https://ntrs.nasa.gov/search.jsp?R=19750002861 2020-03-23T03:38:06+00:00Z

NASA CR-132531

(NASA-CR-132531) STATISTICAL ANALYSIS OF GENERAL AVIATION VG-VGH DATA (Technology, Inc.) 134 p HC $5.75 CSCL 01C

N75-10933

Unclas
G3/05 02364

STATISTICAL ANALYSIS OF GENERAL AVIATION VG-VGH DATA

Larry E. Clay
Raymond L. Dickey
Martin S. Moran
Kenneth W. Payauys
Thomas P. Severyn

Prepared under Contract No. NAS1-12389 by

TECHNOLOGY INCORPORATED
Instruments and Controls Division
P. O. Box 3036, Overlook Branch
Dayton, Ohio 45431

DEC 1974
RECEIVED
NASA STI FACILITY
INPUT BRANCH

for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA CR-132531

STATISTICAL ANALYSIS OF GENERAL AVIATION VG-VGH DATA

Larry E. Clay
Raymond L. Dickey
Martin S. Moran
Kenneth W. Payauys
Thomas P. Severyn

FOREWORD

This report, prepared by Technology Incorporated, Dayton, Ohio, documents the statistical analysis of general aviation VG-VGH data. All data contained herein were collected from general aviation aircraft operations over the past 10 years.

The NASA Langley Research Center was the procuring agency for this program under NASA Contract No. NAS1-12389. The Technical Representative for NASA was Mr. Joseph W. Jewel, Jr.

For Technology Incorporated, the principal personnel active in this program were as follows: Kenneth W. Payauys succeeded by Raymond L. Dickey, Project Engineer; Larry E. Clay, Senior Research Engineer; Martin S. Moran, Research Engineer; Thomas P. Severyn, Jr. Research Engineer; Ruth E. Meyers, Data Processing Specialist; James E. Kirchmer, Data Processing Specialist.

The contents of this report reflect the views of the authors who are responsible for the accuracy of the analysis presented herein. The contents do not necessarily reflect the official views or policies of the NASA Langley Research Center. This report does not constitute a standard, specification, or regulation.

ABSTRACT

In support of a NASA program to represent the loads spectra of general aviation aircraft operating in the Continental United States, VG and VGH data collected since 1963 in eight operational categories [(1) twin-engine executive, (2) single-engine executive, (3) personal, (4) instructional, (5) commercial survey, (6) aerial application, (7) commuter, and (8) aerobatic] were processed and analyzed to determine or prepare the following: (a) adequacy of data sample and current operational categories, (b) parameter distributions required for valid data extrapolation, (c) envelopes of equal probability of exceeding the normal load factor (n_z) versus airspeed for gust and maneuver loads, (d) probability of exceeding current design maneuver, gust, and landing impact n_z limits, (e) fatigue spectra for gust, maneuver, and landing impact n_z loads, and (f) relationship between design and operational airspeeds. Significant findings included the following: (1) the data distributions were mostly log-normal, the rest being normal; (2) the Instructional and Commercial Survey categories had the highest probability of exceeding the design n_z limits for maneuver and gust, respectively; (3) while the Aerial Application and Instructional categories required only 860 and 3393 landings, respectively, to experience landing impacts of 1.67 Δn_z, the other categories required more than 19,000 landings to reach this level; (4) of the 24 aircraft types, 17 had airspeeds above the cruise velocity (V_C), but none had airspeeds above the dive velocity (V_D); the Personal category had the highest probability of exceeding V_C; the Instructional and Commercial Survey categories had the highest V/V_C ratios (approximately 1.2); and the Twin-Engine Executive category had the highest V/V_D ratio (approximately 0.925); and (5) each of the eight operational categories had a distinct load spectrum which reflected the operational characteristics of the category definition, and the various aircraft types within each operational category generally had loads which conformed closely with the average spectrum.

TABLE OF CONTENTS

PRECEDING PAGE BLANK NOT FILMED

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS - Continued

LIST OF ILLUSTRATIONS - Concluded

LIST OF TABLES

1. INTRODUCTION

1.1 Background of General Aviation VG/VGH Program

In 1963 NASA initiated a program to collect an operational data sample representative of the United States general aviation fleet. The following eight operational categories were defined to collectively represent general-aviation-aircraft usage: (1) twin-engine executive, (2) single-engine executive, (3) personal, (4) instructional, (5) commercial survey, (6) aerial application, (7) commuter, and (8) aerobatic. Reference 1 lists typical missions in these categories as follows:

Twin- and single-engine executive:

Charter flights - cargo and personnel.

Business flights - company and individual.

Instrument check flights - training for instrument card.

Instructional flights - check-out for larger aircraft.

Personal:

Flying club owned - aircraft flown by club with 3 to 21 members: used for pleasure, instruction, or business flights.

Individually owned - 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 flights - all instrumented airplanes owned by flying schools; used as basic trainers for private license; also used by student after solo for cross-country flight.

Commercial survey:

Pipeline-patrol flights - patrols flown from 76 to 91 meters (250 to 300 feet) above terrain to check for leaks or breaks in the pipeline.

Forest-patrol flights - patrols flown 457 meters (1500 feet) above terrain for fire detection. When fire is spotted, descents are made to 61 to 91 meters (200 to 300 feet) to check condition of terrain around the fire.

Pathfinder flights - flies to fire perimeter and marks drop area. Descents are made to 15 to 46 meters (50 to 150 feet) above terrain to insure turbulence is not too severe for chemical bomber during dropping run. Chemical bomber drops are observed, and effects on fire are noted.

Fish-spotting flights - patrols flown 457 to 610 meters (1500 to 2000 feet) above water. Occasional descents are made to 91 to 152 meters (300 to 500 feet).

Aerobatic:

Noncompetitive flights - aircraft flown by amateurs. Occasional aerobatics are performed, usually as individual maneuvers.

Competitive flights - aircraft flown in airshows, in national and international aerobatic competition, and in practice sessions. Obligatory maneuvers, one immediately after another, are performed in a restricted cube of air.

Aerial application:

Crop dusting and/or spraying flights - aircraft flown at heights ranging from 0.9 to 5.5 meters (3 to 18 feet) above crops. Spreading runs are characterized by sharp pushover at start and hard pull-up at end of spreading runs.

Commuter:

Operational flights - normally scheduled passenger carrying operations.

Crew flights - crew training, or flights on which structural or mechanical tests are made on the aircraft.

These operational categories do not generally correspond to the Reference 2 aircraft categories (normal, utility, acrobatic) because, except for the aerobatic and aerial application operational categories, the operators select aircraft on the basis of performance and/or cost instead of design maneuver capability.

The analysis will examine about 12,000 hours of VGH and 70,000 hours of VG data. To obtain the data sample, three types of aircraft were generally selected as representative of each operational category. The type of operation, the number of basic types of aircraft, the number of aircraft, and the hours of data used in the analysis are listed in

Table I. The basic VG-VGH data were collected from aircraft selected nationwide to avoid a geographical bias. All instrumented aircraft were owned by individuals or companies who participated on a voluntary basis. The data collection objective for each instrumented aircraft was 1000 hours of in-flight data during each of the four calendar quarters.

TABLE I. SUMMARY OF RECORDED DATA

Operational Category	Type of Data	No. of Aircraft Types	No. of Aircraft	Hours of Data
Twin-engine executive	VG	3	18	14,722
	VGH	5	9	3,377
Single-engine executive	VG	3	15	8,430
	VGH	3	8	1,366
Personal	VG	3	15	5,456
	VGH	3	2	724
Instructional	VG	4	17	10,357
	VGH	5	6	2,843
Commercial survey	VG	2	14	26,089
	VGH	4	4	2,291
Aerial application	VG	3	7	1,857
	VGH	2	2	484
Commuter	VG	3	5	4,000
	VGH	2	2	1,510
Aerobatic	VG	3	5	382
	VGH	0	0	0

Two types of NASA recorders, the VGH and the VG recorder, were used to collect the data. The VGH recorder is an oscillograph which records a time history of indicated airspeed, pressure altitude, and c.g. normal acceleration at a rate of approximately one minute of elapsed time per 1.27 cm (0.5 inch) along a 70-mm-wide film. The VG recorder records an envelope of maximum c.g. normal accelerations and their corresponding airspeeds for the period of operation (a one-flight duration to several hundred hours) while the recording medium is installed. References 3 and 4 detail the VG and VGH recorders, respectively.

The VGH oscillograph data was reduced to digital samples of indicated airspeed and pressure altitude at one-minute intervals during the recorded flights and digital samples of c.g. normal acceleration, indicated airspeed, and pressure altitude at each acceleration peak and trough outside the prescribed thresholds ($\pm$0.4g for general aviation aircraft and $\pm$0.2g for airline aircraft). The VG data was reduced to the maximum and minimum c.g. normal acceleration in each 10-knot indicated airspeed interval, the maximum indicated airspeed attained, and the number of flight hours during the period that each recording slide was installed.

Table II summarizes the pertinent data for the instrumented aircraft. With a breakdown by aircraft operational category, this table lists the type and number of installations, the amount of recorded data, and the pertinent aircraft configuration and operational characteristics.

TABLE II. CHARACTERISTICS OF INSTRUMENTED AIRCRAFT

VG hr: 14,722, VGH hr: 3,377

	Twin-engine executive type								
	1	2	3	4	5A	5B	5C	6	5D
V-G installations	0	0	0	8	4	3	1	1	1
V-G hours	0	0	0	7191	3035	2730	145	486	1135
VGH installations	4	1	2	1	1	0	0	0	0
VGH hours	824	693	357	350	1153	0	0	0	0
Maximum gross weight									
kN	117.7	55.6	40.0	21.4	21.5	22.7	22.2	30.2	23.1
lb	26 455	12 500	9000	4800	4830	5100	4990	6800	5200
Wing span:									
m	16.3	11.5	14.0	11.3	11.0	11.2	11.2	12.1	11.2
ft	53.5	37.6	45.9	37.0	36.0	36.9	36.9	39.8	36.9
Wing area:									
m^2	41.0	21.5	26.0	19.2	16.3	16.3	16.3	18.6	16.3
ft^2	441	231.8	279.7	207	175	175	175	200	175
Type propulsion	Turbojet	Turbojet	Turboprop	Piston	Piston	Piston	Piston	Piston	Piston
V_C at sea level, knots	368	350	208	172	182	182	182	200	182
V_{NE} at sea level, knots	[a]437	[a]258	234	216	215	223	219	236	219
V_D at sea level, knots	465	400	260	240	239	248	243	262	24[illegible]
Δn_m at V_C	3.50	3.40	2.70	2.80	2.80	2.80	2.80	2.60	2.80
$-\Delta n_m$ at V_C	2.00	2.76	2.68	2.52	2.52	2.52	2.52	2.44	2.52
Δn_g at V_C	3.40	2.44	2.10	2.10	1.97	1.84	1.91	1.93	2.35

[a]Maximum operating speed

VG hr: 8430, VGH hr: 1366

	Single-engine executive type												
	7A	7B	8A	8B	8C	8D	8E	8G	8F	9A	9B	9C	9D
V-G installations	2	1	0	2	1	2	1	0	1	1	2	0	2
V-G hours	1160	137	0	898	23	1392	277	0	1202	785	1170	0	1386
VGH installations	2	0	1	0	0	0	1	1	1	1	0	1	0
VGH hours	237	0	149	0	0	0	229	16	175	424	0	136	0
Maximum gross weight													
kN	12.9	12.9	11.8	12.3	12.3	13.1	13.9	14.7	15.1	11.3	11.8	11.8	12.5
lb	2900	2900	2650	2775	2775	2950	3125	3300	3400	2550	2800	2650	2800
Wing span:													
m	11.0	11.0	10.0	10.0	10.0	10.0	10.2	10.2	10.2	11.0	11.0	11.0	11.0
ft	36.0	36.0	32.8	32.8	32.8	32.8	33.5	33.5	33.5	36.0	36.0	36.0	36.2
Wing area.													
m^2	16.5	16.5	16.5	16.5	16.5	16.5	16.8	16.8	16.8	16.2	16.2	16.2	16.2
ft^2	178	178	177.6	177.6	177.6	177.6	181	181	181	174	174	174	174
Type propulsion	Piston	Piston	Piston	Piston	Piston	Piston	Piston	Piston	Piston	Piston	Piston	Piston	Piston
V_C at sea level, knots	156	156	139	152	152	174	161	165	165	139	139	139	139
V_{NE} at sea level, knots	197	197	175	175	182	195	195	195	195	160	167	162	167
V_D at sea level, knots	219	219	217	217	201	217	217	217	217	177	186	180	186
Δn_m at V_C	2.80	2.80	3.40	3.40	3.40	3.40	3.40	3.40	3.40	2.80	2.80	2.80	2.80
$-\Delta n_m$ at V_C	2.57	2.52	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.52	2.52	2.52	2.52
Δn_g at V_C	2.55	2.45	2.40	2.58	2.88	2.75	2.43	2.35	2.37	2.50	2.33	2.33	2.50

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

TABLE II. - Concluded

VG hr: 5476, VGH hr: 724 VG hr: 10,357, VGH hr: 2,843

	Personal type					Instructional type						
	10A	10B	11	12A	12B	13	14	15	16A	16B	16C	17
V-G installations	1	2	3	1	6	4	6	2	1	1	3	[illegible]
V-G hours	608	988	1202	98	2560	862	3751	844	1246	1173	2481	[illegible]
VGH installations	1	0	1	0	4	2	1	1	1	0	0	1
VGH hours	209	0	276	0	231	1008	494	311	811	0	0	219
Maximum gross weight:												
kN	9.8	10.2	11.5	9.8	10.7	6.7	7.3	8.7	6.7	7.1	[illegible]	[illegible]
lb	2200	2300	2575	2200	2400	1500	1650	1950	1500	1600	1700	2250
Wing span												
m	11.0	11.0	10.7	9.1	9.1	10.7	9.1	9.1	10.2	10.2	10.0	10.7
ft	36.0	36.2	35.0	30.0	30.0	35.2	30.0	30.0	33.4	33.6	32.7	35.0
Wing area												
m^2	16.2	16.2	15.5	14.9	14.9	15.8	13.7	14.9	14.9	14.9	14.6	16.8
ft^2	174	174	167	160	160	170	147	160	160	160	157	181
Type propulsion	Piston	Piston	Piston	Piston	Piston	Piston	Piston	Piston	Piston	Piston	Piston	Piston
V_C at sea level, knots	122	126	130	122	122	87	96	12[illegible]	104	104	104	117
V_{NE} at sea level, knots	148	158	164	148	148	117	129	149	137	141	151	147
V_D at sea level, knots	165	175	182	165	165	130	143	164	152	156	156	164
Δn_m at V_C	2.80	2.80	2.80	2.80	2.80	3.52	3.40	2.80	3.40	3.40	3.40	2.60
$-\Delta n_m$ at V_C	2.52	2.52	2.52	2.52	2.52	2.20	2.76	2.52	2.76	2.76	2.76	2.52
Δn_g at V_C	2.40	2.77	2.42	2.30	2.30	2.38	2.00	2.30	2.59	2.46	2.40	2.46

VG hr: 26,089, VGH hr: 2,291

	Commercial survey type							
	9A	9B	9D	16A	16C	18	19	49
V-G installations	6	0	1	6	1	0	0	0
V-G hours	1006	0	3014	19 950	2119	0	0	0
VGH installations	0	1	0	1	0	0	1	1
VGH hours	0	670	0	1303	0	0	95	223
Maximum gross weight:								
kN	11.3	12.5	12.5	6.7	7.1	6.7	13.1	311.4
lb	2550	2800	2800	1500	1600	1500	2950	70 000
Wing span:								
m	11.0	11.0	11.0	10.2	10.0	10.7	10.0	30.9
ft	36.0	36.0	36.2	33.33	32.7	35.2	32.8	101.3
Wing area								
m^2	16.2	16.2	16.2	14.9	14.6	16.6	16.5	92.9
ft^2	174	174	174	160	157	178.5	177.6	1000.0
Type propulsion	Piston	Piston	Piston	Piston	Piston	Piston	Piston	Piston
V_C at sea level, knots	139	139	139	104	104	96	152	182
V_{NE} at sea level, knots	160	167	167	137	141	129	219	
V_D at sea level, knots	177	186	186	152	156	143	243	312
Δn_m at V_C	2.80	2.80	2.80	3.40	3.40	3.40	5.00	
$-\Delta n_m$ at V_C	2.52	2.52	2.52	2.76	2.76	2.76	4.00	
Δn_g at V_C	2.50	2.33	2.50	2.59	2.40	2.52	2.26	

VG hr: 382 VGH hr: 0 | VG hr: 1857 VGH hr: 484 | VG hr: 4060 VGH hr: 1510

	Aerobatic type				Aerial application type			Commuter type		
	20	21	21A	22	23	24	25	26	27	28
V-G installations	1	2	1	1	2	3	2	2	2	1
V-G hours	50	164	141	27	690	813	354	787	2068	1205
VGH installations	0	0	0	0	1	1	0	1	0	1
VGH hours	0	0	0	0	309	175	0	915	0	595
Maximum gross weight:										
kN	7.3	8.9	8.9	5.1	26.7	12.9	20.0	51.6	37.8	46.3
lb	1650	2000	2000	1150	6000	2900	4500	11 600	8500	10 400
Wing span										
m	9.8	9.5	9.5	Upper, 5.3 Lower, 5.2	13.5	11.0	Upper, 10.9 Lower, 10.4	19.8	15.3	14.0
ft	32.0	31.3	31.3	Upper, 17.3 Lower, 16.9	44.3	36.2	Upper, 35.7 Lower, 34.0	65	50.3	45.9
Wing area:										
m^2	15.7	16.0	16.0	Upper, 4.6 Lower, 4.5	30.3	17.0	Upper, 15.6 Lower, 14.9	39.0	27.3	26.0
ft^2	169	172	172	Upper, 50.0 Lower, 48.4	326.6	183.0	Upper, 168.0 Lower, 160.0	420	293.9	279.7
Type propulsion	Piston	Piston	Piston	Piston	Piston	Piston	Piston	Turboprop	Piston	Turboprop
V_C at sea level, knots	114	109	109	126	117	108	87	164	178	226
V_{NE} at sea level, knots	226	174	174	176	148	135	128	202	234	226
V_D at sea level, knots	251	200	200	195	164	151	142	225	260	282
Δn_m at V_C	5.00	5.00	5.00	5.00	2.80	2.80	3.20	2.21	2.70	2.29
$-\Delta n_m$ at V_C	6.00	4.00	4.00	4.00	2.90	2.52	2.00	2.50	2.60	2.31
Δn_g at V_C	3.10	------	------	3.07	1.78	1.83	1.85	2.35	1.95	1.95

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

1.2 Program Objective

The program objective was to provide the following:

1) A check on the adequacy of the sample size for statistical analysis.

2) The statistical distributions of the parameters required for extrapolation.

3) Envelopes of equal probability of exceeding n_z versus airspeed for gust and maneuver loads.

4) The probability of exceeding current design maneuver and gust limit loads for the aircraft categories, namely, normal, utility, and acrobatic.

5) A review of the adequacy of design categories to account for operational experiences.

6) Fatigue spectra for gust, maneuver, and landing impact loads.

7) The probability of exceeding the design landing gear load factor.

8) Airspeed practices in relation to design airspeeds.

9) Recommendations for future data collection and presentation.

2. RESULTS AND DISCUSSION

2.1 Recorded Data Sample Size

Table I lists the number of hours of VG and VGH data, the number of aircraft types, and the number of instrumented aircraft in each operational category.

The number of recorded VGH hours and VG records in each operation is a significant parameter in estimating the design probabilities. The minimum required sample size for the VG and VGH data was established by constructing a two-way contingency table and applying the chi-squared goodness-of-fit test. Accordingly, the minimum sample sizes for the VG and VGH data were found to be 125 records and 150 hours, respectively. Therefore, the sample size for the Aerobatic category in both the VG and VGH data was inadequate, and the sample sizes for the Aerial Application and Commuter categories in the VG data were inadequate. However, all the VGH data for the Commuter category were recorded on only two instrumented aircraft which is not sufficiently representative of commuter-type aircraft.

In practice it is often assumed that an observed variate conforms to some particular distribution. It is then desirable to determine the size of data sample required to adequately describe the distribution of the parent population. One widely used technique is to test the independence of two randomly chosen data samples by the construction of a two-way contingency table. If the probability of occurrence of a particular value of the variate is independent of the random sample that it is taken from, then the random sample distribution is assumed to adequately describe the parent distribution.

Suppose that n individuals or items are classified according to two criteria A and B, that there are r classifications $A_1, A_2, \ldots, A_r$ in A and s classifications $B_1, B_2, \ldots, B_s$ in B, and that the number of individuals belonging to A_i and B_j is N_{ij}. We have then a r x s contingency table with cell frequencies N_{ij} and $\Sigma N_{ij} = n$:

	B_1	B_2	B_3	...	B_s
A_1	N_{11}	N_{12}	N_{13}	...	N_{1s}
A_2	N_{21}	N_{22}	N_{23}	...	N_{2s}
A_3	N_{31}	N_{32}	N_{33}	...	N_{3s}
.					
.					
A_r	N_{r1}	N_{r2}	N_{r3}	...	N_{rs}

As a further notation we shall denote the row totals by N_i and the column totals by N_j; that is,

$$N_i = \sum_j N_{ij} \quad \text{and} \quad N_j = \sum_i N_{ij}$$

Of course,

$$\sum_i N_i = \sum_j N_j = n$$

The n individuals will be regarded as a sample of size n from a multinominal population with probabilities p_{ij} ($i=1, 2, \ldots, r$; $j=1,2, \ldots, s$). Let the null hypothesis, H_0, be that the A and B classifications are independent, i.e., that the probability that an individual falls in B_j is not affected by the A class in which the individual belongs. When the null hypothesis is not true, there is said to be an interaction between the two classification criteria. Two statistical events A_i and B_j are said to be independent if

$$P\{A_i \cap B_j\} = P\{A_i\}\ P\{B_j\}$$

Thus the null hvpothesis is

$$H_o : p_{ij} = p_i p_j$$

where $\Sigma\ p_i = 1\ ;\ \Sigma\ p_j = 1$

Now construct the statistic

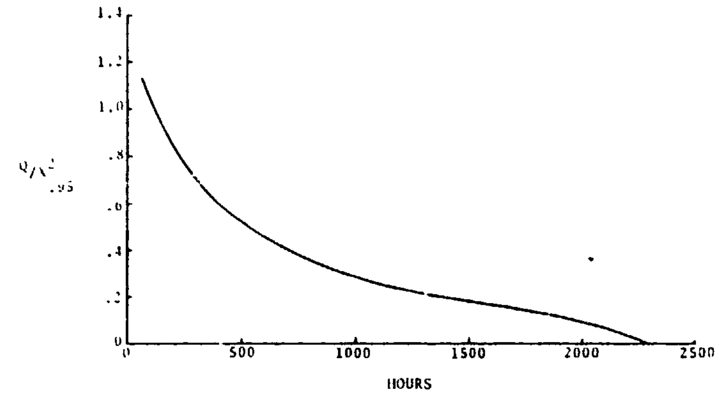
$$Q = \sum_{i,j} \frac{[N_{ij} - n(N_i/n)(N_j/n)]^2}{n(N_i/n)(N_j/n)}$$

where $N_{ij} - n(N_i/n)(N_j/n)$ is the difference between the actual number of occurrences of a particular value of the variate N_{ij} and the predicted number if H_o is true. Of course,

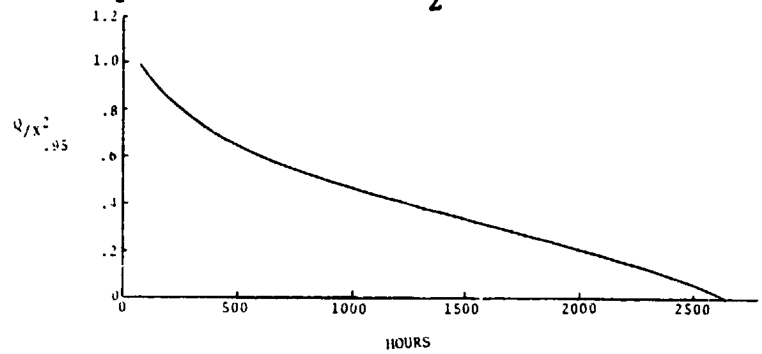
$$N_i/n = p_i\ ;\ N_j/n = p_j$$

It can then be shown that the statistic Q has approximately the chi-square distribution with (r-1)(s-1) degrees of freedom. The test criterion is to reject H_o for large Q. Thus, Q will tend to be small for H_o true and large for H_o false. The value of the chi-squared statistic Q is then compared with the critical value with (r-1)(s-1) degrees of freedom and the desired significance level.

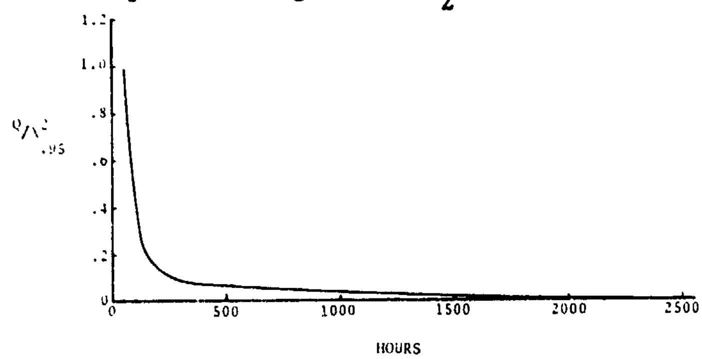
Contingency tables were constructed and the chi-squared goodness-of-fit test was applied in the VGH sample size investigation. Figures 1(a) through 1(d) present the results. The point at which the ratio of Q to $X^2_{.95}$ exceeds 1.0 is the point at which the data sample distribution no longer adequately describes the parent distribution. Positive and negative maneuver and gust accelerations were investigated. The positive maneuver sample exhibited the largest amount of VGH hours required for an adequate sample size. The same test was applied to the VG data. The results are shown in Figure 2.



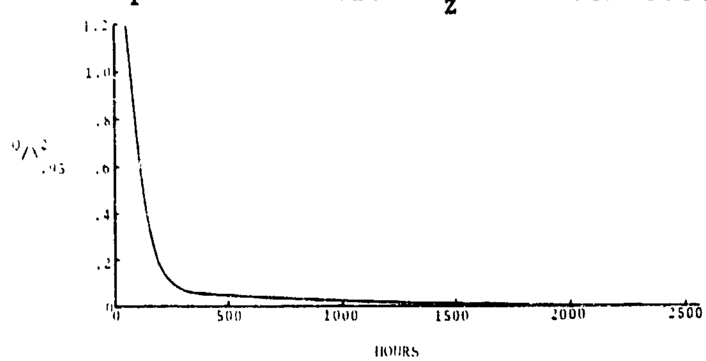
a. Composite Positive n_z's in VGH Maneuvers



b. Composite Negative n_z's in VGH Maneuvers



c. Composite Positive n_z's in VGH Gusts



d. Composite Negative n_z's in VGH Gusts

Figure 1. Plot of Hours vs. Sample Size Index for Composite VGH Positive and Negative Maneuver and Gust n_z's

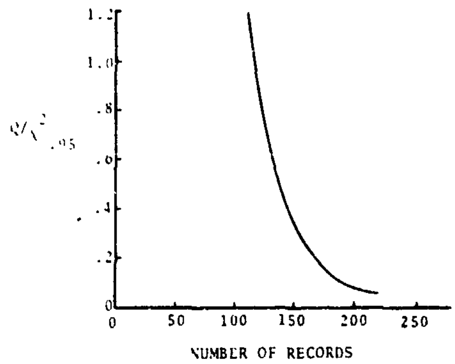


Figure 2. Plot of Records vs. Sample Size Index for Composite VG n_z's

2.2 Observed Statistical Distributions

In extrapolating the load factor distributions to determine the probabilities of exceeding the design limits, it was necessary to fit a distributional form to the recorded data. Three standard distributions, normal, log-normal, and exponential (a special case of the Weibull distribution), were considered. A widely used procedure to establish the data distribution is the chi-square test. However, since this method requires a great deal of data, its application is limited. An alternative method is to plot the data on various types of probability paper (normal, log-normal, and Weibull). Then the plot which most closely approximates a straight line indicates the distribution type and consequently the corresponding paper type best suited to display the data. Figures 3 through 5 are samples of plots on each paper type. Since, as apparent, the plot on the log-normal paper most closely approximates a straight line and therefore best represents the data distribution, the data for each airspeed level in each of the operational categories were plotted on log-normal paper. Most of the recorded data conformed to the log-normal distribution, with the rest of the data resembling a normal distribution. None of the recorded data resembled an exponential distribution.

Except in a few flights where the instrumented aircraft within an operational category flew obviously different missions or where a single instrumented aircraft flew two distinct missions, there was no evidence to indicate that a load factor frequency distribution contained two or more sets of unrelated events. Flights where the instrumented aircraft within an operational category flew different missions were evident in the Commercial Survey and Aerial Application VGH data presented in Table IV (extreme values per flight). The distribution for aircraft type 23 in the Aerial Application category in Table IV also shows a dip at a Δn_z value of +0.7g. Those flights with maximum accelerations below a Δn_z of +0.8g were mostly cross-country flights and not the aircraft's primary crop-dusting mission which generally had maximum Δn_z values above +1.0g.

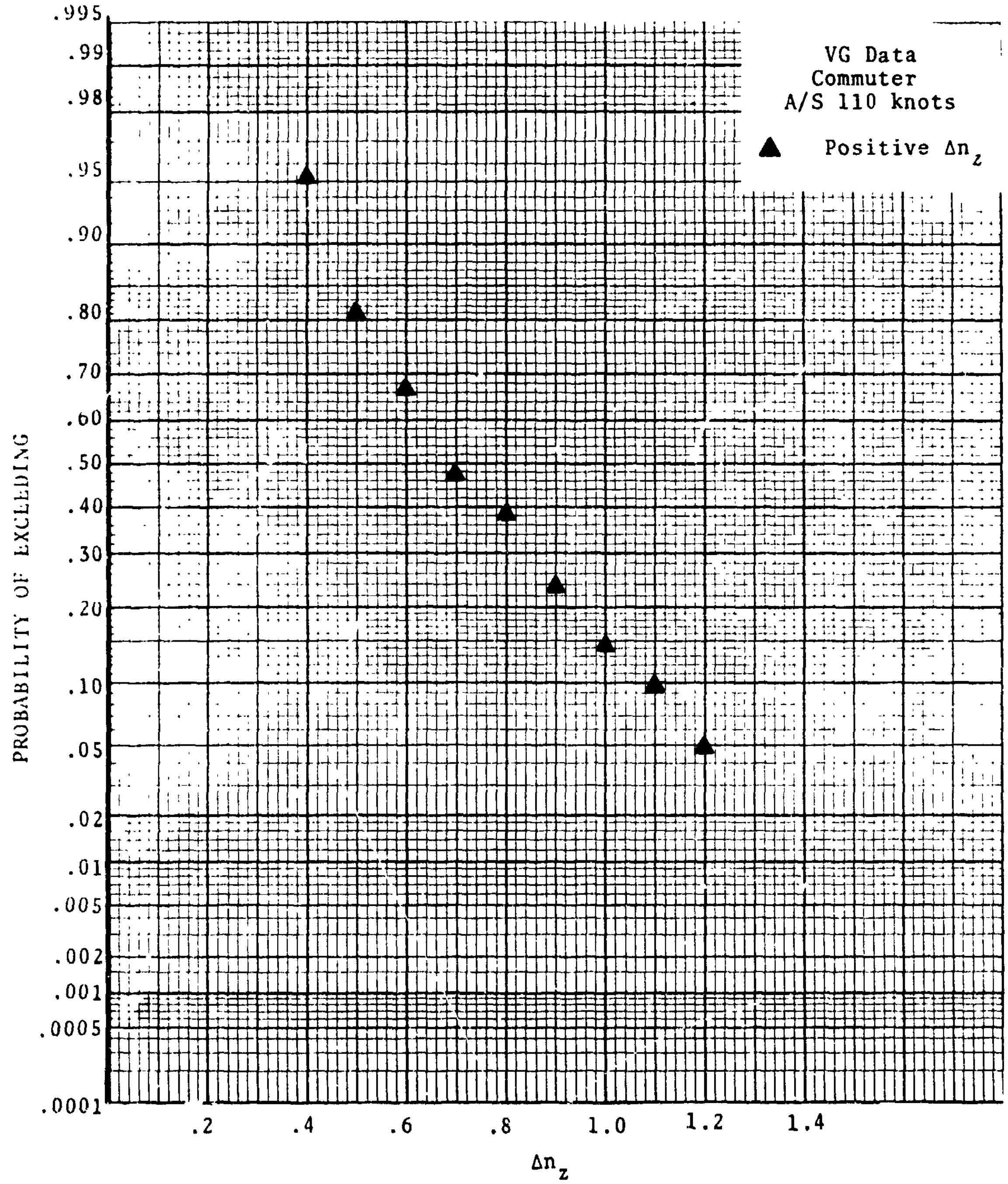


Figure 3. Sample of VG n_z Data Plotted as a Normal Distribution

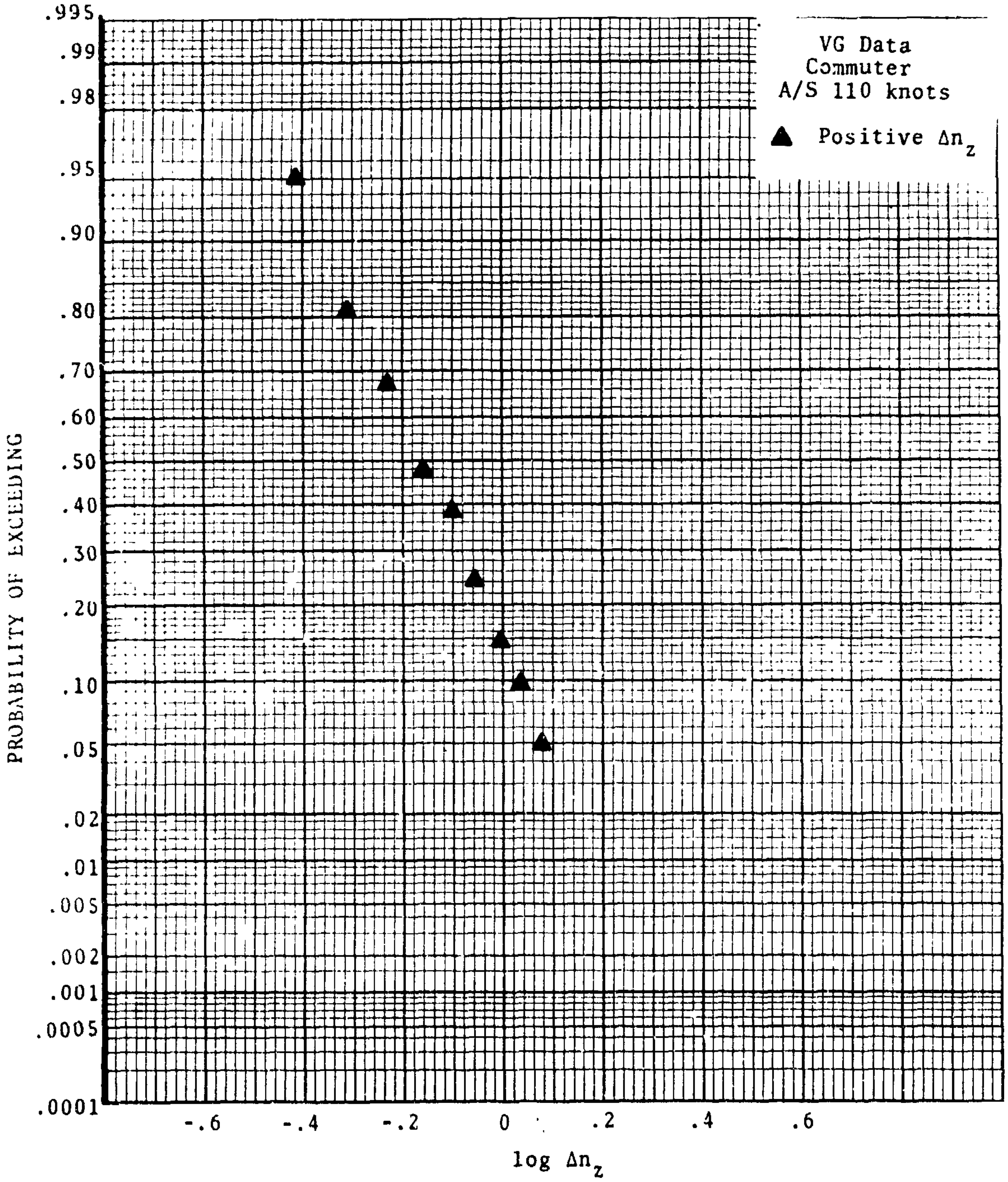


Figure 4. Sample of VG n_z Data Plotted as a Log-Normal Distribution

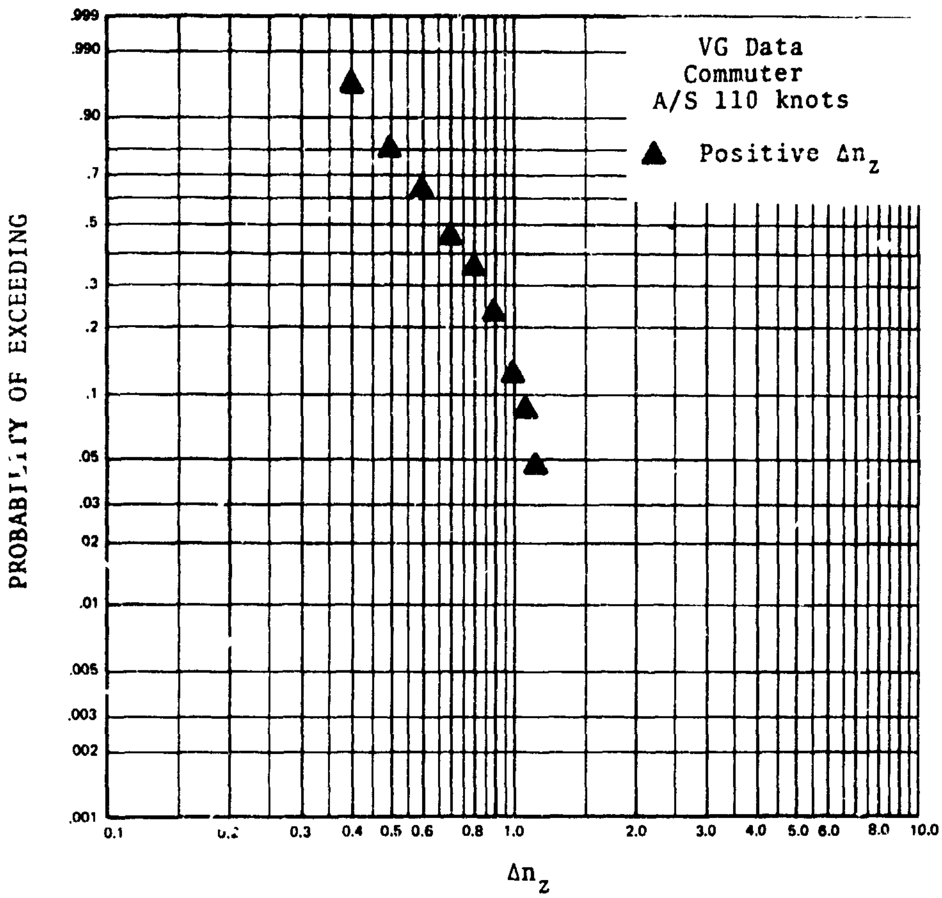


Figure 5. Sample of VG n_z Data Plotted as an Exponential Distribution

2.3 V-N Probability Distributions

Three V-N constant probability envelopes were constructed for each operational category from the VG data. The three envelopes represent 50%, 90%, and 95% probability levels and are based on an expected service life of 20,000 flight hours. This means that an aircraft flying 20,000 hours in a given operational category has a constant probability of not exceeding the Δn_z-airspeed combinations which define the envelope boundary. The three envelopes can also be interpreted as a 50%, 10%, or 5% probability that an aircraft will exceed the envelope boundary at least once during 20,000 flight hours. To construct the V-N envelopes for each operational category required first plotting the log of the Δn_z occurrences for each airspeed range on log-normal probability paper (see Figure 6). (In all tables and text discussions, the parameters are generally denoted by single values which represent the lower limits of the respective parameter ranges.) These "probability-of-exceeding-Δn_z" curves yield a linear relationship between the log Δn_z values and the probability of a single Δn_z occurrence exceeding a Δn_z value. From these plots, and by considering each Δn_z occurrence as a single statistical trial, it is possible to determine the probability of a single trial exceeding any Δn_z value. Dividing the total number of flight hours by the total number of Δn_z occurrences at a given airspeed in a particular operational category gives the expression for a statistical trial in terms of flight hours. With a single trial expressed in flight hours, the number of statistical trials occurring at each airspeed in 20,000 flight hours for a particular operational category can be calculated. It is assumed that the statistical trials (Δn_z occurrences expressed in flight hours) for the 20,000 flight hours satisfy the requirements for Bernoulli trials. That is, each trial has but two possible outcomes. Either the trial exceeds a particular Δn_z value or it does not. Second, each trial is independent of all other trials. Finally, the probability of exceeding a particular Δn_z value is constant from trial to trial. With the above assumption, the Δn_z values for the constant probability envelopes may be calculated as follows:

$$\{P(NE)\}^n = P_E$$

$$P(NE) = \{P_E\}^{1/n}$$

$$P(E) = 1 - P(NE)$$

where P(NE) = probability of not exceeding a particular Δn_z value in a single trial

P(E) = probability of exceeding a particular Δn_z value in a single trial

P_E = constant probability envelope value (0.5, 0.9, 0.95)

n = number of trials at a given airspeed in 20,000 flight hours for a particular operational category

$\{P(NE)\}^n$ = probability of not exceeding a particular Δn_z value during n consecutive trials

Once P(E) is calculated at a given P_E value for a particular operational category and airspeed, the corresponding probability-of-exceeding-n_z curve can be used to determine the Δn_z value. These Δn_z values are plotted versus airspeed for each operational category to form the three constant probability envelopes.

In the construction of these envelopes, the VG, rather than the VGH, data were used since the VG data provided the larger data sample.

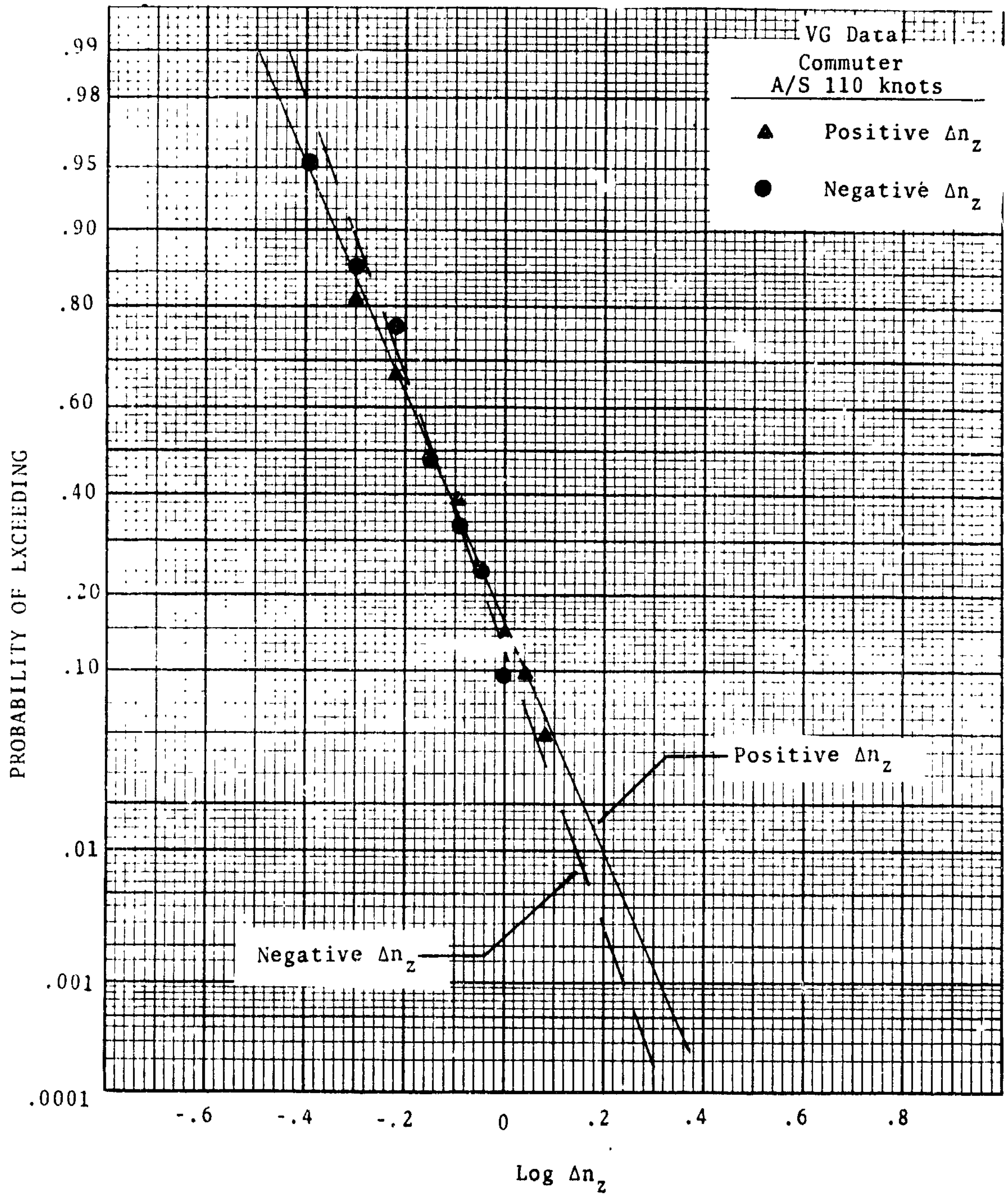


Figure 6. Probability-of-Exceeding-Δn_z Curve at 110-Knot Airspeed for VG Data

Figures 7 through 13 show the constant probability envelopes for all the operational categories except Aerobatic which did not have enough Δn_z occurrences to construct valid probability-of-exceeding-Δn_z curves for each airspeed.

Figure 7 shows the constant probability envelopes for the Twin-Engine Executive category. The envelope data compare favorably with the operational usage data presented in Table III. Figure 8 shows the constant probability envelopes for the Single-Engine Executive category. Again, the envelope data closely resemble those of the operational usage data presented in Table III.

Figure 9 shows the constant probability envelopes for the Personal category. The extreme values at 150 knots in each set of envelopes do not have corresponding values in the operational usage data presented in Table III. The probability-of-exceeding-Δn_z curve for the 150-knot airspeed was constructed from only 20 Δn_z occurrences and not all of the data points fall on any one of the three statistical distributions. However, since the probability-of-exceeding-Δn_z curves for all other airspeeds in the Personal category were found to be log-normal distributions, the 150-knot distribution was also analyzed as log-normal. The tendency of the data points, as shown in Figure 14, to curve downward suggests that a linear extrapolation would yield higher than actual Δn_z values.

Figure 10 shows the constant probability envelopes for the Instructional category. The envelope data conform well with the operational data presented in Table III. Figure 11 shows the constant probability envelopes for the Commercial Survey category. The envelope data are the same as the operational data presented in Table III. The Commercial Survey and Aerial Application were the only two categories whose probability-of-exceeding-Δn_z curves were constructed as normal, rather than log-normal, distributions. None of the categories had curves with an exponential distribution.

Figure 12 shows the constant probability envelopes for the Aerial Application category. The extreme values at 90 knots in the positive Δn_z envelopes do not have corresponding values in the operational usage data presented in Table III. The probability-of-exceeding-Δn_z curve was analyzed as a log-normal distribution for the 90-knot airspeed and as a normal distribution for all other airspeeds. Any error in the linear extrapolation will of course be larger on a log scale than on a linear scale. An extreme Δn_z at low airspeed could also be due to a flap operation and a low-altitude approach.

Figure 13 shows the constant probability envelopes for the Commuter category. The extreme values at 190 knots in the negative Δn_z envelopes do not have corresponding values in the operational usage data presented in Table III. The probability-of-exceeding-Δn_z curves were constructed from only 17 Δn_z occurrences. Again, any small error in the extrapolation would be compounded on the log scale.

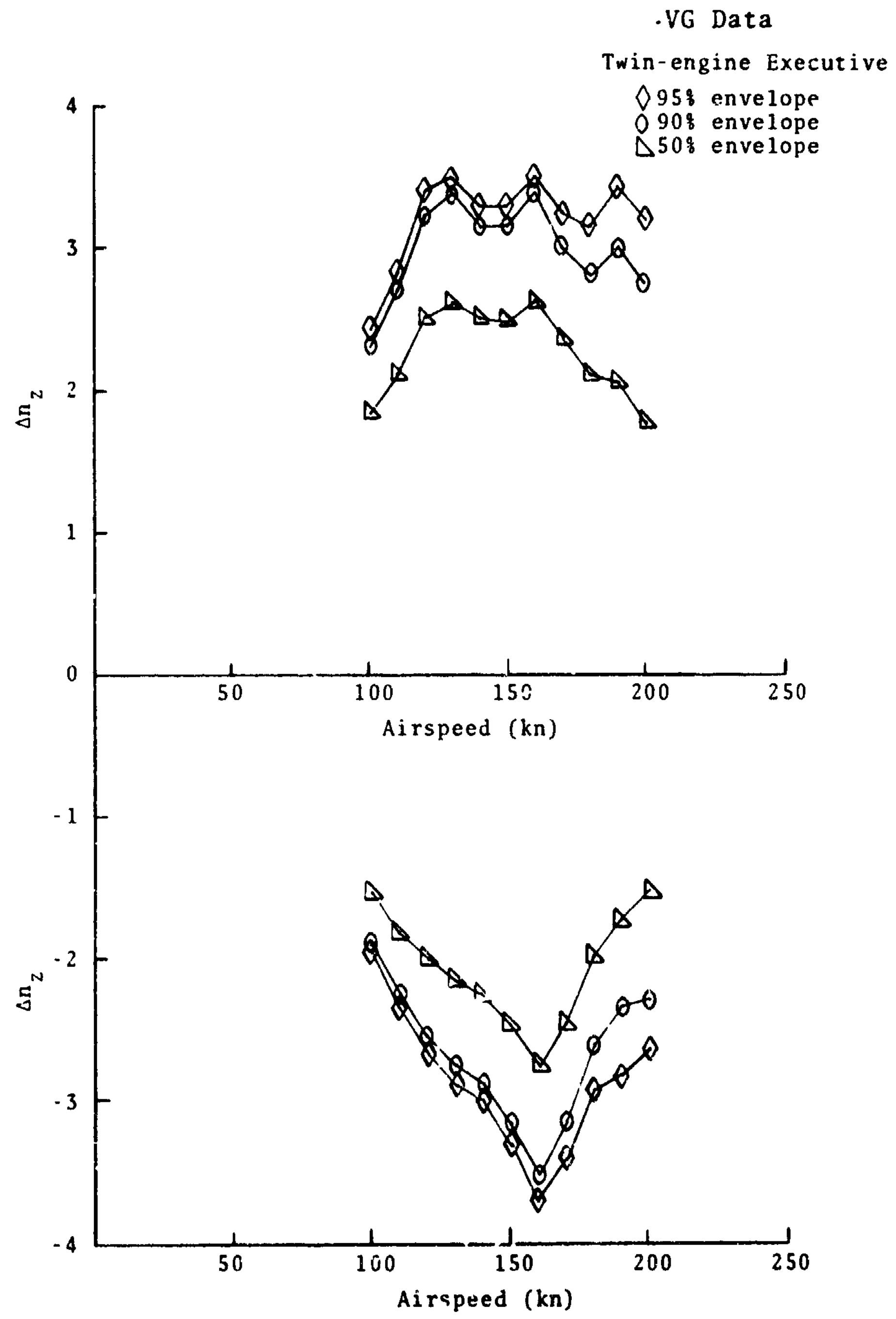


Figure 7. V-N Probability Distribution for Twin-Engine Executive Category Based on 20,000 Flight Hours of VG Data

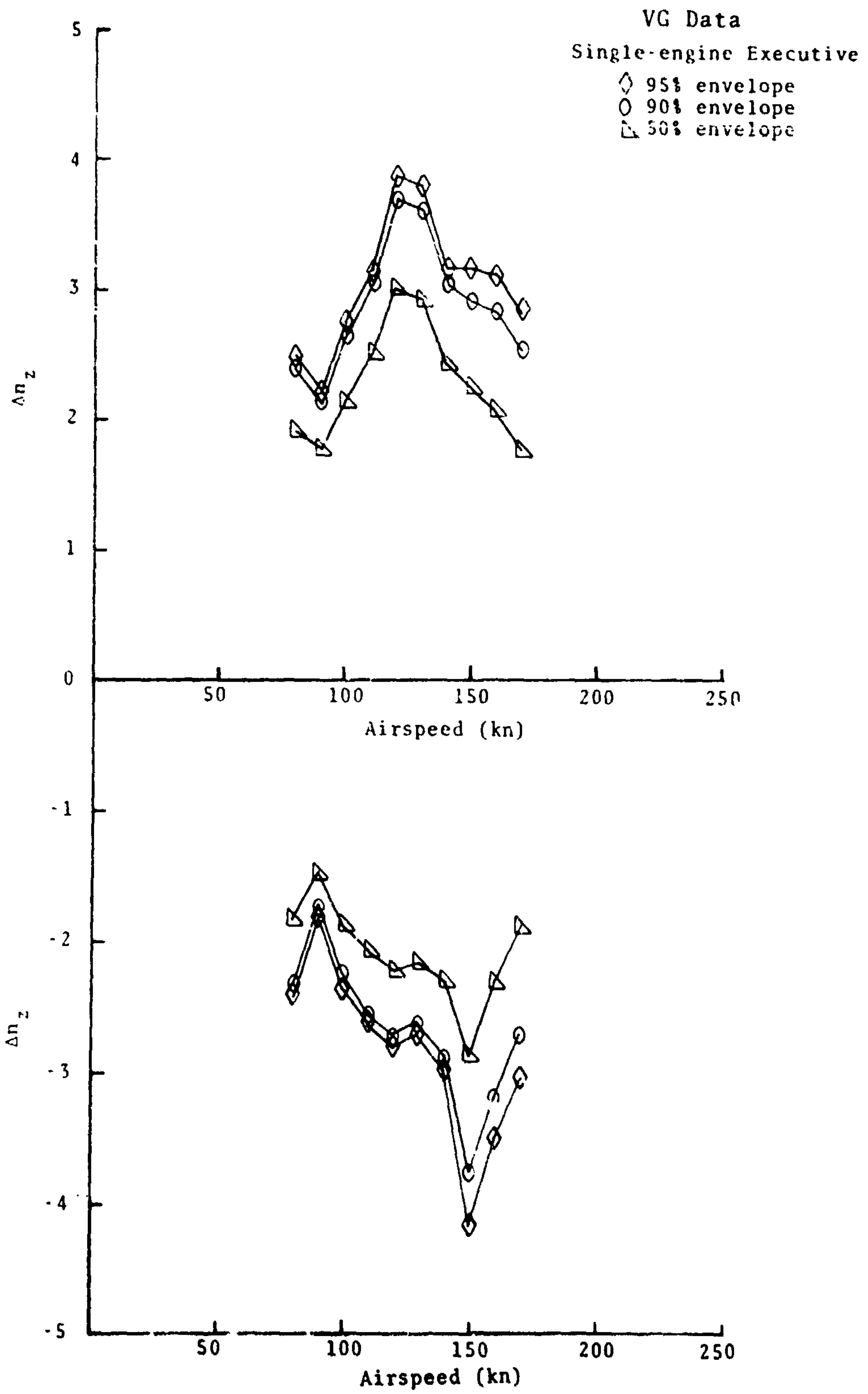


Figure 8. V-N Probability Distribution for Single-Engine Executive Category Based on 20,000 Flight Hours of VG Data

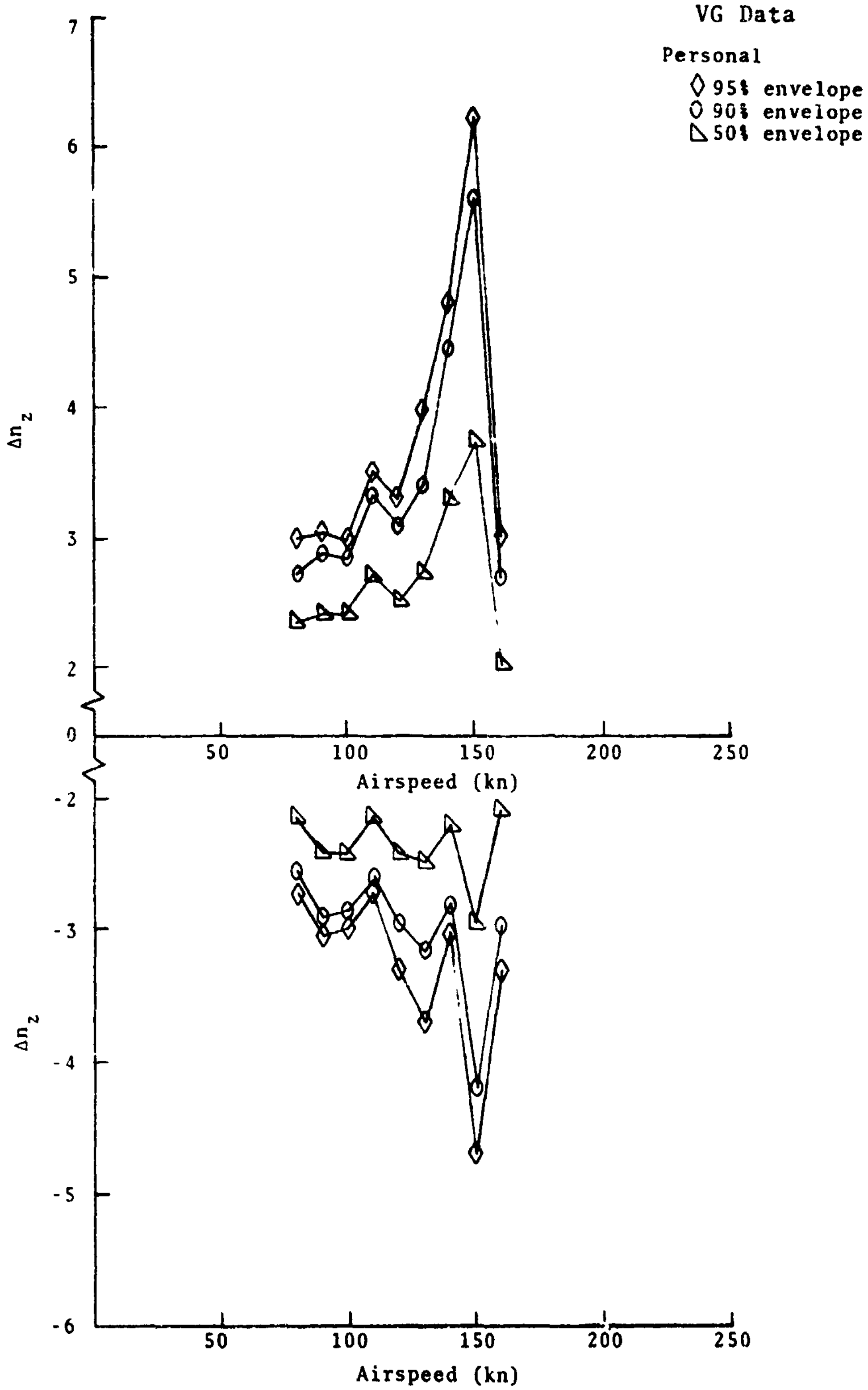


Figure 9. V-N Probability Distribution for Personal Category Based on 20,000 Flight Hours of VG Data

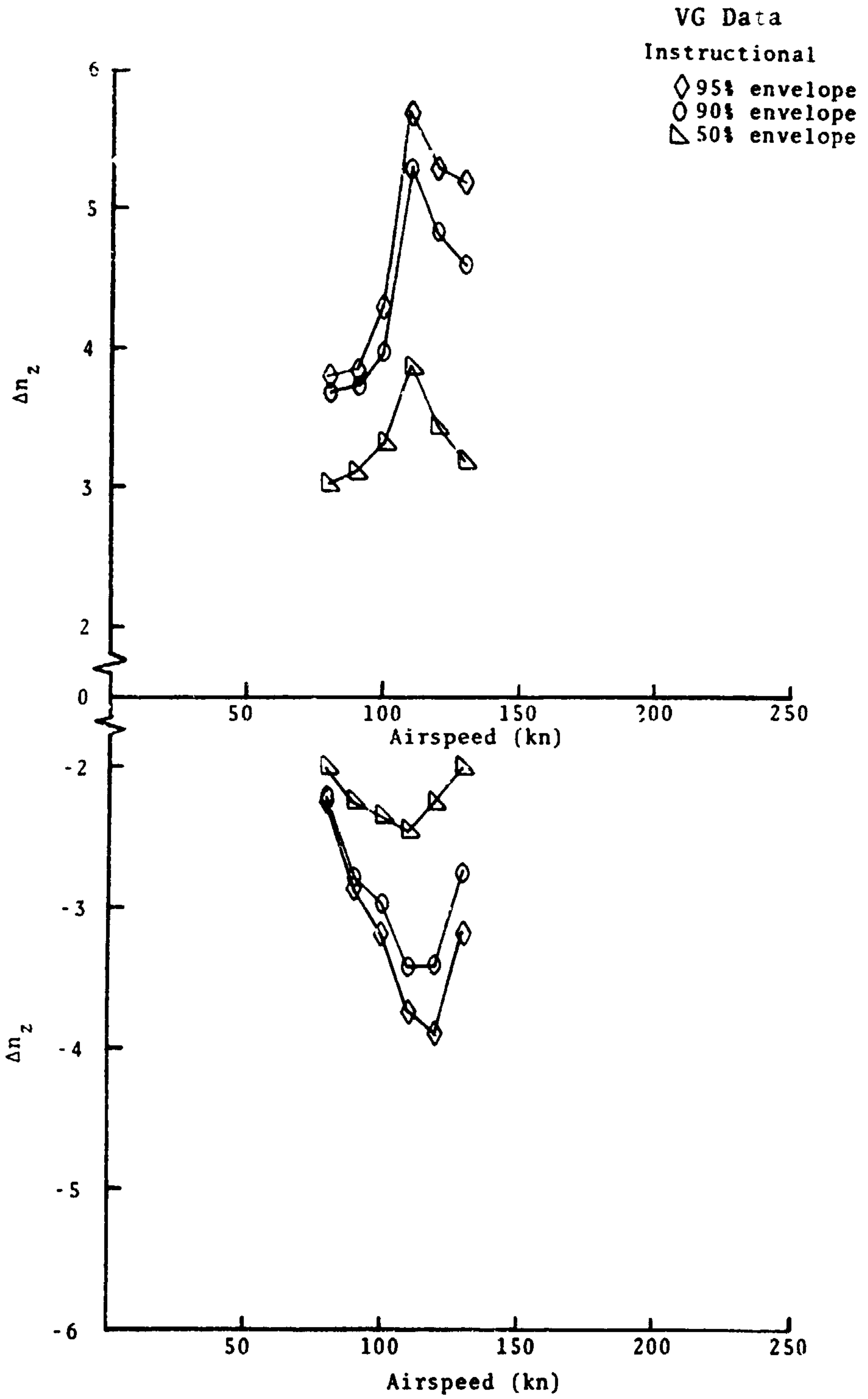


Figure 10. V-N Probability Distribution for Instructional Category Based on 20,000 Flight Hours of VG Data

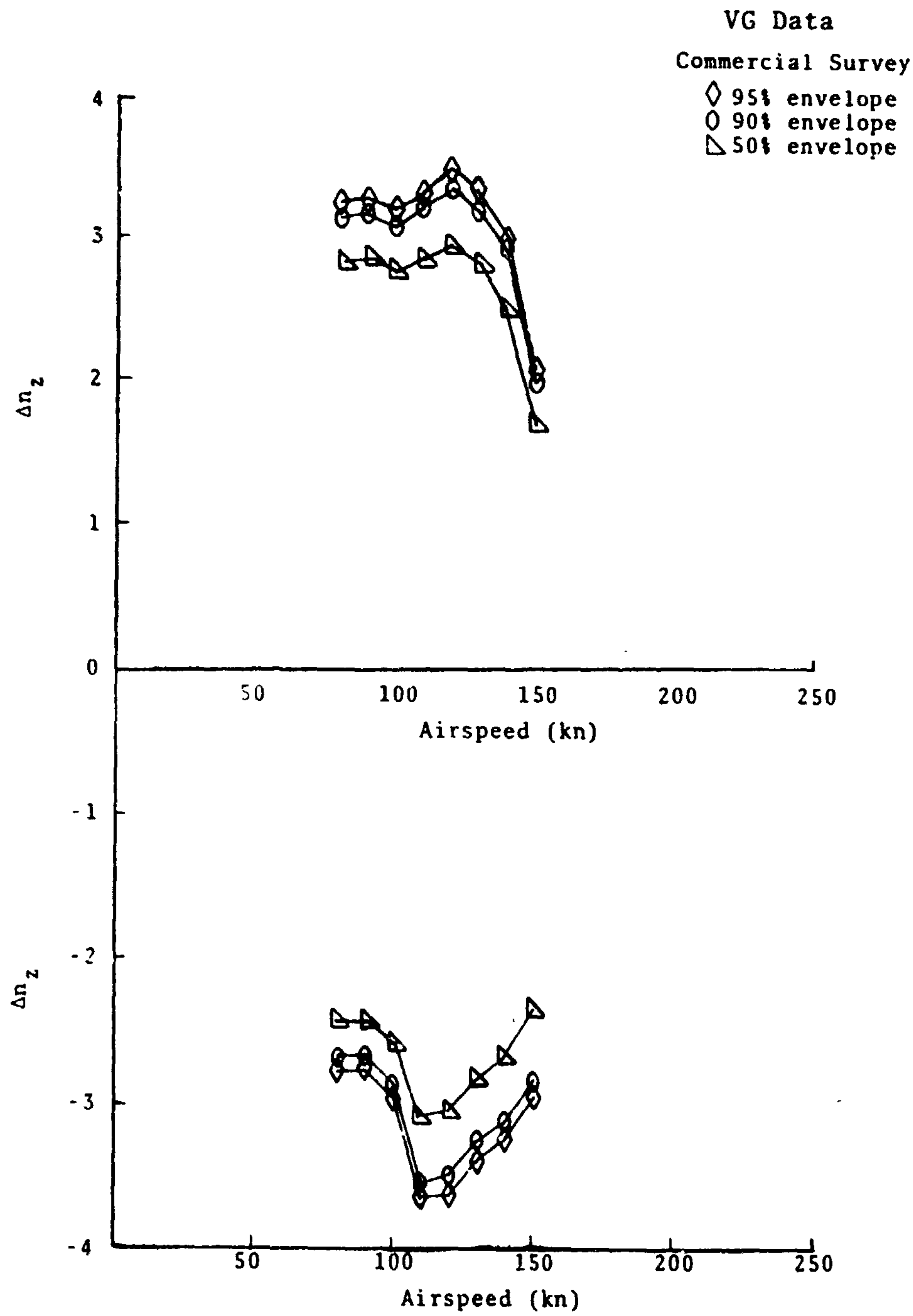


Figure 11. V-N Probability Distribution for Commercial Survey Category Based on 20,000 Flight Hours of VG Data

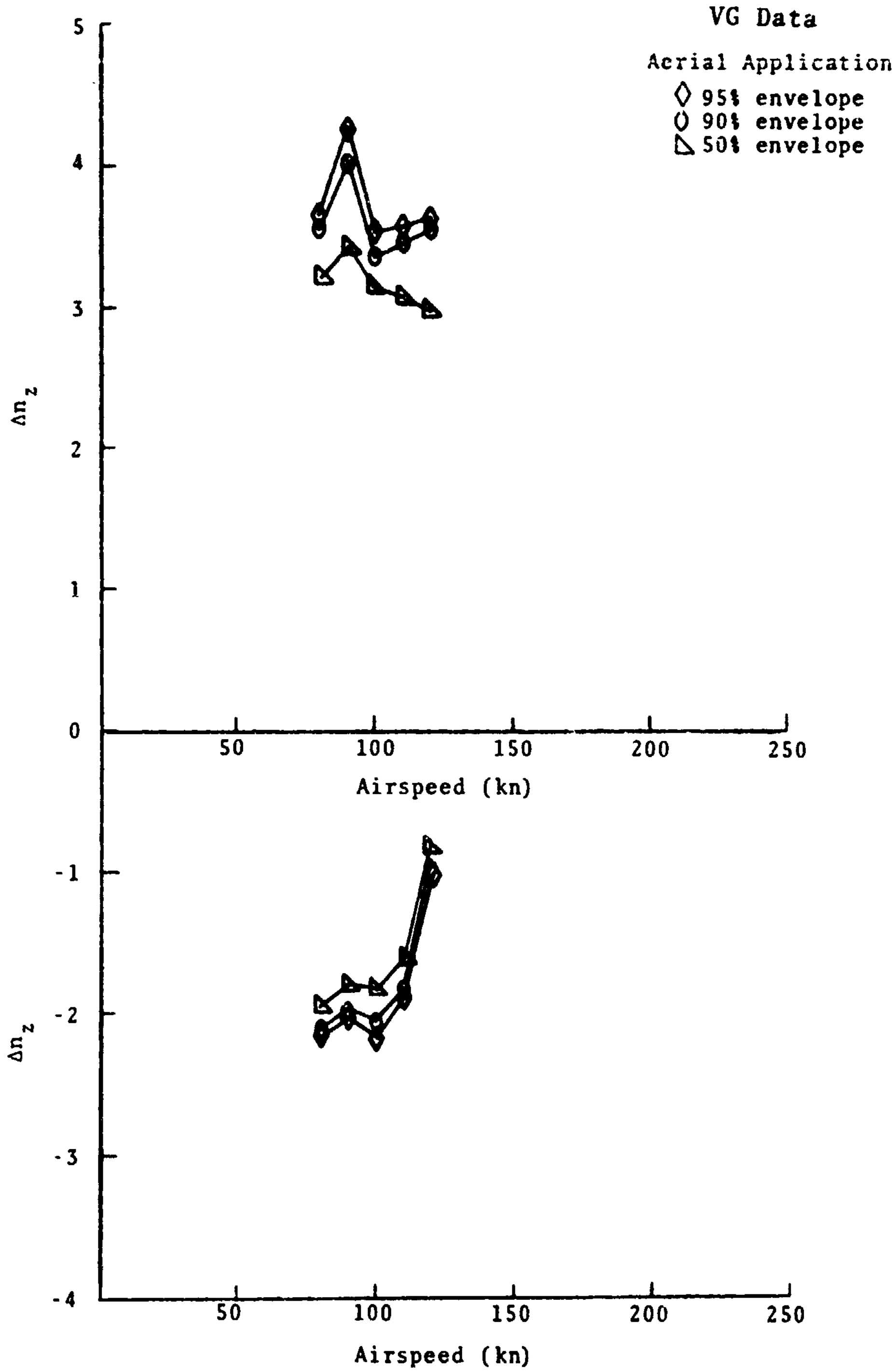


Figure 12. V-N Probability Distribution for Aerial Application Category Based on 20,000 Flight Hours of VG Data

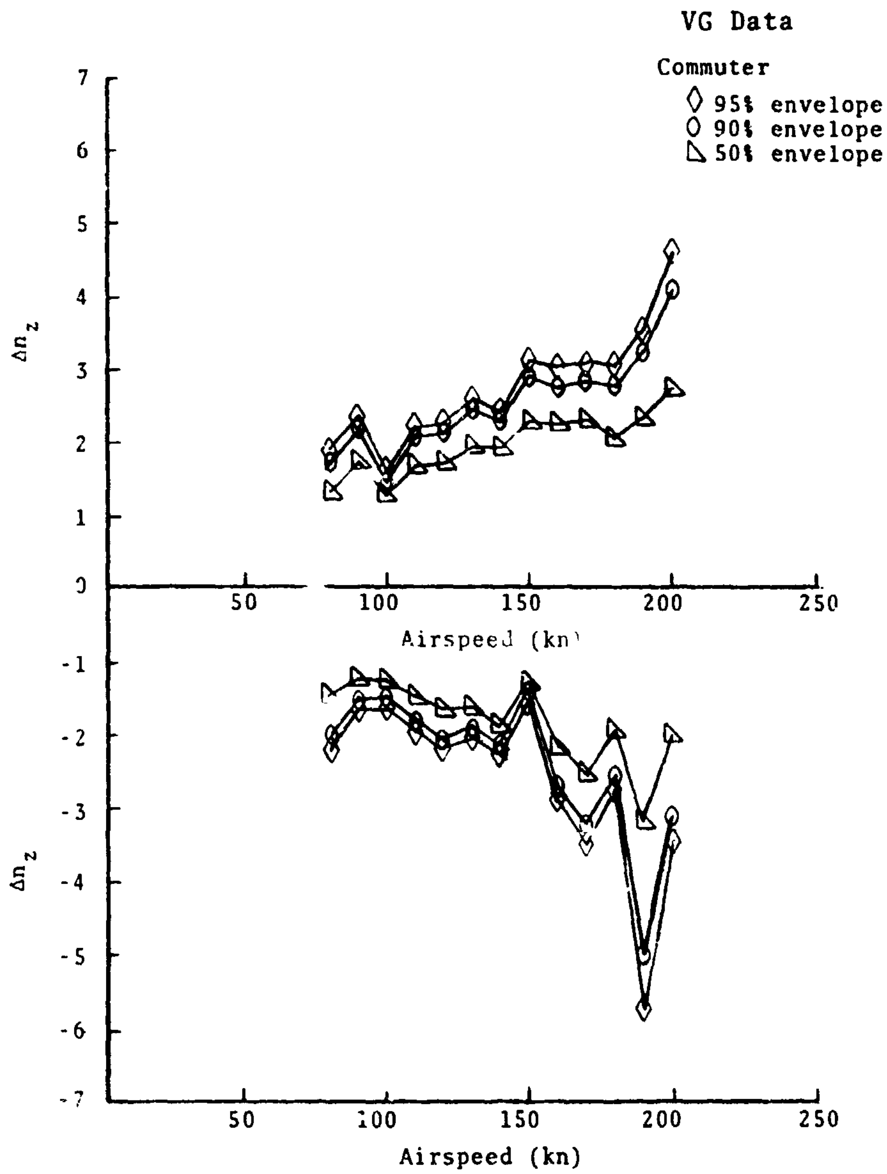


Figure 13. V-N Probability Distribution for Commuter Category Based on 20,000 Flight Hours of VG Data

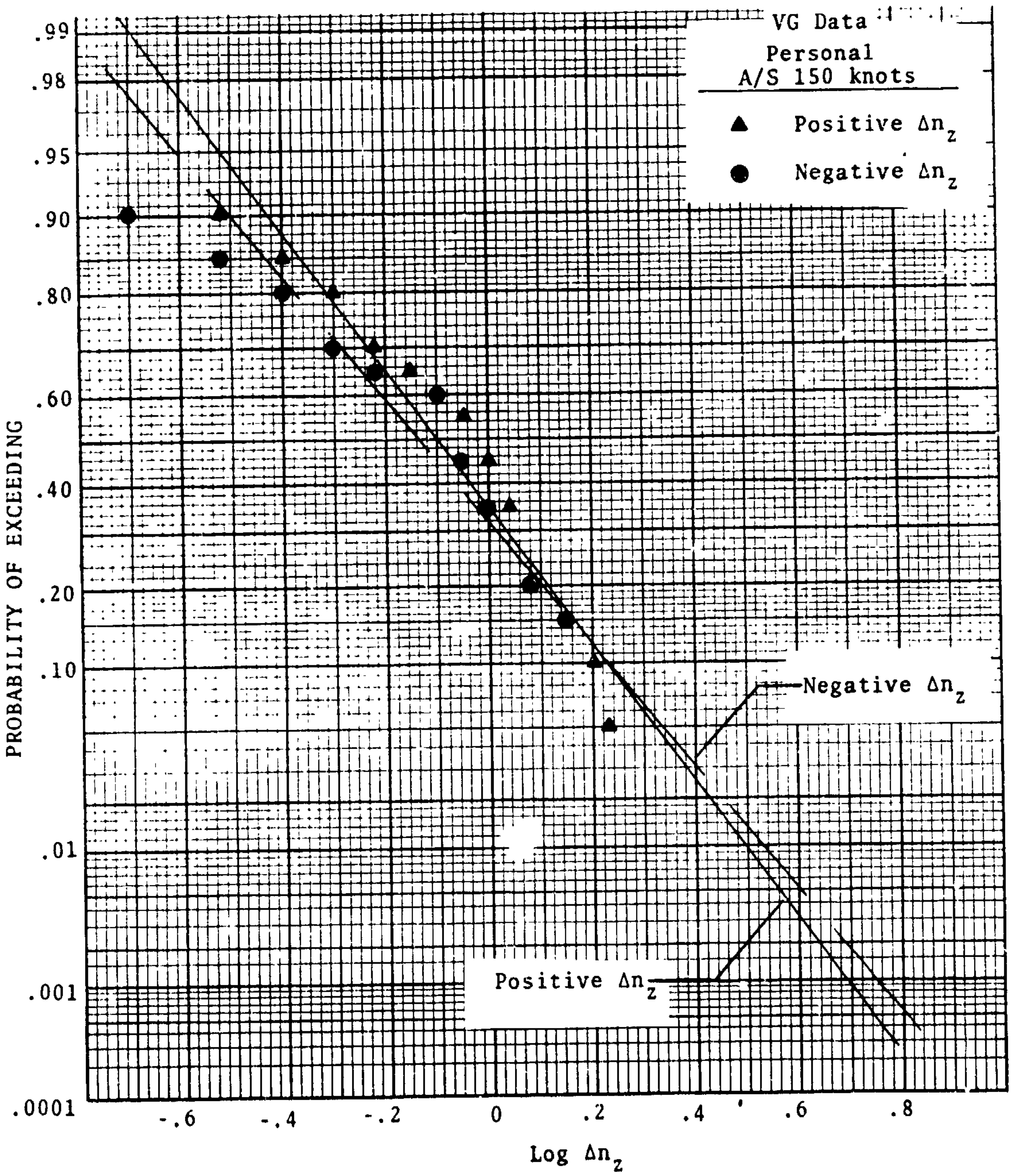


Figure 14. Probability-of-Exceeding-Δn_z Curve at 150-Knot Airspeed for VG Data

TABLE III. EXTREME VG VALUES BY OPERATIONAL CATEGORY

VG hr: 14,722

OPERATION: TWIN ENGINE EXECUTIVE — INDICATED AIRSPEED (KN)

ΔNZ	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	TOTAL
0.0												2	1	2	2	2					9
0.1				1	1						1	6	7	15	8	2	2	1	1		45
0.2			2	7	5	9	7	4	6	3	5	14	12	18	15	3					110
0.3			9	24	23	17	18	10	4	6	6	14	16	16	6						169
0.4			26	28	35	29	23	34	29	13	21	23	27	21	9	2					320
0.5			26	46	37	34	30	30	23	25	28	30	28	14	1	3					355
0.6			33	32	32	31	29	23	24	25	34	32	21	4	1						321
0.7			16	23	21	26	21	11	13	21	22	17	16	5	1		1			1	215
0.8			21	16	22	16	14	23	19	22	22	15	3	[illegible]							194
0.9			14	13	21	13	14	17	15	25	19	13	10	2							176
1.0			31	17	13	21	30	32	39	36	28	15	5	3	1						271
1.1			10	6	11	12	9	12	18	10	8	9	3								108
1.2			5	5	2	9	10	13	8	11	11	3	1	3	1						82
1.3			9	1	1	2	9	5	7	7	3	6	4	1							55
1.4			8	2		3	4	2	9	11	6	2	2	2	2						53
1.5			3	1		2	2	3	3	6	3	3									26
1.6			4	1			2	1	4		1	3	1								17
1.7			4	2	1			2			1										10
1.8			1				1	1	2	1	2	1		1							10
1.9										1	3	1	1		1						7
2.0			1			1	1	1	2												6
2.1										1											1
2.2																					
2.3										1											1
2.4							1														1
2.5								1			1										2
2.6																					
2.7																					
2.8																					
2.9																					
3.0																					
3.1																					
3.2																					
3.3																					
3.4																					
3.5																					
3.6																					
3.7																					
3.8																					
3.9																					
4.0																					
4.1																					
TOT			223	225	225	225	225	225	225	225	225	209	158	108	48	12	3	1	1	1	2564

OPERATION: TWIN ENGINE EXECUTIVE — INDICATED AIRSPEED (KN)

ΔNZ	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	TOTAL
-0.0												1	4	2	4						11
-0.1											1	7	4	7	5	4	2				30
-0.2				5	3	2	2	2	3	3	1	11	10	13	10	1	1	1			68
-0.3			12	15	14	14	14	12	10	6	6	18	12	25	7	2			1	1	169
-0.4			17	20	34	29	25	30	20	16	14	19	29	18	14	4					289
-0.5			33	55	48	43	40	30	31	15	22	17	30	14	4	1					383
-0.6			34	42	39	34	36	22	22	19	33	24	18	9	1						333
-0.7			24	27	29	21	29	26	20	23	23	27	17	6							272
-0.8			25	26	23	33	25	31	25	28	24	27	7	2							276
-0.9			26	14	18	19	19	18	21	30	32	20	9	6	1						233
-1.0			28	11	13	18	16	25	31	36	27	20	12	4							241
-1.1			5	1	2	4	8	10	13	11	12	6	2	1	1						76
-1.2			5	2		2	3	9	13	14	13	4	3								68
-1.3			5	2	2	3	2	3	7	8	3	4									39
-1.4			3	1		2	3	1	2	4	2										18
-1.5			1	1				2	3	7	5										19
-1.6			3	1				1		1											6
-1.7						1	2	1	3	1	1	2		1	1						13
-1.8				1			1	1		1	2	1	1								8
-1.9				1					1												2
-2.0			1					1		1	1										4
-2.1			1								1										2
-2.2																					
-2.3																					
-2.4																					
-2.5										1	1										2
-2.6												1									1
-2.7																					
-2.8																					
-2.9																					
-3.0																					
-3.1											1										1
-3.2																					
-3.3																					
-3.4																					
-3.5																					
-3.6																					
-3.7																					
-3.8																					
-3.9																					
-4.0																					
-4.1																					
TOT			223	225	225	225	225	225	225	225	225	209	158	108	48	12	3	1	1	1	2564

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

TABLE III. - Continued

VG hr: 9430

OPERATION: SINGLE ENGINE

INDICATED AIRSPEED (KN)

ΔNZ	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	TOTAL
0.0											1		1								2
0.1		1								5	3	4									13
0.2	1	3		1	2	2		1	3	9	4	5	2	2							35
0.3	9	14	20	8	6	4	4	4	3	19	13	8	4	1							117
0.4	15	23	24	19	11	2	3	4	10	9	5	5									130
0.5	17	18	20	17	20	15	5	11	15	17	16	8	3								182
0.6	16	20	26	30	24	14	16	17	20	13	7	5									208
0.7	9	12	14	15	18	23	25	15	18	10	3	2									164
0.8	10	12	10	14	14	14	13	15	20	11	7	1									141
0.9	6	8	8	12	11	14	12	15	9	4	2										101
1.0	10	8	10	10	12	19	16	15	15	8		1									124
1.1	4	3	1	7	6	8	8	5	7	8	4										61
1.2	7	1		2	7	6	5	11	6	4	1	1									51
1.3	6	5	3	1	3	7	9	10	5	2	1										52
1.4	5	4		1	2	3	4	5	3		2										29
1.5	2	2	2	1		2	5	1	1			1									17
1.6	3	1			2	2	2	3	2												15
1.7	1	1			1	2	1	1													7
1.8	4	2					4	1													11
1.9	1						3	2	1												7
2.0	1					2	1														4
2.1							1	1	1												3
2.2							1	1													2
2.3	4																				4
2.4							1														1
2.5																					
2.6																					
2.7																					
2.8								1													1
2.9																					
3.0																					
3.1																					
3.2																					
3.3																					
3.4																					
3.5																					
3.6																					
3.7																					
3.8																					
3.9																					
4.0																					
4.1																					
TOT	131	139	138	138	139	139	139	139	139	119	69	41	10	3							1482

OPERATION: SINGLE ENGINE

INDICATED AIRSPEED (KN)

ΔNZ	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	TOTAL
-0.0	2	2	2		1					1	2			1							11
-0.1			3	1	1					8	2	1	1	2							19
-0.2	1	3	3						1	9	8	10	2								37
-0.3	5	12	11	12	8	6	4	3	7	11	8	8	4								99
-0.4	21	29	24	21	13	2	5	5	10	12	6	1	1								150
-0.5	21	14	33	25	25	11	11	10	8	19	9	7	1								194
-0.6	10	24	23	33	26	22	9	13	22	10	5	3									200
-0.7	12	6	16	20	24	27	20	18	20	13	8	2									186
-0.8	14	7	9	13	19	22	19	18	21	7	5	5	1								160
-0.9	10	7	5	7	8	21	24	21	11	7	8										129
-1.0	5	11	5	4	7	14	18	24	17	8	2	3									118
-1.1	5	2	1		3	5	7	11	8	4	2										48
-1.2	5	3	1	2	1	4	8	3	4												31
-1.3	3	6			1	3	7	3	7	4											34
-1.4	2	4					1	5	1		3	1									17
-1.5	4	2			1		1	1		2											11
-1.6	3	1			1		2	3		1											11
-1.7	2	1				1	2														6
-1.8		1	2							1											4
-1.9	5	1				1		1			1										9
-2.0	1						1		1	1											4
-2.1										1											1
-2.2									1												1
-2.3																					
-2.4																					
-2.5		2																			2
-2.6																					
-2.7																					
-2.8																					
-2.9																					
-3.0																					
-3.1																					
-3.2																					
-3.3																					
-3.4																					
-3.5																					
-3.6																					
-3.7																					
-3.8																					
-3.9																					
-4.0																					
-4.1																					
TOT	131	138	138	138	139	139	139	139	139	119	69	41	10	3							1482

TABLE III. - Continued

VG hr: 5456

OPERATION: PERSONAL — INDICATED AIRSPEED (KN)

ΔNZ	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	TOTAL
0.0								2													2
0.1							1	1	1			1									4
0.2		1	1			1	4	4	2	2		2									17
0.3		2	2			4	6	2	2	1	2	1									22
0.4		12	4	3	1	5	12	8	5	1		1									52
0.5		12	8	5	4	6	9	7	4	2	4		1								62
0.6		17	13	8	5	10	11	9	4	1	3										81
0.7		8	9	8	14	14	6	5		2		1									67
0.8		9	18	17	17	15	10	9	1		1										97
0.9		9	16	20	14	5	6	6	1	2		1									80
1.0		15	15	23	19	12	19	6	3	2											114
1.1		8	10	13	13	15	4	4	4	3											74
1.2		9	10	9	16	17	8	4	2	1	1										77
1.3		2	8	5	5	5	7	4			1										37
1.4		1	3	5	3	6	5	5	1	1	1										31
1.5		1	2	2	6	1	2	1	3												18
1.6		2	1	5	4	4	2	1	1	1											21
1.7	1			1	3	1		1		1											8
1.8			2	2		2	1		1												8
1.9		1	1			1			1												4
2.0		1	1		1	1	1														5
2.1		1		1			1														3
2.2			1																		1
2.3																					
2.4									1												1
2.5					1	1			1												3
2.6																					
2.7																					
2.8																					
2.9																					
3.0																					
3.1																					
3.2																					
3.3																					
3.4																					
3.5																					
3.6																					
3.7																					
3.8																					
3.9																					
4.0																					
4.1																					
TOT	1	111	125	127	126	126	115	79	38	20	13	7	1								889

OPERATION: PERSONAL — INDICATED AIRSPEED (KN)

ΔNZ	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	TOTAL
-0.0																					
-0.1						1	3		2	2											8
-0.2		1				2	5	11	4	1		2									26
-0.3		5	1		1	2	5	4	2	1	2	2									25
-0.4		8	4	1	3	8	13	9	3	2	2	1	1								55
-0.5		14	14	13	3	8	14	4	7	1	2										80
-0.6		13	15	12	9	12	12	8	3	1	1	1									87
-0.7	1	14	19	18	17	9	5	9			2										94
-0.8		17	21	22	24	17	11	10	1	3		1									127
-0.9		13	13	19	20	26	17	5	3	2											112
-1.0		14	20	15	19	18	11	9	6	3	2										117
-1.1		4	5	7	8	8	10	6	1		1										50
-1.2		1	2	7	8	7	3		1	1											30
-1.3		2	6	4	6	10	1	1	1												31
-1.4			4	4	1	1	3		2	3											18
-1.5		2		2	2	2	1		1		1										11
-1.6					2			1	1												4
-1.7				1		1		1													3
-1.8		1	1		1																3
-1.9		1		1																	2
-2.0		1																			1
-2.1					1		1	1													3
-2.2																					
-2.3																					
-2.4																					
-2.5				1																	1
-2.6																					
-2.7					1																1
-2.8																					
-2.9																					
-3.0																					
-3.1																					
-3.2																					
-3.3																					
-3.4																					
-3.5																					
-3.6																					
-3.7																					
-3.8																					
-3.9																					
-4.0																					
-4.1																					
TOT	1	111	125	127	126	126	115	79	38	20	13	7	1								889

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

TABLE III. - Continued

VG hr: 10,357

OPERATION: INSTRUCTIONAL — INDICATED AIRSPEED (KN)

ΔNZ	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	TOTAL
0.0						1		1													2
0.1					3				1			1									5
0.2					4	5	4		4												17
0.3			1	2	2	7	3	3	2												20
0.4		2	1	1	7	9	2	4	2												28
0.5		4	4	6	14	7	2	3	2												42
0.6		10	6	5	6	5	3	4				1									40
0.7	1	7	7	13	13	10	4	1	1		1										58
0.8	1	6	6	11	7	6	4	1													42
0.9	2	10	9	10	8	4	2	2		1											48
1.0	3	18	17	13	17	8	5	3	1		1										86
1.1	3	10	12	10	4	5	3	2	1	2											52
1.2	3	13	12	12	16	7	2	3	1												69
1.3	6	16	21	11	9	10	1	1													75
1.4	3	18	16	16	7	3	5	1	1												70
1.5	1	7	11	13	8	7	2	1													50
1.6	2	4	11	13	6	1	2	1													40
1.7		5	5	7	9	3	2														31
1.8		2	6	1	3	1															13
1.9	2	1	2	1	3	1	2														12
2.0		2	2	4	2		1			1	1										13
2.1			1	3	1			1													6
2.2	1	2	2	2	1	1															9
2.3			2	1	1	1															5
2.4	1		1	2		1	2														7
2.5																					
2.6			1		1																2
2.7						1															1
2.8						2															2
2.9																					
3.0																					
3.1		1																			1
3.2																					
3.3																					
3.4		1																			1
3.5			1					1													2
3.6																					
3.7																					
3.8																					
3.9																					
4.0							1														1
4.1																					
TOT	29	139	157	157	152	106	52	33	16	4	3	2									850

OPERATION: INSTRUCTIONAL — INDICATED AIRSPEED (KN)

ΔNZ	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	TOTAL
-0.0					5	16	6	4	3	2	1										37
-0.1					1	5	8	4	3												21
-0.2		1			10	7	2	1	2			1									24
-0.3					11	17	7	6	2	1											44
-0.4	1	4	1	5	10	7	6	6	1												41
-0.5		6	6	7	18	11	5	4	2		1	1									61
-0.6		13	8	18	19	10	5	2	1												76
-0.7	3	16	12	20	16	12	3	2	1												85
-0.8	2	20	32	20	22	3	3	1													103
-0.9	6	19	26	34	10	7	2				1										105
-1.0	8	28	32	24	20	4	1	1													118
-1.1	3	7	14	7		2	2	1		1											37
-1.2		5	6	9		2	1		1												24
-1.3	3	9	10	5	3																30
-1.4	1	2	5	5	2	1															16
-1.5	1	3	5	1	3																13
-1.6		3	1			1															5
-1.7	1	2		2	2																7
-1.8																					
-1.9			1	2	1																4
-2.0		1																			1
-2.1																					
-2.2																					
-2.3					1	1															2
-2.4																					
-2.5																					
-2.6																					
-2.7							1														1
-2.8																					
-2.9																					
-3.0																					
-3.1								1													1
-3.2																					
-3.3																					
-3.4																					
-3.5																					
-3.6																					
-3.7																					
-3.8																					
-3.9																					
-4.0																					
-4.1																					
TOT	29	139	159	159	154	106	52	33	16	4	3	2									856

TABLE III. - Continued

VG hr: 26,089

OPERATION: COMMERCIAL SURVEY

INDICATED AIRSPEED (KN)

ΔNZ	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	TOTAL
0.0						6	1	2			2										11
0.1					6	10	4	1	2	1	1										25
0.2		1	2	3	6	12	4	5	1	1	1										36
0.3	7	1		6	10	13	7	8	1	3	1	1									58
0.4	15	13	11	7	8	16	7	9	1	5	2										94
0.5	18	14	11	10	13	12	10	6	6	7	4										111
0.6	17	9	8	10	12	15	11	8	5	5	3	1									104
0.7	14	13	16	5	17	9	6	6	10	6	1										103
0.8	14	18	7	12	23	9	5	6	3	4	1										102
0.9	16	18	14	12	23	12	11	6	7	8											127
1.0	48	25	32	35	30	21	22	8	9	4	1										235
1.1	22	29	21	24	20	11	14	8	9	2											160
1.2	21	39	24	33	22	12	7	9	6												173
1.3	18	30	34	25	17	19	13	8	4	1	1										170
1.4	10	19	24	22	15	9	10	10	3												121
1.5	14	23	22	15	15	18	4	10	2												123
1.6	11	15	23	17	17	9	10	4	2												108
1.7	4	19	19	17	3	14	3	1	3												83
1.8	5	14	8	9	13	6	1	3		1											60
1.9	1	3	8	16	12	2	5	2													49
2.0		10	17	11	15	11	2	1	1												[illegible]8
2.1		4	10	13	6	6	4	1													44
2.2		1	9	11	10	3	2	1	1												38
2.3		2	2	6	7	3	6	2	1												29
2.4		2	1	7	4	1	2														17
2.5		2	3		3	3		1	1												13
2.6		1	1	2	1	1	1	1													8
2.7								1													1
2.8		1					1	1													3
2.9			1				1														2
3.0																					
3.1																					
3.2							1	1													2
3.3									1												1
3..																					
3.5										1											1
3.6						1															1
3.7																					
3.8																					
3.9																					
4.0																					
4.1																					
TOT	255	326	328	328	328	263	175	130	79	49	18	2									2281

OPERATION: COMMERCIAL SURVEY

INDICATED AIRSPEED (KN)

ΔNZ	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	TOTAL
-0.0					1	8	3	1	1		1										15
-0.1	2	2	2	4	11	16	8	4	1		2										52
-0.2	8	10	8	8	6	8	4	8		4	3										67
-0.3	10	7	8	6	6	13	7	10	1	4	2	2									76
-0.4	22	9	6	7	6	14	11	10	2	4	3										94
-0.5	29	14	8	5	11	20	20	12	3	6	4										132
-0.6	53	38	15	10	13	13	7	3	10	4	2										168
-0.7	43	56	22	15	26	27	10	7	11	3											220
-0.8	34	42	40	30	28	16	11	5	2	7											215
-0.9	21	52	46	39	38	23	6	7	11	3											246
-1.0	11	40	75	52	54	20	19	12	8	5											296
-1.1	9	6	32	35	25	10	7	6	9	2											141
-1.2	1	8	16	30	14	9	7	4	3	1											93
-1.3	4	4	16	31	20	16	7	11	3	1	1										114
-1.4	3	6	7	19	21	8	7	3		1											75
-1.5		6	8	11	10	5	7	6	1												54
-1.6	2	2	7	5	5	5	4	2	2												34
-1.7	1	4	2	3	5	5	5														25
-1.8		8	2	5	9	7	3	3	2												39
-1.9	2	2	3	6	6	2		3		1											[illegible]
-2.0		4	1	1	[illegible]	4	4		1												18
-2.1		2		2	1	2	2	1													10
-2.2		1		1	1	3	1	2	2	1											12
-2.3		1	1		2	2	2	1	1												10
-2.4			1	2		1	1	1		1											7
-2.5		1			2		1	2	1												7
-2.6						1	5	1													7
-2.7		1	1			1															3
-2.8							2	1													3
-2.9			1			1			1	1											4
-3.0					1	1	2	2													6
-3.1									1												1
-3.2					1	1															2
-3.3																					
-3.4																					
-3.5																					
-3.6																					
-3.7						1															1
-3.8																					
-3.9				1																	1
-4.0																					
-4.1																					
-4.2																					
-4.3																					
-4.4							1														1
-4.5					1			1	1												3
TOT	255	326	328	328	32[illegible]	263	174	129	78	49	18	2									2277

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

TABLE III. - Continued

VG hr: 1857

OPERATION: AERIAL APPLICATION

INDICATED AIRSPEED (KN)

ΔNZ	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	TOTAL
0.0						1															1
0.1																					
0.2																					
0.3				1		1	1														3
0.4																					
0.5		1				1	1														3
0.6	1	1			1	3	1														7
0.7		1				1															2
0.8	1					1															2
0.9		2																			2
1.0	2		1		1		1														5
1.1	2	1			1																4
1.2		1	4	2	2																9
1.3	1	3	2	2	1	1															10
1.4	3		1	3		2															9
1.5	1	2	1	2	1	1	1														9
1.6		3	1	2	1	2															9
1.7	2	1	3		2																8
1.8	3	2	2	2	2																11
1.9	1		2	2	2																7
2.0			1		3	1	1														6
2.1	1	2		2		1															6
2.2																					
2.3	2																				2
2.4	1		1	1																	3
2.5			1																		1
2.6			1			1															2
2.7																					
2.8																					
2.9																					
3.0				2	1																3
3.1		1			1																2
3.2																					
3.3																					
3.4																					
3.5																					
3.6																					
3.7																					
3.8																					
3.9																					
4.0																					
4.1																					
TOT	21	21	21	21	19	17	6														126

OPERATION: AERIAL APPLICATION

INDICATED AIRSPEED (KN)

ΔNZ	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	TOTAL
-0.0					1	1	1														3
-0.1							1														1
-0.2						2	1														3
-0.3			1	2		1	1														5
-0.4					2	2	2														6
-0.5	1			1	1																3
-0.6	2	1		1		3															7
-0.7					1	2															3
-0.8		2			2	2															6
-0.9	2		3		4	2															11
-1.0	2	3	3	6	3	1															18
-1.1	1	4	2	2	2	1															12
-1.2	5	3	5	4																	17
-1.3	2	3	2	2	1																10
-1.4	2	3	2	3	2																12
-1.5	1	1	1																		3
-1.6	3	1	2																		6
-1.7																					
-1.8																					
-1.9																					
-2.0																					
-2.1																					
-2.2																					
-2.3																					
-2.4																					
-2.5																					
-2.6																					
-2.7																					
-2.8																					
-2.9																					
-3.0																					
-3.1																					
-3.2																					
-3.3																					
-3.4																					
-3.5																					
-3.6																					
-3.7																					
-3.8																					
-3.9																					
-4.0																					
-4.1																					
TOT	21	21	21	21	19	17	6														126

TABLE III. - Continued

VG hr: 4060

OPERATION. COMMUTER

INDICATED AIRSPEED (KN)

ΔNZ	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	TOTAL
0.0																					
0.1		1												1	1						3
0.2			1	1									1	4	1	2					10
0.3				2	1	1						3	2	1	1	1	1				13
0.4			1	3	4	3	3	1		1	2	1	2		2						23
0.5			2		1	3	1	1	1	2	2				2	1					16
0.6			1	3	5	4	5	2	1	1	1	2	1	3	1						30
0.7					1	2	3	3	6	2	3	1	3	2							26
0.8				3	6	3	1	1		1		1	4	1	1						22
0.9			1	7	1	2	3	7	[illegible]	1	2	4	1	2							34
1.0					1	1	3		5	6	4	1	1	2	1						25
1.1				1		1	1	3		2	1	2	2		1						14
1.2						1	1	1	2	2	3	2									12
1.3								2	3	1	1	2	1								10
1.4										2											2
1.5											1	1									2
1.6											1	1									2
1.7																					
1.8																					
1.9													1								1
2.0														1		1		1	1		4
2.1															1		1				2
2.2																				1	1
2.3																					
2.4																					
2.5																					
2.6																					
2.7																					
2.8																					
2.9																					
3.0																					
3.1																					
3.2																					
3.3																					
3.4																					
3.5																					
3.6																					
3.7																					
3.8																					
3.9																					
4.0																					
4.1																					
TOT		1	6	20	20	21	21	21	21	21	21	21	19	17	12	5	2	1	1	1	252

OPERATION: COMMUTER

INDICATED AIRSPEED (KN)

ΔNZ	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	TOTAL
-0.0																				1	1
-0.1	1	1												1	3						6
-0.2			1	1									1	2		1					6
-0.3				1	1	1						1	1	2	1	1	2		1		12
-0.4			1	3	5	2	2	1	1			1	2	2	2			1			23
-0.5			1	7	5	2	2			1	1	2	3		1						25
-0.6			2	3	3	6	2	4	1		1	2	1	1	4	1					31
-0.7				4	4	3	6		3	2	3		1			2					28
-0.8					1	2	3	6	2	6	3	4		3							30
-0.9				1		3	1	3	4	[illegible]	3	2	2								23
-1.0						2	2	3	5	7	2	2	5	4							32
-1.1			1		1		1	1	1	1	1	1	1		1						10
-1.2							1	2	1		2	1	1								8
-1.3								1	1		3			2							7
-1.4									1			1									2
-1.5							1					3									4
-1.6									1		2	1	1								5
-1.7																					
-1.8																					
-1.9																					
-2.0																					
-2.1																					
-2.2																					
-2.3																					
-2.4																					
-2.5																					
-2.6																					
-2.7																					
-2.8																					
-2.9																					
-3.0																					
-3.1																					
-3.2																					
-3.3																					
-3.4																					
-3.5																					
-3.6																					
-3.7																					
-3.8																					
-3.9																					
-4.0																					
-4.1																					
TOT	1	1	6	20	20	21	21	21	21	21	21	21	19	17	12	5	2	1	1	1	253

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

TABLE III. - Concluded

VG hr: 382

OPERATION: ACROBATIC

INDICATED AIRSPEED (KN)

ΔN	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	TOTAL
0.0									1												1
0.2																					
0.4																					
0.6																					1
0.8	1																				2
1.0	[illegible]																				2
1.2	1						1														10
1.4	1	6	1																		2
1.6		1	1																		3
1.8				1	1			1													3
2.0	1		1			1															4
2.2			3								1										1
2.4				1																	2
2.6				1								1									2
2.8			1	1																	2
3.0				2									1	1							2
3.2													1								5
3.4				1	3																5
3.6					3						1			1							3
3.8													1								[illegible]
4.0	1	1				2						1									10
4.2	1	2	1			3	3														10
4.4		1				1	1	3	1	2	1										6
4.6				1	1							2	1					1	1		12
4.8			1	1			2	1	2	2	2										[illegible]
5.0		1	2	1	1			1	3	1											9
5.2				1	1	1		1	1	1		1		1			1				4
5.4			1		1			1			1					1					6
5.6	1				1	2	1			1											7
5.8		1	1	1		1			1	1			1								9
6.0						1	2	1			2	1	1		1						6
6.2				1	1				1	1				1			1				5
6.4							1	1		1		1	1								8
6.6						1		1	1	1	1	2	1								4
6.8							2	1	1												13
7.0								1	1	1	1	2	2	1	1	1					
7.2																					
7.4																					
7.6																					
7.8																					
8.0																					
8.2																					
TOT	[illegible]	13	13	13	13	13	13	13	13	12	12	11	10	5	2	2	2	1	1		175

OPERATION: ACROBATIC

INDICATED AIRSPEED (KN)

ΔNZ	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	TOTAL
-0.0												1									1
-0.2									1		1		1	1				1			4
-0.4							1	1		1	1						1				[illegible]
-0.6	1	1								1			1								[illegible]
-0.8			1								1	1	1	1					1		[illegible]
-1.0					1								1	1			1				4
-1.2						1															
-1.4																					
-1.6				1																	1
-1.8												1									1
-2.0	1																				
-2.2																					
-2.4		1							1												[illegible]
-2.6	1	1	1								1										
-2.8			1	1																	
-3.0	2	2	1																		[illegible]
-3.2	2	2		1	1																[illegible]
-3.4	1	2	2	4		1		1		1		1									
-3.6	1	1	2		2				1												11
-3.8	1			1	1	2	2	1	1												4
-4.0					1	2		1													[illegible]
-4.2					1	1	2			1											5
-4.4					1	1	1	1				1									8
-4.6		1	1	1	1	1	1	1	1												4
-4.8	1							1	1		1										6
-5.0						1				1	1			1	1	1					2
-5.2						1			1												2
-5.4										2											
-5.6							2			1			1		1	1					6
-5.8							1														1
-6.0									1	1	2	1									5
-6.2								2	1	1											4
-6.4	1	1	1	1			1	1				1									7
-6.6	1	1						1	1		1		1								6
-6.8			1	1	2	2	2	2	3	2	3	3	3	1							25
-7.0												1	1								2
-7.2																					
-7.4																					
-7.6																					
-7.8																					
-8.0																					
-8.2																					
TOT	13	13	13	13	13	13	13	13	13	12	12	11	10	5	2	2	2	1	1		175

The data in the constant probability envelopes conform quite well with the operational usage data for all seven categories having sufficient Δn_z occurrences for each airspeed. In the 90% and 95% envelopes, the Δn_z values were usually considerably higher than the corresponding values in the operational data. This was expected since the Δn_z occurrences can be considered random events that would have a statistical distribution only within some range of Δn_z. The limits on this range are determined somewhat by the structural limitations of the aircraft and the effectiveness of the control system, but mostly by pilot actions. While the Δn_z occurrences may conform to a standard distribution within this range, the standard distribution will show a finite probability for a Δn_z occurrence beyond the limits of this range. Because of its larger data sample, the VG data was used to construct the constant probability envelopes. If VGH data had been used, the gust loads could have been separated from the maneuver loads. The gust loads could be treated as true random occurrences since they are an exponential function of altitude and are randomly generated by an external energy source. Maneuver loads would have to be treated as a conditional distribution which would be truncated at the limits of the Δn_z range.

2.4 Design Limit Probability Levels

2.4.1 Gust and Maneuver Design Limit Loads

The probability levels for current gust and maneuver design limit loads and ultimate (1.5 x design) limit loads were calculated from the VGH data presented in Table IV. The probability levels were based on 10,000 and 20,000 flight hours and were calculated for all operational categories except Aerobatic. Each probability level represents the probability of exceeding a particular limit load at least once in either 10,000 or 20,000 flight hours. Again it was necessary to first construct the probability-of-exceeding-Δn_z curves for both gust and maneuver loads for each operational category. These curves show the probability of exceeding a given Δn_z in a single flight. Each flight was considered to be a statistical trial, and these trials were assumed to satisfy the requirements for Bernoulli trials. The number of trials (flights) in 10,000 and 20,000 hours was calculated for each operational category. The probability P(E) of exceeding a particular limit load at least once in either 10,000 or 20 000 flight hours was calculated as follows:

$$P_{NE} = 1 - P_E$$

$$P(NE) = P_{NE}^n$$

$$P(E) = 1 - P(NE)$$

where P_E = probability of exceeding a given Δn_z in a single trial (as read from probability-of-exceeding-Δn_z curves)

P_{NE} = probability of not exceeding a given Δn_z in a single trial

P(NE) = probability of not exceeding a given Δn_z in n consecutive trials

n = number of trials in either 10,000 or 20,000 flight hours

Tables V through VIII present the results of the above calculations. As indicated in these tables, the operational categories have the following trends: Instructional has the highest probability of exceeding the design and ultimate n_z limits during maneuver; Aerial Application has a high probability of exceeding the design n_z limits but a low probability of exceeding the ultimate n_z limits during maneuver; Commercial Survey has the highest probability of exceeding the design and ultimate n_z limits due to gust; and Aerial Application has almost a zero probability of exceeding the design n_z limits due to gusts.

2.4.2 Maneuver Load-Gross Weight Relationships

Relationships between recorded maneuver loads and design gross weights were determined over the range of aircraft gross weights in the normal aircraft category. The three Δn_z values at each gross weight represent 50%, 90%, and 95% probability levels and are based on 20,000 flight hours. An aircraft flying 20,000 hours at a given gross weight has a 50%, 90%, or 95% probability of never exceeding the corresponding Δn_z value. The technique for computing these Δn_z values is the same as that discussed in Section 2.3, V-N Probability Distributions. Since the actual weight conditions corresponding to the recorded n_z values were not available, Figure 15 is a plot of Δn_z versus design gross weight for each of the three probability levels. Also shown in Figure 15 is a curve of the minimum design load factor as stated in FAR Part 23, Section 23.337 for the normal aircraft category. Table IX presents the design gross weights, number of recorded flight hours, number of recorded flights, and Δn_z values for each probability level.

TABLE IV. EXTREME VGH VALUES PER FLIGHT BY OPERATIONAL CATEGORY

VGH hr: 3377

POSITIVE MANUEVER
OPERATION 991 -- TWIN ENGINE EXECUTIVE

	ΔNZ																		
A/C TYPE	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.2	TOTAL
4	53	17	11	6	3	1	1	2				1							95
2	290	139	66	39	23	15	3	5	4	1	1		2	1		2		1	592
3	20	7	4	2	3	1		1	1				1	1			1		42
5A	132	60	46	24	16	7	7	10	3	2	1		2						310
1	36	26	9	13	7	6	2	3	2	4	1	1							110
TOTAL	531	249	136	84	52	30	13	21	10	7	3	2	5	2		2	1	1	1149

NEGATIVE MANUEVER
OPERATION 991 -- TWIN ENGINE EXECUTIVE

	ΔNZ															
A/C TYPE	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	TOTAL
4	24	4	2		1												31
2	228	63	32	7	8												338
3	5	2	1														8
5A	73	28	10	4	3	1											119
1	32	6	2	1	1												42
TOTAL	362	103	47	12	13	1											538

VGH hr: 1366

POSITIVE MANUEVER
OPERATION 992 -- SINGLE ENGINE EXECUTIVE

	ΔNZ															
A/C TYPE	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	TOTAL
7A	12	2	1	2													17
9A	54	28	14	14	7	7	1	2	2	3	5						137
8	86	41	26	19	3	11	3	5	1	1	2	1		2			201
TOTAL	152	71	41	35	10	18	4	7	3	4	7	1		2			355

NEGATIVE MANUEVER
OPERATION 992 -- SINGLE ENGINE EXECUTIVE

	ΔNZ																	
A/C TYPE	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.[illegible]	3.2	TOTAL
7A	4																		4
9A	48	13	14	17	11	8	5												116
8	42	15	9	1	1	1	1												70
TOTAL	94	28	23	18	12	9	6												190

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

TABLE IV. - Continued

VGH hr: 724

POSITIVE MANUEVER
OPERATION 993 -- PERSONAL

A/C TYPE	ΔNZ .4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.2	TOTAL
128	38	17	15	11	5	4	5	3		2	1		1				1		103
10A	21	8	4	5	4		1	1											44
11	26	7	4	2		3												1	43
TOTAL	85	32	23	18	5	7	6	4		2	1		1				1	1	190

NEGATIVE MANUEVER
OPERATION 993 -- PERSONAL

A/C TYPE	ΔNZ .4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	TOTAL
128	18	7	9	1	2	1		1		1							40
10A	7	4	2	3	4												20
11	7	1			1	1											10
TOTAL	32	12	11	4	7	2		1		1							70

VGH hr: 2843

POSITIVE MANUEVER
OPERATION 994 -- INSTRUCTIONAL

A/C TYPE	ΔNZ .4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.3	2.4	3.1	3.2	TOTAL
14	56	44	30	29	18	10	15	13	4	4	1	1	3	1		1	1	1					232
16	115	77	50	54	45	32	21	14	17	14	6	11	9	2	2	4	1	1					475
17	84	36	33	26	13	14	8	2	2	4	1		1					1	1				226
15	52	38	24	34	19	14	20	6	5	1		3	1	1		1		1	1	1	2	1	224
13	183	121	80	58	46	43	35	23	20	17	10	9	5		3	2		1					657
TOTAL	490	316	217	201	141	113	99	58	48	40	24	24	18	4	5	8	2	5	1	1	2	1	1809

NEGATIVE MANUEVER
OPERATION 994 -- INSTRUCTIONAL

A/C TYPE	ΔNZ .4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	TOTAL
14	51	29	9	8		3													100
16	92	40	30	9	6	4	3				1								185
17	78	30	25	9	4	2	1												149
15	38	35	11	5	4	3	3												99
13	158	118	76	23	7	2	1		1										386
TOTAL	417	252	151	54	21	14	8		1		1								919

TABLE IV. - Continued

VGH hr: 2291

POSITIVE MANUEVER
OPERATION 995 -- COMMERCIAL SURVEY

	ΔNZ															
A/C TYPE	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
19	5	6	5	3		2	1		2		4		3	3	1	1
16A	17	14	9	18	22	33	46	77	77	57	24	13	10	8	9	1
9B	42	19	18	14	11	8	6	5	1	4					1	1
49	14	16	22	16	22	20	14	19	25	21	9	7	3	3		
TOTAL	78	55	54	51	55	63	67	101	105	82	37	20	16	14	11	3

POSITIVE MANEUVER
OPERATION 995 -- COMMERCIAL SURVEY (CONTINUED)

	ΔNZ														
A/C TYPE	2.0	2.1	2.2	2.3	2.4	2.6	2.7	2.8	2.9	3.1	3.3	3.4	3.5	3.6	TOTAL
19	6		3	2	2	5	2	3	3	2	1	2	1	1	69
16A		1													436
9B															130
49	1														212
TOTAL	7	1	3	2	2	5	2	3	3	2	1	2	1	1	847

NEGATIVE MANUEVER
OPERATION 995 -- COMMERCIAL SURVEY

	ΔNZ																
A/C TYPE	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	TOTAL
19	20	12	9	3		1	1										46
16A	26	10	1			1	2	1									41
9B	21	13	4		2					1							41
49	53	31	9	4	4	1											102
TOTAL	120	66	23	7	6	3	3	1		1							230

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

TABLE IV. - Continued

VGH hr: 484

POSITIVE MANUEVER
OPERATION 996 -- AERIAL APPLICATION

ΔNZ

A/C TYPE	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	TOTAL
24	71	127	126	119	86	67	49	39	14	12	2	3	3	2									720
23	16	15	13	6	18	18	47	75	101	164	167	190	178	144	111	65	41	20	10	6	3	1	1409
TOTAL	87	142	139	125	104	85	96	114	115	176	169	193	181	146	111	65	41	20	10	6	3	1	2129

NEGATIVE MANUEVER
OPERATION 996 -- AERIAL APPLICATION

ΔNZ

A/C TYPF	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	TOTAL
24	174	98	45	14	6												337
23	63	55	107	167	315	317	195	98	21		1			1		1	1341
TOTAL	237	153	152	181	321	317	195	98	21		1			1		1	1678

VGH hr: 1510

POSITIVE MANUEVER
OPERATION 997 -- COMMUTER

ΔNZ

A/C TYPF	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	TOTAL
28	20	7	3	2	4					1							37
26	102	21	11	9	2	4	1		1	1		1	3				156
TOTAL	122	28	14	11	6	4	1		1	2		1	3				193

NEGATIVE MANUEVER
OPERATION 997 -- COMMUTER

ΔNZ

A/C TYPF	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	TOTAL
28	7	1	2													10
26	56	13	4	6	2	1										82
TOTAL	63	14	6	6	2	1										92

TABLE IV. - Continued

VGH hr: 3377

POSITIVE GUST
OPERATION 991 -- TWIN ENGINE EXECUTIVE

A/C TYPE	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.1	TOTAL
									ΔNZ									
4	60	34	23	9	14	4	4	1	2	1							1	153
2	178	98	36	24	13	4	1						1	1				356
3	83	41	16	4	4	2	2		2									154
5A	234	165	82	43	21	10	3		2	1	1	2	1					565
1	57	16	8	4	2		1											89
TOTAL	612	354	165	84	54	20	11	1	6	2	1	2	2	1			1	1316

NEGATIVE GUST
OPERATION 991 -- TWIN ENGINE EXECUTIVE

A/C TYPE	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	TOTAL
									ΔNZ								
4	50	34	21	12	6	2	7		4				1				137
2	163	97	44	21	2	6	1										334
3	82	42	15	7	8	2			1								157
5A	243	155	63	41	17	8	5	4		1	1						538
1	54	16	7	2	1	1											81
TOTAL	592	344	150	83	34	19	13	4	5	1	1		1				1247

VGH hr: 1366

POSITIVE GUST
OPERATION 992 -- SINGLE ENGINE EXECUTIVE

A/C TYPE	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	TOTAL
									ΔNZ								
7A	39	53	34	24	13	7	3	2	1								176
9A	118	93	81	69	38	18	3	5	3	1	2	1					432
8	78	73	81	72	57	34	24	13	8	5	3	1			1		450
TOTAL	235	219	196	165	108	59	30	20	12	6	5	2			1		1058

NEGATIVE GUST
OPERATION 992 -- SINGLE ENGINE EXECUTIVE

A/C TYPE	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.2	2.4	TOTAL
									ΔNZ										
7A	45	43	31	27	12	3	4								1				166
9A	116	105	80	42	37	12	7	4	2	2	3		1						411
8	118	95	67	51	41	40	17	10	3	4							1	1	448
TOTAL	279	243	178	120	90	55	28	14	5	6	3		1		1		1	1	1025

TABLE IV. - Continued

VGH hr: 724

POSITIVE GUST
OPERATION 993 -- PERSONAL

									ΔNZ								
A/C TYPE	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	TOTAL
12B	92	52	21	10	1	2	1										179
10A	49	40	18	5	4			1			1						118
11	49	40	15	16	9	5											134
TOTAL	190	132	54	31	14	7	1	1			1						431

NEGATIVE GUST
OPERATION 993 -- PERSONAL

									ΔNZ								
A/C TYPE	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	TOTAL
12B	86	42	23	12	5	1				1							170
10A	42	33	17	6	1	1	1			1							102
11	62	25	18	7	4		1	1	1								119
TOTAL	190	100	58	25	10	2	2	1	1	2							391

VGH hr: 2843

POSITIVE GUST
OPERATION 994 -- INSTRUCTIONAL

									ΔNZ										
A/C TYPE	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.1	3.3	TOTAL
14	184	88	26	13	2		1												314
16A	150	145	82	38	20	10	1	2		2		1					1	1	453
17	77	58	18	9	2														164
15	113	67	35	14	6	2		1		1									239
13	584	252	58	23	8	7	2		1		1	1							937
TOTAL	1108	610	219	97	38	19	4	3	1	3	1	2					1	1	2107

NEGATIVE GUST
OPERATION 994 -- INSTRUCTIONAL

									ΔNZ								
A/C TYPE	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	TOTAL
14	166	89	21	5	1	2	1										285
16A	164	121	73	38	15	5	3	4		1	2					1	428
17	95	44	19	9		1		1									169
15	122	73	27	5	7	5								1			240
13	529	180	48	23	7	2				1							790
TOTAL	1076	507	188	80	30	15	4	5		2	2			1		1	1911

TABLE IV. - Concluded

VGH hr: 2291

POSITIVF GUST
OPERATION 995 -- COMMFRCIAL SURVEY

A/C TYPF	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.2	TOTAL
									ΔNZ									
19	8	9	14	13	7	6	5	1		2	2							67
16A	13	49	84	120	86	90	31	16	3	5	2				1		1	501
9B	15	54	67	55	28	27	12	5	2	4	2		3	1				275
49	9	3	5															17
TOTAL	45	115	170	188	121	123	48	22	5	11	6		3	1	1		1	860

NEGATIVE GUST
OPERATION 995 -- COMMERCIAL SURVEY

A/C TYPF	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.1	2.4	TOTAL
									ΔNZ										
19	9	14	11	7	15	5	2	2	1	2	1			1					70
16A	15	47	49	66	100	71	54	33	23	22	7	5	3	1			1		497
9B	9	30	57	64	44	26	27	9	5	2	1		1					1	276
49	11		1	2															14
TOTAL	44	91	118	139	159	102	83	44	29	26	9	5	4	2			1	1	857

VGH hr: 484

POSITIVF GUST
OPERATION 996 -- AERIAL APPLICATION

A/C TYPF	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	TOTAL
									ΔNZ								
24	34	18	4	1													57
23	16	5	2														23
TOTAL	50	23	6	1													80

NEGATIVE GUST
OPERATION 996 -- AERIAL APPLICATION

A/C TYPE	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	TOTAL
									ΔNZ								
24	43	13	4	1													61
23	4	7				1											12
TOTAL	47	20	4	1		1											73

VGH hr: 1510

POSITIVF GUST
OPERATION 997 -- COMMUTER

A/C TYPE	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	TOTAL
									ΔNZ								
28	164	126	68	40	28	9	10	2	1	2							450
26	320	120	67	45	6	6		2	1		1		1				569
TOTAL	484	246	135	85	34	15	10	4	2	2	1		1				1019

NEGATIVE GUST
OPERATION 997 -- COMMUTER

A/C TYPF	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	TOTAL
									ΔNZ								
28	149	105	72	50	25	20	8	2	5	1	2		1				440
26	344	110	69	21	15	8	2	1	1								571
TOTAL	493	215	141	71	40	28	10	3	6	1	2		1				1011

TABLE V. PROBABILITY OF EXCEEDING MANEUVER DESIGN LOADS IN 10,000 FLIGHT HOURS OF EXTRAPOLATED VGH DATA

Operational Category	Aircraft Category	Design Limit n_z	Design Limit Probability	Design Ultimate n_z	Design Ultimate Probability
Twin-engine Executive	normal	+3.8	.487	+5.7	.017
		-1.52	.000	-2.28	.000
Single-engine Executive	normal	+3.8	.717	+5.7	.031
		-1.52	.315	-2.28	.047
Personal	normal	+3.8	.321	+5.7	.007
		-1.52	.046	-2.28	.004
Instructional	utility	+4.4	.877	+6.6	052
		-1.76	.514	-2.64	.084
Commercial Survey	utility	+4.4	.000	+6.6	.000
		-1.76	.013	-2.64	.004
Aerial Application	normal	+3.8	.850	+5.7	.000
		-1.52	.000	-2.28	.000
Commuter	normal	+3.8	.372	+5.7	.020
		-1.52	.003	-2.28	.000

TABLE VI. PROBABILITY OF EXCEEDING MANEUVER DESIGN LOADS IN 20,000 FLIGHT HOURS OF EXTRAPOLATED VGH DATA

Operational Category	Aircraft Category	Design Limit n_z	Design Limit Probability	Design Ultimate n_z	Design Ultimate Probability
Twin-engine Executive	normal	+3.8	.737	+5.7	.033
		-1.52	.001	-2.28	.000
Single-engine Executive	normal	+3.8	.920	+5.7	.061
		-1.52	.531	-2.28	.092
Personal	normal	+3.8	.538	+5.7	.014
		1.52	.089	-2.28	.007
Instructional	utility	+4.4	.985	+6.6	.101
		-1.76	.764	2.64	.161
Commercial Survey	utility	+4.4	.000	+6.6	.000
		-1.76	.026	-2.64	.007
Aerial Application	normal	+3.8	.978	+5.7	.000
		-1.52	.000	-2.28	.000
Commuter	normal	+3.8	.606	+5.7	.040
		-1.52	.005	-2.28	.000

TABLE VII. PROBABILITY OF EXCEEDING GUST DESIGN LOADS IN 10,000 FLIGHT HOURS OF EXTRAPOLATED VGH DATA

Operational Category	Aircraft Category	Design Limit		Design Ultimate	
		Δn_z	Probability	Δn_z	Probability
Twin-engine Executive	normal	+2.4	.106	+3.6	.002
		-2.4	.065	-3.6	.003
Single-engine Executive	normal	+2.4	.271	+3.6	.001
		-2.4	.188	-3.6	.000
Personal	normal	+2.4	.002	+3.6	.000
		-2.4	.004	-3.6	.000
Instructional	utility	+2.5	.007	+3.75	.000
		-2.5	.009	-3.75	.000
Commercial Survey	utility	+2.5	.516	+3.75	.005
		-2.5	.729	-3.75	.014
Aerial Application	normal	+2.4	.000	+3.6	.000
		-2.4	.000	-3.6	.000
Commuter	normal	+2.4	.709	+3.6	.006
		-2.4	.390	-3.6	.009

TABLE VIII. PROBABILITY OF EXCEEDING GUST DESIGN LOADS IN 20,000 FLIGHT HOURS OF EXTRAPOLATED VGH DATA

Operational Category	Aircraft Category	Design Limit		Design Ultimate	
		Δn_z	Probability	Δn_z	Probability
Twin-engine Executive	normal	+2.4	.201	+3.6	.005
		-2.4	.126	-3.6	.001
Single-engine Executive	normal	+2.4	.468	+3.6	.001
		-2.4	.343	-3.6	.001
Personal	normal	+2.4	.005	+3.6	.000
		-2.4	.007	-3.6	.000
Instructional	utility	+2.5	.015	+3.75	.000
		-2.5	.018	-3.75	.000
Commercial Survey	utility	+2.5	.765	+3.75	.010
		-2.5	.926	-3.75	.029
Aerial Application	normal	+2.4	.000	+3.6	.000
		-2.4	.001	-3.6	.000
Commuter	normal	+2.4	.374	+3.6	.012
		-2.4	.628	-3.6	.017

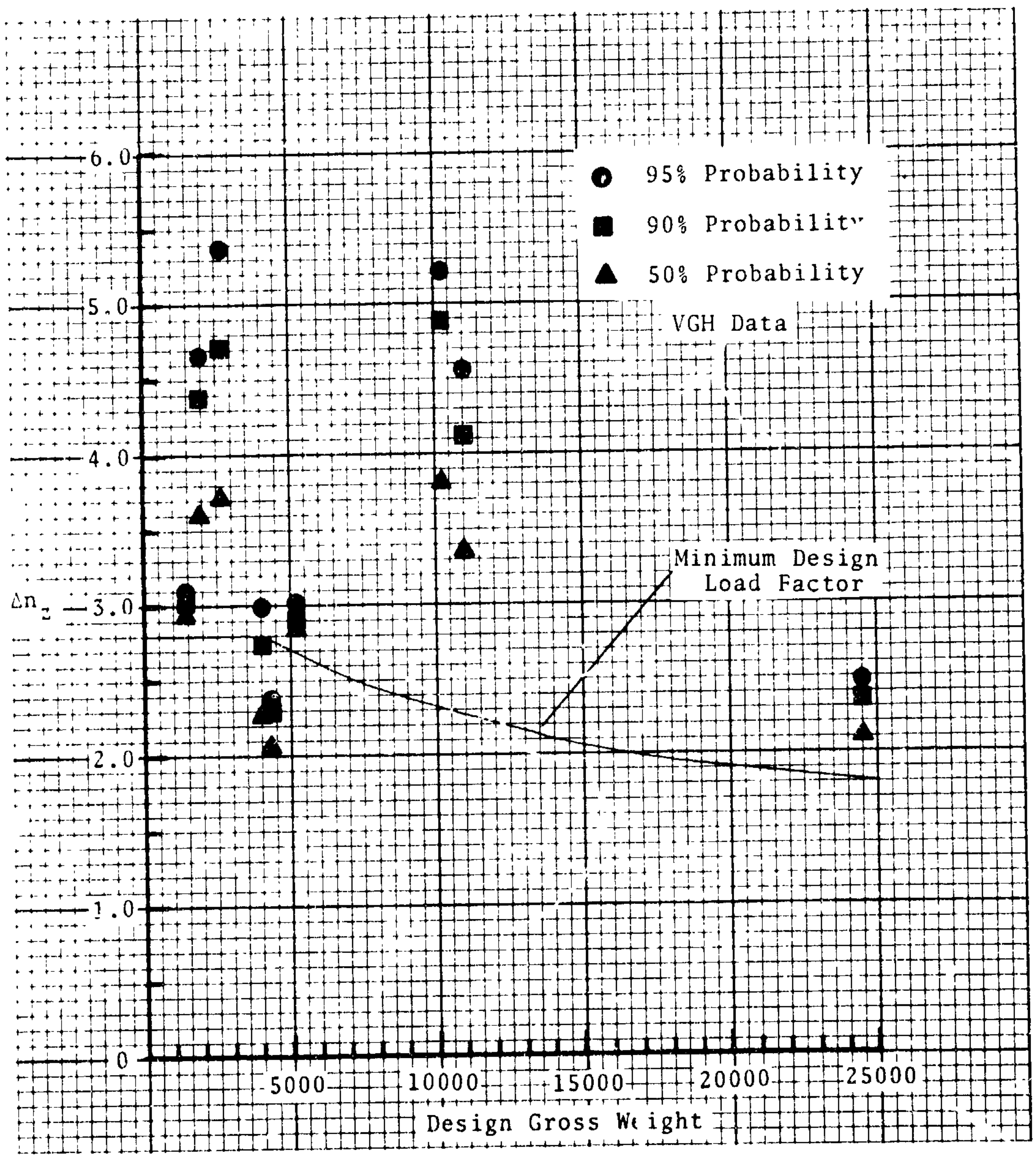


Figure 15. Maneuver Δn_z Versus Design Gross Weight for Three Probability Levels in VGH Data

TABLE IX. MANEUVER LOAD-DESIGN GROSS WEIGHT RELATIONSHIPS DURING 20,000 HOURS OF EXTRAPOLATED VGH DATA

Design Gross Weight (lb)	VGH Data		Probability of Never Exceeding Δn_z		
	Hours	Flights	95%	90%	50%
1,450	1007.1	3117	3.10	3.03	2.94
1,950	310.6	522	4.66	4.38	3.61
2,700	569.1	562	5.37	4.71	3.73
4,000	349.8	582	2.99	2.74	2.27
4,300	1152.8	1578	2.38	2.29	2.07
5,200	309.0	1417	3.03	2.99	2.86
10,250	914.7	3277	5.24	4.89	3.82
11,000	693.0	830	4.56	4.12	3.36
24,500	824.1	731	2.47	2.35	2.12

2.5 Review of Categories

As previously noted, the eight operational categories do not correspond to the FAA aircraft categories, normal, utility, and acrobatic. Although the eight operational categories more closely identify the operational load experiences of the various aircraft, the following analysis indicates the need for their further refinement.

Figures 16-a, 16-b, and 16-c show that both the magnitude and the frequency of the U_{de}'s for the Twin-Engine Executive category are greater in the 1829 to 6096 meters (6,000 to 20,000 ft) altitude range than in the 6,096 to 15,240 meters (20,000 to 50,000 ft) altitude range. Since aircraft flying in these two altitude ranges experience different gust and maneuver loads, the Twin-Engine Executive category should be separated into two categories, one for the higher flying turbojets and the other for the turboprop and piston aircraft.

The examination of the VG data by aircraft type shows that when aircraft in the Single-Engine Executive and Personal categories fly at common airspeeds, their Δn_z's vary little. Although the single-engine executive aircraft can operate at higher airspeeds, the data analysis would not be affected by combining the two categories. Figure 10 shows that the constant probability envelopes for the Personal category are considerably higher than the FAR minimum maneuver load limits for aircraft in the normal aircraft category.

The examination of the VGH data for the Commercial Survey category shows that three of the four aircraft types in this category had very different maneuver load experiences. This suggests further breakdown of the Commercial Survey category by mission type.

2.6 Fatigue Spectra

From the distribution of repeated acceleration peaks recorded in the VGH data, fatigue spectra were derived for three types of load conditions: gust, maneuver, and landing impact. The gust accelerations were converted to derived gust velocity, U_{d_e}. The gust and maneuver n_z peak distributions are presented in Tables X and XI. The landing impact accelerations were normalized by dividing the load factor n_z by 2.67, the minimum design inertia load factor.

2.6.1 Derived Gust Velocity (U_{d_e})

2.6.1.1 U_{d_e} Computations

A derived gust velocity U_{d_e} was computed for each gust acceleration peak in the VGH data by using the following equation:

$$n_z = 1 + \frac{K_g \, U_{d_e} \, V_e a}{498(W/S)}$$

where K_g = subsonic gust alleviation factor = $\frac{0.88\ \mu g}{5.3 + \mu g}$

μg = airplane mass ratio = $\frac{2(W/S)}{\rho \bar{c} a g}$

U_{d_e} = derived gust velocity (fps)

ρ = atmospheric density (slugs/ft^3)

W/S = wing loading (psf)

$\bar{c}$ = mean aerodynamic chord (ft)

g = gravitational constant (ft/sec^2)

V_e = equivalent airspeed (knots)

a = slope of normal force coefficient (1/rad)

TABLE X. MANEUVER LOADS IN VGH DATA BY OPERATIONAL CATEGORY

VGH hr: 3377

OPERATION: TWIN ENGINE EXECUTIVE

n_z POSITIVE ACCELERATION

SPEED (KIAS)	.2	.3	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
LESS	1																	
50			1															
60			1	1														
70			16	1		2												
80	1		36	3	3	1	1											
90			53	14	5	3		1	1									
100	1		71	18	6	7		1										
110	2	1	78	26	14	5	4		2		1				1			
120	32	2	98	31	15	10	7	5	1	2				1	1			
130	63	18	105	38	24	10	7	6	3	5		1						
140	68	16	46	40	25	15	9	7	6	5	1	1	1					
150	64	12	100	27	26	8	7	7	7	1	1							
160	57	10	97	26	17	5	5			1	1							
170	67	13	71	22	11	3	3											
180	68	25	55	21	5	6		1	2									
190	69	22	50	21	4	6	1	2	2	1					2			
200	80	24	48	10	12	4	4	1		2								
210	65	15	[illegible]	28	10	6	3	3	1		1					1		
220	63	26	49	23	17	4	3	1	2									
230	90	26	[illegible]	31	14	10	4	1	1	1	1		1					
240	1[illegible]1	38	57	46	14	8	5		1	1	1				2			2
250	90	16	77	34	17	15	3	1	1				1					
260	73	1	46	30	17	10	2	1	1	2								
270	47	13	61	18	7	4	3	2		2	2	1						
280	36	16	33	14	8	7	1	2	1			1		1				
290	33	9	[illegible]	15	13	2	1	3	1		1	2						
300	35	11	[illegible]	19	11	3	3	1		1		2				1		
310	27	10	36	21	[illegible]		6	1					1					
320	13	5	44	7	6	5	5	4			2							
330	12	6	33	[illegible]	1	7	1		1				1					
340	27	1	22	10	5	2		2										
350	6	1	21	10	3			1										
360	3		9	3		2												
370	2		6	4	1	1												
[illegible]	1		3		2						1	1						
TOTAL	1195	345	1815	892	322	166	88	50	29	24	13	9	5	2	6	2		2

OPERATION: TWIN ENGINE EXECUTIVE

n_z POSITIVE ACCELERATION

SPEED (KIAS)	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	TOTAL
LESS																	1
50																	1
60																	2
70																	19
80																	45
90																	77
100																	104
110																	134
120																	205
130																	286
140																	287
150																	248
160																	217
170																	196
180																	187
190																	189
200																	185
210																	203
220																	205
230																	265
240																	316
250																	273
260																	211
270																	157
280																	132
290																	13[illegible]
300																	122
310																	97
320																	97
330																	64
340			1														53
350																	42
360																	16
370																	14
[illegible]																	8
TOTAL			1														4788

TABLE X. - Continued

OPERATION: TWIN ENGINE EXECUTIVE

Δn_z

NEGATIVE ACCELERATION

VEL. (KIAS)	-.2	-.3	-.4	-.5	-.6	-.7	-.8	-.9	-1.0	-1.1	-1.2	-1.3	-1.4	-1.5	-1.6	-1.7	TOTAL
LESS			4		3												7
50			8	4	2		1										15
60			21	6	1												28
70			7	6	3	1											17
80	1		1	3	2												23
90	3		26	2	3		1										33
100	3	1	30	10	2	2	2	1									51
110	7	1	17	7	1	2	2										37
120	9	2	14	7	1	1											34
130	37	4	16	5	3		3										68
140	36	8	26	2	3		1										76
150	52	3	27	3			3										84
160	50	7	32	2													91
170	46	7	19	3		1											76
180	38	8	22		1	2											71
190	41	9	30		5	1											86
200	23	8	33	2	4	2											72
210	39	5	33	8	3												88
220	41	11	36	4	1												93
230	56	11	39	23	6												135
240	65	9	36	18	3	2	1										137
250	50	7	47	11	7		1										123
260	44	13	36	8	2	1	2										106
270	26	8	30	12		1											77
280	15	8	36	4	1		1										65
290	20	4	29	1	2												56
300	15	13	20	4	5												57
310	[illegible]	5	13	5		1											44
320	11	4	6	2													23
330	3		7	2													12
340	3	1	5	1													10
350	2		4														6
360			1														1
370																	
ABOVE	1																1
TOTAL	757	157	[illegible]	165	64	17	18	1									1903

VGH hr: 1366

OPERATION: SINGLE ENGINE EXECUTIVE

Δn_z

POSITIVE ACCELERATION

VEL. (KIAS)	.2	.3	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	TOTAL
LESS																	
50																	
60			1	1													2
70	5	2	12	10	2												31
80	28	10	28	8	2	2											78
90	78	33	32	14	5	9	2	1	1	1							176
100	17	9	45	23	13	10	3	5	3		1	2	1				132
110	30	6	65	31	10	7	5	6	2	1	2		3				170
120	149	45	97	58	23	13	5	10	1	3	1	5					410
130	30	11	69	36	27	10	2	3	3	3			1				195
140	4	[illegible]	48	20	13	7	6	2	1	2	2					2	107
150		5	34	10	5	6		2		1			1				64
160		1	9	4	2	2	1	1					1	1			22
170				1												1	2
180																	
190																	
200																	
210																	
220																	
230																	
240																	
250																	
260																	
270																	
280																	
290																	
300																	
310																	
320																	
330																	
340																	
350																	
360																	
370																	
ABOVE																	
TOTAL	341	127	430	216	102	66	24	32	11	11	6	7	7	1		3	1384

TABLE X. - Continued

OPERATION: SINGLE ENGINE EXECUTIVE [illegible]

n_z

NEGATIVE ACCELERATION

FLT. (KIAS)	-.2	-.3	-.4	-.5	-.6	-.7	-.8	-.9	-1.0	-1.1	-1.2	-1.3	-1.4	-1.5	-1.6	-1.7	-1.8	-1.9
LESS			[illegible]	1	[illegible]													
50					1		1											
60		[illegible]	[illegible]	1	[illegible]	[illegible]			1									
70	2	[illegible]	[illegible]	5	[illegible]	2												
80	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1												
90	[illegible]	[illegible]	[illegible]	2	1	1		1										
100	[illegible]	[illegible]	[illegible]	[illegible]	2	2	2	1	1									
110	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5	6	[illegible]	2									
120	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4	[illegible]	2									
130	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	1											
140			[illegible]	[illegible]	2	1	2	1										
150			[illegible]	2														
160																		
170																		
180																		
190																		
200																		
210																		
220																		
230																		
240																		
250																		
260																		
270																		
280																		
290																		
300																		
310																		
320																		
330																		
340																		
350																		
360																		
370																		
ABOVE																		
TOTAL	[illegible]	[illegible]		[illegible]	[illegible]	25	16	10	6									

OPERATION: SINGLE ENGINE EXECUTIVE

n_z

NEGATIVE ACCELERATION

FLT. (KIAS)	-2.0	-2.1	-2.2	-2.3	-2.4	-2.5	-2.6	-2.7	-2.8	-2.9	-3.0	-3.1	-3.2	-3.3	-3.4	-3.5	TOTAL
LESS																	[illegible]
50																	[illegible]
60																	13
70																	[illegible]
80																	[illegible]
90																	[illegible]
100																	[illegible]
110																	[illegible]
120				2									1				[illegible]
130																	[illegible]
140																	23
150																	4
160																	
170																	
180																	
190																	
200																	
210																	
220																	
230																	
240																	
250																	
260																	
270																	
280																	
290																	
300																	
310																	
320																	
330																	
340																	
350																	
360																	
370																	
ABOVE																	
TOTAL				2									1				808

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

TABLE X. - Continued

VGH hr: 724

OPERATION: PERSONAL

n_z

POSITIVE ACCELERATION

VEL. (KTAS)	.2	.3	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
LESS			8	1				1										
50			[illegible]	5	4													
60			16	7	[illegible]	1	1											
70			[illegible]	8	[illegible]	5	1	1	1				1					
80			[illegible]	30	12	11	4	2	2									
90			76	40	25	13	7	8	2	1		1			1			
100			61	31	14	7	4	3	1	1	1							
110			[illegible]	7	2	2	3	3	2	1		1						
120			3	[illegible]				1		1								
130			[illegible]	2	3													
140			[illegible]															
150			[illegible]															
160																		
170																		
180																		
190																		
200																		
210																		
220																		
230																		
240																		
250																		
260																		
270																		
280																		
290																		
300																		
310																		
320																		
330																		
340																		
350																		
360																		
370																		
ABOVE																		
TOTAL			[illegible]	136	71	45	20	19	8	4	1	2	1		1			

OPERATION: PERSONAL

n_z

POSITIVE ACCELERATION

VEL. (KTAS)	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	TOTAL
LESS																	10
50																	14
60																	26
70																	59
80																	132
90																	180
100																	123
110																	43
120			1														17
130																	10
140																	1
150																	1
160																	
170																	
180																	
190																	
200																	
210																	
220																	
230																	
240																	
250																	
260																	
270																	
280																	
290																	
300																	
310																	
320																	
330																	
340																	
350																	
360																	
370																	
ABOVE																	
TOTAL			1														616

TABLE X. - Continued

OPERATION PERSONAL

VEL. (KIAS)	-.2	-.3	-.4	-.5	-.6	-.7	-.8	-.9	-1.0	-1.1	-1.2	-1.3	-1.4	-1.5	-1.6	-1.7	TOTAL
							n_z NEGATIVE ACCELERATION										
LESS			53	19	18	6	1										97
50			13	9	3	2											27
60			4	1	[illegible]	1	4			1							21
70			11	5	1		1										18
80			4	3	3	1	3										14
90			12	3	[illegible]	1		1									17
100			[illegible]	2		1	1										10
110																	1
120			1														1
130				1													2
140																	
150																	
160																	
170																	
180																	
190																	
200																	
210																	
220																	
230																	
240																	
250																	
260																	
270																	
280																	
290																	
300																	
310																	
320																	
330																	
340																	
350																	
360																	
370																	
ABOVE TOTAL			109	43	33	12	10	1		1							208

VGH hr: 2843

OPERATION INSTRUCTIONAL

VEL. (KIAS)	.2	.3	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
							n_z POSITIVE ACCELERATION											
LESS		5	526	210	107	45	20	8	7	10	3	2	3					
50		1	314	157	90	56	39	23	14	7	9	3	2	1			2	1
60		2	824	346	176	114	67	43	34	19	16	11		8	5	1	1	
70		9	1157	503	273	160	109	79	54	26	29	17	8	7	3			
80		5	1023	461	254	162	122	60	46	31	22	11	7	7	4	2	2	
90		7	580	307	182	112	59	44	39	16	12	13	8	4	5	3	1	2
100			99	87	63	36	25	20	13	10	8	4	4	5	1	2		1
110			12	16	13	6	11	6	5	3	1	3	3	3	4	2	1	1
120					2	[illegible]	1	2	1	1	1		2	1	2			
130								1							1			1
140			1						1									
150																		
160																		
170																		
180																		
190																		
200																		
210																		
220																		
230																		
240																		
250																		
260																		
270																		
280																		
290																		
300																		
310																		
320																		
330																		
340																		
350																		
360																		
370																		
ABOVE TOTAL		34	4526	2087	1170	633	448	286	214	123	101	64	37	36	25	9	9	9

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

TABLE X. - Continued

OPERATION: INSTRUCTIONAL

Δn_z

VEL. (KIAS)	POSITIVE ACCELERATION 2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	TOTAL
LESS																	944
50																	723
60	1																1663
70																	2434
80																	2229
90		4		1	1		1										1395
100			1							1							370
110	1	2	1					1	1			1					100
120	2																17
130							1										4
140												1					3
150																	
160																	
170																	
180																	
190																	
200																	
210																	
220																	
230																	
240																	
250																	
260																	
270																	
280																	
290																	
300																	
310																	
320																	
330																	
340																	
350																	
360																	
370																	
ABOVE																	
TOTAL	4	6	2	1	1		2	1	1	1		2					9882

OPERATION: INSTRUCTIONAL

Δn_z

VEL. (KIAS)	NEGATIVE ACCELERATION -.2	-.3	-.4	-.5	-.6	-.7	-.8	-.9	-1.0	-1.1	-1.2	-1.3	-1.4	-1.5	-1.6	-1.7	-1.8	-1.9	TOTAL
LESS		10	1438	835	379	137	48	11	9	1		1					1	1	2871
50		1	276	105	63	10	4	1	2	1				2	1				465
60	1	3	270	107	56	20	10	6	5	2	1		1					1	483
70		1	438	169	90	48	26	23	18	14	3	5	1	2	6				849
80		2	400	181	108	52	33	19	21	10	2	5		1					834
90			116	56	25	23	11	4	4		2	2	1	1		3			248
100			17	4	7	2			1				1				1		33
110				1															1
120																			
130																			
140																			
150																			
160																			
170																			
180																			
190																			
200																			
210																			
220																			
230																			
240																			
250																			
260																			
270																			
280																			
290																			
300																			
310																			
320																			
330																			
340																			
350																			
360																			
370																			
ABOVE																			
TOTAL	1	17	2955	1458	728	292	132	69	60	28	8	13	4	6	7	3	2	2	5784

TABLE X. - Continued

VGH hr: 2291

OPERATION: COMMERCIAL SURVEY

Δn_z

POSITIVE ACCELERATION

VEL. (KIAS)	.2	.3	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
LESS			9	6	24	19	21	13	13	5	2	1						
50			11	17	32	34	30	20	15	14	8	1		1				
60			144	153	356	463	434	395	253	161	69	28	6	2				
70	1	[illegible]	1071	1447	1737	1984	1931	1581	1132	603	309	120	33	7	7	5	1	
80		9	2031	2323	1718	1344	1012	682	383	196	67	34	21	13	7	3	3	
90			516	175	263	156	78	44	36	9	9	6	6	9	4	3	7	1
100	4		223	150	96	65	41	34	28	18	11	4	3	2	3	2	3	
110	21	4	124	130	72	55	[illegible]	40	24	22	15	6	7	4	6	2	5	
120	223	71	[illegible]	82	61	38	34	34	30	17	17	12	7	7	3	9	4	
130	436	137	89	51	36	24	13	15	9	12	14	17	13	9	7	8	4	5
140	481	197	71	51	31	17	19	11	5	8	3	12	9	6	2	3	6	4
150	983	230	94	39	22	14	7	5	5	2	6	5	4	1		1	1	
160	297	176	[illegible]	34	26	10	15	16	10	10	12	9	5	2	3			
170	467	226	57	48	34	12	9	13	10	11	9	6	4	4	1	1	1	
180	232	145	67	17	15	9	5	17	10	11	12	8	5	4	1	2	1	
190	89	42	14	13	15	7	8	8	3		13	6	2	5	2	3	1	
200	31	11	9	6	2	5		1		2	4	10	3	7	1	2	1	
210	9	6	8	2	4		2		1	1	9	4	2	3	2	2	2	6
220	12	5	3		4	4	1		3					1			6	5
230		1	2	1		1					2							2
240	2								2									1
250	1					1		1										
260																		
270																		
280																		
290																		
300																		
310																		
320																		
330																		
340																		
350																		
360																		
370																		
ABOVE																		
TOTAL	3661	1247	4754	4765	4529	4266	3703	2930	2007	1101	589	291	129	87	51	43	45	25

OPERATION: COMMERCIAL SURVEY

Δn_z

POSITIVE ACCELERATION

VEL. (KIAS)	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	TOTAL
LESS																		113
50																		224
60																		2613
70																		11921
80																		9551
90	1																	1525
100	1																	740
110	2	1			1													587
120	3	2	2	1		1	3		1						1			750
130	3	1	3	1	2	1	2	1										880
140	4	4	5		3	2	2	2	2	2		1						945
150	4			2		2	1		2			1		2				1337
160										2					1			1197
170																1	1	907
180	1																	567
190	1					1												235
200	1																	96
210	1					1												64
220						3			1									48
230			2						1	1								13
240																		5
250																		3
260																		
270																		
280																		
290																		
300																		
310																		
320																		
330																		
340																		
350																		
360																		
370																		
ABOVE																		
TOTAL	22	8	12	4	6	11	8	3	7	5		2		2	2	1	1	34316

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

TABLE X. - Continued

OPERATION: COMMERCIAL SURVEY

Δn_z

NEGATIVE ACCELERATION

VEL. (KIAS)	-.2	-.3	-.4	-.5	-.6	-.7	-.8	-.9	-1.0	-1.1	-1.2	-1.3	-1.4	-1.5	-1.6	-1.7	TOTAL
LESS			8	4	1			1									14
50			3	1	1												5
60			19		4			1			1						25
70			16	11	1	1			3								32
80			22	10			1	1	1	3							39
90			31	4	5		2	1	1			1					45
100			29	11	6	1			1								47
110	5		26	9													40
120	44	9	9	4	1	2											68
130	108	22	16	19	1		2										166
140	179	58	22	10		2	1										272
150	316	36	31	10	?	2											396
160	421	70	21	14	5		2										533
170	77	16	14	2				1									130
180	55	5	3	3	2												68
190	21	10	5	1		2											39
200	5	6	.														20
210	1	5	1	1	3												11
220	2																2
230																	
240																	
250																	
260																	
270																	
280																	
290																	
300																	
310																	
320																	
330																	
340																	
350																	
360																	
370																	
ABOVE																	
TOTAL	[illegible]	[illegible]	270	105	37	10	8	5	6	3	1	1					1951

VGH hr: 484

OPERATION: AERIAL APPLICATION

Δn_z

POSITIVE ACCELERATION

VEL. (KIAS)	.2	.3	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
LESS																		
50		1	5	2	1		2	1								1		
60		2	520	387	249	116	68	24	5	3	2				1			
70		1	3509	3050	2479	1878	1394	777	362	188	83	26	16	9	4	2		
80		7	3536	3582	3394	3013	2684	2342	1991	1350	873	561	332	207	94	38	19	8
90		2	1107	1277	1479	1650	1837	1733	1515	1430	1221	1019	756	547	331	219	131	78
100			64	67	53	65	70	84	85	87	62	65	65	61	51	39	33	23
110			3		1	1	1	2	1	2	1	3			1	2		
120																		
130																		
140																		
150			98	125	134	146	124	100	112	92	100	57	50	71	28	25	11	9
160						1												
170																		
180																		
190																		
200																		
210																		
220																		
230																		
240																		
250																		
260																		
270																		
280																		
290																		
300																		
310																		
320																		
330																		
340																		
350																		
360																		
370																		
ABOVE																		
TOTAL		13	8632	8490	7790	6870	6180	5063	4071	3152	2342	1731	1219	895	540	326	194	118

TABLE X. - Continued

OPERATION: AERIAL APPLICATION Δn_z

POSITIVE ACCELERATION

VEL. (KIAS)	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	TOTAL
LESS																	
50																	13
60																	1377
70																	13778
80	1	2															24034
90	27	11	5	3	1												16409
100	18	11	6	4	1												1014
110			1		1												20
120																	
130																	
140																	
150	3																1275
160																	1
170																	
180																	
190																	
200																	
210																	
220																	
230																	
240																	
250																	
260																	
270																	
280																	
290																	
300																	
310																	
320																	
330																	
340																	
350																	
360																	
370																	
ABOVE																	
TOTAL	49	24	12	7	3												57921

OPERATION: AERIAL APPLICATION Δn_z

NEGATIVE ACCELERATION

VEL. (KIAS)	-.2	-.3	-.4	-.5	-.6	-.7	-.8	-.9	-1.0	-1.1	-1.2	-1.3	-1.4	-1.5	-1.6	-1.7	-1.8	-1.9	TOTAL[1]
LESS					1														1
50			10	8	5	4		1											28
60			135	62	40	29	12	3											280
70	1	4	1221	857	791	740	628	295	82	19	2							1	4641
80		6	1960	1410	1299	1128	1093	679	334	97	10					1			8024
90		3	512	400	304	243	231	173	128	65	19		1						2079
100			20	13	12	9	8	9	6	1									92
110			1																1
120			1																1
130																			
140							1												1
150			103	76	51	56	61	38	8										363
160																			
170																			
180																			
190																			
200																			
210																			
220																			
230																			
240																			
250																			
260																			
270																			
280																			
290																			
300																			
310																			
320																			
330																			
340																			
350																			
360																			
370																			
ABOVE																			
TOTAL	1	13	[illegible]	2821	2502	2208	2034	1198	558	182	31		1			1		1	[illegible]

TABLE X. - Concluded

VGH hr: 1510

OPERATION: COMMUTER

Δn_z

VEL. (KIAS)	POSITIVE ACCELERATION .2	.3	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	TOTAL
LESS																	
50																	
60			1														1
70			5		1												6
80			9	1	1												11
90		2	17	6	1	2											28
100			32	3	2	2		1									40
110			14	4	2	2		1		1							24
120			18	4	3	2		1	1	1					1		31
130			35	8	3	4			1				2		1		54
140			32	12	5	4	2			2	1	1			1		60
150			24	1	3		1	2									31
160			10	1	1	1	1										14
170			7	5	1									1			14
180			2	1	1		5					1					10
190			5	4													9
200			1		1												2
210			1														1
220																	
230						1											1
240																	
250																	
260																	
270																	
280																	
290																	
300																	
310																	
320																	
330																	
340																	
350																	
360																	
370																	
ABOVE																	
TOTAL		2	213	50	25	18	9	5	2	4	1	2	2	1	3		337

OPERATION: COMMUTER

Δn_z

VEL. (KIAS)	NEGATIVE ACCELERATION -.2	-.3	-.4	-.5	-.6	-.7	-.8	-.9	-1.0	-1.1	-1.2	-1.3	-1.4	-1.5	-1.6	-1.7	TOTAL
LESS																	
50				1													1
60				1	1												2
70			1	1	1												3
80			7	2													9
90			24	2	3												29
100			22	4		3	1										30
110			8		1	3											12
120			4	2		2											8
130			7	3	2			1									13
140			8	2	1		2										13
150			2	3		1											6
160																	
170			1														1
180																	
190																	
200																	
210			1														1
220																	
230																	
240																	
250																	
260																	
270																	
280																	
290																	
300																	
310																	
320																	
330																	
340																	
350																	
360																	
370																	
ABOVE																	
TOTAL			85	21	9	9	3	1									128

TABLE XI. GUST LOADS IN VGH DATA BY OPERATIONAL CATEGORY

VGH hr: 3377

OPERATION: TWIN ENGINE EXECUTIVE

Δn_z

POSITIVE ACCELERATION

VEL. (KIAS)	.2	.3	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	TOTAL
LESS																	
50	1																1
60	1		1			1											3
70	1		9			1											11
80		1	16	1	2												20
90	1	1	54	4	2												62
100	3	1	40	18	3	3	2										70
110	19	2	179	46	20	12	1										279
120	52	10	208	52	16	8	1	1	1								349
130	107	22	311	96	35	6	4	1	1	1		1					585
140	95	14	539	211	74	26	10	3	3		2	1					978
150	96	20	794	352	146	56	25	10	3	1				1	1		1505
160	117	21	1147	394	151	50	28	12			4		1	1			1926
170	131	32	741	284	122	33	7	3	1		1						1355
180	141	28	224	80	26	9	3	1									512
190	158	28	155	35	13			1	1								391
200	173	48	109	38	3	5	2	1	1								380
210	192	31	73	13	5												314
220	221	44	52	12	6	3	1										339
230	265	70	81	27	6	4											453
240	291	78	137	31	5	7	1										550
250	247	54	112	35	8	3	1	2									462
260	218	63	87	20	10	10	1	1									410
270	198	24	77	39	7	3	1	1							1		351
280	184	18	51	19	10	2	2										286
290	214	37	47	14	4	1											317
300	133	25	33	18	2		1	1	1								214
310	108	27	36	19	6	2	2										200
320	54	22	34	4	5	8	1										128
330	28	7	33	3	7	4	3										85
340	23	3	28	11	2	3	1										71
350	5	1	7	2		1											16
360			8		2												10
370			2														2
ABOVE																	
TOTAL	3477	732	5425	1878	698	261	98	38	12	2	7	2	1	2	2		12635

OPERATION: TWIN ENGINE EXECUTIVE

Δn_z

NEGATIVE ACCELERATION

VEL. (KIAS)	-.2	-.3	-.4	-.5	-.6	-.7	-.8	-.9	-1.0	-1.1	-1.2	-1.3	-1.4	-1.5	-1.6	-1.7	TOTAL
LESS	1																1
50																	
60				1													1
70			4														4
80			14	2	1												17
90	2		43	5	3		1										54
100	2	1	112	37	10	1					1						164
110	10		107	36	14	3	1										171
120	37	8	110	28	6	4			1								194
130	57	11	279	72	32	3	4		4	1							463
140	72	14	450	183	76	27	5	2	2						1		832
150	70	26	717	334	134	41	19	9	6	2	1	1					1360
160	100	33	853	389	126	53	17	10	5	1	3		1				1591
170	117	32	614	222	63	31	9	4	2								1094
180	91	37	217	67	12	5		1									430
190	136	60	134	59	6	2	1	1									399
200	126	49	83	32	10	4	4										308
210	182	62	76	22	9	1	1										353
220	222	47	60	17	5	2											[illegible]
230	151	29	94	26	8	2											310
240	247	69	56	25	8	1	2										418
250	220	44	59	18	2	5											349
260	201	64	78	30	6	2											381
270	163	15	97	31		4		3									322
280	160	25	66	17	3			2									73
290	186	42	56	16	5												305
300	91	35	50	18	2	1											187
310	84	22	43	18	5	1		1									174
320	49	21	33	16	5	4		1									129
330	25	11	25	4	2	1	1										69
340	19	5	27	17	9	2	2		4								82
350	3	1	4	2	1												11
360	1	1	[illegible]	2	[illegible]												16
370																	
ABOVE																	
TOTAL	2815	754	4573	1746	565	200	67	34	21	4	5	1	1		1		10793

TABLE XI. - Continued

VGH hr: 1366

OPERATION: SINGLE ENGINE EXECUTIVE

Δn_z

POSITIVE ACCELERATION

VEL. (KIAS)	.2	.3	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	TOTAL
LESS			5	1	2													8
50			3	2	2													7
60		1	7	1														9
70	6	5	30	15	5	1												62
80	44	11	143	32	11	3	4											248
90	67	32	421	121	31	9	2	2					1					686
100	12	27	617	187	47	13	6	4	1									914
110	156	114	1721	648	224	87	33	12	3	1	1		2					3002
120	268	229	3377	1291	407	1[illegible]6	69	22	7	6	2	1		1				[illegible]
130	39	144	2249	1098	359	144	43	28	9	5	2		1	1			1	4122
140	3	99	2289	1177	449	177	79	29	13	4	6							4315
150		17	1906	1117	431	234	93	45	19	14	5	5	3					[illegible]
160			520	305	131	53	26	16	6	3	3	1						1064
170			15	4	5	2	2	2	1									31
180																		
190																		
200																		
210																		
220																		
230			1															
240																		
250																		
260																		
270																		
280																		
290																		
300																		
310																		
320																		
330																		
340																		
350																		
360																		
370																		
ABOVE																		
TOTAL	535	663	13306	5330	2133	920	357	160	59	33	19	7	7	2			1	[illegible]

OPERATION. SINGLE ENGINE EXECUTIVE

Δn_z

NEGATIVE ACCELERATION

VEL. (KIAS)	-.2	-.3	-.4	-.5	-.6	-.7	-.8	-.9	-1.0	-1.1	-1.2	-1.3	-1.4	-1.5	-1.6	-1.7	-1.8	-1.9
LESS			1															
50																		
60			7	2														
70	13	4	29	9	2	2												
80	42	14	130	31	8	1												
90	67	36	334	134	39	18	6					1						
100	31	31	876	232	88	24	10	4			1							
110	153	109	2022	669	212	80	26	13	6	3	1		1					
120	166	99	1644	567	223	74	40	12	4	3	1	1	1		1			
130	38	94	1717	588	179	64	35	8	3	1			1				1	
140		41	1753	912	319	157	60	21	7	3	2	3						
150		12	1531	952	379	183	90	46	14	6	[illegible]	1						
160		1	432	248	108	42	21	10	4	4								
170			21	9	5	3												
180																		
190																		
200																		
210																		
220																		
230																		
240																		
250																		
260																		
270																		
280																		
290																		
300																		
310																		
320																		
330																		
340																		
350																		
360																		
370																		
ABOVE																		
TOTAL	510	441	10497	4353	1562	648	[illegible]88	114	38	20	6	6	3		1		1	

TABLE XI. - Continued

OPERATION SINGLE ENGINE EXECUTIVE

n_z

VEL. (KTAS)	-2.0	-2.1	-2.2	-2.3	-2.4	-2.5	-2.6	-2.7	-2.8	-2.9	-3.0	-3.1	-3.2	-3.3	-3.4	-3.5	TOTAL
								NEGATIVE ACCELERATION									
LESS																	1
50																	
60																	9
70																	59
80																	[illegible]
90																	635
100																	1247
110																	[illegible]
120																	[illegible]
130																	[illegible]
140					1												[illegible]
150																	[illegible]
160																	[illegible]
170																	[illegible]
180																	
190																	
200																	
210																	
220																	
230																	
240																	
250																	
[illegible]																	
TOTAL					1												[illegible]

VGH hr: 724

OPERATION PERSONAL

n_z

VEL. (KTAS)	.2	.3	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	TOTAL
								POSITIVE ACCELERATION									
LESS			[illegible]	4	1	1											14
50			[illegible]	3	1												11
60			[illegible]	7	[illegible]	1	1	1		1							33
70			[illegible]	6	4	[illegible]											[illegible]
80		[illegible]	[illegible]	[illegible]	[illegible]	5		1									386
90			[illegible]	145	[illegible]	5	3										752
100			[illegible]	84	[illegible]	3	1	1	1								487
110			[illegible]	[illegible]	23	[illegible]	4	1									[illegible]
120		[illegible]	34	[illegible]	[illegible]	13	6	2									[illegible]
130		[illegible]	24	[illegible]	[illegible]	9	6	2									350
140			[illegible]	9	1	3		1									43
150			[illegible]			1											[illegible]
160																	
170																	
180																	
190																	
200																	
210																	
[illegible]																	
TOTAL		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9	1	1							[illegible]

TABLE XI. - Continued

n_z

NEGATIVE ACCELERATION

[illegible]	-.2	-.3	-.4	-.5	-.6	-.7	-.8	-.9	-1.0	-1.1	-1.2	-1.3	-1.4	-1.5	-1.6	-1.7	TOTAL
[illegible]			[illegible]	9	[illegible]	1											15
[illegible]			[illegible]														3
[illegible]			[illegible]	3													16
[illegible]			[illegible]	[illegible]		1											[illegible]
[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	1										[illegible]
[illegible]		1	[illegible]	[illegible]	[illegible]	8	[illegible]	[illegible]									[illegible]
[illegible]			[illegible]	[illegible]	43	10	[illegible]		1								534
[illegible]		2	[illegible]	[illegible]	[illegible]	11	3			1							[illegible]
[illegible]			[illegible]	38	[illegible]	5	1	1	1		[illegible]						[illegible]
[illegible]			[illegible]	[illegible]	13	2											[illegible]
[illegible]			[illegible]	8	4												30
[illegible]			[illegible]														1
TOTAL		1	[illegible]	[illegible]	[illegible]	43	12	3	2	1	1						[illegible]

VGH hr: 2843

n_z

POSITIVE ACCELERATION

[illegible]	.2	.3	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
[illegible]		1	[illegible]	[illegible]	[illegible]	[illegible]	3	[illegible]			1			[illegible]				
[illegible]			[illegible]	[illegible]	15	11	[illegible]	[illegible]				[illegible]						
[illegible]		[illegible]	[illegible]	173	[illegible]	1	[illegible]	2	1			1						
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7	1		1							
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14	7	1	3				1				
[illegible]		3	[illegible]	[illegible]	[illegible]	[illegible]	7	[illegible]		2			1					
[illegible]			[illegible]	[illegible]	[illegible]		1					1						
[illegible]			24	[illegible]	[illegible]													
[illegible]			3			1												
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	50	29	3	5	2	3	1	2				

TABLE XI. - Continued

OPERATION: INSTRUCTIONAL

ALT. (KIAS)	POSITIVE ACCELERATION 2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	TOTAL
LESS																	86
50																	183
60																	1103
70																	2921
80																	3527
90		2												1			1167
100																	220
110																	30
120																	4
130																	
140																	
150																	
160																	
170																	
180																	
190																	
200																	
210																	
220																	
230																	
240																	
250																	
260																	
270																	
280																	
290																	
300																	
310																	
320																	
330																	
340																	
350																	
360																	
370																	
ABOVE																	
TOTAL		2												1			9241

OPERATION: INSTRUCTIONAL

ALT. (KIAS)	NEGATIVE ACCELERATION -.2	-.3	-.4	-.5	-.6	-.7	-.8	-.9	-1.0	-1.1	-1.2	-1.3	-1.4	-1.5	-1.6	-1.7	-1.8	-1.9	TOTAL
LESS			87	39	13	6	2	1											148
50			91	15	4	2													112
60		2	688	115	29	5				1									943
70		9	1979	444	92	34	9	4		1		2	1						2575
80		12	2198	637	188	71	21	9	4	1			1	1				1	3146
90		3	785	262	84	30	12	3	2	2				2	1	1	1		1188
100			153	66	10	2	1	1											233
110			15	6	4	1													26
120			2	1															3
130																			
140																			
150				1															1
160																			
170																			
180																			
190																			
200																			
210																			
220																			
230																			
240																			
250																			
260																			
270																			
280																			
290																			
300																			
310																			
320																			
330																			
340																			
350																			
360																			
370																			
ABOVE																			
TOTAL		26	5998	1589	424	151	45	18	6	5		2	2	3	1	1	1	1	8273

TABLE XI. - Continued

VGH hr: 2291

OPERATION COMMERCIAL SURVEY

n_z

POSITIVE ACCELERATION

VELO KNOTS	.2	.3	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
LESS			34	17	4													
50		1	[illegible]	[illegible]	14	[illegible]	1	[illegible]	1									
60			77	470	12	60	15	4										
70		7	477	2731	1101	411	149	52	24	5	1							
80	3	33	[illegible]	[illegible]	[illegible]	3221	737	170	24	11	[illegible]	3	2		1			
90	2	118	[illegible]	7744	[illegible]	968	163	41	15	7	3	4	2		1			
100		2	[illegible]	357	243	71	36	25	10	5	1	[illegible]						
110				[illegible]	[illegible]	[illegible]	[illegible]	29	[illegible]	5	4	[illegible]	1		1	[illegible]		
120	[illegible]		[illegible]	[illegible]	34	35	12	2	[illegible]	1		[illegible]						
130	[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	6	[illegible]	[illegible]			[illegible]						
140	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2	2	1								
150	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	2		[illegible]				1					
160	51	[illegible]	[illegible]	[illegible]	9	[illegible]						1						
170	[illegible]	[illegible]	[illegible]	7	3	[illegible]		1										
180	[illegible]	[illegible]	6	1	4													
190	79	15	1		1													
200	[illegible]	8																
210	[illegible]	[illegible]	[illegible]															
220	4	7	[illegible]															
230	[illegible]	2																
240		1																
250																		
260																		
270																		
280																		
290																		
300																		
310																		
320																		
330																		
340																		
350																		
360																		
370																		
ABOVE																		
TOTAL	350	349	[illegible]	[illegible]	16953	4963	1177	342	91	39	11	14	6		3	1		

OPERATION COMMERCIAL SURVEY

n_z

POSITIVE ACCELERATION

VELO KNOTS	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	TOTAL
LESS																	55
50																	205
60																	1460
70																	9700
80																	47092
90																	54303
100																	5463
110																	2031
120																	868
130																	320
140																	272
150																	152
160																	128
170																	160
180																	92
190																	46
200																	18
210																	22
220																	13
230																	3
240																	2
250																	
260																	
270																	
280																	
290																	
300																	
310																	
320																	
330																	
340																	
350																	
360																	
370																	
ABOVE																	
TOTAL			1														141417

TABLE XI. - Continued

OPERATION COMMERCIAL SURVEY

n_z

VEL. (KIAS)	-.2	-.3	-.4	-.5	-.6	-.7	-.8	-.9	-1.0	-1.1	-1.2	-1.3	-1.4	-1.5	-1.6	-1.7	-1.8	-1.9
						NEGATIVE ACCELERATION												
LESS			22	13	6	1		1										
50			65	39	12	9	1	1										
60			470	262	88	40	12	7										
70	1	14	3529	2112	868	358	144	37	26	4	2	3	2					
80		101	24878	17796	7511	3425	1274	527	225	70	19	16	4	3	2			
90		71	23337	17556	9684	4253	1734	619	247	99	41	17	8	2	2	1		
100		5	5028	2263	994	406	185	75	34	6	6	1						
110		1	1992	877	313	147	58	20	11	6	5	1	2		1	1		
120	2		143	61	33	3	5	1	2									
130		1	225	92	26	6	3					1						
140	9	6	153	65	23	7	9	3		1								
150	71	13	55	22	10	6	2	2										
160	117	40	20	9	1	2		1										
170	76	18	12	2	1	3	1											
180	23	5	2	3														
190	26	10	2															
200	14	2	5	2														
210	2	5		2														
220	3	1	1															
230	4	2									2						2	
240		1																
250																		
260																		
270																		
280																		
290																		
300																		
310																		
320																		
330																		
340																		
350																		
360																		
370																		
ABOVE																		
TOTAL	340	295	54046	41175	19560	[illegible]	3428	1294	548	186	75	39	16	5	5	2	2	

OPERATION COMMERCIAL SURVEY

n_z

VEL. (KIAS)	-2.0	-2.1	-2.2	-2.3	-2.4	-2.5	-2.6	-2.7	-2.8	-2.9	-3.0	-3.1	-3.2	-3.3	-3.4	-3.5	TOTAL
							NEGATIVE ACCELERATION										
LESS																	43
50																	127
60																	873
70																	7100
80					1												55675
90		4															57681
100																	9396
110																	3435
120																	260
130																	356
140																	276
150																	181
160																	194
170																	112
180																	33
190																	38
200																	23
210																	9
220																	7
230																	7
240																	1
250																	
260																	
270																	
280																	
290																	
300																	
310																	
320																	
330																	
340																	
350																	
360																	
370																	
ABOVE																	
TOTAL		4			1												134600

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

TABLE XI. - Continued

VGH hr: 484

OPERATION: AERIAL APPLICATION

n_z

POSITIVE ACCELERATION

VEL. (KIAS) LESS	.2	.3	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	TOTAL
50																	6
60			[illegible]	1													67
70			[illegible]	12	[illegible]	1											111
80			[illegible]	15	[illegible]												30
90			[illegible]	4	[illegible]												9
100			[illegible]	2	[illegible]												1[illegible]
110			[illegible]														
120																	
130																	
140																	
150																	
160																	
170																	
180																	
190																	
200																	
210																	
220																	
230																	
240																	
250																	
260																	
270																	
280																	
290																	
300																	
310																	
320																	
330																	
340																	
350																	
360																	
370																	
[illegible]																	
TOTAL			[illegible]	[illegible]	[illegible]	[illegible]											[illegible]

OPERATION: AERIAL APPLICATION

n_z

NEGATIVE ACCELERATION

VEL. (KIAS) LESS	-.2	-.3	-.4	-.5	-.6	-.7	-.8	-.9	-1.0	-1.1	-1.2	-1.3	-1.4	-1.5	-1.6	-1.7	TOTAL
50																	
60			[illegible]														6
70			46	10	1	1		1									53
80		1	74	13	2												95
90			11	4	1												16
100			[illegible]														3
110																	
120																	
130																	
140																	
150																	
160																	
170																	
180																	
190																	
200																	
210																	
220																	
230																	
240																	
250																	
260																	
270																	
280																	
290																	
300																	
310																	
320																	
330																	
340																	
350																	
360																	
370																	
[illegible]																	
TOTAL		1	[illegible]	[illegible]	4	1		1									[illegible]

TABLE XI. - Concluded

VGH hr: 1510

OPERATION: COMMUTER

Δn_z

VEL. (KIAS)	POSITIVE ACCELERATION .2	.3	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	TOTAL
LESS																	
50			1														1
60			2	1													3
70			2														2
80			7	2													9
90			14	2	1												17
100			11	2		1											14
110			30	12	3	3							1				49
120			116	39	12	4				2					1		174
130		2	262	58	22	11	4	1	1	1			1				363
140		2	549	101	44	26	5	4	1	1	1						734
150		2	368	96	43	18	4	2	1								534
160			171	57	17	12	3	2									262
170			220	86	36	15	4	3	3	1		1					369
180			432	167	55	19	16	5	3	1	1	1					700
190			590	223	62	16	6	2	1								900
200			153	77	34	11	9	4	5		1	1					295
210			37	19	7	3		2									68
220																	
230			3														3
240																	
250																	
260																	
270																	
280																	
290																	
300																	
310																	
320																	
330																	
340																	
350																	
360																	
370																	
ABOVE																	
TOTAL		6	2268	942	336	139	51	25	15	6	3	3	2		1		4497

OPERATION: COMMUTER

Δn_z

VEL. (KIAS)	NEGATIVE ACCELERATION -.2	-.3	-.4	-.5	-.6	-.7	-.8	-.9	-1.0	-1.1	-1.2	-1.3	-1.4	-1.5	-1.6	-1.7	TOTAL
LESS																	
50																	
60																	
70				2													2
80				1													1
90			4	1	2	1											8
100			21	6	3												30
110			41	13	4	3	2	2									65
120		1	55	14	8	2											80
130		3	245	49	30	7	1	1									336
140		2	532	112	49	14	10	4	2	1	1						727
150		2	377	109	35	11	5	3									542
160			155	61	19	8	1		1								244
170			221	91	34	12	8	5	1	2							374
180			348	182	62	29	12	9	3	1	2						648
190			555	244	105	36	15	5	5		1		2		1		969
200			132	80	31	20	4	7	1		2						277
210			22	6	2							1					31
220			2														2
230				2													2
240																	
250																	
260																	
270																	
280																	
290																	
300																	
310																	
320																	
330																	
340																	
350																	
360																	
370																	
ABOVE																	
TOTAL		8	2710	923	383	143	58	36	13	4	6	1	2		1		4338

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

The values of V_e and σ were computed from the mid-values of the 10-knot indicated airspeed interval and the 2000-foot pressure altitude interval containing the recorded data at the gust acceleration peak. The aircraft weight was assumed to be constant for each instrumented aircraft and was set equal to a normal operating weight estimated by the operator.

In the analysis of derived gust data computed from recorded c.g. vertical accelerations, it is important to note that (1) the relation between Δn_z and U_{de} is inversely proportional to V_e so that the effects of inaccuracies in Δn_z measurements are magnified in U_{de} values at very low airspeeds, and (2) since the Δn_z measurements were not taken inside the digitizing thresholds (± 0.4g for most aircraft), the corresponding U_{de} values omitted were as large as 14 to 17 feet per second for the various operations so that the validity of the presented U_{de} spectrum is limited to the range outside approximately ± 16 feet per second. Table XII presents the calculated U_{de} peaks with a breakdown by operational category and airspeed range.

2.6.1.2 U_{de} Spectra

The cumulative frequencies of positive and negative U_{de} peaks per nautical mile are presented in Figure 16 for the seven operational categories represented by the VGH data. The low altitude spectra for 0 to 1829 meters (0 to 6000 ft) in Figure 16-a were most severe for the Commercial Survey category and least severe for the Aerial Application category. The middle altitude spectrum for 1829 to 6096 meters (6,000 to 20,000 ft) in Figure 16-b were relatively closely grouped with the Commercial Survey category having the most severe spectrum. As shown in Figure 16-c, only the Twin-Engine Executive category had a gust spectrum above 6096 meters (20,000 ft).

As described above, it is likely that the U_{de} spectra below 16 ft/sec (5 m/sec) are biased by the acceleration digitizing threshold at the lower airspeeds. For this reason, the U_{de} curves in the region of bias are shown as dashed lines.

2.6.2 Gust Accelerations

The cumulative frequencies of positive and negative gust load factors per nautical mile are presented in Figure 17. The largest gust acceleration of 3.3 was recorded by an aircraft in the Instructional category and the highest frequency of gust acceleration peaks was recorded by an aircraft in the Commercial Survey category.

2.6.3 Maneuver Normal Load Factors

The cumulative frequencies of positive and negative maneuver normal load factors per hour, per flight, and nautical mile are presented in Figures 18-a, 18-b, and 18-c, respectively.

TABLE XII. U_{d_e} PEAKS IN VGH DATA BY OPERATIONAL CATEGORY

VGH hr: 3377

a. Operation 991 - Twin Engine Executive

Positive U_{d_e} Peaks

TABLES BY OPERATION 991
DERIVED GUST (POSITIVE) VS VELOCITY

VEL.	DERIVED GUST 0	4	8	12	16	20	24	28	32	36	40	44	48	52	ABOVE	TOTAL
LESS																
50										1						1
60								1			2					3
70					7	2		1							1	11
80				4	10	4	1		1							20
90				35	21	3	1	2								62
100			5	37	21	1	4	1		1						70
110			36	171	58	10	3	1								279
120			120	169	47	10	2	1								349
130			233	263	69	15	5	4								585
140			604	300	55	16	2	1								978
150		53	997	363	73	17			1	1						1505
160		38	1524	299	51	7	3	3	1							1926
170		102	993	226	33	10	1									1355
180		55	338	92	21	6										512
190		19	290	64	12	5										
200		1	253	103	21	2										[illegible]
210		27	187	80	18	1	1									314
220		38	219	65	12	3	1	1								339
230		97	242	90	21	3										453
240		134	284	113	14	5										550
250		151	209	89	6	3	4									462
260		163	184	41	19	2	1									410
270		175	119	49	6	1					1					351
280		167	88	26	5											286
290		204	98	12	2	1										317
300		131	69	10	3	1										214
310		113	71	12	3	1										200
320		61	50	14	3											128
330		36	33	13	3											d5
340		32	32	7												71
350		7	8	1												16
360		4	6													10
370		2														2
ABOVE																
TOTAL		1910	7282	2748	614	130	27	14	3	3	3				1	12635

Negative U_{d_e} Peaks

TABLES BY OPERATION 991
DERIVED GUST (NEGATIVE) VS VELOCITY

VEL.	DERIVED GUST 0	-4	-8	-12	-16	-20	-24	-28	-32	-36	-40	-44	-48	-52	ABOVE	TOTAL	+-TOTL
LESS												1				1	1
50																	1
60								1								1	4
70					4											4	15
80				4	9	3						1				17	37
90				30	18	4	2									54	116
100			9	101	44	9				1						164	234
110			22	112	31	6										171	450
120			58	99	29	6	1	1								194	543
130			204	199	41	15	2	1	1							463	1048
140		1	491	282	43	14			1							832	1010
150		50	945	271	71	15	5	3								1360	2865
160		33	1194	287	59	12	3	3								1591	3517
170		66	820	155	41	11		1								1094	2449
180		53	277	73	21	2	4									430	942
190		19	266	58	31	3	2									379	770
200		2	188	92	23	3										308	688
210		21	194	112	21	3	2									353	667
220		59	195	89	7	3										353	692
230		53	164	80	11	1	1									310	763
240		119	208	76	13	1		1								418	968
250		143	150	46	6	3										348	810
260		141	175	60	5											381	791
270		133	149	33	4	3										322	673
280		138	115	18		2										273	559
290		176	112	15	2											305	622
300		80	93	13	1											187	401
310		84	73	16	1											174	374
320		52	67	8	1		1									129	257
330		33	32	2	2											69	154
340		26	47	8	1											82	153
350		5	6													11	27
360		10	5													15	25
370																	2
ABOVE																	
TOTAL		1497	6259	2339	540	119	23	11	2	1		2				10793	23428

TABLE XII. - Continued

VGH hr: 1366

b. Operation 992 - Single Engine Executive

Positive U_{de} Peaks

TABLES BY OPERATION 992
DERIVED GUST (POSITIVE) VS VELOCITY

VEL.	DERIVED GUST 0	4	8	12	16	20	24	28	32	36	40	44	48	52	ABOVE	TOTAL
LESS					2	3	1	2								8
50				1	3	1	2									7
60			1	7	1											9
70		5	9	36	10	2										62
80		43	121	69	10	5										248
90		83	482	110	7	3			1							686
100		148	678	79	8	1										914
110		1200	1579	199	21	1	1	1								3002
120	30	3233	2313	249	27	2	1	1								5856
130	11	2069	1848	161	29	1	2		1							4122
140	2	2192	1861	228	27	5										4315
150		1975	1647	224	37	8										3891
160		634	372	49	9											1064
170		17	10	4												31
180																
190																
200																
210																
220																
230		1														1
240																
250																
260																
270																
280																
290																
300																
310																
320																
330																
340																
350																
360																
370																
ABOVE																
TOTAL	43	11600	10921	1416	191	32	7	4	2							24216

Negative U_{de} Peaks

TABLES BY OPERATION 992
DERIVED GUST (NEGATIVE) VS VELOCITY

VEL.	DERIVED GUST 0	-4	-8	-12	-16	-20	-24	-28	-32	-36	-40	-44	-48	-52	ABOVE	TOTAL	+-TOTL
LESS					1											1	9
50																	7
60				7	2											9	18
70		10	19	23	6	1									1	60	122
80		42	115	64	4	1										226	474
90		80	417	121	15	1										635	1321
100		240	913	128	15		1									1297	2211
110		1364	1737	170	19	4	1									3295	6297
120	25	1575	1119	103	10	3	1									2836	8692
130	13	1629	969	105	10	2		1								2729	6851
140		1631	1438	186	17	6					1					3279	7594
150		1587	1406	199	21	2			1							3216	7107
160		529	303	32	6											870	1934
170		27	11													38	69
180																	
190																	
200																	
210																	
220																	
230																	1
240																	
250																	
260																	
270																	
280																	
290																	
300																	
310																	
320																	
330																	
340																	
350																	
360																	
370																	
ABOVE																	
TOTAL	38	8714	8447	1138	126	20	3	2	1		1				1	18491	42707

TABLE XII. - Continued

VGH hr: 724
c. Operation 993 - Personal

Positive U_{de} Peaks

TABLES BY OPERATION 993
DERIVED GUST (POSITIVE) VS VELOCITY

VEL.	DERIVED GUST 0	4	8	12	16	20	24	28	32	36	40	44	48	52	ABOVE	TOTAL
LESS				2	4	6	1			1						14
50				4	6	1										11
60			12	11	5	2	1	2								33
70			70	50	3	2										125
80		4	295	81	5		1									386
90		135	523	90	4											752
100		97	374	13	2	1										487
110		93	190	23	1											307
120		291	268	20	2											581
130		243	97	10												350
140		34	8	1												43
150		5	1													6
160																
170																
180																
190																
200																
210																
220																
230																
240																
250																
260																
270																
280																
290																
300																
310																
320																
330																
340																
350																
360																
370																
ABOVE																
TOTAL		902	1838	305	32	12	3	2		1						3095

Negative U_{de} Peaks

TABLES BY OPERATION 993
DERIVED GUST (NEGATIVE) VS VELOCITY

VEL.	DERIVED GUST 0	-4	-8	-12	-16	-20	-24	-28	-32	-36	-40	-44	-48	-52	ABOVE	TOTAL	+-TOTL
LESS					7	5	2		1							15	29
50				3												3	14
60			7	7	2											16	49
70			49	59	6											114	239
80		4	208	76	4											292	678
90		63	436	79	10	2										590	1342
100		72	404	53	5											534	1021
110		80	162	26		1										269	576
120		121	71	5	2	1										200	781
130		196	68	1												265	615
140		21	9													30	73
150		1														1	7
160																	
170																	
180																	
190																	
200																	
210																	
220																	
230																	
240																	
250																	
260																	
270																	
280																	
290																	
300																	
310																	
320																	
330																	
340																	
350																	
360																	
370																	
ABOVE																	
TOTAL		558	1414	309	36	9	2		1							2329	5424

TABLE XII. - Continued

VGH hr: 2843
d. Operation 994 - Instructional

Positive Ud_e Peaks

TABLES BY OPERATION 994
DERIVED GUST (POSITIVE) VS VELOCITY

VEL.	DERIVED GUST 0	4	8	12	16	20	24	28	32	36	40	44	48	52	ABOVE	TOTAL
LESS				18	43	9	5	5	3			2		1		86
50			46	81	35	9	9	1	1	1						183
60			778	274	37	11	2	1								1103
70		6	2439	414	55	6	1									2921
80		967	2166	344	41	7	1	1								3527
90		417	617	112	15	3			2							1166
100		50	159	10			1									220
110		21	9													30
120		2	2													4
130																
140																
150																
160																
170																
180																
190																
200																
210																
220																
230																
240																
250																
260																
270																
280																
290																
300																
310																
320																
330																
340																
350																
360																
370																
ABOVE																
TOTAL		1463	6216	1253	226	45	19	8	6	1		2		1		9240

Negative Ud_e Peaks

TABLES BY OPERATION 994
DERIVED GUST (NEGATIVE) VS VELOCITY

VEL.	DERIVED GUST 0	-4	-8	-12	-16	-20	-24	-28	-32	-36	-40	-44	-48	-52	ABOVE	TOTAL	+-TOTL
LESS				66	53	18	10		1							148	234
50			42	58	10	1	1									112	295
60			594	220	27	1		1								843	1946
70		2	2150	377	38	5	2	1								2575	5496
80		694	2078	318	41	8	3	1		1					1	3145	6672
90		332	721	107	19	4	3	1		1				1		1189	2355
100		62	157	12	2											233	453
110		6	18	2												26	56
120		2	1													3	7
130																	
140																	
150		1														1	1
160																	
170																	
180																	
190																	
200																	
210																	
220																	
230																	
240																	
250																	
260																	
270																	
280																	
290																	
300																	
310																	
320																	
330																	
340																	
350																	
360																	
370																	
ABOVE																	
TOTAL		1099	5761	1160	190	37	19	4	1	2				1	1	8275	1751

TABLE XII. - Continued

VGH hr: 2291
e. Operation 995 - Commercial Survey

Positive U_{de} Peaks

TABLES BY OPERATION 995
DERIVED GUST (POSITIVE) VS VELOCITY

VEL.	DERIVED GUST 0	4	8	12	16	20	24	28	32	36	40	44	48	52	ABOVE	TOTAL
LESS				22	22	8	2	1								55
50			21	131	45	5	2	1								205
60			718	526	95	20	1									1360
70		1	6593	2202	340	62	8									9206
80		8749	49512	8344	461	18	5	1	1		1					67092
90		21715	30754	1423	86	15	2	2	1	2						54000
100		211	4813	282	45	10	2									5363
110		356	1375	226	59	8	3	3								2030
120		249	525	61	11	2										848
130		107	180	22	10	5	1									320
140		111	125	26	5	3	2									272
150		63	64	33	17	3	1	1								1[illegible]
160		31	30	32	19	8	4	3	1							128
170		9	49	58	31	7	2	1	2	1						160
180		2	51	27	4	4		3	1							92
190			22	16	6	1		1								46
200			8	8	2											18
210			11	8	3											22
220			4	7	2											13
230			1	2												3
240				2												2
250																
260																
270																
280																
290																
300																
310																
320																
330																
340																
350																
360																
370																
ABOVE																
TOTAL		31599	94856	13458	1263	179	35	17	6	3	1					141417

Negative U_{de} Peaks

TABLES BY OPERATION 995
DERIVED GUST (NEGATIVE) VS VELOCITY

VEL.	DERIVED GUST 0	-4	-8	-12	-16	-20	-24	-28	-32	-36	-40	-44	-48	52	ABOVE	TOTAL	+-TOTL
LESS				14	14	12	1	1	1							43	98
50			6	78	32	9	1	1								127	332
60			429	354	82	12	2									879	2239
70	1	4	5044	1685	308	47	7	4								7100	16306
80		6478	39954	8084	1151	148	25	8	1						1	55850	122942
90		16868	33124	5956	627	84	9	3		4					6	56681	110681
100		1012	6935	912	109	26	1	1								8996	14359
110		852	2206	311	49	12	2	2		1						3435	5455
120		93	143	21	3											260	1108
130		153	188	11		1	1									354	674
140		144	101	22	6	2		1			5					281	553
150		53	40	59	15	7	6	1								181	363
160		22	40	78	30	13	9		2							194	322
170		4	46	32	16	8	1	2	1	1	1					112	272
180		2	16	8	4		3									33	125
190			21	9	6	2					1					39	85
200			13	2	5	3										23	41
210			2	5		2										9	31
220			3	1	3											7	20
230			1	2								2			2	7	10
240			1													1	3
250																	
260																	
270																	
280																	
290																	
300																	
310																	
320																	
330																	
340																	
350																	
360																	
370																	
ABOVE																	
TOTAL	1	25685	88313	17644	2460	388	68	24	5	6	7	2			9	134612	276029

TABLE XII. - Continued

VGH hr: 484

f. Operation 996 - Aerial Application

Positive U_{de} Peaks

TABLES BY OPERATION 996
DERIVED GUST (POSITIVE) VS VELOCITY

VEL.	DERIVED GUST 0	4	8	12	16	20	24	28	32	36	40	44	48	52	ABOVE	TOTAL
LESS																
50																
60			3	2		1										6
70			47	14	5	1										67
80			99	11	1											111
90		4	14	12												30
100			4	4	1											9
110			1													1
120																
130																
140																
150																
160																
170																
180																
190																
200																
210																
220																
230																
240																
250																
260																
270																
280																
290																
300																
310																
320																
330																
340																
350																
360																
370																
ABOVE																
TOTAL		4	168	43	7	2										224

Negative U_{de} Peaks

TABLES BY OPERATION 996
DERIVED GUST (NEGATIVE) VS VELOCITY

VEL.	DERIVED GUST 0	-4	-8	-12	-16	-20	-24	-28	-32	-36	-40	-44	-48	-52	ABOVE	TOTAL	+-TOTL
LESS																	
50																	
60			2	3	1											6	12
70			42	6	9	1			1							59	126
80			83	11	1											95	206
90		1	9	5	1											16	46
100			1	2												3	12
110																	1
120																	
130																	
140																	
150																	
160																	
170																	
180																	
190																	
200																	
210																	
220																	
230																	
240																	
250																	
260																	
270																	
280																	
290																	
300																	
310																	
320																	
330																	
340																	
350																	
360																	
370																	
ABOVE																	
TOTAL		1	137	27	12	1			1							179	403

TABLE XII. - Concluded

VGH hr: 1510

g. Operation 997 - Commuter

Positive U_{de} Peaks

TABLES BY OPERATION 997
DERIVED GUST (POSITIVE) VS VELOCITY

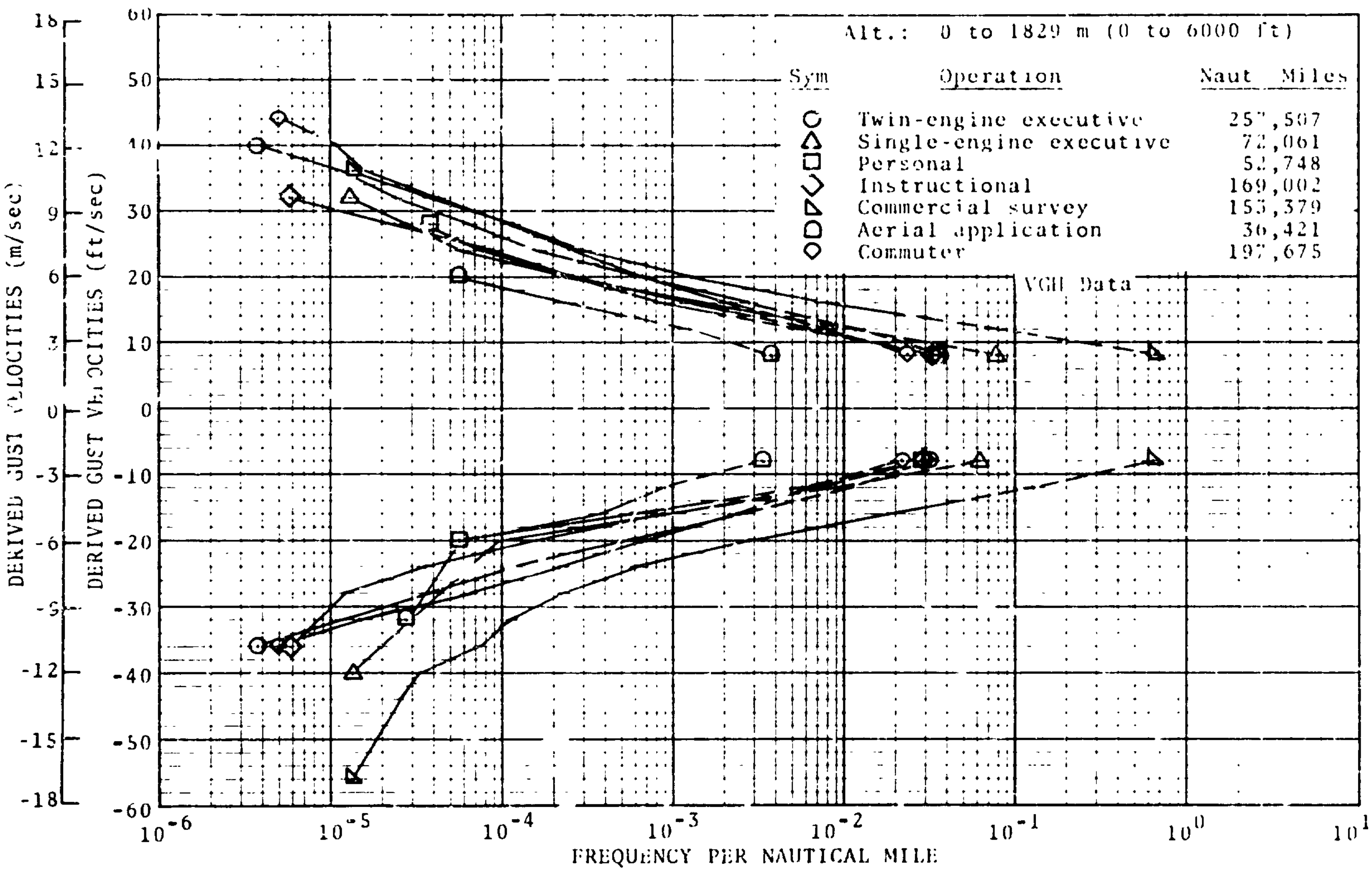
VEL.	DERIVED GUST 0	4	8	12	16	20	24	28	32	36	40	44	48	52	ABOVE	TOTAL
LESS																
50									1							1
60							2	1								3
70							2									2
80					2	2	5									9
90				8	4	3	1	1								17
100				7	4	2	1									14
110				28	12	7	1				1					49
120			36	89	37	5	2	3	1			1				174
130			164	137	48	9	1	2	1	1						363
140			484	193	44	8	2	2	1							734
150			318	176	29	9	1	1								534
160			111	118	23	8	2									262
170			181	139	36	6	5	1	1							369
180			419	221	40	14	4	2								700
190			678	197	20	4	1									900
200			201	69	14	9	1	1								295
210			54	11	2	1										68
220																
230			3													3
240																
250																
260																
270																
280																
290																
300																
310																
320																
330																
340																
350																
360																
370																
ABOVE																
TOTAL			2649	1393	315	87	31	14	5	1	1	1				4497

Negative U_{de} Peaks

TABLES BY OPERATION 997
DERIVED GUST (NEGATIVE) VS VELOCITY

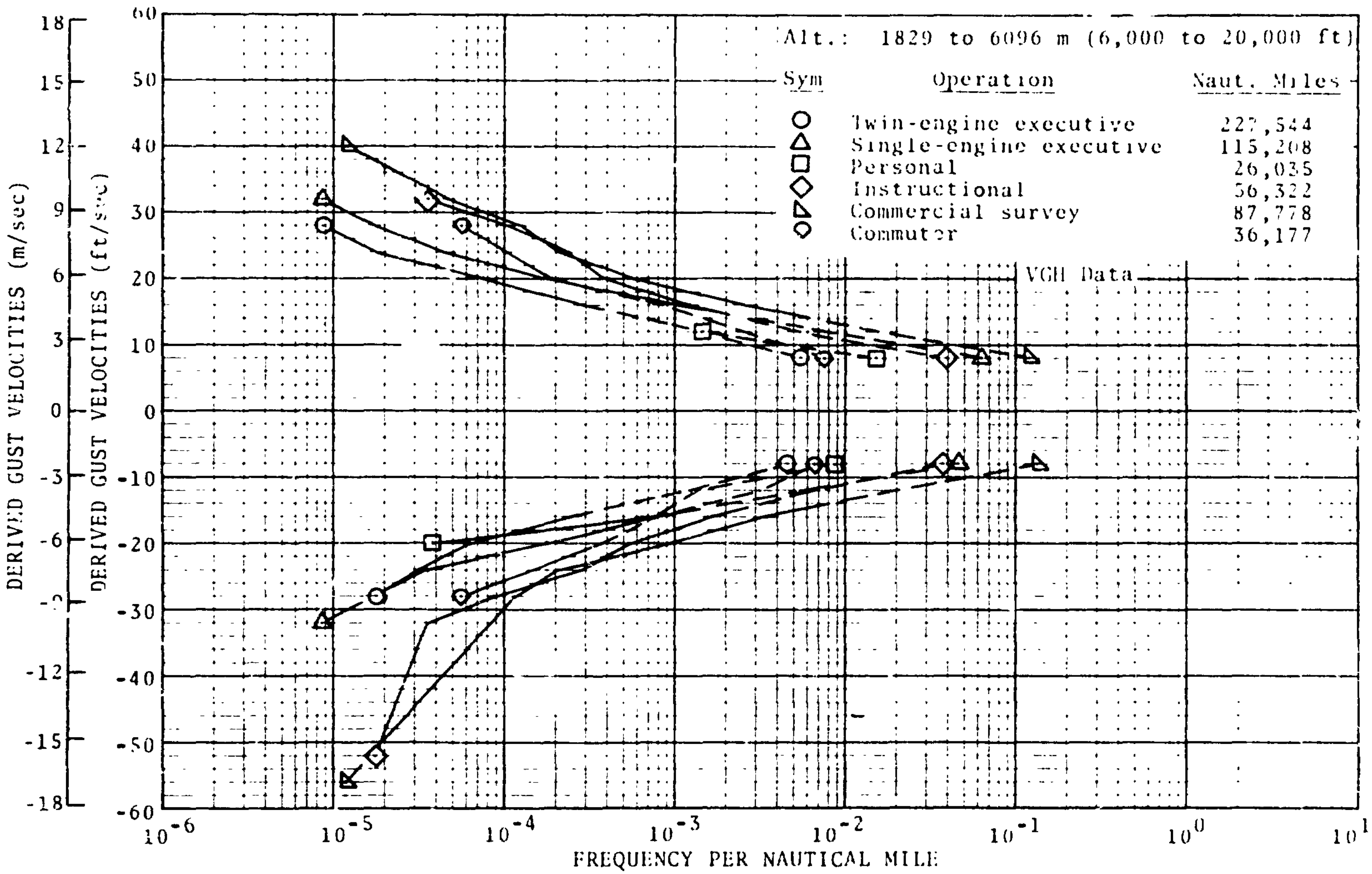
VEL.	DERIVED GUST 0	-4	-8	-12	-16	-20	-24	-28	-32	-36	-40	-44	-48	-52	ABOVE	TOTAL	+-TOTL
LESS																	
50																	1
60																	3
70									2							[illegible]	4
80						1											10
90					4	2	2									8	25
100				14	11	5										30	44
110				36	18	7	4									65	114
120			23	26	25	5	1									80	254
130			136	151	37	12										336	699
140			482	180	42	17	3	3								727	461
150			338	173	23	7	1									542	1076
160			106	110	20	7		1								244	506
170			162	166	30	8	6	2								374	743
180			339	236	51	14	6	2								548	1346
190			647	254	51	10	4		2	1						969	969
200			188	64	16	7	2									277	72
210			27	3			1									31	99
220			2													2	2
230			2													2	5
240																	
250																	
260																	
270																	
280																	
290																	
300																	
310																	
320																	
330																	
340																	
350																	
360																	
370																	
ABOVE																	
TOTAL			2452	1413	328	102	30	8	4	[illegible]						[illegible]338	8835

...ILITY OF THE
ORIGINAL PAGE IS POOR



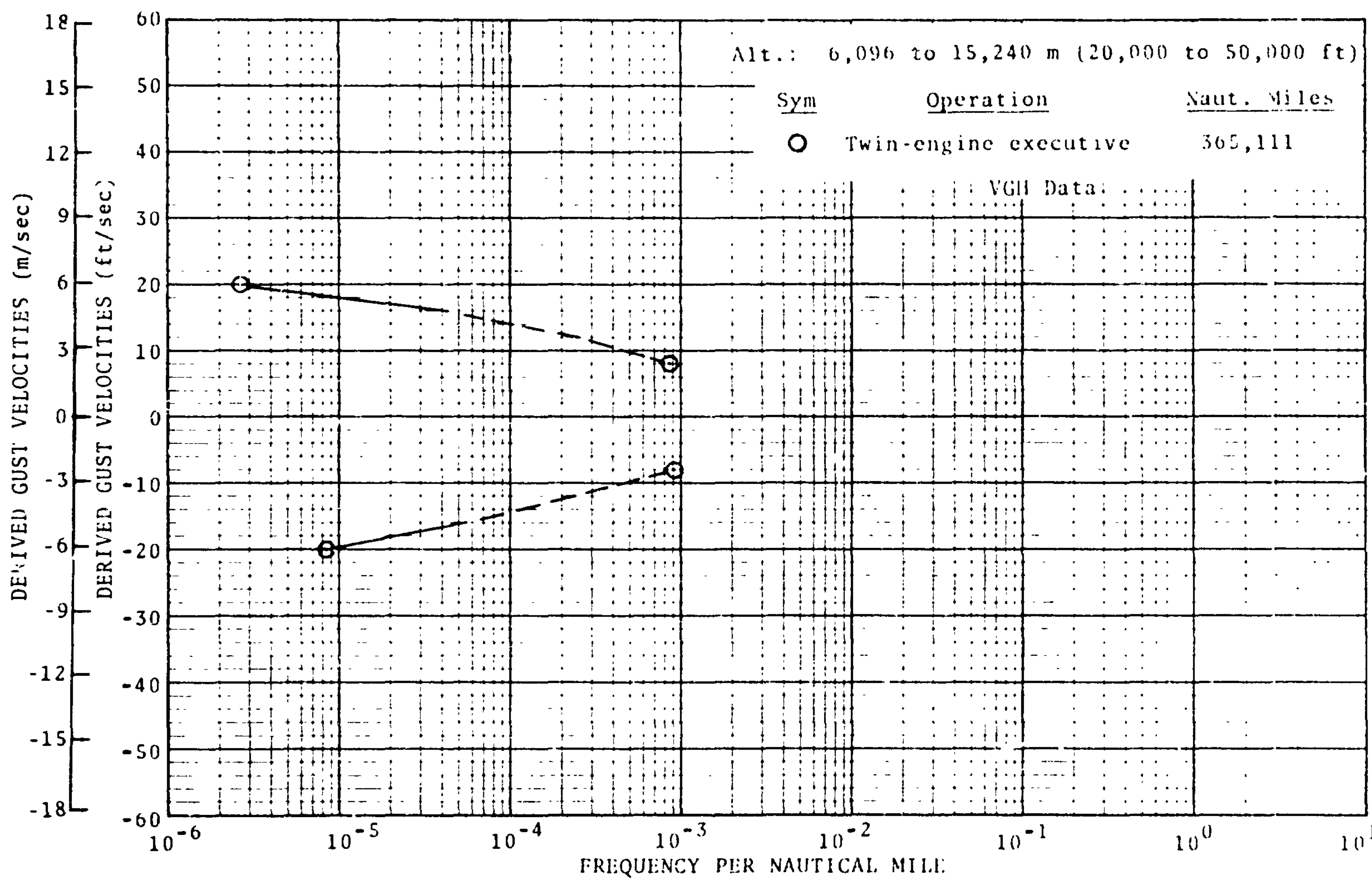
a. Altitude: 0 to 1829 m (0 to 6000 ft)

Figure 16. Ude Cumulative Frequencies for Three Altitude Ranges in VGH Data



b. Altitude: 1829 to 6096 m (6,000 to 20,000 ft)

Figure 16. - Continued



c. Altitude: 6096 to 15,240 m (20,000 to 50,000 ft)

Figure 16. - Concluded

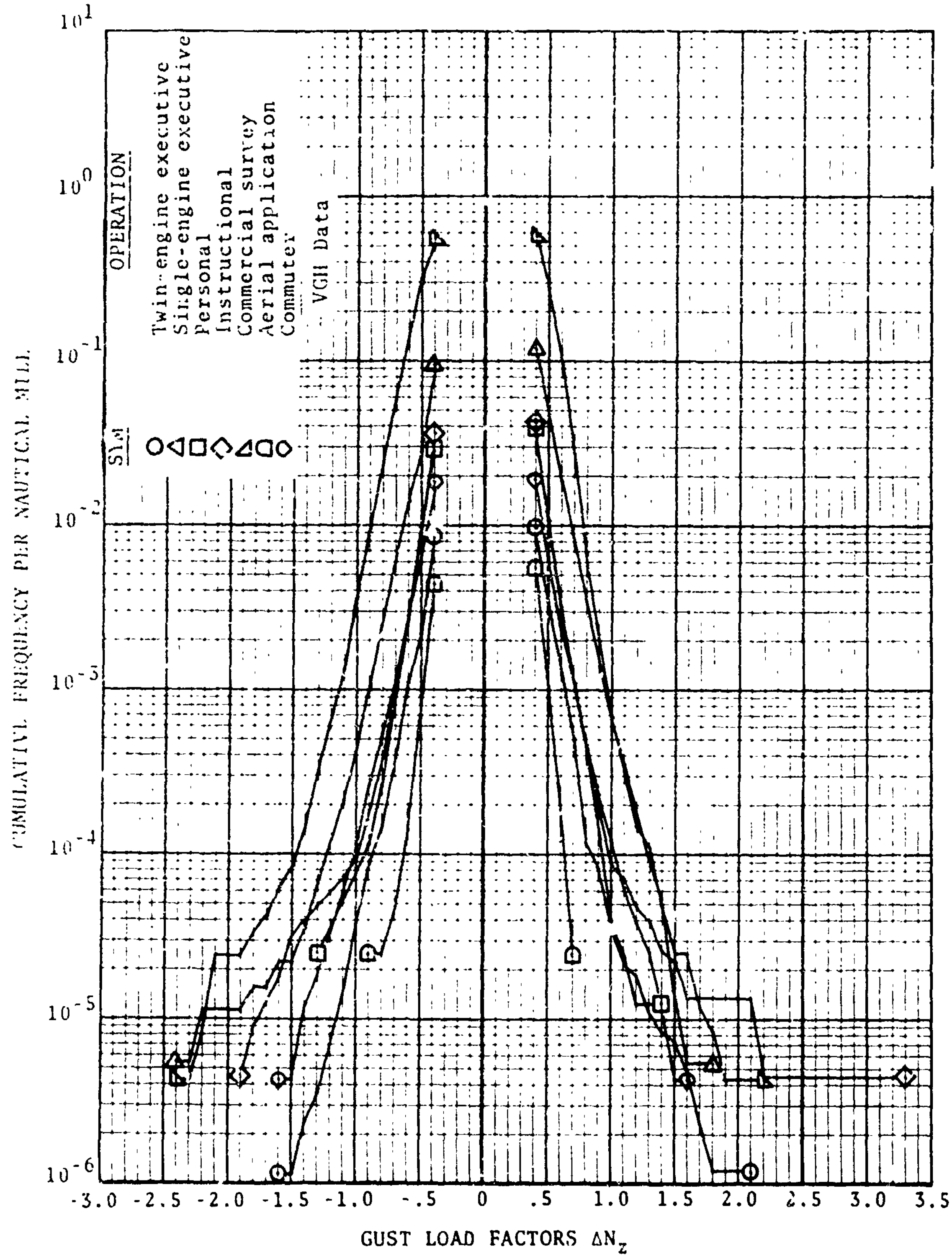
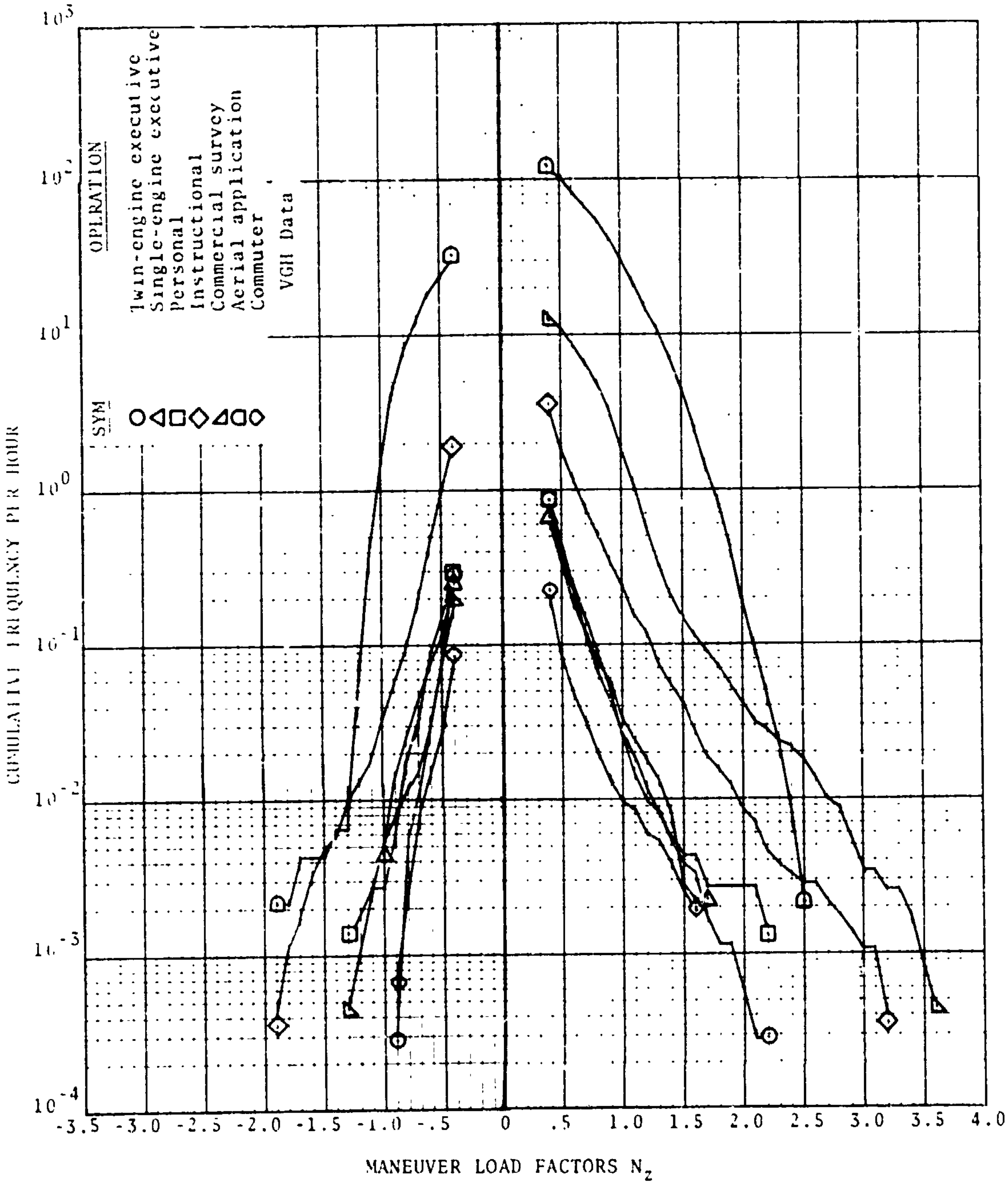
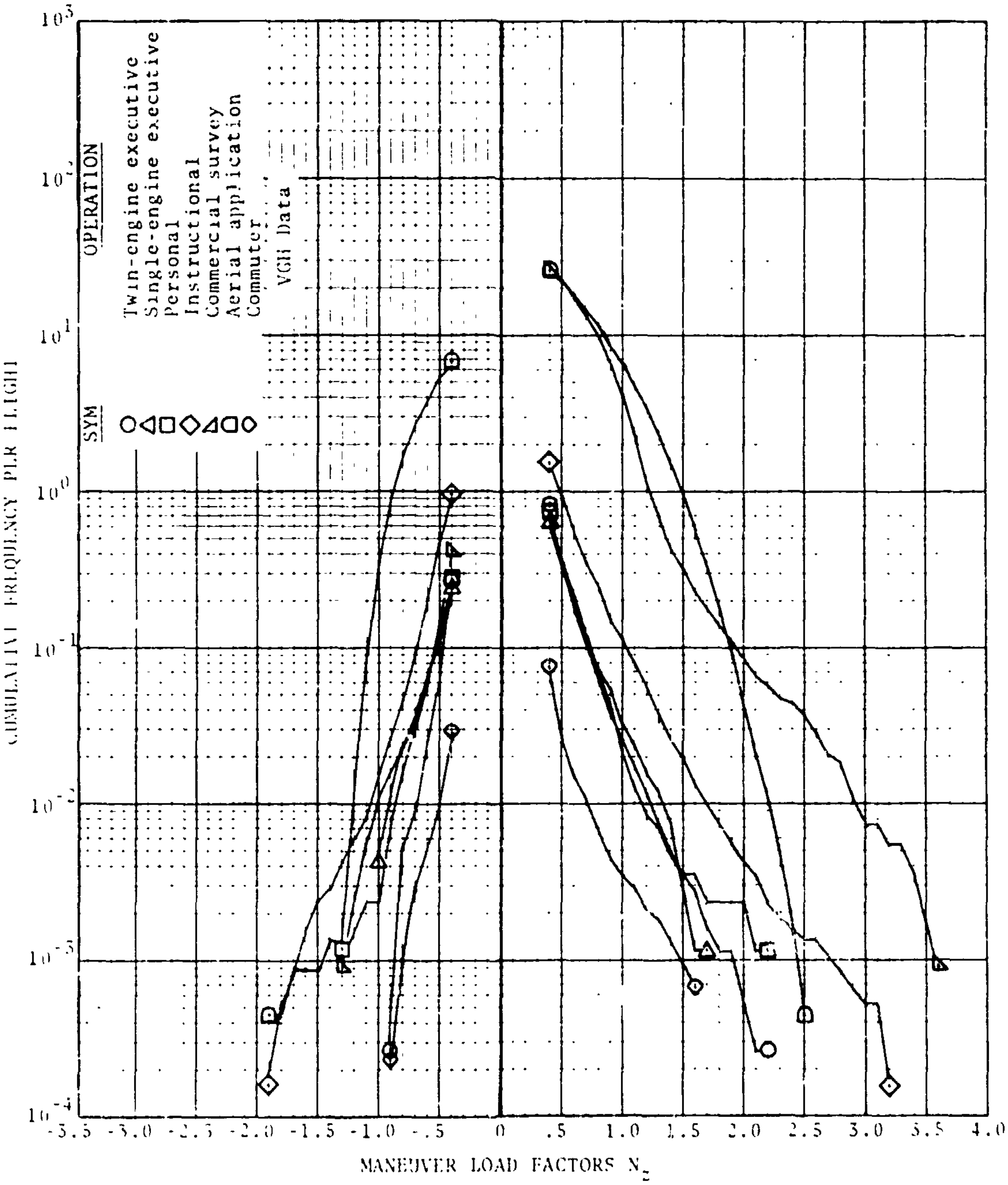


Figure 17. Gust Load Factor Cumulative Frequencies in VGH Data



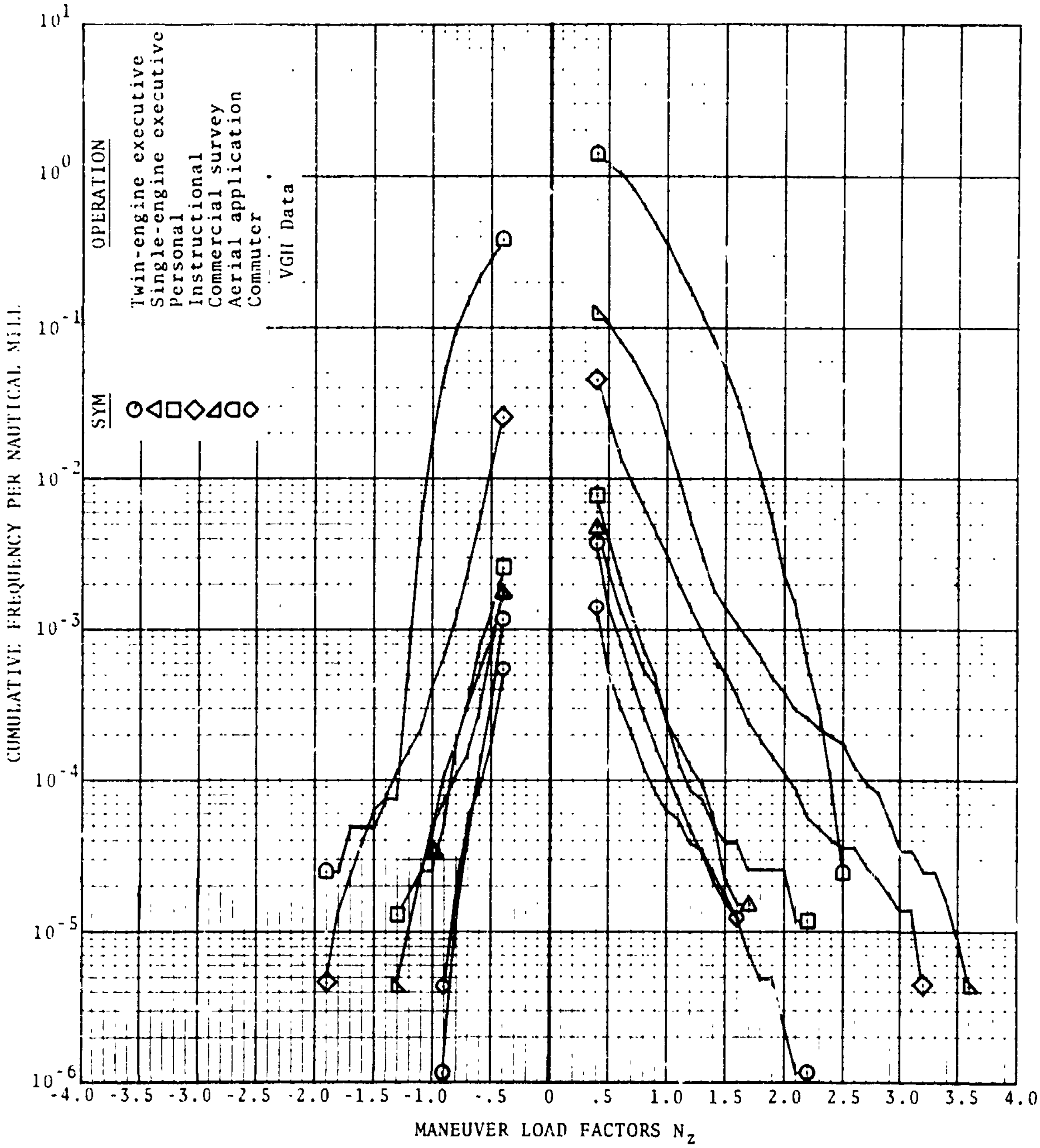
a. Frequency per Hour

Figure 18. Maneuver Load Factor Cumulative Frequencies in VGH Data



b. Frequency per Flight

Figure 18. - Continued



c. Frequency per Nautical Mile

Figure 18. - Concluded

The Aerial Application category has the highest frequency of maneuver loads with 100 peaks per hour above 0.5 n_Z, one peak per hour above 1.77 n_Z, and one peak per hundred hours above 2.38 n_Z. The Commercial Survey and Instructional categories have the next highest frequencies at all levels up to 2.5 n_Z and the highest frequencies above 2.5 n_Z. The most extreme negative maneuver load of -1.9 n_Z was recorded by an aircraft in the Instructional category.

2.6.4 Landing Impact Acceleration Ratios

The cumulative frequencies of the positive impact acceleration ratio, $n_Z/2.67$, per landing are presented in Figure 19. The 2.67 divisor is the minimum ground load design inertia load factor specified in Reference 2. The largest landing impact acceleration was recorded by an aircraft in the Instructional category but the highest frequencies at all $n_Z/2.67$ ratios below 0.95 were recorded by aircraft in the Aerial Application category.

2.7 Landing Impact Probabilities

The $\Delta n_{z_{max}}$ values in this section are the initial positive landing impact accelerations recorded during each landing impact. With the Δn_Z's grouped in 0.1g increments, the data represent the combined values from operational and checkout flights.

Since the recorded Δn_z's are the initial positive values, they may not be the maximum values that occurred during landing impacts. Therefore, the small percentage of occurrences in the Δn_z range from 0.0g to 0.1g were excluded to make the frequency distribution for each operation more realistic. Further investigation showed that these exclusions would have had negligible effect on the analysis.

Table XIII summarizes the number of operational and checkout landings for the aircraft types in each operational category.

2.7.1 Analysis

The extreme value theory discussed in Reference 5 was used in the analysis of the frequency distributions of landing impact data. The theory provides a limiting form of the maximum value distribution; this form is a simple analytic function. This section outlines the procedures used in deriving the frequency distributions and control curves, and presents the statistical data. Table XIV lists the symbols used in the following discussion.

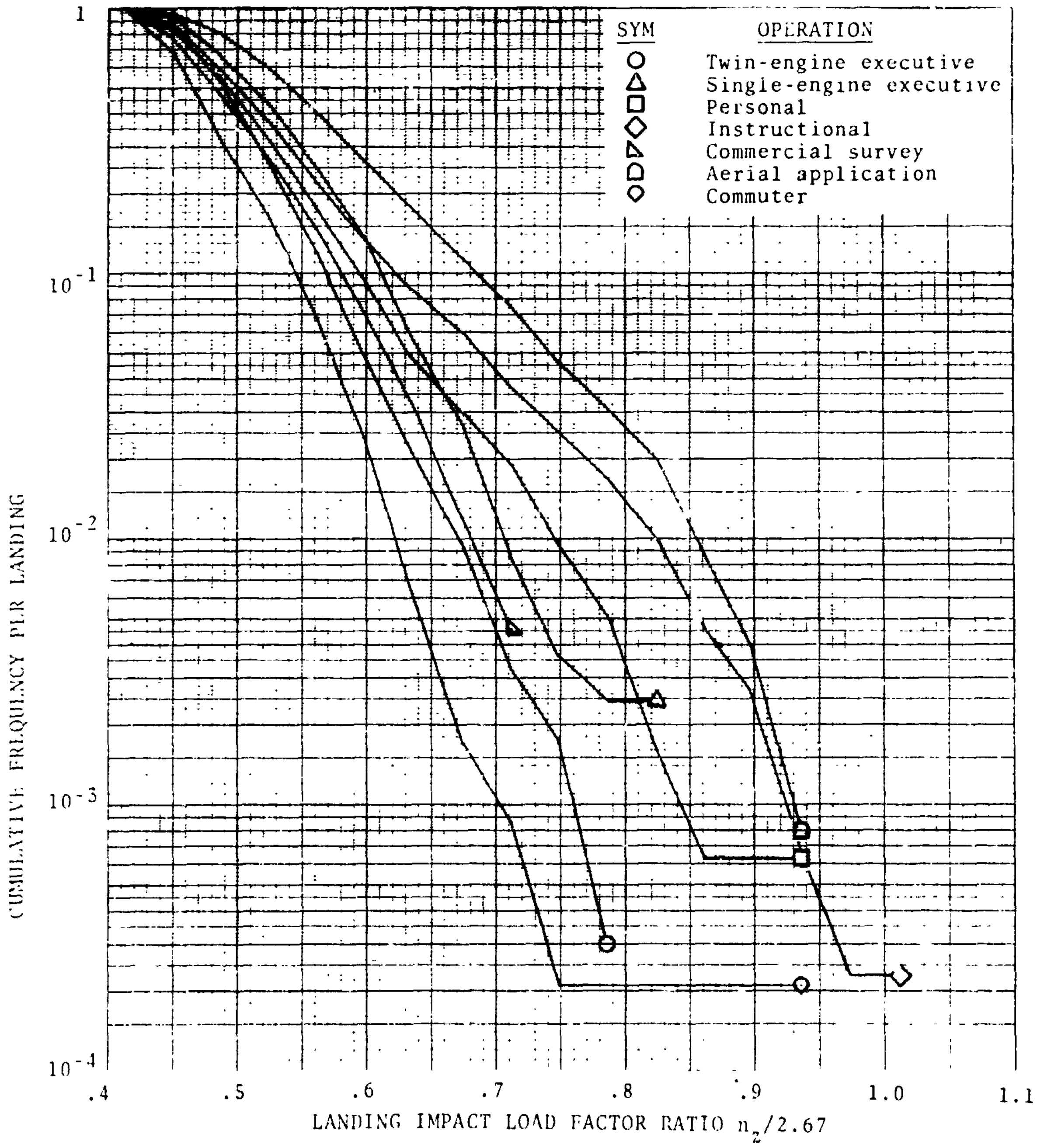


Figure 19. Landing Impact Acceleration Ratio Cumulative Frequencies

TABLE XIII. SUMMARY OF OPERATIONAL AND CHECKOUT LANDINGS BY OPERATIONAL CATEGORY AND AIRCRAFT TYPE

Operational Category/ Aircraft Type	Number of Landings		
	Operational Flights	Checkout Flights	Total
Twin Engine Executive Totals	2975	422	3397
Aircraft Type 1	749	164	913
Aircraft Type 2	595	63	658
Aircraft Type 3	167	31	198
Aircraft Type 4	504	23	527
Aircraft Type 5A	960	141	1101
Single Engine Executive Totals	784	36	820
Aircraft Type 7A	108	0	108
Aircraft Type 8E	260	10	270
Aircraft Type 9A	382	22	404
Aircraft Type 9C	34	4	38
Personal Totals	1642	0	1642
Aircraft Type 10A	260	0	260
Aircraft Type 11	256	0	256
Aircraft Type 12b	1126	0	1126
Instructional Totals	4422	0	4422
Aircraft Type 13	1904	0	1904
Aircraft Type 14	731	0	731
Aircraft Type 15	236	0	236
Aircraft Type 16A	1104	0	1104
Aircraft Type 17	447	0	447
Aerial Application Totals	1245	0	1245
Aircraft Type 23	921	0	921
Aircraft Type 24	324	0	324
Commercial Survey Totals	671	1	672
Aircraft Type 9B	293	1	294
Aircraft Type 16A	378	0	378
Commuter Totals	4977	15	4992
Aircraft Type 26	2621	10	2631
Aircraft Type 28	2356	5	2361
TOTALS	16716	474	17190

TABLE XIV. SYMBOLS USED IN LANDING IMPACT STUDY

α	statistical parameter of extreme value distribution
u	statistical parameter of extreme value distribution
y	reduced variable, defined by $y = \alpha(x-u)$
x	random variable
$F^*(y)$	$1-W^*(y)$
$W^*(y)$	cumulative probability distribution of y, defined as $e^{-e^{-y}}$
n	number of maximum values
m	number of value in order from smallest to largest
f	number of occurrences in a $\Delta n_{z_{max}}$ band
$(\sigma\sqrt{n})_m$	reduced standard error of mth of n values
V_{d_e}	derived gust velocity
$T(x)$	return period, number of occurrences required to equal or exceed a value of x
c	Euler's number, equals 0.5772
S_m	standard deviation of mth value, equals $\frac{(\sigma\sqrt{n})_m}{\alpha\sqrt{n}}$
—	a bar over a symbol indicates the mean value of the variable

2.7.2 Equations and Procedures

The following paragraphs present the equations and procedures used in calculating the extreme value distributions.

After the raw data in $\Delta n_{z_{max}}$ bands of 0.1g were first summed from largest to smallest band, a relative cumulative frequency was calculated. This frequency is represented by the symbols (⊙) in Figures 20 through 27.

The mean values $\bar{\Delta} n_{z_{max}}$ and $\bar{\Delta} n_{z_{max}}{}^2$ were then calculated by

$$\bar{\Delta} n_{z_{max}} = \frac{\Sigma\ \Delta n_{z_{max}} \cdot f}{n} \quad \text{and} \quad \bar{\Delta} n_{z_{max}}{}^2 = \frac{\Sigma\ \Delta n_{z_{max}}{}^2 \cdot f}{n}$$

where the $\bar{\Delta} n_{z_{max}}$ values are the midpoints of the $\Delta n_{z_{max}}$ bands.

The reduced standard error was then calculated by

$$(\sigma\sqrt{n})m = [\bar{\Delta} n_{z_{max}}{}^2 - (\bar{\Delta} n_{z_{max}})^2]^{1/2}$$

Next the statistical parameters of the extreme value distribution were computed by

$$\frac{1}{\alpha} = \frac{\sqrt{6}(\sigma\sqrt{n})m}{\pi} \qquad u = \bar{\Delta} n_{z_{max}}{}^2 - 1/\alpha(0.5772)$$

Then the reduced variable distribution was computed by

$$y = \alpha(\Delta n_{z_{max}} - u)$$

From the foregoing computations, the cumulative probability and corresponding smallest value for the probability distributions were calculated by

$$W^*(y) = e^{-e^{-y}} \qquad F^*(y) = 1 - W^*(y)$$

The smallest value for the probability distributions of the reduced variable were then plotted as solid lines in Figures 20 through 27. Table XV presents sample calculations for arbitrary data.

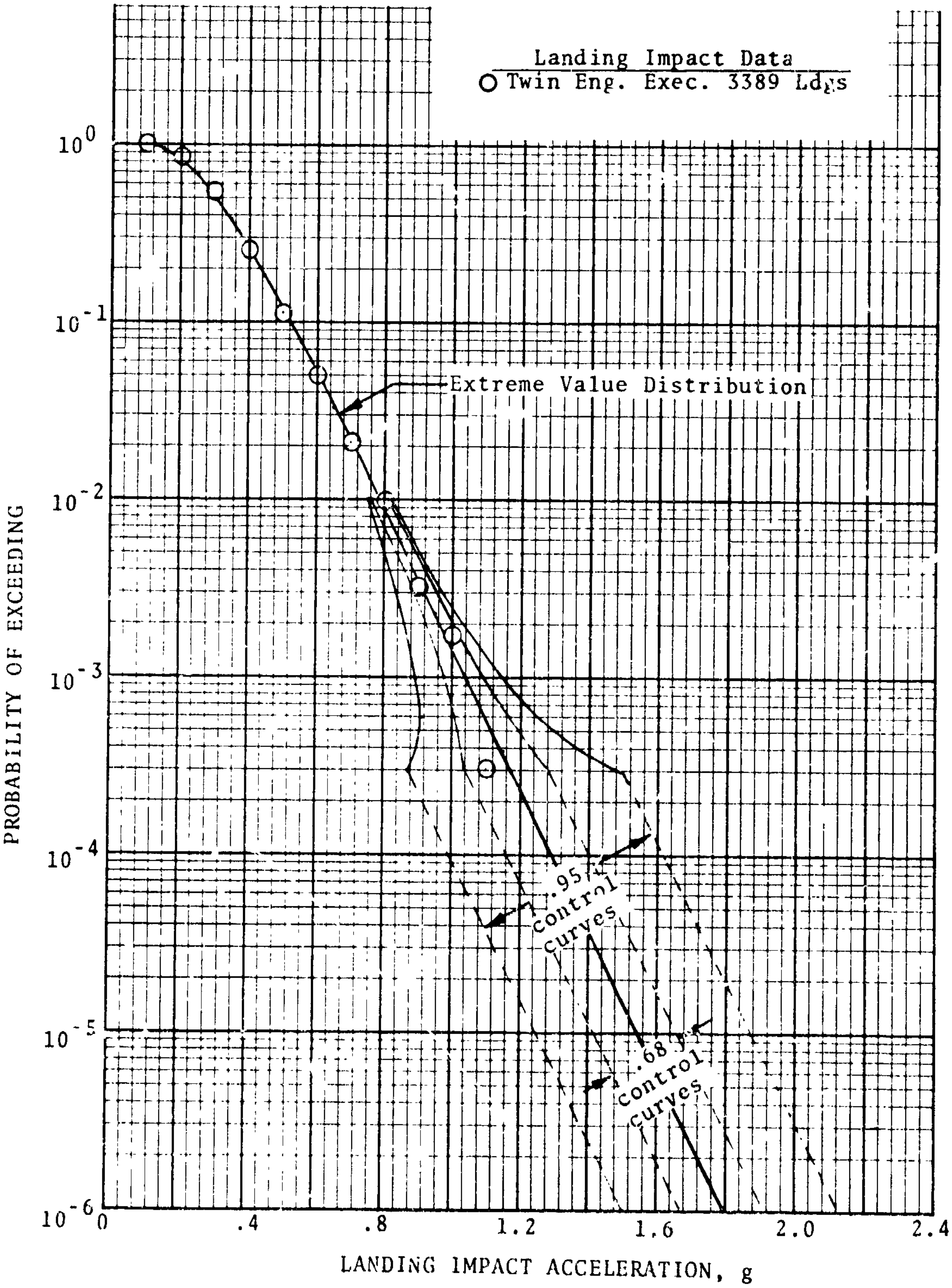


Figure 20. Landing Impact Data for Twin-Engine Executive Category

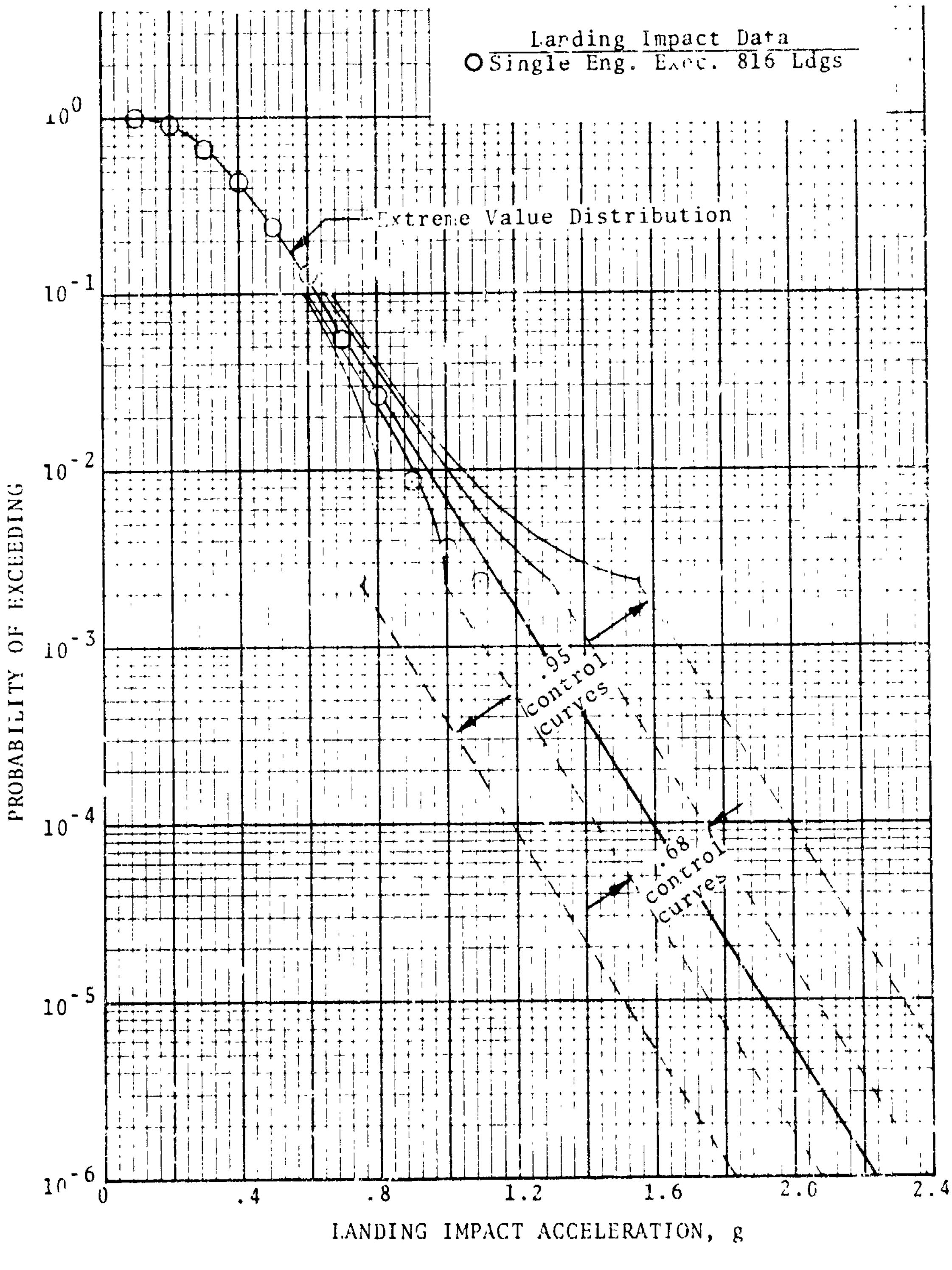


Figure 21. Landing Impact Data for Single-Engine Executive Category

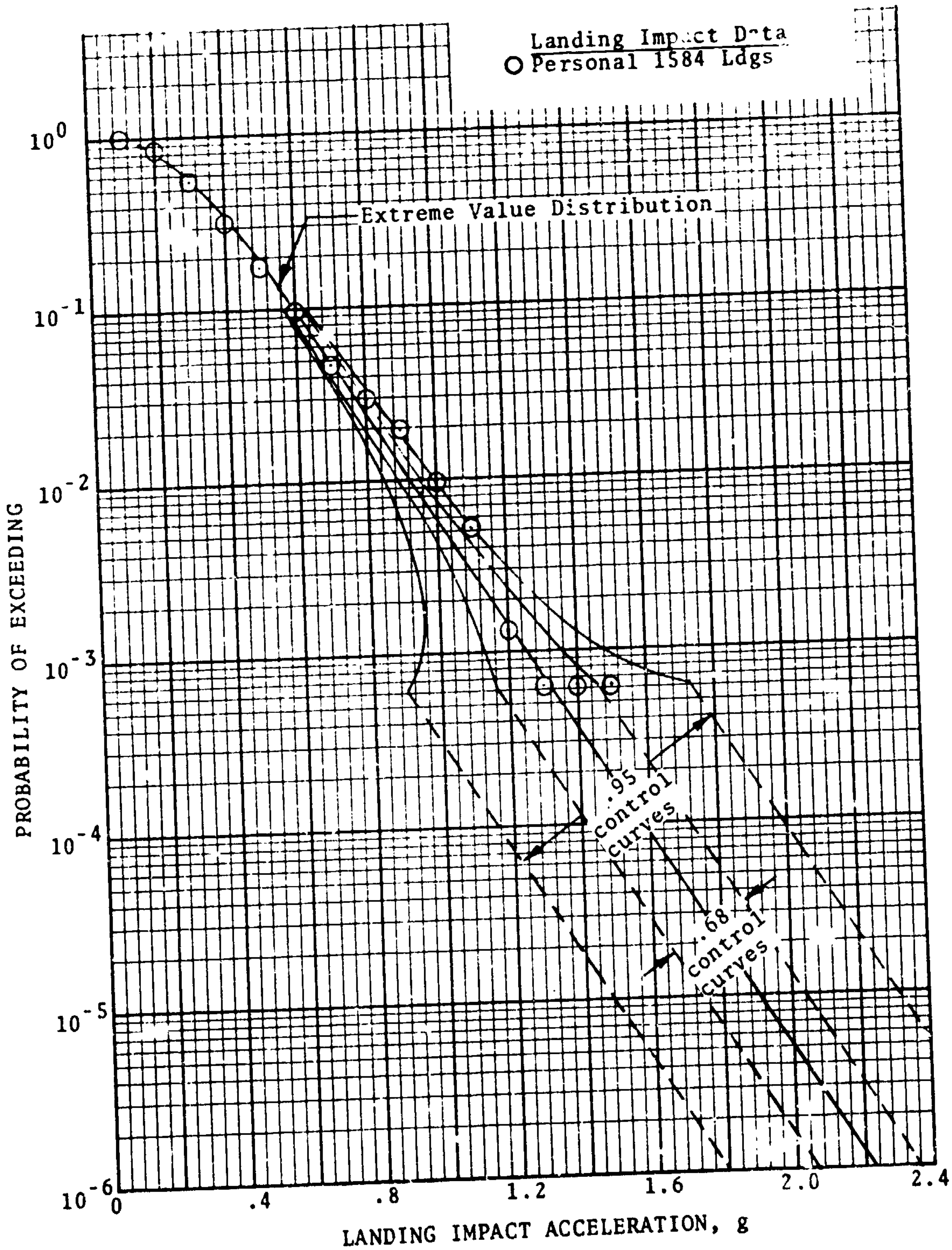


Figure 22. Landing Impact Data for Personal Cat.gory

C-2

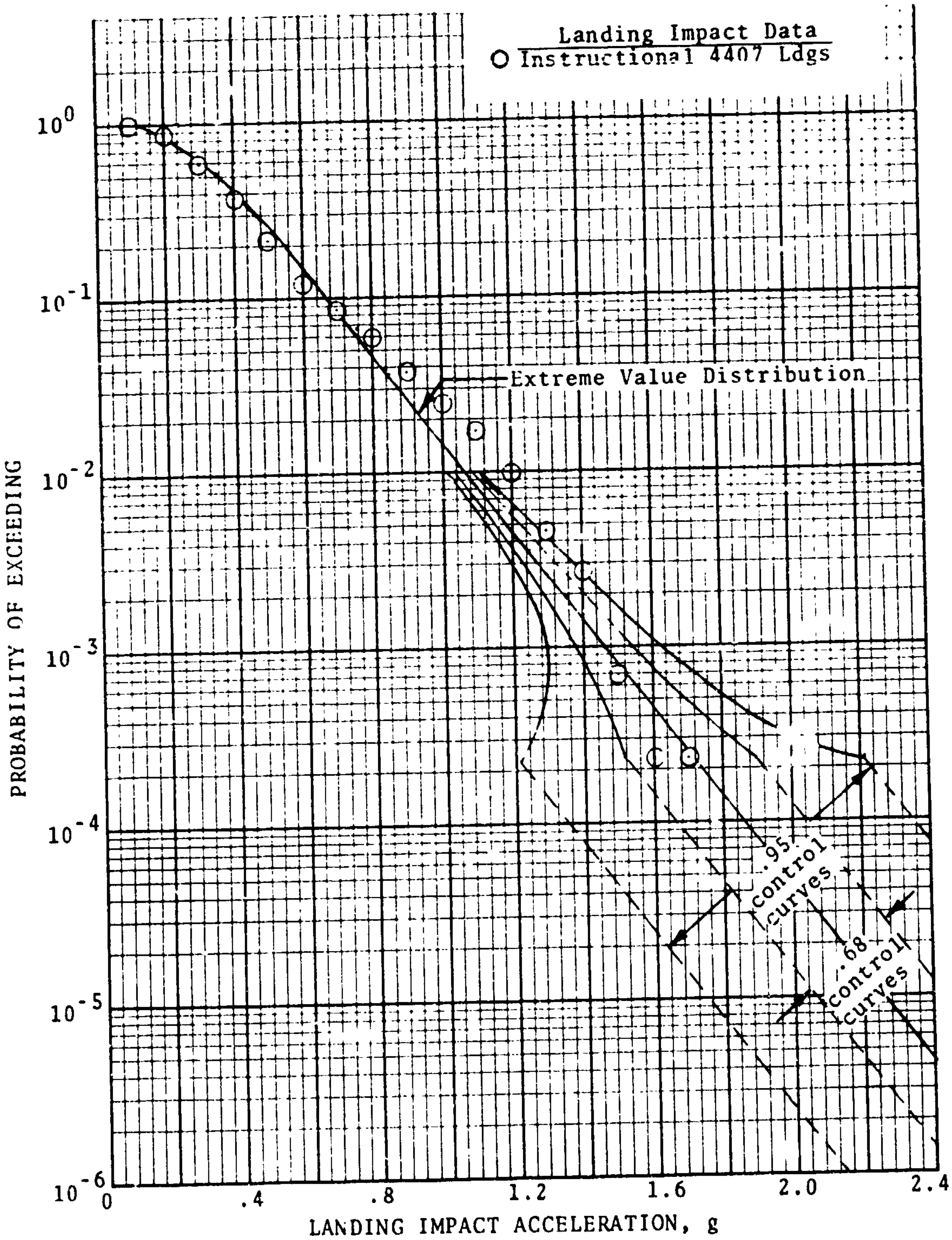


Figure 23. Landing Impact Data for Instructional Category

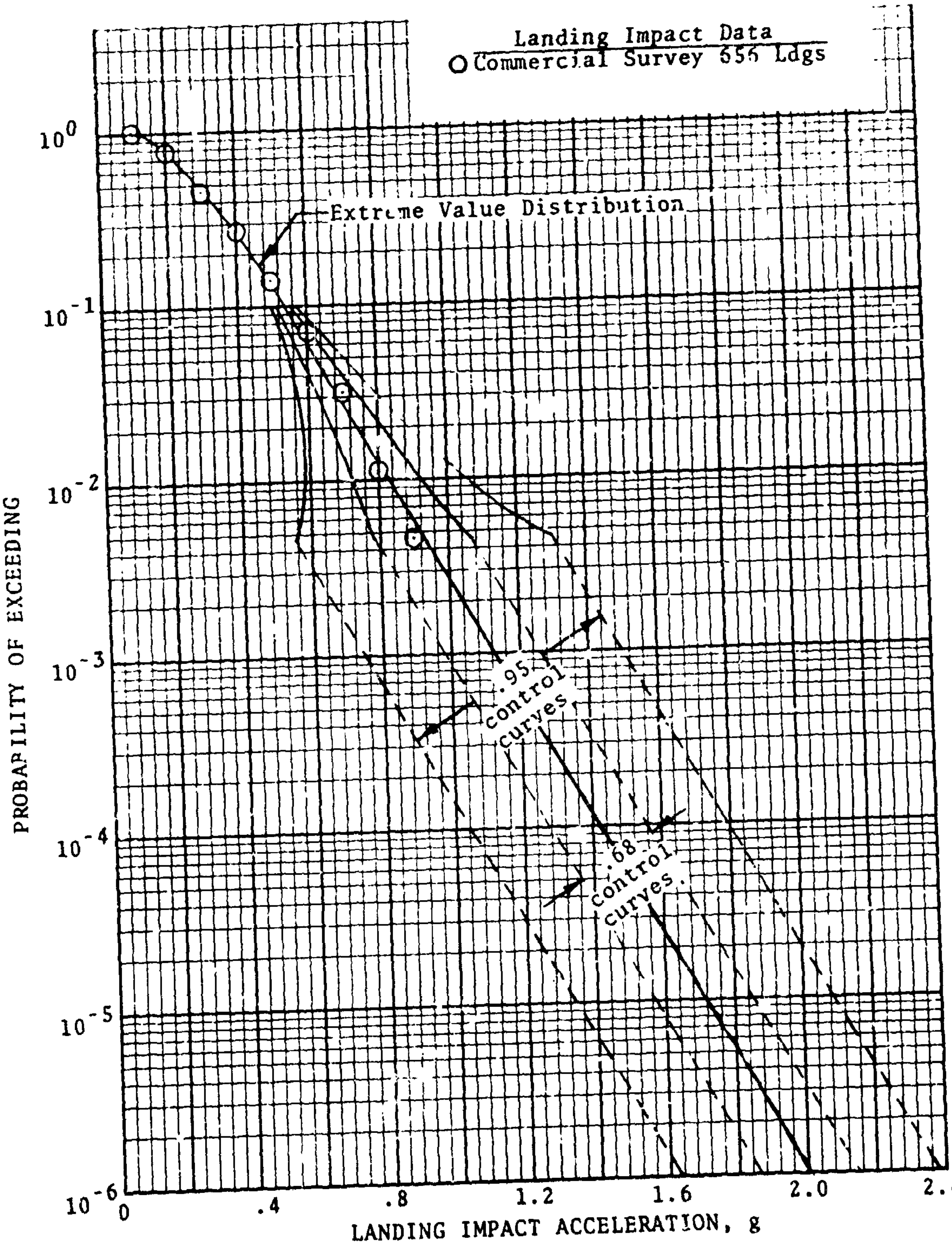


Figure 24. Landing Impact Data for Commercial Survey Category

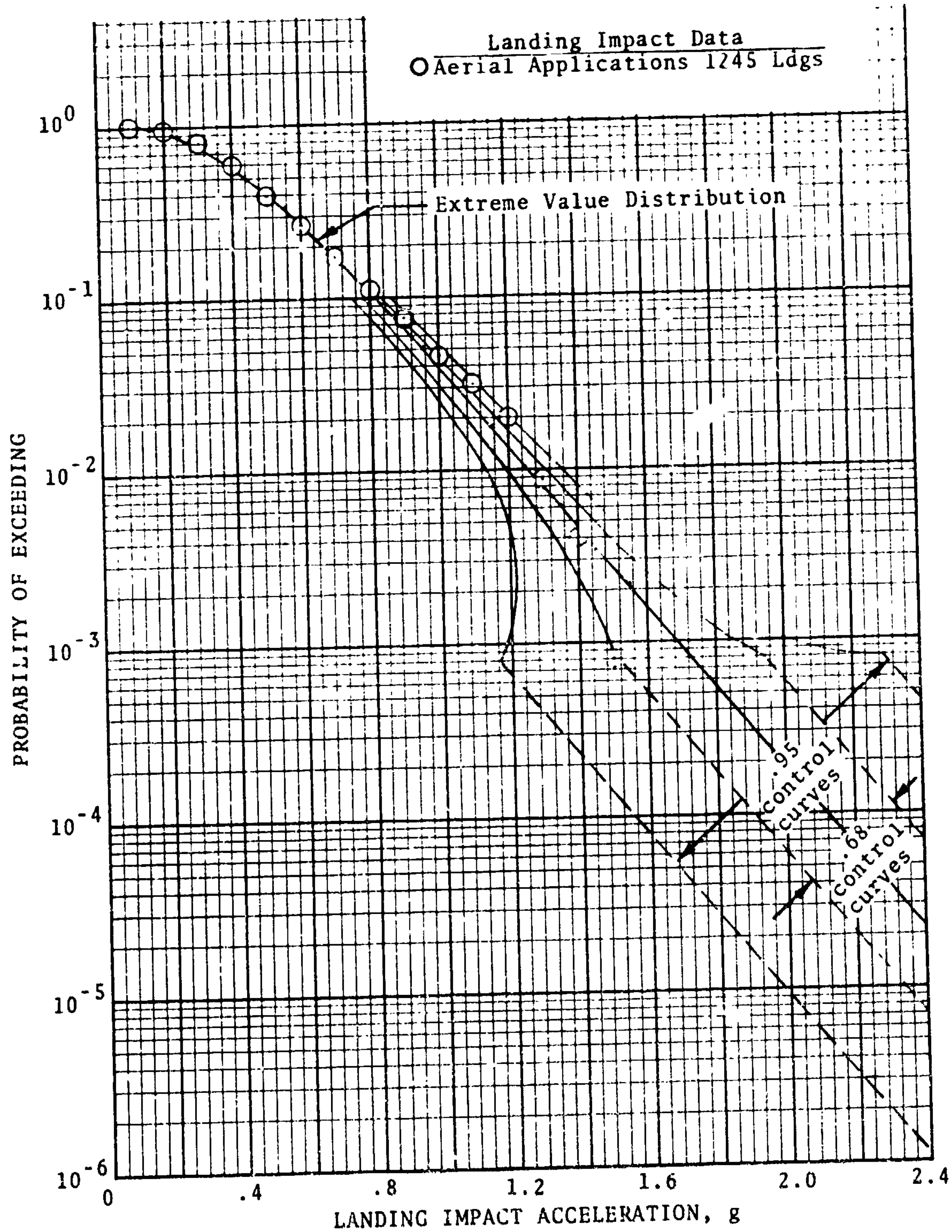


Figure 25. Landing Impact Data for Aerial Applications Category

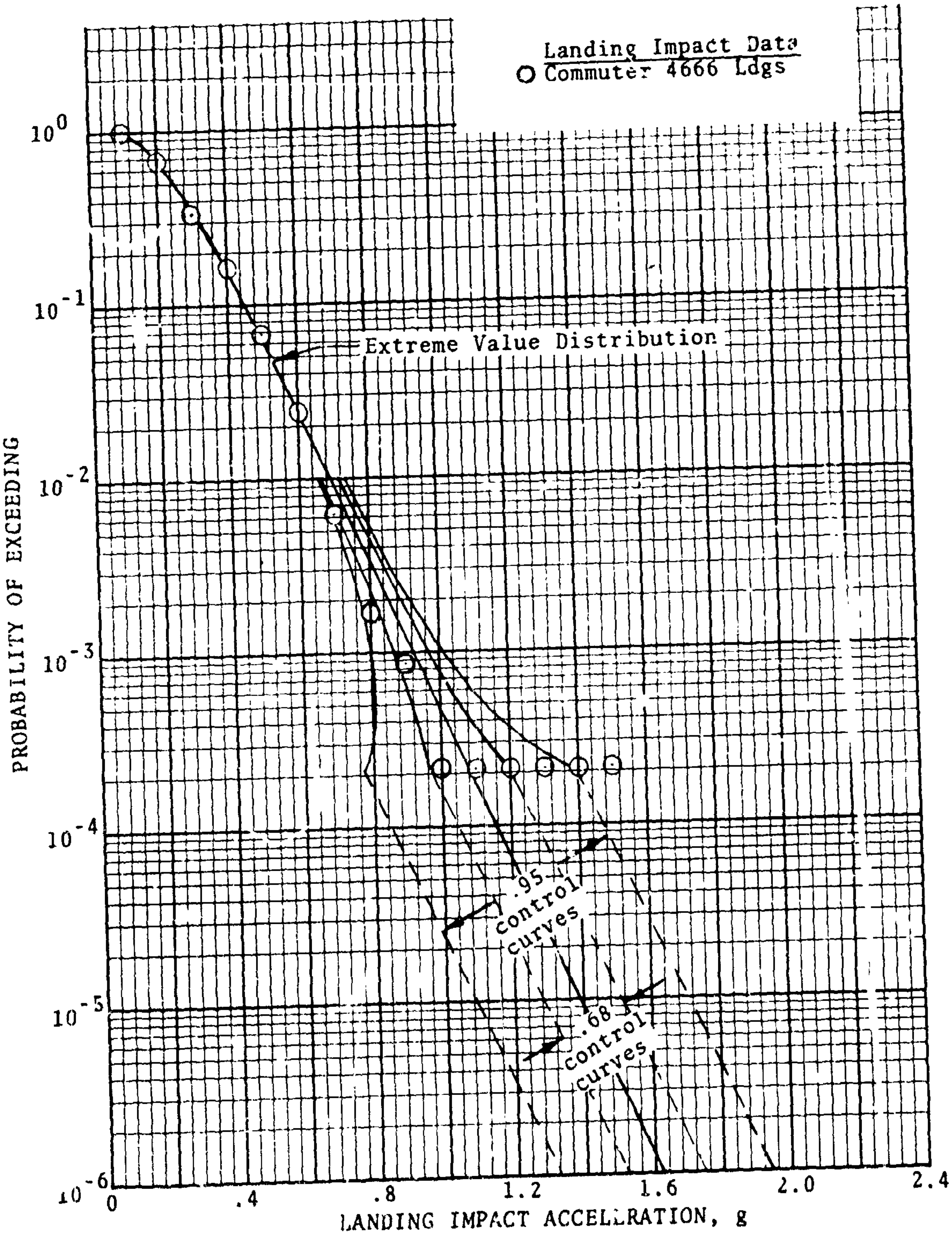


Figure 26. Landing Impact Data for Commuter Category

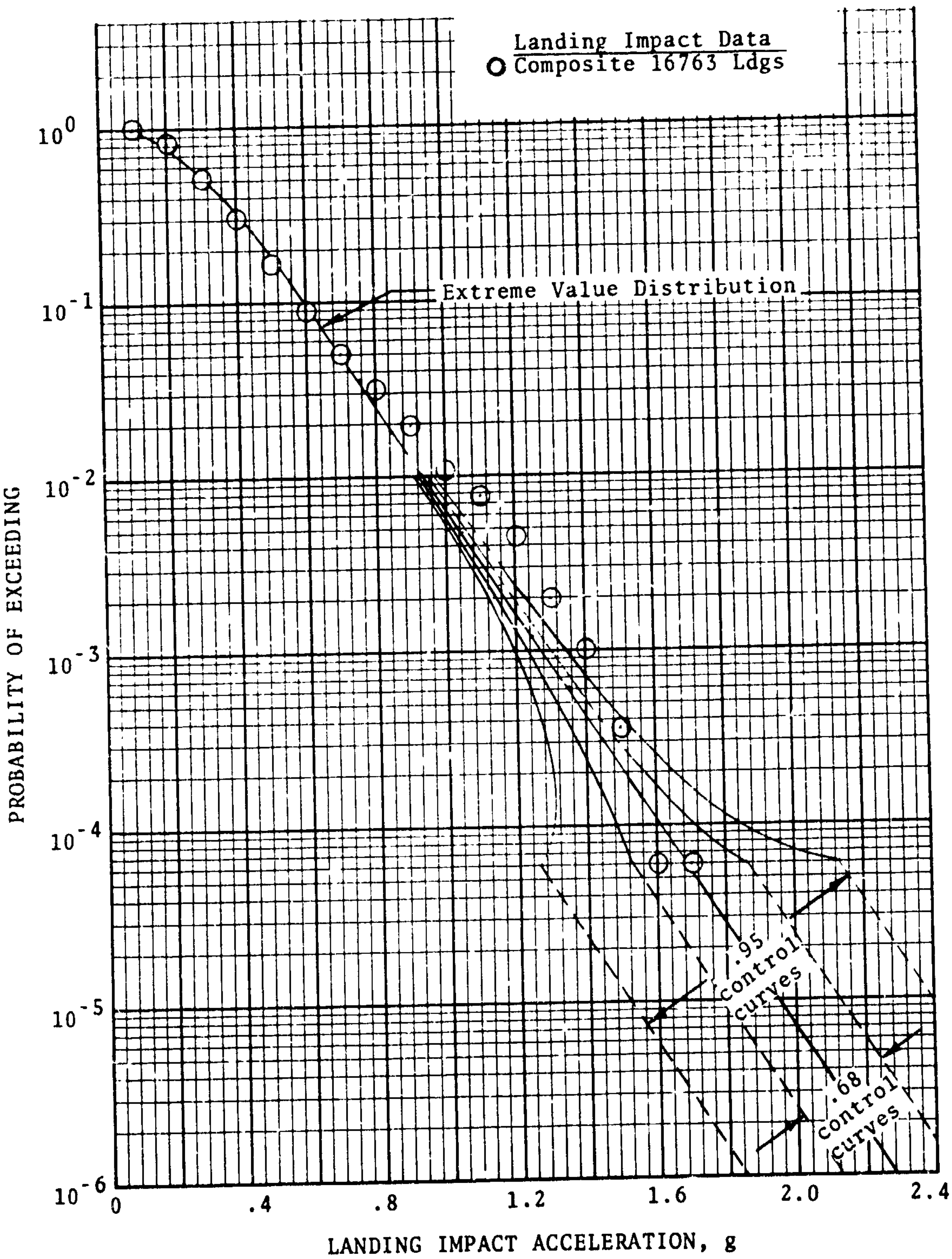


Figure 27. Landing Impact Data for Category Composite

TABLE XV. SAMPLE CALCULATIONS FOR EXTREME LANDING IMPACT PROBABILITY DISTRIBUTIONS

$\Delta n_{z_{max}}$ Band	$\Delta n_{z_{max}}$	f	εf	Pr(f)	$\Delta n_{z_{max}} \cdot f$	$\Delta n_{z_{max}}^2 \cdot f$	y	F*(y)
0.1-0.3	0.2	53	87	1.00	10.6	2.12	-0.350	0.758
0.3-0.5	0.4	24	34	0.391	9.6	3.84	1.486	0.203
0.5-0.7	0.6	10	10	0 115	6.0	3.60	3.321	0.035

$\overline{\Delta n}_{z_{max}} = 0.301$ $\overline{\Delta n}_{z_{max}}^2 = 0.110$

$(\sigma\sqrt{n})m = 0.139$ $1/\alpha = 0\ 109$

$u = 0.238$

With a breakdown by operational category, Table XVI summarizes the maximum impact Δn_z for each landing in the entire data sample by listing the number of such occurrences in the respective Δn_z bands.

After the extreme value curves were developed, a method was needed to measure the reliability of the sample estimates. As indicated in Reference 5, the "control curve" method derived by E. J. Gumbel provides a simple and rapid method of indicating the reliability of extreme value distributions. With this method, the standard deviation for the different curves at various levels of probability is calculated by

$$Sm = \frac{(\sigma\sqrt{n})_n}{\alpha\sqrt{n}}$$

The extreme value curve plus or minus the standard deviation gives a 0.68 probability, and plus or minus two times the standard deviation gives a 0.95 probability, that a sample value lies within the interval.

For the ultimate value, the interval about the distribution for 0.68 probability was found to be

$$\pm Sn = \frac{1.14}{\alpha}$$

for 0.95 probability

$$\pm Sn = \frac{2.97}{\alpha}$$

The penultimate 0.68 and 0.95 probabilities were found to be

$$\pm S_{n-1} = \frac{0.754n}{\alpha(n-2)} \quad \text{and} \quad \pm S_{n-1} = \frac{1.73n}{\alpha(n-2)}$$

respectively.

The control intervals were extended along the extrapolated portion of the extreme value curve since the interval around the most probable largest value does not depend on the number of occurrences.

TABLE XVI. MAXIMUM LANDING IMPACT LOAD OCCURRENCES IN Δn_z BANDS BY OPERATIONAL CATEGORY

	Operational Category						
Δn_{zmax} Band	Twin Engine Exec	Single Engine Exec	Person	Instr	Aerial Applic	Commer Survey	Commut
0.1-0.2	500	71	253	303	50	144	1516
0.2-0.3	1117	202	463	1304	187	206	1528
0.3-0.4	876	188	367	969	268	129	845
0.4-0.5	495	153	228	676	246	84	458
0.5-0.6	234	89	123	375	168	47	206
0.6-0.7	96	67	75	203	111	25	84
0.7-0.8	38	24	28	114	73	13	21
0.8-0.9	22	15	16	99	48	5	4
0.9-1.0	5	4	16	56	37	5	3
1.0-1.1	5	1	7	32	19		
1.1-1.2	1		6	32	13		
1.2-1.3		2	1	24	14		
1.3-1.4				10	6		
1.4-1.5				7	4		
1.5-1.6			1	2	1		1
1.6-1.7							
1.7-1.8				1			
TOTAL-n	3389	816	1584	4407	1245	656	4666

2.7.3 Design Load Factor

In smoothing the irregular probability curve of the recorded data, the extreme value theory provides a consistent and rational basis for extrapolation beyond the limits of the recorded data. Since the frequency distributions are of the exponential type, the number of occurrences required to reach or exceed a given Δn_z level can be computed by

$$\log_e T(\Delta n_z) = \alpha(x - u) \quad \text{(Reference 6)}$$

or

$$T(\Delta n_z) = e^{\alpha(x - u)} = e^y$$

Using these equations and the data from Table XVI, the number of landings required to reach or exceed the minimum design impact load factor of 2.67g can be determined. Table XVII presents these totals for each operational category.

TABLE XVII. LANDINGS REQUIRED TO REACH OR EXCEED MINIMUM DESIGN LOAD FACTOR

Operational Category	Ldgs to Reach or Exceed Min. Design Load Factor
Twin Engine Executive	269,297
Single Engine Executive	19,295
Personal	19,554
Instructional	3,393
Aerial Application	860
Commercial Survey	81,321
Commuter	1,507,121
Composite	14,739

2.7.4 Low-Range Occurrences

As mentioned previously, the occurrences in the 0.0- to 0.1-Δn_z range were excluded in the extreme value calculations. The following discusses the effect of these exclusions on the frequency distributions derived.

Table XVIII lists the number of Δn_z occurrences omitted in the extreme value calculations and the corresponding percentage of the total landings for each operational category.

On the basis of the percentages in Table XVIII, the extreme value distributions for the Commuter category were recalculated with the $\Delta n_{z_{max}}$ occurrences in the 0.0g to 0.1g range. Figure 28 depicts the curves derived with and without the low-range impacts. As apparent, the difference between the two extreme value curves is negligible. The control curves were not derived since they would reflect the same magnitude differences. The high acceleration values between 1.2g and 1.5g would not be present if more landing data was available.

TABLE XVIII. SUMMARY OF 0.1G TO 0.2G DATA

Operational Category	No. of Occurrences	Percentage of Landings
Twin Engine Executive	8	0.23
Single Engine Executive	4	0.49
Personal	58	3.53
Instructional	15	0.34
Aerial Applications	0	0.0
Commercial Survey	16	2.38
Commuter	326	6.53

2.8 Airspeed Practices

As calculated from VGH airspeed data, the probabilities of exceeding the design cruising speed ratio, V/V_C, and the design dive speed ratio, V/V_D, are presented in Figures 29 through 35 and Figures 36 through 42, respectively. In each figure, each symbol set represents a particular aircraft in the operation type, and the dashed line indicates the average probability for the ratios at incremental V/V_C and V/V_D levels.

Although 17 of the 24 aircraft types had airspeeds above V_C, none had airspeeds above V_D. The highest probability of a V_C exceedance is in the data for the Personal category. The highest V/V_C ratios, approximately 1.2, are in the data for the Instructional and Commercial Survey categories. The highest V/V_D ratio, approximately 0.925, is in the data for the Twin-Engine Executive category.

Based on the Unusual Events VG data, Figure 43 presents the probability of exceeding the V/V_D ratio on a log-normal scale. For each of seven of the operational categories, the curves are average probabilities at incremental V/V_D levels. The maximum V/V_D point in the curve for the Twin-Engine Executive category represents only one occurrence at that level. The high values in the curve for the Instructional category are based on seven airspeeds with V/V_D ratios at or above 1.0 as recorded on two different aircraft types.

For each of the seven operational categories, Figures 44 through 50 present histograms of the percentage of flight time spent in airspeed ranges for each aircraft type and the aircraft composite in a category.

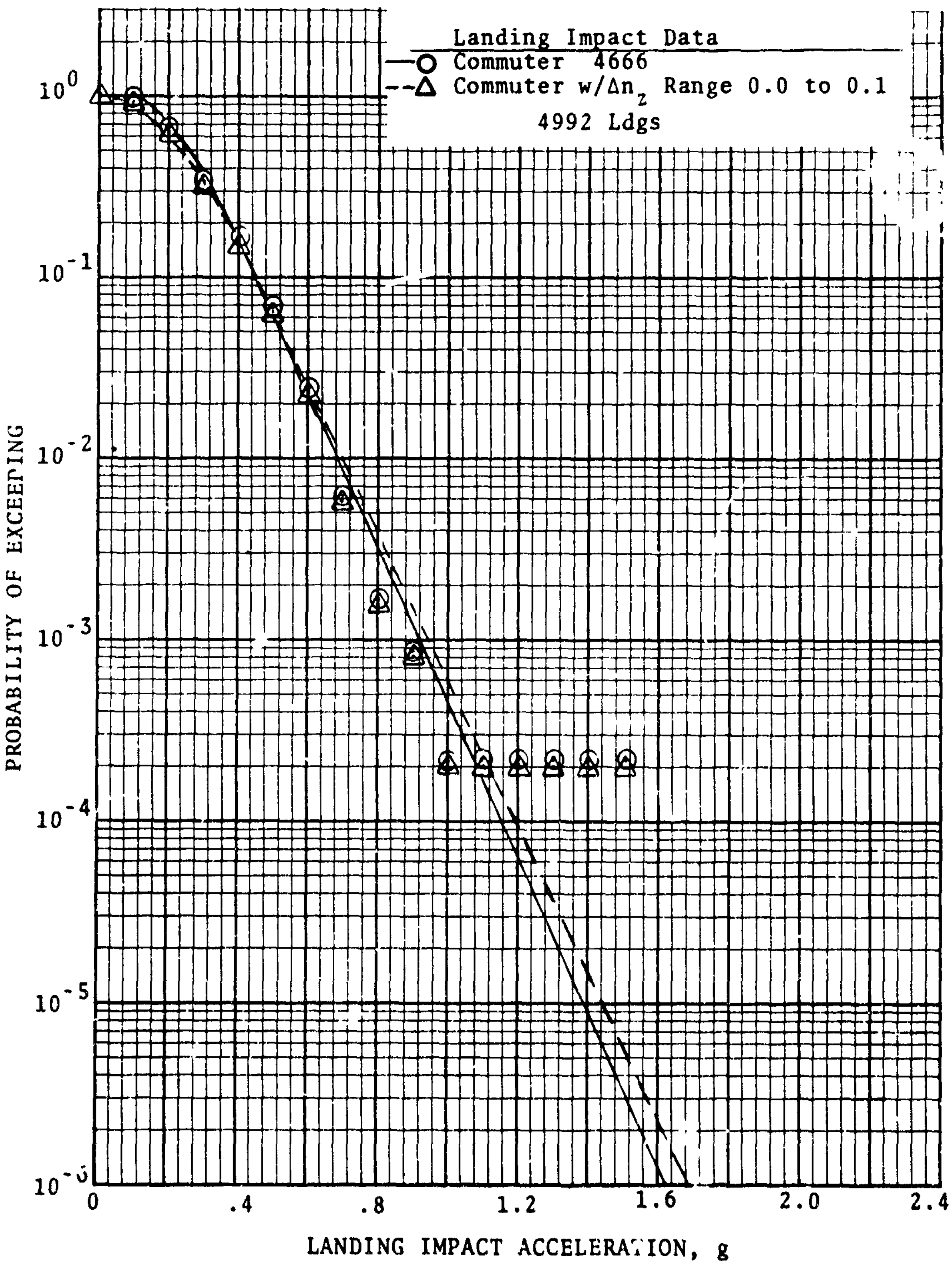


Figure 28. Landing Impact Data With and Without Low-Range Impacts for Commuter Category

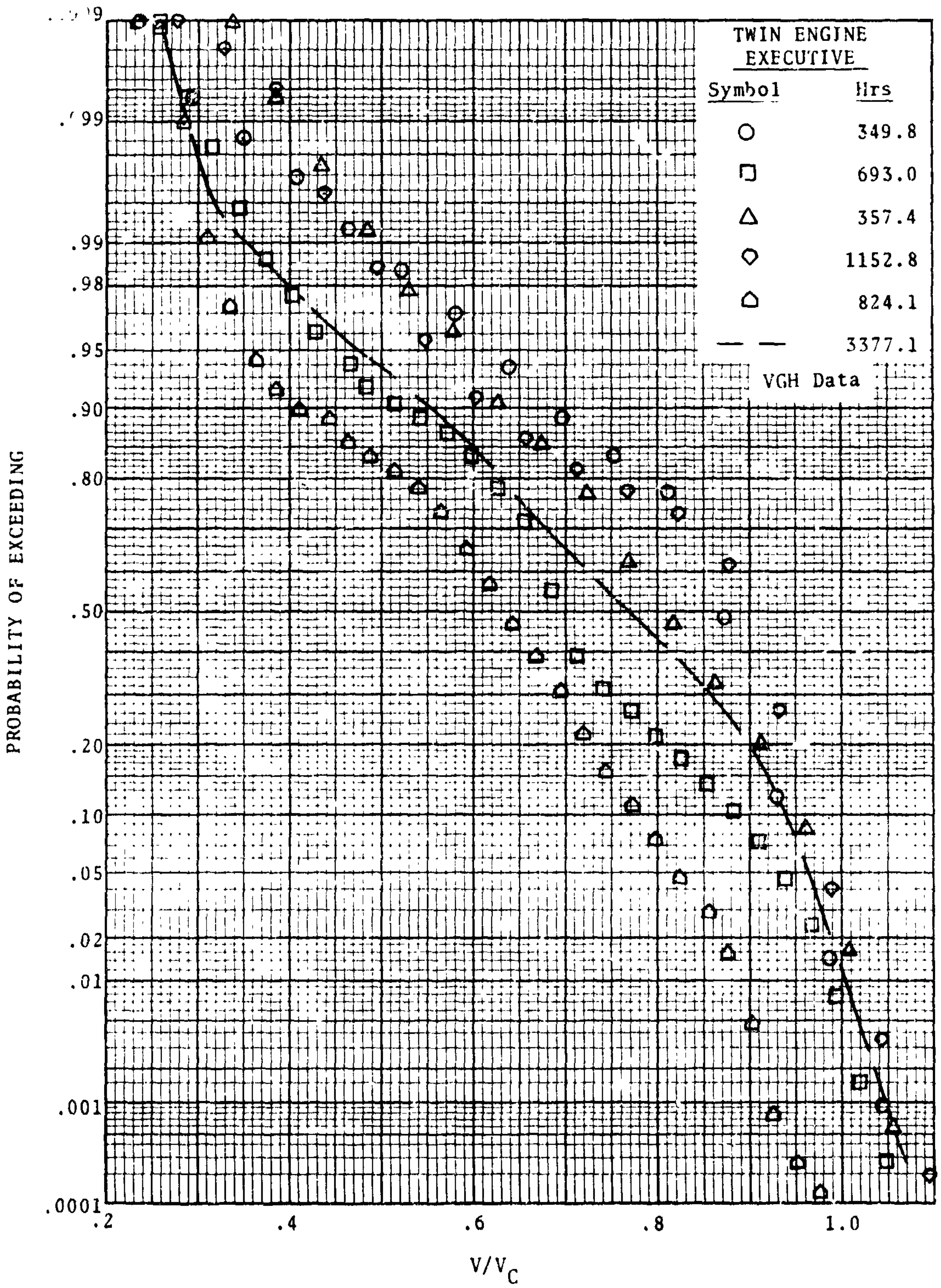


Figure 29. Probability of Exceedance Versus V/V_C for Twin-Engine Executive Category

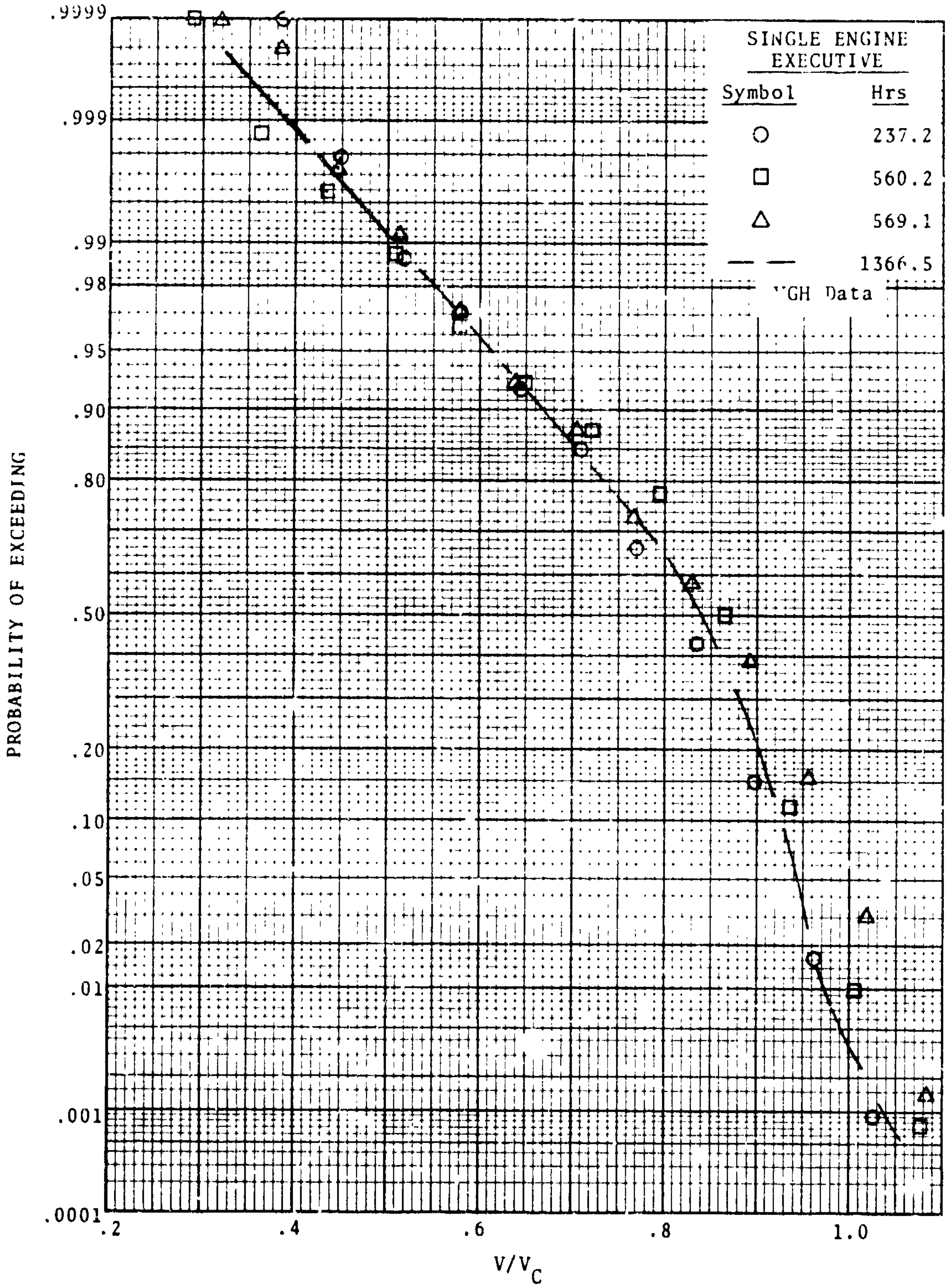


Figure 30. Probability of Exceedance Versus V/Vc for Single-Engine Executive Category

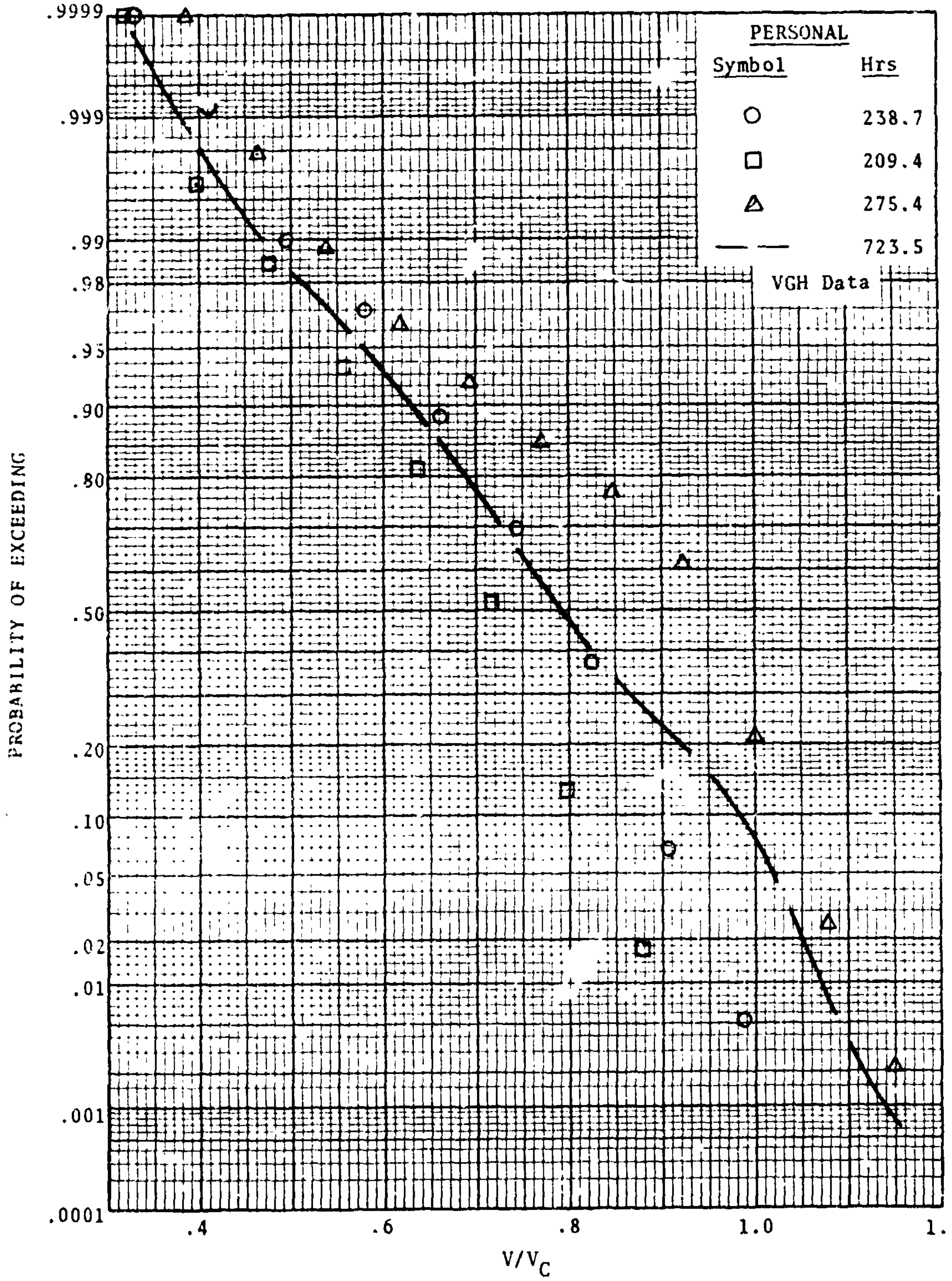


Figure 31. Probability of Exceedance Versus V/V_C for Personal Category

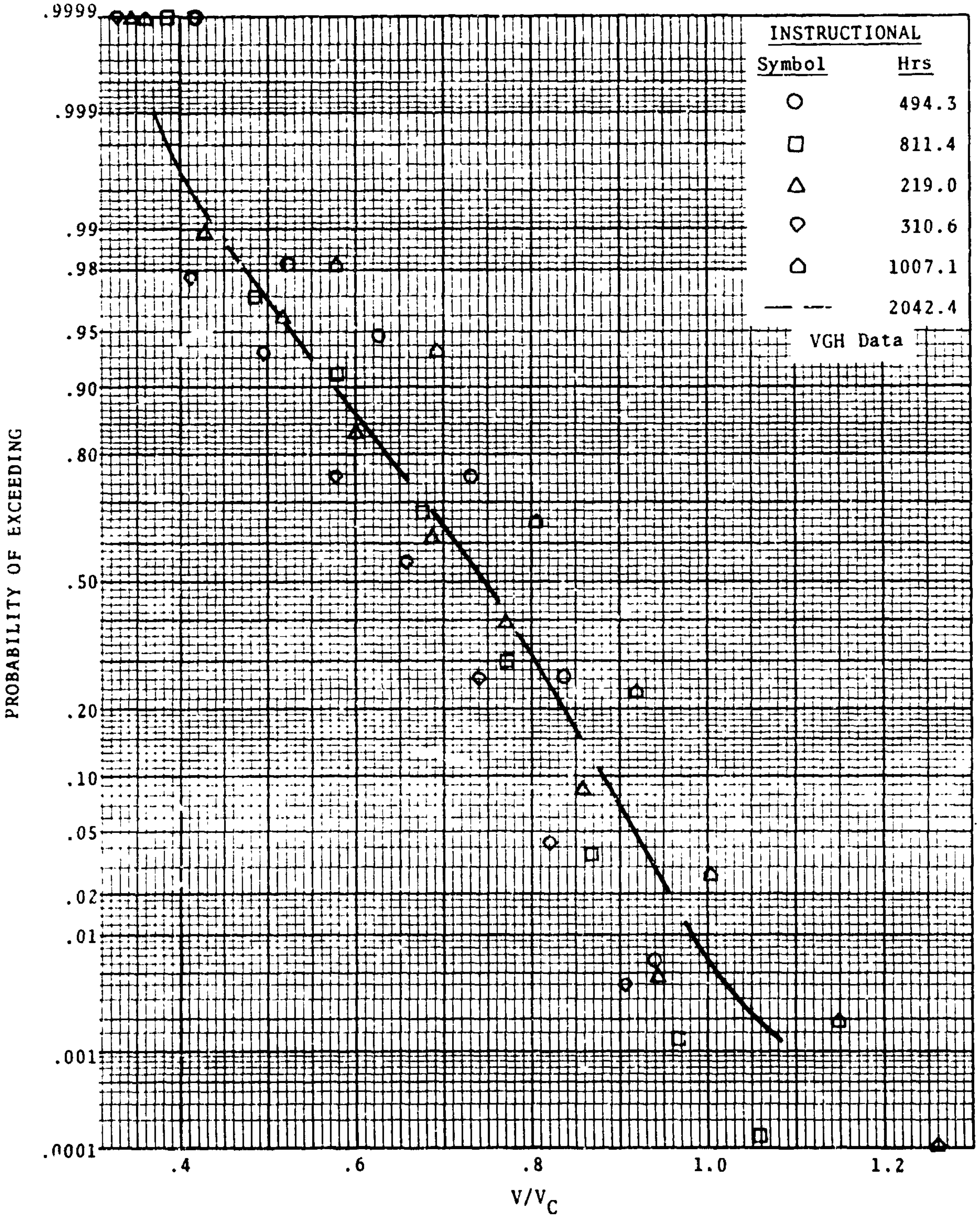


Figure 32. Probability of Exceedance Versus V/V_C for Instructional Category

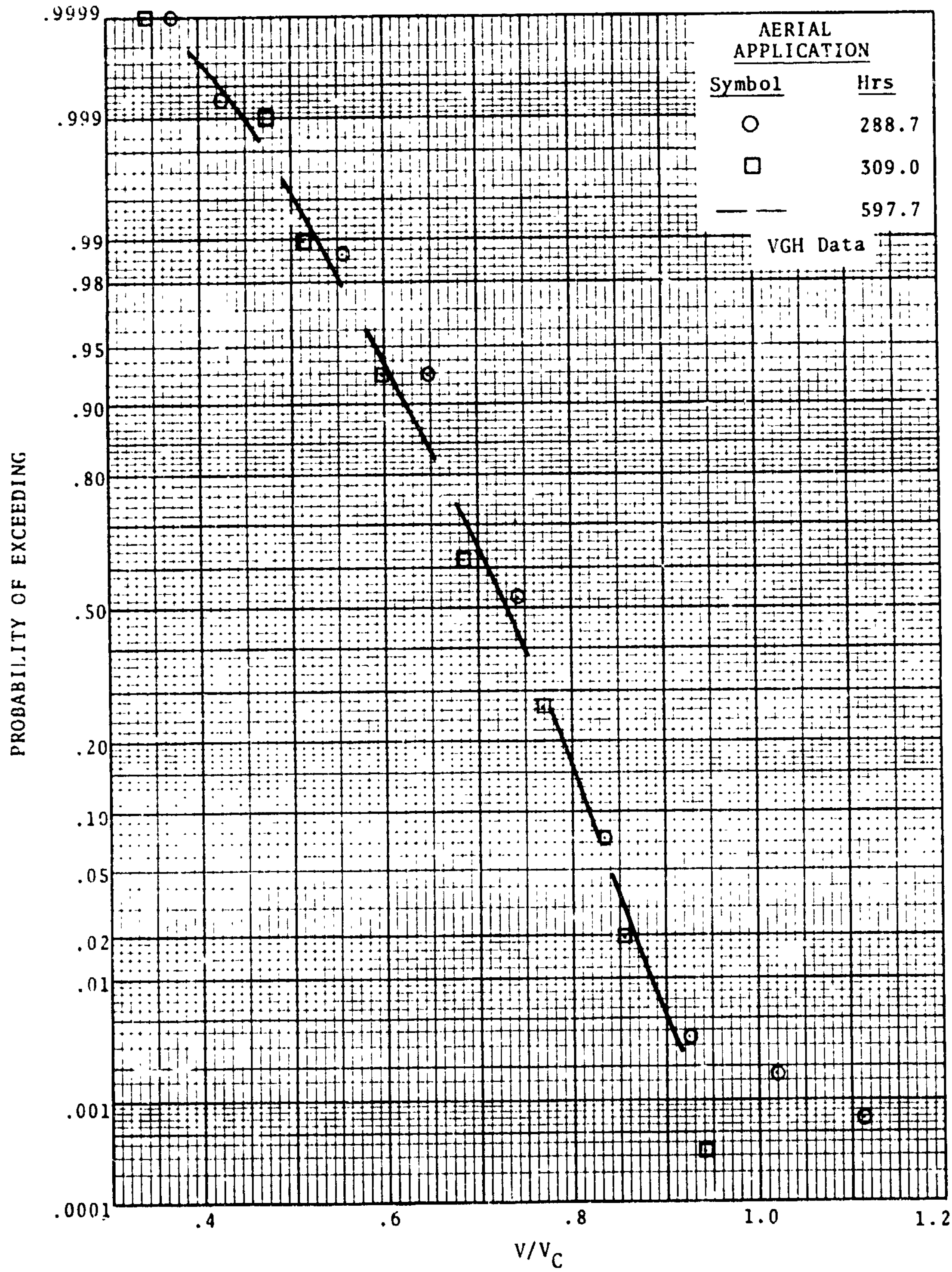


Figure 33. Probability of Exceedance Versus V/V_C for Aerial Application Category

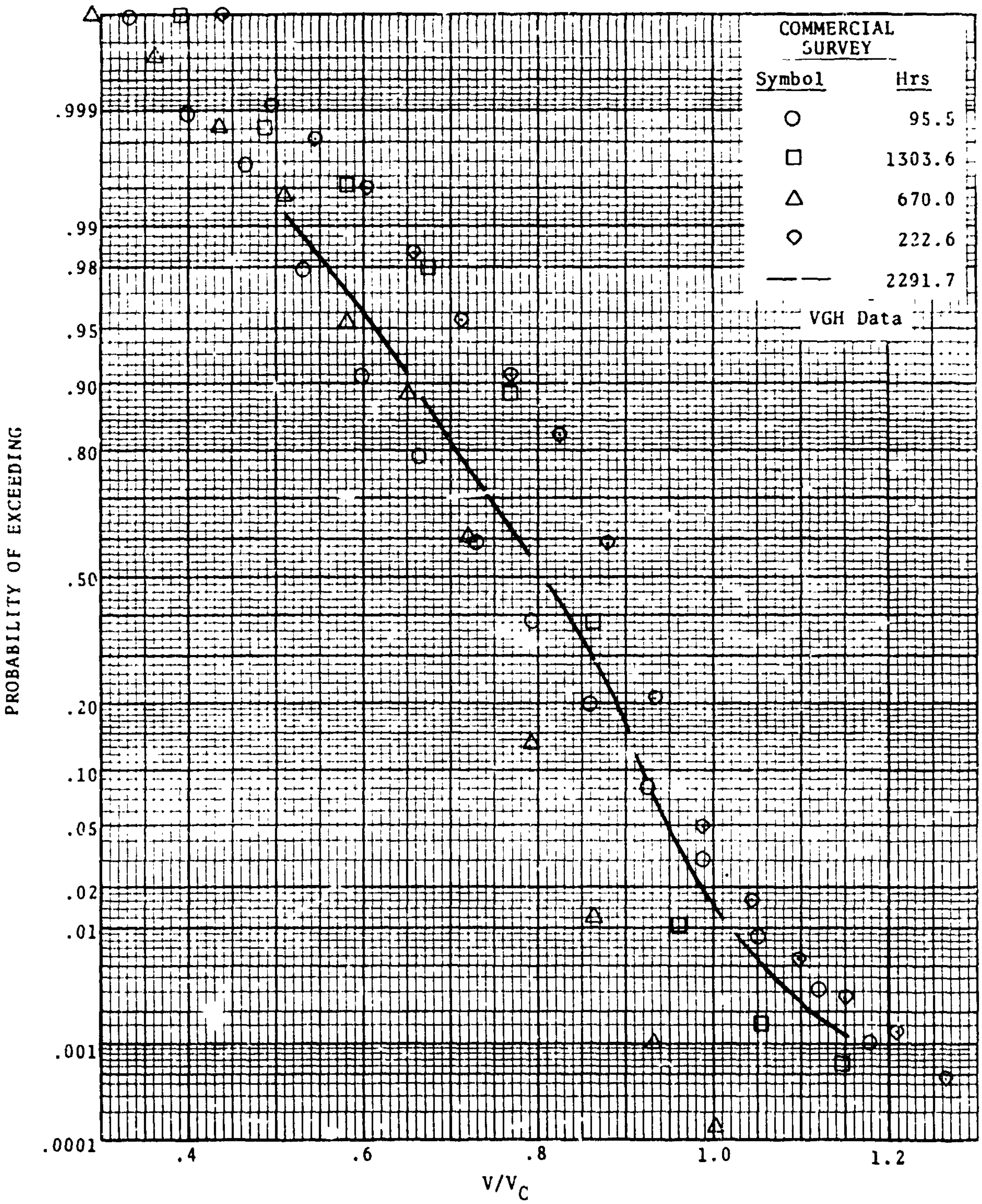


Figure 34. Probability of Exceedance Versus V/V_C for Commercial Survey Category

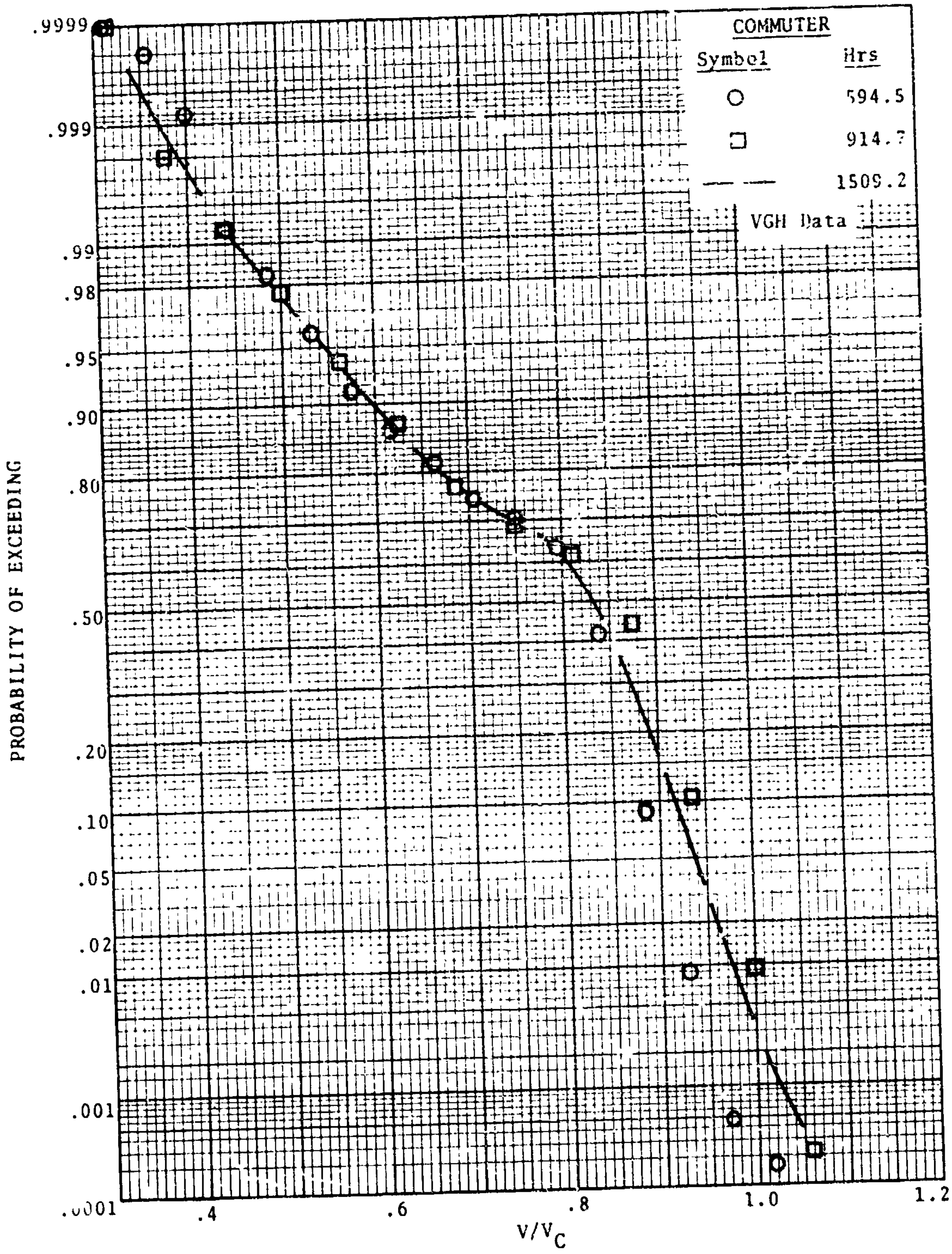


Figure 35. Probability of Exceedance Versus V/Vc for Commuter Category

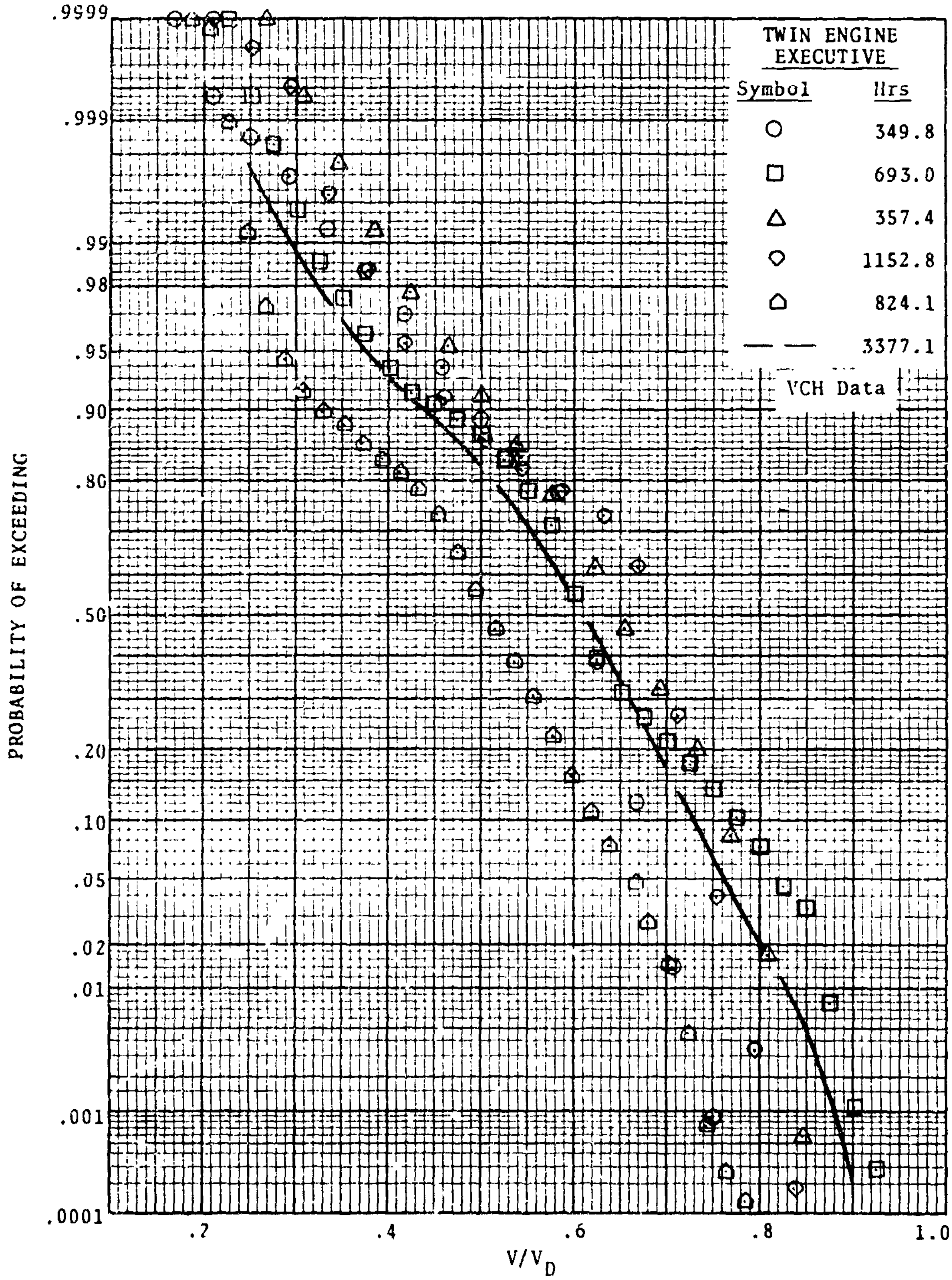


Figure 36. Probability of Exceedance Versus V/V_D for Twin-Engine Executive Category

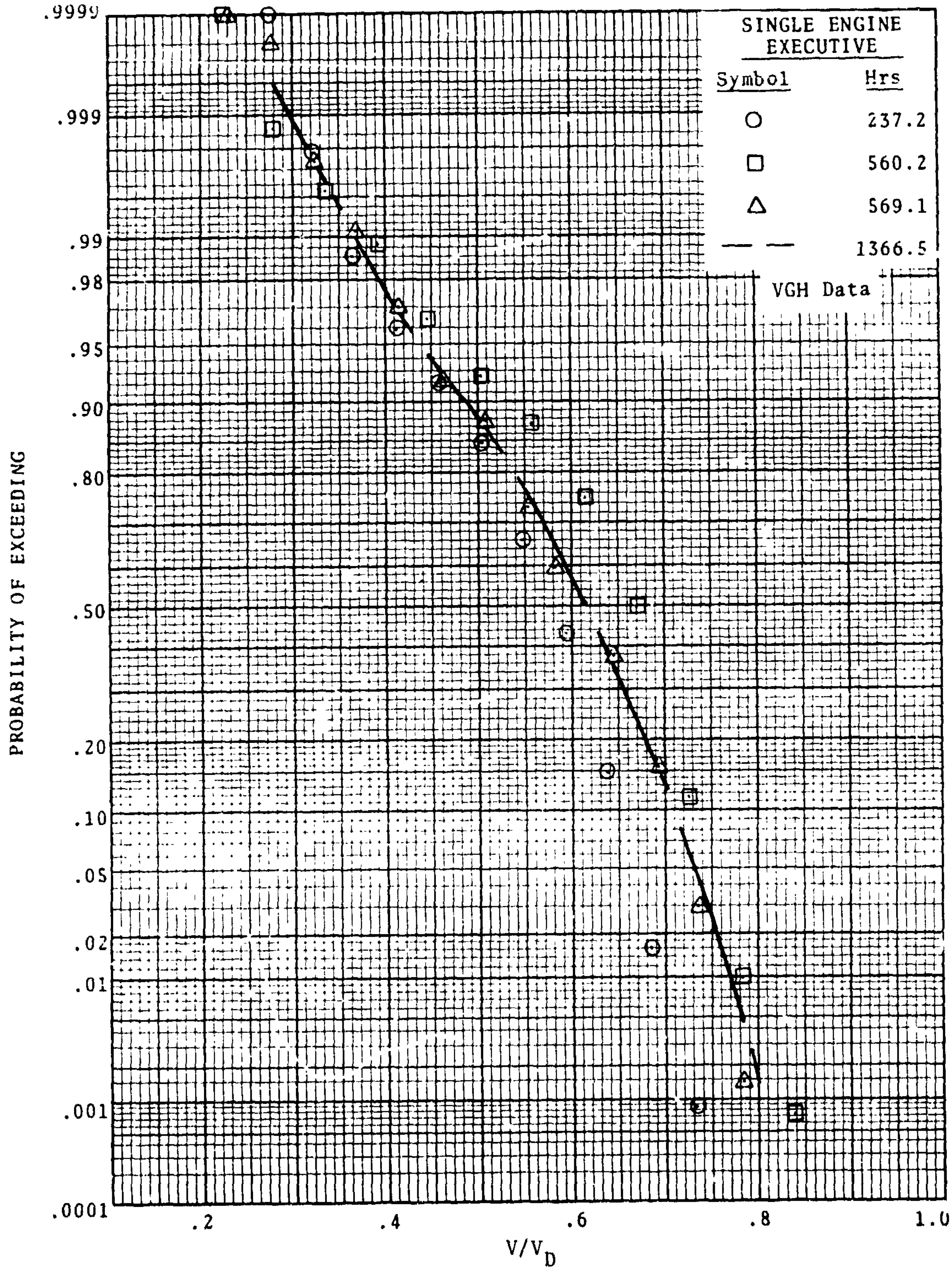


Figure 37. Probability of Exceedance Versus V/V_D for Single-Engine Executive Category

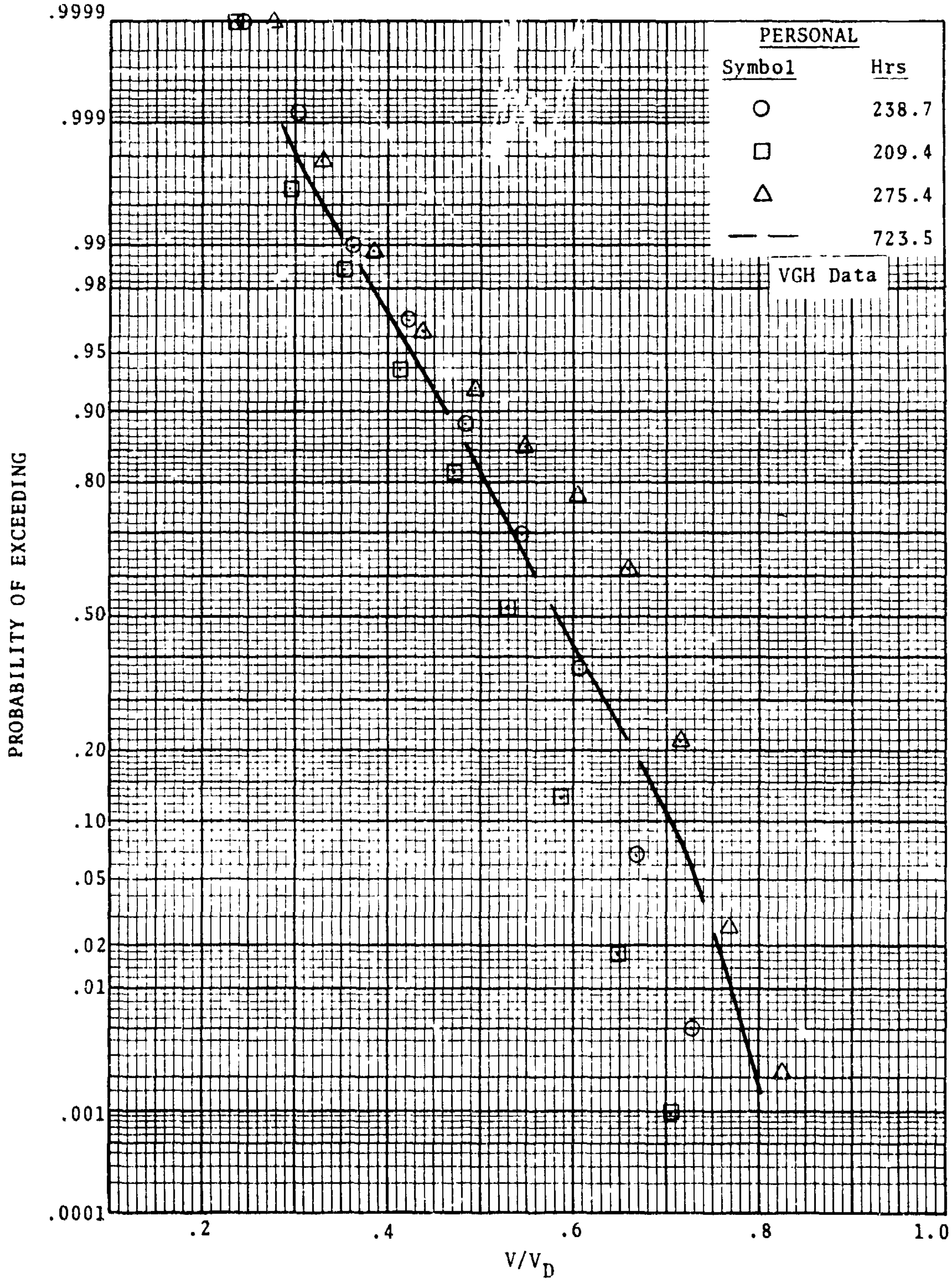


Figure 38. Probability of Exceedance Versus V/V_D for Personal Category

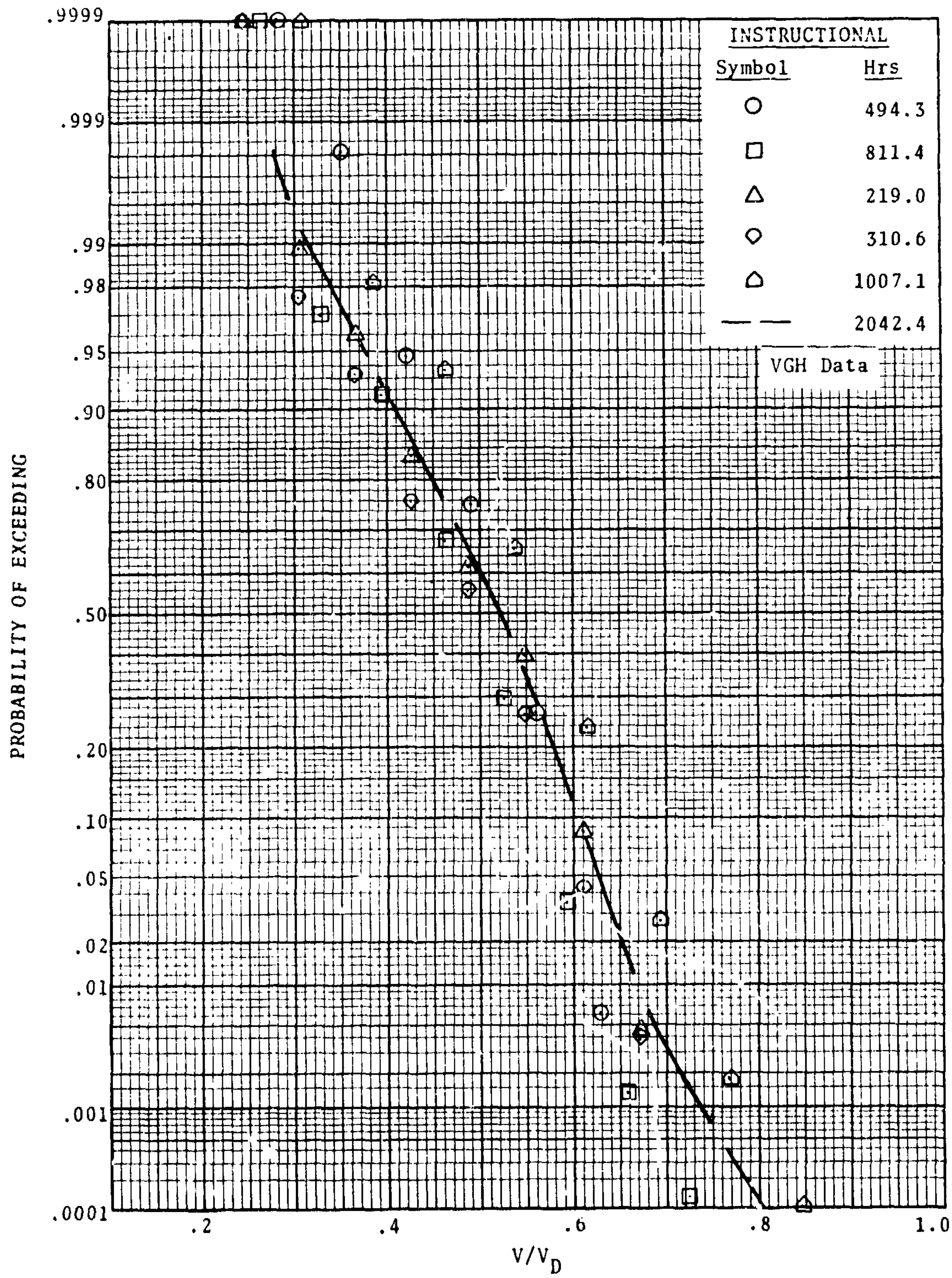


Figure 39. Probability of Exceedance Versus V/V_D for Instructional Category

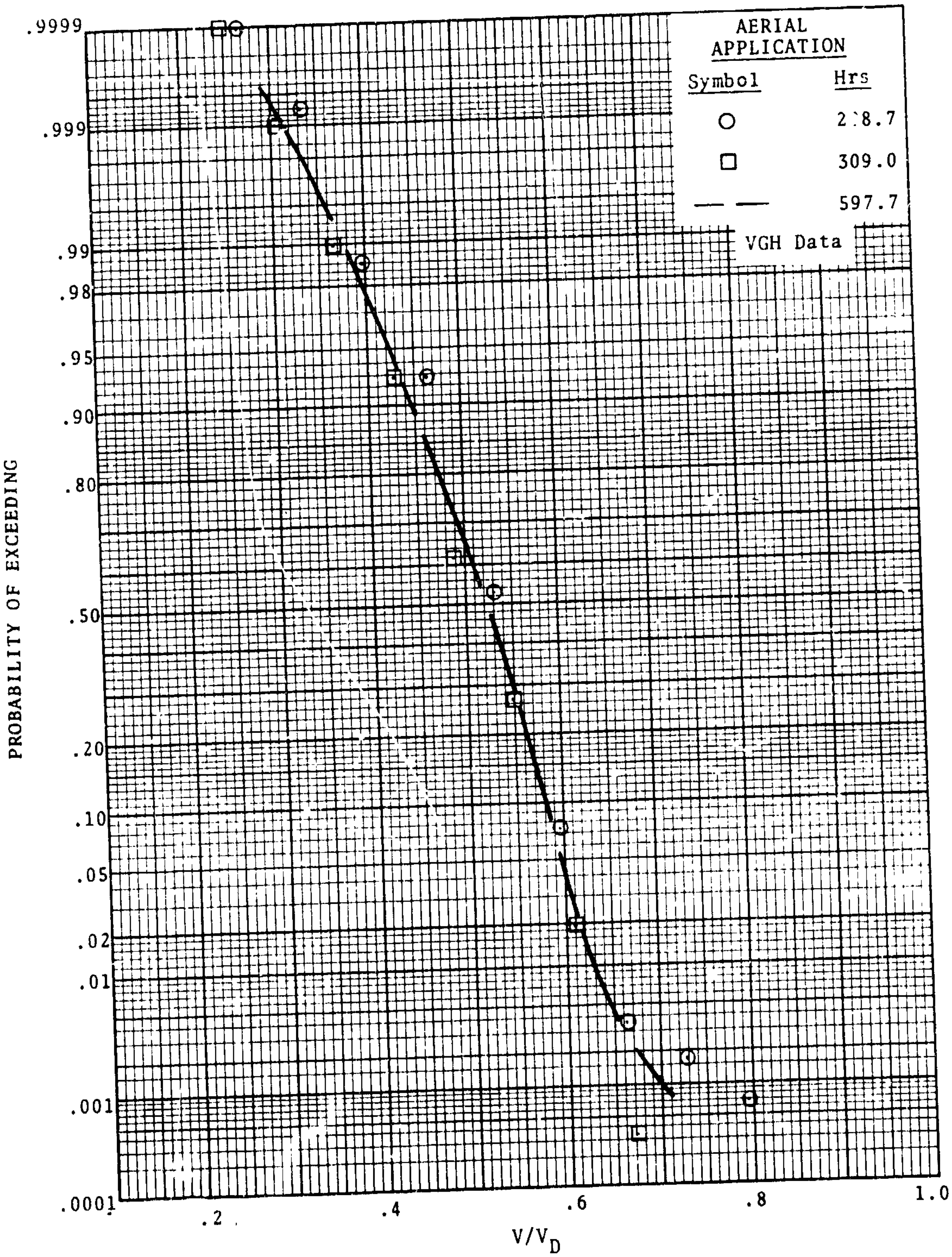


Figure 40. Probability of Exceedance Versus V/V_D for Aerial Application Category

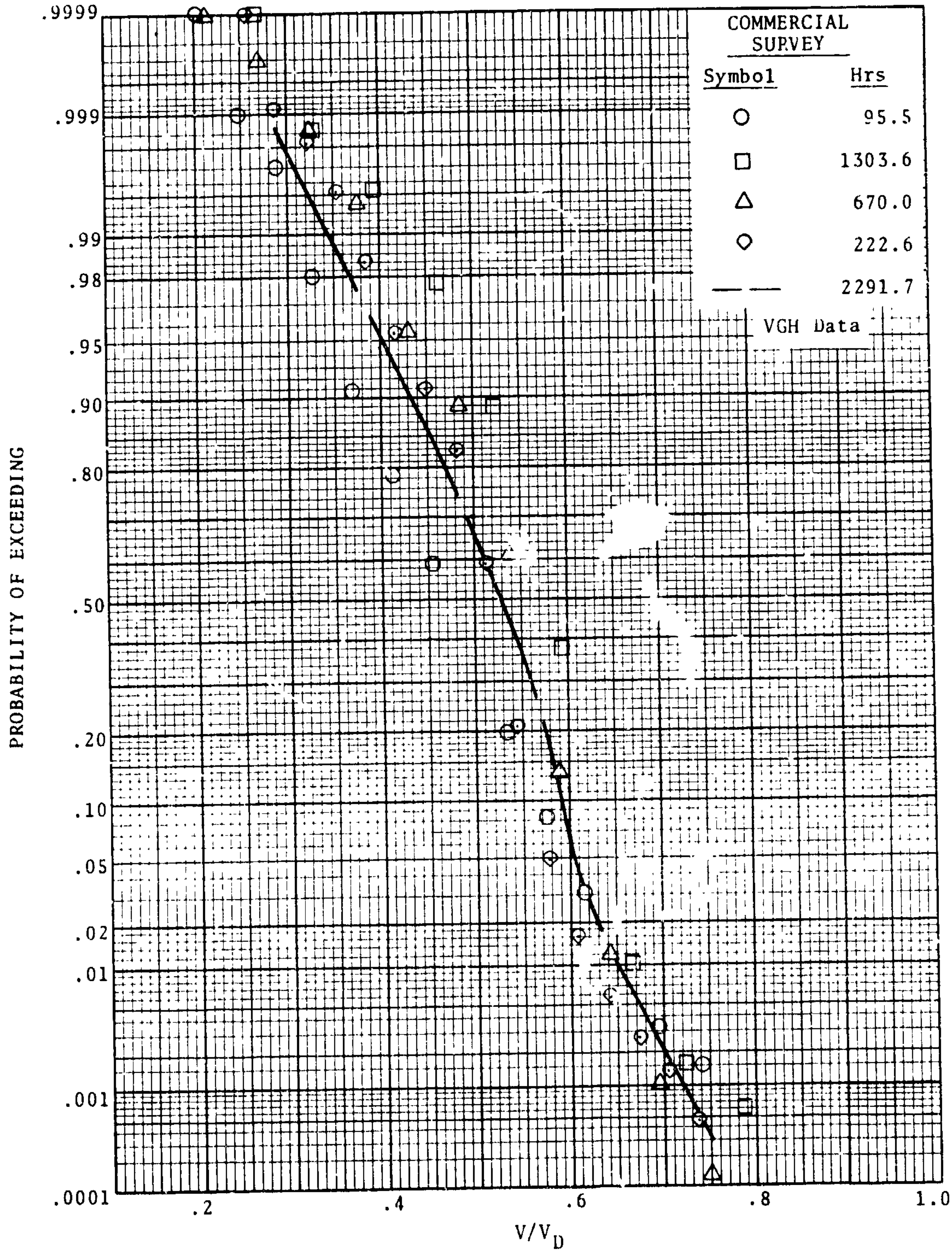


Figure 41. Probability of Exceedance Versus V/V_D for Commercial Survey Category

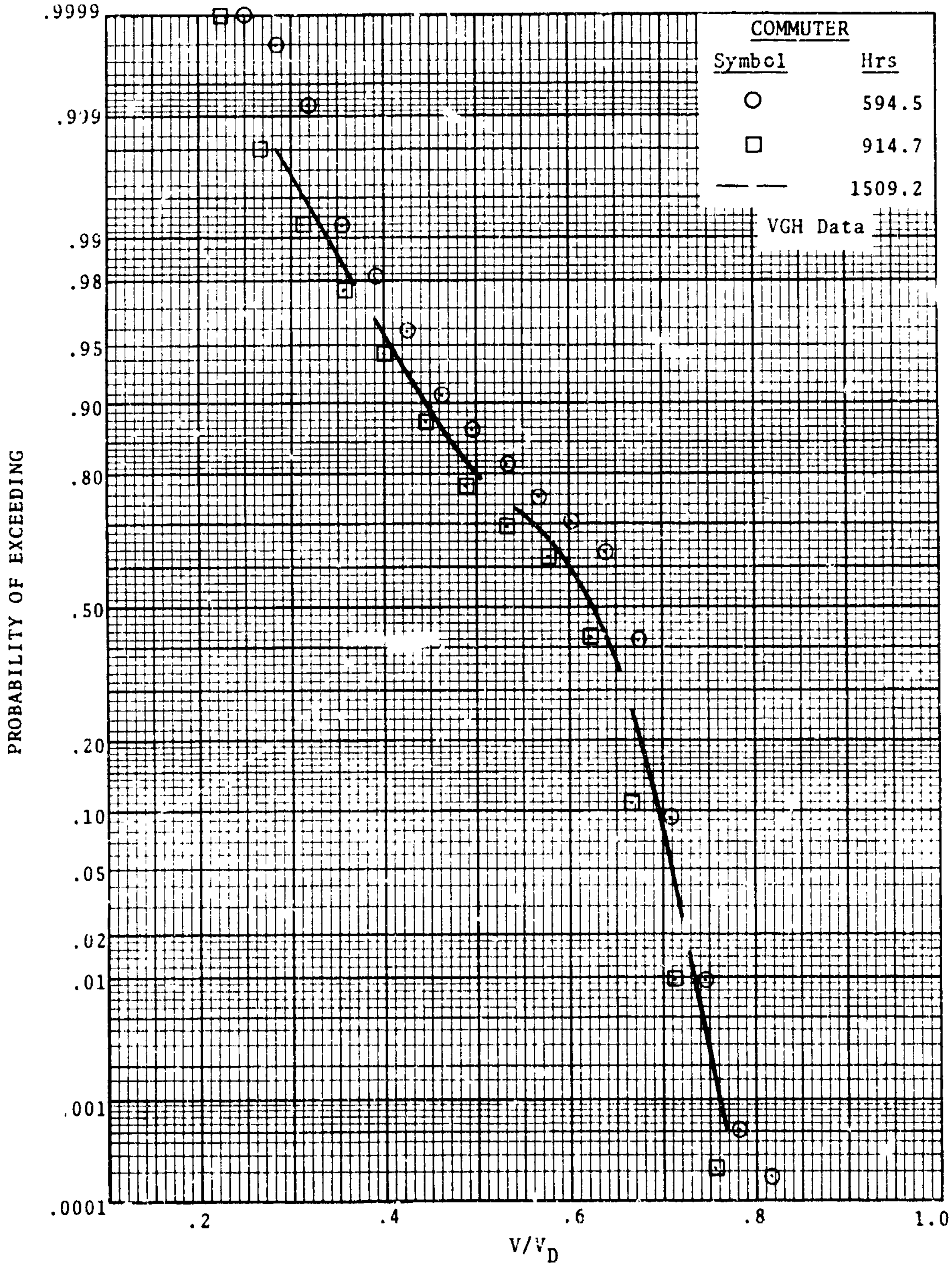


Figure 42. Probability of Exceedance Versus V/V_D for Commuter Category

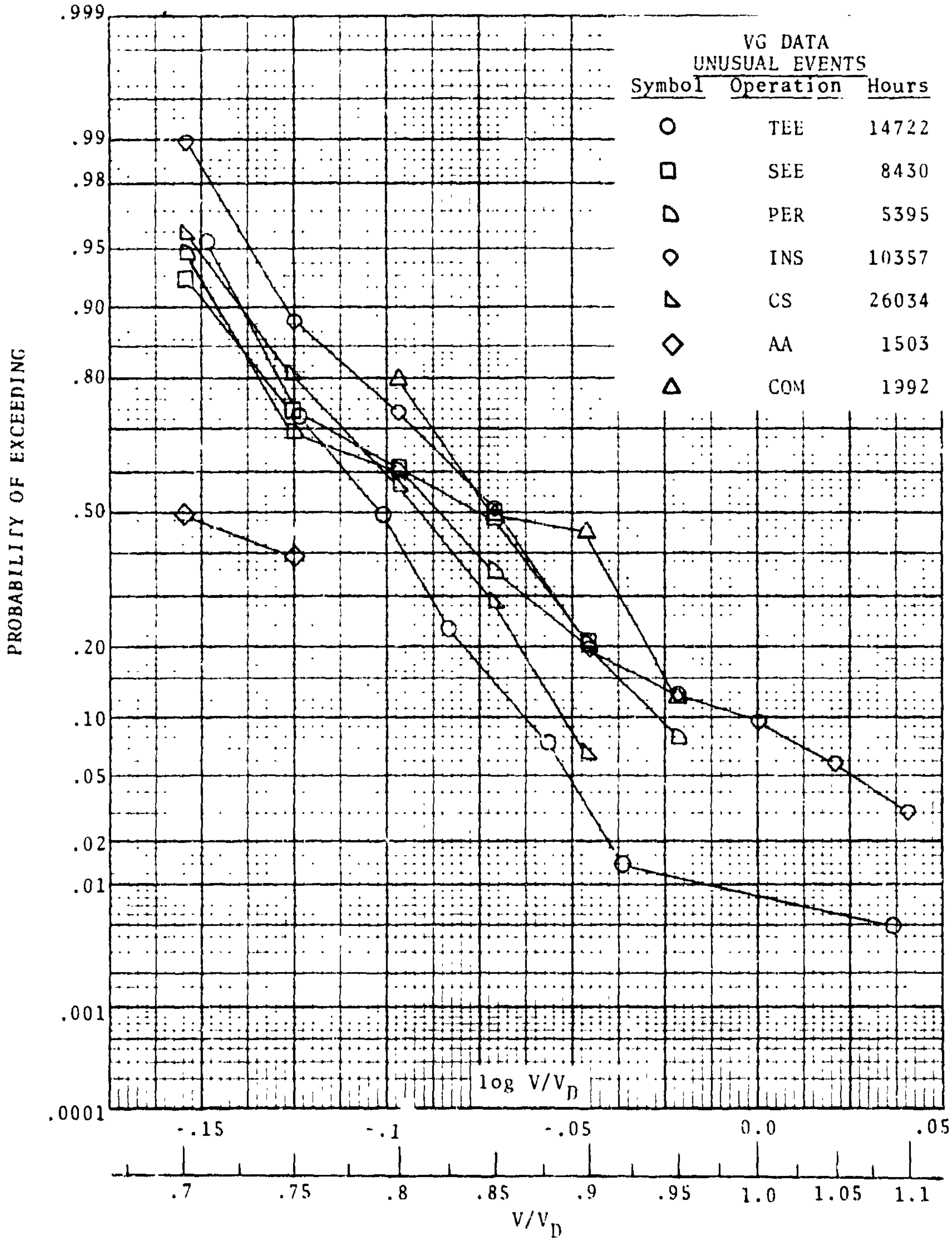


Figure 43. Probability of Exceedance Versus V/V_D for Unusual Events VG Data

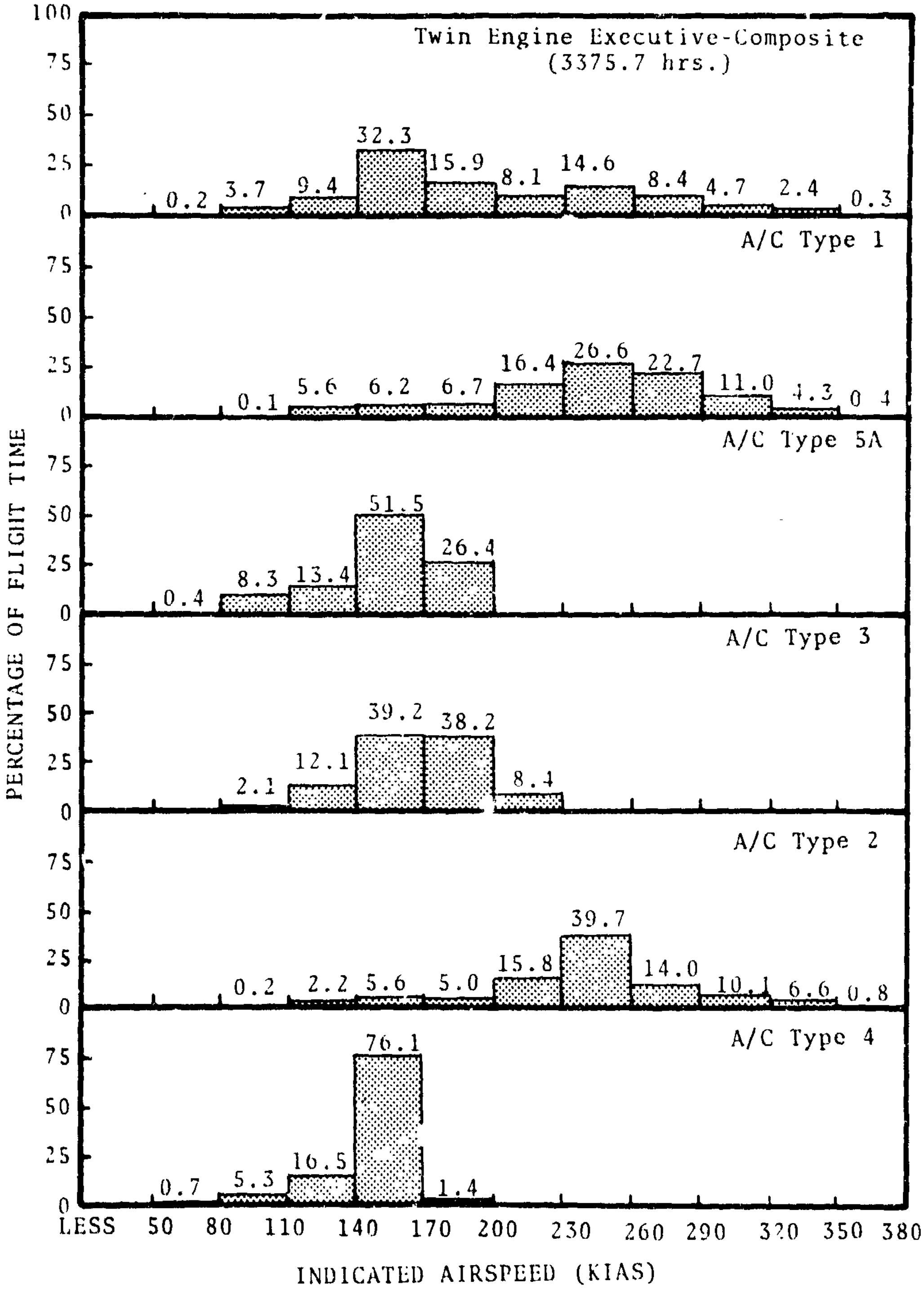


Figure 44. Percentage of Time in Airspeed Ranges for Twin-Engine Executive Category

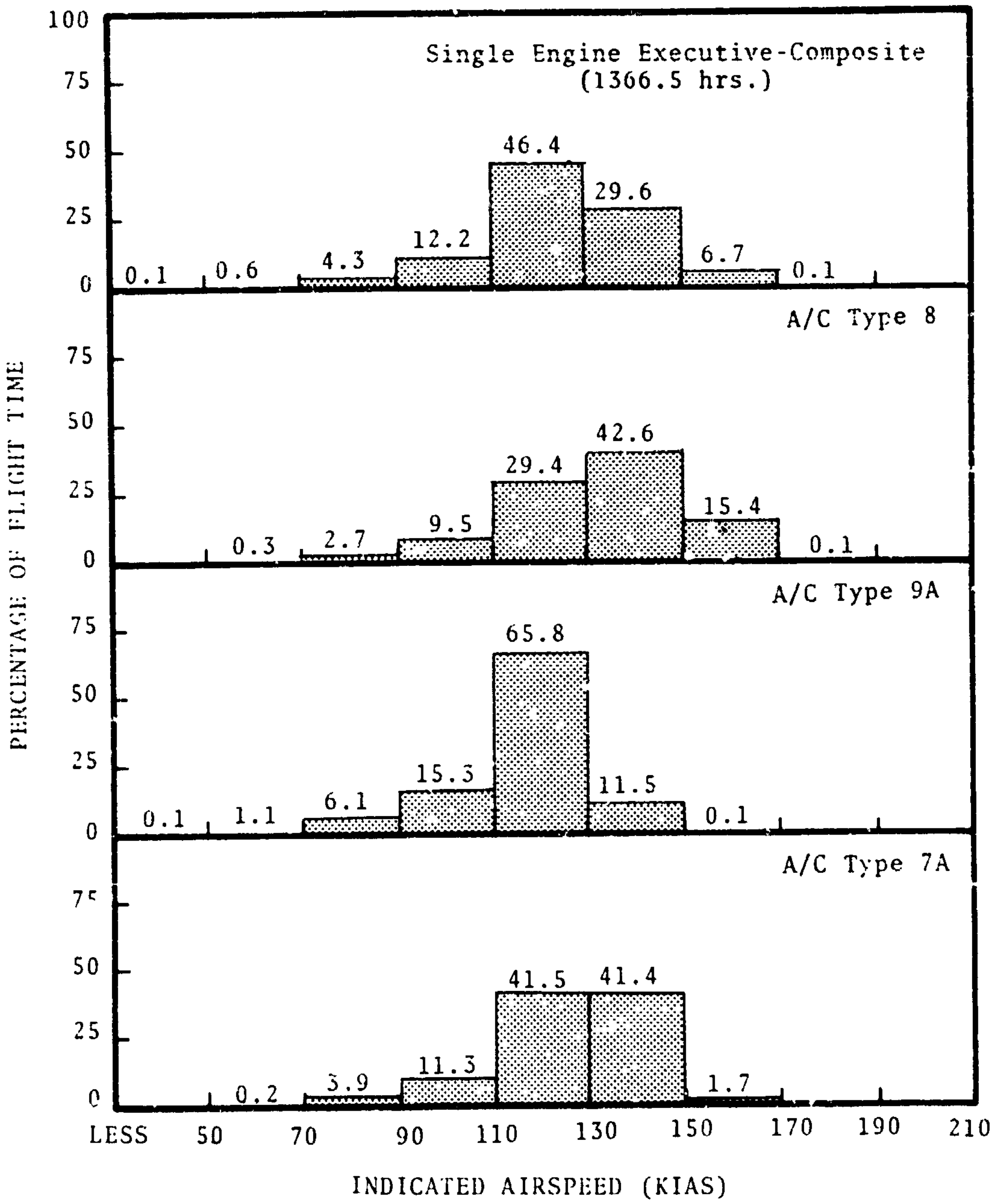


Figure 45. Percentage of Time in Airspeed Ranges for Single-Engine Executive Category

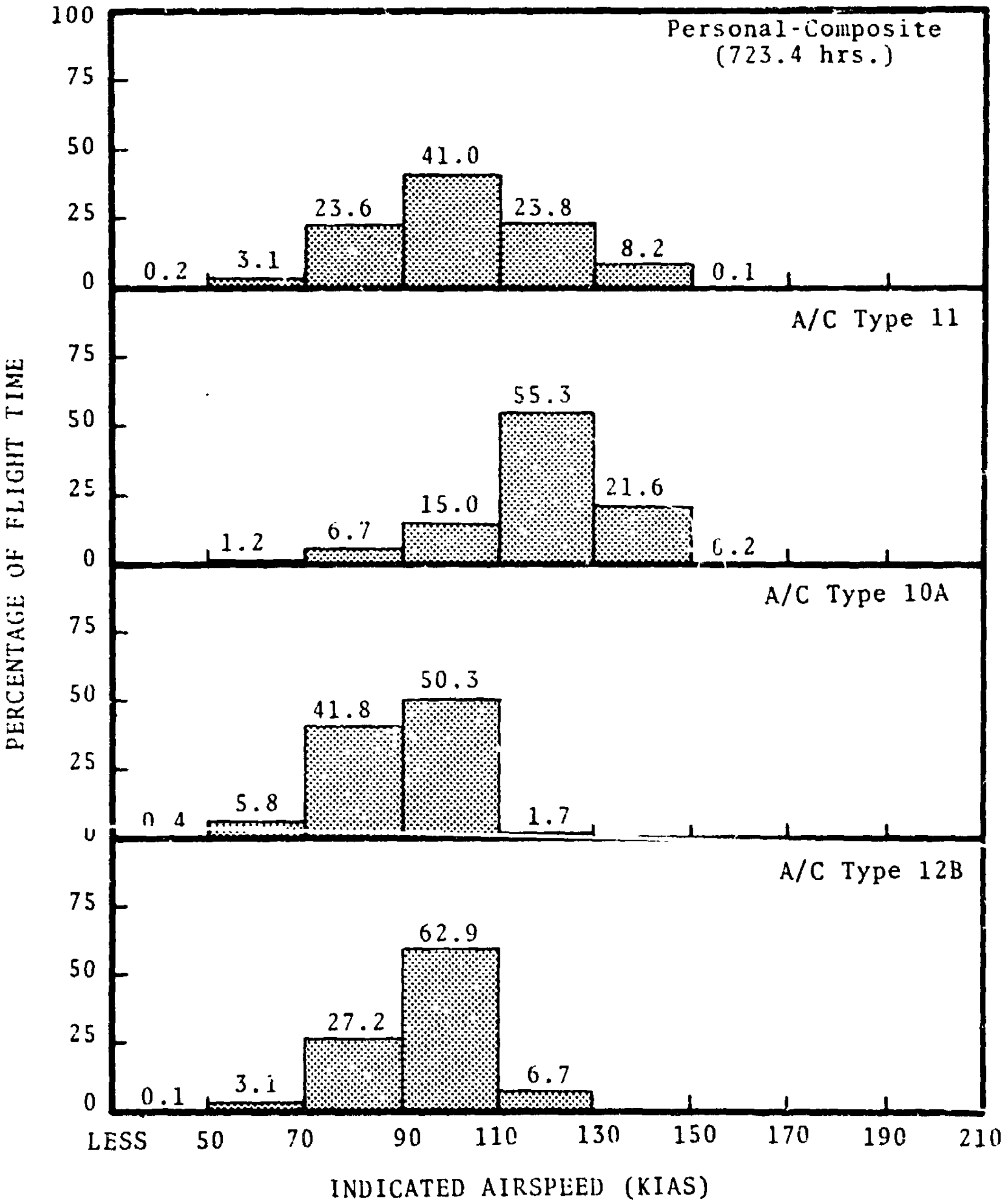


Figure 46. Percentage of Time in Airspeed Ranges for Personal Category

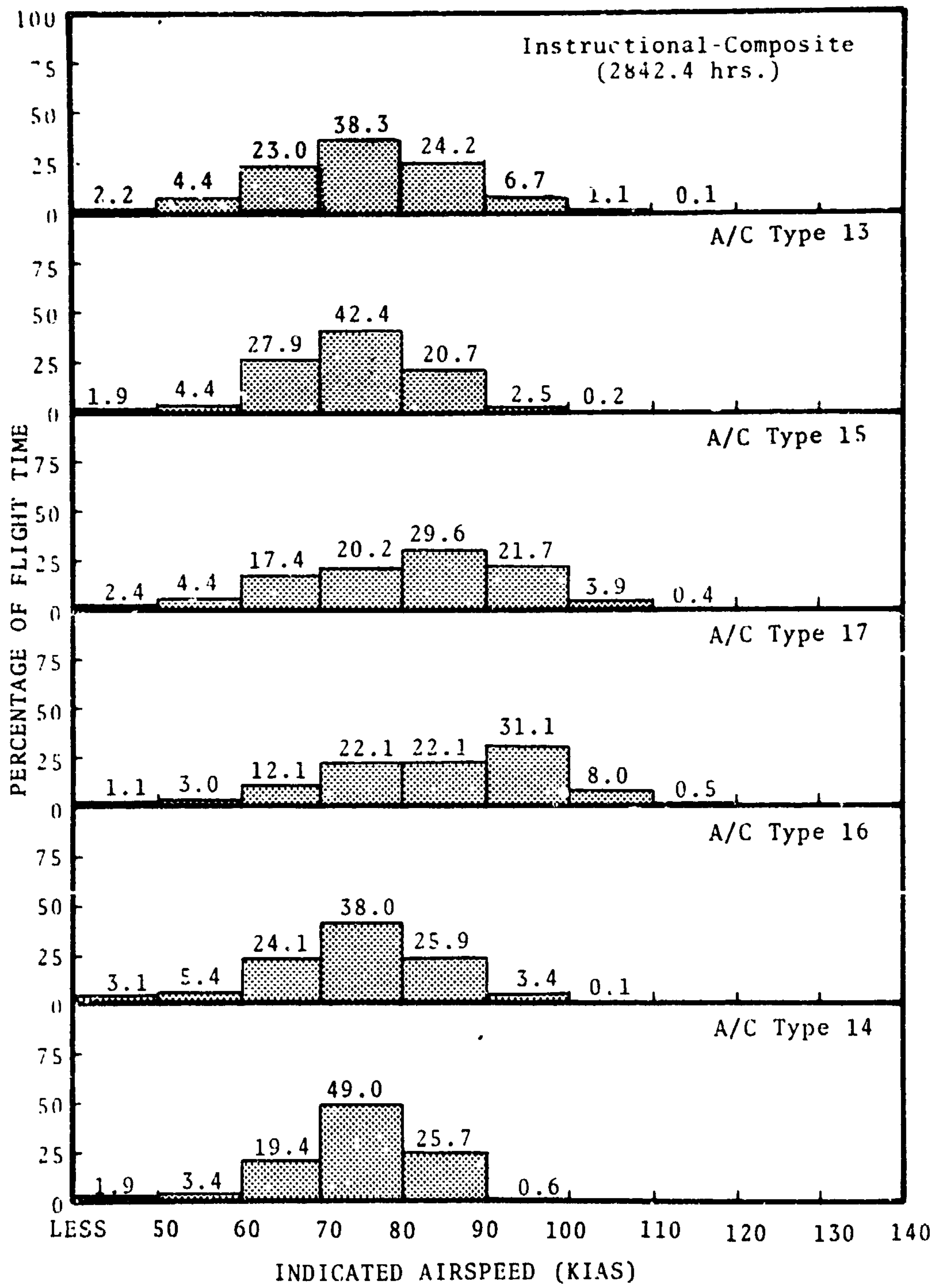


Figure 47. Percentage of Time in Airspeed Ranges for Instructional Category

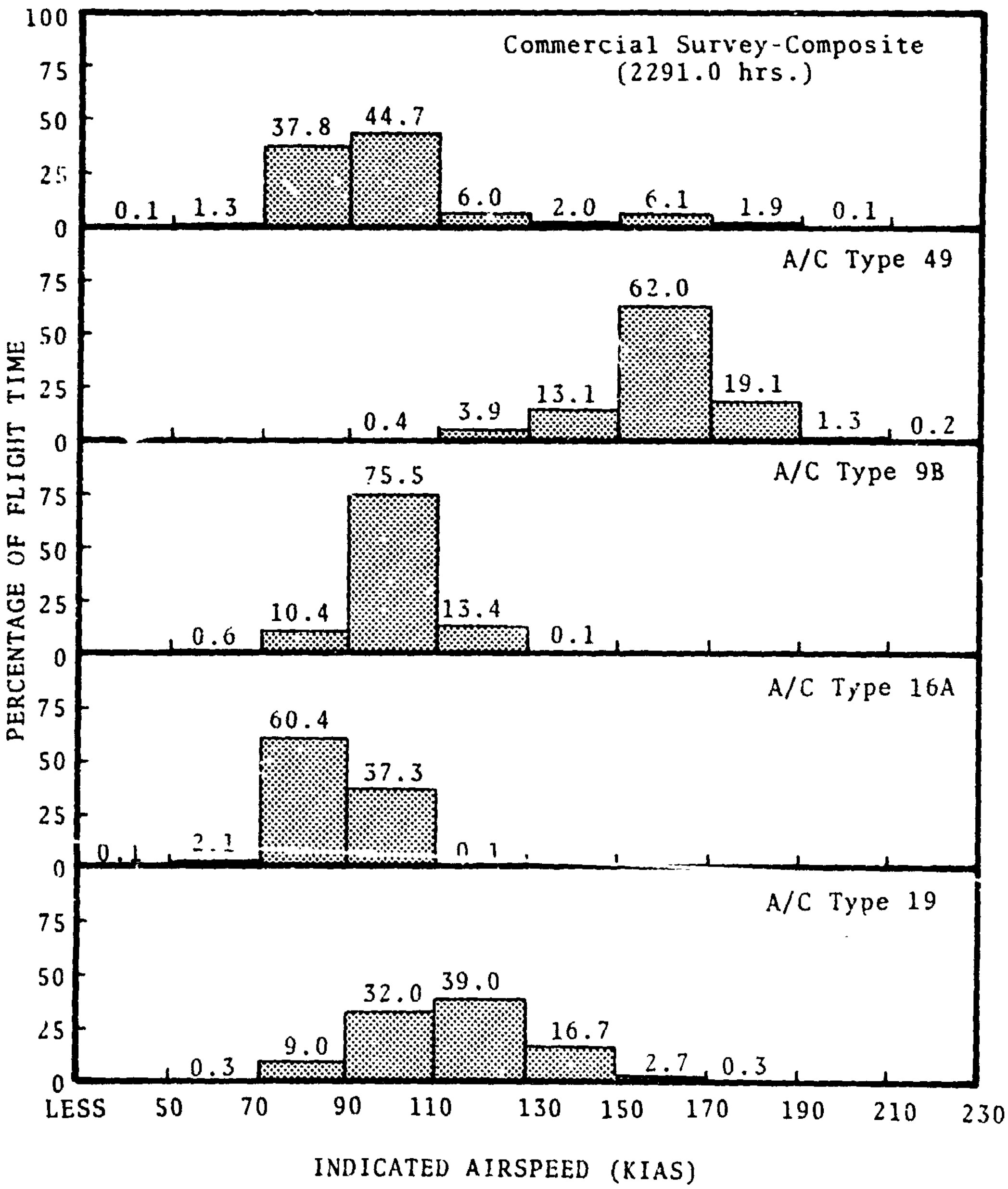


Figure 48. Percentage of Time in Airspeed Ranges for Commercial Survey Category

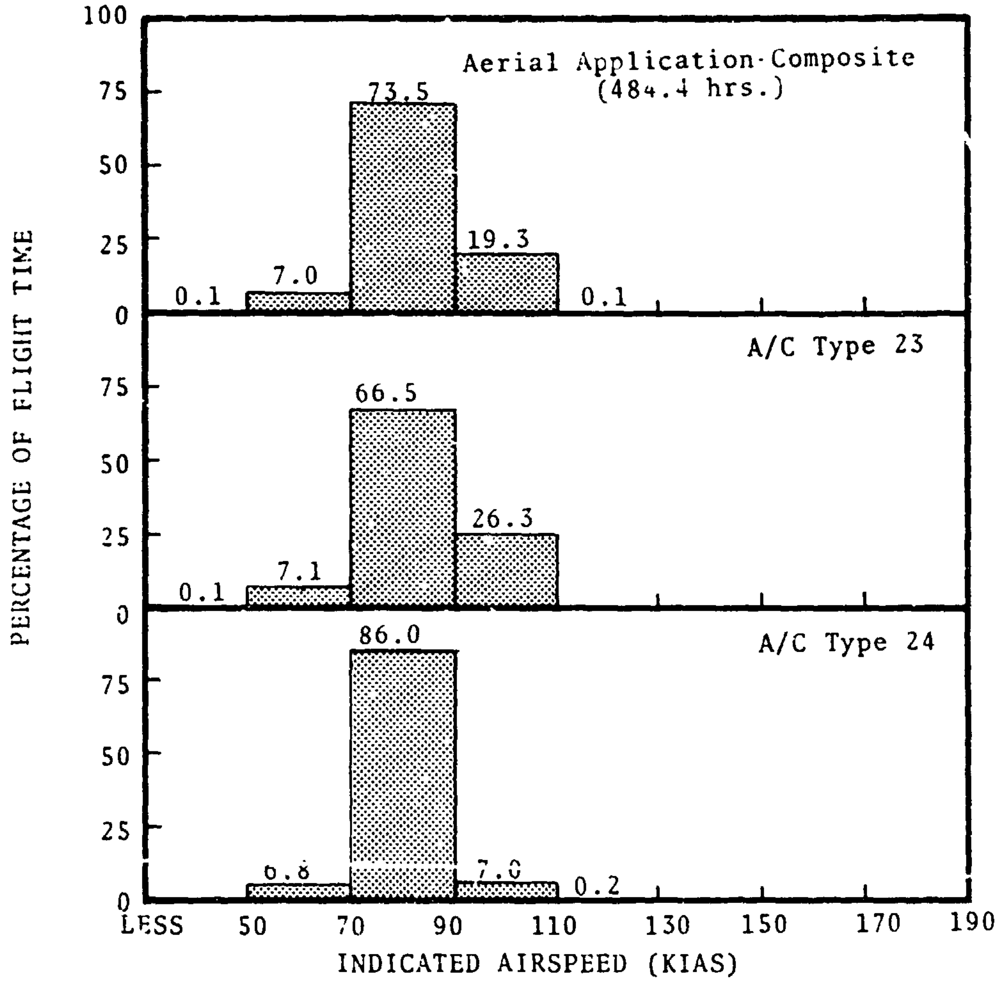


Figure 49. Percentage of Time in Airspeed Ranges for Aerial Application Category

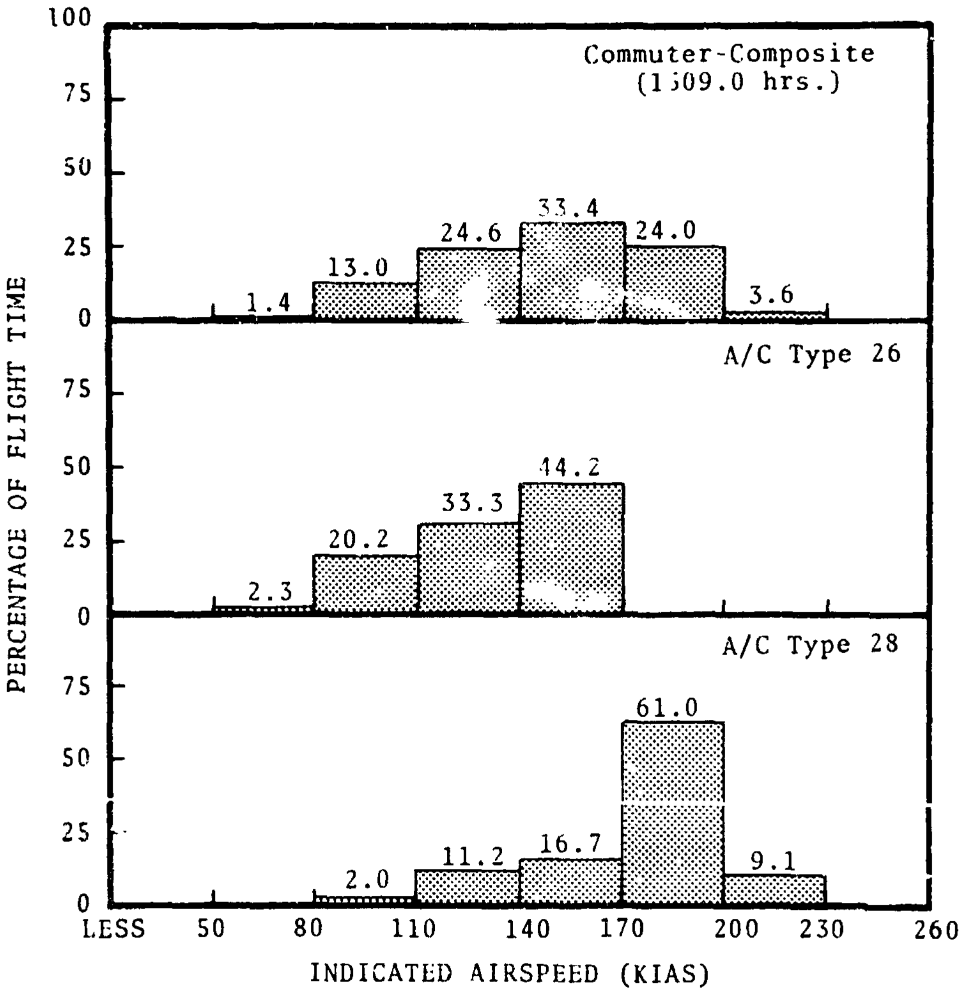


Figure 50. Percentage of Time in Airspeed Ranges for Commuter Category

3. CONCLUSIONS

On the basis of the number of recorded flight hours, the VGH data sample was adequate for all operational categories except the Aerobatic category. On the basis of the number of records, the VG data sample was inadequate for the Aerobatic, Aerial Application, and Commuter categories. The flight hours in the VG and VGH data could not be compared since the VG recorder registers only extreme values and the number and frequency of coincident peak values are unknown.

The observed data distributions were log-normal in most cases and approximately normal in the rest. The Commercial Survey category had two distinct data distributions, one enroute to and from the operational mission and the other during the mission performance.

The Instructional and Aerial Application categories had the highest probability of exceeding the design positive n_z limits for maneuver; the Instructional category had the highest probability of exceeding the design negative n_z limits for maneuver, and the Commercial Survey category had the highest probability of exceeding the design n_z limits for gust.

The Aerial Application and Instructional categories had the most severe landing impact data since they required 860 and 3393 landings, respectively, to attain 1.67 Δn_z while the other categories required more than 19,000 landings to reach this level.

Of the 24 instrumented aircraft types, 17 had airspeeds above V_C, but none had airspeeds above V_D. The Personal category had the highest probability of exceeding V_C; the Instructional and Commercial Survey categories had the highest V/V_C ratios, approximately 1.2; and the Twin-Engine Executive category had the highest V/V_D ratio, approximately 0.925.

Each of the eight operational categories had a distinct load spectrum which reflected the operational characteristics of the category definition, and the various aircraft types within each operational category generally had loads which conformed closely with the average spectrum. The data for the Twin-Engine Executive category could be analyzed better by separating the data for turbojets from the data for turboprop and piston aircraft. Because of the close similarity in the performance results, the Single-Engine and Personal categories could be combined to simplify the analysis.

4. RECOMMENDATIONS

A statistical method to substantiate the adequacy of the sample size should be determined by periodic reduction and analysis of the data while it is being recorded. Comparison of each analysis to previous analyses should yield information concerning the adequacy of data already recorded.

The V-N data for the constant probability envelopes, such as those shown in Figures 7 through 13, should be refined to assess the design requirements for the high-airspeed, high-acceleration regime.

The landing impact spectra should also be investigated by using sink rates instead of load factors because of the complex dynamic transfer function inherent in the landing gear system.

REFERENCES

1. Jewel, Joseph W., NASA Aircraft Safety and Operation, Problems Conference, May 4-6, 1971, NASA SP-270.
2. FEDERAL AVIATION REGULATIONS, TITLE 14, Part 23.
3. Taback, Israel, The NACA 0.1-Damped V-G Recorder, NACA TN 2194, 1950.
4. Richardson, Norman R., NACA VGH Recorder, NACA TN 2265, 1951.
5. Press, H., The Application of Statistical Theory of Extreme Values to Gust-Load Problems, NACA Report 991, 1949.
6. Gumbel, E.J., Applied Mathematics Series 33, National Bureau of Standards, Department of Commerce, 1954.
7. Pratt, K.G., and Walker, W.G., A Revised Gust-Load Formula and a Re-evaluation of V-G Data Taken on Civil Transport Airplanes from 1933 to 1950, NACA Report 1206, 1953.