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A SUMMARY OF OPERATING CONDITIONS EXPERIENCED BY THREE MILITARY HELICOPTERS AND A MOUNTAIN-BASED COMMERCIAL HELICOPTER

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SUMMARY

The results of a survey of the flight conditions experienced by three military helicopters engaged in simulated and actual military missions, and a commercial helicopter operated in the mountainous terrain surrounding Denver, Colo., are presented. The data, obtained with NASA helicopter VGHN recorders, represent 813 flights or 359 flying hours, and are compared where applicable to previous survey results.

The current survey results show that none of the helicopters exceeded the maximum design airspeed. One military helicopter, used for instrument flight training, never exceeded 70 percent of its maximum design airspeed.

The rates of climb and descent utilized by the IFR training helicopter and of the mountain-based helicopter were generally narrowly distributed within all the airspeed ranges. The number of landings per hour for all four of the helicopters ranged from 1.6 to 3.3.

The turbine-engine helicopter experienced more frequent normal-acceleration increments above a threshold of ±0.4g (where g is acceleration due to gravity) than the mountain-based helicopter, but the mountain-based helicopter experienced acceleration increments of greater magnitude.

Limited rotor rotational speed time histories showed that all the helicopters were operated at normal rotor speeds during all flight conditions.

INTRODUCTION

Design and service life criteria for helicopters are based on expected stress histories that will occur throughout the helicopter's predicted mission flight profiles. Some characteristic moment measurements related to classifiable flight conditions have been determined for one type of helicopter and reported in references 1 to 3. The mission flight profiles, however, must be determined from actual operating experience in order that classifiable flight conditions can be quantitatively weighted on a realistic basis. The NASA (formerly NACA) has been conducting helicopter operational surveys for several years in order to provide information that reflects actual helicopter operating conditions. Results of previous helicopter operational surveys are presented in references 4 to 6.

The continuous modernization of helicopters and of operating proce-
dures extends the application of helicopters to an increasingly larger L
variety of missions and, thus, new variations in flight profile. The 1
operations surveyed for this report are principally of a new type of 1
mission. These operations include military helicopters engaging in both 5
simulated and actual military missions in the vicinity of Fort Rucker, 7
Ala., and a mountain-based helicopter operating in the vicinity of Denver, Colo., and extending into the Grand Canyon and to the slopes of Mount Evans. The purpose of this paper is to present more extensive information on the time spent within the classifiable flight conditions - climb, en route, and descent - and to compare the current survey results with the prior studies whenever possible.

HELICOPTER OPERATIONS

The three military helicopters operated in the vicinity of Fort Rucker, Ala., were all of the single-rotor variety. One, a turbine-engine helicopter of medium gross weight, about 5,500 pounds, was the first of its type to be surveyed by the NASA. The survey on this aircraft was conducted over a period of approximately 12 months during which time 480 flights, representing approximately 205 flying hours, were recorded. (A survey on another turbine-engine helicopter of this same type is being continued.) The second military helicopter, about 12,000 pounds gross weight, was used principally to fly Instrument Flight Rules (IFR). During this survey, 110 flights, representing 69 flying hours, were recorded over a period of about 4 months. The third military helicopter was a twin-engine transport type of about 30,000 pounds gross weight. The missions of this helicopter were generally limited to local-load lifting tasks. Fifty-eight flights, representing approximately 35 flying hours, were recorded during a period of about 3 months before the survey was discontinued.

The high-altitude commercial helicopter operating in the Denver area was also a single-rotor type with a gross weight of approximately 2,300 pounds. This operation was surveyed over a period of about 13 months during which time 165 flights, representing approximately

50 flying hours, were recorded. This helicopter was employed in a variety of charter missions such as geological surveys in the Grand Canyon and wild life census on mountain slopes where the pressure altitudes range up to 13,000 feet. Even the missions of ordinary character were conducted at altitudes above 5,200 feet.

INSTRUMENTATION AND DATA EVALUATION

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The data for these surveys were obtained by use of NASA helicopter VGHN recorders which record time histories of airspeed, center-of-gravity normal acceleration, pressure altitude, and rotor rotational speed. Before the instruments were modified to record rotor rotational speed, they were the same type as the one described in reference 7. The film drums were customarily replaced at intervals coinciding with the helicopter's periodic maintenance schedule. These intervals are usually 20 or 25 hours flying time, compared to a maximum record running time, including ground time, of $16\frac{2}{3}$ hours.

Previous analyses, presented in references 4 to 6, have shown that an approximate 10-percent sampling of the flight records, along with random checks for accuracy, will provide results representative of the total flight profile. When the total quantity of records was small, more frequent random checks were required which increased the percentage evaluated. For the mountain-based helicopter, 26 percent of the flights were analyzed; 17 percent, for the turbine-engine helicopter; 31 percent, for the IFR training helicopter; and about 13 percent, in the case of the heavy transport helicopter, which was not treated as fully as the other three operations because the survey was not representative and, therefore, discontinued.

The analysis procedure thus pertains to the compilation of the measured quantities on a sampling basis, but in all cases the complete flight records are visually edited for unusual occurrences. Furthermore, it should be noted that the results of each operational survey on an individual basis are of minimum value for design predictions. Therefore, whenever possible, current operational data are considered in relation to previous operational results.

The classifiable flight conditions are climb, en route, and descent and are readily identifiable from the flight time histories. The flight conditions are further classified with respect to the time spent in the various airspeed regimes and in the various rates of change of operating altitude regimes. Furthermore, where the data are sufficient, center-of-gravity normal accelerations are included. In the treatment of rotor rotational speed, time histories were not recorded in sufficient quantity from any of the operations to permit a quantitative analysis. The analysis is therefore restricted to qualitative comments on the available records.

RESULTS AND DISCUSSION

The results are presented as a breakdown of operating experience according to time spent within the classifiable flight conditions for the mountain-based commercial helicopter, for the turbine-engine military helicopter, and for the IFR training military helicopter. The 30,000-pound transport helicopter was placed temporarily under severe operating restrictions which precluded the obtaining of realistic flight conditions data. The results obtained from this helicopter are therefore presented in summary form only.

Operating Conditions

A summary of the flight profiles of the four helicopters surveyed for this report is presented in table I. This summary includes the 30,000-pound helicopter that is not treated to a more thorough analysis in the ensuing text. For comparison purposes, a similar summary from reference 6 is included in table I. For the present survey, the percent of time in climb ranges from 12.2 to 18.8, time en route ranges from 59.4 to 75.9 percent, and time in descent ranges from 11.6 to 21.8 percent. A comparison of these results with those of reference 6 shows that the percentage range of time spent in each condition has been expanded in this survey.

Operating Airspeed

The operating airspeed experience for the mountain-based helicopter, the turbine-engine helicopter, and the IFR training helicopter is presented in figure 1. The percent of flight time within the various airspeed ranges is shown with respect to indicated airspeed. The airspeed is subdivided into incremental categories of 20 knots except for the initial range which is measured from 0 to 40 knots. Experience has shown that the airspeed indicator is quite insensitive from 0 to 20 knots and, therefore, reliability of the recorded data within this range would be doubtful. The airspeed is also presented in terms of percent of maximum design airspeed V_{max} for each helicopter. The maximum operational speed is obtained from the pilot's handbook in each case and is shown on the figure. The total airspeed experience is presented in figure 1(a).

Figure 1(b) presents the airspeed as it was accumulated in the flight conditions of climb, en route, and descent.

The treatment of airspeed with respect to maximum design airspeed is based on the consideration that V_{max} is very often determined by retreating blade stall rather than power available. Thus, operating airspeed accumulated in excess of V_{max} would indicate flight in a condition of increased rotor moment as described in reference 2. Examination of figure 1(a) shows that none of the three helicopters were operated in excess of V_{max}, and the IFR training helicopter was never operated in excess of 70 percent V_{max}.

The airspeed experiences of the mountain-based helicopter and of the turbine-engine helicopter compare favorably with the results of reference 6 in that the largest percentage of total time was spent at an average of 62.5 and 70 percent V_{max}, respectively. The IFR training helicopter spent the largest percent of its time at about 47 percent V_{max}.

In the initial airspeed range between 0 and 40 knots, vibratory moments during transition and landing approach become very large (ref. 3). Figure 1(a) shows that in the initial airspeed range the mountain-based helicopter was operated about 35 percent of the time; the turbine-engine helicopter, about 18 percent of the time; and the IFR trainer, only about 4 percent of the time. Except for the mountain-based helicopter, these values compare favorably with those of reference 6. However, the high percentage recorded by the mountain-based helicopter is partly due to the fact that the initial airspeed range extends to 50 percent of that helicopter's V_{max}.

Figure 1(b) is a presentation of the airspeed experience for the three operations according to its occurrence in the three flight conditions of climb, en route, and descent. This separation by flight condition, in addition to providing proper weighting to the maneuver conditions of climb and descent, allows for weighting the en route condition with respect to the low to moderate periodic bending moments occurring for a large number of cycles.

The en route condition of the mountain-based helicopter is also presented in altitude categories of 5,000 to 7,000 feet, 7,000 to 9,000 feet, and 9,000 to 13,000 feet. The separation by altitude helps to show the varied nature of the operation. The two military helicopters were operated primarily at a pressure altitude of 2,500 feet or less; thus, the contribution of altitude variation to their flight profile was considered negligible.

Operating Rates of Climb and Descent

The percent of time spent at the various rates of climb and descent by the three helicopters - mountain-based, turbine-engine, and IFR training - is presented in figure 2. In this figure the percent of time in climb and descent is based on the total time spent in each of those conditions by each of the helicopters. The helicopter was considered to be climbing or descending when the rate of change in altitude was greater than ±300 feet per minute, and the rates were read up to the nearest 100 feet per minute. The total experience is presented according to its occurrence within the separate airspeed ranges.

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A comparison of the rates of climb of the three helicopters (figs. 2(a) to 2(c)) indicates the nature of the different missions in which they were engaged. The mountain-based helicopter (fig. 2(a)) was operated at low airspeeds and low rates of climb, principally 300 to 400 feet per minute at 40 to 60 knots. Also, many of the mountain-based helicopter flight profiles were characterized by only one flight condition, climbing from an operating base to some landing point at a higher altitude. The succeeding flight would be characterized by descent only to the original starting point.

The mission requirements of the two military helicopters were less demanding with respect to altitude and payload; thus, a broader variation in airspeed and rate of climb was permitted. The turbine-engine helicopter (fig. 2(b)), performing varied military missions, recorded the same kind of wide distribution in rate of climb as the military helicopter, performing a similar mission, reported in reference 6. The rate of climb of the turbine-engine helicopter was principally 400 to 800 feet per minute up to an airspeed of 80 knots. The regularity of flight profile of the IFR training helicopter (fig. 2(c)) indicates similar trends as those recorded by the airmail helicopter in reference 6. The IFR trainer was operated principally at 400 to 700 feet per minute at 40 to 80 knots.

The rates of descent of the three helicopters are presented in figures 2(d) to 2(f). The rates of climb and descent utilized by the IFR training and the mountain-based helicopters were generally narrowly distributed within all the airspeed ranges. The turbine-engine helicopter and the IFR training helicopters had similar distributions in rates of descent as the military helicopter and the airmail helicopter, respectively, of reference 6.

The treatment of the rate of climb and descent with airspeed is to show the conditions of horizontal and vertical velocity since the flow pattern varies in climb and descent according to these two components. Prototype testing at rates of descent and climb of a particular helicopter would show conditions of adverse flow, conditions of blade stress, and the number of cycles in a given stress condition. A designer could then allow for time spent in possible adverse flight regimes.

The number of landings per flying hour is considered significant in that each one represents a transition and a flareout. The mountain-based helicopter made 165 flights in 50 flight hours for 3.3 landings per hour. The turbine-engine helicopter averaged 2.3 landings per hour, the IFR trainer averaged 1.6 landings per hour, and the heavy transport also averaged 1.6 landings per hour. These quantities are lower than those reported in reference 6 in which an airmail and a military helicopter recorded 5.9 and 5.4 landings per flying hour, respectively.

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Center-of-Gravity Normal Acceleration

The normal accelerations were analyzed on a sampling basis consistent with the analysis of the other features of the flight profile. Normal-acceleration results published in references 4 to 6 show that for ordinary occurrences the sampling treatment is sufficiently representative of the total distribution. In the process of visually editing the flight records, unusual occurrences were noted and a more detailed study was required.

The normal accelerations of the mountain-based helicopter were for the most part ordinary, but were interspersed with short periods of frequently occurring accelerations of fairly high magnitude. An example of this condition is shown in figure 3. This figure presents two records of actual flights which occurred in succession. The flight shown in figure 3(a), of unusual character, was followed immediately by that of figure 3(b), of ordinary character. Normal-acceleration time histories similar to the one presented in figure 3(a) occurred in less than 10 percent of the recorded flights, but accounted for more than 90 percent of the acceleration increments that exceeded the threshold of ±0.4g. Because of this disproportionate concentration, the sampling technique was not considered adequate to provide a true representation of the total experience. Therefore, the entire quantity of records was analyzed for values above an increment of ±0.4g; thus, the actual number of accelerations that were experienced by the mountain-based helicopter is provided. In the treatment of this total quantity, the frequency-of-occurrence curves were found to have different slopes than those of reference 5. Figure 4 presents the frequency of occurrence of normal accelerations encountered by the mountain-based helicopter. The data are plotted at the mean values of the incremental accelerations occurring within 0.1g bandwidths. Since this helicopter was operated at pressure altitudes varying from 5,000 to 13,000 feet, the normal-acceleration results shown in figure 4 present the frequencies of occurrence by altitude categories of 5,000 to 7,000 feet 7,000 to 9,000 feet, and 9,000 to 13,000 feet. The terrain features described by pilot's comments indicate that these conditions contribute as much as altitude to the frequencies of occurrence.

The two military helicopters, the turbine-powered and the IFR training, recorded no unusual normal-acceleration time histories. Thus, only the increments exceeding ±0.4g that occurred within the sample flights analyzed were counted. These are tabulated in table II. Also, all the mountain-based helicopter accelerations exceeding a threshold of ±0.4g are included in table II. These results are further separated by the flight conditions of climb, en route, and descent for ready comparison with similar results published in reference 6. Examination of table II shows that the number of acceleration increments per flying hour of the turbine-engine helicopter was greater than that of the mountain-based helicopter, but the mountain-based helicopter experienced acceleration increments of greater magnitude. The numbers of accelerations per hour in excess of ±0.4g without respect to magnitude or flight condition were considerably greater than those reported in reference 6. The accelerations per hour were 1.85 for the IFR training, 3.96 for the mountain-based, and 5.45 for the turbine-engine helicopter compared to 0.27 and 1.28 for the airmail and military helicopters, respectively, of reference 6.

Among the three operations the largest acceleration increments recorded were 1.0g and -0.9g from the mountain-based helicopter.

Rotor Rotational Speed

Only a small quantity of the flight records provided rotor rotational speed time histories. However, where records were available all the helicopters were operated at normal rotor rotational speeds during all flight conditions, which compares generally well with the results of reference 6.

From the limited records available, the mountain-based helicopter recorded some unusual rotor operating time histories. No extreme operating rotor speeds were noted, but in some cases the rotor speed surged from cruise to 4 or 5 percent above cruise and back to cruise at a fairly rapid rate. This rapid rotor variation was accompanied by an equally rapid incidence of low-magnitude normal accelerations (0.25 to 0.35g increments). The reasons for this behavior are unknown.

CONCLUDING REMARKS

Surveys have been made of the flight conditions under which three military helicopters engaged in simulated and actual military missions, and a commercial helicopter engaged in mountainous, high-altitude missions were operated.

The results show that none of the helicopters was operated in excess of the maximum design airspeed. One of the military helicopters, used for instrument flight training, actually recorded no speed in excess of 70 percent of the maximum design airspeed. The largest percentage of total time of the mountain-based and turbine-engine helicopters was spent at an average of 62.5 and 70 percent of the maximum design airspeed which compares favorably with previous investigations.

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The rates of climb and descent utilized by the IFR training and the mountain-based helicopters were generally narrowly distributed within all the airspeed ranges. The number of landings per flying hour ranged from 1.6 to 3.3 - somewhat lower than previous results which ranged from 5.4 to 5.9.

The center-of-gravity normal accelerations above a threshold of ±0.4g of the turbine-engine helicopter were more frequent than those of the mountain-based helicopter, but the mountain-based helicopter experienced more varied and erratic acceleration time histories and also acceleration increments of greater magnitude. The number of accelerations per hour in excess of ±0.4g, without respect to magnitude or flight condition, ranged from 1.85 to 5.45 as compared to 0.27 and 1.28 from the previous investigation. Among the three operations the largest acceleration increments recorded were 1.0g and -0.9g from the mountain-based helicopter.

Limited rotor rotational speed time histories showed that all the helicopters were operated at normal rotor speeds during all flight conditions.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., August 11, 1960.

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TABLE I.- SUMMARY OF FLIGHT PROFILES OF SEVERAL HELICOPTERS

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Type of helicopter	Type of operation	Percent of time in indicated flight condition			Data obtained from -
		Climb	En route (a)	Descent	
5,500-pound, turbine-powered, single-rotor	Military utilization	18.8	59.4	21.8	Present survey
12,000-pound, single-rotor	IFR training	12.5	75.9	11.6	Present survey
30,000-pound, twin-engine, single-rotor	Load lifting	16.0	66.6	17.4	Present survey
2,300-pound, single-rotor	High altitude	12.2	75.9	11.9	Present survey
6,700-pound, single-rotor	Airmail	17.0	71.0	12.0	Ref. 6
5,500-pound, tandem-rotor	Military	13.5	75.7	10.8	Ref. 6
5,000-pound, single-rotor	Airmail	14.5	73.8	11.7	Ref. 4
2,300-pound, single-rotor	Airmail	14.0	77.0	9.0	Ref. 5

[a]En route is defined as the flight condition where changes in altitude are less than ±300 feet per minute.

TABLE II.- NORMAL ACCELERATIONS OF THREE HELICOPTERS INCLUDING

ALL INCREMENTS ABOVE A THRESHOLD OF ±0.4g

Acceleration increment, Δa_n, g units	Number of accelerations experienced by -								
	Turbine-engine helicopter			IFR training helicopter			Mountain-based helicopter		
	Climb	En route	Descent	Climb	En route	Descent	Climb	En route	Descent
0.45	21	65	19				4	40	1
.50	8	13	5		5	1	1	15	3
.55	2	2	1		3	2	1	14	2
.60	4	4	1		2			11	1
.65								6	
.70	3		1					3	
.75									
.80								6	
.85								2	1
.90								3	
.95									
1.00								2	
Total	38	84	27	0	10	3	6	102	8
-0.45	5	19	5				3	37	4
-.50	1	2	1		21	1	1	9	1
-.55		1					1	12	
-.60		2	5		3			2	1
-.65					1			3	1
-.70			1		1			2	
-.75			1						
-.80								2	
-.85								2	
-.90								1	
Total	6	24	13	0	26	1	5	70	7
Flight hours per condition	6.6	20.9	7.7	2.7	16.4	2.5	6.1	37.9	6.0

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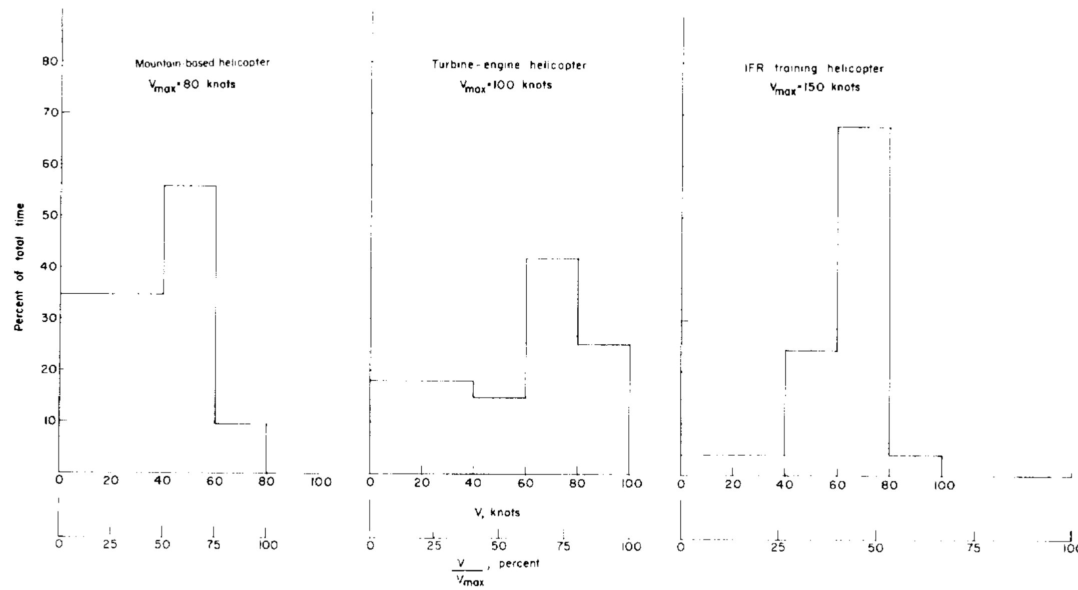
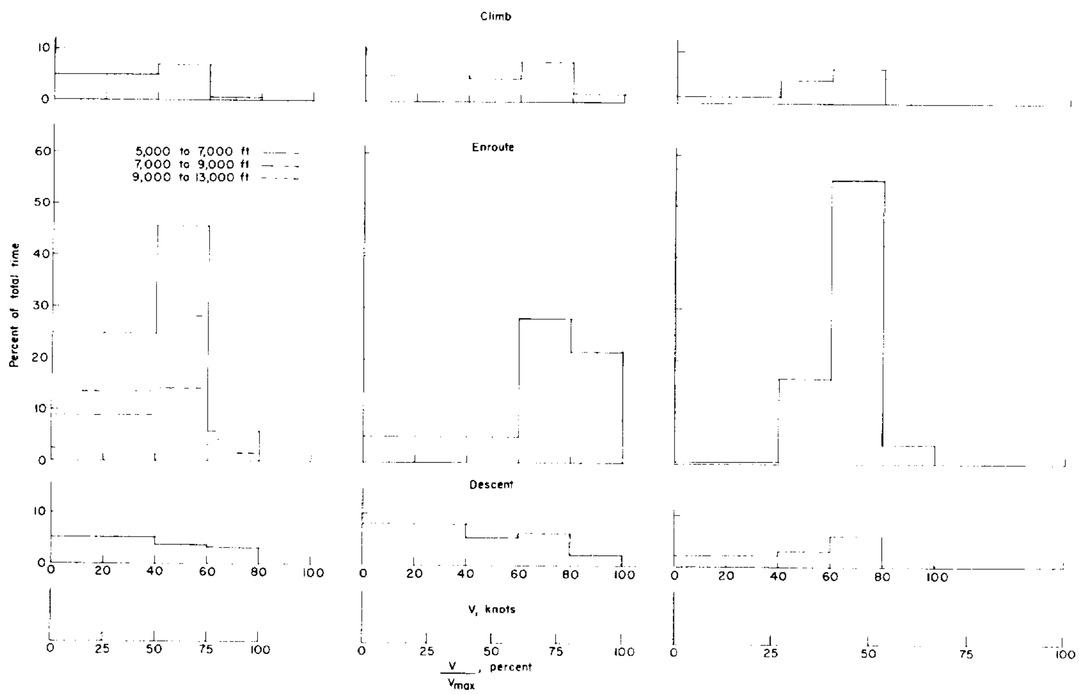
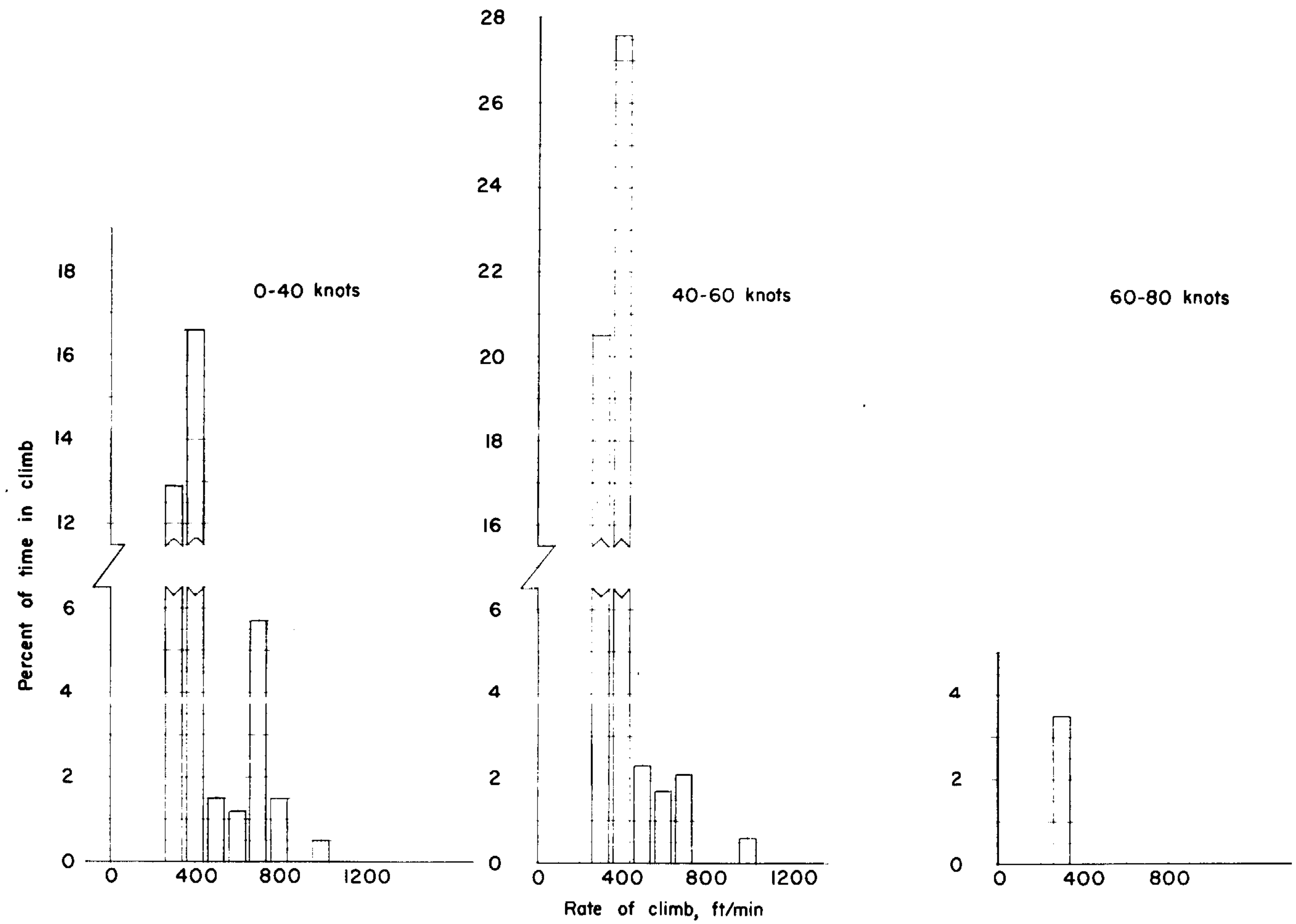


(a) Total airspeed.



(b) Airspeed according to the flight conditions of climb, en route, and descent.

Figure 1.- Operating airspeed utilized by three helicopters. Indicated V_{max} is based on pilot handbook data.



(a) Rates of climb; mountain-based helicopter.

Figure 2.- Operating rates of climb and descent of a mountain-based helicopter and two military helicopters.

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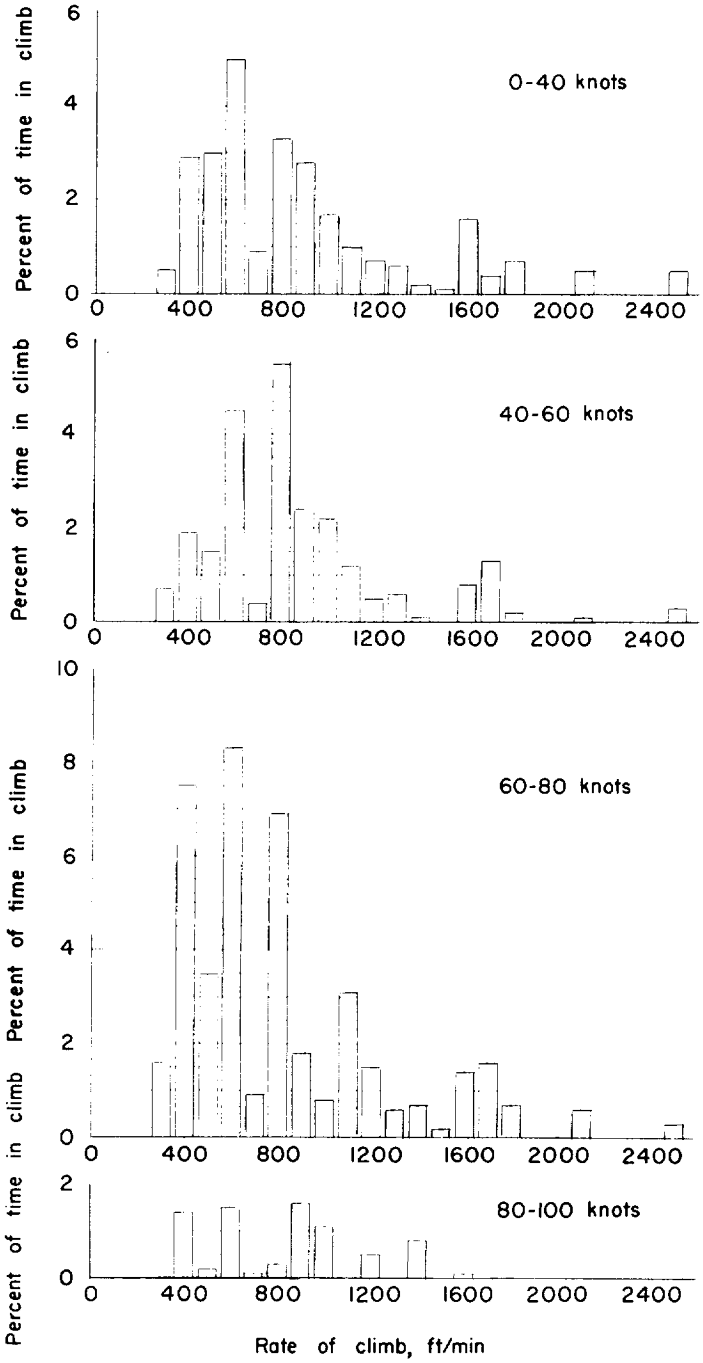
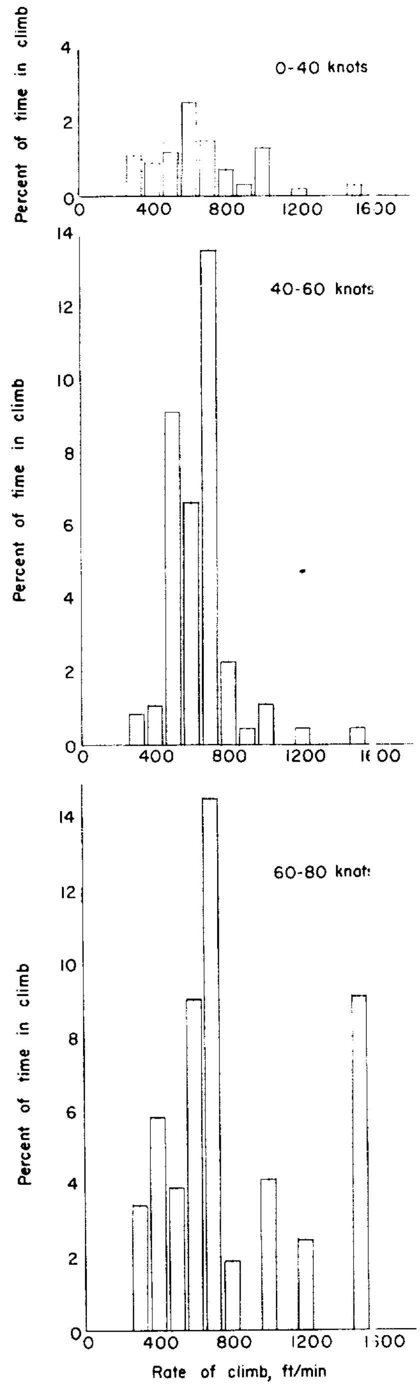


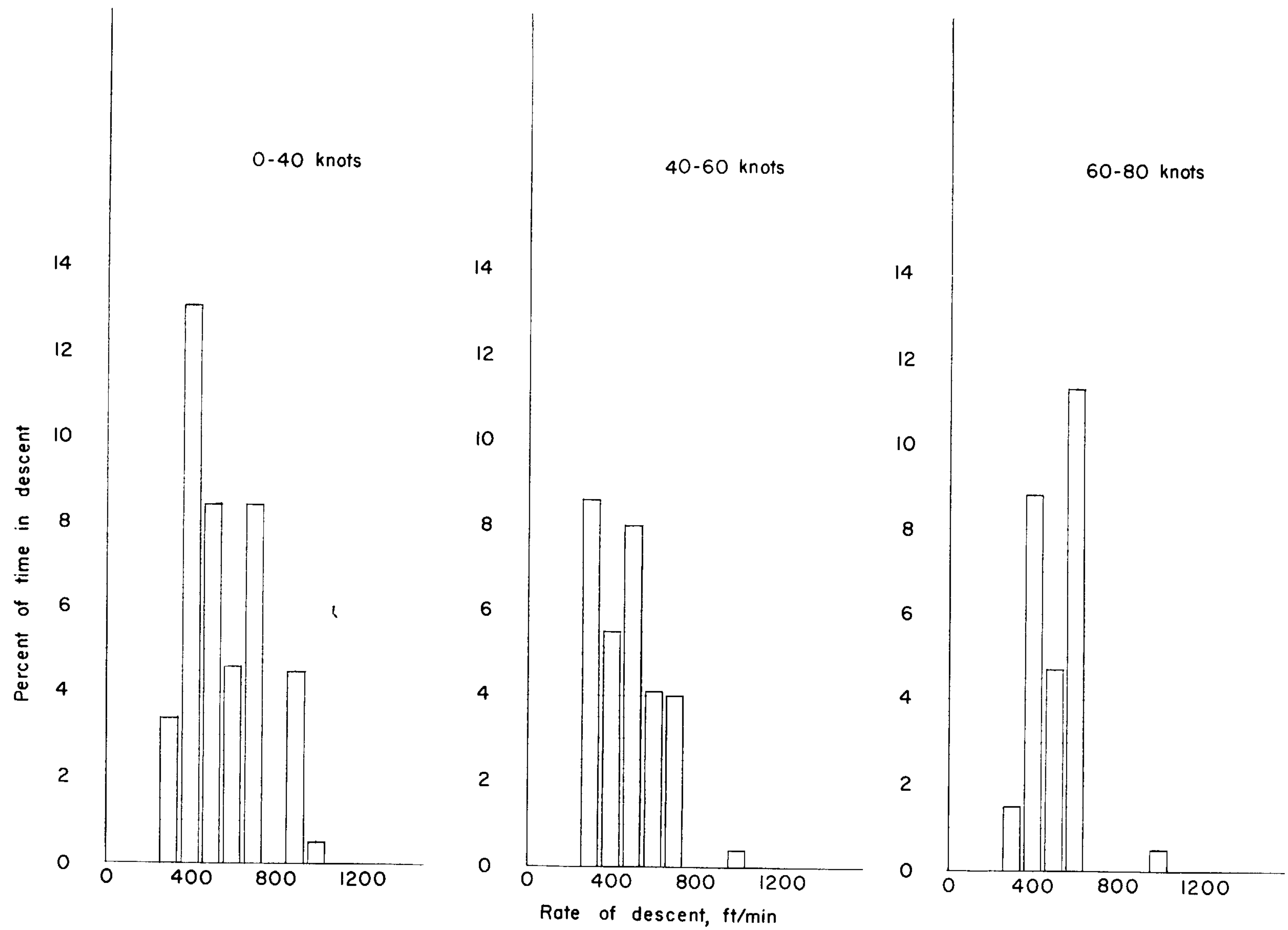
(b) Rates of climb; turbine-engine helicopter.

Figure 2.- Continued.



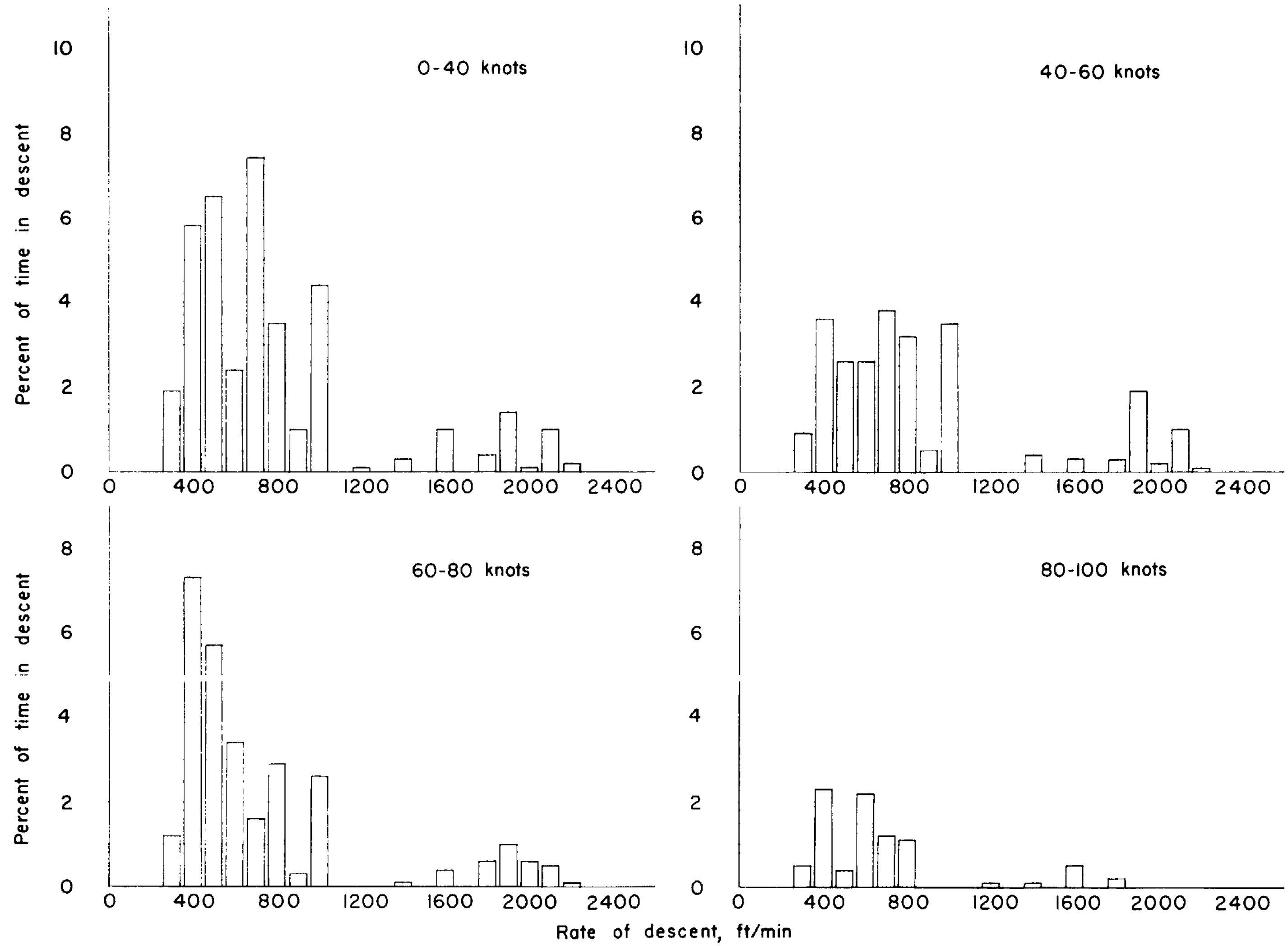
(c) Rates of climb; IFR training helicopter.

Figure 2.- Continued.



(d) Rates of descent; mountain-based helicopter.

Figure 2.- Continued.



(e) Rates of descent; turbine-engine helicopter.

Figure 2.- Continued.

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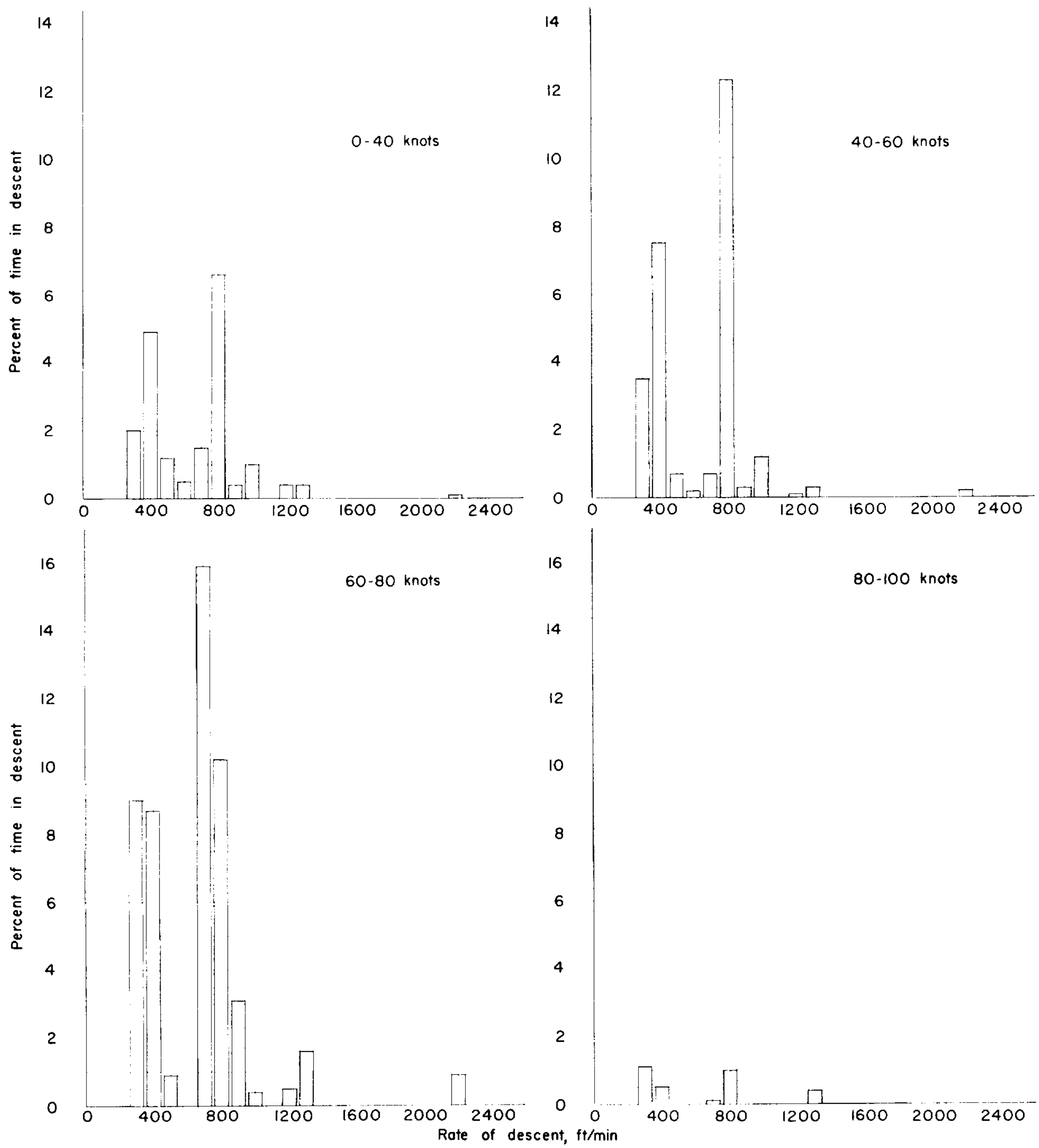
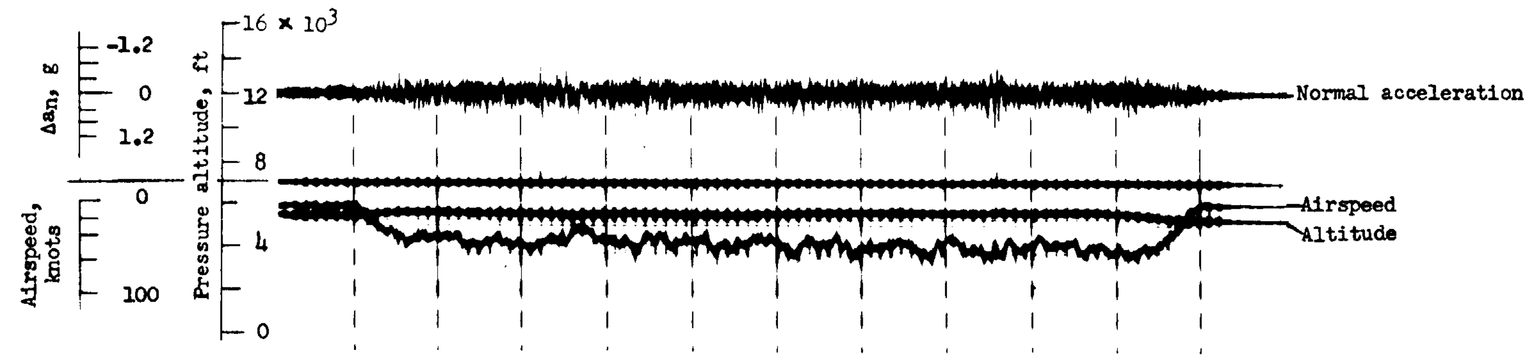
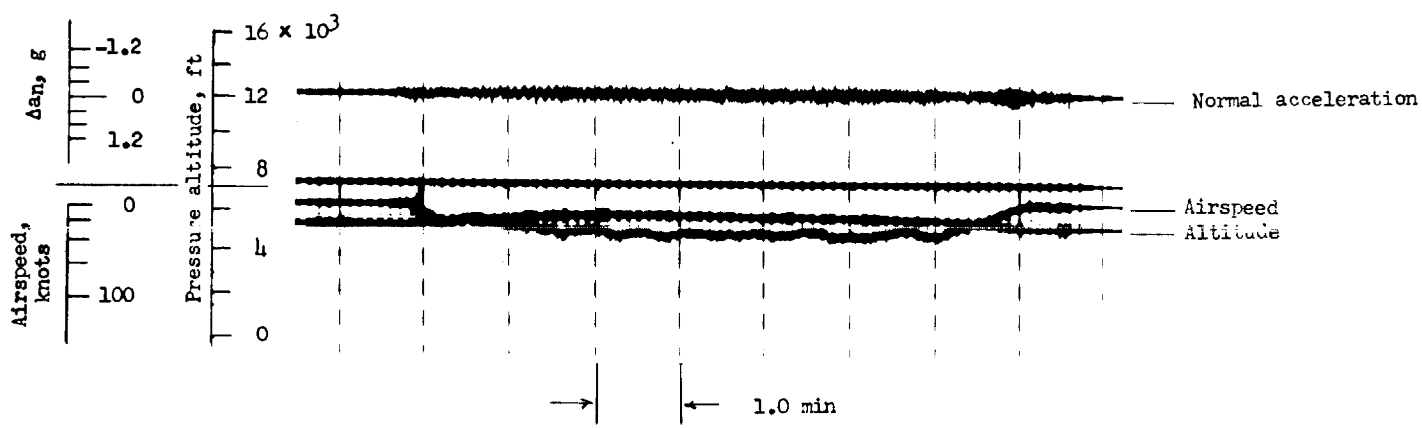


(f) Rates of descent; IFR training helicopter.

Figure 2.- Concluded.



(a) Flight profile time history of unusual character.



(b) Flight profile time history of ordinary character.

Figure 3.- Actual flight profile time histories from the mountain-based helicopter.

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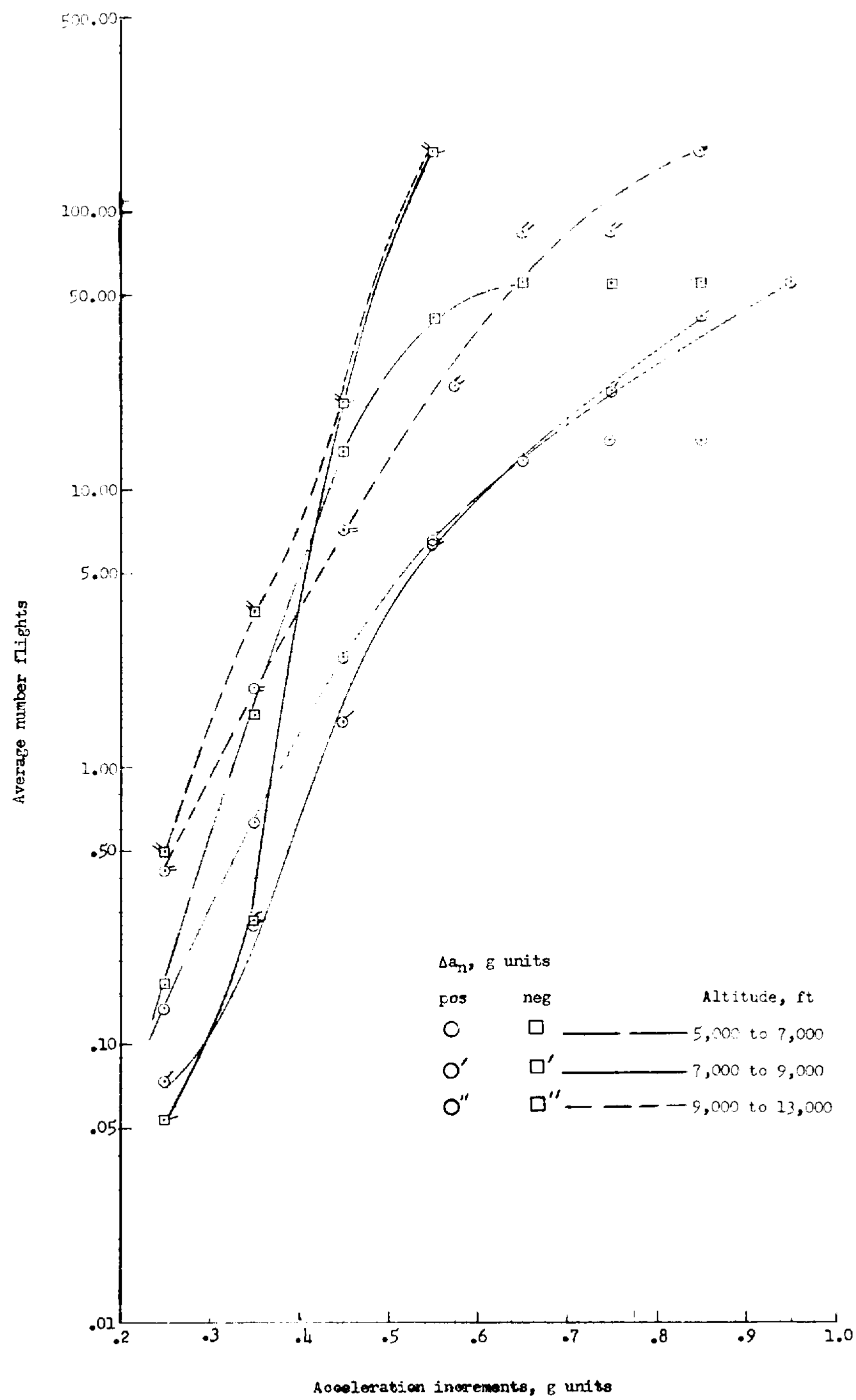

Figure 4.- Comparison by altitude of the average number of flights required to equal or exceed a given acceleration increment experienced by a mountain-based helicopter.