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OPERATIONAL EXPERIENCES OF A COMMERCIAL HELICOPTER FLOWN IN A LARGE METROPOLITAN AREA

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16. Abstract

A survey of commercial helicopter-operating experiences was conducted using a helicopter flight recorder in order to provide a basis for extending helicopter design and service-life criteria. These data are representative of 182 flight hours accumulated during 1414 flights comprised of the separate legs of the total route structure employed. The operating experiences are presented in terms of the time spent within different airspeed brackets, within the classifiable flight conditions of climb, en route, and descent, at various rates of climb and descent, and at different rotor rotational speeds. Normal acceleration occurrences above the incremental value of ±0.4g and pitch angular rates in excess of ±3°/s are also presented.

The results indicated that the helicopter spent a majority of the flight time at airspeeds either below 40 knots or above 100 knots, and exceeded the handbook never-exceed velocity only on a few occasions. Rates of climb and descent were concentrated at values below 5.1 m/s (1000 ft/min) particularly for higher airspeeds. Normal acceleration experiences were low, both in the total number and peak value realized; however, an extremely large number of pitch angular-velocity experiences were noted. Rotor rotational speeds were normal with no occurrences above the upper red-line limit.

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SUMMARY

A survey of commercial helicopter-operating experiences was conducted using a helicopter flight recorder in order to provide a basis for extending helicopter design and service-life criteria. These data are representative of 182 flight hours accumulated during 1414 flights comprised of the separate legs of the total route structure employed. The operating experiences are presented in terms of the time spent within different airspeed brackets, within the classifiable flight conditions of climb, en route, and descent, at various rates of climb and descent, and at different rotor rotational speeds. Normal acceleration occurrences above the incremental value of ±0.4g and pitch angular rates in excess of $\pm 3^{\circ}/s$ are also presented.

The results indicated that the helicopter spent a majority of the flight time at airspeeds either below 40 knots or above 100 knots, and exceeded the handbook never-exceed velocity only on a few occasions. Rates of climb and descent were concentrated at values below 5.1 m/s (1000 ft/min) particularly for higher airspeeds. Normal acceleration experiences were low, both in the total number and peak value realized; however, an extremely large number of pitch angular-velocity experiences were noted. Rotor rotational speeds were normal with no occurrences above the upper red-line limit.

INTRODUCTION

The frequency of occurrence of flight loads and stresses actually experienced by a helicopter may differ from those values estimated by manufacturers in determining structural fatigue life. Therefore, when a helicopter enters service, information on the use of the vehicle is helpful in evaluating the adequacy of predicted frequency-of-occurrence data. These data include time spent in various flight conditions and the stress levels encountered by the vehicle in those flight conditions. The dissemination of such flight-spectrum information, as acquired through routine surveys of various military and commercial helicopter operations, has been an ongoing effort of the National Aeronautics and Space Administration (NASA). This information provides a means of assessing the adequacy of design and service-life criteria, which in turn contributes to improved performance and maintenance of new concepts.

Therefore, the purpose of this paper is to provide additional flight-spectrum data, particularly for helicopters used in a commercial role, in order to supplement previous surveys of military operations (refs. 1 and 2). For this documentation, a flight recorder was installed on a vehicle employed by a commercial helicopter airline operating in the New York metropolitan area. The vehicle is representative of the medium transport class of helicopter used specifically to carry passengers and baggage or cargo. Data from this survey are presented in the form of bar graphs and probability curves. Comparisons with previous results are also made.

HELICOPTER OPERATIONS

The helicopter surveyed was one of four of the same type operated by a carrier that provides local commuter service in the New York metropolitan area. The vehicle had a single-rotor and twin-turbine engines and was configured for carrying 30 passengers at a never-exceed velocity of 128 knots. The maximum gross weight was 8617 kg (19 000 lb). This survey was conducted during three separate 1-month segments spaced throughout a period of 1 year, and was the first of its type to be carried out by NASA. A total of 1414 flights were recorded, representing approximately 182 flying hours. For this survey, a flight was considered as each leg of the total route structure flown by the airline. Consequently, the number of flights represents the number of landings experienced, though not the number of engine start cycles. An overview of the route structure and the approximate distances and flight times between the major terminals served are given in figure 1.

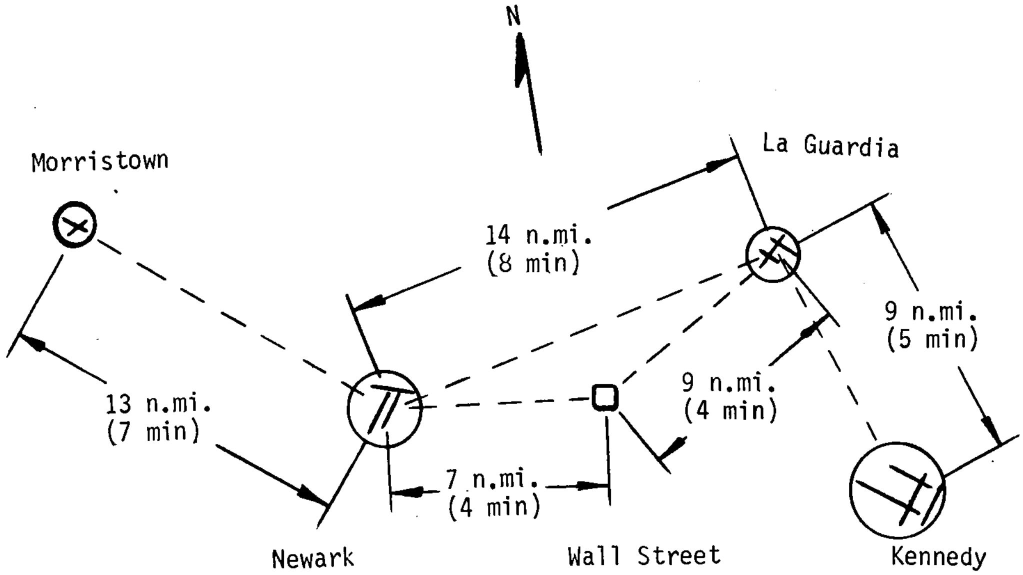


Figure 1.- Approximate distances and flight times between major terminals of the commercial route surveyed.

INSTRUMENTATION AND DATA ANALYSIS

The NASA helicopter flight recorder used for this survey was an improved version of the system employed during past operational surveys. In addition to recording the time histories of airspeed (velocity), normal acceleration, pressure altitude, and rotor rotational speed (VGHN information), the angular rate about the pitch axis was recorded. A significant improvement to the recorder package was the provision for mounting the normal accelerometer and the rate gyro remotely, so that they could be located near the center of gravity of the aircraft. The basic package and film drum could therefore be installed in a more accessible area to expedite film replacement and equipment maintenance. All the records were used to compile unusual occurrence and normal-acceleration (a_n) data. (It should be noted that 46 hours of the a_n data were lost because of a recorder problem.) The compilation of the remaining parameters, as with past surveys, was based on a sampling of about 30 percent of the records to provide results representative of the total profile. Classifications of the flight conditions were as follows: time spent in various airspeed brackets, time spent in climb and descent, normal acceleration and pitch angular-rate occurrences, and rotor rotational speed and landing experiences. A sample time history is shown in figure 2 which clearly identifies the flight conditions of climb, en route, and

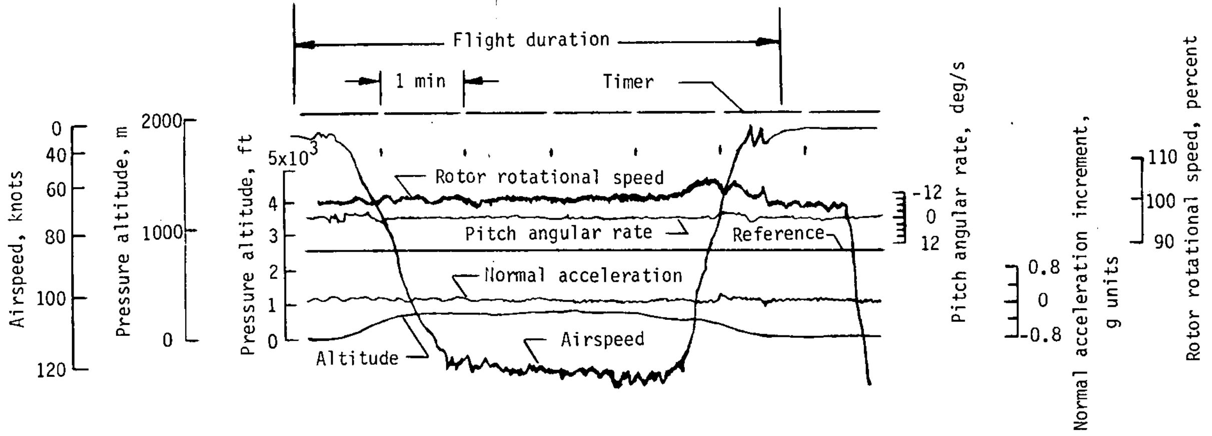


Figure 2.- Sample flight time history.

descent. The helicopter was considered to be climbing or descending when the rate of change in altitude was greater than ±1.5 m/s (±300 ft/min); the rates were read to the nearest 0.5 m/s (100 ft/min).

RESULTS AND DISCUSSION

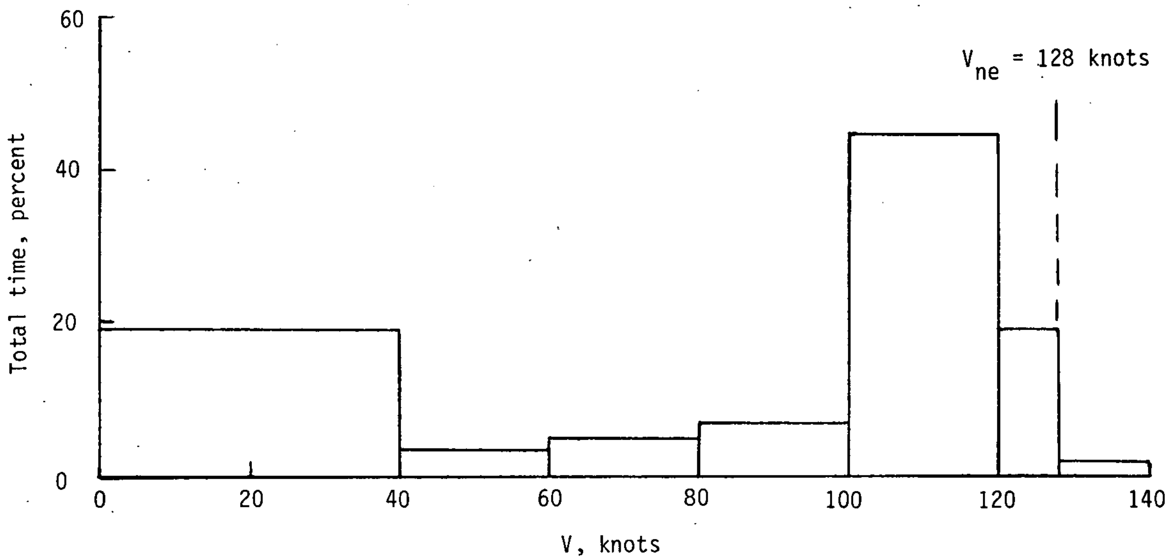
The operating experiences of the commercial helicopter surveyed are presented in terms of times spent within several classifiable flight conditions. A summary of the general profile with the times spent in climb, en route, and descent is presented in table I.

For comparison purposes, summary data are also included from the previous surveys cited in references 1 to 3.

For this commercial operation, 18 percent of the total survey time was spent in climb, 61 percent en route (which included low-altitude operation because of the rate-of-climb/descent criteria), and 21 percent in descent. This utilization is comparable to the commercial survey of reference 3, and is quite similar to the survey of a single-rotor military vehicle noted in reference 2.

Operating Airspeed

The percentage of time spent within various airspeed intervals is presented in figure 3(a). The airspeed is subdivided into categories of 20-knot increments except for the

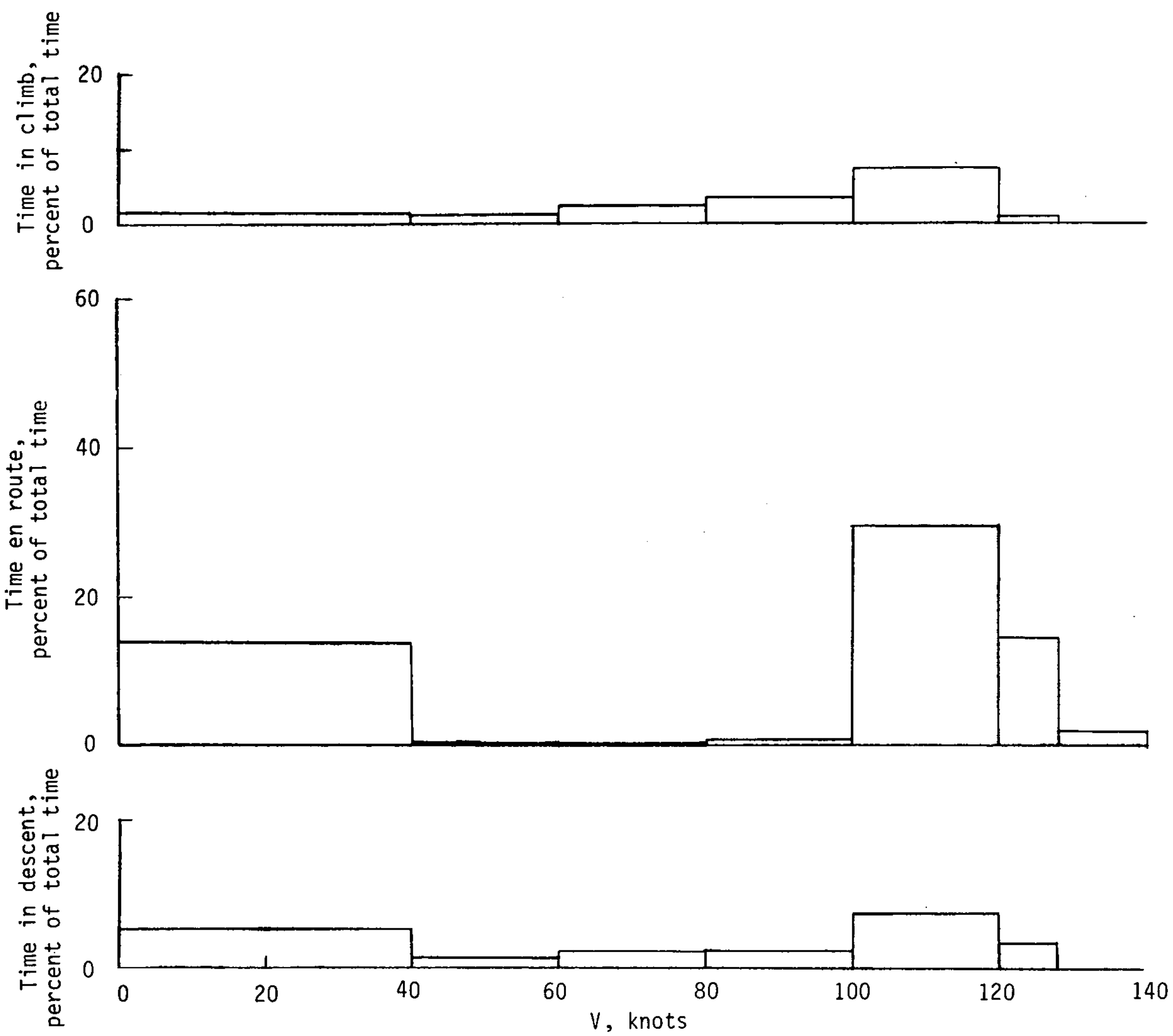


(a) Total survey.

Figure 3.- Operating airspeed experience.

first and last two ranges. The first range is 0 to 40 knots because of airspeed sensor inaccuracies below 40 knots. The last two ranges are between 120 and 140 knots and are divided by the never-exceed velocity (V_{ne}), or red-line value, which is 128 knots.

Similar to the commercial survey noted in reference 3, a significant portion of the total time was spent within the low and high airspeed brackets. These higher time experiences were probably the result of quickly accelerating the vehicle to near-maximum velocity, in order to utilize more effectively the aircraft's capabilities for the timely dispatch of passengers and completion of the flight. The airspeed brackets are further subdivided according to their occurrences within the three flight conditions of climb, en route, and descent as shown in figure 3(b).



(b) Airspeed experience in the flight conditions of climb, en route, and descent.

Figure 3.- Concluded.

In addition to the considerable amount of time spent in the low and high airspeed regimes, figure 3 also indicates that the vehicle was operated above the never-exceed velocity for a small percentage of time. Generally, operating very near or above V_{ne} results in high vibratory torsional and bending moments acting on the rotor blades. These moments are caused by compressibility effects on the advancing side and/or by blade stall on the retreating side. Similarly, high-blade stresses are encountered, particularly during low-speed transition to landing. The fact that this type of operation is characterized by large amounts of flight time both at high speeds and in low-speed transitions should be of significance to the helicopter designer.

Climb and Descent Rates

The percentages of time spent within different rates of climb and descent are presented in figures 4 and 5, respectively, for various airspeed intervals. The percentages in figure 4 are based on the total time in climb; the figure 5 percentages are based on total descent time.

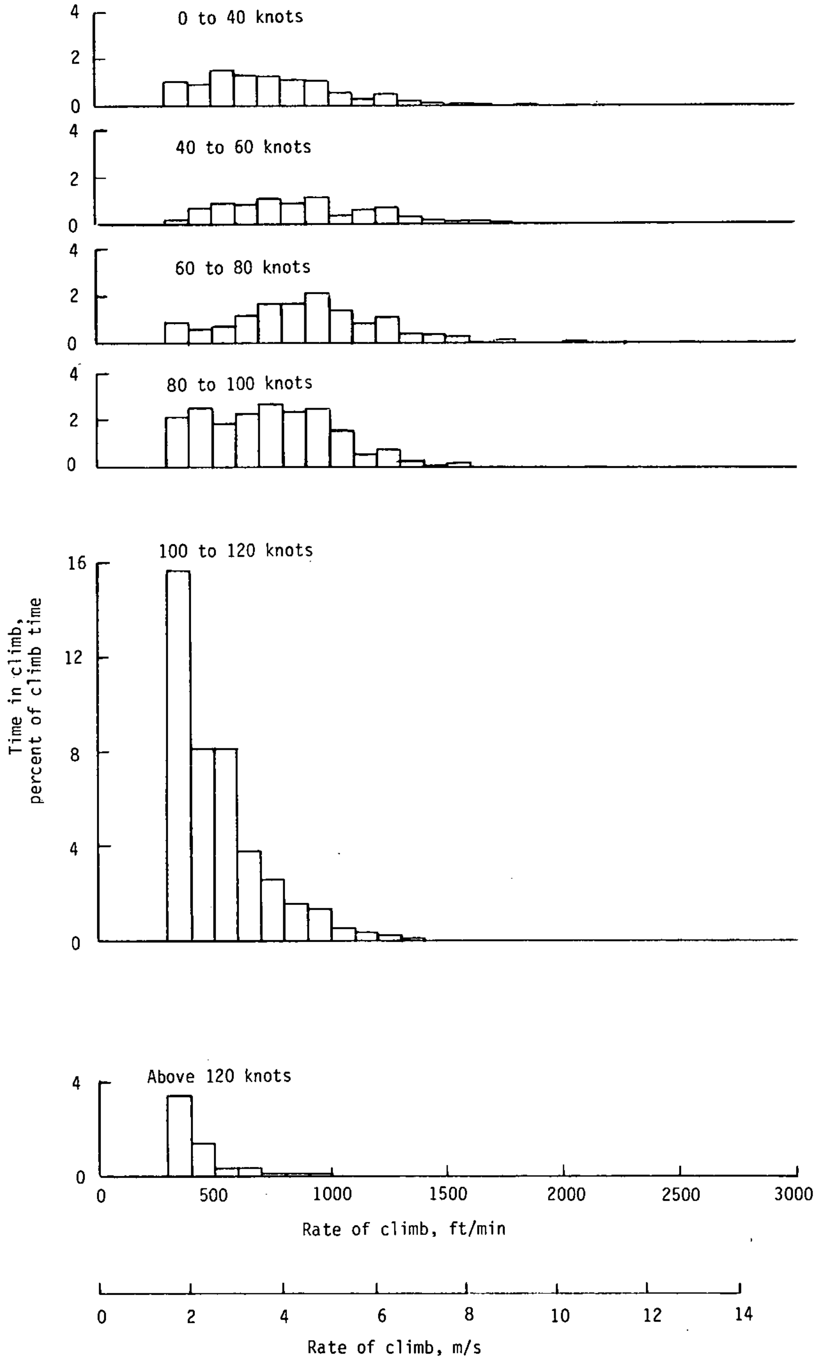


Figure 4.- Operating rates of climb within selected speed brackets.

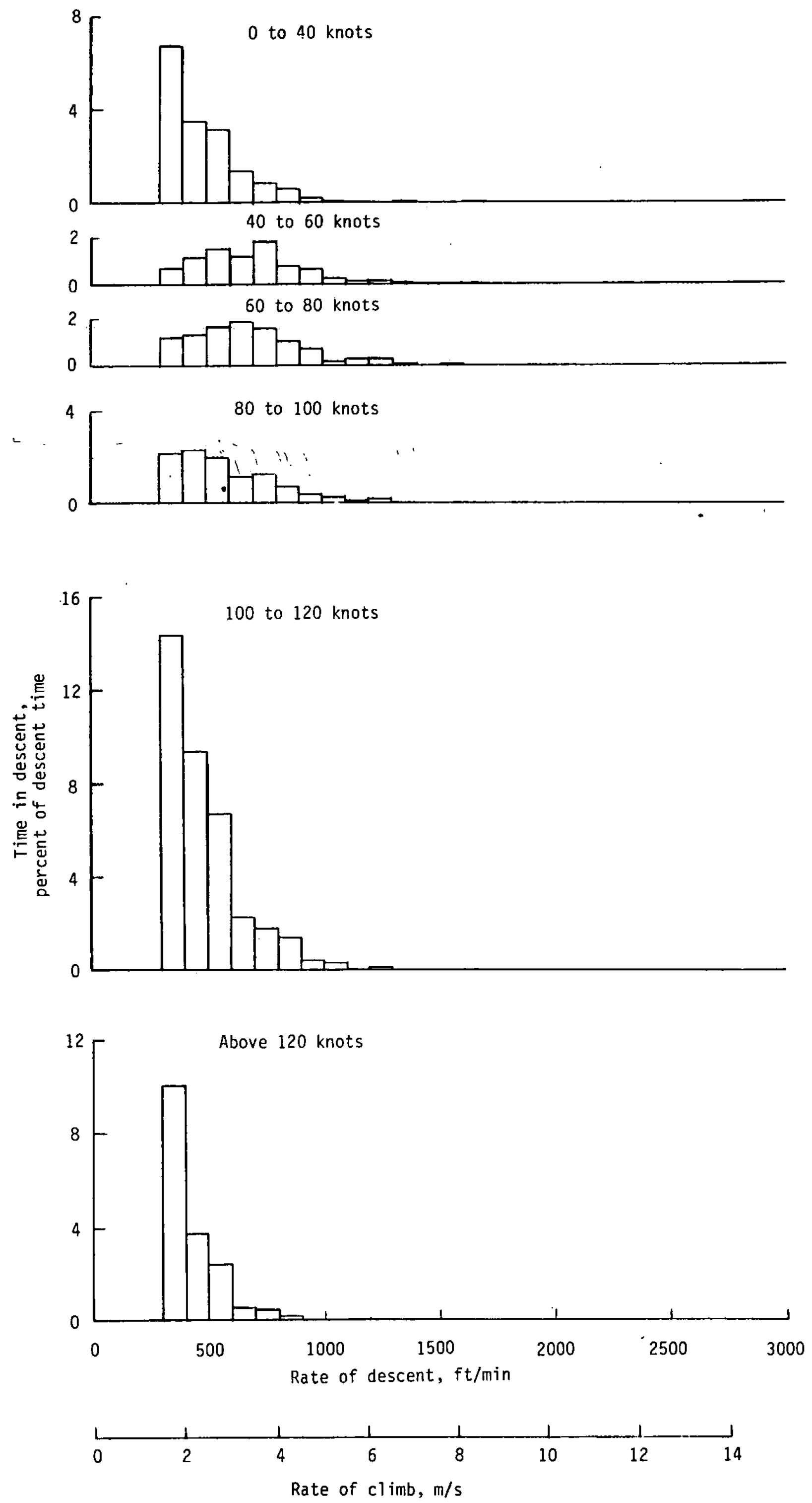


Figure 5.- Operating rates of descent within selected speed brackets.

For the brackets up to 100 knots, the percentages of time spent in rates of climb are low and somewhat uniformly distributed. A significant portion of the climb time occurred above 100 knots. Further, a very small amount of climb time was experienced for rates above 5.1 m/s (1000 ft/min); this amount indicates very little abrupt or severe maneuvering, and this result is in agreement with the results of reference 3. The rates of descent (fig. 5) show a concentration at the lower values, but with a slight increase noted in the lower airspeed brackets. This trend is consistent with normal helicopter utilization, particularly when considering the high degree of precision required for the approach and landing phase. These results are also consistent with experiences from previous surveys. Since rates of descent above 5.1 m/s (1000 ft/min) were also infrequently employed, such utilization indicates the operator's consideration for the passenger's comfort.

Additional insight is provided regarding the time distribution of the rates of climb and descent which are shown as summary plots in figure 6. Treated as a probability curve,

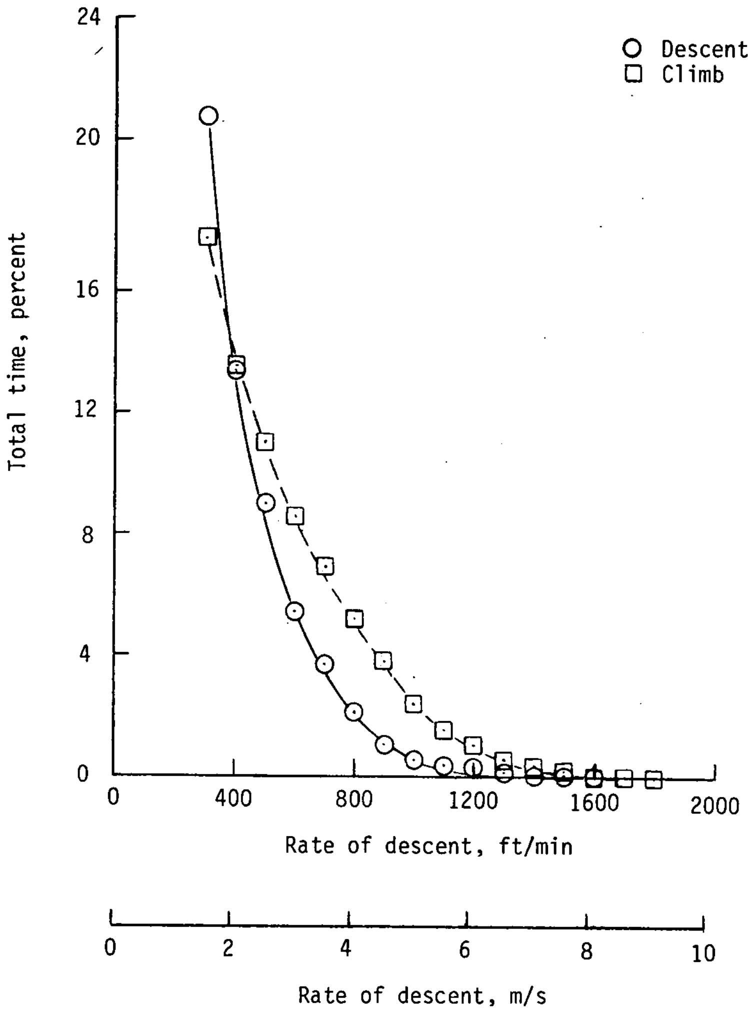


Figure 6.- Percentage of total flight time that a given rate of climb or descent was exceeded.

the figure shows the percentage of the total flight time in which the vehicle exceeded a specific rate of climb or descent during the survey. Approximately 3 percent of the total flight time was spent above a climb rate of 5.1 m/s (1000 ft/min) while only about 1 percent was spent in excess of 5.1 m/s (1000 ft/min) rate of descent. These results, particularly with respect to descent rates, represent a reduction in such experiences as compared with previous surveys.

Landing Occurrences

A frequency-of-occurrence item that may be important to the helicopter designer is the number of landings experienced for a given time period, since each landing represents a transition, a flare, and ground impact. For this survey, 1414 landings were noted during the 182 flight hours recorded. Therefore, the average for this operation was 7.8 landings per hour, which agrees with the earlier commercial survey of reference 3. However, the average is about twice that realized during previous military operations.

Normal Acceleration

The normal-acceleration occurrences for the commercial helicopter surveyed were determined by analyzing the total 136 hours of acceleration data available. The analysis indicated no unusual trends in the levels of acceleration experienced and the overall frequency of occurrences was consistent with past surveys.

The distribution of the incremental normal accelerations which exceeded ±0.4g within the flight conditions of climb, en route, and descent is given in table II. The number of accelerations per hour in excess of ±0.4g for all the flight conditions was 0.59. This experience is below the values reported in references 1 and 2 for previous military operations which was 1.0 to 4.0 accelerations per hour in excess of ±0.4g. However, the value from the present survey is greater than the number reported in reference 3 for a comparable commercial helicopter application, which was 0.13 accelerations per hour in excess of ±0.4g.

From the data shown in table II, the frequency of occurrences of normal accelerations is presented graphically in figure 7. This figure shows the number of both positive and negative acceleration peaks that can be expected to reach or exceed a specified increment during each 1000 hours of flight. Also, the data from this commercial survey are compared with the acceleration results from previous operational surveys. These data include acceleration probability curves from the commerical operation of reference 3 and the average of the light observation-helicopter data from reference 1. It is evident that the number of acceleration experiences from the present survey is comparable to the results from reference 3 and is much lower than the results from reference 1. No attempt was made to separate maneuver from gust loads; however, since over 50 percent

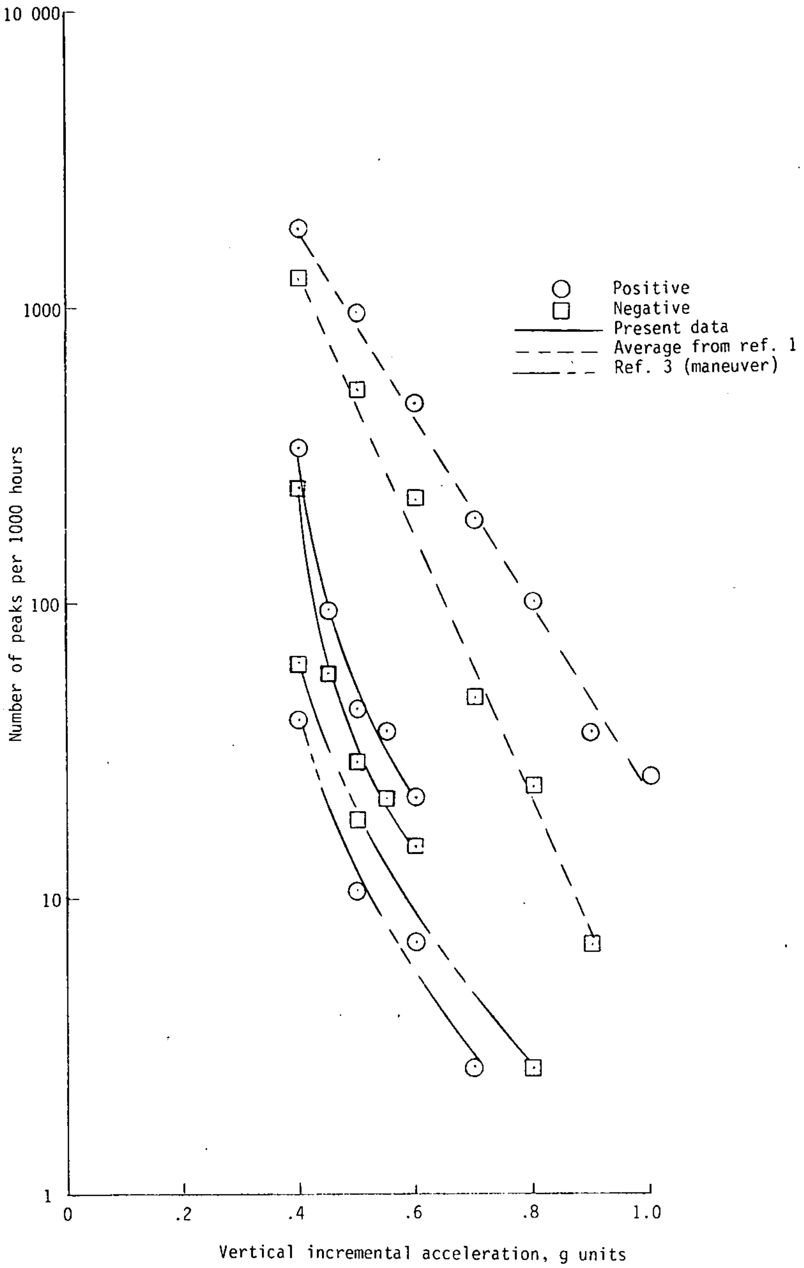


Figure 7.- Frequency of occurrence, per 1000 hours, of normal acceleration increments.

of the incremental acceleration values occurred en route, it is believed that a large portion of the encounters can be attributed to wind gusts.

Pitch Angular Rate

The aircraft's angular-velocity experiences about the pitch axis were analyzed by a sampling of approximately 30 percent of the flight data, a technique which is consistent with the procedures used for the previous surveys reported in references 1 and 2. The distributions of pitch-rate peaks which exceeded $\pm 3^{\circ}/s$ are given in table III for the flight conditions of climb, en route, and descent. Based on the occurrences noted, the number of pitch angular rates per hour of flight in excess of $\pm 3^{\circ}/s$ for all flight conditions was approximately 56. By comparison, the results of reference 3 indicated a probability of 4 peaks per hour that would be in excess of a $\pm 3^{\circ}/s$ pitch rate.

The pitch-rate peak distribution is also presented as probability curves for each 1000 hours of operation; the curves are shown in figure 8. Both the positive and negative pitch rates expected to exceed the threshold of $\pm 3^{\circ}/s$ are presented; in addition, the comparable pitch-rate data from reference 3 are presented. Although the trends for both of these commercial helicopter operations are similar, the present survey indicates a greater number of experiences and a more equal distribution between the positive and negative pitch rates. The fact that a vibration absorber was incorporated into the rotor head on an otherwise similar vehicle could explain the higher level of pitch-rate occurrences for the present survey. With such a means to suppress rotor-induced structural loads and vibrations feeding back to the pilot, his sensitivity to more frequent control inputs would be reduced during maneuver flight. An additional influence could be the short route segments flown within the congested and complex air-traffic environment of the New York metropolitan area; such an environment would require more frequent control inputs.

Rotor Rotational Speed

The percentages of time spent at various rotor rotational speeds, based on a sampling 63.6 hours of the flight data, are presented in figure 9. This figure shows that over 95 percent of the total flight time was spent operating within 98- to 105-percent rotor rpm. More specifically, about 75 percent of the time was spent in the 98- to 102-percent band. This percentage is similar to previous commercial data, though lower than past military results. The time spent above 102-percent rpm could be attributed to the short route segments flown; the short route segments are characterized by an increase in descent time. Despite the larger amount of time spent above 100-percent rpm, no experiences outside the manufacturer's recommended operating limits were noted during examination of all the records.

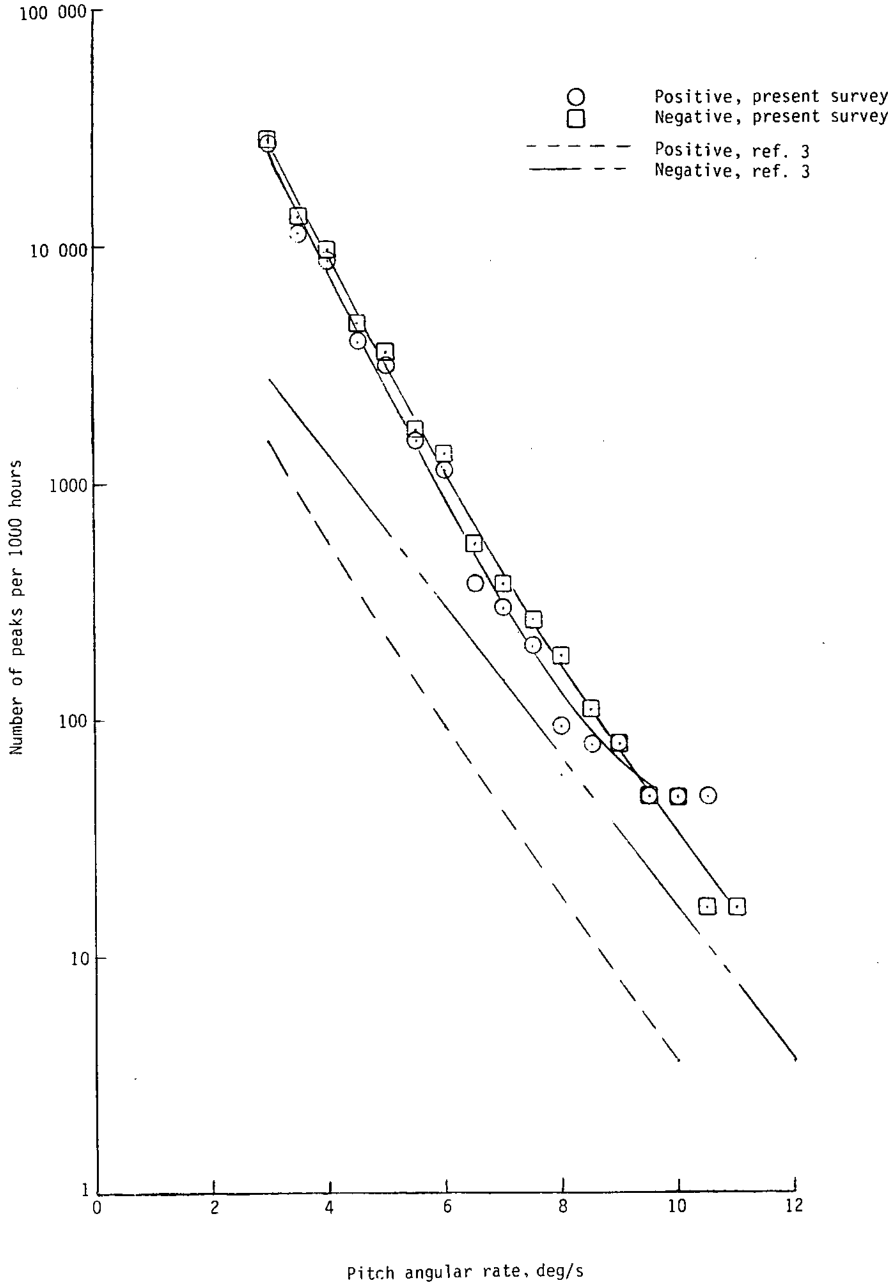


Figure 8.- Frequency of occurrence, per 1000 hours, of pitch angular rates.

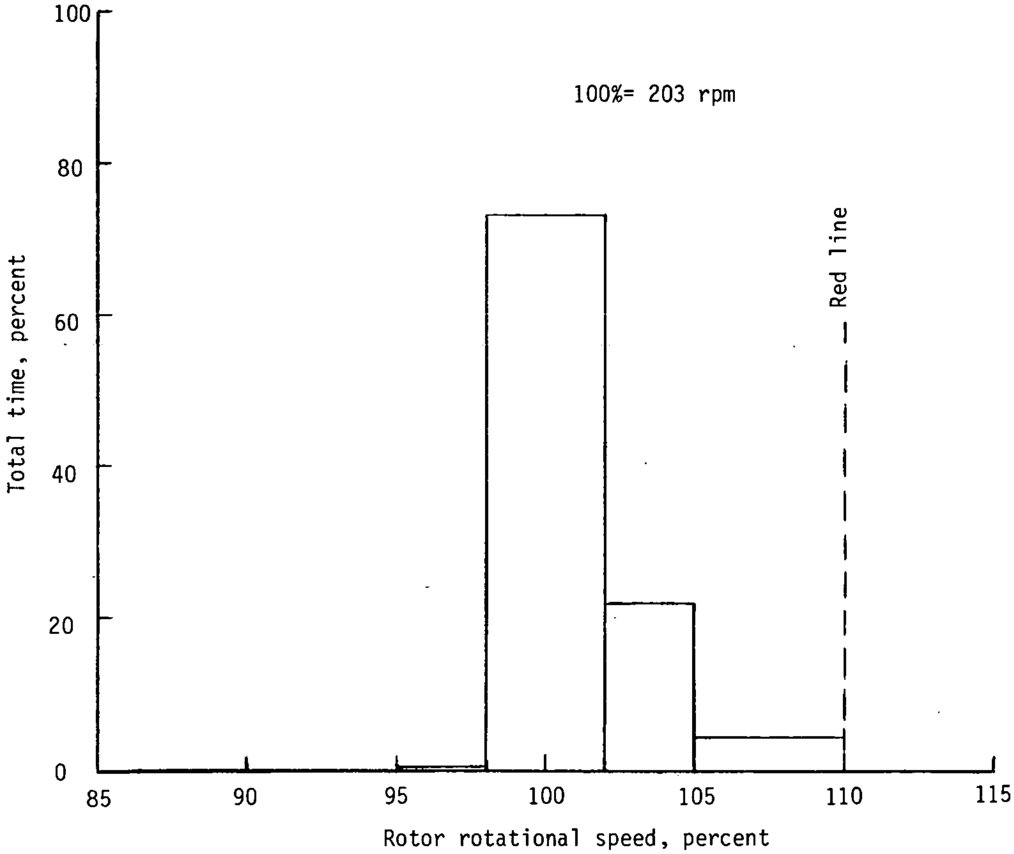


Figure 9.- Operating rotor rotational-speed experience.

CONCLUDING REMARKS

An improved helicopter flight recorder, developed by the National Aeronautics and Space Administration, was employed to acquire operational flight profiles of a large commercial helicopter providing commuter air service in the New York metropolitan area. The general results indicated that the vehicle was used in a manner similar to previous commercial experiences though different from past military applications.

The helicopter was operated above the never-exceed velocity for a small segment of the flight time. More significantly, the vehicle was flown at airspeeds either below 40 knots or above 100 knots for a large portion (85 percent) of the total time.

The rates of climb and descent were distributed throughout the speed range, though at higher airspeeds the rates were concentrated at values below 5.1 m/s (1000 ft/min). The number of landings per hour was 7.8 for this operation; the number was comparable to the numbers realized during previous commercial operations, though higher than past military experiences.

The results also indicated that the center-of gravity normal accelerations above a threshold of ±0.4g were comparable – higher than earlier commerical surveys, but substantially lower than previous military results. The number of accelerations per hour in excess of ±0.4g, regardless of the magnitude or flight conditions, was 0.59, or about one such acceleration experience for every 2 hours of operation. More important, no incremental accelerations greater than ±0.65g were recorded; this peak was much lower than the experiences from past helicopter surveys.

Pitch angular rates above a threshold of $\pm 3^{\circ}/s$ were found to occur more frequently when compared to previous experiences. Based on the data analyzed, 56 such occurrences were observed for each hour of operation, regardless of magnitude or flight condition.

Finally, rotor rotational-speed time histories indicated no rotor overspeeds beyond the red-line value (110 percent). In addition, 95 percent of the total time was spent within 98- to 105-percent rotor rpm.

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Hampton, Va. 23665
May 1975

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TABLE I.- SUMMARY OF FLIGHT PROFILES

Type	Operation	Percentage			Source
		Climb	En route	Descent	
8617 kg (19 000 lb), twin-turbine, single-rotor	Commercial carrier	18	61	21	Present survey
Helicopter A, 1165 kg (2570 lb), turbine, single-rotor	Military utilization	10	78	12	Reference 1
Helicopter B, 1134 kg (2500 lb), turbine, single-rotor	Military utilization	10	77	13	Reference 1
Helicopter C, 952 kg (2100 lb), turbine, single-rotor	Military utilization	9	78	13	Reference 1
Load lifter, 17 233 kg (38 000 lb), twin-turbine engine, single-rotor	Load lifting	11	74	15	Reference 1
2494 kg (5500 lb), turbine, single-rotor	Military utilization	18.8	59.4	21.8	Reference 2
7710 kg (17 000 lb), twin-turbine, single-rotor	Commercial carrier	16.4	67.6	[a] 16.0	Reference 3

[a] Reference 3 en route when altitude change was less than 2 m/s (±400 ft/min).

TABLE II.- INCREMENTAL ACCELERATIONS ABOVE A THRESHOLD OF ±0.4g

[Total flight hours surveyed, 136]

Acceleration increments, Δa_n, g units	Acceleration experienced in flight conditions of –		
	Climb	En route	Descent
0.40	3	20	10
.45		2	5
.50			1
.55	1		1
.60		2	1
Total	4	24	18
-0.40	1	19	7
-.45		1	2
-.50			1
-.55			1
-.60			2
Total	1	20	13

TABLE III.- PITCH ANGULAR VELOCITIES ABOVE A THRESHOLD OF $\pm 3^{\circ}/s$

Pitch angular velocity, deg/s	Number experienced in –			Pitch angular velocity, deg/s	Number experienced in –		
	Climb	En route	Descent		Climb	En route	Descent
3.0	314	224	511	-3.0	295	233	432
3.5	67	25	70	-3.5	65	38	109
4.0	119	40	141	-4.0	84	61	175
4.5	20	3	25	-4.5	29	10	35
5.0	41	13	51	-5.0	34	20	68
5.5	10	1	13	-5.5	4	2	17
6.0	20	1	27	-6.0	21	4	24
6.5	3		2	-6.5	2		9
7.0	4		2	-7.0	2	1	3
7.5	1		6	-7.5	2	1	3
8.0			1	-8.0	1		4
8.5				-8.5		2	
9.0			2	-9.0			2
9.5				-9.5			
10.0				-10.0	1		1
10.5	1		2	-10.5			
11.0				-11.0			1
Total	600	307	853	Total	540	372	883
Total, hrs	11.3	39.1	13.2	Total, hrs	11.3	39.1	13.2

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