet in twin-engine executive operations and airplane type 15, a light single-engine piston aircraft used for fish spotting in commercial survey operations, that the general aviation aircraft experienced gust accelerations that were closer to the design gust load factor than did the aircraft in commercial transport operations. The most severe gust acceleration was recorded by aircraft type 13 in instructional operations. This gust acceleration exceeded the design gust envelope by 34 percent. It is inferred from the data that although the design gust load factors for general aviation aircraft are higher than those of transport aircraft, the margin between the gust load experience and the design gust load factor is less than that for the transport aircraft. It is suspected that the more severe gust acceleration experience of the general aviation aircraft may be due to: operations in the lower atmosphere where more turbulence is present; operations of the general aviation aircraft at higher speeds relative to the design cruising speed; and to a slightly lower design gust velocity for the general aviation aircraft.

GUST VELOCITIES - The derived gust velocity experience per flight mile of aircraft in the five types of operations is shown on figure 13.

The hatched bands in the figures represent the derived gust velocity experience for three types of short-haul jet transports and for four types of long-haul piston transports. Two of the general aviation operations, instructional and commercial survey, had aircraft that encountered gust velocities of a given magnitude more frequently than the piston transports; commercial survey operations more frequently for gust velocities below 24 fps and instructional operations more frequently for gust velocities larger than 24 fps. Both of these operations had one aircraft type that experienced gust velocities of a given value at a significantly lower frequency than the other two aircraft types in the operation. Aircraft in twin-engine executive, single-engine executive, and personal operations experienced gust velocities that were generally within or above the gust velocity experience of the short-haul jet transport aircraft.

MANEUVER ACCELERATION FRACTION - The maneuver acceleration fraction data from aircraft in the five types of general aviation operations and for short-haul jet transport operations are shown in figure 14. Each figure indicates the cumulative frequency per flight mile along the ordinate and the maneuver acceleration fraction along the abscissa. For these data the maneuver acceleration fractions were obtained by dividing the incremental maneuver accelerations by the incremental maneuver limit load factor at V_C.

With the exceptions of aircraft in twin-engine executive operations, aircraft type 7 in single-engine executive operations and airplane type 15 in commercial survey operations, the general aviation aircraft experienced maneuver loads that for a given frequency of occurrence were closer to the design maneuver limit load factor than the maneuver load experience for short-haul jet transport aircraft. Airplane type 13 used for pipeline patrol in commercial survey operations illustrates the high rate of maneuvers required for this type of flying. While the maximum maneuver acceleration fraction was only about .6, the frequency with which the lower maneuver acceleration fractions were experienced was from 10 to 100 times that for aircraft in other types of operations. It therefore appears that from a fatigue standpoint, aircraft engaged in pipeline patrol operations are subjected to a more severe maneuver loading than any of the general aviation aircraft evaluated.

LANDING IMPACT ACCELERATIONS - The probability of equaling or exceeding an initial positive incremental acceleration during landing touchdown is shown on figure 15. All of the landing accelerations from the three types of propeller-driven aircraft in each operation were combined in the figure to show the relative relationships of the landing accelerations for the five operations. The probability of three types of short-haul jet transports equaling or exceeding a given landing acceleration is also given for comparison.

All general aviation aircraft, for a given probability, recorded larger landing impact accelerations than the commercial transport aircraft. The most severe landing accelerations, for a given probability of occurrence, were recorded by aircraft in instructional operations, and the least severe by aircraft in twin-engine executive and commercial survey operations. The highest landing acceleration, 1.5g incremental, was recorded by an aircraft in personal operations. The difference between the landing accelerations for short-haul commercial jet transport and general aviation aircraft are believed to result from two primary factors - the more sophisticated landing gear systems used on the transport airplanes, and better prepared surfaces the transport airplanes land on.

SAMPLE SIZE - Figure 16 indicates the effect of sample size on maneuver and gust acceleration distributions per flight mile for one airplane type. For brevity, only the one data sample - obtained from airplane type 3 used in twin-engine executive operations - will be discussed.

The VGH records comprising the data sample were separated into two groups, one group containing roughly half the flight hours of the other group. In addition, efforts were also made to select for each group records that were taken in the four seasons. The cumulative frequency per flight mile the gust or maneuver accelerations were experienced for each of the sample groups, and for the total sample, were then determined and plotted on the figures for comparison.

Examining first the maneuver acceleration distribution, it appears that the 291-hour sample provides basically the same distribution as the 447-hour sample. There is, in fact, little difference between the 447-hour sample and the 156-hour sample.

For the gust acceleration distributions, however, neither the 291- or the 156-hour sample is close enough to the 447-hour sample to be considered representative, which indicates that the data sample has not stabilized and more data should be acquired.

The significance inferred from these comparisons of sample sizes is that the data presented are as yet limited, are subject to possible changes as more data are acquired, and should for the present be regarded as preliminary information.

AEROBATICS - Figure 17 presents VG and VGH data on aircraft involved in aerobatic operations. Since this operation has only recently been included in the general aviation program, the data presented are limited - the VG data represent four hours flight time and the VGH data represent eleven hours flight time. It was felt, however, that because of the current interest in aerobatic flight and the significant results obtained from the VGH data, this information should be presented.

Figure 17(a) and 17(b) give VG signatures of 26 individual aerobatics performed during the tests. The ordinate is load factor, and the abscissa is indicated airspeed. The various maneuvers have been grouped into five basic types, identified at the top of the group as rolls, loops, reversements, stalls, and skids and slips. All of the maneuvers were "positive" aerobatics - no inverted aerobatics were performed. Negative load factors were experienced primarily during rolls and one type of reversement, a split S, and generally did not exceed -1.0g. The highest positive load factors, less than 4.0g, were recorded in a reversement (split S) and a loop (square loop). These maximums were less than the +6.0g or -3.0g required for certification in the aerobatic category.

In figure 17(c) peak acceleration data are shown for three types of aerobatic flying. The data indicated by the circular symbols are the peak positive and negative accelerations recorded when one specific maneuver was performed. The data indicated by the square symbols are the peak positive and negative accelerations recorded during a complete flight in which a continuous series of aerobatics - called an obligatory group - were practiced. The diamond symbols indicate the peak positive and negative accelerations measured during a complete flight in which obligatory groups of aerobatics were performed during aerobatic competition at a national air show. Airspeeds associated with the accelerations are shown along the bottom of the figure, and the design flight envelope for the aircraft performing the aerobatics is denoted by the solid outline in the center of the figure. All pilots involved in the tests were experienced aerobatic pilots.

Except for a few isolated points, the data are contained within the design flight envelope. The load factor for the individual aerobatics varied, of course, with the type maneuver performed; the square loop imposed the highest positive load factor, 5.1, and the outside loop the highest negative load factor, 3.0.

It was thought that the maximum loads experienced during practice obligatory groups would be less than those experienced during the heat of competition; however, the data did not indicate this to be true. The maneuvers causing the peak accelerations in the practice and competition aerobatic flights are not identifiable. However, it is suspected that the high accelerations occur when stall maneuvers, such as hammerheads or tail slides, are followed by vertical half rolls - which allow the airspeed to build up - and then by negative tuck unders to outside loops or snap rolls.

While individual aerobatics produced accelerations that were within the required limits for aerobatic certification, the obligatory group aerobatics exceeded the negative limit of this requirement. Nineteen of the 28 practice and competition flights contained negative accelerations in excess of -3.0g. Three of the flights registered negative accelerations larger than -4.0g.

Although the aerobatic data presented are limited, it does show rather severe exceedances of the minimum required negative maneuver limit load factor and therefore suggests that consideration should be given to extending the minimum required negative load factor.

CONCLUDING REMARKS

Even though the results which have been obtained are in some respects preliminary, they do provide an insight into the operational experiences of general aviation aircraft and an initial basis for assessing some of the airworthiness requirements.

In general, the overall inflight acceleration data from aircraft in five of the general aviation operations were contained within the design flight envelope. However, exceedances of the design flight envelope from gust and maneuver inputs were recorded by aircraft in twin-engine executive and instructional operations.

A limited sample of data from aerobatic operations show significant exceedances of the minimum negative limit load factor required by FAR-23 for certification in the aerobatic category when obligatory groups of maneuvers are performed.

The margin between the actual gust and maneuver load experience and the design gust and maneuver limit load factor was generally less for general aviation aircraft than for commercial transport aircraft.

Aircraft used for pipeline patrol work in commercial survey operations are subjected to a more severe gust and maneuver loading, from a fatigue standpoint, than any of the general aviation aircraft evaluated.

The percent time flown in rough air ranged from 21 to 97 percent of the flight time. This compares to a maximum of 12 percent for commercial transport operations.

Design cruise speeds were exceeded by aircraft in all operations. Specific types of aircraft appeared to exceed the design cruise speed more often than other types. Aircraft used in instructional and personal operations were flown above the design cruise speed more frequently than aircraft in other types of operations.

All general aviation aircraft experienced higher landing accelerations than commercial transport aircraft used in short-haul operations. Aircraft in instructional operations experienced the most severe landing impact accelerations.

REFERENCES

1. Taback, Israel: The NACA V-G Recorder. NACA TN 2194, 1950.

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

TABLE I.- BASIC CHARACTERISTICS OF THE INSTRUMENTED AIRCRAFT.

	TWIN ENGINE EXECUTIVE					SINGLE ENGINE EXECUTIVE			PERSONAL			INSTRUCTIONAL			COMMERCIAL SURVEY		
AIRCRAFT TYPE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	8	13	15
ENGINE TYPE	JET	TURBO PROP.	PISTON	PISTON	PISTON	PISTON	PISTON	PISTON	PISTON	PISTON	PISTON	PISTON	PISTON	PISTON	PISTON	PISTON	PISTON
MAXIMUM WEIGHT, LB	12,500	9,000	4,800	4,830	8,500	2,650	2,900	2,800	2,400	2,200	2,575	1,650	1,600	1,500	2,800	1,600	1,500
WING AREA, FT^2	231.8	279.7	207	175	293.9	177.6	178	174	160	174	167	147	160	170.2	174	160	178.5
WING LOADING, LB/FT^2	54.5	32.1	23.2	27.6	28.9	14.9	16.3	16.1	15.0	12.6	15.4	11.2	10.0	8.8	16.1	10.0	8.4

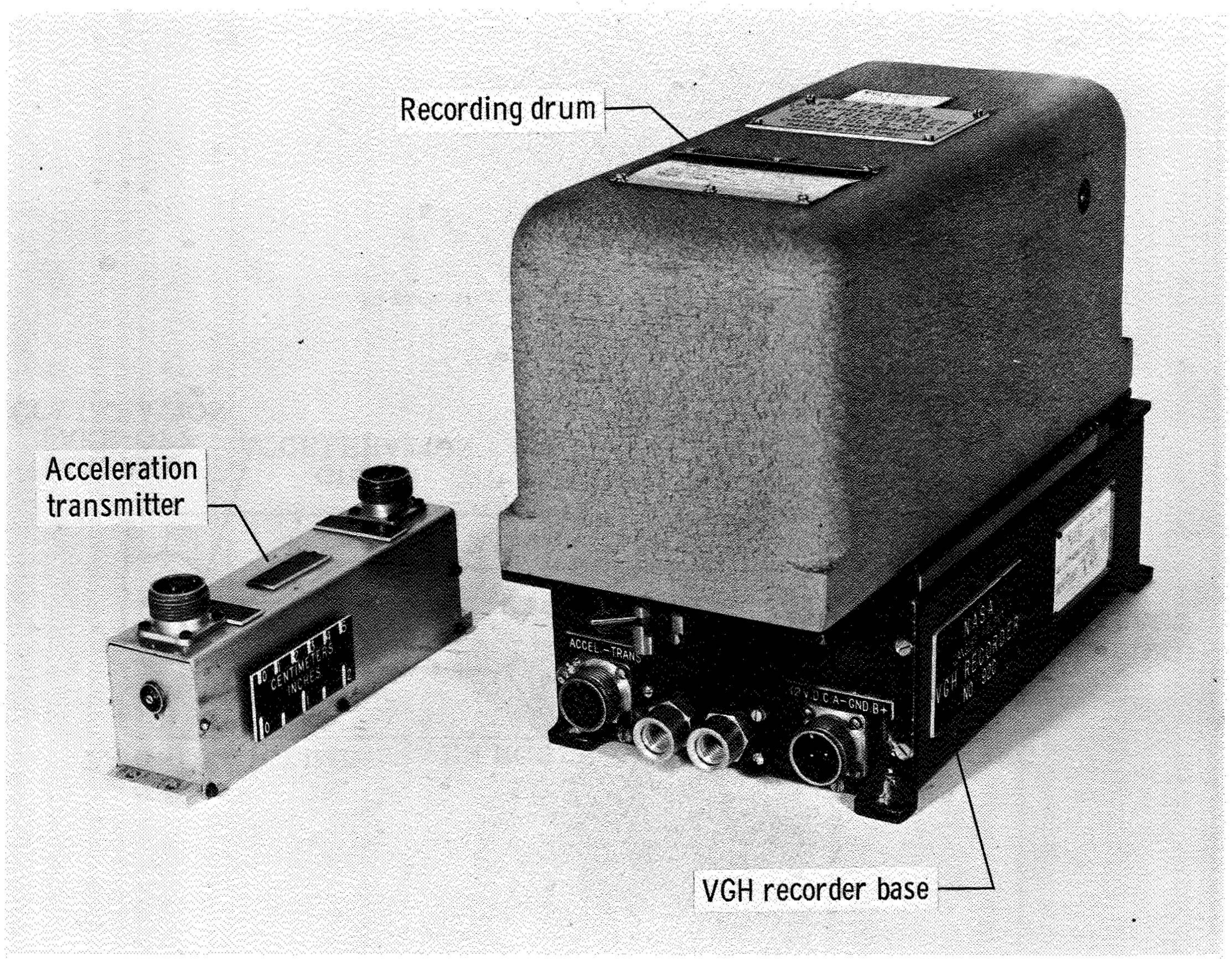


Figure 1.- NASA VGH recorder.

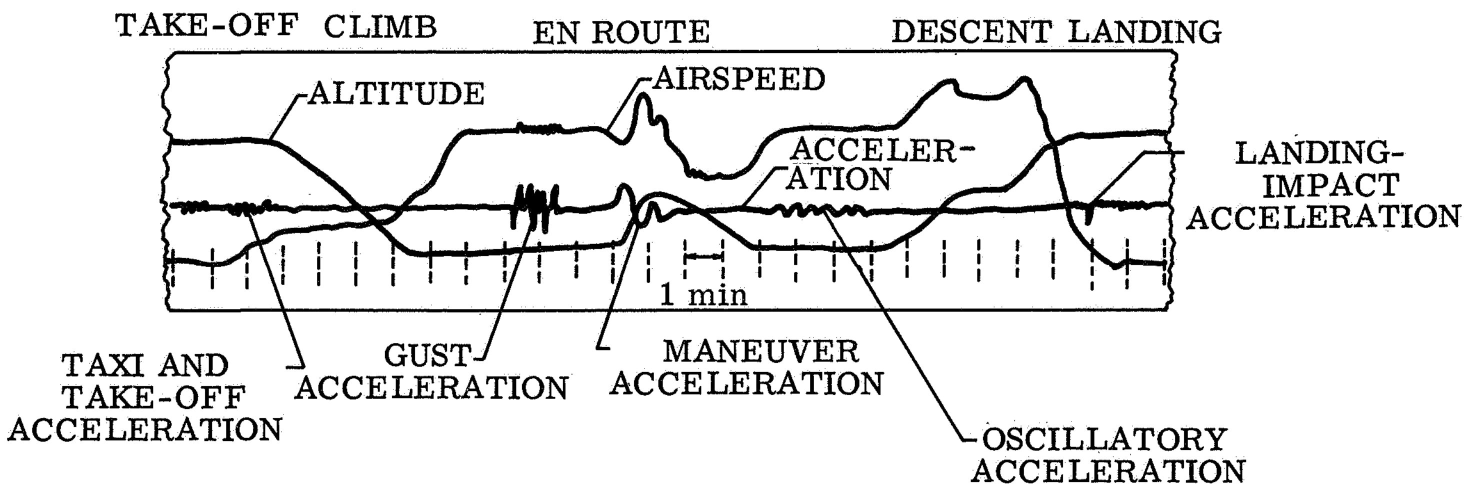


Figure 2.- Illustrative VGH record.

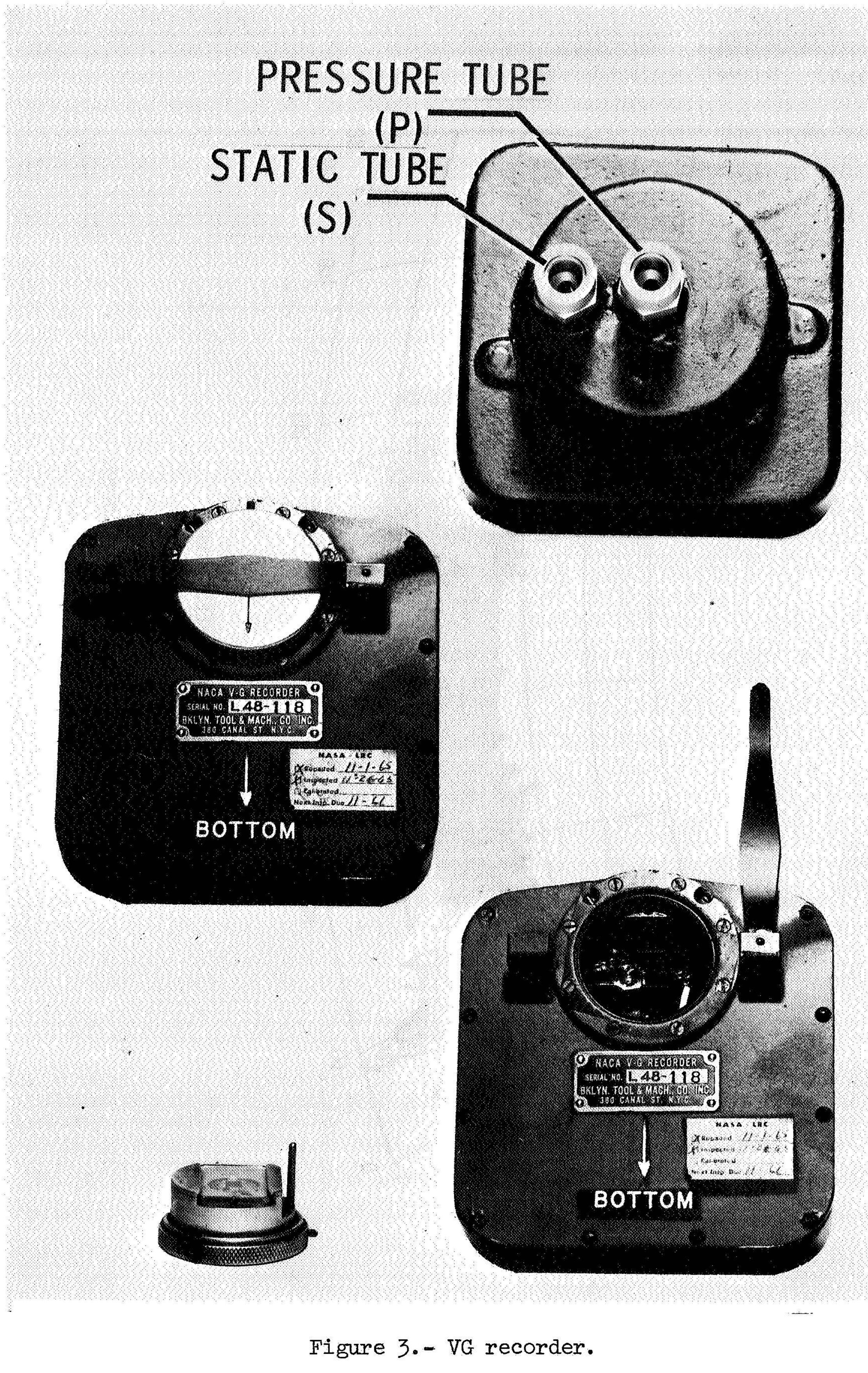


Figure 3.- VG recorder.

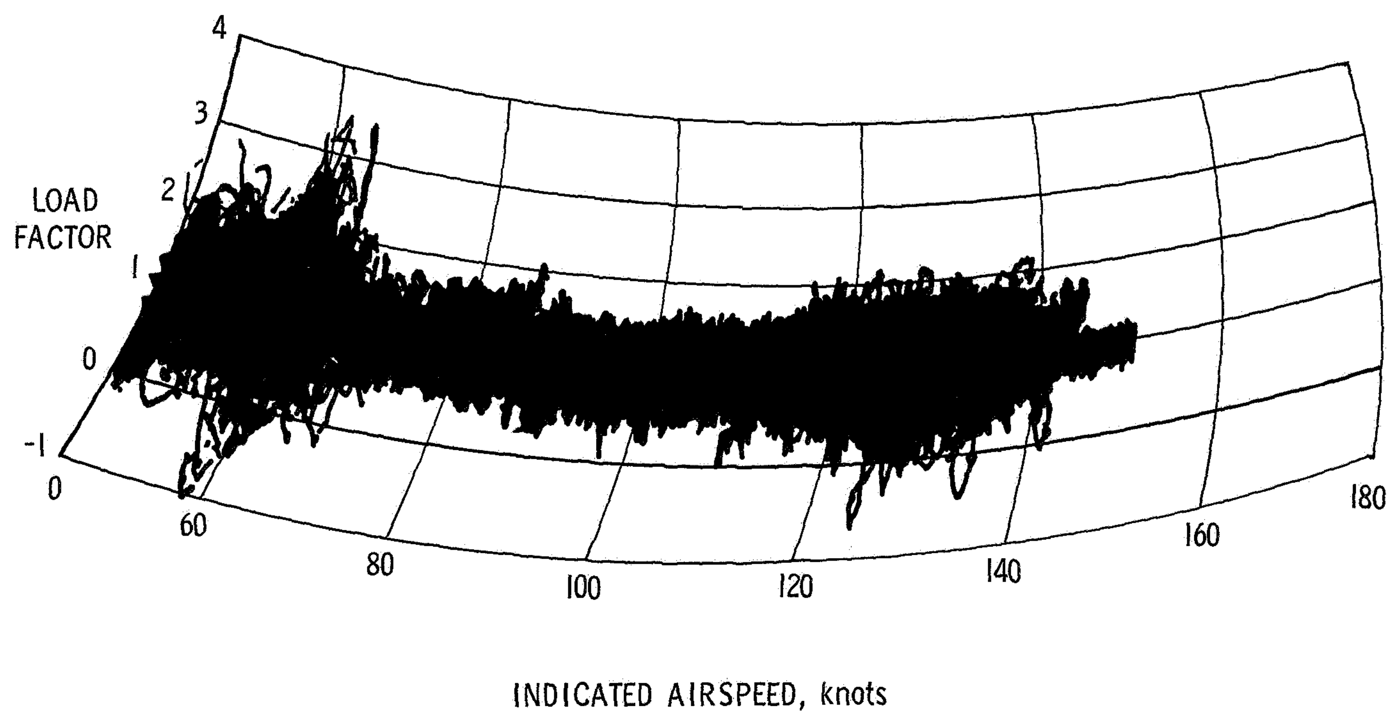


Figure 4.- Example of VG record.

Figure 5.- Location of instrumented aircraft.

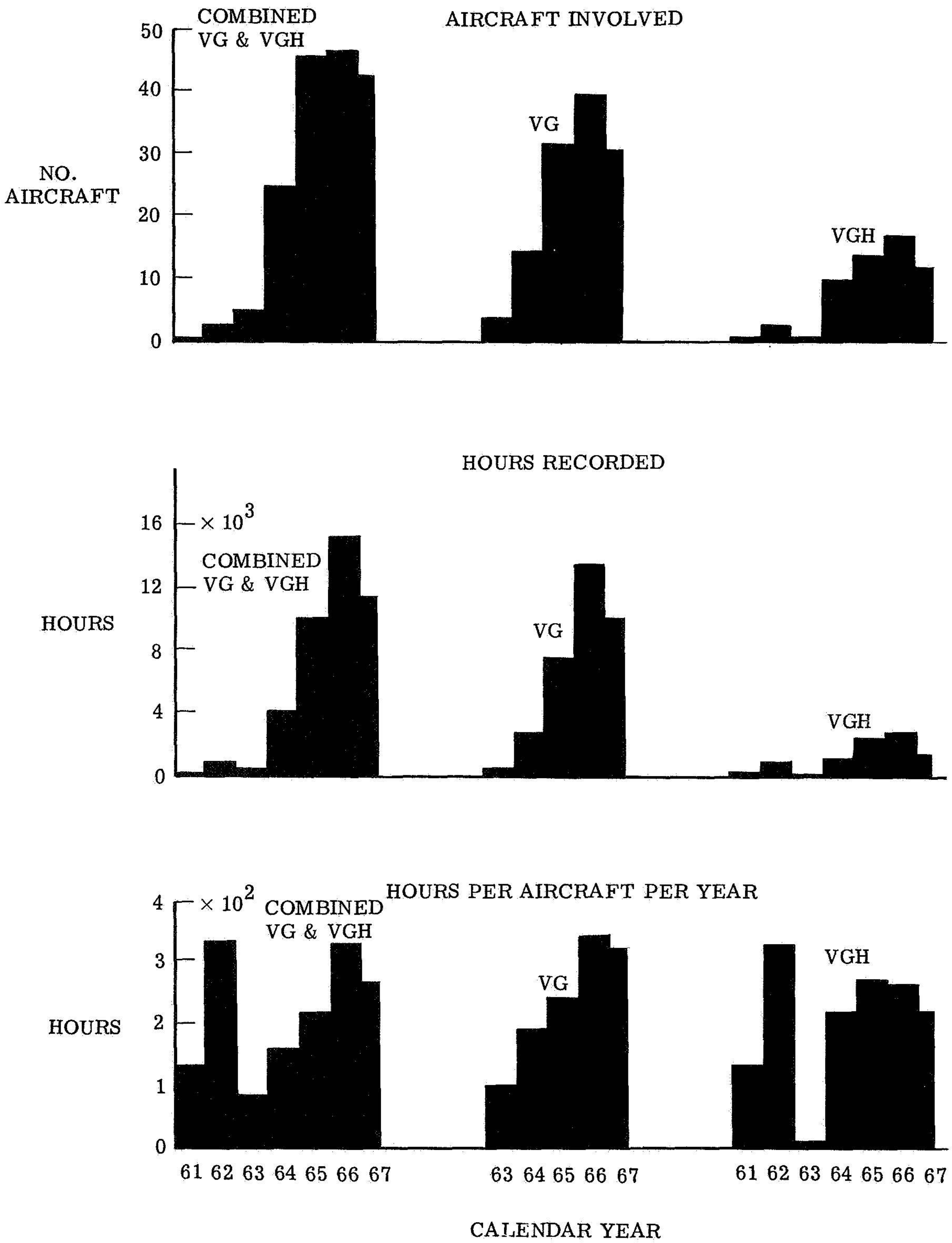


Figure 6.- Status of general aviation program.

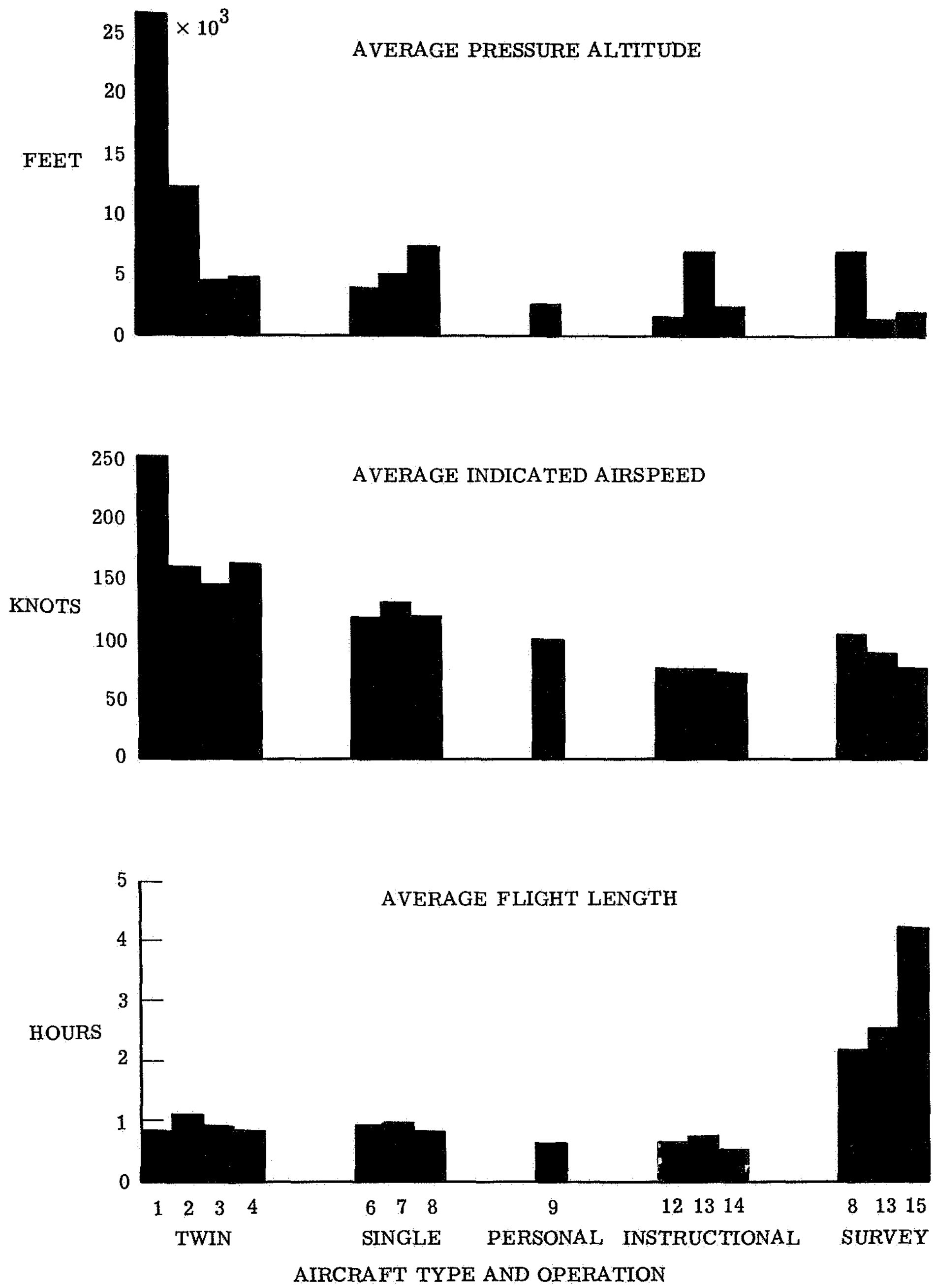
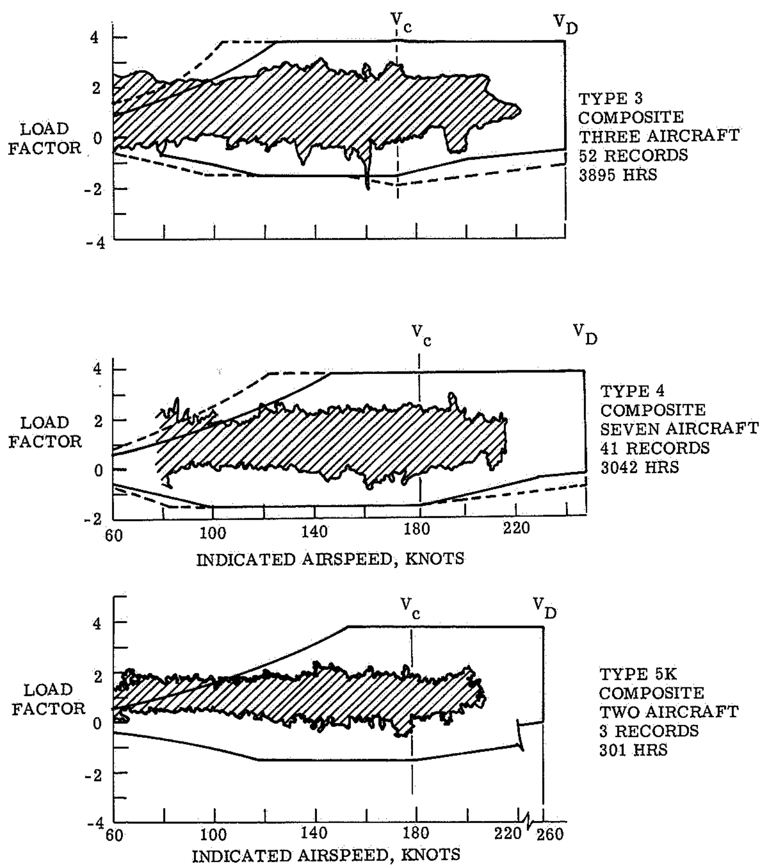
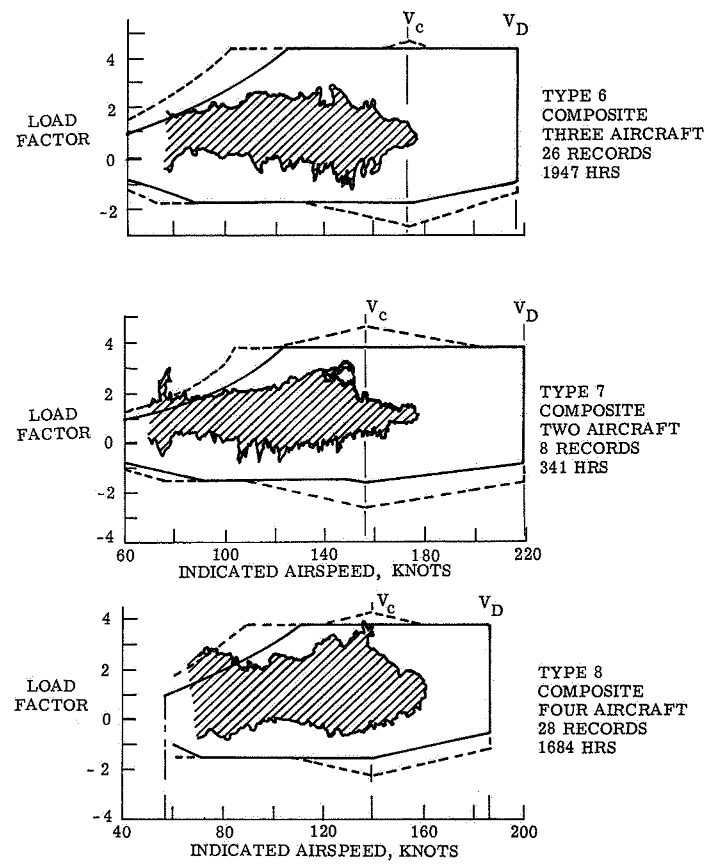


Figure 7.- Typical mission characteristics of instrumented aircraft. VGH data.

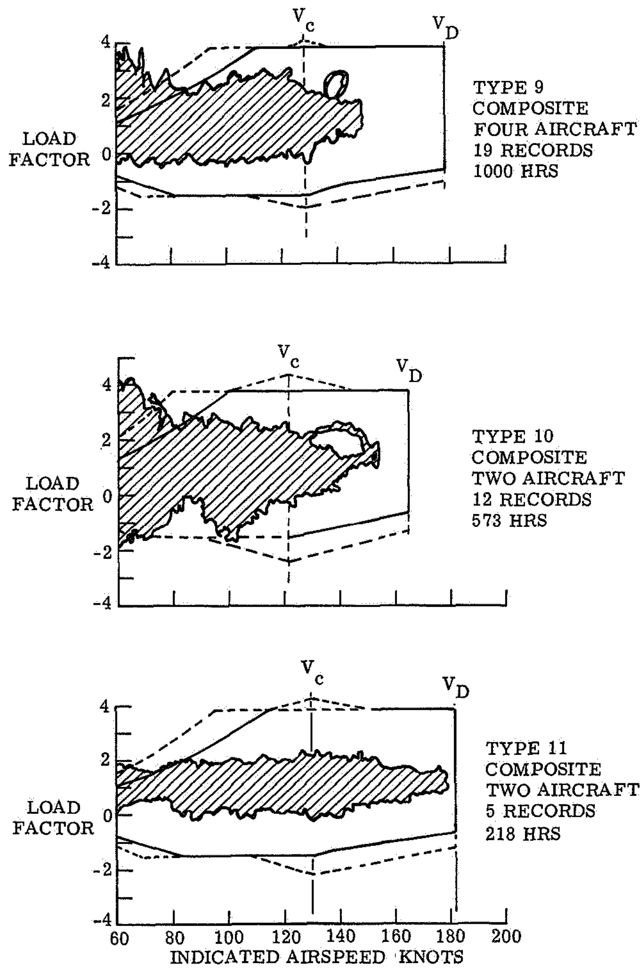


(a) Twin-engine executive.

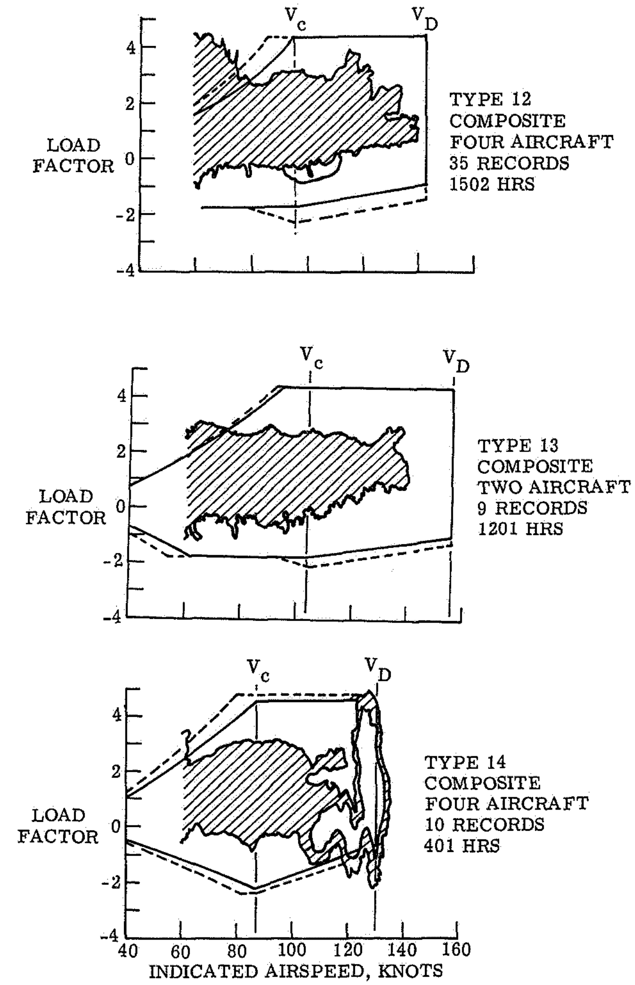


(b) Single-engine executive.

Figure 8.- Composite VG records from aircraft in five types of operations.

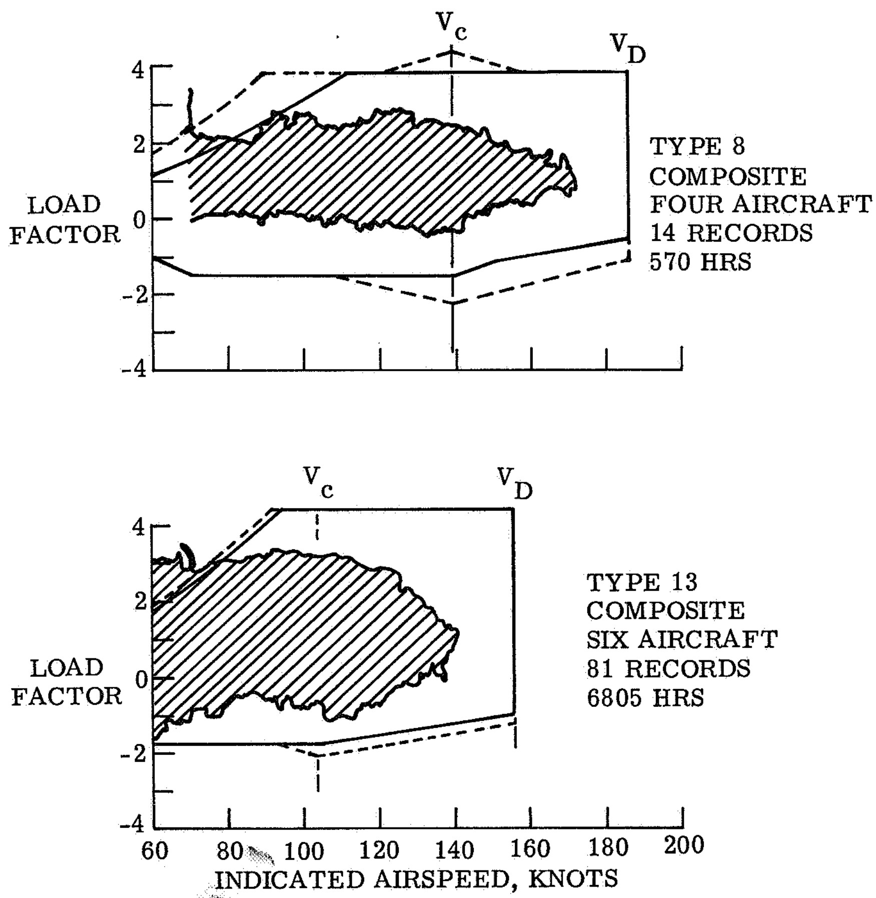


(c) Personal.



(d) Instructional.

Figure 8.- Continued.



(e) Commercial survey.

Figure 8.- Concluded.

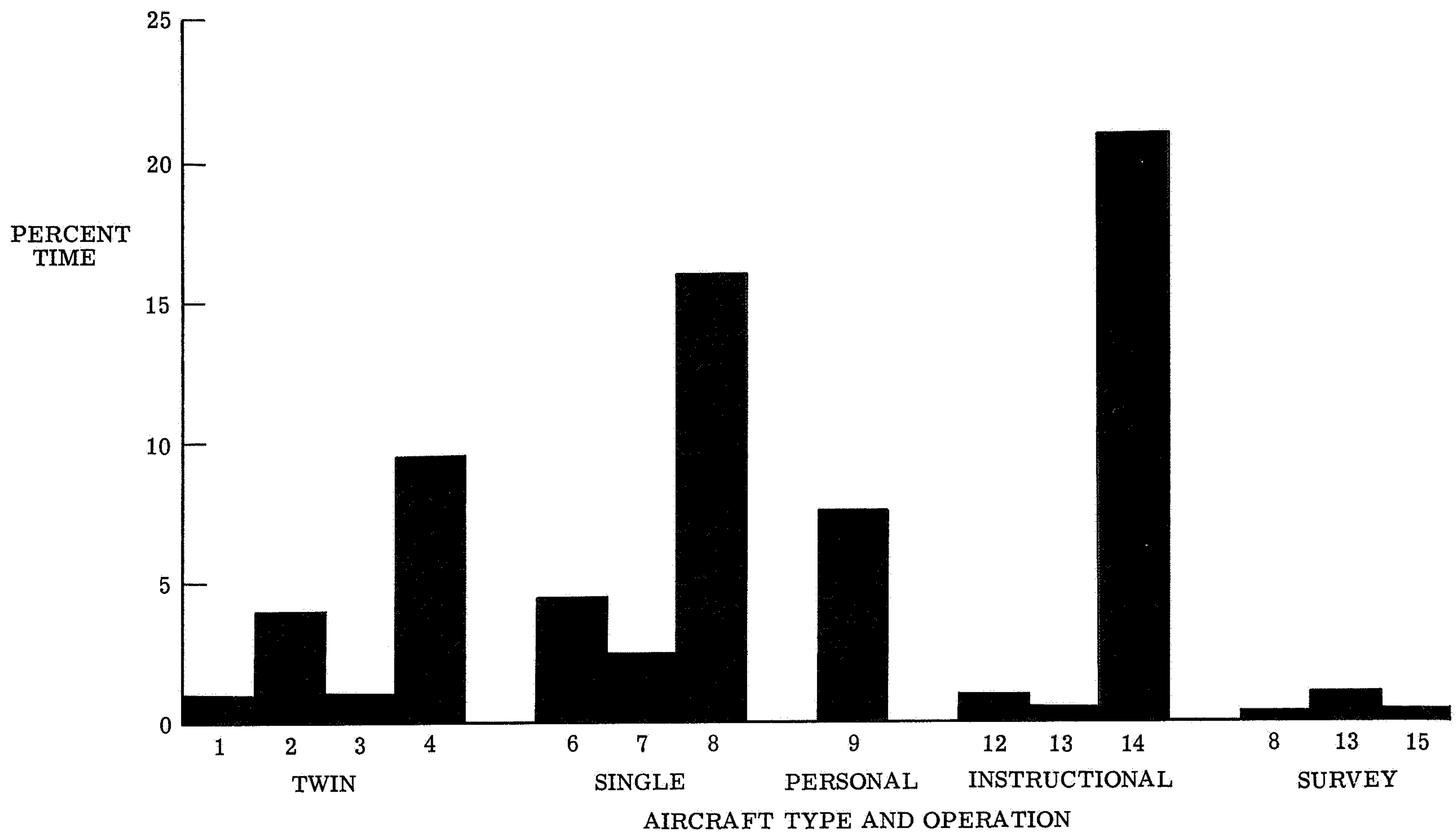
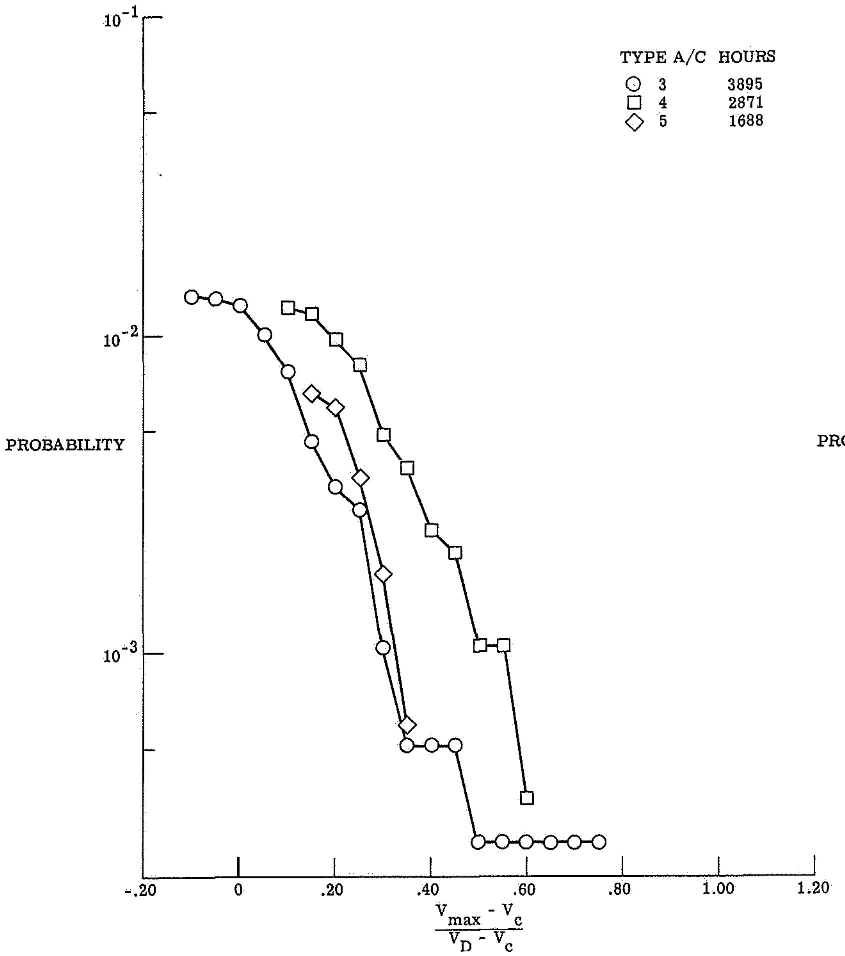
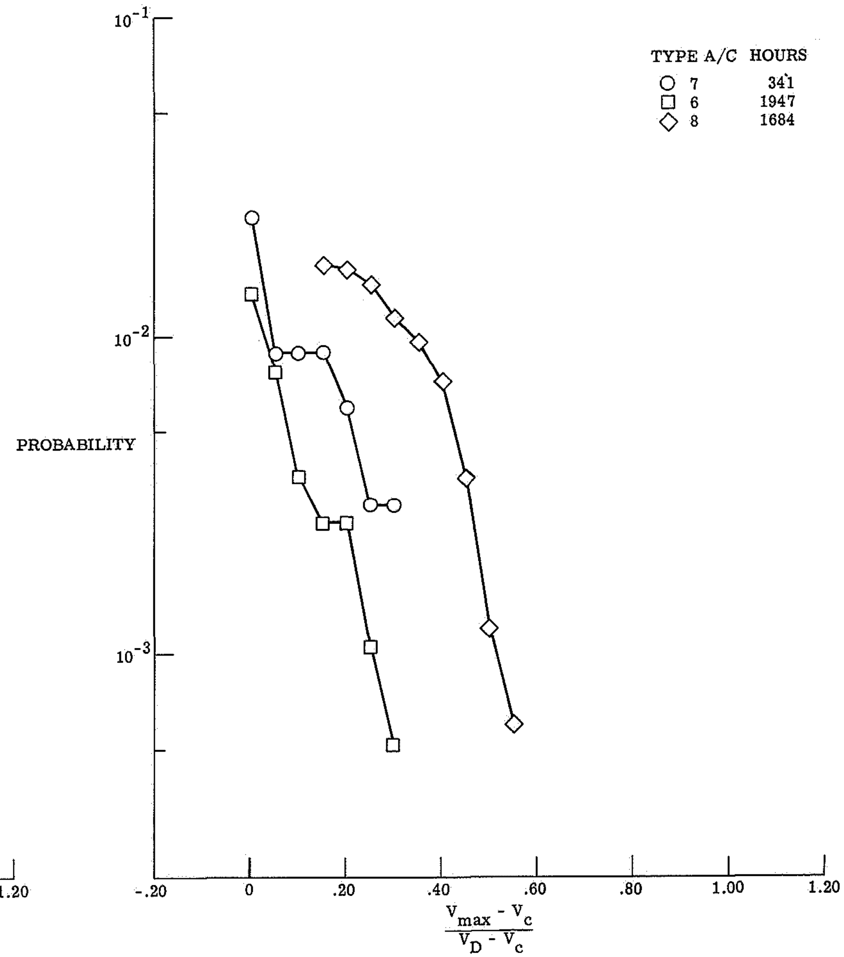


Figure 9.- Percent time aircraft in five types of operations were flown above the design cruise speed. VGH data.

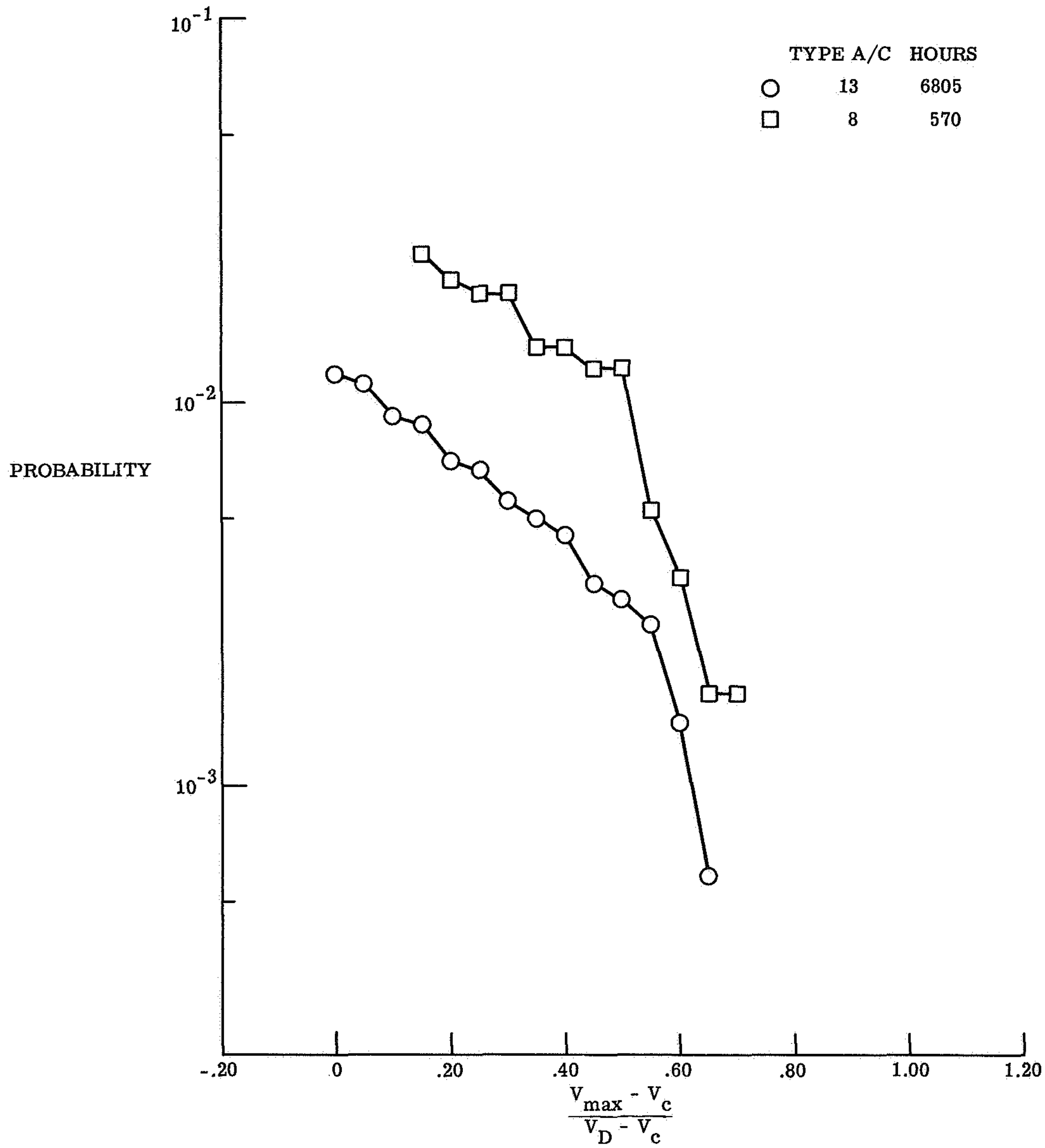


(a) Twin-engine executive.



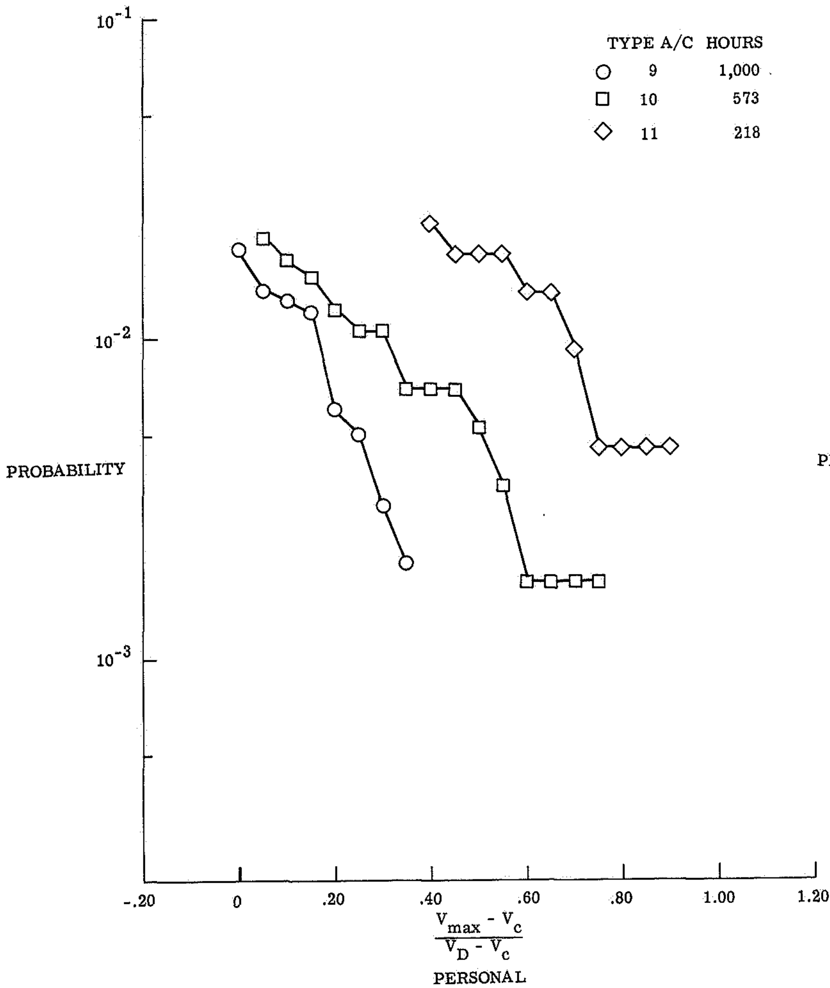
(b) Single-engine executive.

Figure 10.- Probability per flight hour of equaling or exceeding the design cruise speed for aircraft in five types of operations.

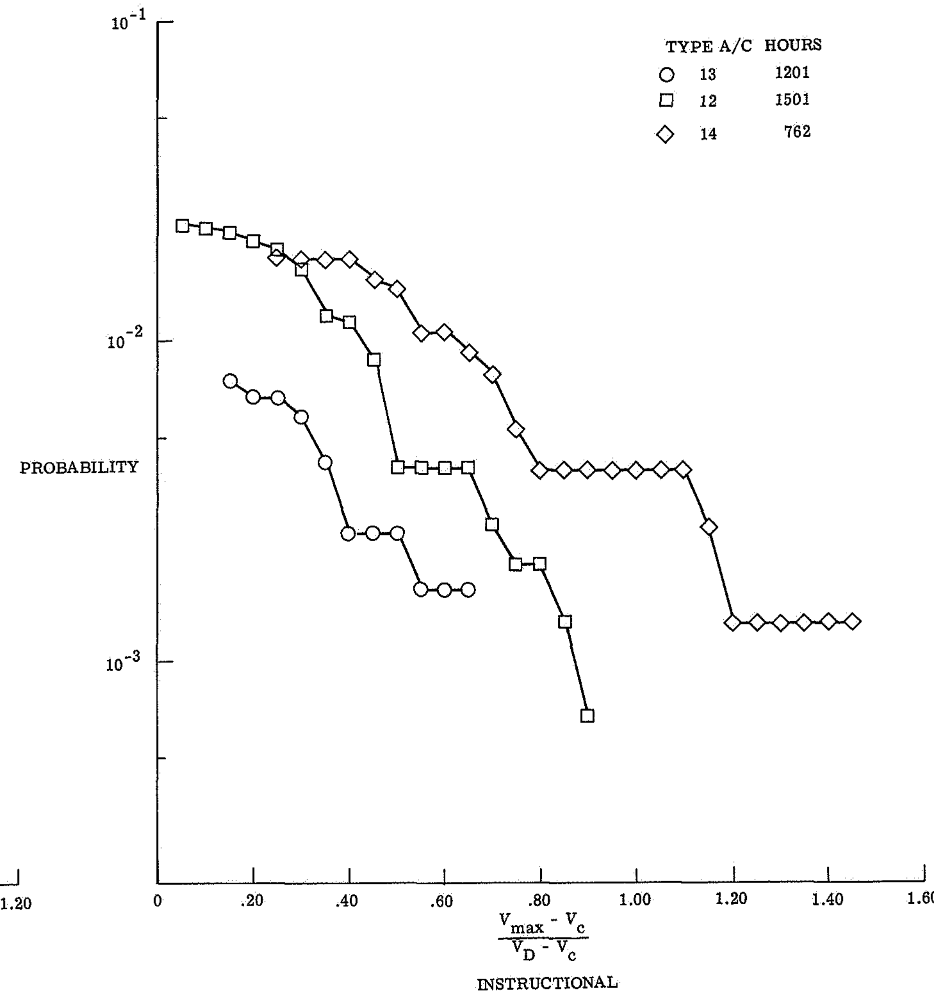


(e) Commercial survey.

Figure 10.- Concluded.

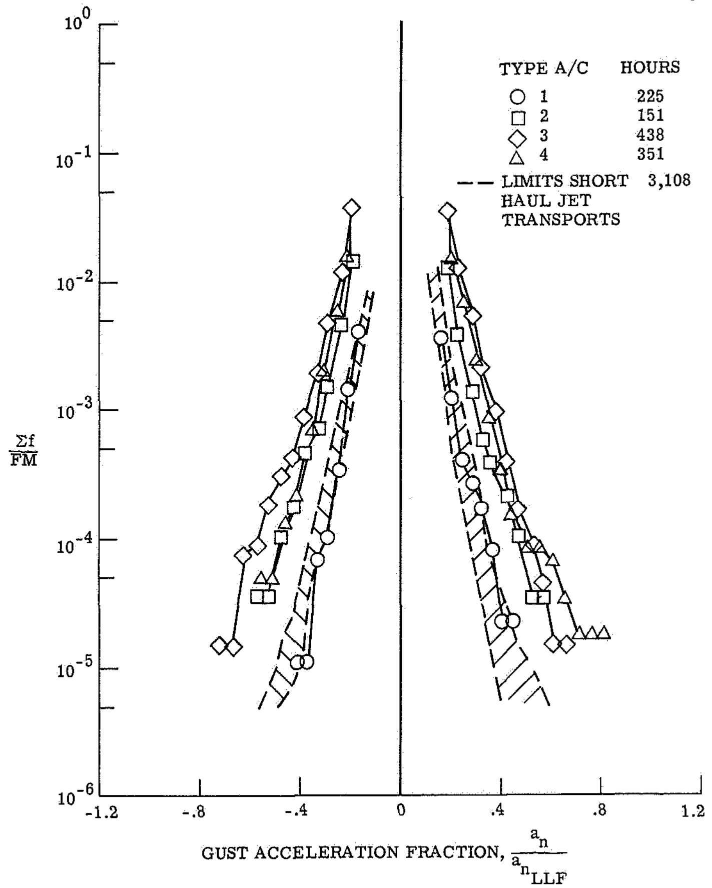


(c) Personal.

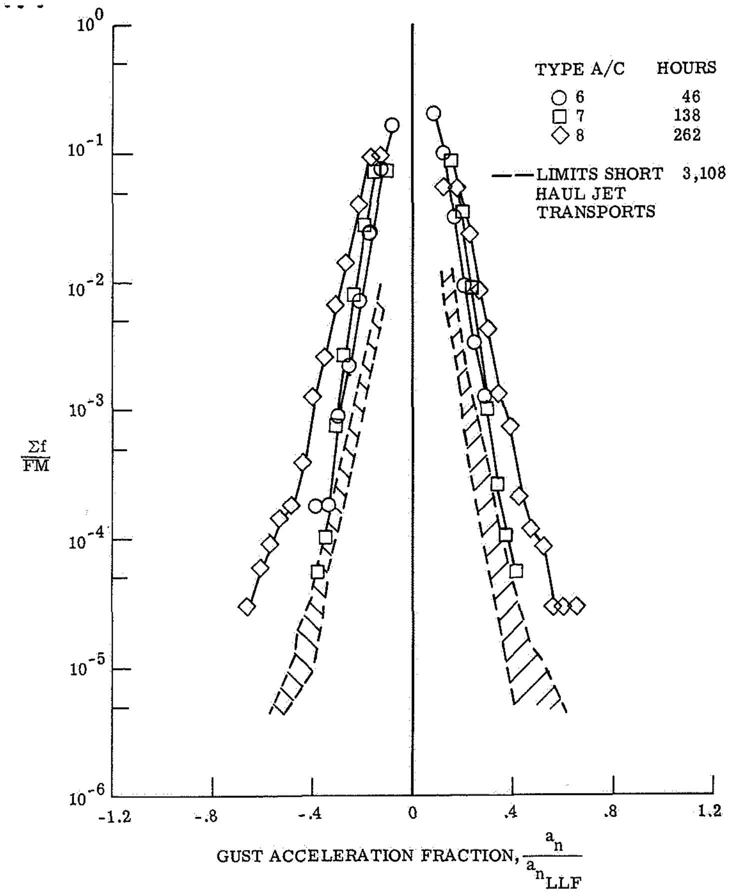


(d) Instructional.

Figure 10.- Continued.



(a) Twin-engine executive.



(b) Single-engine executive.

Figure 12.- Gust acceleration fraction experience per flight mile for aircraft in five types of operations.

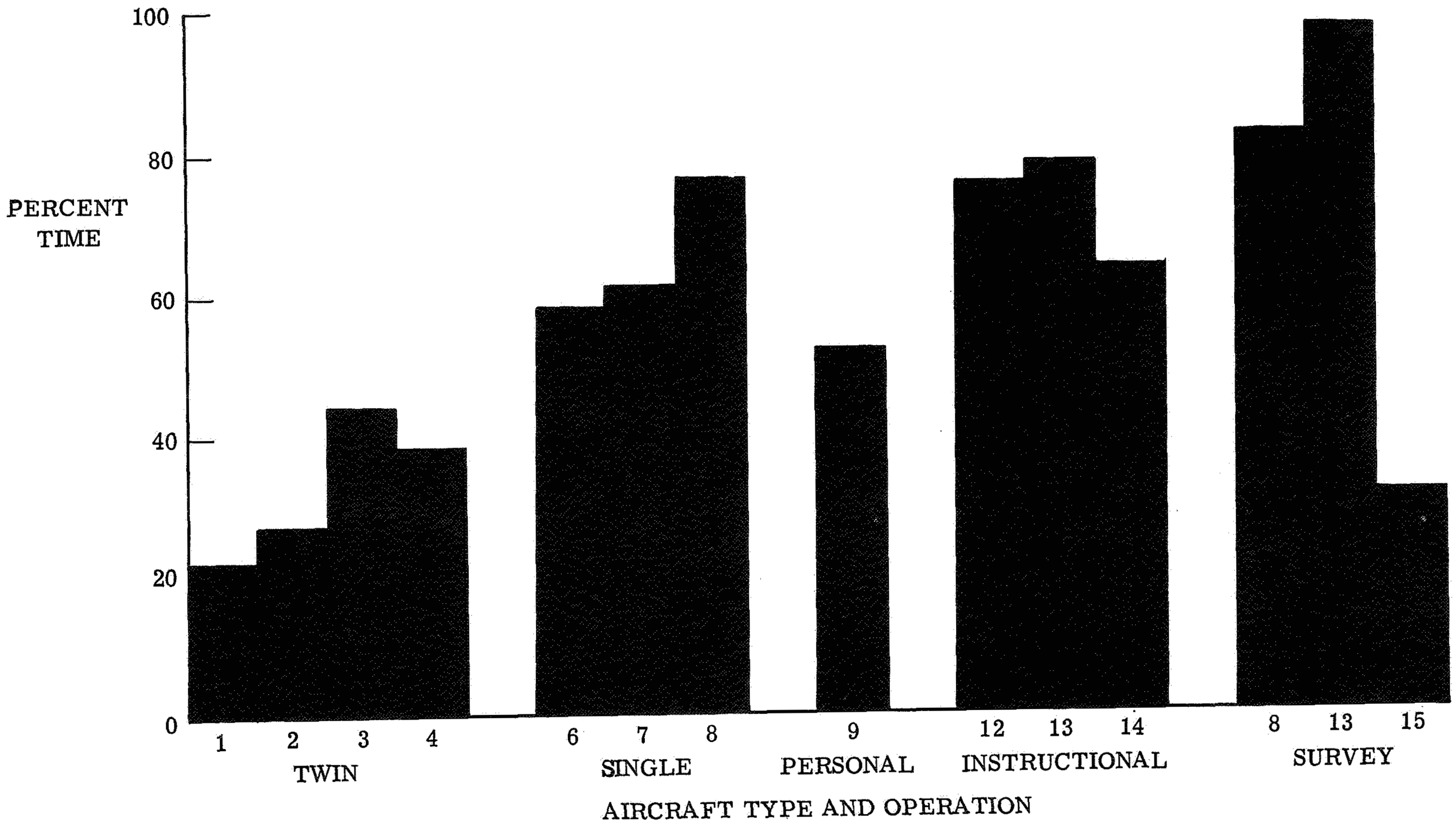
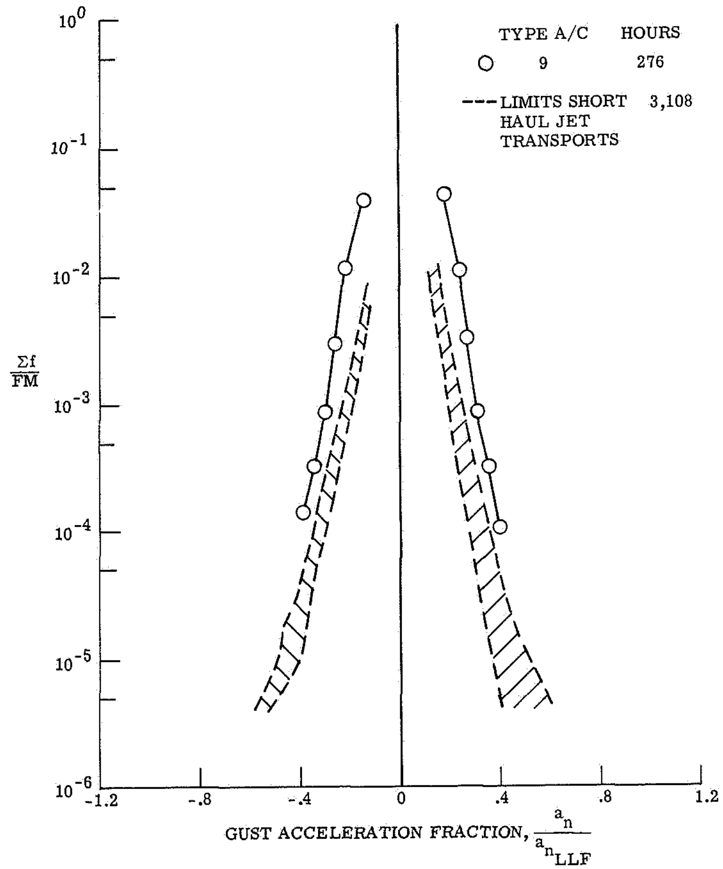
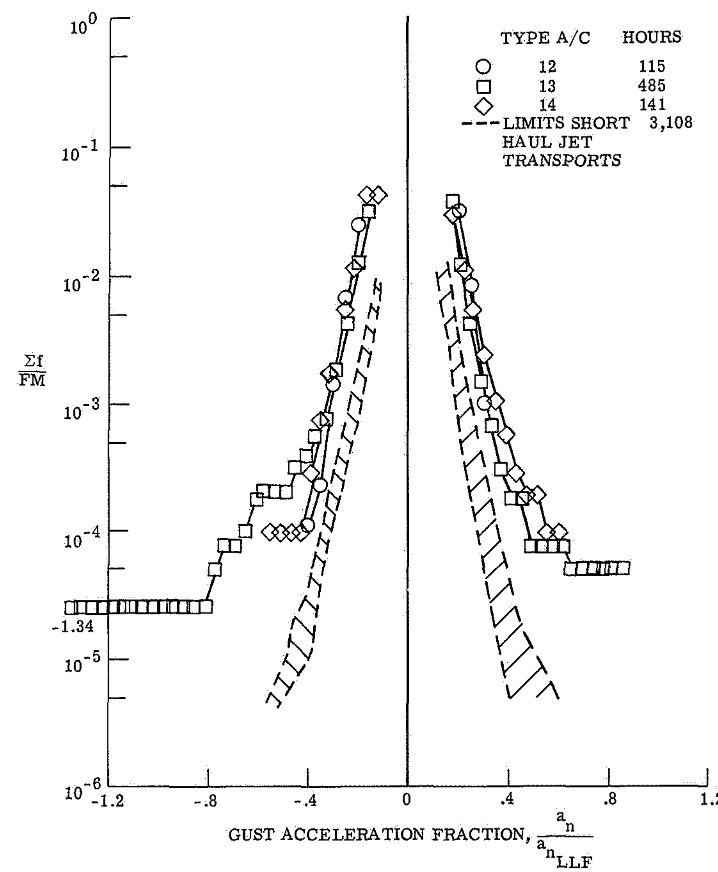


Figure 11.- Percent time flown in rough air by aircraft in five types of operations. VGH data.

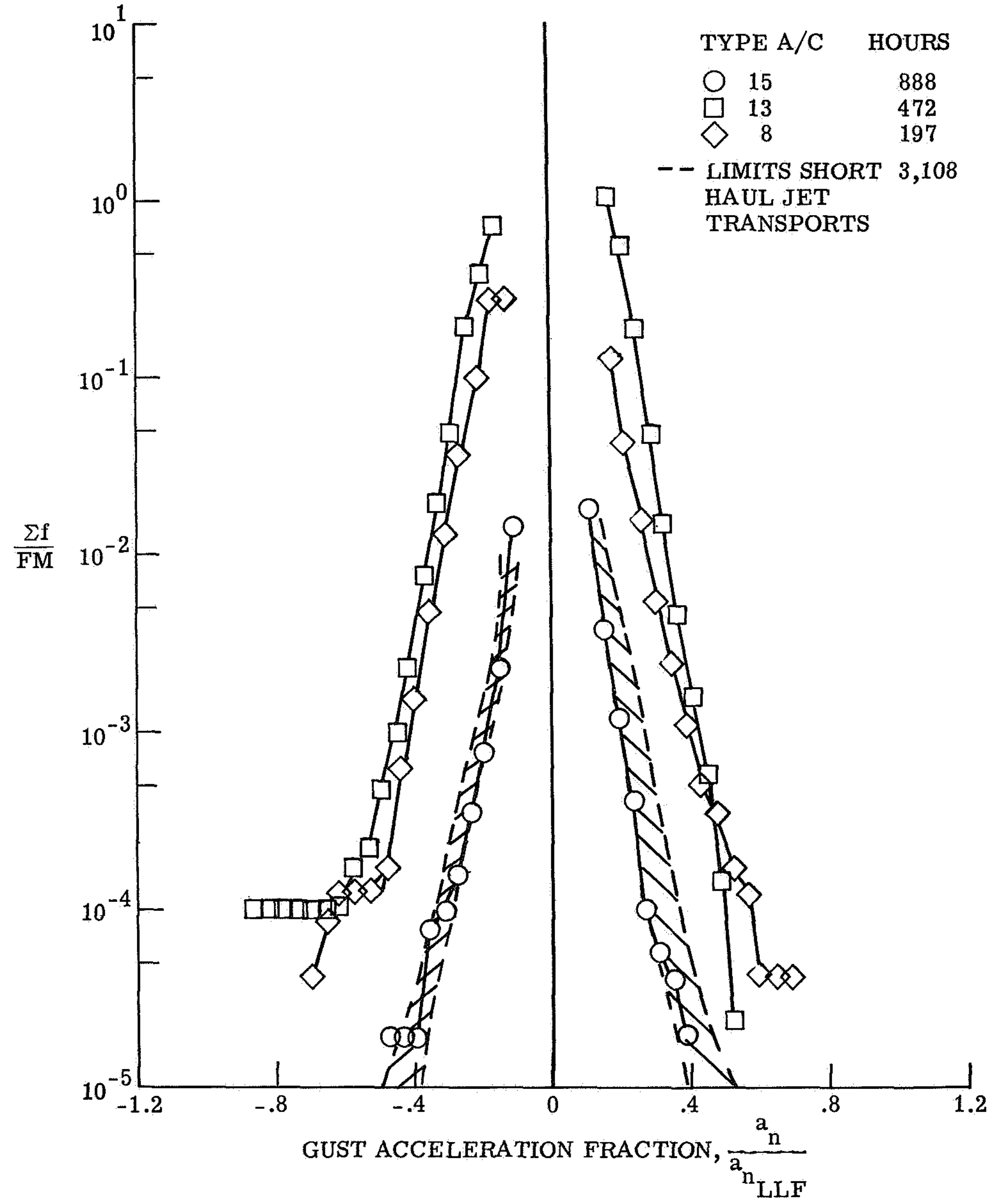


(c) Personal.



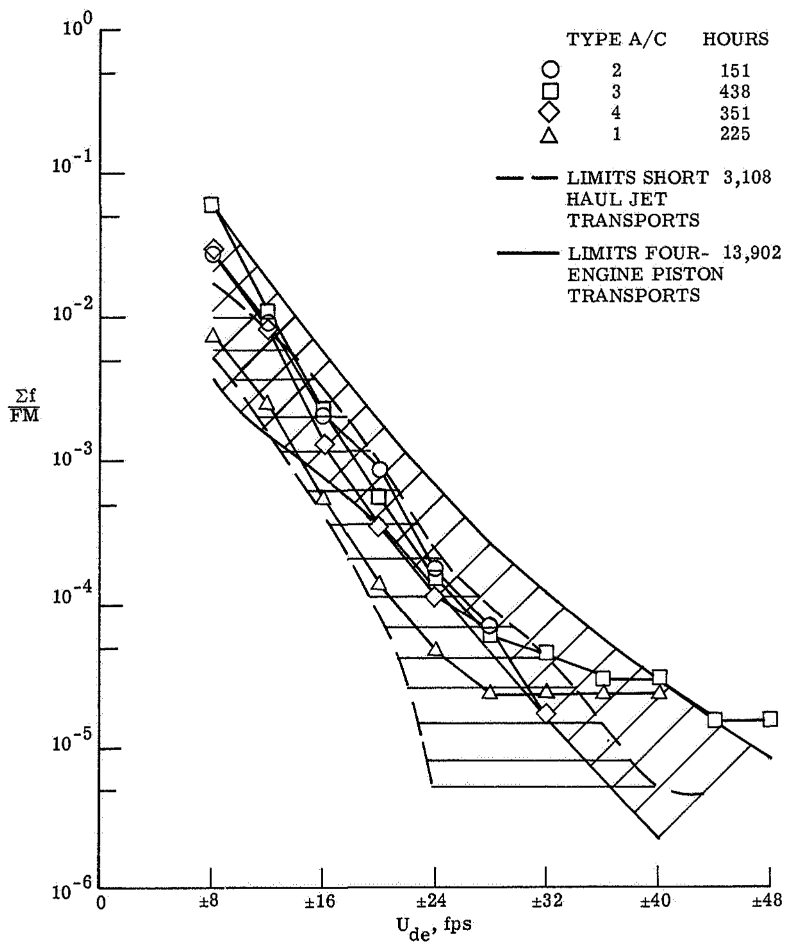
(d) Instructional.

Figure 12.- Continued.

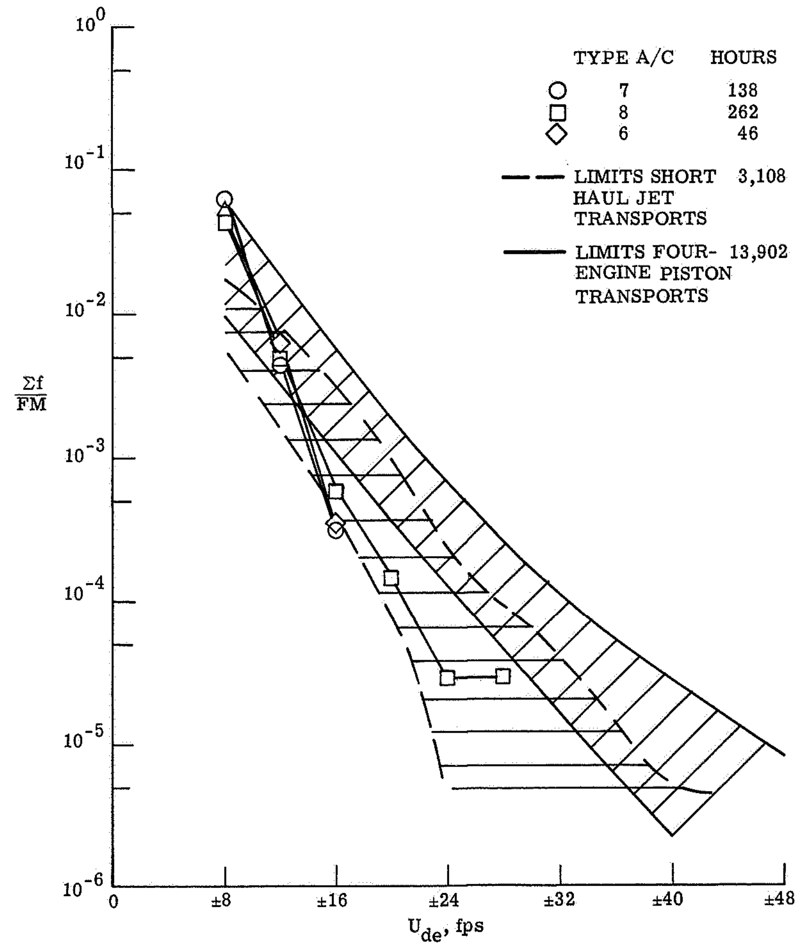


(e) Commercial survey.

Figure 12.- Concluded.

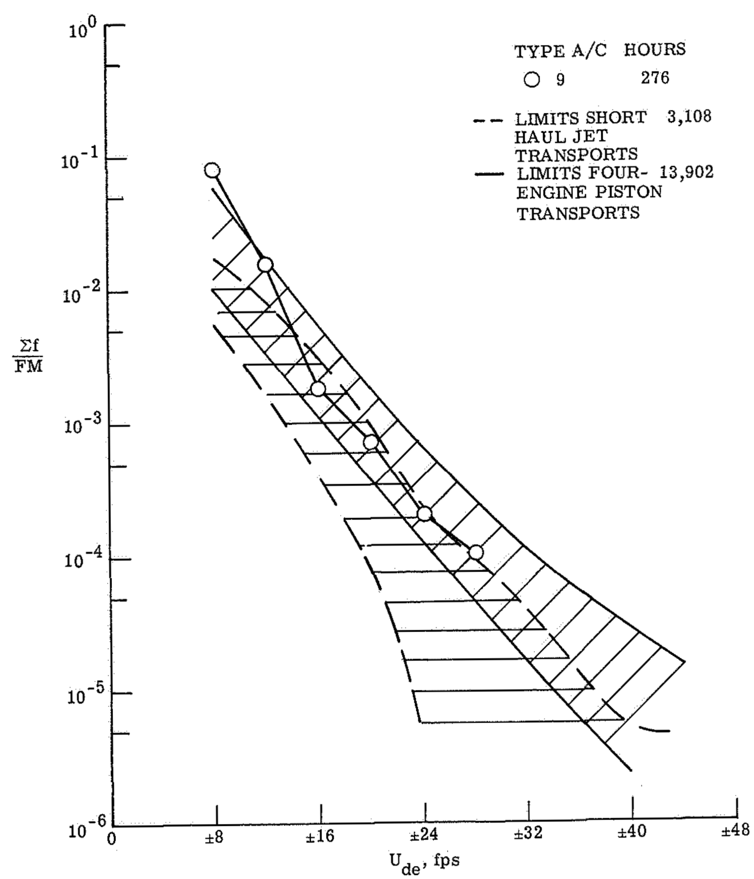


(a) Twin-engine executive.

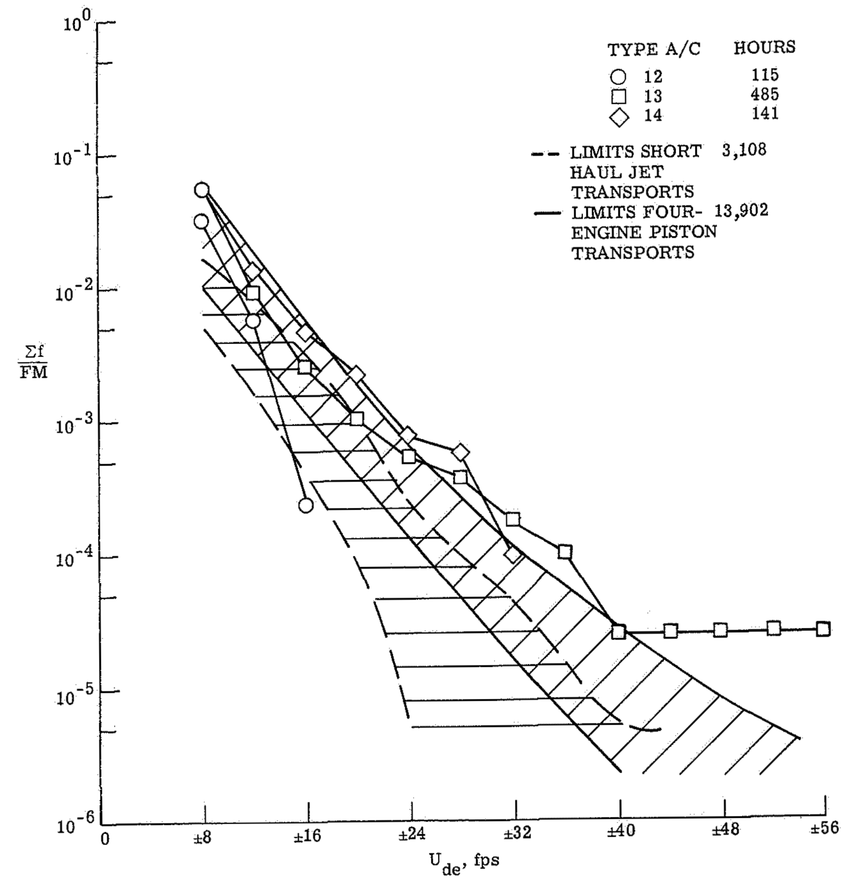


(b) Single-engine executive.

Figure 13.- Derived gust velocity experience per flight mile for aircraft in five types of operations. VGH data.

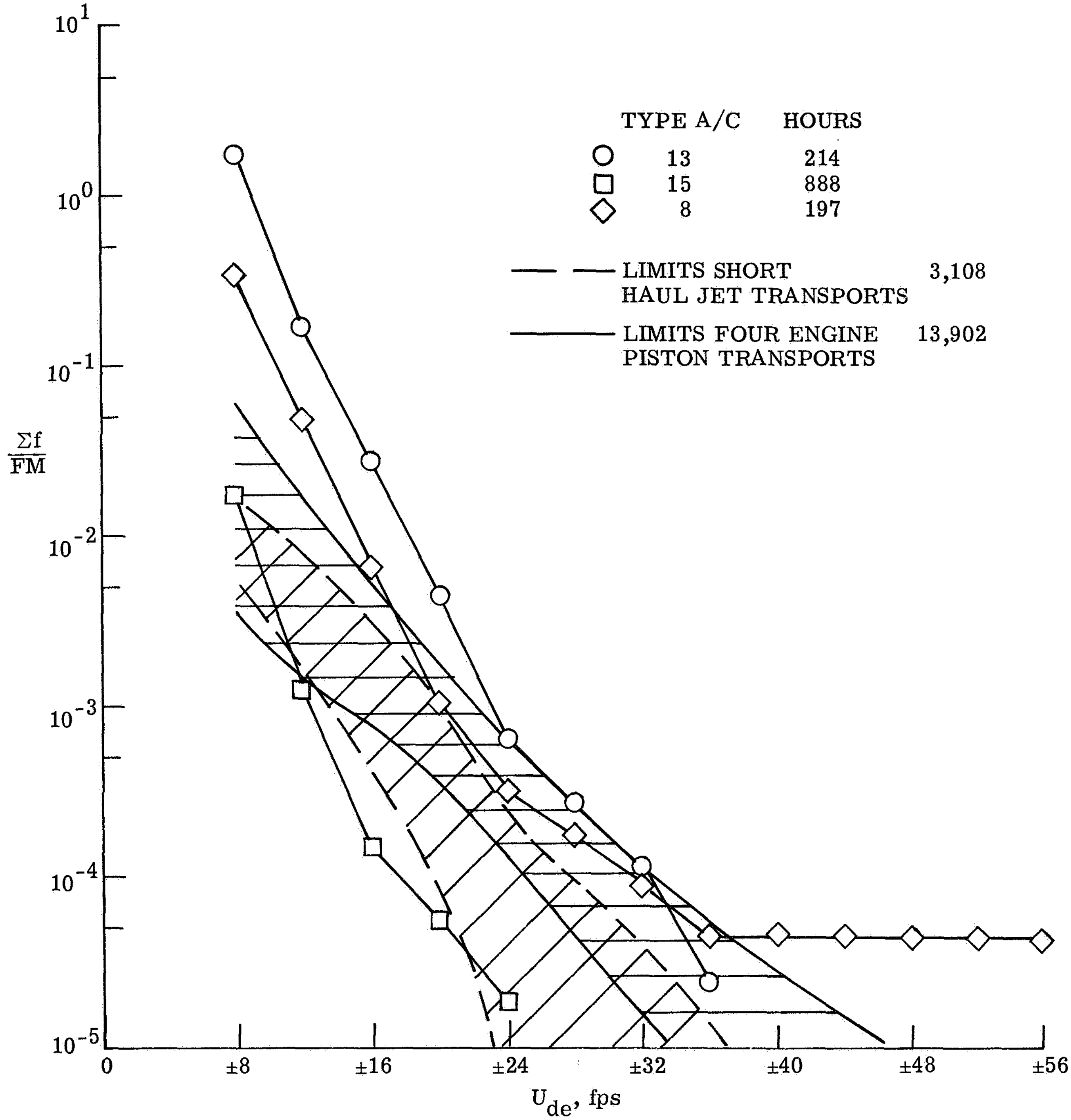


(c) Personal.



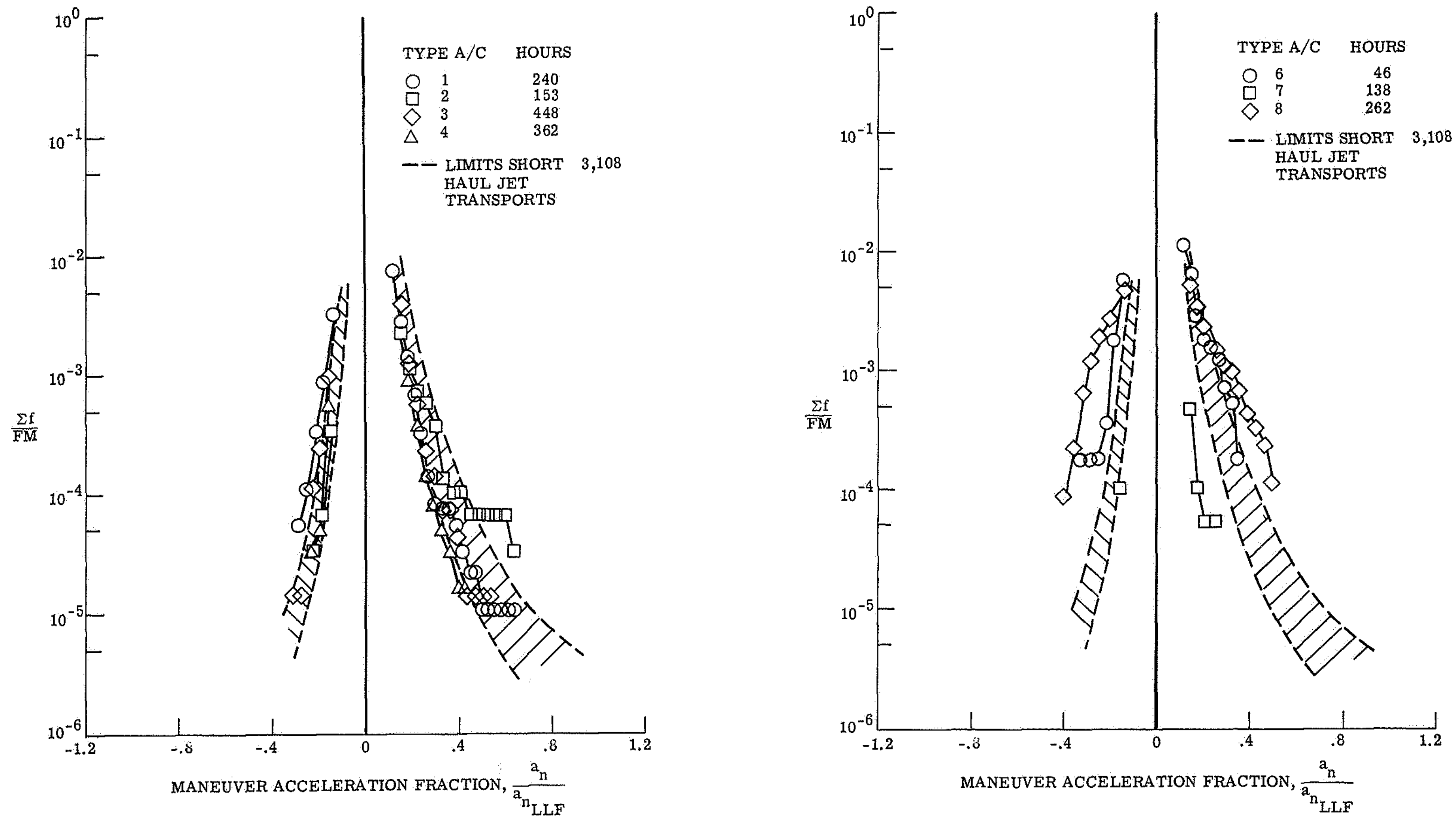
(d) Instructional.

Figure 13.- Continued.



(e) Commercial survey.

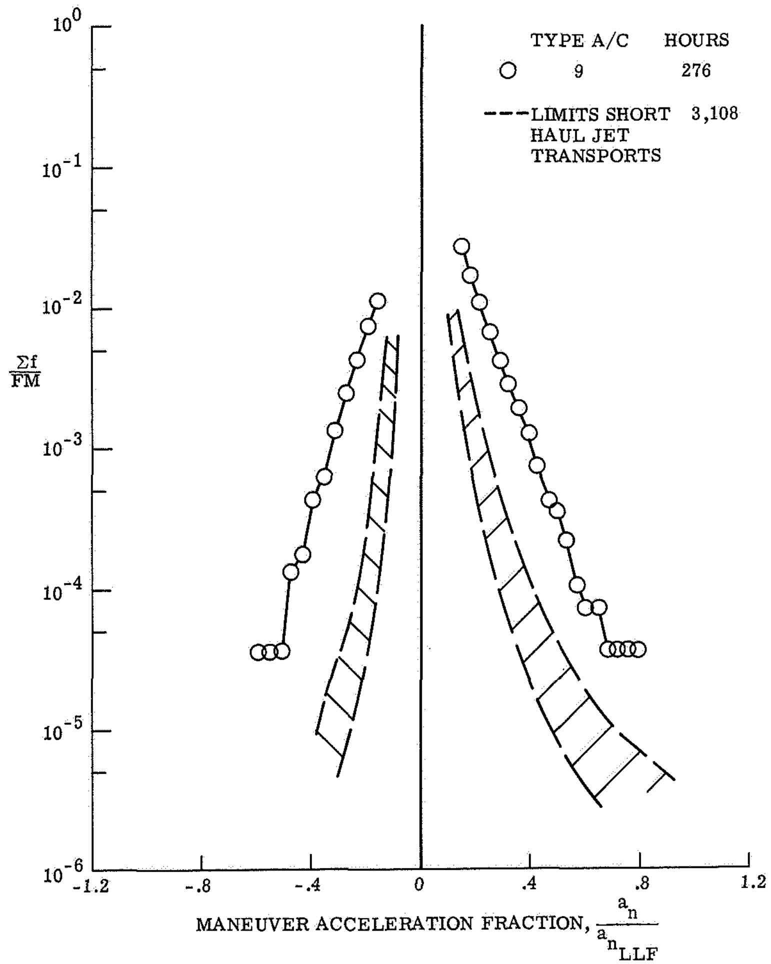
Figure 13.- Concluded.



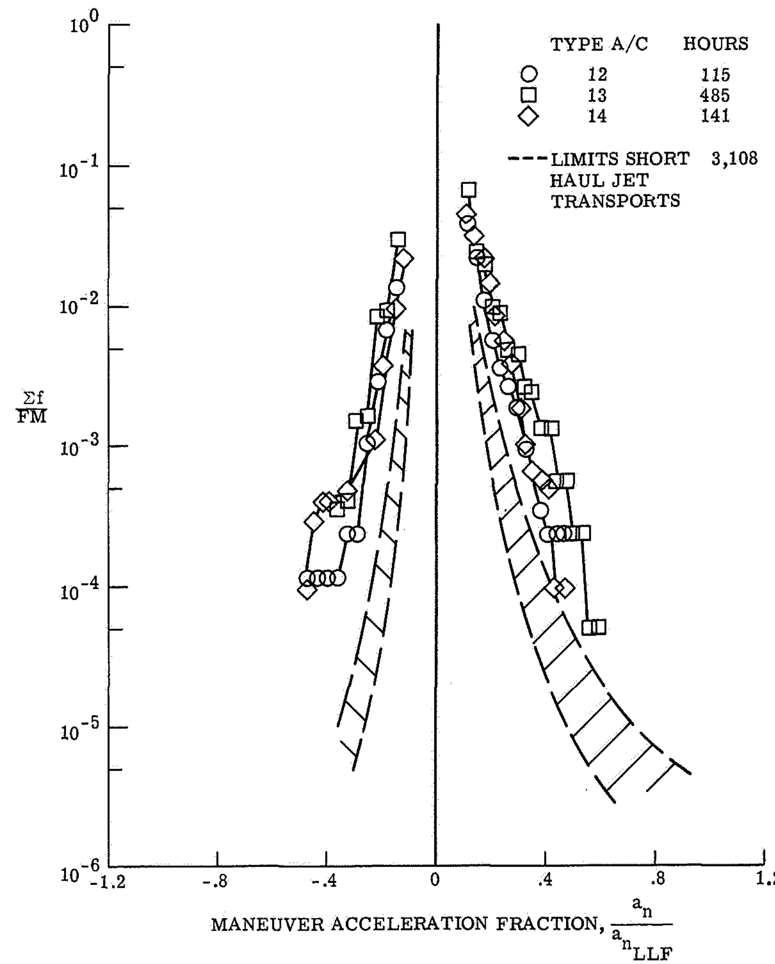
(a) Twin-engine executive.

(b) Single-engine executive.

Figure 14.- Maneuver acceleration fraction experience per flight mile for aircraft in five types of operations. VGH data.

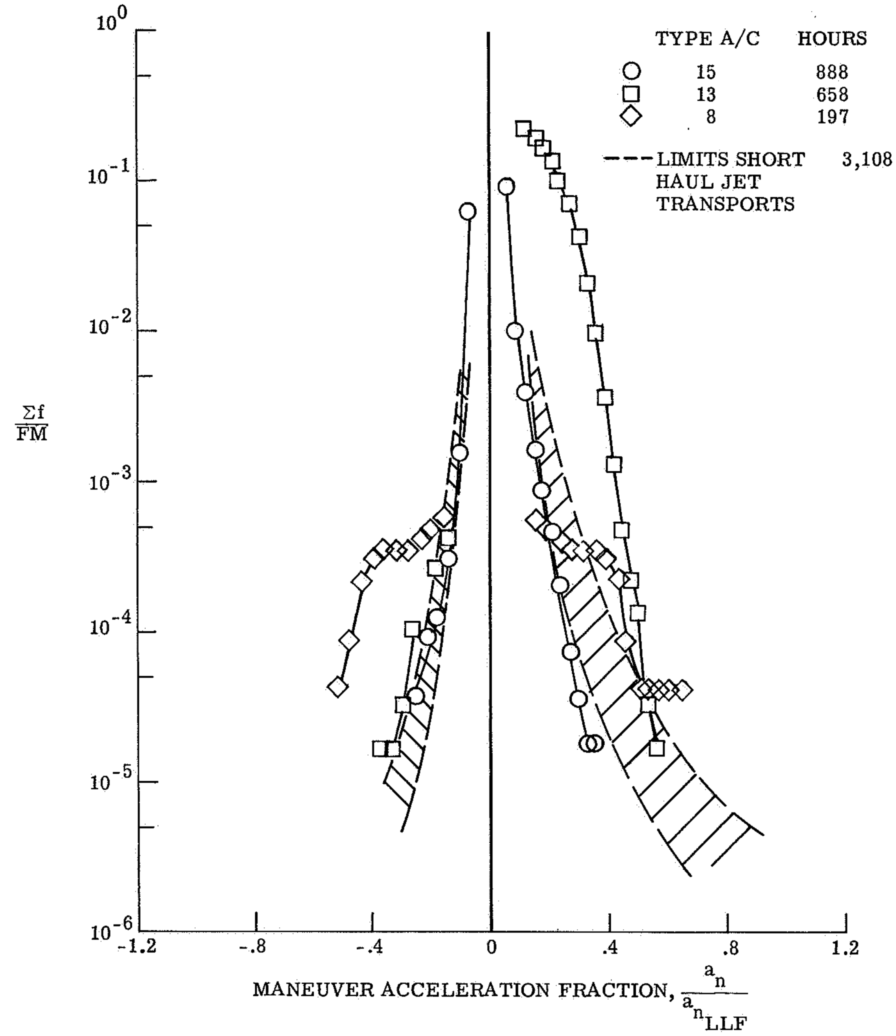


(c) Personal.



(d) Instructional.

Figure 14.- Continued.



(e) Commercial survey.

Figure 14.- Concluded.

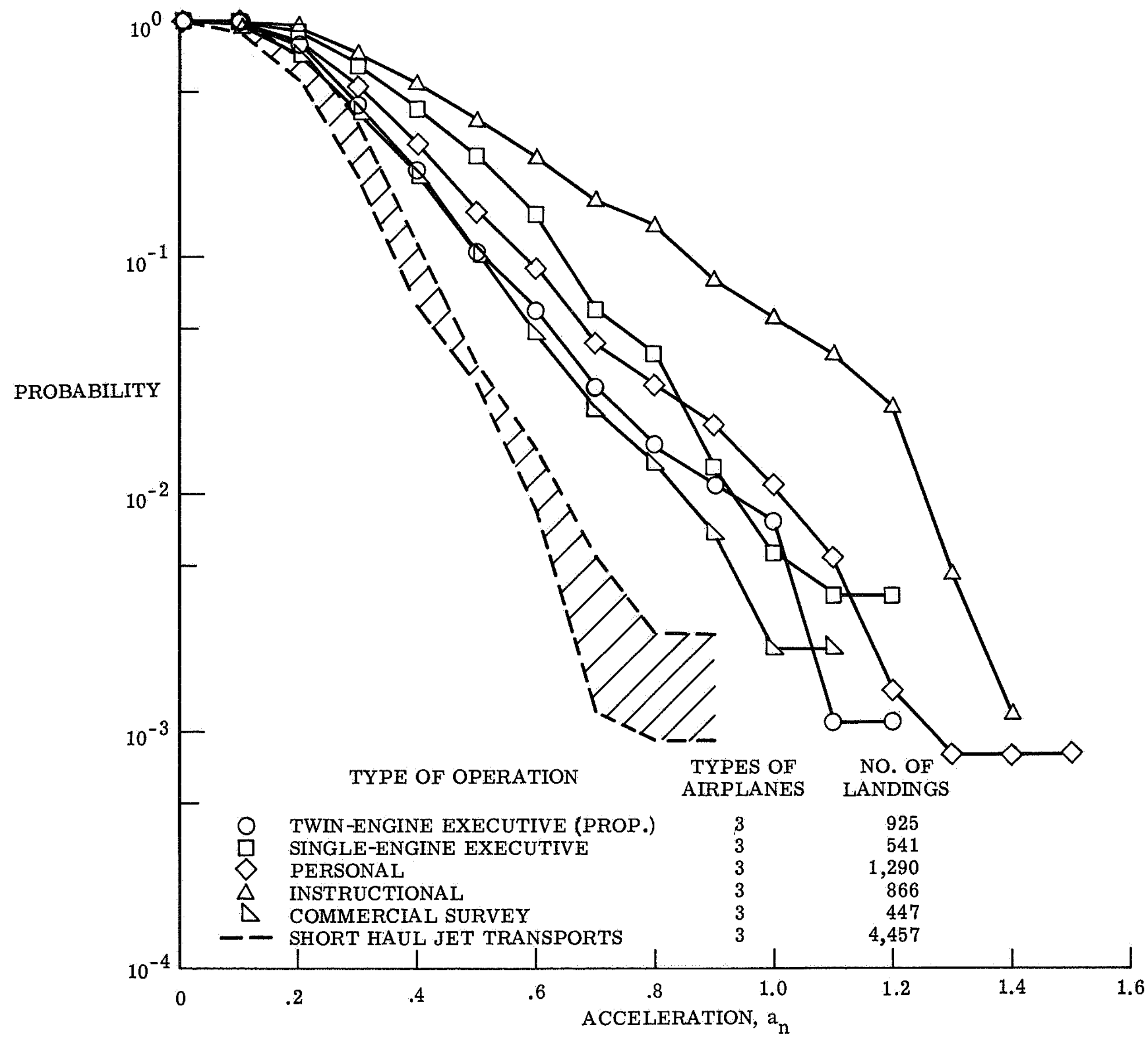
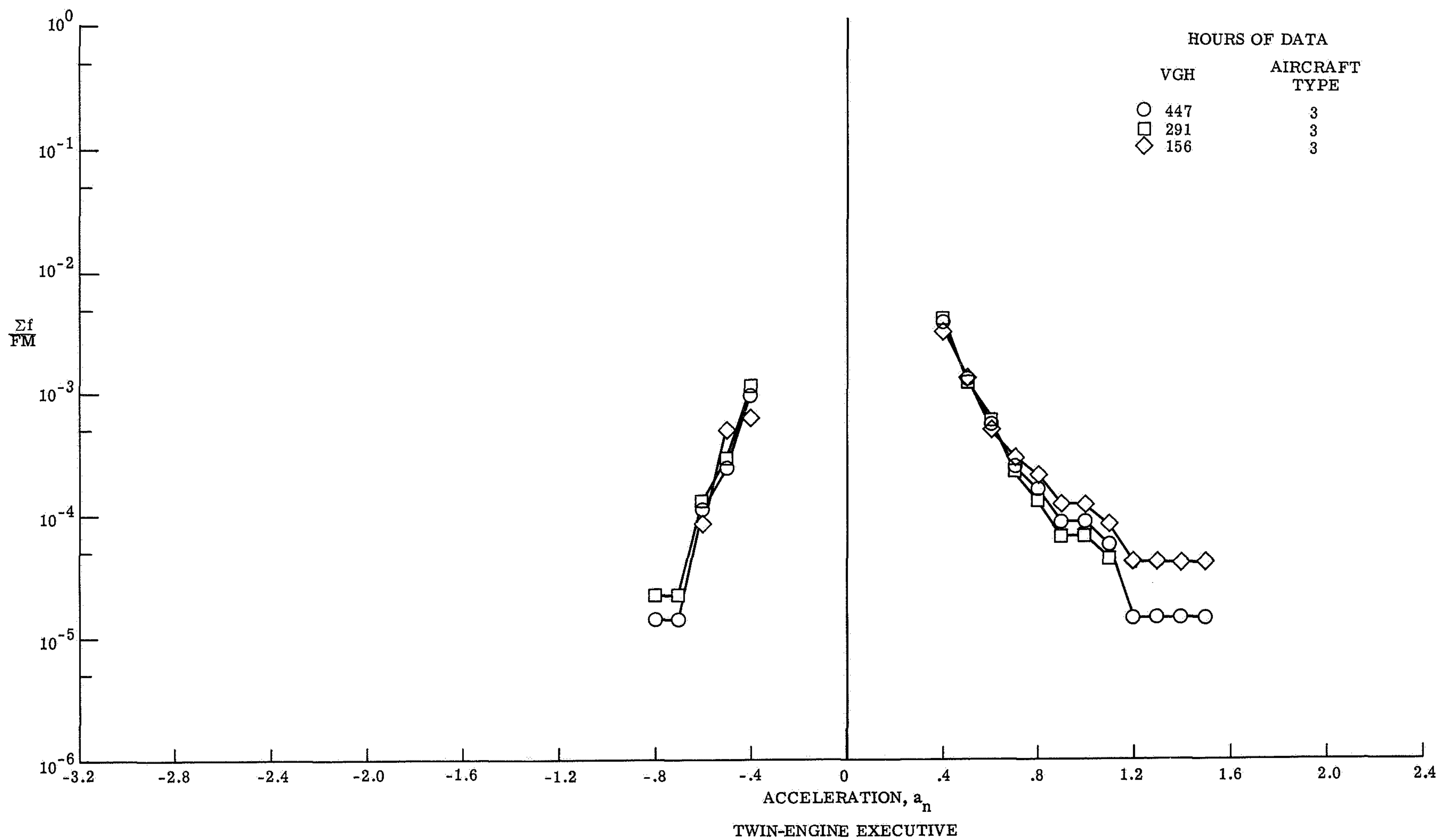
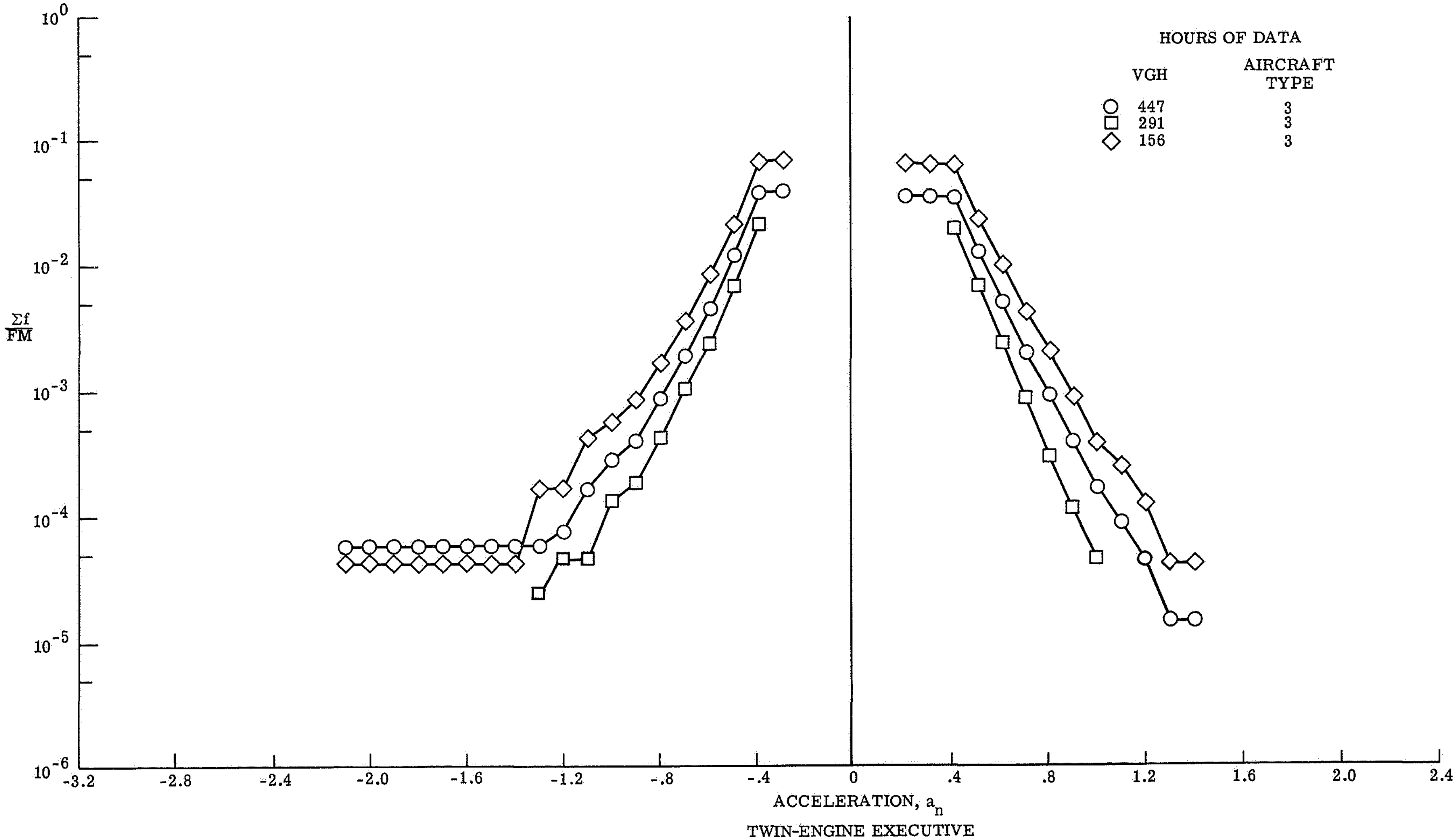


Figure 15.- Probability of equaling or exceeding various landing impact accelerations for aircraft in five types of operations. VGH data.



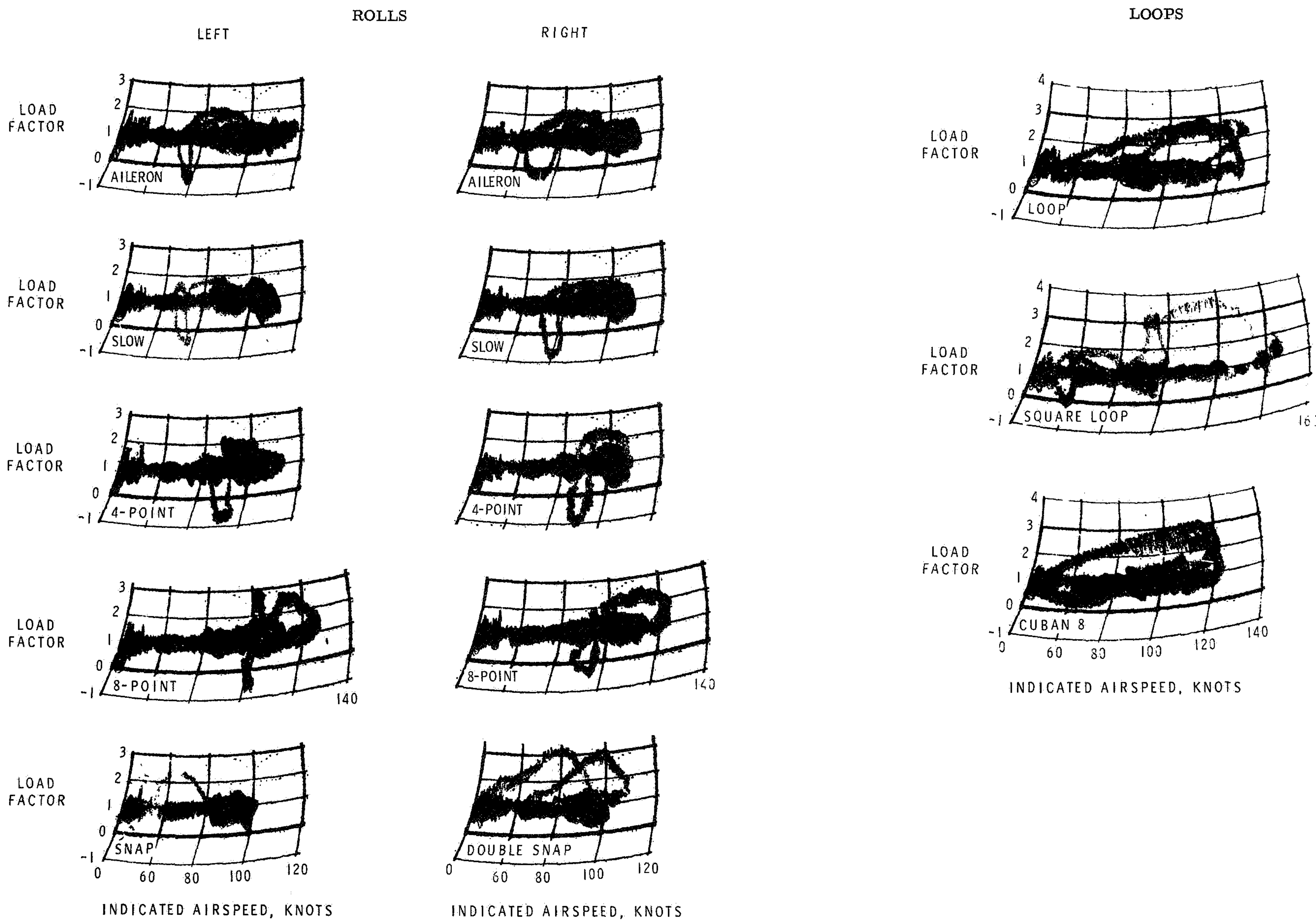
(a) Maneuver accelerations.

Figure 16.- Effect of sample size on acceleration distributions per flight mile. VGH data.



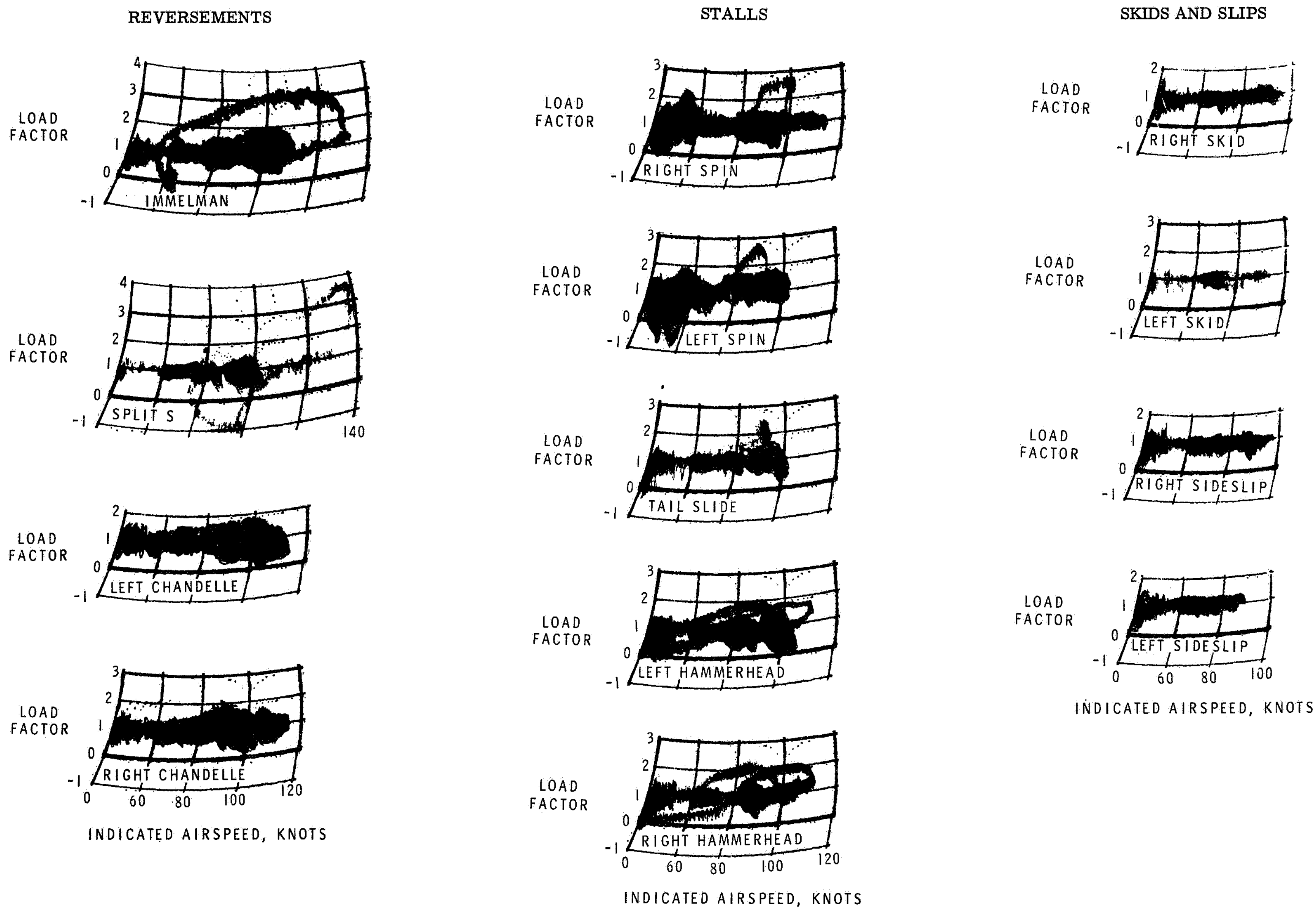
(b) Gust accelerations.

Figure 16.- Concluded.



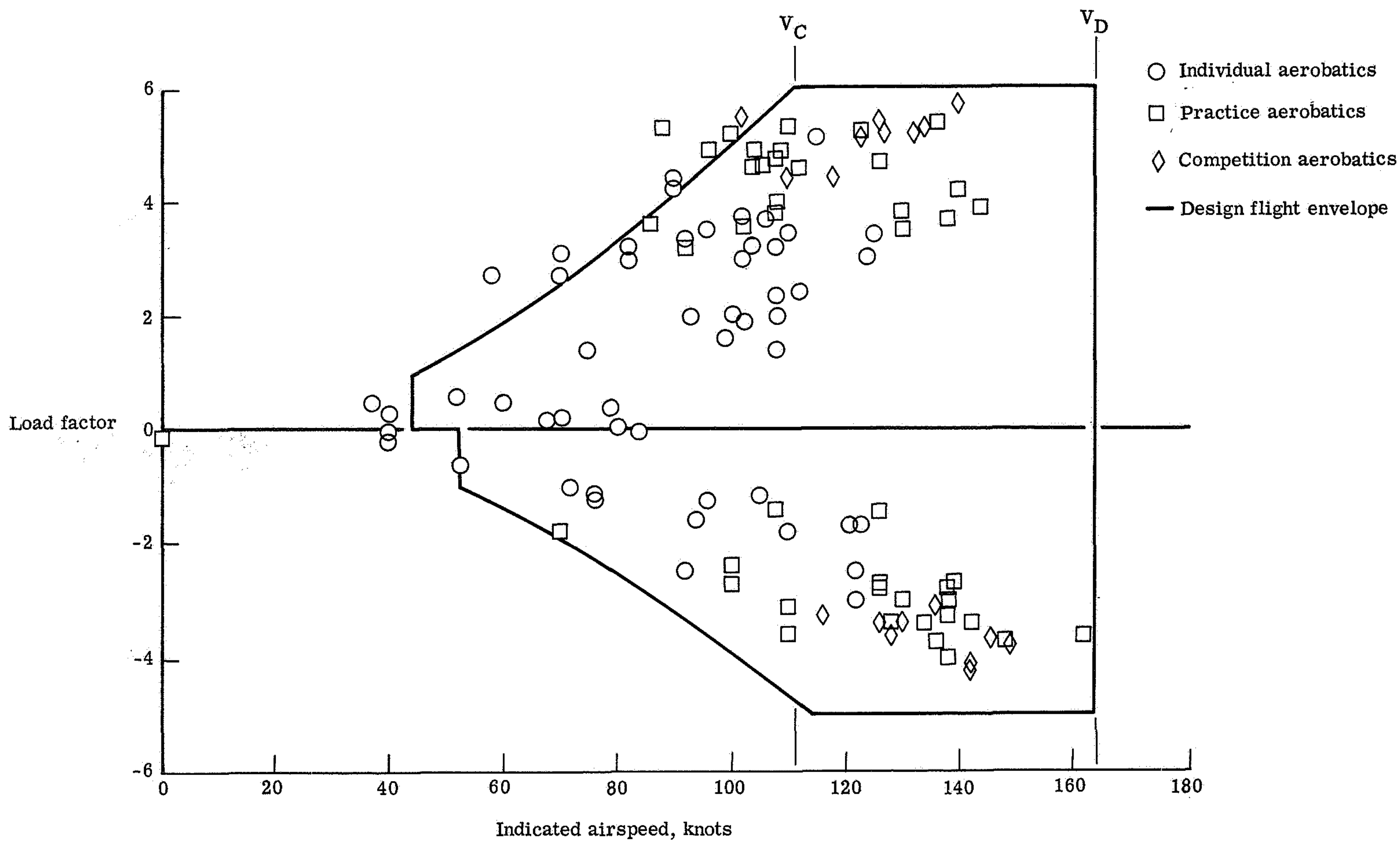
(a) VG data.

Figure 17.- Load factors experienced during various aerobatics.



(b) VG data.

Figure 17.- Continued.



(c) VGH data.

Figure 17.- Concluded.

NASA-Langley, 1968