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VIBRATION EFFECTS ON HELICOPTER RELIABILITY AND MAINTAINABILITY

Angelo C. Veca

United Aircraft Corporation

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By

Angelo C. Veca

April 1973

EUSTIS DIRECTORATE
U. S. ARMY AIR MOBILITY RESEARCH AND DEVELOPMENT LABORATORY
FORT EUSTIS, VIRGINIA

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SIKORSKY AIRCRAFT DIVISION
UNITED AIRCRAFT CORPORATION
STRATFORD, CONNECTICUT

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13. ABSTRACT

In this study, differences in reliability and maintainability data were examined on two groups of USAF H-3 helicopters with distinctly different vibration characteristics. One H-3 helicopter group was equipped with the rotor-mounted vibration absorber, a device which reduces helicopter vibration induced by the rotor, and a second aircraft group did not have the absorber. The aircraft were alike in all other respects.

The analyses performed on these data show a significant reduction in the failure rate and direct maintenance for the H-3 helicopters with absorbers and with reduced vibration levels. The overall H-3 helicopter failure rate and corrective maintenance are reduced by 48% and 38.5%, respectively. The average reduction in vibration level was 54.3%. Correspondingly, life-cycle costs show a significant reduction of approximately 10% for the overall aircraft. At the subsystem and component levels, the same reductions are shown in almost every case with the exception of certain navigation and avionics components.

There are at least 25 military vibration specifications and standards which specify vibration criteria for design or test of airborne equipment. No obvious conflicts were found in these specifications, but they are lacking in requirements which clearly describe realistic vibration exposure times for the entire helicopter air vehicle system and its components.

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FORT EUSTIS, VIRGINIA

SUMMARY

This study assesses the effect of helicopter vibration environment on helicopter subsystem reliability, maintainability, and life-cycle costs, and the adequacy of design and acceptance test specifications applicable to helicopter vibration.

In this study, differences in reliability and maintainability data were examined on two groups of USAF H-3 helicopters with distinctly different vibration characteristics. One H-3 helicopter group was equipped with the rotor-mounted bifilar vibration absorber, a device which reduces helicopter vibration induced by the rotor, and a second aircraft group did not have the absorber. The aircraft were alike in all other respects.

The analyses performed on these data show a significant reduction in the failure rate and direct maintenance for the H-3 helicopters with absorbers and with reduced vibration levels. The overall H-3 helicopter failure rate and corrective maintenance are reduced by 48% and 38.5%, respectively. The average reduction in vibration level was 54.3%. Correspondingly, life-cycle costs show a significant reduction of approximately 10% for the overall aircraft. At the subsystem and component levels, the same reductions are shown in almost every case with the exception of certain navigation and avionics components.

There are at least 29 military vibration specifications and standards which specify vibration criteria for design or test of airborne equipment. No obvious conflicts were found in these specifications, but they are lacking in requirements which clearly describe realistic vibration exposure times for the entire helicopter air vehicle system and its components.

As shown by this study, reduction in vibration levels can significantly improve reliability and reduce maintenance and life-cycle costs. The results also suggest that the useful life of an aircraft can be extended beyond current limits simply by reducing vibration exposure.

FOREWORD

The work for this study was authorized by Contract DAAJ02-71-C-0037, Project 1F163204DB38, issued by the Eustis Directorate, U. S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia under the technical cognizance of Major A. Gilewicz.

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Mr. James Duh, Loads & Criteria, Vibration Level Mapping and Calculations.

Mr. Michael Starzyk, Standards, Specification Assessment.

Mr. Spencer Lauer and Mr. Thomas Chernesky, Technical Computing, AFM 66-1 Data Reduction.

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LIST OF SYMBOLS

A	lateral acceleration amplitude
B	vertical acceleration amplitude
DH/D	down hours per day
F_n	primary rotor excitation frequency, rad per sec
g	gravitational acceleration, 32.2 ft per sec^2
H_z	vibratory frequency, cycles per sec
LCC	life-cycle costs
MI	maintenance sensitivity index
MMH/FH	maintenance man-hours per flight hour
MTBF	mean time between failures
n	number of blades
OD	operational day, hr
OP_{ave}	average operational payload, lb
PL	aircraft payload, lb
$\ddot{R}$	total vibration response
R	mean square ratio
RI	reliability sensitivity index
t	mission time, hr
T	test statistic
V_c	cruise speed, kt
$\ddot{X}$	lateral acceleration
$\ddot{Z}$	vertical acceleration
$\Delta\lambda$	change in failure rate
λ	failure rate: failures per 1000 flight hours
λ_a	abort rate

INTRODUCTION

Vibration has a recognized influence on the reliability and maintainability of helicopter airborne equipment. Airborne equipment failure rates - such as those associated with hydraulics, power train, structure, furnishings and flight controls - are expected to be related to the frequency, amplitude, and duration of the vibration environment. It is not readily apparent, however, whether or not this effect of vibration is highly significant or economically important.

The methods available for predicting reliability and maintainability stress the importance of the environmental effects which may degrade the reliability of airborne equipment. To date, the prediction handbooks provide a constant multiplier factor K for ranges of environmental effects to be applied to laboratory or bench failure rates; however, these K's attempt to combine in one value the effects of humidity, altitude, shock, vibration, sand, dust, etc. Because different airborne equipments are affected to different degrees by each environment, more accuracy in the reliability prediction can be attained by developing failure rates around each environmental factor.

Component failure rates in fixed-wing application are demonstrably lower than those of equivalent or similar components used in helicopters. This observation is verified to some extent by comparing fixed-wing and helicopter failure rates appearing in the Bureau of Naval Weapons Failure Rate Data Handbook.[1]

Figures 1 and 2 illustrate the comparison for hydraulic actuators and selected electronic components. This trend suggests that lower vibration levels inherent in fixed-wing aircraft lead to better component reliability, but other major differences in the applications also exist. At the same time, however, significant reductions in maintenance have been reported on commercial S-61 model helicopters when they were equipped with vibration-reducing equipment.[2]

The deleterious effect of vibration on reliability is not readily separated from other environmental effects. Starting in 1970, however, a unique opportunity to relate helicopter vibration data to field reliability data became possible with the installation of rotor-mounted vibration absorbers on USAF CH-3 helicopters. Recorded reliability data and measured vibration data on these type aircraft before and after the installation of the absorber were available. The measured vibration data were acquired from a test program conducted on three CH-3 helicopters at Sikorsky Aircraft. Reliability data were acquired on operational aircraft currently in the field from the USAF AFM 66-1 maintenance data reporting system.

The study reported herein evaluated vibration levels and reliability and maintainability records for CH-3 helicopters with and without the vibration absorbers installed. Two CH-3 helicopter populations consisting of 15 aircraft each were selected for this study. One aircraft group was initially placed into service with the absorber and the other group was placed into service without the absorber; each aircraft group had

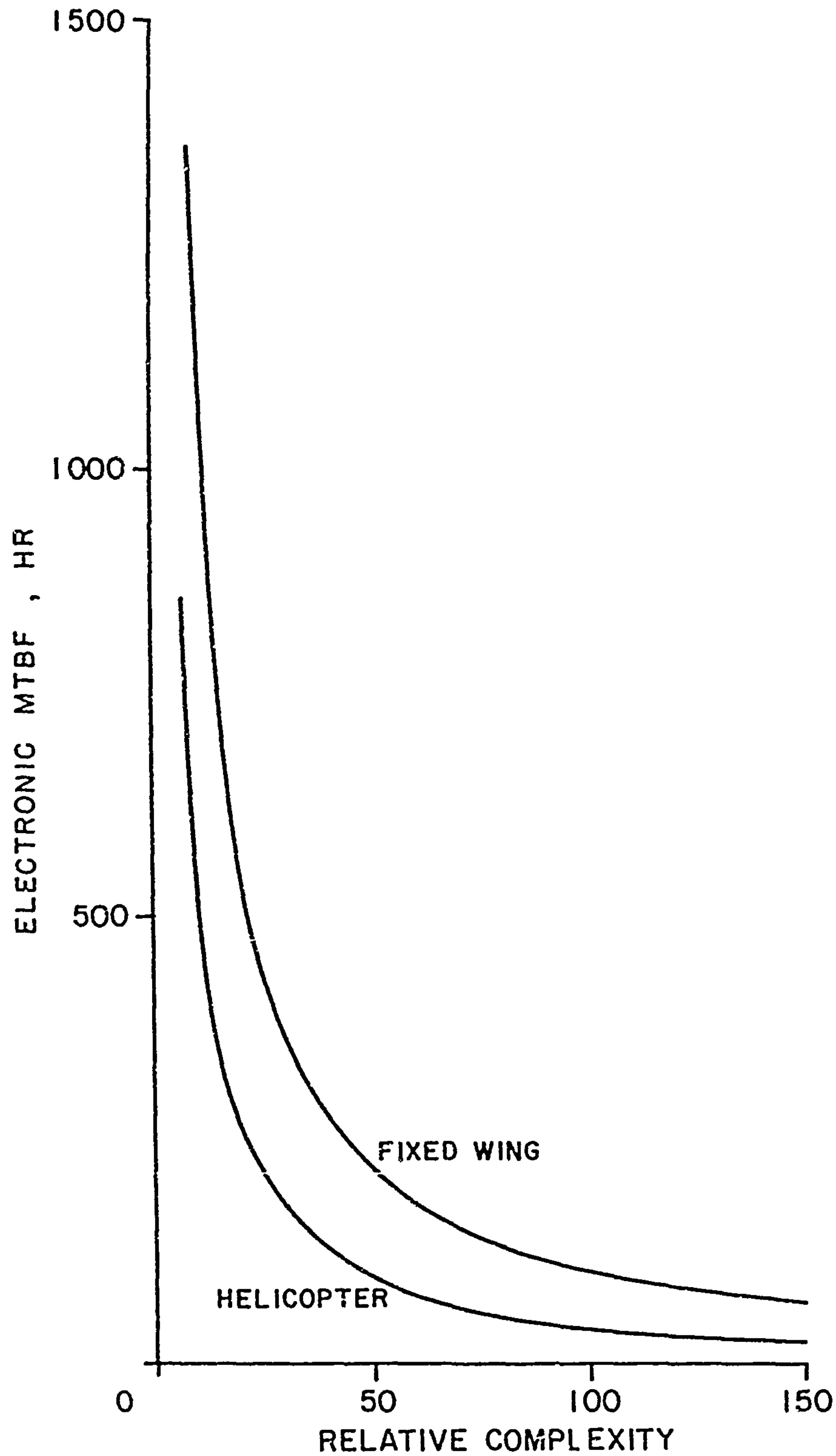

Figure 1. Fixed-Wing Electronic Reliability vs Rotary-Wing Reliability.

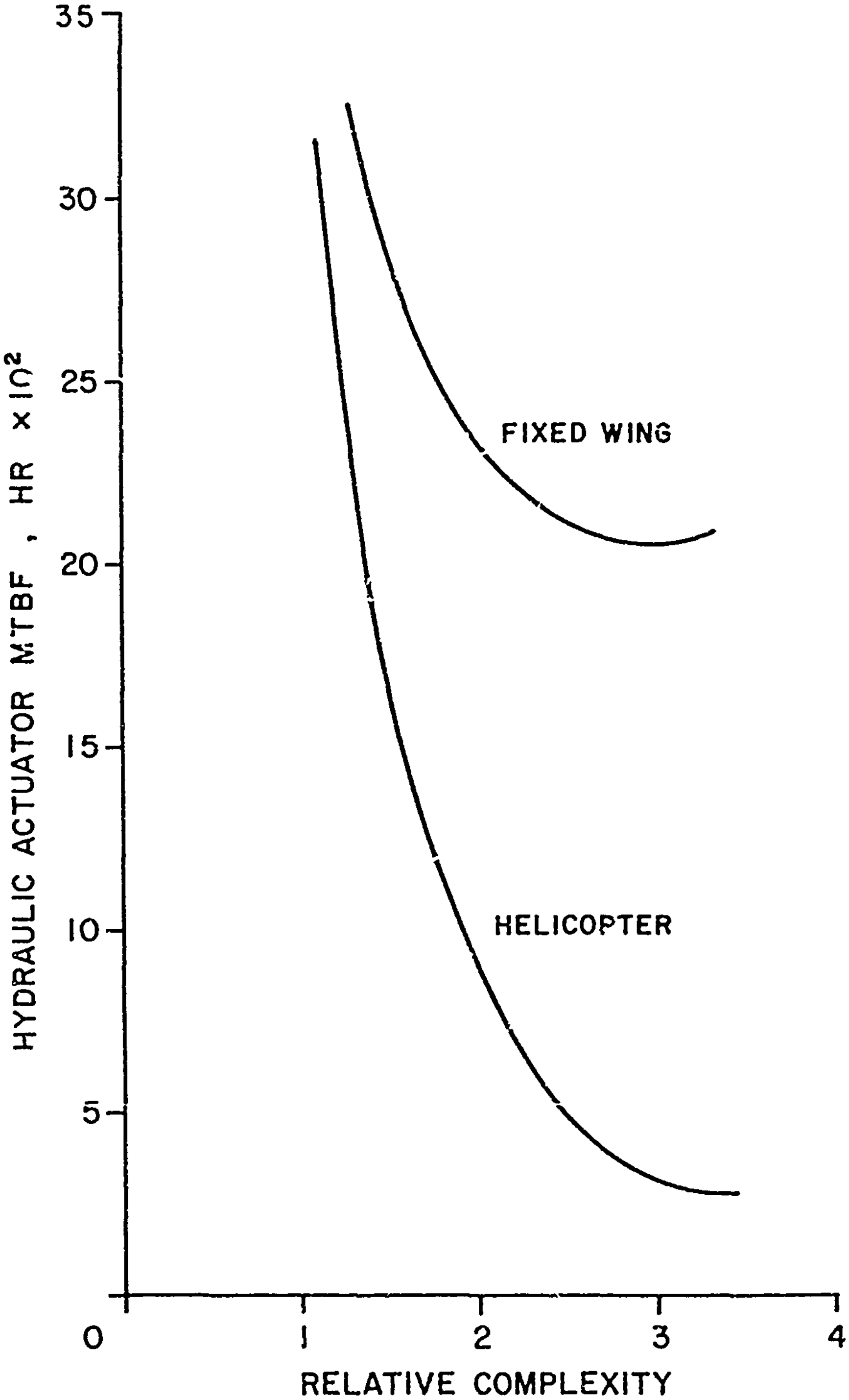

Figure 2. Fixed-Wing Hydraulic Reliability vs Rotary-Wing Hydraulic Reliability.

approximately the same number of flight hours for the time period covered by the study. The vibration data and reliability data were generated and recorded prior to commencement of this study. Changes in CH-3 R/M levels due to changes in vibration levels are summarized in this report.

METHODS AND RESULTS

AIRCRAFT POPULATION AND DATA SEPARATION

At the time the study commenced there were 15 H-3 helicopters which entered service equipped with the vibration absorber. Thus, a corresponding group of 15 H-3 helicopters were selected as a control group without the absorber. Figures 3 and 4 illustrate the helicopter and the vibration absorber respectively.

The AFM 66-1 data received from WPAFB contain information on all H-3 aircraft in service, and the computer programs at Sikorsky Aircraft were modified to allow the extraction of those data which would be applicable to the study. For the "without-vibration-absorber aircraft," data were taken from 15 aircraft serial numbers selected from the last group of aircraft delivered without the absorber. Only data prior to January 1970, the date of initial delivery of vibration absorber kits to the USAF, were used. Information for the "with-vibration-absorber aircraft" was taken, by aircraft serial number, only from aircraft delivered with absorbers installed.

The flight-hour totals for each aircraft were determined from the aircraft logs or from flight times provided by field service reports. In conjunction with the determination of total flight time, the time spent in performing various missions was also considered since reported reliability and maintainability data may be sensitive to the particular mission. Detailed mission profiles were obtained for the two fleets, and no significant differences were found in the way, purpose, and length of time the aircraft were being used. Therefore, reliability and maintainability sensitivity to missions flown was assumed to be equivalent for both groups of aircraft.

The total number of flight hours accumulated by each aircraft over the 14-month period covered by the AFM 66-1 data along with aircraft locations are provided in Table I. The percentage utilization for each mission is presented in Table II.

The geographical locations of the sample groups of aircraft suggest that they may have been exposed to large differences in climatic conditions and that this would impact upon the reliability and maintainability data studied. The aircraft without the absorber are located in geographical regions ranging from the Tropic Zone to the Temperate Zone (14°N Lat to 52°N Lat). The aircraft with the absorber are located in geographical regions ranging from the northern portion of the Temperate Zone to a region above the Arctic Circle, the North Frigid Zone (61°N Lat to 76°N Lat). Climatological surveys were investigated and the aircraft without the absorber were exposed to mean daily temperatures ranging from 40°F to 89°F, mean annual snowfall ranging from 10 inches to 23 inches, and mean wind speed ranging from 6 kt to 9 kt. The aircraft with the absorber were exposed to mean daily temperatures ranging from 5°F to 42.6°F, mean annual rainfall of 5.5 inches to 17 inches, mean annual snowfall ranging from 10.5 inches to 36 inches, and mean wind speeds ranging from 5 kt to 7 kt.

Figure 3. H-3 helicopter.

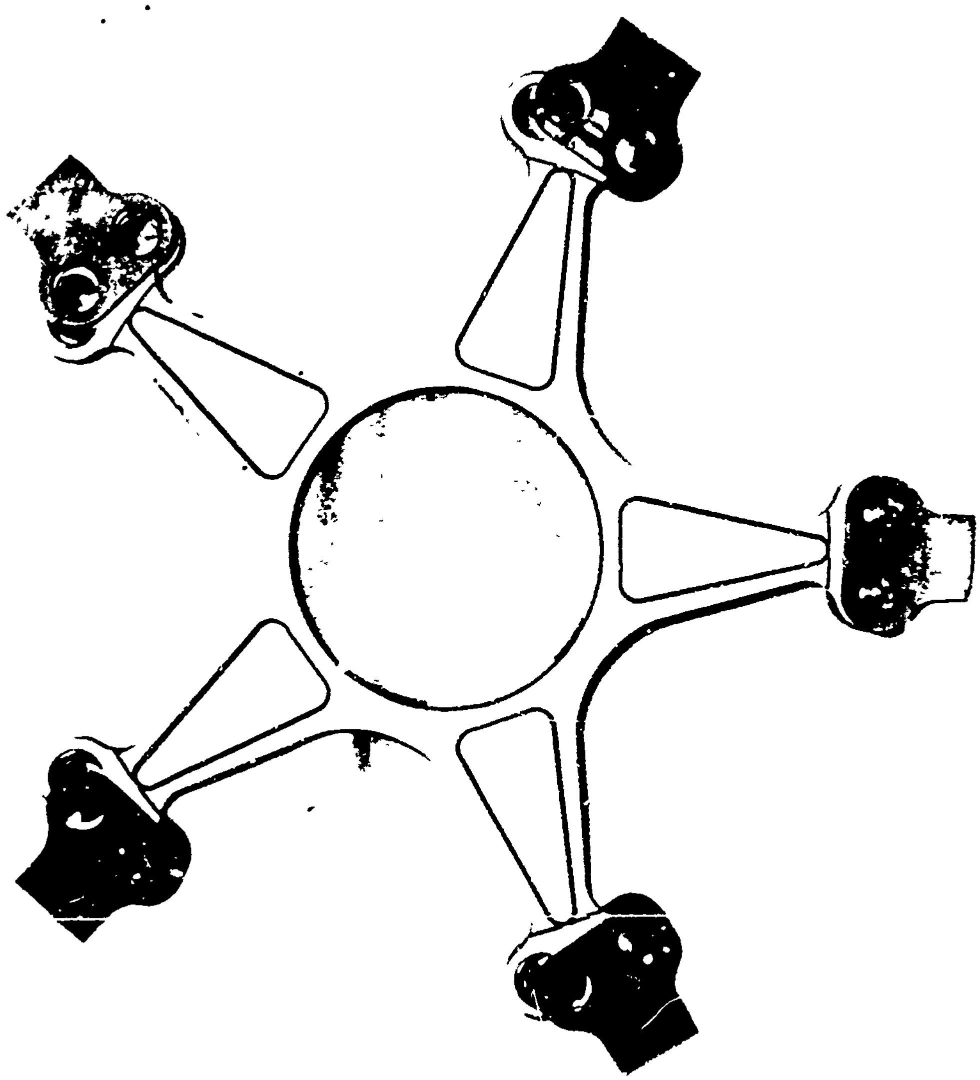

Figure 4. Bifilar Tuned Vibration Absorber.

TABLE I. SELECTED H-3 AIRCRAFT, LOCATIONS, AND TIMES

Aircraft Serial Number	Accumulated Flight Hours (Utilization)	Date Entered Service	Location
Without Absorber	(3/68 - 4/69)		
66-13284	525	6/67	Eglin AFB, Fla.
-13285	530	7/67	Forbes AFB, Kan.
-13286	557	7/67	Eglin AFB, Fla.
67-14705	520	12/67	Forbes AFB, Kan.
-14707	595	6/68	Shaw AFB, S.C.
-14711	684	3/68	Eglin AFB, Fla.
-14713	725	3/68	Eglin AFB, Fla.
-14714	559	4/68	Eglin AFB, Fla.
-14715	116	4/68	Woodbridge, G.B.
-14716	125	5/68	Woodbridge, G.B.
-14717	126	5/68	Woodbridge, G.B.
-14719	425	7/68	Forbes AFB, Kan.
-14720	476	8/68	Shaw AFB, S.C.
-14723	180	9/68	Clark AFB, P.I.
-14724	85	10/68	Clark AFB, P.I.
Total Hr	6228		
With Absorber	(1/70 - 4/71)		
69-5798	490	4/70	Thule AFB, Greenland
-5789	510	4/70	Thule AFB, Greenland
-5800	511	4/70	Alaskan Air Com.
-5801	550	4/70	Alaskan Air Com.
-5802	445	5/70	Alaskan Air Com.
-5803	405	5/70	Alaskan Air Com.
-5804	500	6/70	Alaskan Air Com.
-5805	495	6/70	Alaskan Air Com.
-5806	450	7/70	Alaskan Air Com.
-5807	415	7/70	Alaskan Air Com.
-5808	335	8/70	Alaskan Air Com.
-5809	345	9/70	Alaskan Air Com.
-5810	300	10/70	Alaskan Air Com.
-5811	230	11/70	Alaskan Air Com.
-5812	190	1/71	Alaskan Air Com.
Total Hr	6171		

TABLE II. H-3 AIRCRAFT MISSION PROFILE

Mission	Percentage Utilization
Training	33.6
Rescue	9.6
Logistics	48.8
Other	8.0

The climatological summaries for each location cited in Table I are contained in Appendix I. The ranges of climatological conditions cited above are within the specified range of values for the H-3 aircraft. The data accumulation period for each population extended over a period of 14 months (more than a full year), so that it cannot be argued that the absorber aircraft benefited by postponing maintenance from winter months to the more favorable summer months. It appears that the climatic differences tend to favor the group of aircraft without the vibration absorber (warm/temperate) as opposed to the aircraft with the absorber (cold/arctic). In consequence then, it would appear that the values of reliability and maintainability would be biased in favor of the aircraft without the vibration absorber and may reduce the apparent effect of lower vibration levels on reliability and maintainability values for aircraft with the absorber.

The conclusion of this report as to the beneficial effect of vibration reduction on improving reliability and maintainability may therefore be conservative when considering the climatic difference.

DETERMINATION OF VIBRATION MAGNITUDES

The measured vibration data were acquired from a test program conducted on three H-3 helicopters at Sikorsky, whereas the reliability data were acquired on operational aircraft currently in the field from the USAF AFM 66-1 maintenance data reporting system. The question arises as to the rigor of using vibration data taken from aircraft different from those from which the reliability data are taken and pooling these data to form the basis of this study. It has long been an established procedure in the aircraft industry to acquire various data on a sample of aircraft and to apply the results of these data throughout the entire fleet of aircraft.

Vibrations are induced in the helicopter and its components by the main rotor at a frequency = Hz or $F_n/2\pi$

$$F_n = n\Omega \qquad (1)$$

where F_n = frequency, radians per second

n = number of rotor blades

Ω = rotor speed, radians per second

Vibration data used in this study were taken from the flight test results recorded on H-3 helicopters both with and without a bifilar vibration absorber. These tests measured the vertical and lateral vibration amplitudes and directions at various points through the aircraft at the dominant frequency of 17 H_z, and values obtained are shown in Table III (as extracted from the test report).

TABLE III. AIRCRAFT VIBRATION RESPONSE*

Station (in.)	Butt Line (in.)	Water Line (in.)	Without Absorber Vertical Accel (g)	Without Absorber Lateral Accel (g)	Without Absorber R_{max} (g)	With Absorber Vertical Accel (g)	With Absorber Lateral Accel (g)	With Absorber R_{max} (g)
95	21(RT)	107	0.17	0.31	0.35	0.11	0.29	0.31
95	21(LT)	107	0.20**	0.31	0.31	0.09	0.29	0.30
187	39(RT)	107	0.17	0.22	0.28	0.09**	0.16	0.16
187	39(LT)	107	0.17	0.22	0.28	0.17	0.16	0.23
243	39(RT)	107	0.22	0.32	0.39	0.05	0.19	0.20
243	39(LT)	107	0.24	0.32	0.40	0.16	0.19	0.25
290	39(RT)	107	0.19	0.33	0.38	0.35	0.13	0.14
290	39(LT)	107	0.13	0.33	0.35	0.16	0.13	0.21
379	39(RT)	107	0.25	0.23	0.34	0.15	0.17	0.23
379	39(LT)	107	0.17**	0.23	0.23	0.05**	0.17	0.17
243	10(RT)	181.5	0.39	1.16	1.22	0.23	0.42	0.49
243	10(LT)	181.5	0.77	1.16	1.39	0.35	0.42	0.55
290	10(RT)	181.5	0.75	1.34	1.54	0.25	0.45	0.51
290	10(LT)	181.5	0.56	1.34	1.45	0.15	0.45	0.47
542	0	160	0.24**	0.90	0.90	0.13	0.57	0.58
709.5	0	225	0.19	1.90	1.90	0.24	0.94	0.97

*Vibration Frequency of Five Per Rotor Revolution

** $\phi = 90^\circ$ or 270°

Since the aircraft systems and components are exposed to both the vertical and lateral motions simultaneously and experience the resultant effect, the lateral and vertical vibration components were combined to provide a single resultant vibration value. Longitudinal vibration is not included because past flight surveys have shown it to be negligible. The procedure used to determine the vibration response magnitude is provided by the equations below.

Given $\ddot{Y} = A \operatorname{Sin} (F_n t + \phi)$ (2)

$\ddot{Z} = B \operatorname{Sin} F_n t$ (3)

where $\ddot{Y}$ = lateral acceleration

A = lateral acceleration amplitude

$\ddot{Z}$ = vertical acceleration

B = vertical acceleration amplitude

ϕ = relative phase angle

then the total response is

$$\ddot{R} = \left[\ddot{Y}^2 + \ddot{Z}^2\right]^{\frac{1}{2}} \quad (4)$$

$$\ddot{R} = \left[A^2/2\,(1 - \cos 2F_n t \cos 2\phi + \sin 2F_n t \sin 2\phi) + B^2/2(1 - \cos 2F_n t)\right]^{\frac{1}{2}} \quad (5)$$

The vectorial addition of the vertical and lateral components of vibration results in equation (5) above and is valid for any phase angle ϕ. The phase angles used in calculating the values shown in Table III were taken directly from the flight test data to the nearest 90°. Setting the time derivative of equation (5) equal to zero and substituting 0, 90°, 180°, or 270° results in equations (6), (7) and (8):

$$|\ddot{R}|_{max} = (A^2 + B^2)^{\frac{1}{2}} \quad @\ \phi = 0^\circ \text{ or } 180^\circ \quad (6)$$

$$|\ddot{R}|_{max} = A \text{ for } A > B \quad @\ \phi = 90^\circ \text{ or } 270^\circ \quad (7)$$

$$|\ddot{R}|_{max} = B \text{ for } B > A \quad @\ \phi = 90^\circ \text{ or } 270^\circ \quad (8)$$

The absolute value of $|\ddot{R}|_{max}$ (the maximum one-half peak to peak value of the vibration level) is dependent upon the relative phase angle ϕ.

The equations (6), (7), and (8) were used to determine the resultant vibration levels shown in Table III. The phase angles for most locations are 0° and 180° where equation (6) applies, and the locations where phase angles are 90° or 270° are noted by an asterisk. In these cases, the larger of the two magnitudes (lateral or vertical) represent the vector sum where equations (7) and (8) apply.

The resultant vibration responses for the 16 pairs of vertical and lateral vibration components are given in Table III and are mapped schematically in Figure 5 and in Figure 6 for the H-3 helicopter without and with the vibration absorber respectively.

Sample Calculation

Case I:
From equation (5),

$$\phi = 0^\circ \text{ or } 180^\circ$$

$$\ddot{R} = (A^2 + B^2)^{\frac{1}{2}} \cos F_n t \qquad (9)$$

To find $|\ddot{R}|_{max}$ $$\frac{\partial \ddot{R}}{\partial t} = 0 = F_n \; (A^2 + B^2)^{\frac{1}{2}} \cos F_n t \qquad (10)$$

Therefore, $F_n t = \pi/2, \; 3\pi/2$

giving $$|\ddot{R}|_{max} = (A^2 + B^2)^{\frac{1}{2}} \qquad (6)$$

Given: Vibration Level at Station 95, Butt Line 21(RT), Water Line 107

$\ddot{Y} = 0.31g\angle 0^\circ$ $\quad \ddot{Z} = 0.17.g\angle 0^\circ$ (Table III, without absorber)

$$|\ddot{R}|_{max} = 0.35g$$

Case II:
From Equation (5),

$$\phi = 90^\circ \text{ or } 270^\circ$$

$$\ddot{R} = \{A^2(\cos^2 F_n t) + B^2(\sin^2 F_n t)\}^{\frac{1}{2}} \qquad (11)$$

To find $|\ddot{R}|_{max}$, $$\frac{\partial \ddot{R}}{\partial t} = 0 = \{A^2(\cos^2 F_n t) + B^2(\sin^2 F_n t)\}^{-\frac{1}{2}} \{B^2 - A^2\} \cos F_n t \sin F_n t \qquad (12)$$

Therefore, $F_n t = 0, \; \pi/2, \; \pi, \; 3\pi/2$

Giving: $$|\ddot{R}|_{max} = A \text{ if } A>B \qquad (7)$$

$$= B \text{ if } B>A \qquad (8)$$

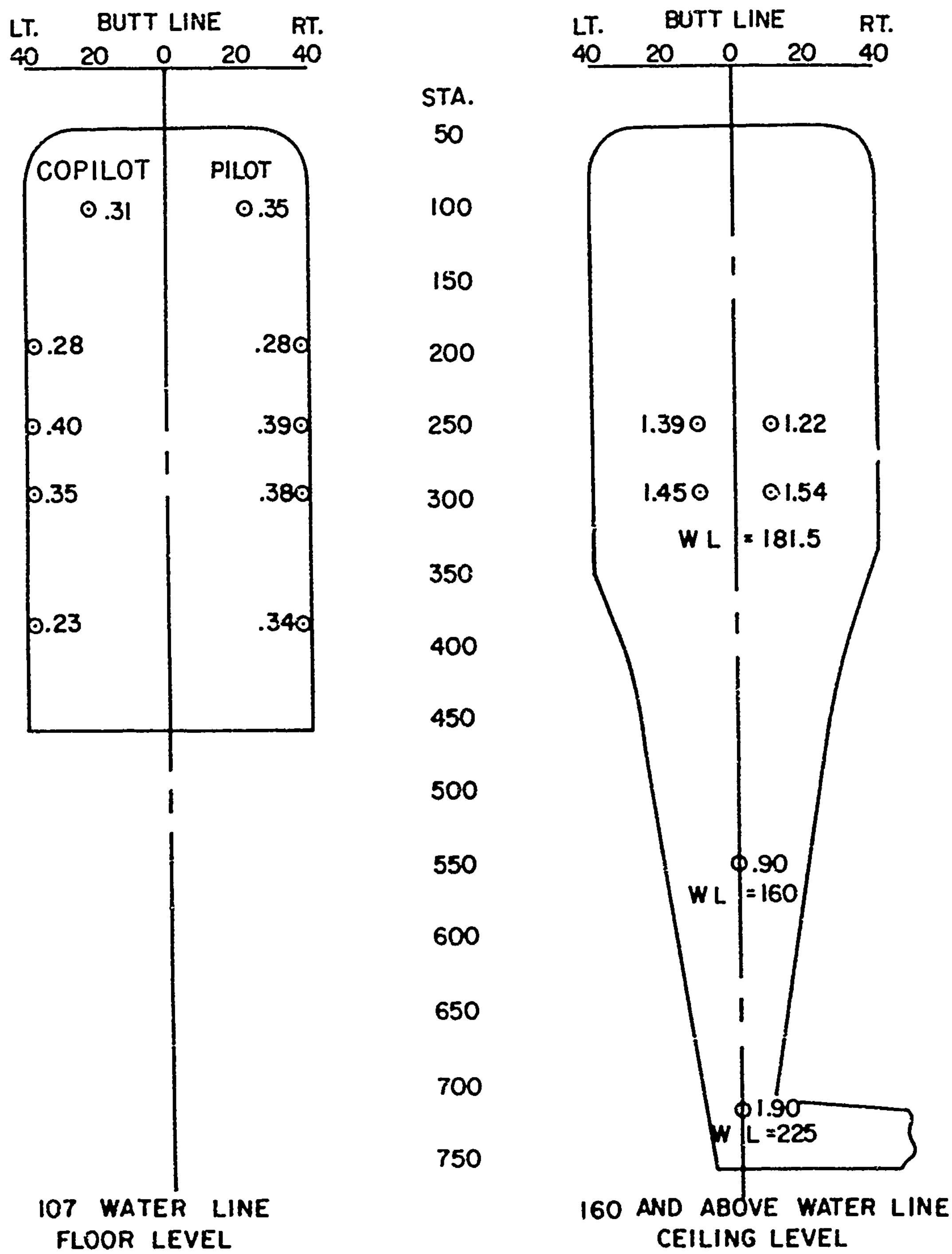

Figure 5. Total Vibration Response g
Without Absorber.

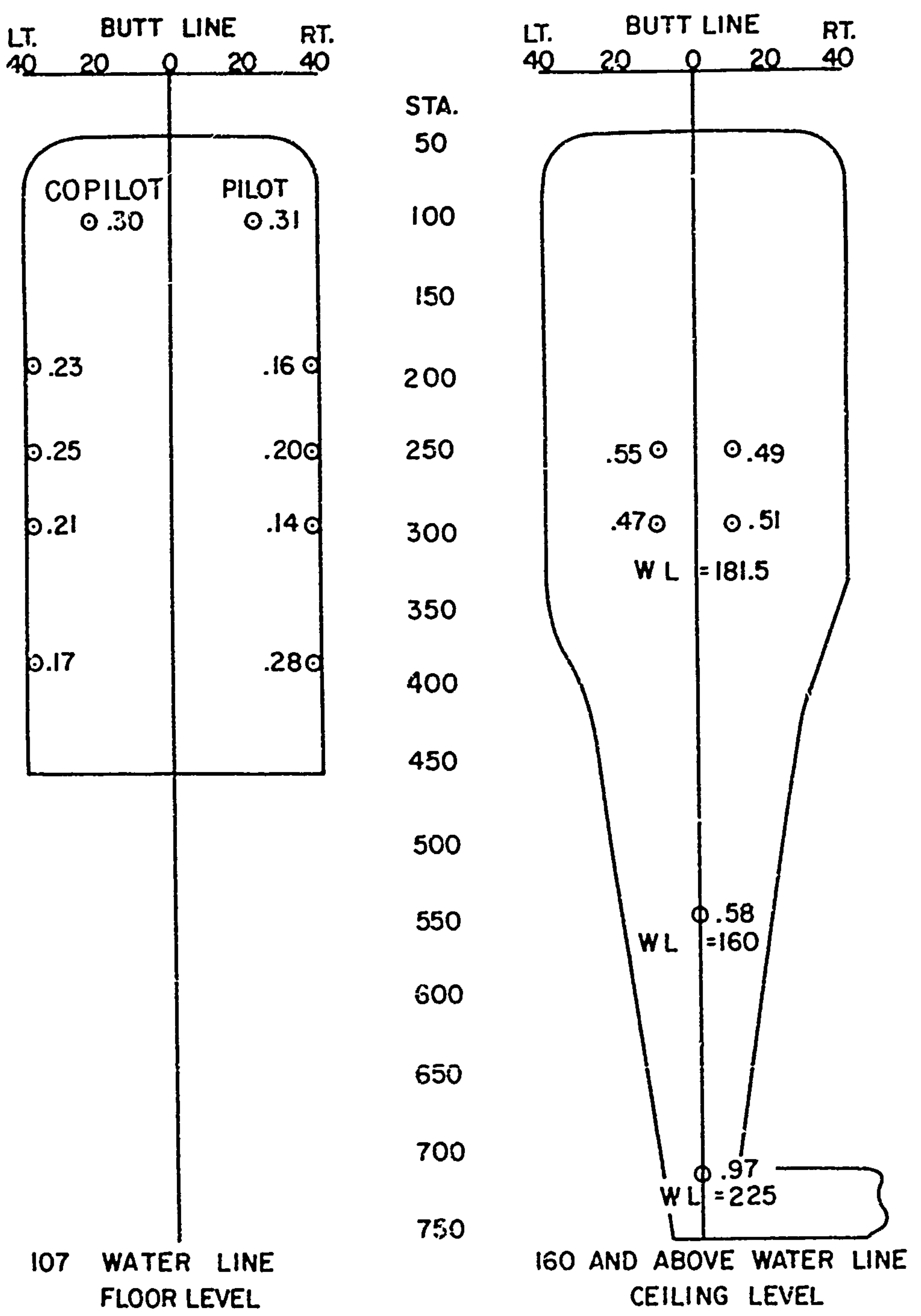

Figure 6. Total Vibration Response g
With Absorber.

Given: Vibration Level at Station 95, Butt Line 21(LT), Water Line 107

$$\ddot{Z} = 0.31\angle 0^{\circ} \qquad \ddot{Y} = 0.20g\angle 90^{\circ} \quad \text{(Table III, without absorber)} \tag{13}$$

$$|\ddot{R}|_{max} = 0.31g \tag{14}$$

The overall vibration characteristics throughout the H-3 aircraft were defined from the 16 pairs of measured vibration data points by making a linear point-to-point interpolation or extrapolation (as the case demanded).

To illustrate the procedure, the interpolation and extrapolation of the ceiling data points (water line 181.5) were carried out as follows for the without-absorber case:

At butt line 10 left the $|\ddot{R}|_{max}$ values were assumed to vary linearly through the value of 1.39g at station 243 and the value of 1.45g at station 290 to yield the interpolated value of 1.40g at station 250 and an extrapolated value of 1.46g at station 300. This is illustrated in Figure 7.

Similarly, at butt line 10 right the $|\ddot{R}|_{max}$ values of 1.22g at station 243 and 1.54 at station 290 were assumed to vary linearly to yield an interpolated value of 1.27g at station 250 and an extrapolated value of 1.60 at station 300. This is illustrated in Figure 8.

Curves were then passed through the station 250 data points to provide an estimate of the highest value near butt line zero and to fall off with constant slope either side of butt line zero. This shaping of the curve is suggested by the data points obtained, which seem to show maximum amplitudes at butt line zero near the rotor source of excitation. The lower values at BL-40 are also consistent with the lower measured levels on the floor below, (Figure 5). This procedure yielded butt line zero values 1.35g at station 250 and 1.60g at station 300. This process is illustrated in Figure 9.

The peak value of 1.60g, station 300, butt line zero, water line 181.5 near the main rotor station, the center of vibration excitation, was taken as the maximum value at the point, and the drop-off from 1.60g to 1.35g in going from station 300 to station 250 was assumed to continue at constant rate proceeding toward the nose of the aircraft. Proceeding from station 300 toward the rear of the aircraft, a straight-line drop-off from the maximum value of 1.60g to $|\ddot{R}|_{max}$ value of 0.90g measured at station 542 was assumed. In proceeding further toward the rear, a straight line with increasing values of $|\ddot{R}|_{max}$ was assumed until the measured value of 1.9g was reached at station 709.5. This procedure is illustrated in Figure 10, and represents a logical way of connecting the limited number of data points with a continuous line.

Similar reasoning was used to establish the $|\ddot{R}|_{max}$ values along the butt line

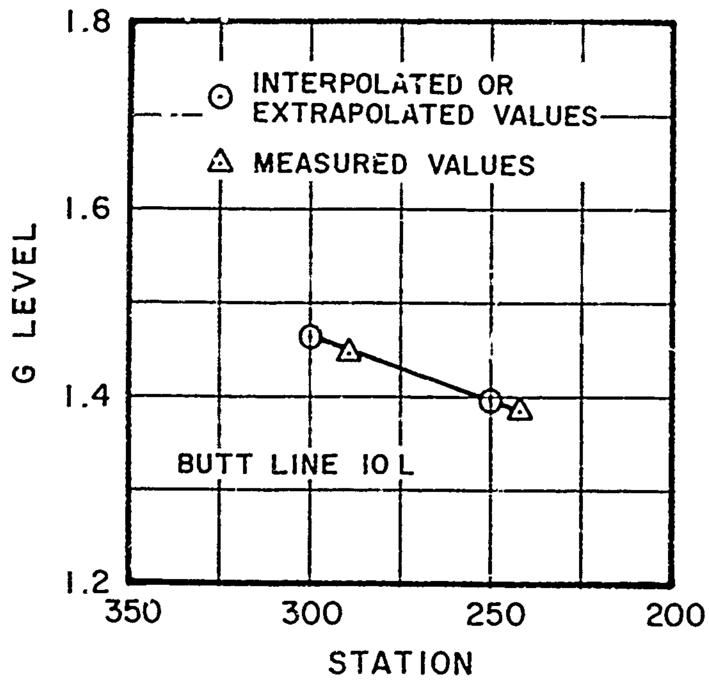

Figure 7. Extrapolation, Interpolation Vibration g Levels BL 10(LT) WL 181.5.

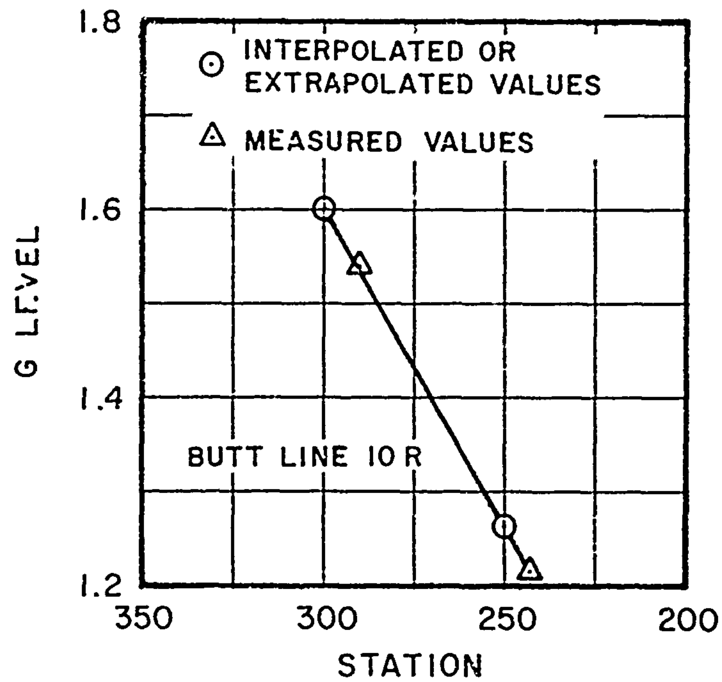

Figure 8. Extrapolation, Interpolation Vibration g Levels, BL 10(RT) WL 181.5.

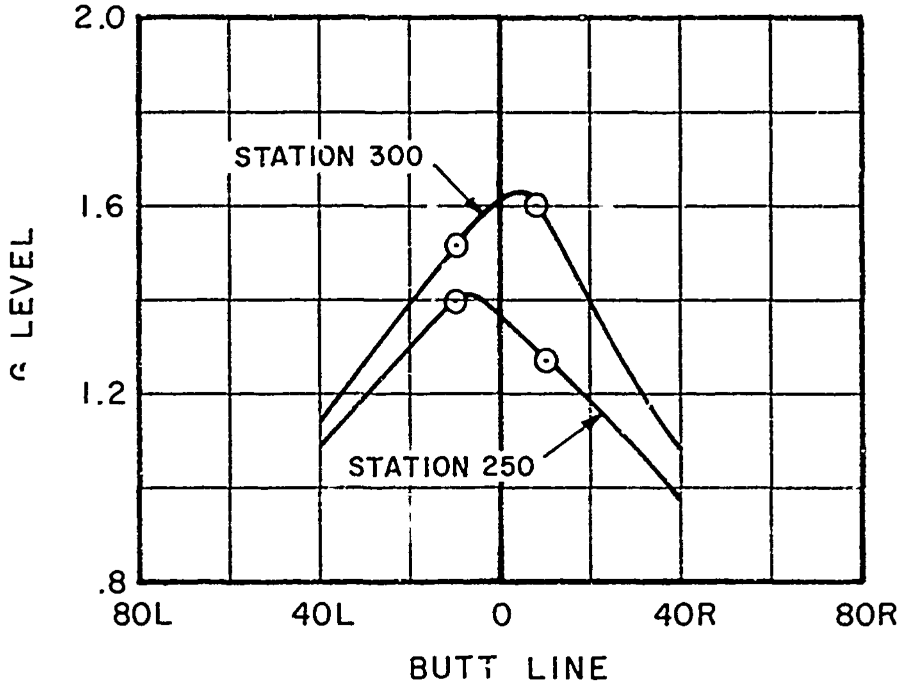

Figure 9. Extrapolation, Interpolation Vibration g Levels Sta. 250 and Sta. 300, WL 181.5.

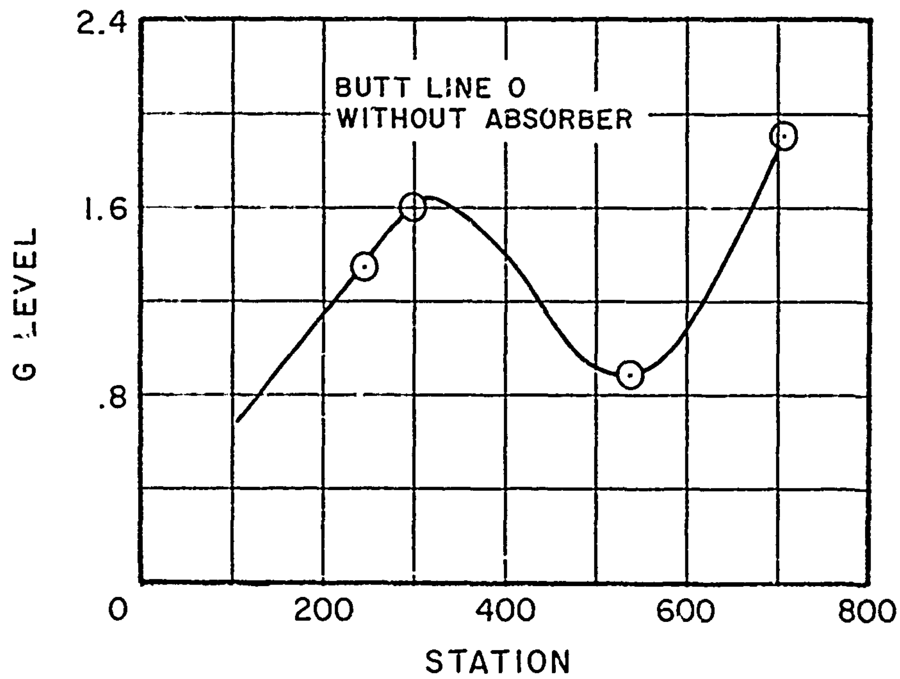

Figure 10. Extrapolation, Interpolation Vibration g Levels, BL 0, WL 181.5.

corresponding to 20 and 40 inches left and right of butt line zero at the ceiling water line, for the floor level, and for the without and with vibration cases. Subsequent to the establishment of $|R|_{max}$ values at the floor and ceiling water line levels, a straight-line interpolation was used to establish values for the water lines between or beyond the floor or ceiling levels.

Figures 11 and 12 show the completed process for the without-absorber and with-absorber cases, as described above, for the floor level and ceiling level vibration magnitudes.

Vibration profiles, Figures 13 and 14, were developed from Figures 11 and 12 in order to portray the relative vibration amplitudes without absorber and with absorber at the ceiling and floor and provide a before/after picture at these water lines. These illustrations portray relative magnitude of the resultant vibration of the vertical and lateral vibration. The direction of vibration at each station is not indicated.

Ranges of stations, butt lines, or water lines are specified as the location for some of the components considered in the study. The linear assumptions as to the vibration magnitudes acting on the component were applied and evaluated so that the lowest and highest vibration level is shown over the range of locations for the particular component.

<u>Sample Calculation Establishing g Level at a Point or Range of Points</u>

Case I: Vibration Level at a point (without absorber)

Component: Nose Landing Gear Kneeling Control

Location: Station 270, Butt Line 20R, Water Line 190

Vibration Level: Station 270, Butt Line 20R, Water Line 107 = 0.38g

Vibration Level: Station 270, Butt Line 20R, Water Line 181.5 = 1.24g

Change in g level = 0.86g, Change in Water Line = 74.5 inches

Δg/inch = 0.86/74.5 = 0.0115g/inch

Distance from Reference Water Line = 190 - 181.5 = 8.5 inches

Total g change from reference point = (8.5) (0.115) = 0.10g

Vibration Level at Water Line 190 = 1.24g + 0.10g = 1.34g

The same procedure is carried out for the with absorber condition.

Case II: Vibration Level at two points (without absorber)

Component: Anticollision Light

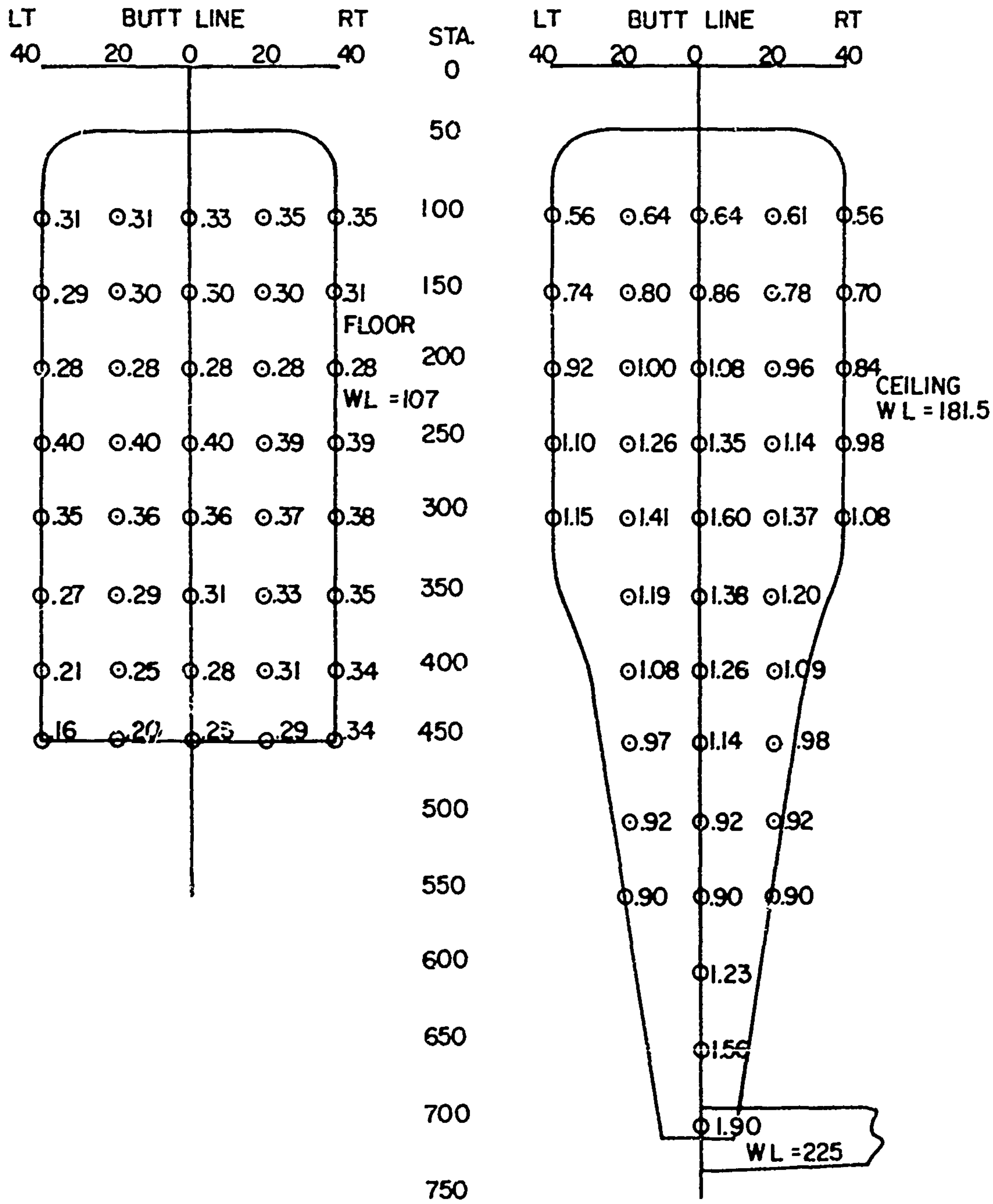

Figure 11. Linear Extrapolation, Interpolation of Vibration g Level for Entire CH-3 Aircraft Without Vibration Absorber.

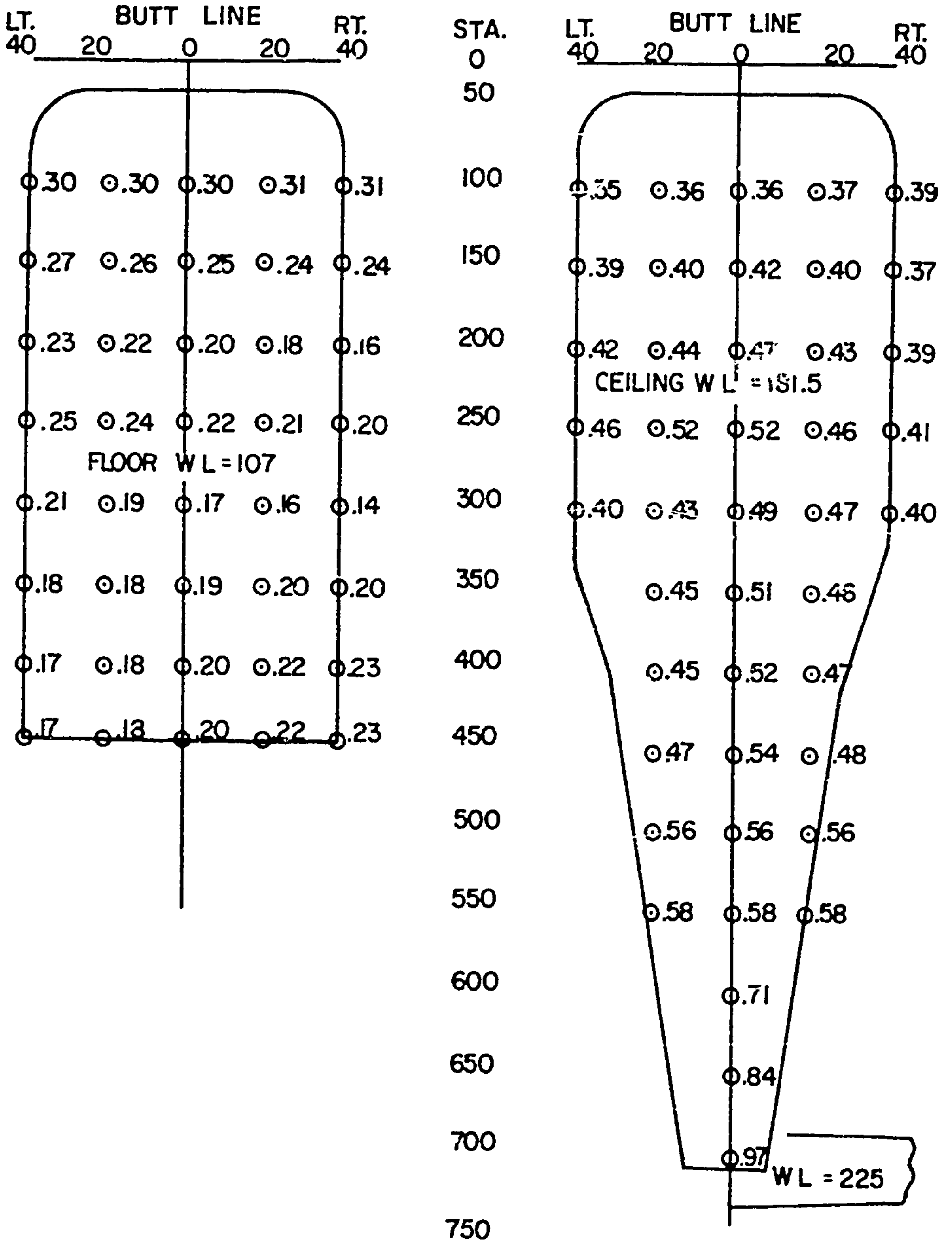

Figure 12. Linear Extrapolation, Interpolation of Vibration g Level for Entire CH-3 Aircraft With Vibration Absorber.

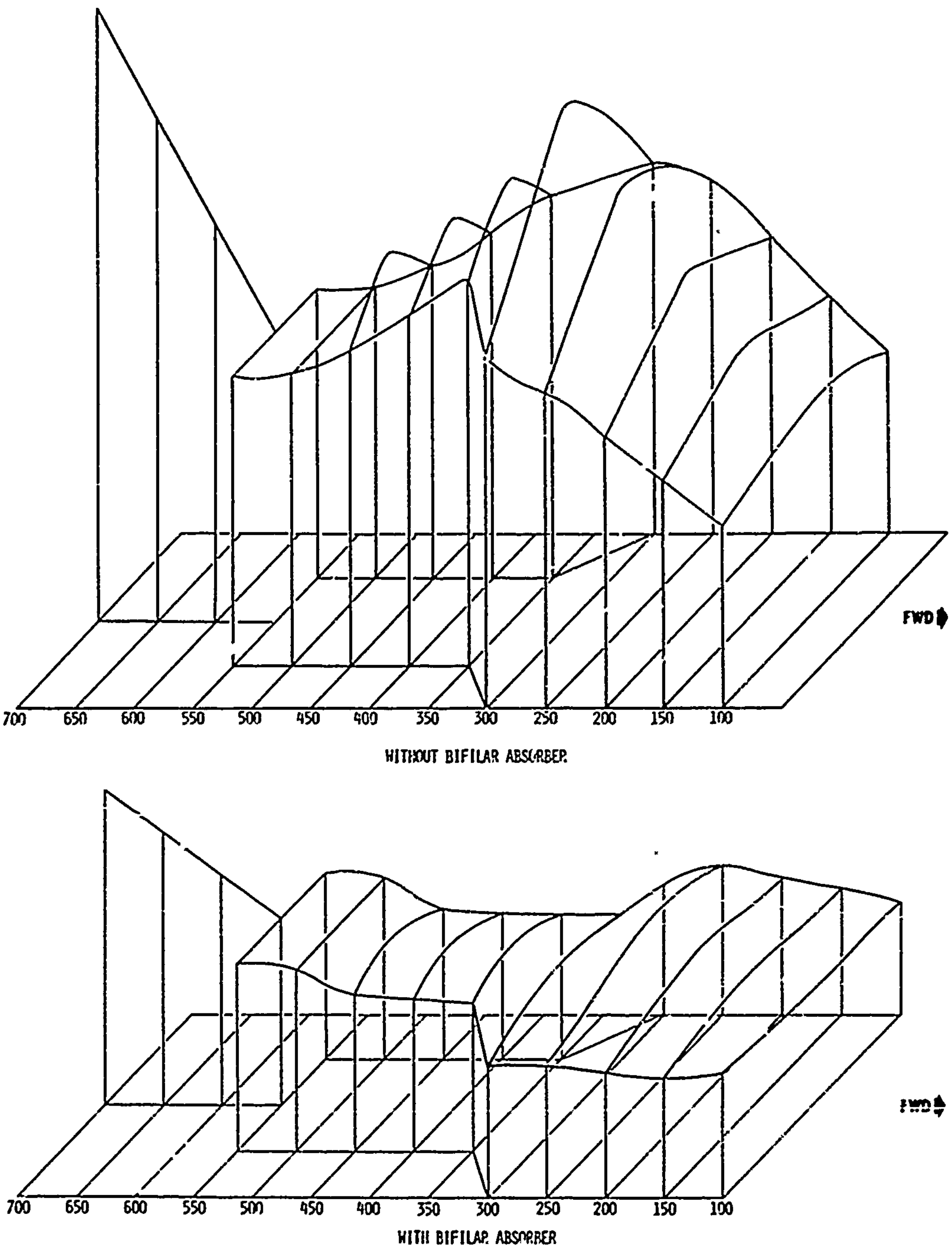

Figure 13. Vibration Magnitude Profile Without and With Vibration Absorber at Cabin Ceiling Level, WL 181.5.

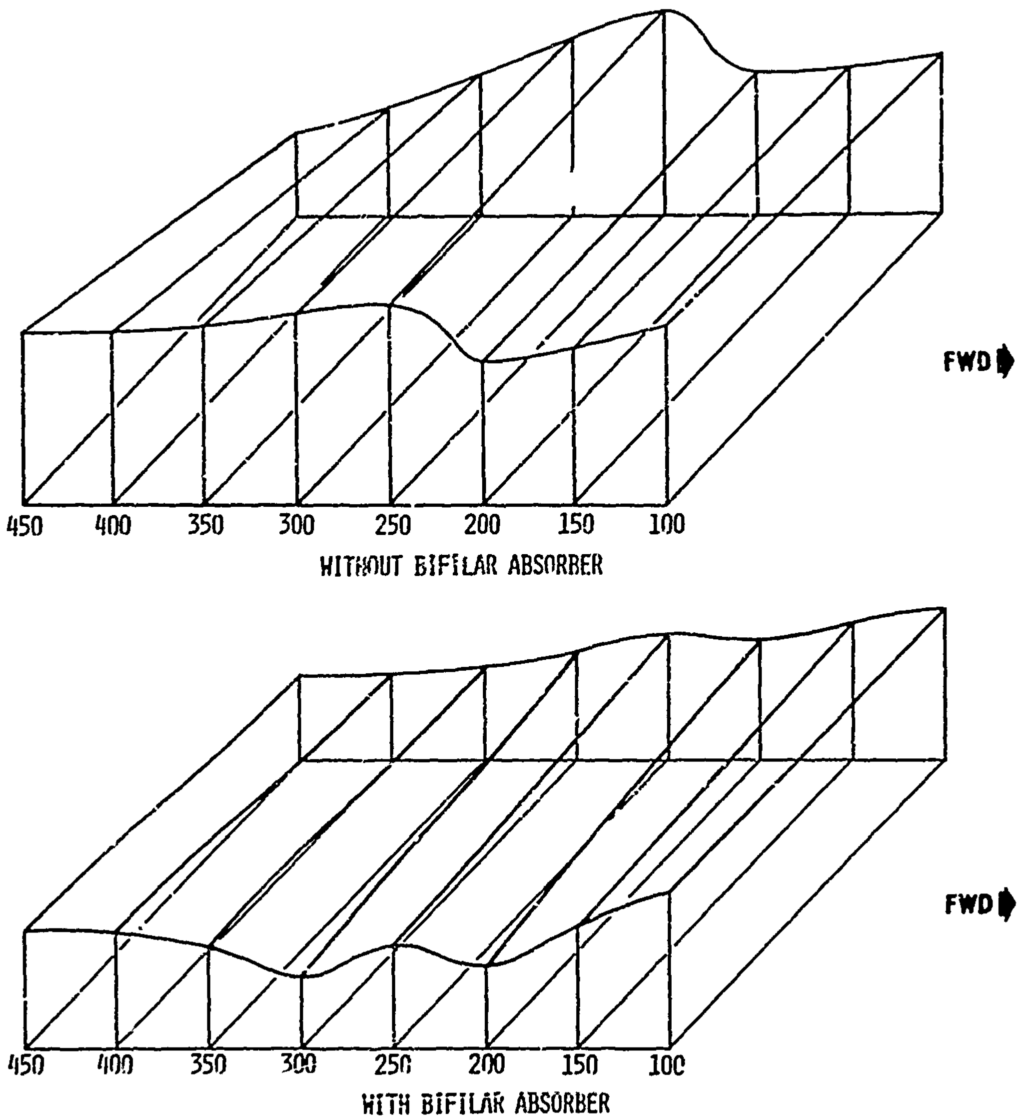

Figure 14. Vibration Magnitude at Cabin/Cockpit Floor Level, WL 107.

Locations: Stations 250 and 720, Butt Line 0 - 0, Water Lines 80 and 225

Vibration Level: Station 250, Butt Line 0, Water Line 107 = 0.40

Vibration Level: Station 250, Butt Line 0, Water Line 181.5 = 1.30

Change in g level = 0.90

Δg/inch = 0.90/74.5 = 0.121

Distance from reference = (80 - 107) = -27 inches

Total g change = (-27) (0.0121) = -0.32g

Vibration Level at the point = 0.40 - 0.32 = 0.08g

The vibration magnitude of the light at Station 720, Butt Line 0, Water Line 181.5 is the exact measurement of g level made at the point (Table III).

Reliability and Maintainability Data Source Used and Data Analysis

The reliability and maintainability data used to perform this study were obtained from the U. S. Air Force Maintenance Management System[3] and contained the failure and maintenance data for the two groups of aircraft which are discussed in this report. These data were prepared and recorded by the U. S. Air Force within the normal routine of aircraft operation and are considered complete to the extent required by USAF directives provided by Reference 3. These data were collected and recorded prior to the start of the study and were not specifically collected by the USAF in support of this study, nor were these data edited in any manner. Information pertaining to the aircraft discussed in the study has been extracted from the bulk data and listed in Table I covering a 14-month period of operation and representing 6228 flight hours and 6171 flight hours for the nonabsorber and absorber equipped aircraft respectively. The reliability and maintainability information contained in the AFM 66-1 tapes consist of date, job number, aircraft tail number, quantity of failures, action taken, when discovered, parts removed, how malfunctioned, man-hours, work performed on or off the aircraft, and work unit code number. Wo unit codes identify preventive maintenance tasks as well as components which required corrective maintenance. The data were sorted by work unit code, quantity of failures, and maintenance man-hours for each aircraft subsystem and component.

Because of the large number of discrete work unit codes assigned to the H-3 (approximately 2000), covering 37 general subsystem codes, the effect of vibration on reliability and maintainability on those items reflecting more than 10 to 15 failures within each general subsystem code for the ten subsystem codes reflecting the highest number of failures or maintenance man-hours is discussed.

The engine/powerplant subsystem was not considered in this study because engine data is identified by engine serial number and is not traceable to a particular aircraft tail number.

The average failure rate for a given work unit code was computed by taking the ratio between the total number of failures recorded and the total accumulated flight hours on each sample group of aircraft. Similarly, the average maintenance man-hour per 1000 flight hours, MMH/KFH, for a given work unit code was computed by taking the ratio between the man-hours recorded and the total accumulated flight hours for each sample group of aircraft.

The result of this procedure is shown in Table IV at the subsystem level and in Table V for the highest ranked components within a subsystem.

Tables IV and V provide an overall view as to the dramatic impact of vibration reduction at the subsystem level on reliability and maintainability.

The next procedure was to separate out from all systems, those classes of components considered to possess similar reliability characteristics. This was done for lights, switches, wires, plugs, connectors, hoses, lines, tubing, valves and relays. All AFM 66-1 data were used and all items having failures recorded against them, regardless of the quantity of failures, were tabulated along with the computation of the average failure rate λ and the maintenance man-hours per flight hour, MMH/KFH. The intent of this procedure was to determine if a behavior pattern of vibration with respect to reliability and maintainability could be recognized other than the dramatic differences in failure rate and maintenance man-hours per flight hours evidenced in Tables IV and V. These results presented in Tables IV, VII, VIII, IX, X, XI had no readily discernible characteristic other than that which is evidenced at the subsystem level. The locations or range of location for all components can be related to the actual aircraft by referring to the locating grid in Figure 15.

The term "average failure rate" was generated because it was not possible to establish the type of failure distribution which fit the reliability data. A failure distribution could not be established because time-to-failure information was not included in the AFM 66-1 data. Past studies on the reliability characteristics on major components of the H-3 helicopter indicated an exponential distribution modified by early and wearout failure phenomena. However, since a constant failure or an early failure or wearout phenomenon could not be established for the data used, the term "average failure rate" is used.

TABLE IV. TOTAL AIRCRAFT SYSTEM COMPARISON RELIABILITY AND CORRECTIVE MAINTENANCE

Aircraft Subsystem	Failure Rates (10^{-3}) W/Out Absorber	Failure Rates (10^{-3}) With Absorber	Failure Rate	-MMH/KFH W/Out Absorber	-MMH/KFH With Absorber	MMH/KFH
Airframe	223.7	107.8	115.9	592.3	209.7	382.6
Drive	108.7	47.6	61.1	371.8	216.5	155.3
Utilities	64.1	13.8	50.3	106.4	26.3	80.1
Landing Gear	91.5	44.8	46.7	289.6	189.8	99.8
Lights	119.6	29.3	90.3	240.7	45.6	195.1
Fuel	56.2	22.8	33.4	118.8	50.8	68.0
Flt. Control	58.4	22.8	35.6	209.5	60.5	149.0
Rotor	80.4	51.0	29.4	321.4	278.8	42.6
Cockpit/Fus.	33.1	9.9	23.2	48.9	23.2	25.7
Electrical	35.6	12.4	23.2	79.4	26.2	53.2
Hyd. Power	37.1	17.1	20.0	76.3	19.9	56.4
Inter Comm.	39.5	21.2	18.3	71.2	49.7	21.5
Radio Nav.	65.5	50.2	15.3	209.0	217.7	-8.7
Air Cond/Heat	27.1	18.3	8.8	95.7	36.1	59.6
Auto Pilot	28.4	16.6	11.8	94.2	88.6	5.6
Emer. Equip	12.7	2.4	10.3	15.9	1.4	14.5
Aux Power Unit	44.5	36.2	8.3	125.9	107.4	18.5
HF Comm.	14.9	6.7	8.2	69.3	33.5	35.8
UHF Comm.	23.1	17.6	5.5	67.9	93.1	-25.2
IFF	8.2	2.9	5.3	21.9	12.3	9.6
Misc. Comm.	8.7	4.7	4.0	13.4	9.3	4.1
Weap. Del.	1.9	0.2	1.7	4.3	0.3	4.0
Emer. Comm.	0.2	0.2	0	0.2	0.3	-0.1
VHF	9.2	9.4	-0.2	38.8	36.4	2.4
Radar Nav.	40.0	40.4	-0.4	163.7	188.2	-24.5

* Minus sign indicates an increase in rate.

TABLE V. [illegible] OF RELIABILITY AND [illegible] MAINTENANCE AT [illegible] G LEVEL

COMPONENT NAME	WITHOUT ABSORBER (W/O) FAILURES	FAILURE RATE (10^{-3})	MMH	MMH/KFH	WITH ABSORBER (W) FAILURES	FAILURE RATE (10^{-3})	MMH	MMH/KFH	Δ-(W/O-W) FAILURE RATE (10^{-3})	MMH/KFH	LOCATION S.T.A.	B.L.	W.L.	G LEVEL WITHOUT ABSORBER	G LEVEL WITH ABSORBER	ΔG (w/o-w)
Airframe																
[illegible] Frames		5.[illegible]		93.2		2.6		6.1	2.4	77.1	[illegible]	[illegible]	195 - 25[illegible]	0.35/0.93	0.18/0.41	[illegible]/0.5[illegible]
Engine Work Platform		9.6		62.8		9.3		14.6	0.3	48.2	[illegible] - 245	[illegible]	193 - 210	1.24/1.12	0.43/0.58	0.81/0.54
Transmission Work Platform		8.2		21.5		4.6		11.4	3.6	10.1	[illegible] - 290	[illegible]	190 - 210	1.32/1.19	0.44/0.53	0.8[illegible]/0.66
Engine Fwd. Cowling		12.7		34.1		3.7		0.8	9.0	23.3	[illegible]	[illegible]	195 - 210	0.95/1.11	0.43/0.49	[illegible]/0.62
Engine Aft Cowling		11.2		19.3		5.9		7.9	5.3	11.4	[illegible]	[illegible]	190 - 210	1.22/1.42	0.46/0.59	[illegible]/0.83
Aft [illegible]		10.4		15.1		7.0		11.8	3.4	3.3	[illegible]	[illegible]	[illegible]	1.23/1.63	0.45/0.57	[illegible]
Main Pylon Structure		8.2		17.2		3.6		6.1	4.6	11.1	[illegible]	[illegible]	[illegible]	1.35/1.67	0.45/0.54	[illegible]/1.13
Access Panels		7.5		17.0		3.6		5.6	3.9	11.4	330 - 360	[illegible]	190 - 225	1.33/1.63	0.45/0.57	[illegible]/1.06
Bottom Skin		6.7		16.5		1.0		2.9	5.7	13.6	365 - 400	45 [illegible]	80 - 115	0.12/0.35	0.10/0.21	0.02/0.14
Aft Ramp		5.0		16.2		1.3		4.6	3.7	11.6	[illegible] - 540	[illegible]	[illegible] - 145	0.25/0.71	0.15/0.54	0.10/0.17
[illegible] Pylon Fairing		6.4		11.0		0		0	6.4	11.0	[illegible]	[illegible]	[illegible]	1.35/1.67	0.45/0.54	0.90/1.13
All Other Airframe Systems		132.8		278.4		65.2		127.9	77.6	150.5	--	--	--	0.97/1.23(Av)	0.36/0.49(Av)	
Drive																
M.G.B. Press. Transmitter		5.4		6.3		0.7		0.8	4.7	5.5	260	0	190	1.35	0.49	0.86
M.G.B. [illegible]		7.7		[illegible]		2.6		11.7	5.1	17.3	260	0	190	1.35	0.49	0.8[illegible]
[illegible] Lubelines		7.2		12.6		3.4		3.5	3.8	9.1	[illegible]	[illegible]	[illegible] - 210	1.15/1.49	0.51/0.58	[illegible]/0.91
M.G.B. Torque Transmitter		10.1		16.2		1.1		1.2	9.0	15.0	[illegible]	[illegible]	[illegible]	1.40/1.33	0.59/0.56	0.81/0.87
[illegible] Clutch		9.2		50.0		4.6		34.8	4.6	15.2	295	[illegible]	195	1.49	0.47	1.02
Main Gearbox		2.9		87.6		2.0		90.0	0.9	-2.4	245 - 290	[illegible]	185 - 215	1.39/1.76	0.50/0.56	0.89/1.[illegible]
M.G.B. [illegible]		2.2		22.7		0.3		1.4	1.9	21.3	245 - [illegible]	[illegible]	[illegible] - 215	1.40/1.77	0.51/0.56	[illegible]/1.21
[illegible] Flexible Hoses		4.2		29.3		0.5		0.8	3.7	28.5	[illegible] -300	[illegible] -204	206	1.38/1.46	0.49/0.59	[illegible]/0.81
All Other Drive Systems		59.8		125.1		32.4		72.3	27.4	55.8				1.36/1.56(Av)	0.50/0.56(Av)	

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TABLE V - Continued

COMPONENT NAME	WITHOUT ABSORBER (W/O) FAILURES	FAILURE RATE (10^{-3})	MMH	MMH/KFH	WITH ABSORBER (W) FAILURES	FAILURE RATE (10^{-3})	MMH	MMH/KFH	Δ - (W/O-W) FAILURE RATE (10^{-3})	MMH/KFH	LOCATION STA	BL	W.L.	G LEVEL WITHOUT ABSORBER	G LEVEL WITH ABSORBER	ΔG (w/o-w)
[illegible]																
[illegible]		7.4		7.6		1.1		2.6	6.3	5.0	120-140	0-[illegible]	115-[illegible]	0.30/0.86	0.26/0.42	0.10/0.44
[illegible]		7.2		11.2		0.3		0.3	[illegible]	10.6	[illegible]	[illegible]	[illegible]	[illegible]	0.11/0.58	[illegible]
[illegible]		5.7		15.5		1.3		1.6	4.2	17.5	160-340	[illegible]	155-210	1.05/1.63	0.42/0.52	0.63/1.11
Fire Detector Control?		4.1		7.1		0.6		1.0	3.5	6.1	180-[illegible]	[illegible]	195-210	1.05/1.63	0.42/0.52	0.63/1.11
[illegible]		3.6		27.1		3.2		18.8	0.4	2.3	120-140	0-[illegible]	115-170	0.30/0.86	0.20/0.42	[illegible]/0.44
[illegible]		2.6		5.7		0.2		0.2	2.4	5.5	120-140	0-[illegible]	115-170	0.30/0.86	0.26/0.42	0.10/0.44
All Other Utility		33.7		34.3		7.1		2.4	26.6	31.9				0.56/1.28(Av	0.29/0.48(Av)	
[illegible]																
[illegible] Gear Shock		2.0		76.0		2.0		35.5	3.4	40.5	130	0	80-120	0.14/0.39	0.22/0.42	0.08/0.03
[illegible] Valve		6.6		23.9		1.6		6.0	5.0	17.9	270	[illegible]	190	1.37	0.50	0.87
Nose Wheel?		7.2		14.3		0		0	7.2	14.3	340	[illegible]	70	0.06/0.17	0.11/0.14	0.05/[illegible]
[illegible] Cylinder		5.1		22.4		2.4		15.2	2.7	7.2	[illegible]	[illegible]	[illegible]	0.27/0.33	0.10/0.24	[illegible]
[illegible]		3.7		8.5		1.3		1.6	2.4	6.9	[illegible]-340	[illegible]	[illegible]-110	0.21/0.39	0.22/0.30	[illegible]
All Other Landing Gear		[illegible]3.5		154.5		37.5		141.5	26.0	13.0				0.41/0.32(Av	0.23/0.28(Av)	
[illegible] (See Detailed Tabulation [illegible], and Figure [illegible])																
[illegible]		22.7		19.4		7.3		6.3	14.4	13.1	[illegible]-495	[illegible]	160-[illegible]	0.95/1.02	0.38/0.56	[illegible]/0.46
[illegible]		18.2		31.9		3.5		4.3	15.2	27.6	[illegible]	[illegible]	[illegible]	0.26/1.39	0.19/0.62	0.07/0.77
Panel Lights		15.4		46.8		4.4		6.8	11.0	40.0	70	[illegible]	145	0.44	0.35	0.09
Anticollision Lights		10.3		19.5		2.1		2.5	8.2	17.0	355, [illegible]	0,0	80, [illegible]	0.31/1.90	0.11/0.97	0.20/[illegible]
Fuselage Lights		13.5		29.6		0.3		0.3	13.2	29.3	415, [illegible]	0,0	80, 225	0.32/1.90	0.08/0.97	0.24/0.9[illegible]
All Other Lights		39.4		93.5		11.2		25.5	28.2	68.0	70-510	[illegible]-40F	80-190	0.44	0.35	0.69

TABLE V - Continued

COMPONENT NAME	WITHOUT ABSORBER (W/O) FAILURES	FAILURE RATE (10^{-3})	MMH	MMH/KFH	WITH ABSORBER (W) FAILURES	FAILURE RATE (10^{-3})	MMH	MMH/KFH	Δ - (W/O-W) FAILURE RATE (10^{-3})	MMH/KFH	LOCATION ST.A	B.L.	W.L	G LEVEL WITHOUT ABSORBER	G LEVEL WITH ABSORBER	ΔG (W/O-W)
Fuel																
Fuel Cells & Auxiliary Tanks		4.0		22.9		3.4		5.6	0.6	17.3	190-370	110L-120	50-1[illegible]	0.37/0.77	[illegible]29/0.59	[illegible]/0.1[illegible]
[illegible], Lines, Tube		7.5		10.0		1.6		2.1	5.9	9.9	140-3[illegible]	110L-11R	[illegible]-210	0.37/1.35	[illegible]/0.52	[illegible]/[illegible]
[illegible]		7.5		14.[illegible]		1.6		3.5	5.9	11.[illegible]	[illegible]-470	[illegible]-35R	[illegible]-15[illegible]	0.36/0.78	[illegible]/0.47	[illegible].07/0.[illegible]
[illegible]		4.7		3.5		1.5		1.1	3.2	7.7	2[illegible]	0	200	1.48	0.60	[illegible].88
All Other Fuel Components		32.5		[illegible]		14.7		39.5	27.8	2[illegible].1				0.65/0.78(Av)	[illegible].36/0.53(av)	
Flight Controls																
[illegible]		15.5		88.5		3.7		7.3	11.8	81.2	[illegible]-200	[illegible]-[illegible]	100-[illegible]	1.49/2.67	[illegible].51/0.59	0.98/[illegible]
[illegible]		[illegible].1		14.0		[illegible]		2.1	3.5	11.[illegible]	[illegible]	[illegible]-20R	[illegible]-210	1.5[illegible]/2.72	0.52/0.59	1.[illegible]/1.1[illegible]
[illegible]		4.4		8.7		0.6		0.8	3.8	7.9	90	0	120	0.47	0.28	0.19
[illegible], Balance		2.8		11.[illegible]		1.3		0.1	1.5	6.5	10,[illegible]	[illegible]	110, 115,[illegible]	0.31/x/1.50	0.31/x/0.84	[illegible]/0.[illegible]
Control Sticks		2.7		3.4		0.9		1.0	1.8	2.4	70-110	[illegible]-20R	120-140	0.35	0.30	0.05
Auxiliary Servos		2.5		4.4		0.4		1.3	2.1	3.1	130	[illegible]	145	0.61	0.33	0.28
[illegible] Friction Lock		[illegible]		4.1		0.8		[illegible].7	1.4	1.4	100	[illegible]	110	0.38/0.42	.29/0.30	[illegible]/0.1[illegible]
[illegible]		2.[illegible]		[illegible]		[illegible]		[illegible]	1.6	4.8	[illegible]	[illegible]	[illegible]	1.62	0.54	1.08
[illegible]		2.[illegible]		4.[illegible]		0		0	1.9	4.3	7[illegible]-[illegible]	10L-[illegible]	115-193	0.[illegible]/1.22	.19/0.43	[illegible].14/0.7[illegible]
All Other Flight Controls		18.4		65.5		12.2		39.0	6.2	26.5				0.79/1.32(Av)	.3[illegible]/0.55(Av)	
[illegible]																
[illegible]		11.[illegible]		17.4		2.6		[illegible].4	8.6	8.0	1[illegible]	[illegible]	1[illegible]-14[illegible]	[illegible].37/0.42	.30/0.33	[illegible].07/0.14
[illegible]		4.7		8.1		0.7		1.4	4.0	6.7	1[illegible]-[illegible]	[illegible]-[illegible]	173-180	[illegible].55/1.11	[illegible].34/0.41	[illegible]/0.70
Litter Assembly		2.4		2.7		0		0	2.4	2.7	170-460	40L-40R	105-27[illegible]	[illegible].25/0.84	.16/0.40	[illegible]/0.74
Floor		4.0		2.4		1.6		1.3	2.4	1.1	120-450	40L-40R	105	0.22/0.32	[illegible]/0.29	0.06/0.03
Misc. Equipment		8.7		12.6		1.6		6.4	7.1	6.2	70-510	40L-40R	105-180	0.30/0.52	.29/0.56	[illegible].01/0.36
All Other Cockpit		2.1		5.7		3.4		4.7	-1.3	1.1				0.34/0.73(Av)	[illegible].25/0.40(av)	

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TABLE V – Continued

COMPONENT NAME	WITHOUT ABSORBER (W/O) FAILURES	FAILURE RATE (10^{-3})	MMH	MMH/KFH	WITH ABSORBER (W) FAILURES	FAILURE RATE (10^{-3})	MMH	MMH/KFH	Δ-(W/O-W) FAILURE RATE (10^{-3})	MMH/KFH	LOCATION S.T.A.	B.L.	W.L.	G LEVEL WITHOUT ABSORBER	G LEVEL WITH ABSORBER	ΔG (W/O-W)
[illegible]		11.3		24.3		1.5		6.8	9.5	17.5	120	[illegible]	20[illegible]	1.66/1.68	0.45/0.45	1.27/1.23
Inverter		1.2		2.2		0.2		1.0	1.0	1.2	60	102	90	0.33	0.31	0.03
Junction Box		1.4		1.3		0.8		0.5	0.6	0.8	70 - 320	[illegible] 35R	75 - 275	0.20/1.15	0.31/0.40	0.11/0.75
Battery		3.4		10.9		1.9		1.9	1.5	9.0	55	0	170	0.38	0.34	0.04
Circuit Breakers		1.6		5.6		0		0	1.6	5.6	100 - 110	40L - 40R	135 - 180	0.42/0.59	0.33/0.36	0.09/0.23
[illegible]		1.4		4.6		0.8		0.9	0.6	3.7	250	40L	145	0.52	0.33	0.29
[illegible]		[illegible]		9.4		0.8		1.0	1.6	7.4	110	30L	100	0.79	0.30	0.01
Engine Start Relay		2.4		4.9		1.4		0.6	1.0	4.3	120	0	115	0.36	0.29	0.07
All Other Electrical		10.8		17.2		6.0		13.5	4.8	3.7				0.51/1.14(Av)	0.34/0.40(Av)	
[illegible]																
[illegible] Tubes, Lines		10.3		11.2		4.2		4.7	6.1	7.0	115 - 500	80L - 60R	90 - 210	0.27/1.35	0.29/0.56	0.02/0.79
[illegible] Package		5.3		1.9		3.7		4.2	2.1	-2.3	300	30R	190	1.36	0.47	0.89
Pressure Transmitter		5.3		11.2		0.7		1.1	4.6	10.1	300	30R	190	1.36	0.47	0.89
Utility Pump		4.9		23.8		2.1		4.3	2.8	19.5	290	10L	205	1.71	0.59	1.12
[illegible]		3.7		3.1		2.4		1.6	1.3	1.5	310	10R	210	1.79	0.61	1.18
All Other Hydraulic		7.1		24.6		4.0		4.0	3.1	20.6				1.30/1.35(Av)	0.49/0.56(Av)	
[illegible]																
Connectors Plugs		12.85		24.5		9.9		20.3	2.9	4.2	140	[illegible]	180	0.32/0.75	0.22/0.41	0.10/0.34
Cords/Jacks		9.3		22.8		3.4		14.4	5.9	8.4	90,170, [illegible]	[illegible]	10,170, 170, [illegible]	0.32/0.75	0.22/0.41	0.10/0.34
Control Panels		2.5		8.7		4.9		8.1	3.6	0.6	[illegible]	[illegible]	[illegible]	0.34/0.75	0.21/0.75	0.13/0
Set Controls		3.4		6.1		1.6		3.4	1.8	2.7	90	[illegible]	130	0.34	0.21	0.13
All Other ICS		6.5		9.1		2.4		3.5	4.1	5.6				0.33/0.75(Av)	0.22/0.52(Av)	

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TABLE V - Concluded

COMPONENT NAME	WITHOUT ABSORBER (W/O) FAILURES	WITHOUT ABSORBER (W/O) FAILURE RATE (10^{-3})	WITHOUT ABSORBER (W/O) MMH	WITHOUT ABSORBER (W/O) MMH/KFH	WITH ABSORBER (W) FAILURES	WITH ABSORBER (W) FAILURE RATE (10^{-3})	WITH ABSORBER (W) MMH	WITH ABSORBER (W) MMH/KFH	Δ - (W/O-W) FAILURE RATE (10^{-3})	Δ - (W/O-W) MMH/KFH	LOCATION ST.A.	LOCATION B.L.	LOCATION W.L.	G LEVEL WITHOUT ABSORBER	G LEVEL WITH ABSORBER	ΔG (w/o-w)
[illegible]		[illegible]		[illegible]		[illegible]		17.2	[illegible]	[illegible]	110	[illegible]	[illegible]	0.75	[illegible]	[illegible]
[illegible]		14.0		[illegible]		[illegible]		[illegible]	1.9	[illegible]	90	0	90	[illegible]	[illegible]	[illegible]
[illegible] (A[illegible]N-53)		7.1		[illegible]		[illegible]		[illegible]	[illegible]	[illegible]						
[illegible] (AIN-2[illegible])		3.7		[illegible]		4.7		[illegible]	-1.0	-3.5	100	[illegible]	100	0.31	0.31	0
[illegible]		4.0		[illegible]		7.3		28.1	-3.3	-18.9	110	[illegible]	[illegible]	[illegible]	0.29	0.03
[illegible] Instrumentation Unit		3.1		[illegible]		[illegible]		[illegible]	[illegible]	-19.7	90	0	130	[illegible]	[illegible]	[illegible]
[illegible] Other [illegible]		[illegible]		68.[illegible]		8.1		[illegible]	[illegible]	37.0	[illegible]	[illegible]	100	0.[illegible]/0.75 0.34/0.75(Av)	[illegible]/0.5[illegible] [illegible]/0.51(Av)	[illegible]
[illegible]		12.0		46.1		1.0		[illegible]	11.0	44.7	[illegible]-480	[illegible]-35R	125-275	[illegible]/1.30	0.22/0.52	[illegible]
[illegible] Unit		0.8		5.0		5.0		15.3	-4.2	-10.3	[illegible]	40R	135	1.20	0.48	[illegible]
[illegible]		3.4		20.5		0.3		1.6	3.1	18.[illegible]	[illegible]	20R	170	1.20	0.48	[illegible]
[illegible]		2.6		5.5		1.8		5.9	0.8	-0.4	[illegible]	0	[illegible]	[illegible]	0.22	[illegible]
Electrical		8.3		[illegible]		[illegible]		11.9	-1.9	6.7	440, 445, 110	35L, 0, 35R	105, 270, 110	0.67	0.41	[illegible]
														0.74/1.30(Av)	0.36/0.52(Av)	

Minus Sign indicates increase in maintenance or failure rate.

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[illegible]

COMPONENT NAME	WITHOUT ABSORBER (W/O) FAILURES	WITHOUT ABSORBER (W/O) FAILURE RATE (10^{-3})	WITHOUT ABSORBER (W/O) MMH	WITHOUT ABSORBER (W/O) MMH/KFH	WITH ABSORBER (W) FAILURES	WITH ABSORBER (W) FAILURE RATE (10^{-3})	WITH ABSORBER (W) MMH	WITH ABSORBER (W) MMH/KFH	Δ-(W/O-W) FAILURE RATE (10^{-3})	Δ-(W/O-W) MMH/KFH	LOCATION S.T.A.	LOCATION B.L.	LOCATION W.L.	G LEVEL WITHOUT ABSORBER	G LEVEL WITH ABSORBER	ΔG (w/o-w)
Exterior Lights																
Controllable Spotlight	9	1.45	10.6	1.70	7	1.13	6.0	0.97	0.32	0.73	45	0	230	0.33	0.32	0.01
Exterior Lights (Gen.)	10	1.61	27.2	4.37	0	0	0	0	1.61	4.37	45-125	0-95	80-[illegible]	0.40	0.32	0.08
Position Lights	127	16.77	198.8	31.92	22	3.57	[illegible].5	4.29	15.20	[illegible]7.63	410	95	90	0.33	0.07	0.26
Anticollision Light	[illegible]	10.28	[illegible]	[illegible]	13	[illegible]	15.5	2.51	8.27	17.00	[illegible]	0/0	80/[illegible]	0.08/1.9	0.11/0.97	0.0[illegible]/0.93
[illegible] Lights	[illegible]	13.47	[illegible]	[illegible]	2	[illegible]	[illegible]	0.32	13.15	[illegible]	[illegible]	0/6	80/[illegible]	.05/1.9	0.08/0.97	[illegible]/0.93
Anchor Lights	11	1.77	25.2	4.05	10	[illegible]	11.0	1.78	0.15	2.27	[illegible]	0/0	240/23[illegible]	.32/1.9	0.32/0.97	0.0[illegible]/0.93
Float Lights	36	5.78	62.0	9.95	15	2.43	27.0	4.38	3.35	5.57	[illegible]/320	0/70[illegible]	[illegible]/8[illegible]	.36/.06	0.35/0.09	0.01/0.03
Landing Lights	41	6.[illegible]8	[illegible]	19.57	9	1.46	[illegible].0	9.07	5.12	10.50	75	0	55	0.28	0.09	0.19
Control Searchlight	45	7.22	[illegible]	[illegible]0.15	17	2.75	43.6	7.07	4.47	13.08	[illegible]5	0	60	0.29	0.09	0.20
Loading Light	1	0.16	0.5	0.08	0	0	0	0	0.08	0.08	180/550	0/0	180/145	1.3/0.9	0.52/0.58	0.78/0.32
Internal Lights																
Internal Lights General	[illegible]	9.32	[illegible]7.3	[illegible]	9	[illegible]	12.3	[illegible]	7.69	18.45	140-485	[illegible]	145-165	.75/1.02	0.34/0.56	0.41/0.46
Dome Lights	13	2.08	27.1	4.35	0	0	0	0	2.08	4.35	356	0	180	1.27	0.49	0.73
Cockpit Spotlight	14	2.25	39.2	6.29	1	0.16	1.0	0.16	2.09	6.13	120	0	185	0.69	0.36	0.33
Panel Light	96	15.41	[illegible]1.6	[illegible]	27	4.37	41.9	6.78	11.04	[illegible]	70	[illegible]	145	0.44	0.35	0.09
Emergency Exit Light	133	22.16	[illegible]	[illegible]9.41	48	7.79	38.6	6.25	14.37	13.16	30/485	408/[illegible]	160/16[illegible]	.95/1.02	0.38/0.56	0.57/0.46
Signal Light	8	1.28	15.3	2.46	0	0	0	0	1.28	2.46	140	403	160	0.59	0.36	0.23

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TABLE VII. COMPONENT COMPARISON OF RELIABILITY AND CORRECTIVE MAINTENANCE - SWITCHES

COMPONENT NAME	WITHOUT ABSORBER (W/O) FAILURES	FAILURE RATE (10^{-3})	MMH	MMH/KFH	WITH ABSORBER (W) FAILURES	FAILURE RATE (10^{-3})	MMH	MMH/KFH	Δ-(W/O-W) FAILURE RATE (10^{-3})	MMH/KFH	LOCATION STA	BL	WL.	G LEVEL WITHOUT ABSORBER	G LEVEL WITH ABSORBER	ΔG (w/o-w)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] Gear Steering	5	[illegible]	[illegible]	[illegible]	2	[illegible]	[illegible]	.41	[illegible]	0.33	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] Gear Up Limit	7	[illegible]	[illegible]	[illegible]	1	.16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	100	[illegible]	[illegible]	[illegible]
M.L.G. Down Limit	9	1.44	[illegible]	[illegible]	2	[illegible]	[illegible]	.41	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
M.L.G. Lock Limit	17	[illegible]	[illegible]	[illegible]	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
M.L.G. Cylinder Limit	9	1.44	[illegible]	[illegible]	3	[illegible]	[illegible]	3.57	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
M.L.G. Speed	21	3.37	[illegible]	[illegible]	6	.97	11.5	[illegible]	[illegible]	1.20	[illegible]	[illegible]	[illegible]	.62	[illegible]	[illegible]
Auxiliary Servo Cylinder	11	1.77	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5.43	-1.15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.32	[illegible]
Auxiliary Servo Cylinder Pressure	12	1.93	27.3	4.38	2	.32	1.3	.21	1.61	4.17	[illegible]	[illegible]	190	[illegible]	.53	[illegible]
[illegible] Pressure	24	[illegible]	72.1	[illegible]	6	.97	3.8	.62	[illegible]	10.56	[illegible]	[illegible]	[illegible]	[illegible]	.63	[illegible]
[illegible] Pressure	17	2.73	61.3	[illegible]	8	1.29	6.3	1.02	1.44	8.82	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] Thermal	2	.32	15.5	[illegible]	0	0	0	0	[illegible]	[illegible]	470	0	170	[illegible]	[illegible]	[illegible]
[illegible]	1	[illegible]	[illegible]	[illegible]	0	0	0	0	0.16	1.01	470	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] Control	0	0	0	0	1	.16	[illegible]	.65	-0.16	-0.65	470	0	170	[illegible]	.52	[illegible]
Windshield, Anti-Ice	1	.16	20	3.21	2	.32	3.5	.57	-0.16	2.61	110	0	175	[illegible]	.34	[illegible]
[illegible] Anti-Ice	5	.80	14.2	2.28	1	.16	5.0	.81	0.64	1.47	110	0	175	[illegible]	.34	[illegible]
[illegible] Control, Battery	1	.16	2.0	.32	0	.0	0	0	0.16	0.32	[illegible]	0	[illegible]	[illegible]	.35	[illegible]
[illegible]erator	0	0	0	0	1	.16	3	.48	-0.16	-0.48	100	0	175	[illegible]	.35	[illegible]
Inverter	0	0	0	0	0	0	0	0	0	0	100	0	175	[illegible]	.35	[illegible]
External Power	0	0	0	0	0	0	0	0	0	0	100	0	175	[illegible]	.35	[illegible]
Volt Selector	0	0	0	0	0	0	0	0	0	0	100	0	175	[illegible]	.35	[illegible]
Transformer Rectifier	4	.64	3.3	.53	0	0	0	0	0.64	0.53	100	0	175	[illegible]	.35	[illegible]
Fuel Press.	24	3.85	54.0	8.67	2	.32	2.5	.41	3.53	8.35	240	0	[illegible]	1.48	.60	[illegible]
Internal Aux. Fuel Jettison	3	.48	3.0	.48	4	.64	2.0	.32	-0.16	0.16	270	0	160	[illegible]	[illegible]	[illegible]
Aux. Fuel	12	1.93	20.3	3.26	3	.48	3.5	.57	1.45	2.69	110	0	[illegible]	[illegible]	.33	[illegible]
Extinguisher	2	.32	7.0	1.12	1	.16	2.0	.32	0.16	0.80	95	0	175	[illegible]	.35	[illegible]
Windshield Wiper	1	.16	2.0	.32	0	0	0	0	0.16	0.32	100	0	175	.61	.35	0.26
Rescue Hoist, Mode Selector	3	.48	1.4	.22	0	0	0	0	0.48	0.22	100	0	175	.61	.35	0.26
Hoist	13	2.08	22.1	3.55	10	1.62	5.9	.96	0.46	2.59	130	20R	175	.68	.38	0.30
[illegible] Test	8	1.28	9.2	1.48	13	2.11	8.1	1.31	-0.20	0.37	180	40R	175	.74	.37	0.37
Free Wheel	2	.32	[illegible]	[illegible]	1	.16	[illegible]	.65	0.16	-0.46	100	0	175	.61	.35	[illegible]

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TABLE VII-Concluded

COMPONENT NAME	WITHOUT ABSORBER (W/O)				WITH ABSORBER (W)				Δ - (W/O-W)		LOCATION			G LEVEL WITHOUT ABSORBER	G LEVEL WITH ABSORBER	ΔG (w/o-w)
	FAILURES	FAILURE RATE (10^{-3})	MMH	MMH/KFH	FAILURES	FAILURE RATE (10^{-3})	MMH	MMH/KFH	FAILURE RATE (10^{-3})	MMH/KFH	S.T.A.	B.L.	W.L.			
[illegible]	1	.16	0.5	.09	0	[illegible]	0	0	0.16	0.08	100	0	175	.61	.35	0.26
Cargo	1	.16	2.5	.40	0	0	0	0	0.16	0.40	100	0	175	.61	.35	0.26
	240	49.49		108.47		16.62		25.39								

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TABLE VIII. [illegible] COMPARISON OF RELIABILITY AND CORRECTIVE MAINTENANCE - [illegible]/WIRING

COMPONENT NAME	WITHOUT ABSORBER (W/O) FAILURES	WITHOUT ABSORBER (W/O) FAILURE RATE (10^{-3})	WITHOUT ABSORBER (W/O) MMH	WITHOUT ABSORBER (W/O) MMH/KFH	WITH ABSORBER (W) FAILURES	WITH ABSORBER (W) FAILURE RATE (10^{-3})	WITH ABSORBER (W) MMH	WITH ABSORBER (W) MMH/KFH	Δ-(W/O-W) FAILURE RATE (10^{-3})	Δ-(W/O-W) MMH/KFH	LOCATION S.T.A.	LOCATION B.L.	LOCATION W.L.	G LEVEL WITHOUT ABSORBER	G LEVEL WITH ABSORBER	ΔG (w/o-w)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.19/1.13	0.49/0.49	[illegible]
[illegible]	17	[illegible]	[illegible]	7.10	2	.32	1.8	[illegible]	2.41	7.39	330	[illegible]	165	1.36	0.51	0.87
[illegible]	[illegible]	[illegible]	[illegible]	4.13	0	0	0	0	[illegible]	4.13	[illegible]	0	165	[illegible]	0.29	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4	[illegible]	5.5	[illegible]	0.80	0.30	110	252	110	.32	0.28	0.04
[illegible]	1	.16	0.5	.08	0	0	0	0	0.16	0.08	170	252	140	.49	0.31	0.18
[illegible]	1	.16	0.2	.03	1	.16	1.0	.16	0	-0.13	270	358	[illegible]	1.14	0.43	0.71
[illegible]	4	[illegible]	20.4	[illegible]	1	.16	9.0	1.46	0.48	3.12	270	311	180	1.14	0.43	0.71
[illegible]	[illegible]	.48	2.7	.43	2	.32	4.0	.65	0.16	0.12	85	0	[illegible]	0.26	0.32	-0.06
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12	1.94	19.0	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]	0.26	0.32	-0.06
[illegible]	0	[illegible]	[illegible]	[illegible]	61	9.88	[illegible]	[illegible]	[illegible]	[illegible]	140	354	[illegible]	0.75	0.41	0.34
[illegible]	[illegible]	[illegible]	13.5	2.17	1	.16	1.0	.16	0.80	2.01	[illegible]	0	110	0.73	0.32	0.41
[illegible]	4	[illegible]	15.5	2.48	4	.65	4.0	.65	-0.01	1.83	100	354	100	0.30	0.29	0.01
[illegible]	6	.96	9.0	1.45	5	.81	6.5	1.05	0.15	0.40	270	254	200	1.15	0.43	0.72
[illegible]	[illegible]	.64	2.8	.45	[illegible]	.81	11.5	1.86	-0.17	1.41	100	254	160	0.31	0.31	0
[illegible]	4	.64	37.1	[illegible]	3	.49	6.5	1.79	0.15	4.58	130	102	170	0.75	0.35	0.40
[illegible]	7	1.12	15.0	[illegible]	7	1.13	[illegible]	[illegible]	-0.01	-0.70	[illegible]	0	[illegible]	0.22	0.29	-0.07
[illegible]	11	1.77	14.4	2.34	3	.49	[illegible]	.41	1.28	1.83	100	0	100	0.32	0.29	0.03
[illegible]	5	[illegible]	[illegible]	[illegible]	2	.32	10.0	1.62	.96	4.30	110	[illegible]	100	0.32	0.29	0.03

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TABLE IX. COMPONENT COMPARISON OF RELIABILITY AND CORRECTIVE MAINTENANCE - HOSES/LINES

COMPONENT NAME	WITHOUT ABSORBER (W/O)				WITH ABSORBER (W)				Δ - (W/O-W)		LOCATION			G LEVEL WITHOUT ABSORBER	G LEVEL WITH ABSORBER	ΔG (W/O-W)
	FAILURES	FAILURE RATE (10^{-3})	MMH	MMH/KFH	FAILURES	FAILURE RATE (10^{-3})	MMH	MMH/KFH	FAILURE RATE (10^{-3})	MMH/KFH	S.T.A.	B.L.	W.L.			
[illegible] Flex Hose	4	.67	6.2	.96	0	0	0	0	0.67	0.96	440	[illegible]LR	95	.28/.34	0.17/0.23	0.11/0.11
Aft [illegible]	77	[illegible]	[illegible]	42.00	21	3.40	57.5	9.32	8.96	32.68	505	35LR	125	1.02	0.56	0.46
Landing Gear [illegible]	57	9.15	[illegible]	29.46	21	3.4	43.0	7.11	6.11	22.35	270	0R	200	1.11	0.54	0.57
Landing Gear Actuating (A)	52	8.35	55.1	8.85	23	3.73	21.5	3.48	4.52	5.37	330	10LR	85	.22/.23	.14/.21	0.08/0.02
[illegible] Gear Actuating	10	1.61	7.4	1.19	5	.81	4.5	.73	0.80	0.46	330	10LR	85	.22/.23	.14/.21	0.08/0.02
Landing Gear Misc. Line	28	4.49	32.5	5.22	1	.16	1.0	.16	4.33	5.05	330	50LR	85	.22/.23	.14/.21	0.08/0.02
Landing Gear Misc. Flex. Hose	8	1.28	5.1	.82	0	0	0	0	1.28	0.82	330 160	10LR	85	.22/.23	.14/.21	0.08/0.02
Primary Servo Flex Hose	43	6.90	81.9	13.15	6	.97	5.0	.81	5.93	12.34	280 260	10LR	205	1.56/1.72	0.57/0.56	0.99/1.16
Primary Servo Line	42	6.74	57.9	9.30	18	2.92	13.0	2.11	3.82	7.19	280 260	10LR	205	1.56/1.72	0.57/0.56	0.99/1.16
Main Rotor Head Flex Hose	0	0	0	0	17	2.75	14.0	2.27	-2.75	-2.27	285 255	15LR	235	2.03	0.69	1.34
Engine Front Frame Hose	3	.48	8.0	1.28	0	0	0	0	0.48	1.28	185 225	15LR	200	1.83	0.54	1.29
[illegible] Misc. Line	34	5.46	56.4	9.06	4	.65	9.5	1.46	4.81	7.60	185 225	15LR	200	1.83	0.54	1.29
Aft Line	33	5.29	64.5	10.36	20	3.24	21.0	3.40	2.05	6.96	330	10L	195	1.39	0.49	0.90
Aft Flex Hose	13	2.09	16.8	2.69	13	2.11	10.5	1.70	-0.02	0.99	330	10L	195	1.39	0.49	0.90

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Table [illegible] - Continued

COMPONENT NAME	WITHOUT ABSORBER (W/O) FAILURES	WITHOUT ABSORBER (W/O) FAILURE RATE (10^{-3})	WITHOUT ABSORBER (W/O) MMH	WITHOUT ABSORBER (W/O) MMH/KFH	WITH ABSORBER (W) FAILURES	WITH ABSORBER (W) FAILURE RATE (10^{-3})	WITH ABSORBER (W) MMH	WITH ABSORBER (W) MMH/KFH	Δ-(W/O-W) FAILURE RATE (10^{-3})	Δ-(W/O-W) MMH/KFH	LOCATION S.T.A.	LOCATION B.L.	LOCATION W.L.	G LEVEL WITHOUT ABSORBER	G LEVEL WITH ABSORBER	ΔG (W/O-W)
[illegible] Fuel & Air	8	[illegible]	8.2	2.32	0	0	0	0	1.28	1.32	330	10L	195	1.39	0.49	0.90
[illegible] Line	124	19.91	[illegible].8	3[illegible].61	45	7.29	50.0	8.10	11.62	28.79	250 290	15L	195	1.49	0.52	0.97
[illegible] Flex Hose	50	8.03	[illegible].3	30.56	18	2.92	79.0	12.30	5.11	17.76	250 290	15L	195	1.49	0.52	0.97
[illegible] Cooler Hose	27	4.34	[illegible]	10.26	1	.16	2.0	.32	4.18	9.94	330	0	200	1.72	0.55	1.17
[illegible] Water Tube	3	.48	7.4	1.20	1	.16	0.5	.08	0.32	1.12	70	15LR	145	0.45	0.33	0.12
Hydraulic Power External Coupling	13	2.09	18.0	2.89	3	.49	1.0	.16	1.60	2.73	295	0	190	1.64	0.53	1.11
Utility Hydraulic Flex Hose	[illegible]	13.51	115.[illegible]	13.49	3[illegible]	5.19	44.5	7.21	8.62	11.28	305	1CR	200	1.82	0.58	1.2[illegible]
Utility Hydraulic Tube	65	10.44	2[illegible].4	37.43	16	2.59	13.5	2.19	7.85	37.24	305	1CL	200	1.82	0.58	1.24
Fuel Line	43	6.93	79.8	1[illegible].31	13	1.62	9.1	1.47	5.28	12.81	200 235	40LR	110 200	.37/1.35	0.26/.52	0.11/0.73
Fuel Flex Hose	7	1.12	6.5	1.04	5	.81	2.0	.32	0.31	0.72	200 235	40LR	110 200	.37/1.35	0.26/.52	0.11/0.73
Aux. Fuel Flex Line (Internal)	2	.32	1.6	.26	0	0	0	0	0.32	0.26	200 339	35LR	130	.59	0.34	0.25
Aux. Fuel Flex Line (External)	3	1.28	8.0	1.33	0	0	0	0	1.28	1.38	300	90LR	100	.37	0.14	0.13
Aux. Fuel Tube (External)	4	.64	9.5	1.45	0	0	0	0	0.64	1.45	300	90LR	100	.37	0.14	0.1[illegible]
[illegible] - Hose	12	1.93	23.0	3.84	5	.81	7.5	2.21	1.12	2.03	160	40R	95	.25	0.16	0.09
[illegible] - Tube	4	.64	3.7	.59	3	.49	1.6	.26	0.23	0.33	160	40R	95	.25	0.16	0.09
[illegible] Quick Disconnect	2	.32	4.5	.72	0	0	0	0	0.32	0.72	160	40R	95	.25	0.16	0.09

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TABLE IX - Concluded

COMPONENT NAME	WITHOUT ABSORBER (W/O)				WITH ABSORBER (W)			
	FAILURES	FAILURE RATE (10^{-3})	MMH	MMH/KFH	FAILURES	FAILURE RATE (10^{-3})	MMH	MMH/KFH
Fuel Quick Disconnect	2	.32	8.0	1.28	1	.16	0.5	.08
Vent Tube	6	.96	5.8	.93	0	0	0	0
Sump Tube	2	.32	0.3	.05	1	.16	0.5	.08
Extinguishing Tank	58	9.31	79.9	12.83	10	1.62	8.5	1.38
Extinguishing Flex Hose	15	2.41	27.1	4.34	2	.32	0.9	.36
Rescue Hoist Line	8	1.28	9.7	1.56	2	.32	1.5	.24
Rescue Hoist Tube	16	2.57	27.6	4.43	3	.49	2.0	.32
Windshield Wash Hose	2	.32	6.0	.96	0	0	0	0

COMPONENT NAME	Δ - (W/O-W)		LOCATION			G LEVEL WITHOUT ABSORBER	G LEVEL WITH ABSORBER	ΔG (W/O-W)
	FAILURE RATE (10^{-3})	MMH/KFH	STA.	B.L.	W.L.			
Fuel Quick Disconnect	0.16	1.20	160	40R	95	.25	0.16	0.09
Vent Tube	0.96	0.93	235 250	40LR	130	.34/1.32	0.22/.44	0.12/ 0.73
Sump Tube	0.16	-0.03	370	80LR	90	.21/.22	.16/.20	0.05/ 0.0
Extinguishing Tank	7.69	10.45	220 310	0	200 220	1.53/1.78	0.57/0.66	0.96/ 1.12
Extinguishing Flex Hose	2.09	3.98	220 310	0	200 220	1.53/1.76	0.57/0.66	0.96/ 1.12
Rescue Hoist Line	0.96	1.32	210	40R	170	.78	0.29	0.49
Rescue Hoist Tube	2.08	4.11	210	40R	170	.78	0.29	0.49
Windshield Wash Hose	0.32	0.96	65	20LR	145	.43	0.31	0.12

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[illegible]

COMPONENT NAME	WITHOUT ABSORBER (W/O)				WITH ABSORBER (W)				Δ - (W/O-W)		LOCATION			G LEVEL WITHOUT ABSORBER	G LEVEL WITH ABSORBER	ΔG (w/o-w)
	FAILURES	FAILURE RATE (10^{-3})	MMH	MMH/KFH	FAILURES	FAILURE RATE (10^{-3})	MMH	MMH/KFH	FAILURE RATE (10^{-3})	MMH/KFH	S.T.A.	B.L.	W.L.			
[illegible] Control	[illegible]	[illegible]	[illegible]	4.09	[illegible]	1.08	19.8	3.21	0.45	0.97	[illegible]	40R	140	0.58	0.32	0.26
Pump Relief	0	0	0	0	1	.16	2.0	0.32	-0.16	-0.32	430	40R	160	0.83	0.39	0.44
Pump Shuttle	1	.16	[illegible]	.03	0	0	0	0	0.16	0.03	395	40R	140	0.58	0.32	0.26
Pump Shutoff	1	.16	2.0	.32	0	0	0	0	0.16	0.32	430	40R	160	0.83	0.39	0.44
Nose Gear Accumulator Emergency Release	[illegible]	[illegible]	[illegible]	4.10	2	.32	1.5	0.24	0.64	2.84	320	13L	195	1.21	0.53	0.68
N.L.G. [illegible] Lock	[illegible]	[illegible]	[illegible]	4.93	3	.48	18.0	2.92	0.32	2.01	120	0	120	0.41	0.30	0.11
N.L.G. [illegible]	[illegible]	1.28	27.8	4.46	1	.16	2.0	0.32	1.12	4.14	120	0	110	0.34	0.28	0.06
N.L.G. Shuttle	[illegible]	1.45	40.0	[illegible]	1	.16	0.5	0.08	1.29	6.34	120	0	110	0.34	0.28	0.06
M.L.G. Emergency Release	7	1.12	22.5	3.61	1	.16	1.0	0.16	0.96	3.45	320	13L	195	1.21	0.53	0.68
N.L.G. Thermal Relief	1	.16	4.0	.64	1	.16	4.0	0.64	0	0	120	0	110	0.34	0.28	0.06
N.L.G. Steering Control	[illegible]	10.28	[illegible]	[illegible]	[illegible]	1.94	46.0	7.45	8.34	37.52	270	20R	190	1.34	0.47	0.50
M.L.G. [illegible] Brake	7	1.12	[illegible]	13.29	7	1.13	37.0	5.99	-0.01	4.09	70	[illegible]	115	0.34/0.3[illegible]	0.32/0.33	0.0[illegible]/[illegible].02
M.L.G. Mixer	13	[illegible]	[illegible]	5.75	0	0	0	0	1.60	5.75	265	16R	185	1.33	0.53	0.80
M.L.G. Emergency Release	1	.16	9.0	1.45	2	.32	1.15	0.24	-0.16	1.21	265	16R	185	1:33	0.53	0.80
M.L.G. Emergency Air Release	1	.16	[illegible]	.10	1	.32	0.5	0.08	-0.16	0.02	240	20R	190	1.25	0.48	0.77
Brake Sleet	12	1.93	71.7	11.[illegible]	3	.48	28.0	4.54	1.45	u.97	340	50L,R	70	0.28/0.3[illegible]	.18/.20	0.10/[illegible].27
Primary Control Shutoff	[illegible]	[illegible]	[illegible].8	[illegible].57	0	0	0	0	0.5[illegible]	1.57	310	16R	200	1.66	0.57	1.2[illegible]
Primary Control Check	[illegible]	[illegible]	[illegible]	[illegible]	0	0	0	0	4.98	12.86	310	10R	200	1.66	0.57	1.[illegible]
[illegible] Relief	[illegible]	[illegible]	[illegible]	[illegible]	1	.16	2.0	.3[illegible]	-0.16	-0.32	210	30L,R	200	1.48/1.4[illegible]	0.46/0.47	1.0[illegible]/[illegible].94
[illegible] Inlet	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.32	1.0	.16	4.50	3.82	210	[illegible]L,R	200	1.48,1.4[illegible]	0.48/0.47	1.0[illegible]/[illegible].94
[illegible]	6	[illegible]	[illegible]	[illegible]	2	.32	1.0	.16	0.64	0.93	210	[illegible]L,R	[illegible]00	1.48/1.4[illegible]	0.46/0.47	1.0[illegible]/[illegible].94
A.C. Shutoff	[illegible]	1.28	[illegible]	[illegible]	1	.16	2.0	.32	1.12	1.67	28[illegible]	40L	115	0.44	0.2[illegible]	0.2[illegible]
[illegible] Air Starter	[illegible]	[illegible]	[illegible].5	[illegible]	0	.97	4.0	.65	-0.65	0.03	310	[illegible]0L	200	1.56	0.[illegible]2	1.04
[illegible] Drain	[illegible]	[illegible]	1.4	[illegible]	1	.16	6.0	.97	0.32	0.75	270	0	200	1.59	0.59	1.00
[illegible]	1	.16	[illegible]	[illegible]	0	0	0	0	0.16	0.58	270	0	200	1.59	0.59	1.00
[illegible] Relief	[illegible]	[illegible]	7.4	[illegible]	2	.32	2	.32	0.64	0.87	270	0	200	1.59	0.59	1.00
[illegible] Thermal Relief	[illegible]	[illegible]	[illegible]	[illegible]	0	0	0	0	0.32	1.61	310	0	200	1.73	0.52	1.21
[illegible] Fuel	[illegible]	1.28	7.1	1.17	1	.16	0.5	.08	1.12	1.09	170	40L	200	0.24	0.23	0.01
Water Solenoid	7	1.12	5.2	.83	7	1.13	7.1	1.15	-0.01	-0.32	400	10L	170	0.67	0.41	0.26
A.C. Air Inlet Check	0	0	0	0	3	.49	43.0	6.97	-0.49	-6.97	510	15R	170	1.02	0.56	0.46
[illegible] Effect	[illegible]	1.93	15.1	[illegible]	3	.49	2.5	.41	1.44	2.50	2[illegible]0	0	190	1.[illegible]3	0.52	[illegible].71

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COMPONENT NAME	WITHOUT ABSORBER (W/O) FAILURES	WITHOUT ABSORBER (W/O) FAILURE RATE (10^{-3})	WITHOUT ABSORBER (W/O) MMH	WITHOUT ABSORBER (W/O) MMH/KFH	WITH ABSORBER (W) FAILURES	WITH ABSORBER (W) FAILURE RATE (10^{-3})	WITH ABSORBER (W) MMH	WITH ABSORBER (W) MMH/KFH	Δ - (W/O-W) FAILURE RATE (10^{-3})	Δ - (W/O-W) MMH/KFH	LOCATION ST.A	LOCATION BL	LOCATION W.L.	G LEVEL WITHOUT ABSORBER	G LEVEL WITH ABSORBER	ΔG (W/O-W)
[illegible] Flex Hose	4	.67	[illegible]	.96	0	0	0	0	0.67	0.96	440	[illegible]	95	.28/.34	0.17/0.23	.11/.11
Aft [illegible] Uplock	77	[illegible]	[illegible]	[illegible]	21	3.40	57.5	9.32	8.96	32.08	[illegible]	15LR	125	[illegible].02	0.56	[illegible].46
Landing Gear Kneeling	57	[illegible]	[illegible]	29.46	21	3.4	43.9	7.11	6.11	22.35	470	[illegible]	200	1.11	0.54	[illegible].57
Landing Gear Actuating (A)	52	[illegible]	[illegible]	8.85	23	3.73	[illegible]	3.48	4.52	5.37	330	[illegible]	85	.22/.23	.14/.21	0.08/0.02
Landing Gear Actuating	33	[illegible]	7.4	1.13	5	[illegible]	4.5	.73	0.80	0.46	430	[illegible]	85	.22/.23	.14/.21	[illegible]
Landing Gear Misc. Line	23	[illegible]	[illegible]	5.22	1	.16	1.0	.16	4.33	5.05	330	[illegible]	85	.22/.23	.14/.21	0.08/0.02
Landing Gear Misc. Flex. Hose	8	1.28	5.1	.82	0	0	0	0	1.28	0.82	[illegible]	[illegible]	85	.22/.23	.14/.21	0.08/0.02
Primary Servo Flex Hose	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5.0	[illegible]	5.93	17.34	[illegible]	[illegible]	205	[illegible]/1.72	0.57/0.56	[illegible]
Primary Servo Line	[illegible]	[illegible]	57.9	[illegible]	18	[illegible]	13.0	2.11	3.82	7.19	[illegible]	[illegible]	205	1.50/1.72	0 57/0.56	[illegible]/1.16
Main Rotor Head Flex Hose	0	0	0	0	17	2.75	14.0	2.27	-2.75	-2.27	285 255	15LR	235	[illegible].03	0.69	[illegible].34
[illegible] Front Frame Hose	3	.43	[illegible]	1.28	0	0	0	0	3.48	[illegible]	[illegible]	15LR	[illegible]	1.83	0.54	1.29
Engine Misc. Line	34	[illegible]	[illegible]	9.06	4	.65	9.5	1.46	4.81	7.60	[illegible]	15LR	200	1.83	0.54	1.29
A-J Line	33	5.29	64.5	10.36	20	3.24	21.0	3.40	2.05	[illegible]	330	[illegible]	195	1.39	0.49	0.90
AFT [illegible] Hose	13	[illegible]	16.8	2.69	13	2.11	10.5	1.70	-0.02	0.99	330	[illegible]	195	1.39	0.49	0.90

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TABLE [illegible] - Concluded

COMPONENT NAME	WITHOUT ABSORBER (W/O)				WITH ABSORBER (W)				Δ - (W/O-W)		LOCATION			G LEVEL WITHOUT ABSORBER	G LEVEL WITH ABSORBER	ΔG (w/o-w)
	FAILURES	FAILURE RATE (10^{-3})	MMH	MMH/KFH	FAILURES	FAILURE RATE (10^{-3})	MMH	MMH/KFH	FAILURE RATE (10^{-3})	MMH/KFH	S.T.A.	B.L.	W.L.			
[illegible] Shutoff	41	[illegible]	[illegible]	19.17	5	.81	[illegible]	5.54	5.77	13.63	[illegible]	0	90	0.27	0.24	.03
[illegible]	4	.64	7.5	[illegible]	0	0	0	0	0.64	1.20	210	408	90	0.26	0.18	0.08
[illegible] Drain	10	[illegible]	[illegible]	3.61	0	0	0	0	1.61	3.61	[illegible]	[illegible]	80	0.22	0.17	0.05
Fuel Check	3	.48	2.4	.38	0	0	0	0	0.48	0.38	250	0	105	.38	.21	.17
Flap	2	.32	5.0	.60	0	0	0	0	0.32	0.60	250	0	80	.66	.12	[illegible]
Manual Gate	1	.16	1.5	.24	0	0	0	0	0.16	0.24	[illegible]	408	115	.33	.20	[illegible]
[illegible] Panel	[illegible]	[illegible]	[illegible]	2.05	0	0	0	0	[illegible]	2.05	[illegible] 270	0	90	.17	.24	-0.07
[illegible] Shutoff	3	[illegible]	[illegible]	15.56	0	0	0	0	[illegible]	15.56	250	[illegible]	[illegible]	.34	.26	0.08
Auxiliary Shutoff	4	.64	14.2	[illegible]	1	.16	5.0	.81	0.48	2.12	[illegible]	0	150	.69	.37	[illegible]
[illegible]	1	.16	8.0	1.28	0	0	0	0	0.16	1.28	225	0	90	.15	.15	0
Bleed Selector	22	1.93	52.1	8.37	2	[illegible]	1	.16	1.31	8.05	240	0	200	1.29	[illegible]	0.65
		[illegible]		[illegible]		[illegible]		[illegible]								

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[illegible] - RELAYS

COMPONENT NAME	WITHOUT ABSORBER (W/O) FAILURES	WITHOUT ABSORBER (W/O) FAILURE RATE (10^{-3})	WITHOUT ABSORBER (W/O) MMH	WITHOUT ABSORBER (W/O) MMH/KFH	WITH ABSORBER (W) FAILURES	WITH ABSORBER (W) FAILURE RATE (10^{-3})	WITH ABSORBER (W) MMH	WITH ABSORBER (W) MMH/KFH	Δ - (W/O-W) FAILURE RATE (10^{-3})	Δ - (W/O-W) MMH/KFH	LOCATION S.T.A	LOCATION B.L.	LOCATION W.L.	G LEVEL WITHOUT ABSORBER	G LEVEL WITH ABSORBER	ΔG (w/o-w)
[illegible] Anti-ice Relay	[illegible]	[illegible]	[illegible]	3.45	2	[illegible]	1.5	[illegible]	[illegible]	3.21	[illegible]	30L	170	0.61	0.34	0.27
[illegible] Anti-Ice Control Relay	9	1.45	38.2	6.13	2	0.32	3.0	0.49	1.13	5.64	100	0	185	0.66	0.36	0.30
[illegible] Current Relay	13	2.09	54.2	8.70	16	2.59	41.3	6.69	-0.50	2.01	75	35L	190	0.31	0.29	0.02
Engine Start Relay	15	2.41	38.9	6.22	9	1.45	26.6	4.31	0.96	1.91	70	35LR	110	0.32	0.28	0.04
[illegible] Contactor	5	.80	8.5	1.36	0	0	0	0	0.80	1.36	7[illegible]	[illegible]	110	0.32	0.28	0.04
[illegible]	[illegible]	.96	9.7	1.55	0	0	0	0	0.96	1.55	125	30L	170	0.61	0.34	0.27
[illegible]	7	1.12	22.[illegible]	3.51	1	.16	1.0	.16	0.96	3.35	120	30L	170	0.61	0.34	0.27
[illegible] Reset Relay	1	.16	15.8	2.53	0	0	0	0	0.16	2.53	115	10L	100	0.26	0.29	0.03
[illegible] Power Relay	30	4.82	40.9	6.56	0	0	0	0	4.82	6.56	120	30L	170	0.61	0.34	0.27
AN-25 Relay	6	.96	10.9	1.75	0	0	0	0	0.96	1.75	130	35L	125	0.12	0.31	0.11
		15.42		41.79		4.84		11.69								

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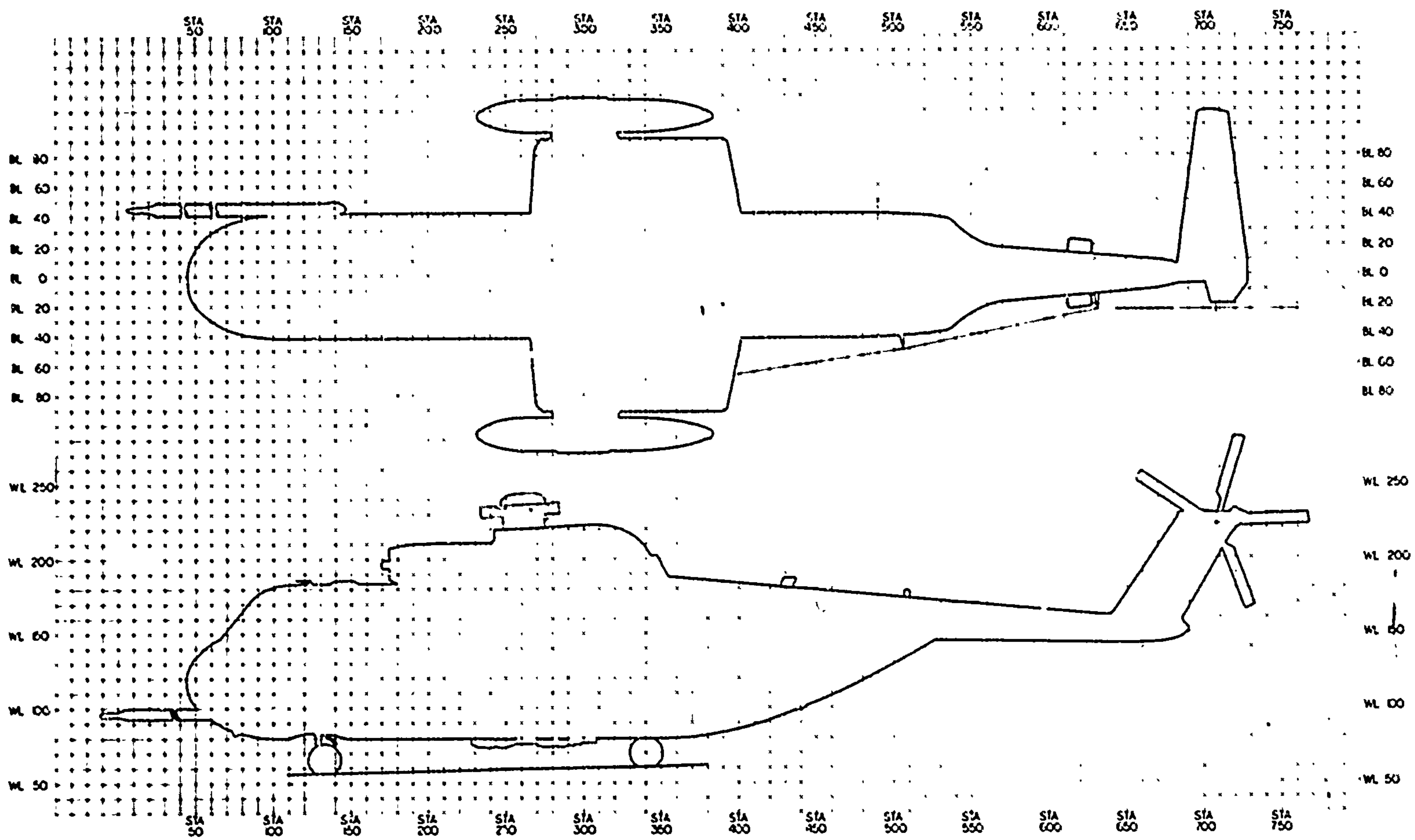


Figure 15. Location Grid for CH-3 Aircraft Components.

The data samples were also sorted by aircraft tail number, and the total average failure rate per aircraft and total maintenance man-hours per flight hour per aircraft were established. The purpose of this procedure was to determine if any unusual differences in reliability or maintainability existed between each aircraft within a group as might be caused by variation in local maintenance policy, record keeping, extent of maintenance facilities, or for any of numerous reasons. The aircraft totals are given in Tables XII and XIII. The one apparent difference was indicated on two absorber-equipped aircraft located in Thule, Greenland (Tail Numbers 69-5798 and 69-5799). The data indicated that there were no part removals charged against these aircraft. However, the data on these aircraft were compared to the other aircraft in the group with the part removal data suppressed (on-aircraft actions only) on the remaining aircraft in an attempt to show equivalent types of data for each aircraft within the group. Total reliability and maintainability were compared on the remaining 13 aircraft in the group and are also shown in Table XIII.

Using the values given in Tables XII and XIII, the mean values were calculated and are presented in Table XIV. Histograms were developed from the tabulated values in Tables XII and XIII and are presented in Figures 35 and 36. From these histograms the 50 percentile and modal values were developed as presented in Table XIV. These parameters, when compared for the differences in the average failure rate and maintenance man-hours per flight hour between each aircraft group, indicate a change in λ and MMH/KFH which is considered to be more than a coincidence resulting from the variation cited earlier and could only be explained by the changed vibration characteristic on the H-3 aircraft. Variations existing between like aircraft at different locations under different geological and climatic conditions, etc., are fairly sizable, but are small compared to the differences between the means of the two fleets, when sample size is considered. It is concluded, then that differences in R&M history are caused by the differences in vibration levels existing between the two groups of aircraft.

The initial intent of the study was to consider the effect of vibration reduction on reliability and corrective maintenance. The AFM 66-1 data also contained information related to the preventive maintenance performed on the aircraft. Since the data were readily available, the study was expanded to separate out the unit codes for preflight, postflight, periodic and special inspections; see Table XV. The information displayed in Table XV shows an increase in the frequency and the maintenance man-hours for preflight inspections and an increase in the maintenance man-hours expended for postflight inspection for the aircraft equipped with vibration absorber. This observation is not consistent with the previous discussion related to corrective maintenance. However, these data represent only the "look" phase of an inspection and not the "fix" phase. That is, any corrective maintenance is chargeable and charged to the work unit code of the component or subsystem that has failed. Indeed, the corrective maintenance data show that there are fewer failed items on the absorber-equipped aircraft, and therefore the additional inspections that are performed or the increased manpower can not be the result of chronic problems with the group of aircraft where the additional inspections are performed as a form

TABLE XII. INDIVIDUAL AIRCRAFT λ AND MMH/KFH - WITHOUT ABSORBER

Serial Number	Flight Hours	On-Aircraft Actions Only				Total			
		Fails	Fails/1000H	MMH	MMH/1000H	Fails	Fails/1000H	MMH	MMH/1000H
66-13284	525	802	1527.6	2474.6	4713.5	896	1706.6	2898.8	5521.5
-13285	530	537	1013.2	956.5	1804.7	586	1105.6	1125.1	2122.8
66-13286	557	1047	1879.7	2959.6	5313.4	1144	2053.8	3415.8	6132.4
67-14705	520	618	1188.4	1463.3	2814.0	696	1338.4	1934.3	3719.8
-14707	595	177	297.4	629.7	1058.3	192	322.6	779.7	1310.4
-14711	684	742	1084.7	1949.4	2850.0	816	1192.9	2363.8	3455.8
-14713	725	804	1108.9	2021.3	2788.0	913	1259.3	2502.5	3451.7
-14714	559	704	1259.3	1722.8	3081.9	778	1391.7	2105.6	3766.7
-14715	116	167	1439.6	501.1	4319.8	179	1543.1	530.6	4574.1
-14716	125	140	1120.0	423.0	3384.0	162	1296.0	488.5	3908.0
-14717	126	143	1134.9	448.7	3561.1	158	1253.9	495.5	3932.5
-14719	425	469	1103.5	905.4	2130.3	528	1242.3	1145.0	2694.1
-14720	476	106	222.6	429.2	901.6	115	241.5	598.2	1256.7
-14723	180	507	2816.6	1148.7	6381.6	519	2883.3	1209.2	6717.7
67-14724	85	402	4729.4	1151.6	13548.2	421	4952.9	1196.8	14080.0
Total	6228	7365	21925.8	19184.9	58650.4	8103	23720.9	22789.4	66644.2

TABLE XIII. INDIVIDUAL AIRCRAFT λ AND MMH/KFH - WITH ABSORBER

Serial Number	Flight Hours	On-Aircraft Actions Only: Fails	Fails/1000H	MMH	MMH/1000H	Total: Fails	Fails/1000H	MMH	MMH/1000H
69-5798	490	97	197.9	557.3	113.7				
-5799	510	88	172.5	452.6	887.4				
5800	511	280	547.9	1142.1	2235	345	675.1	1533.9	30001.7
-5801	550	407	740	1065.9	1938	461	838.1	1285.4	2337
-5802	445	334	750.5	941.8	2116.4	392	880.9	1222.1	2746.2
-5803	405	235	580.2	883.8	2182.2	283	698.7	1103.0	2723.4
-5804	500	321	642	786.8	1573.6	367	734	943.4	1886.8
-5805	495	336	678.7	866.3	1750	387	781.8	1195.4	2414.9
-5806	450	295	655.5	783.4	1740.8	333	740	998.7	2219.3
-5807	415	292	703.6	703.1	1694.2	331	797.5	964.4	2323.8
-5808	335	169	504.4	490.8	1465	213	635.8	704.9	2104.1
-5809	345	221	640	699.7	2028.1	256	742	816.5	2497.1
-5810	300	148	493.3	368.4	1228	166	553.3	429.6	1432
-5811	230	210	913	552.4	2401.7	244	1060.8	652.2	2835.6
69-5812	190	108	568.4	302.7	1593.1	124	652.6	377.2	1985.2
*	6171	3541	8787.9	10597.1	24941.2	3902	9790.6	12271.7	30507.1
**	5171	3356	8417.5	9587.2	23946.1				

* With A/C 69-5798 and 69-5799

** Without A/C 69-5798 and 69-5799

TABLE XIV. COMPARISON OF AIRCRAFT λ AND MMH/KFH BY POPULATION GROUP - ON AIRCRAFT ACTION ONLY

	Failures Per 1000 Hr		MMH/1000 Flight Hr	
	Without Absorber	With Absorber	Without Absorber	With Absorber
Arithmetic Mean	1462	586	3910	1663
50 Percentile	1150	600	2750	1750
Mode	1150	600	2750	1575

Arithmetic Mean: Equal to sum of the values for the individual aircraft divided by the number of aircraft.

50 Percentile: Median Value - the middle value for the 15 aircraft.

Mode: Value occurring most frequently.

TABLE XV. COMPARISON OF SCHEDULED MAINTENANCE ACTIONS AND MAINTENANCE MAN-HOURS

	Without Absorber				With Absorber						% Change	
Insp.	Actions	B* (10^{-3})	MMH	MMH/FH (10^{-3})	Actions	B* (10^{-3})	MMH	MMH/FH (10^{-3})	B (10^{-3})	MMH/FH (10^{-3})	B	MMH/KFH
Preflt.	1782	286.0	9573.0	1536.5	2141	349.9	10880.8	1763.2	-60.9	-226.7	-21.2	-14.7
Pstflt.	1666	267.4	6965.1	1117.9	1143	185.2	10351.4	1677.4	82.2	-559.5	30.8	-50.0
Per.	230	36.6	11421.3	1833.8	49	7.9	3791.7	614.4	28.7	1219.4	78.5	66.5
Spec.	2601	417.6	7850.7	1260.5	2223	360.2	4078.5	660.9	57.4	599.6	13.8	47.6
Total	6279	10007.6	35810.1	5748.7	5556	900.2	29102.4	4715.9	107.4	1032.8	10.7	18.0

* B = Inspections per 1000 flight hours
Minus sign indicates an increase in rate

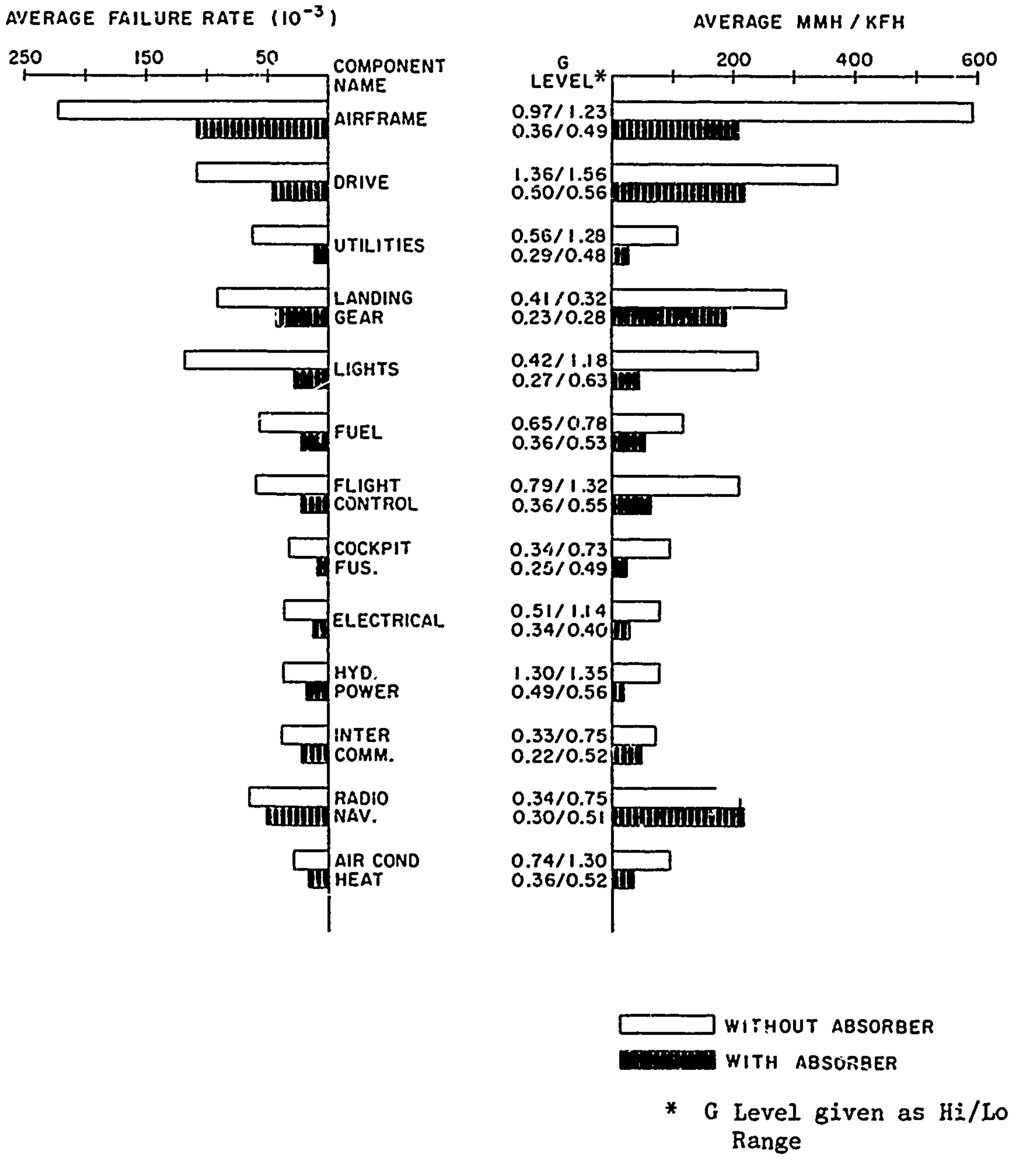


Figure 16. Comparison of Total Average Failure Rate and MMH/KFH for Top 13 Aircraft Subsystems.

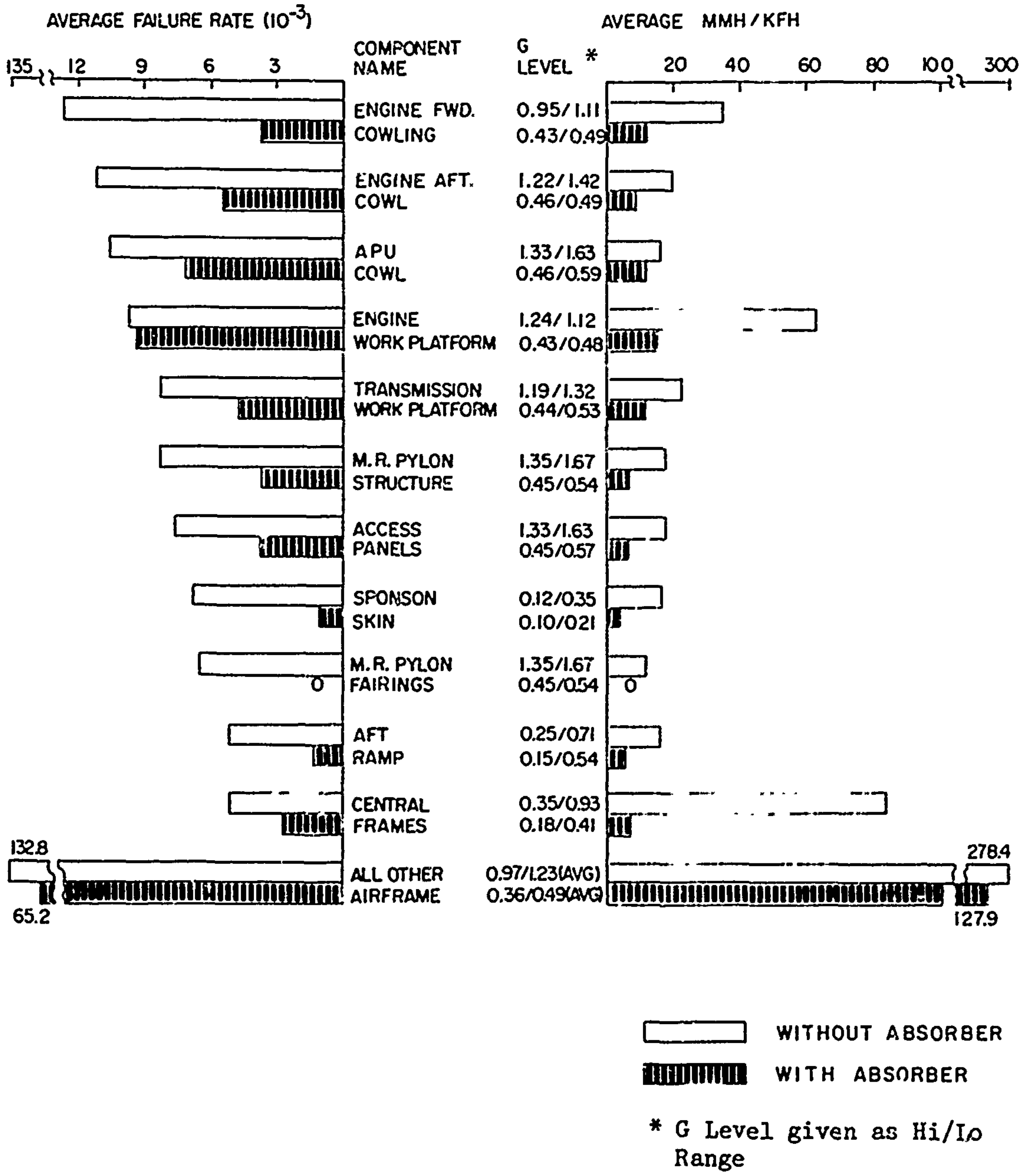


Figure 17. Comparison of Average Failure Rate and MMH/KFH for Selected Airframe Subsystem Components.

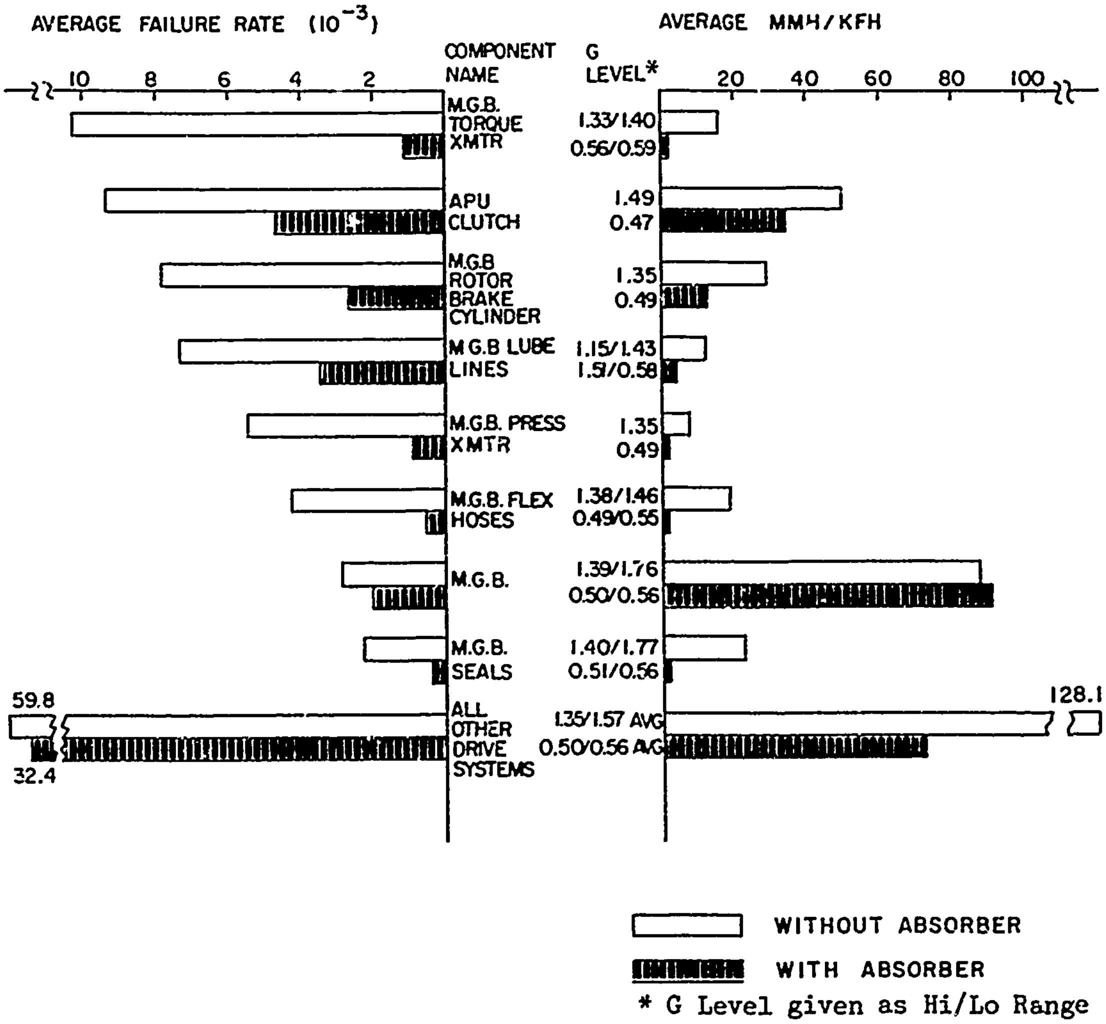


Figure 18. Comparison of Average Failure Rate and MMH/KFH for Selected Drive Subsystem Components.

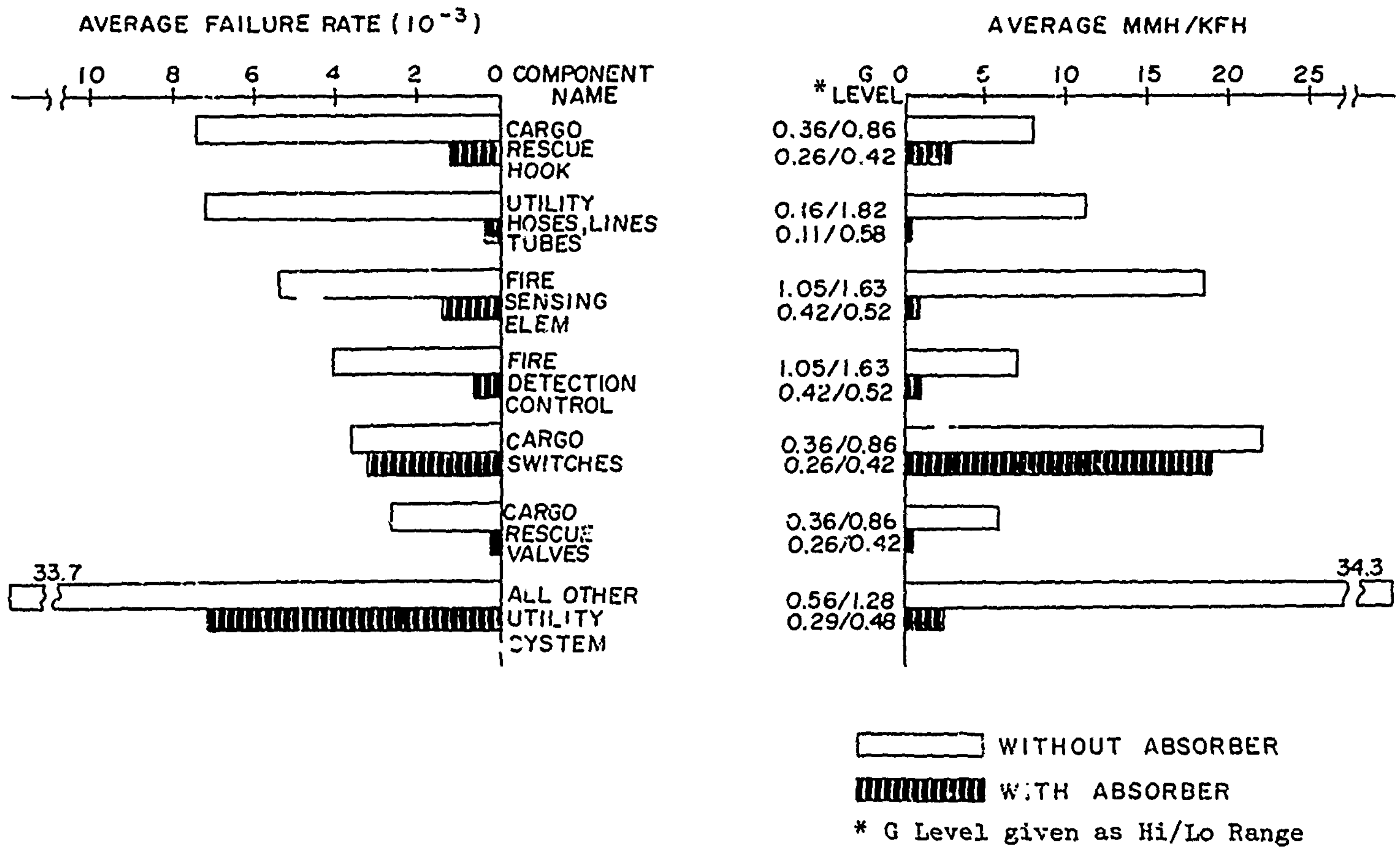


Figure 19. Comparison of Average Failure Rate and MMH/KFH for Selected Utility Subsystem Components.

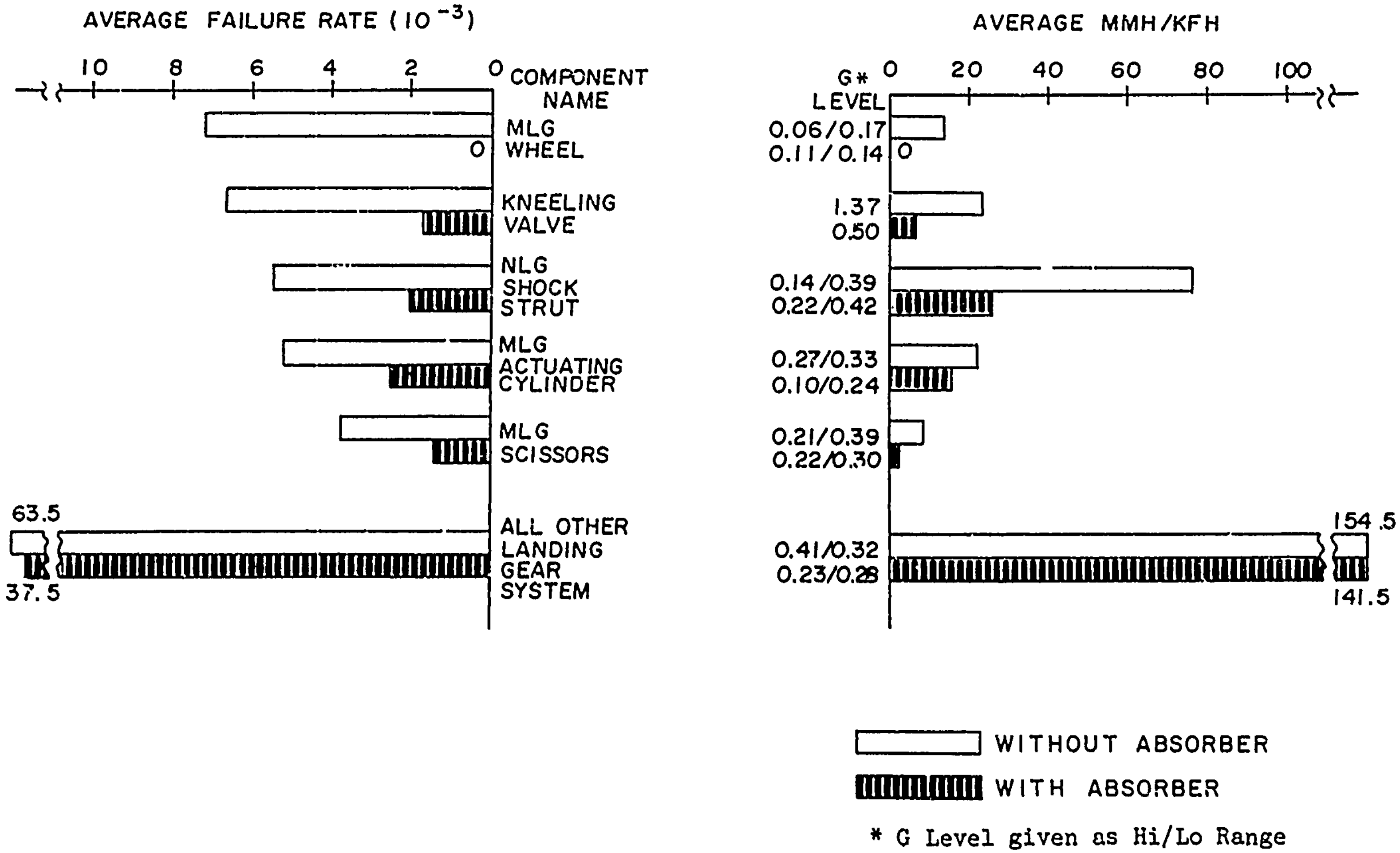


Figure 20. Comparison of Average Failure Rate and MMH/KFH for Selected Landing Gear Subsystem Components.

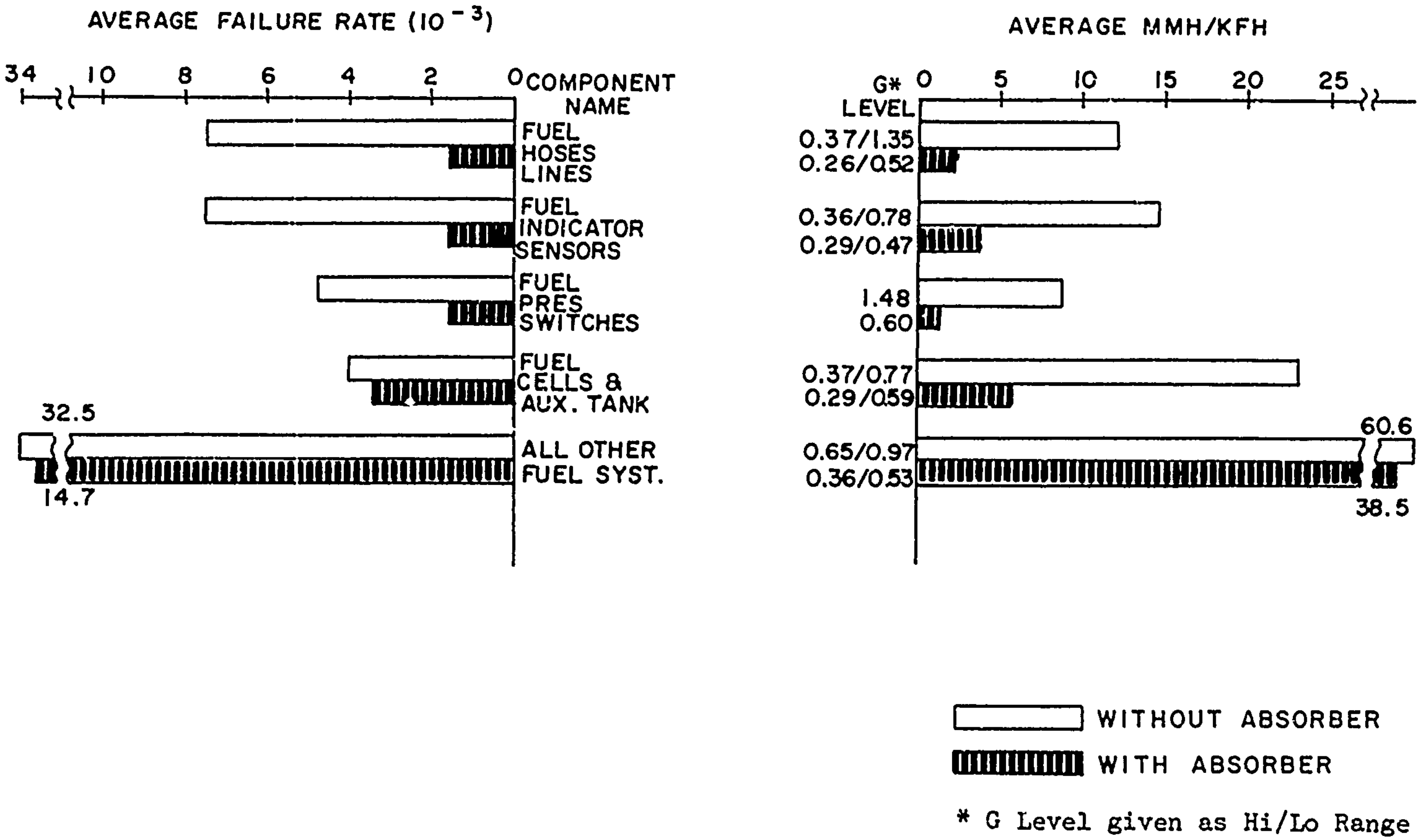


Figure 21. Comparison of Average Failure Rate and MMH/KFH for Selected Fuel Subsystem Components.

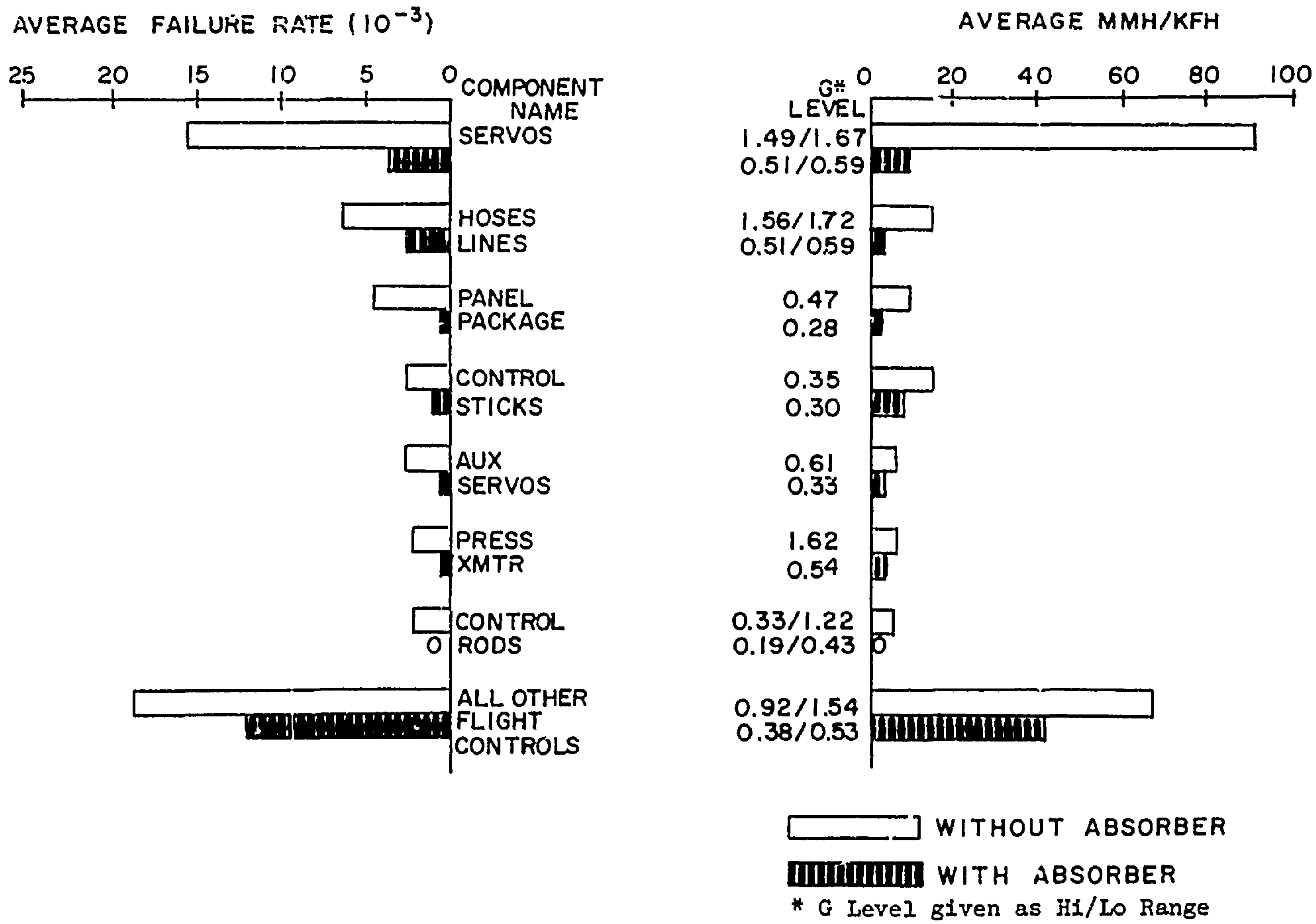


Figure 22. Comparison of Average Failure Rate and MMH/KFH for Selected Flight Control Subsystem Components.

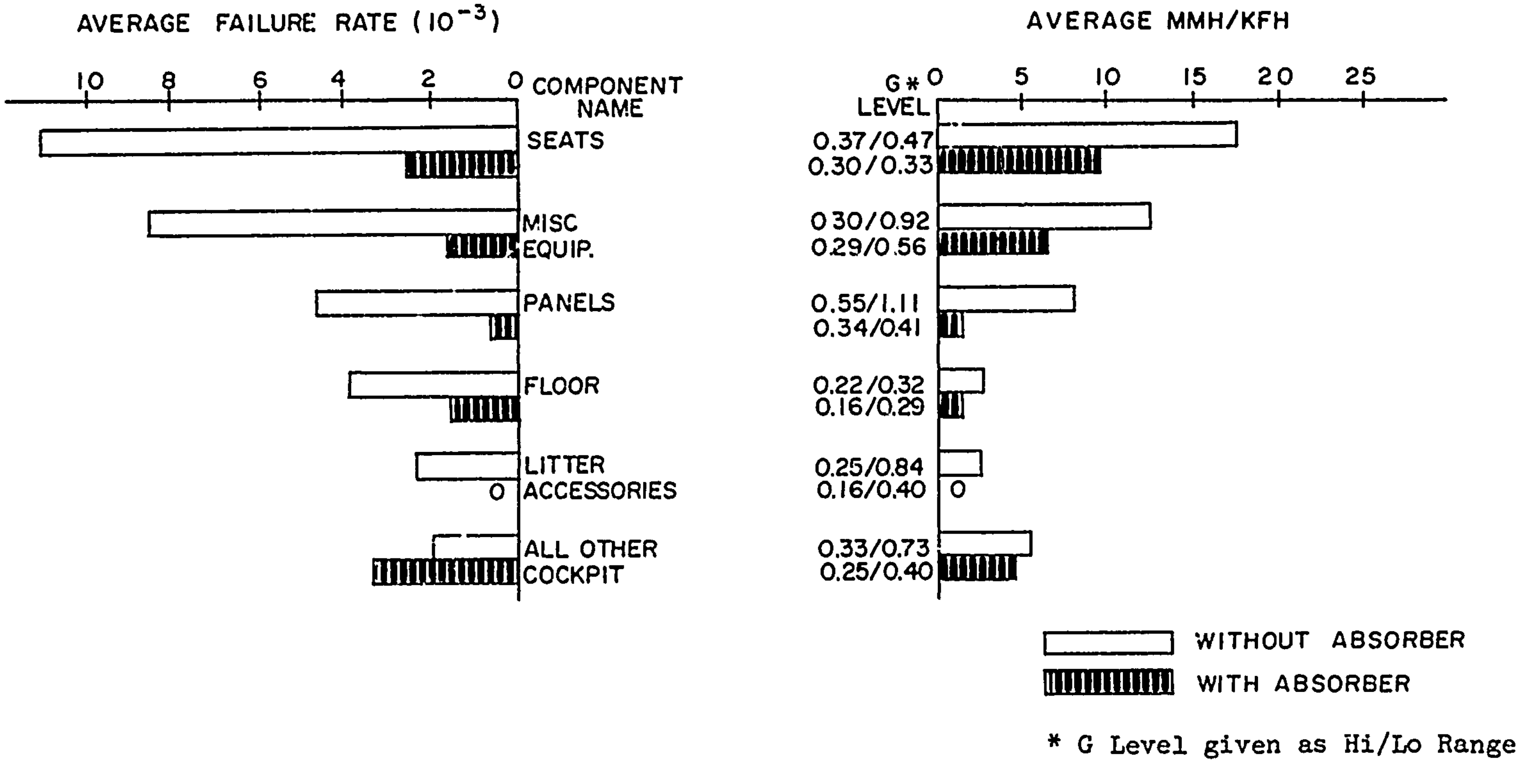


Figure 23. Comparison of Average Failure Rate and MMH/KFH for Selected Cockpit/Fuselage Subsystem Components.

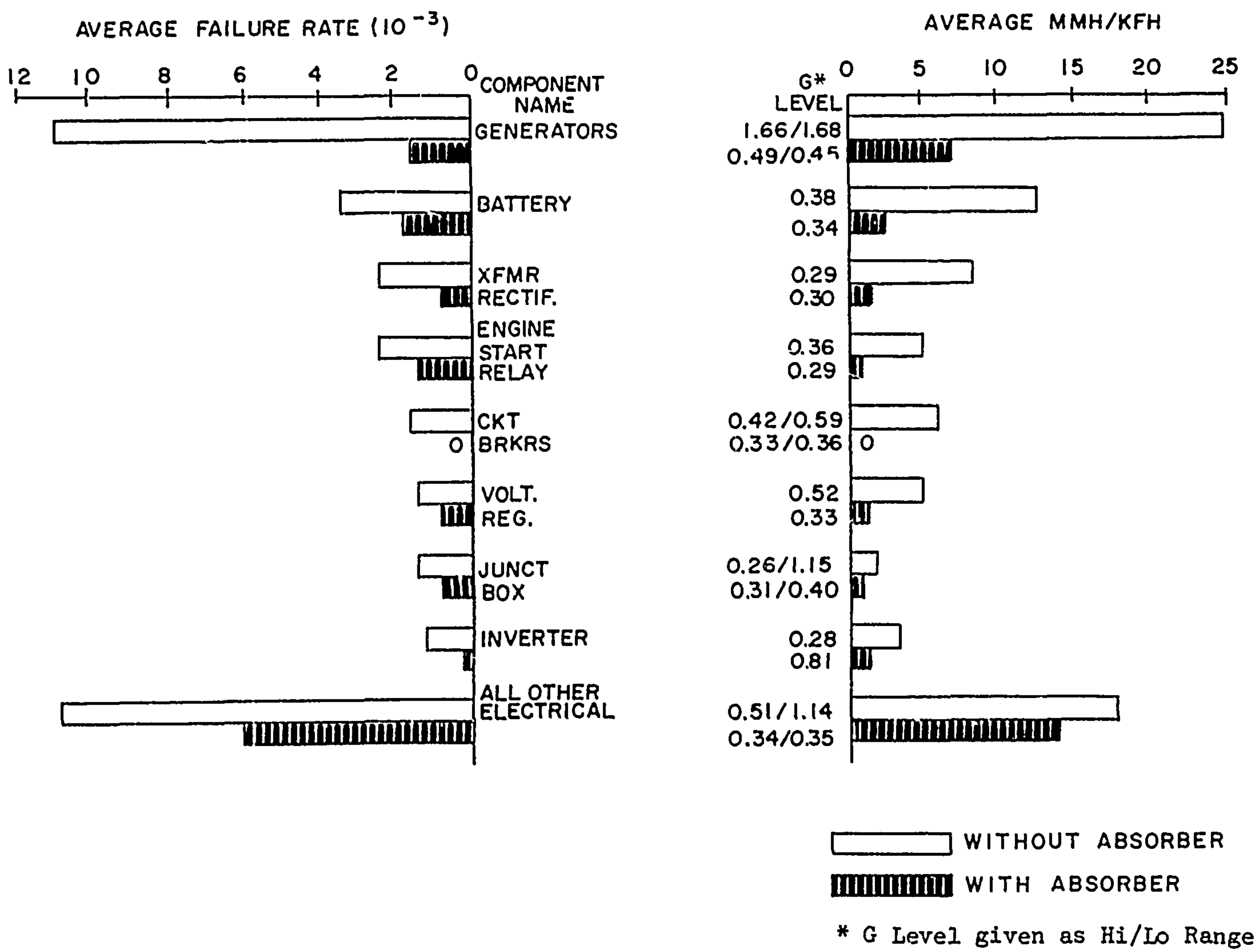


Figure 24. Comparison of Average Failure Rate and MMH/KFH for Selected Electrical Subsystem Components.

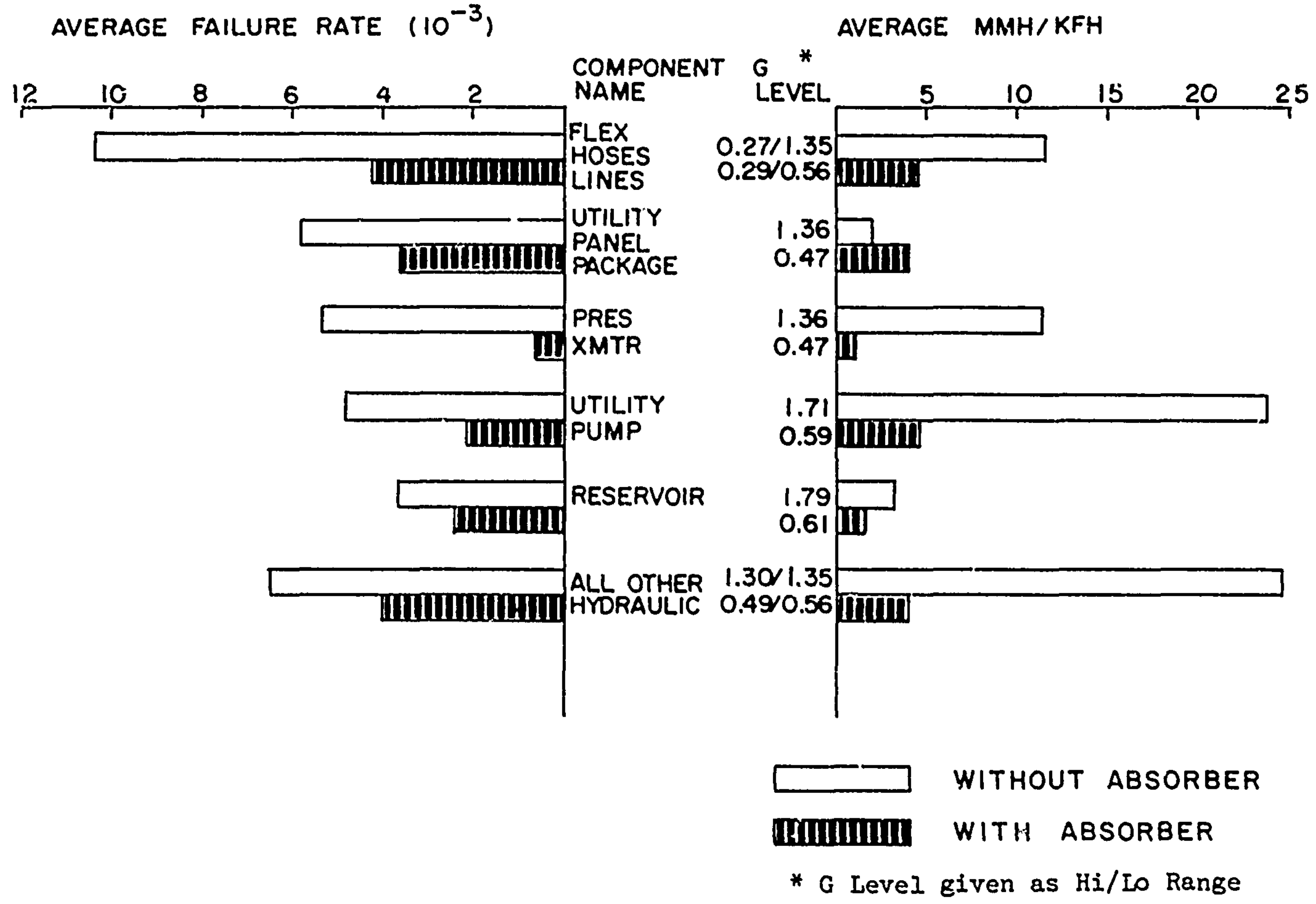


Figure 25. Comparison of Average Failure Rate and MMH/KFH for Selected Hydraulic Power Subsystem Components.

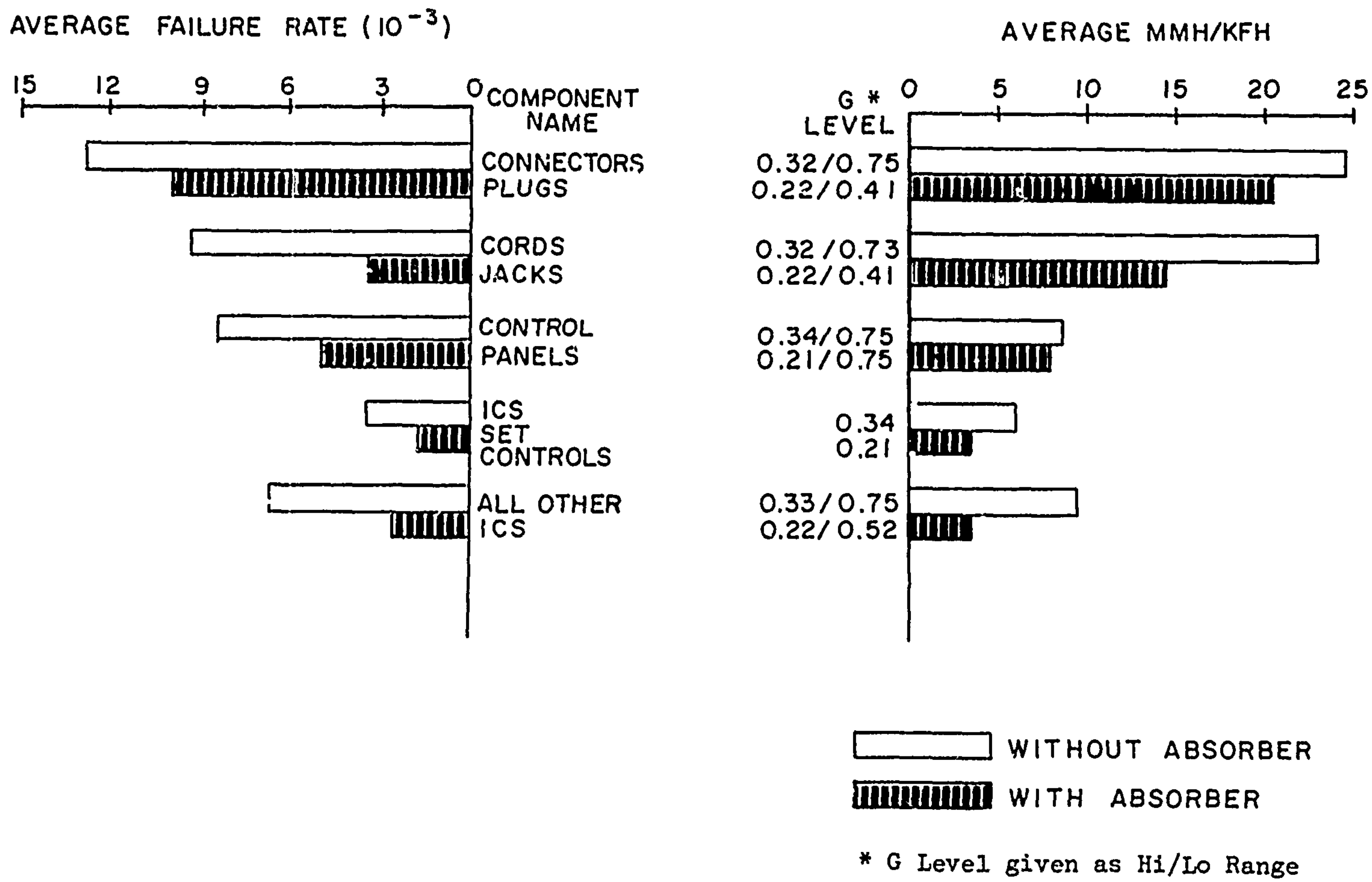


Figure 26. Comparison of Average Failure Rate and MMH/KFH for Selected Intercommunications Subsystem Components.

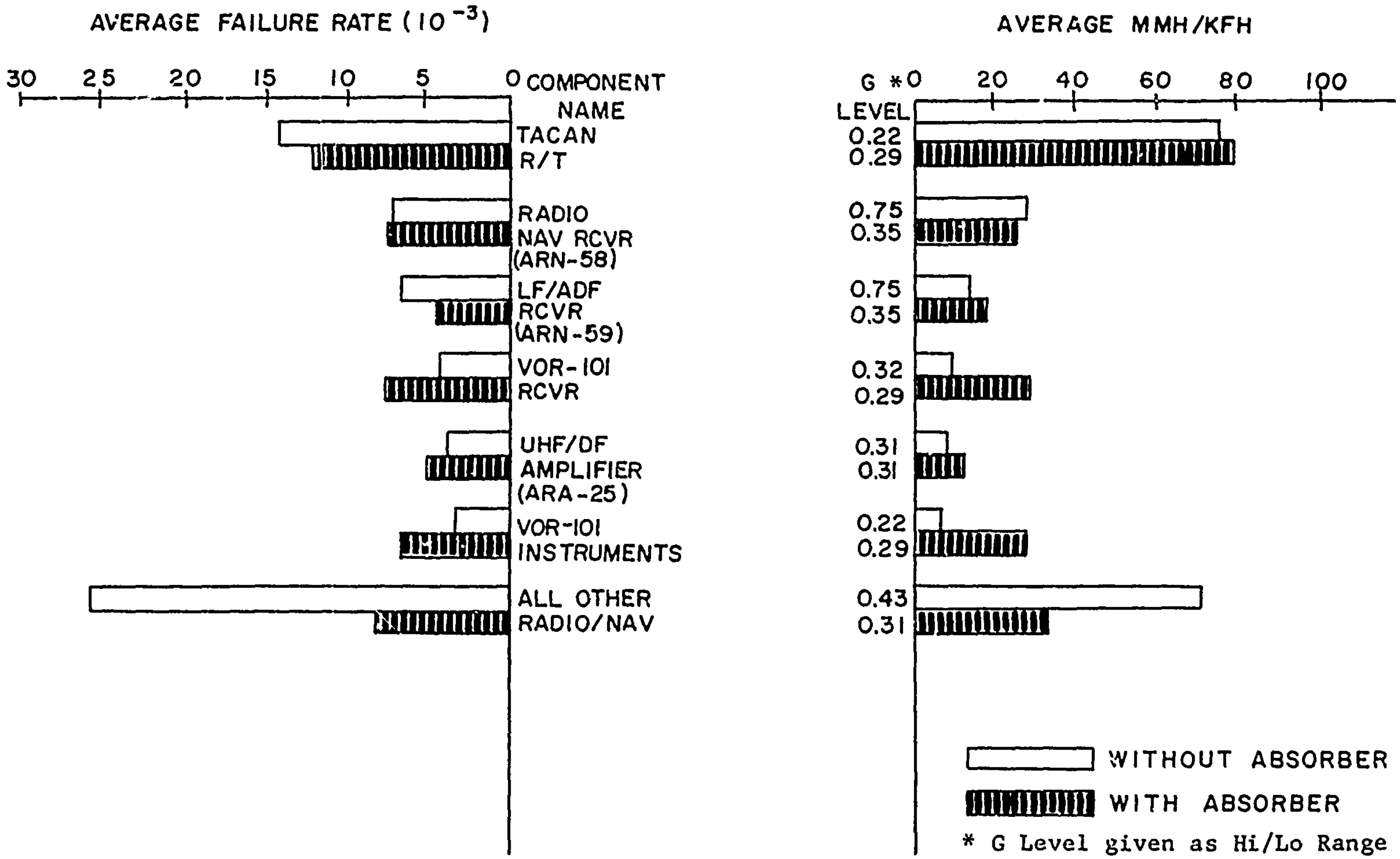


Figure 27. Comparison of Average Failure Rate and MMH/KFH for Selected Radio Navigation Subsystem Components.

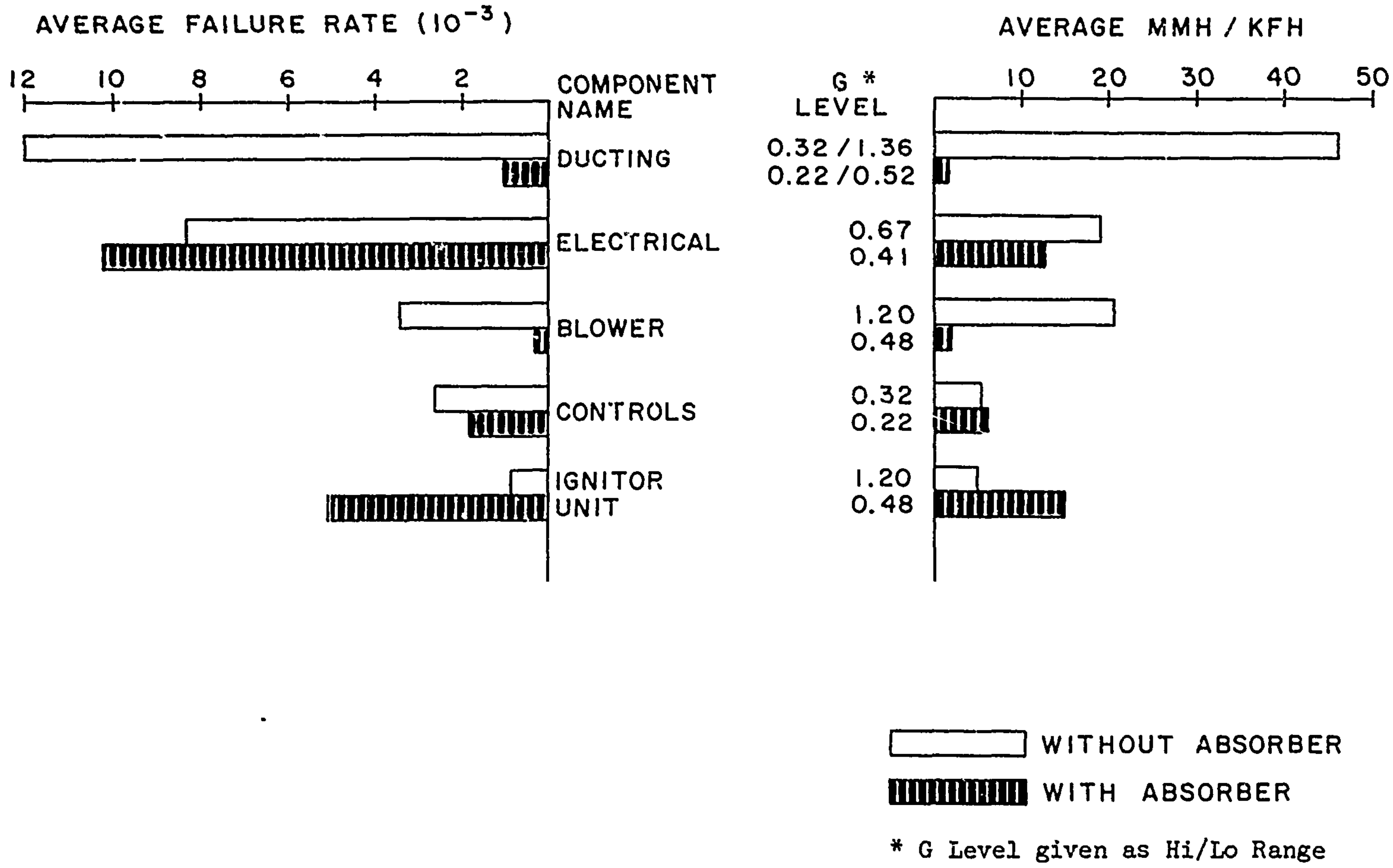


Figure 28. Comparison of Average Failure Rate and MMH/KFH for Selected Airconditioning/Heating Subsystem Components.

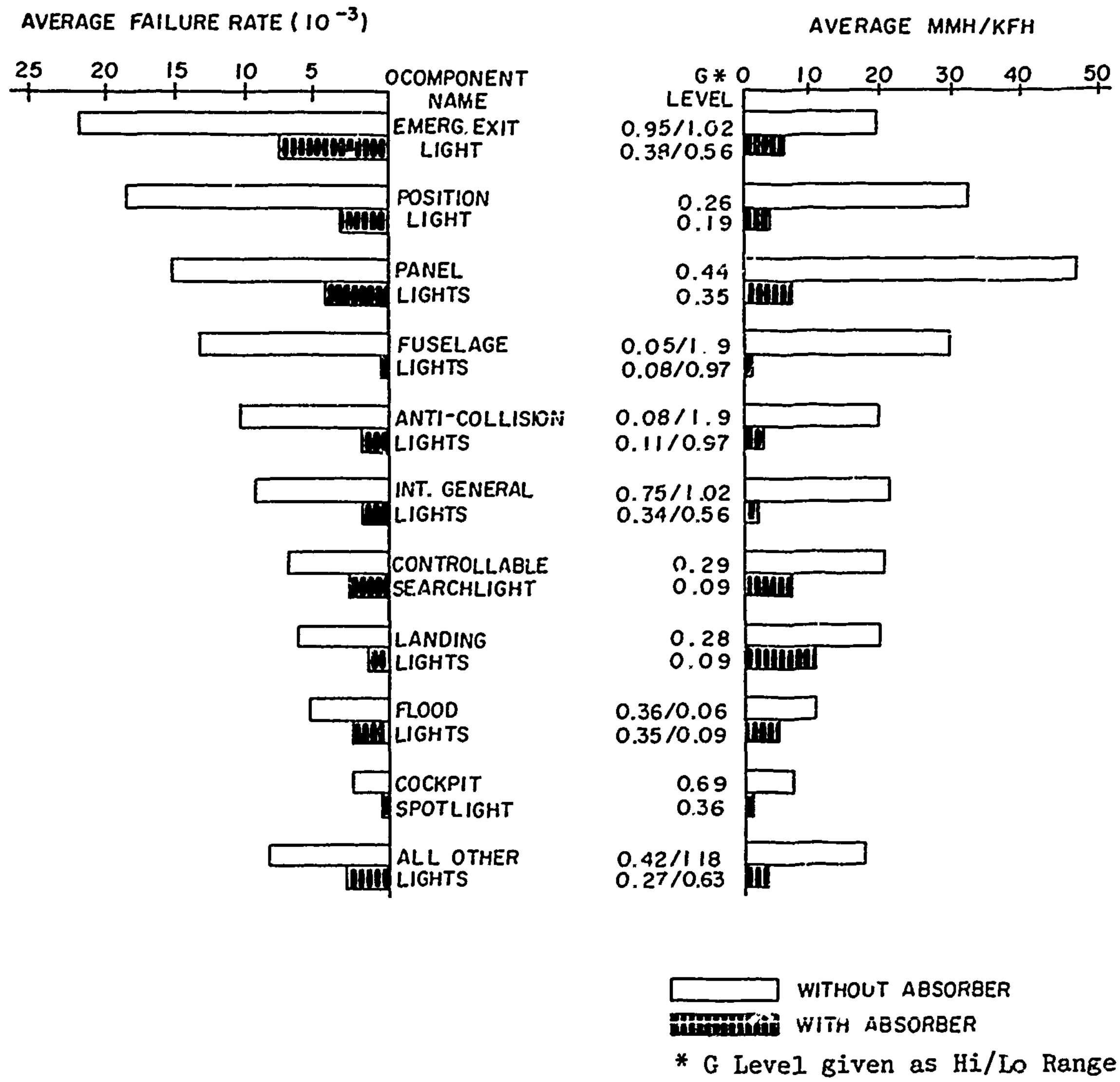
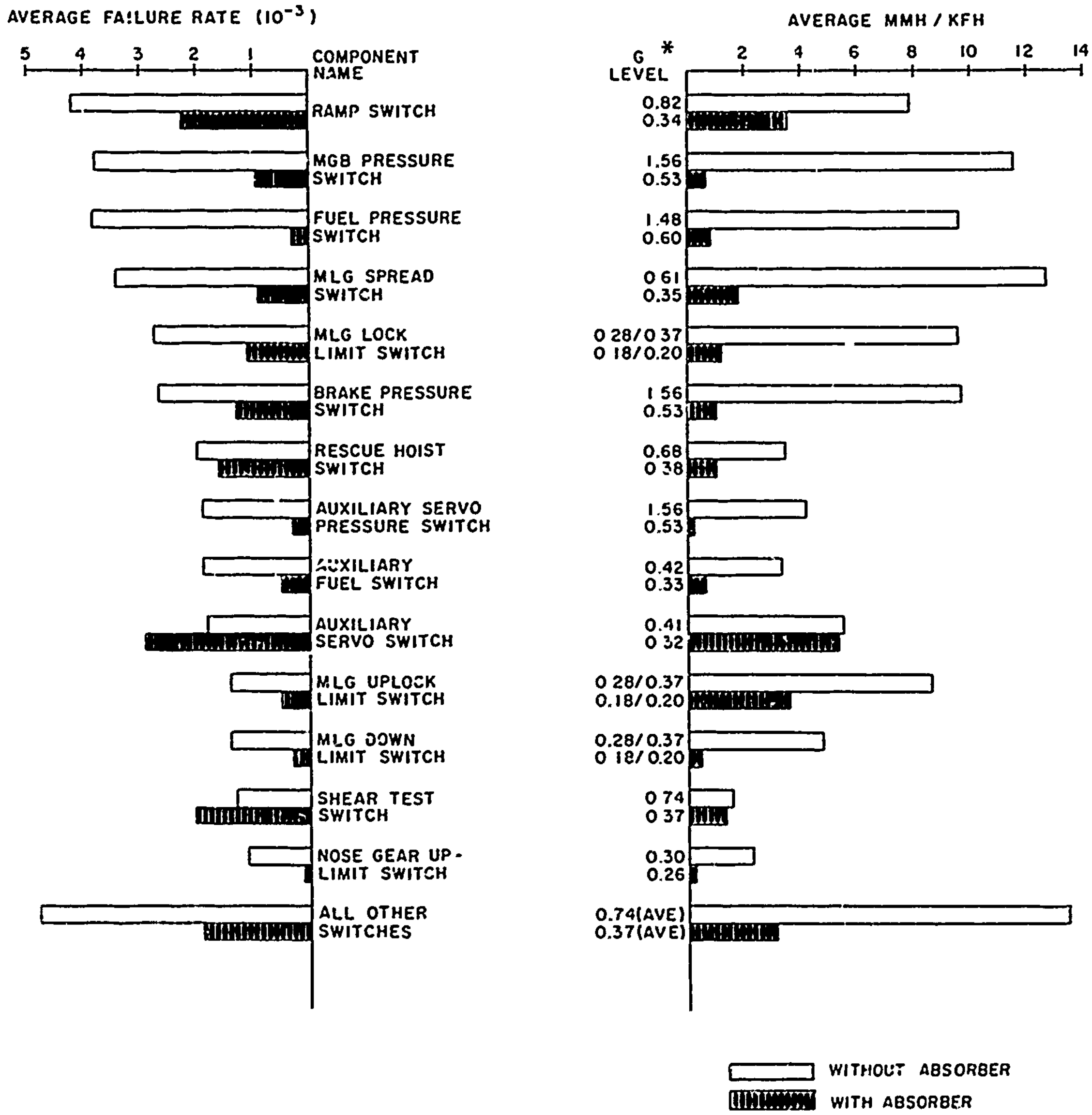


Figure 29. Comparison of Average Failure Rate and MMH/KFH for all Internal and External Lights.



* G Level given as Hi/Lo Range

Figure 30. Comparison of Average Failure Rate and MMH/KFH for all Switches.

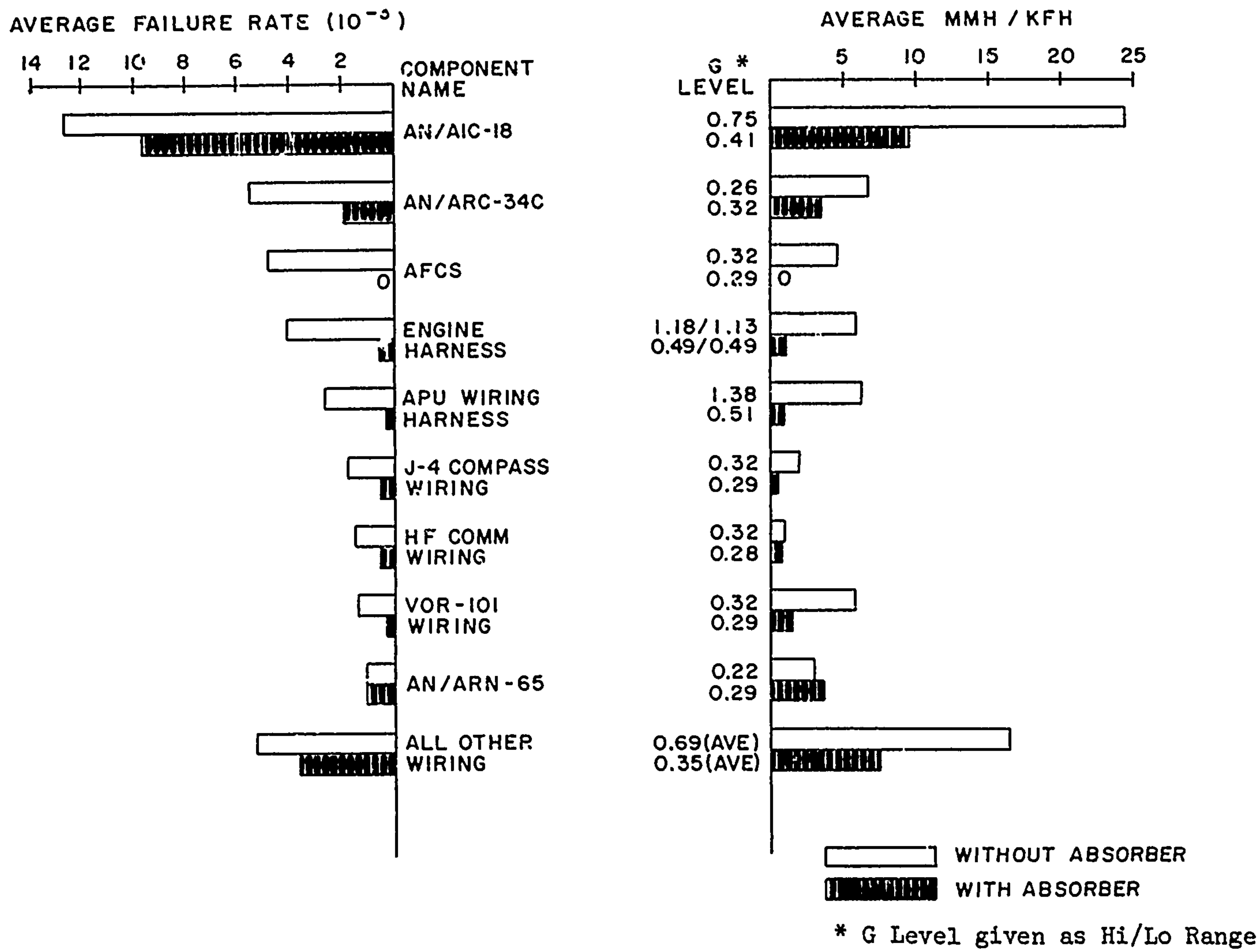
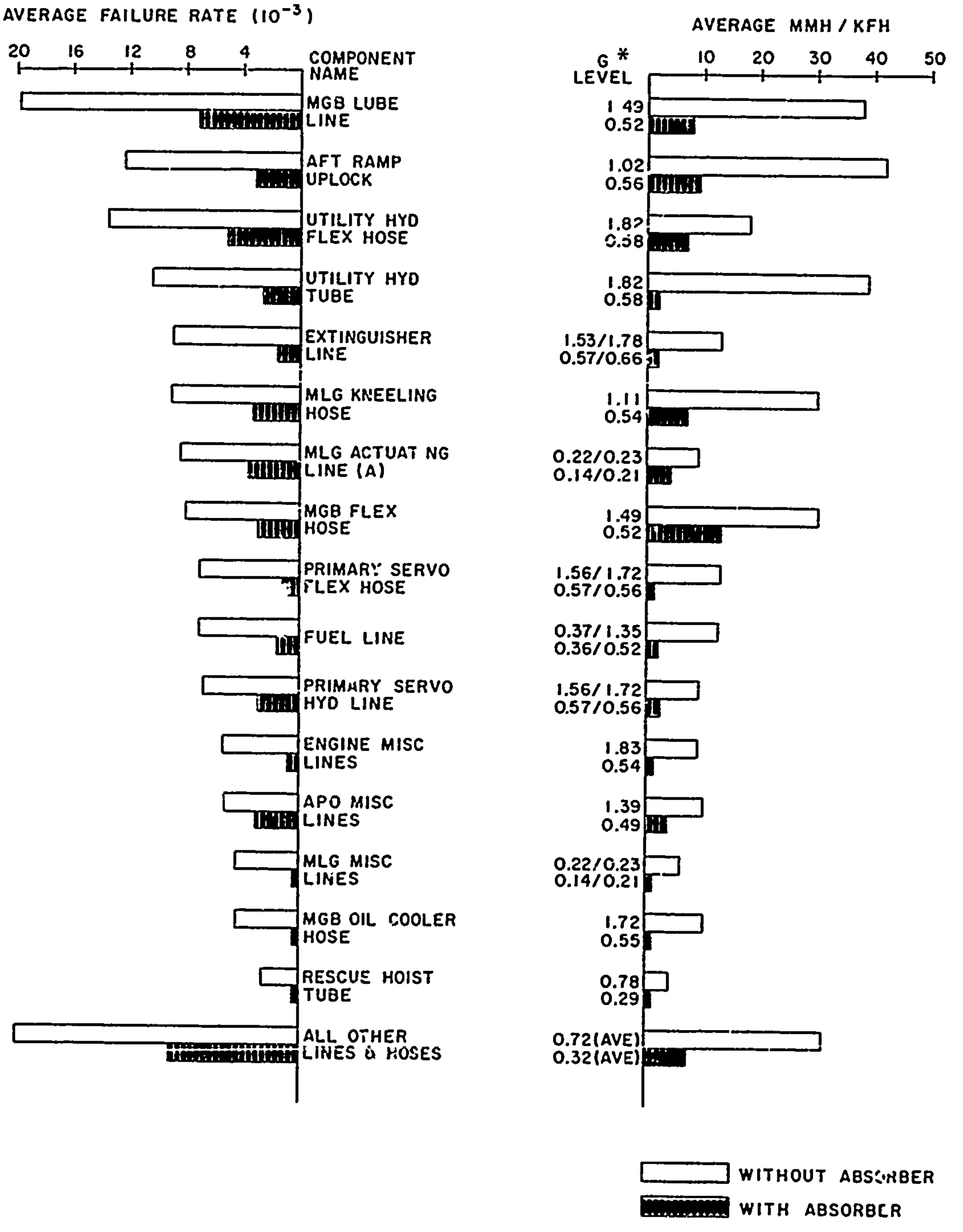


Figure 31. Comparison of Average Failure Rate and MMH/KFH for all Connectors/Plugs/Wiring.



* G Level given as Hi/Lo Range

Figure 32. Comparison of Average Failure Rate and MMH/KFH for all Hoses and Lines.

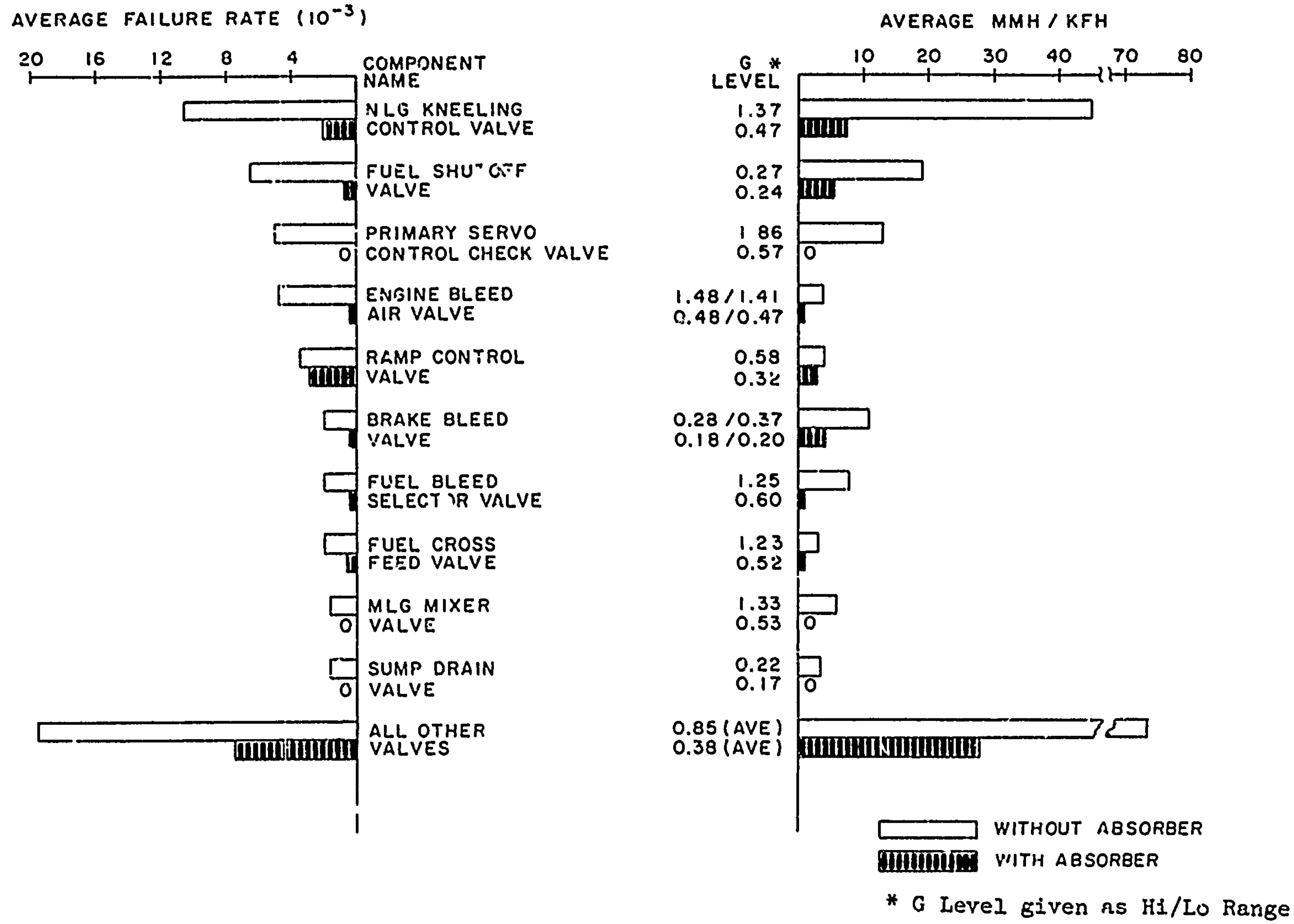
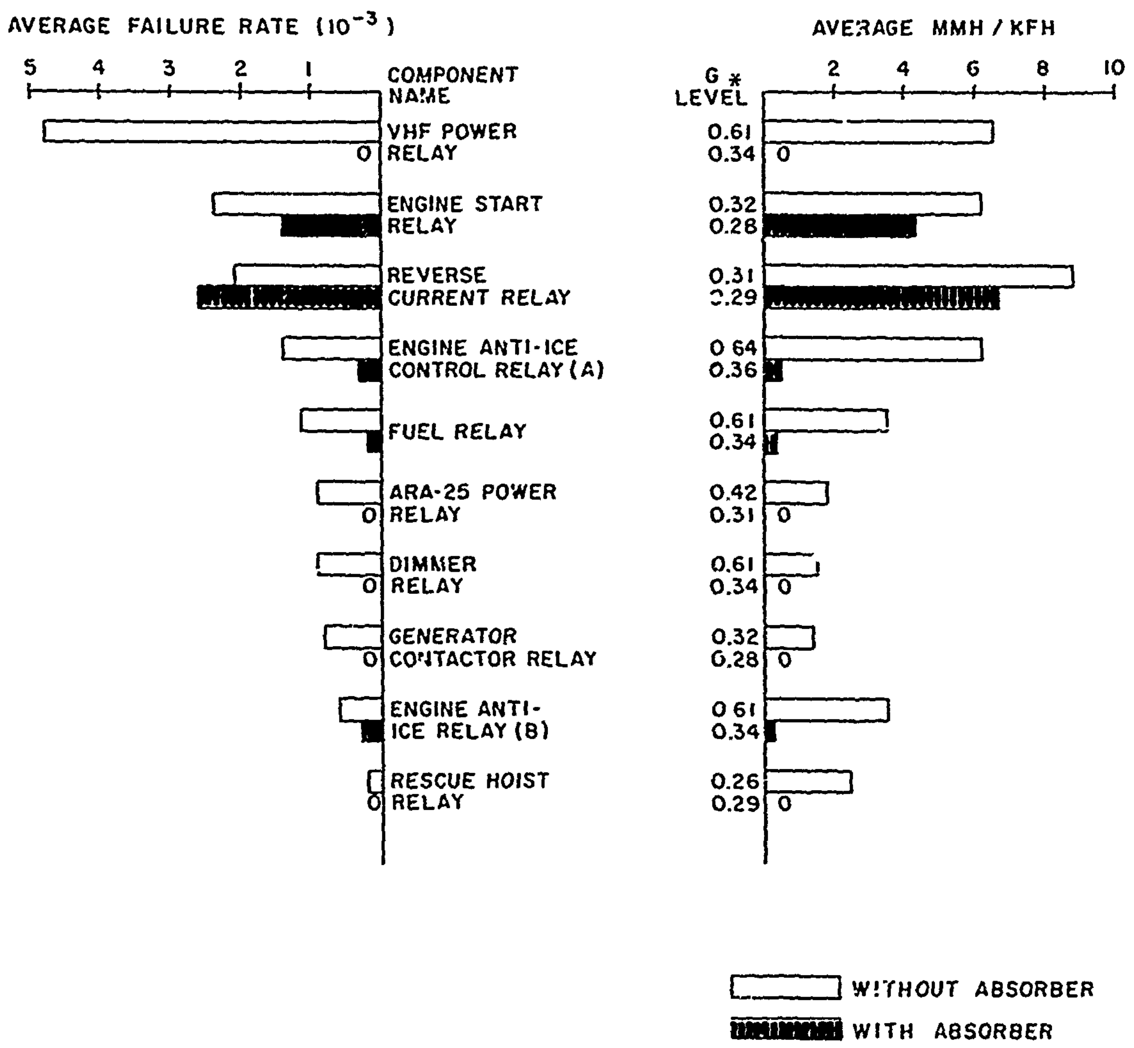


Figure 33. Comparison of Average Failure Rate and MMH/KFH for all Valves.



* G Level given as Hi/Lo Range

Figure 34. Comparison of Average Failure Rate and MMH/KFH for all Relays.

of insurance. The reasons which may explain the additional preventive maintenance are left to conjecture; however, some reasons will be offered.

The average failure rate comparison for the highest ranked components within each major subsystem as presented in Table V, are also presented as bar charts in Figures 16 - 24. These graphic presentations highlight the dramatic reduction in both average failure rate and maintenance man-hours that appears to result from the reduction in vibration.

INDIVIDUAL AIRCRAFT RELIABILITY AND MAINTAINABILITY COMPARISON

The data contained in Tables XII and XIII were sorted in ascending order of average failure rate and maintenance man-hours per 1000 flight hours. The individual aircraft reliability data were divided into subgroups representing incremental changes of 100 failures per 1000 flight hours, and the number of aircraft falling within each increment were counted resulting in the histogram shown in Figure 35. The same process was applied to the individual aircraft maintenance data where incremental subgroups of 500 MMH/KFH were used; see Figure 36.

The histograms show a distinctinve difference in the average failure rate and MMH/KFH and suggest that the two populations of aircraft are made significantly different by installing the vibration absorber in the one group and not the other. A number of different statistical tests may be applied to these data to verify the significance of the difference between the means of the two (with and without absorber) populations. These tests will all confirm that the difference is highly significant. However, since there is not a universally accepted procedure for such a formal test, none is included in this report. These data also lead to the same result at the aircraft level as are shown for the reduced vibration effect on reliability and maintainability at the component and subsystem levels.

An equally important observation which is made from Figures 35 and 36 is that the improved reliability and maintainability characteristics shown for the vibration-absorber-equipped aircraft could not be the sole result of a difference in local maintenance policies and procedures. If such were the case, the reliability data for each group of aircraft would be somewhat the same since the inherent reliability characterictics for each group of aircraft would be the same. The differences in reliability characteristics shown between the aircraft without and with vibration absorber, are, however, logically explained by a change in the inherent reliability characteristics resulting from a lower vibration environment.

LIFE-CYCLE COST MODEL AND LIFE-CYCLE COST DETERMINATION

The LCC model used in the comparative analysis is presented in Figure 37. Items branching off "life-cycle cost" permit evaluating in-the-pocket savings, whereas those extending from "effectiveness" permit estimating savings due to increased individual aircraft utility. Improved utility leads to LCC savings, since the aircraft productivity can be increased by improvements in mission reliability and availability. Then, the same total fleet productivity can be maintained using less aircraft, i.e.,

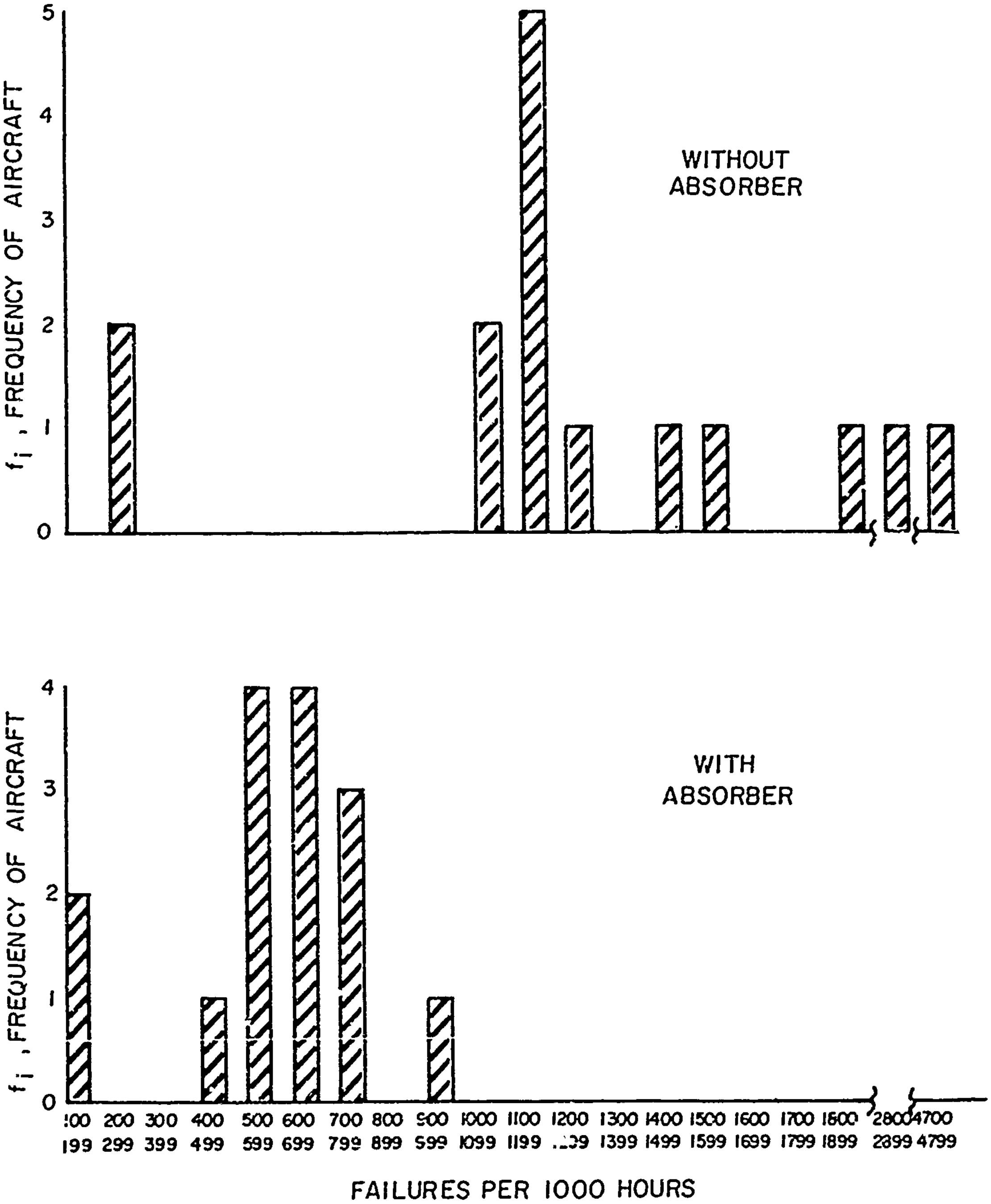


Figure 35. Distribution of Individual Aircraft Failure Rates Comparing Aircraft Groups Without and With Absorber.

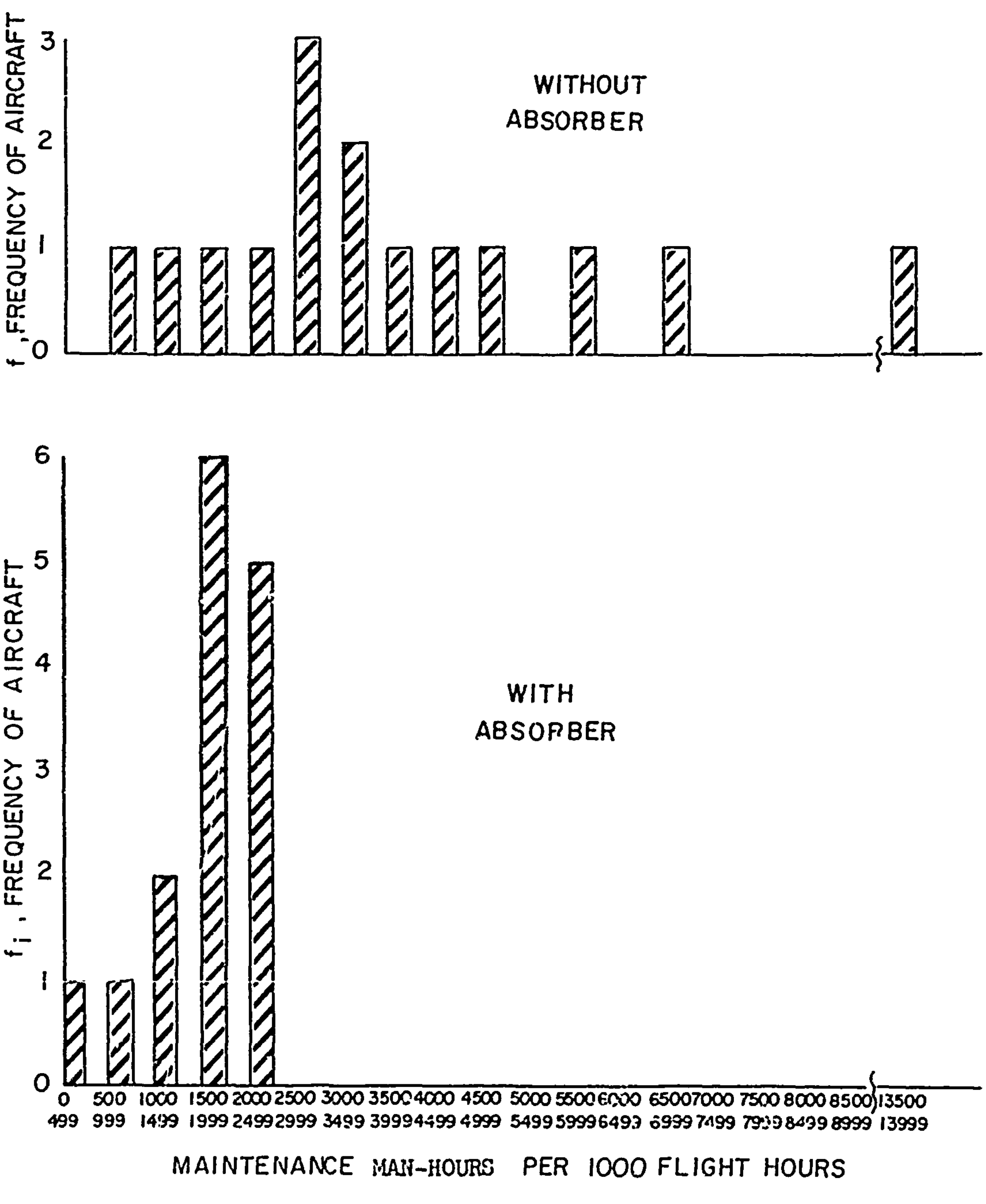
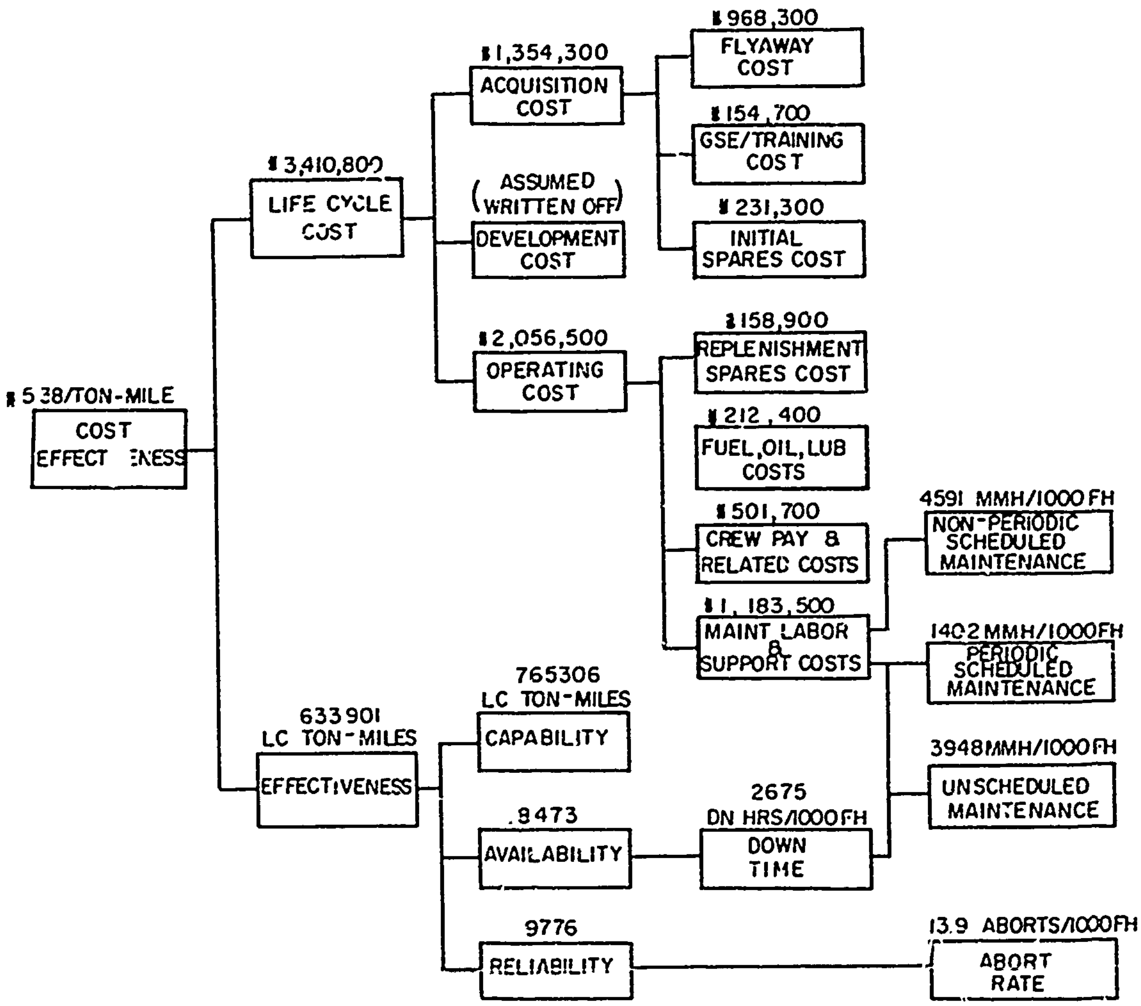


Figure 36. Distribution of Individual Aircraft MMH/FH Comparing Aircraft Groups Without and With Absorber.



NOTE: The purpose of this cost model is to establish LCC sensitivity to environmental changes, not to establish absolute values for pricing purposes.

Figure 37. Life-Cycle Cost Model.

increased mission reliability and availability produces a savings in aircraft acquisition costs. Figure 37 also displays the data used in the model for the H-3 nonbifilar aircraft. The LCC data, down to the third level of cost input (flyaway cost, GSE cost, etc.) represents 1971 values for the CH-3E non bifilar configuration. Unscheduled maintenance man-hours and failure rates are taken from Table IV and adjusted to include the engine subsystem. Scheduled maintenance values are taken from Table XV and adjusted to include engines.

Specifically, downtime is set equal to one-half of unscheduled maintenance plus periodic scheduled maintenance, i.e., it is assumed that two men are used to perform these functions. In its present form Figure 37 shows that downtime is dependent on periodic scheduled maintenance which renders an aircraft unavailable for extended periods of time and is independent of nonperiodic scheduled maintenance which can be done at the discretion of the flight crew so as not to interfere with flight operations.

The set of essential parameter values providing inputs for the LCC model are documented in Table XVI.

The rationale for these life-cycle cost study assumptions shown in Table XVI is as follows. The CH-3E nonbifilar, 1971 cost profile was used as the base cost profile in this study because it existed in the Sikorsky life-cycle cost data bank and was consistent with the aircraft type and time frame in which the study was performed. The 10-year aircraft life cycle is typically used by Sikorsky and throughout the aviation industry for cost effective analyses. For example, under the Sikorsky contract for the Army, DAAJ02-71-C-0046, "Expendable Main Rotor Blade Study," the Army defined the aircraft utilization for the C/E study as 500 hours per year for 10 years. The aircraft utilization of 500 hours per year defined in Table XVI is representative of the H-3 family of helicopters. Indicative of this are the H-3 bifilar aircraft stationed at Elmendorf AFB, Alaska. Between April 1970, and May 1971, these aircraft accumulated 5153.8 flight hours at a rate of 480 flight hours per aircraft per year. The mission time of 1 hour 38 minutes, the aircraft payload capacity of 5000 pounds, and the mission cruise speed of 125 knots are those values specified for the 200-nautical-mile mission for the USAF H-3 long-range helicopter. The average operational payload of 50% is based on Sikorsky studies on CH-3C helicopters operating under a spectrum of world temperature and altitude conditions for typical cargo loads. The unscheduled maintenance value is directly taken from the nonbifilar operational data used in this study. It is the sum of column four in Table IV. Periodic and nonperiodic scheduled maintenance values shown reflect an average value of the nonbifilar and bifilar operational data. These values are derived from columns four and eight of Table XV. The model was to consider that scheduled maintenance man-hour requirements are the same for the nonbifilar and bifilar H-3's modified by the difference between the scheduled maintenance called for the battery absorber vs the bifilar absorber. The aircraft failure rate is taken directly from the nonbifilar operational data used in this report. It is the sum of column one in Table IV. All other information in Table XVI, except for the 24-hour operational day, was based on the nonbifilar and bifilar data printouts. Under hostile

TABLE XVI. LIFE-CYCLE COST MODEL ASSUMPTIONS

ITEM	ASSUMPTIONS
Base Aircraft	CH-3E nonbifilar
Cost Year	1971
Aircraft Life	10 years
Aircraft Utilization	500 flight hours per year
Mission Time	1 hour 38 minutes
Aircraft Payload Capacity	5000 pounds
Average Operational Payload	50 percent of capacity
Mission Cruise Speed	125 knots
Unscheduled Maintenance (Excluding Engines)	3446.5 MMH/1000 FH
Periodic Scheduled Maintenance (Excluding Engines)	1224.1 MMH/1000 FH
Nonperiodic Scheduled Maintenance (Excluding Engines)	4008.2 MMH/1000 FH
Engine Maintenance to Total Aircraft Maintenance Ratio	.127 to 1
Aircraft Downtime	.5 (Unsch. Maint. + Periodic Sch. Maint.)
Mission Abort Rate (Excluding Engines)	10.60 aborts/1000 FH
Engine Aborts to Total Aircraft Aborts Ratio	.237 to 1
Aircraft Failure Rate (Excluding Engines)	1232.3 failures/1000FH
Engine Failure Rate to Total Aircraft Failure Rate Ratio	.095 to 1
Operational Day	24 hours

conditions, the 24-hour operational day would be typical.

The equations for mission reliability, capability, and availability used in the model are as follows:

$$\text{Mission Reliability} = e^{-\lambda_a t} \qquad (15)$$

where λ_a = total aircraft mission abort rate per hour

t = mission time in hours

$$\text{Capability} = PL \times V_c \times OP_{ave} \times \text{aircraft life} \times \text{utilization} \qquad (16)$$

where PL = aircraft payload capability

V_c = cruise velocity in knots

OP_{ave} = average operational payload in percent

$$\text{Availability}^1 = \frac{OD - OD/D}{OD} \qquad (17)$$

where OD = operational day in hours

DH/D = aircraft downtime in terms of down hours per day

The following is a sample calculation using these equations with values taken from Figure 36 and Tables XV and XVI. The values used are:

λ_a = .0139 abort per hour

t = 98/60 hours (2 min of each 98 min flt is hover)

PL = 5000 pounds (2.5 tons)

V_c = 125 knots

OP_{ave} = 50% (15)

OD = 24 hours

$$DH/D = \frac{2.675 \text{ dn hr}}{\text{flt hr}} \times \frac{500 \text{ flt hr/yr}}{365 \text{ days/yr}}$$

$$= 3.664 \text{ down hours per day}$$

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[1] The definition shown is consistent with the availability equation (22) cited on page 83 of Maintainability Principles and Practices, by Blanchard and Lowery, McGraw-Hill, 1969.

Aircraft Life = 10 years

Utilization = 5J0 flight hours per year

Therefore,

$$\underline{\text{Mission Reliability}} = e^{-\lambda_a t} = e^{-(.0139 \times \frac{98}{60})} = .9776$$

Capability = 2.5 tons x .5 x 125 kt x 10 yr x 500 flt hr per yr x (96/98)* = 765,306 ton-naut miles

$$\underline{\text{Availability}} = \frac{24 \text{ operational hr per day} - 3.664 \text{ dn hr per day}}{24 \text{ operational hr per day}}$$

$$= .8473$$

*Only 96 out of 98 minutes is used in forward flight transportation.

The reduction of helicopter vibration provides major savings in life-cycle cost. In the LCC comparative analysis of vibration sensitive subsystems and components reported herein, the installation of the bifilar vibration absorber system saves approximately $350,000. This represents close to 10 percent of the total aircraft LCC.

The cost savings statistics include 13 subsystems in order to encompass the 10 most vibration sensitive subsystems from both the unscheduled maintenance man-hour and failure rate standpoints. In each of the subsystems, the LCC impact of vibration reduction is shown for the categories of unscheduled maintenance, spares, mission reliability, and availability. The savings within these categories are presented in Table XVII.

The total savings for the 13 subsystems is over $365,000. The investment to realize this substantial LCC savings is an $11,000 initial cost for the bifilar system, and an estimated $4,000 operating expense for bifilar scheduled maintenance. Total aircraft LCC improvement may be as high as 15 percent (one and one-half times the 10 percent), since the $350,000 cited above is derived from the 13 subsystems. These subsystems represent only two-thirds of the aircraft, and the reduction in expenditures and failure rates on the remaining subsystems suggests that appreciable expenditure improvement could be incurred. However, no life-cycle cost analyses were made to verify this observation.

A higher degree of confidence may be placed in the economies computed for unscheduled maintenance than in spares because they are based on well-documented H-3 helicopter operational data. Lower confidence must be placed in the spares expenditure reductions, since no direct data feedback source was available indicating spares consumed. The spares cost reduction due to the installation of the bifilar vibration absorber system was calculated by applying the percentage change in subsystem unscheduled maintenance observed on the bifilar aircraft to an estimated subsystem

TABLE XVII. LIFE-CYCLE SAVINGS PER AIRCRAFT RESULTING FROM VIBRATION REDUCTION

SYSTEM	In-The-Pocket Savings		Savings Due To Increased Utility		TOTAL
	Maintenance	Spares	Mission Reliability	Availability	
Airframe	46,356	8,654	424	17,351	72.785
Drive	18,816	69,762	5,807	7,043	101,428
Utility	9,705	7,292	798	3,633	21,428
Landing Gear	12,092	6,431	824	4,526	23,873
Lights	23,638	951	150	8,848	33,587
Fuel	8,239	7,007	237	3,084	18,567
Flight Controls	18,053	18,077	847	6,757	43,734
Cockpit	3,114	1,178	0	1,166	5,458
Hydr. Power	6,833	2,642	0	2,558	12,033
Interphone	2,605	1,334	0	975	4,914
Radio Nav.	-1,054	2,015	0	-395	566
Airconditioning & Anti-Ice	7,221	1,052	0	2,703	10,976
Electrical	6,446	8,182	923	2,413	17,964
TOTAL	162,064	134,577	10,010	60,662	367,313

life-cycle spares cost. These subsystem spares costs are defined in Table XVIII. Confidence in the mission reliability and availability cost improvements is of a level consistent with spares. In mission reliability, the lower confidence results from the relatively small number of abort failures observed in the nonbifilar and bifilar operational data. The nonbifilar abort failure rates for the 13 subsystems are also shown in Table XVIII. Changes in abort rates due to bifilar installation were computed by applying the proportionate changes in bifilar and nonbifilar subsystem failure rates to the abort rates of Table XVIII. In availability, the lower confidence in results stems from the uncertainty in the operational demand and squadron size. Operational demands may vary somewhat without requiring change in fleet size (and change in aircraft acquisition expense). Availability is computed based upon the assumption that an aircraft will be down (unavailable) 1 hour for every 2 hours of unscheduled and periodic scheduled maintenance man-hours expended (on the average, 2 men are used for maintenance). Equations for computing mission reliability and availability were shown in the preceding paragraph.

Life-cycle savings per aircraft for select component types are shown in Table XIX. They are displayed in the same format as Table XVIII and the confidence in the numbers similarly applied. For these component types the savings is about $180,000.

In the life-cycle cost savings listed earlier, these savings were based on a helicopter cost profile in which the development costs were shown as "written off." This is because the CH-3E is a production aircraft and the development cost (the cost incurred during the RDTE phase for developing the total aircraft system) is a past cost that no longer impacts on aircraft buying/selling decisions. The bifilar installation as it impacts the CH-3E is a design modification, and under the cost profile shown in Figure 38 may be included as an acquisition cost "delta." This cost "delta" could be further categorized into nonrecurring costs and recurring costs. For the bifilar installation the nonrecurring cost, when prorated over 100 aircraft, is slightly in excess of $4,000 per aircraft. The recurring cost per aircraft installation is about $6,500. The cost delta for the acquisition of a bifilar CH-3E is therefore approximately $11,000.

TABLE XVIII. LIFE-CYCLE MODEL NONBIFILAR SUBSYSTEM SPARES COSTS AND ABORT RATE

Subsystem	Spares Costs ($)	Abort Rates (Aborts/1000FH)
Airframe	16,700	.37
Drive	124,100	4.66
Utility	9,300	.46
Landing Gear	12,600	.73
Lights	1,300	.09
Fuel	11,800	.18
Flight Control	34,500	.73
Cockpit (Fuselage)*	1,700	.00
Hydraulic Power*	4,900	.00
Interphone	2,900	.00
Radio Navigation*	8,600	.00
Airconditioning/Anti-Ice*	3,200	.00
Electrical	12,600	.64
Thirteen Subsystems Subtotal	244,200	7.86
Aircraft Total	390,200	13.90

*No mission aborts were recorded in either the nonbifilar or bifilar operational data.

TABLE XIX. LIFE-CYCLE SAVINGS PER AIRCRAFT BY COMPONENT TYPE RESULTING FROM VIBRATION REDUCTION

System	In-The-Pocket Savings		Savings Due To Increased Utility		
	Maintenance	Spares	Mission Reliability	Availability	Total
Valves	17,423	13,244	330	6521	37,518
Hoses & Lines	30,859	19,448	949	11551	62,807
Connectors/Plugs/ Wiring	9,681	4,092	0	3623	17,396
Switches	10,068	4,300	465	3765	18,602
Lights	23,638	951	150	8848	33,587
Relays	3,623	5,204	426	1356	10,609
Total	95,292	47,239	2320	35,668	180,519

VIBRATION DESIGN AND ACCEPTANCE TEST SPECIFICATION ASSESSMENT

The objective of this study task was to assess applicable vibration design and acceptance test specifications in light of the reliability and vibration data presented.

The procedure used to perform the assessment consisted of examining the vibration requirements cited in each of the specifications applicable to components and systems used on the H-3 aircraft. Twenty-nine documents were reviewed and are listed in Table XX. These documents are generally applicable to all helicopters and are not necessarily unique to H-3 applications. Three documents were singled out for detailed assessment (MIL-H-8501(A), MIL-STD-810B, and MIL-STD-781B) because they specifically cite the vibration requirements for helicopters, methods for environmental tests such as vibration, and tests for reliability where a vibration environment is simulated. Excerpts from MIL-H-8501(A) and MIL-STD-801B are contained in Appendix II. (The information on reliability testing in MIL-STD-781B is quite extensive; reference a complete copy to support the ensuing discussion).

The specification tree provided in Figure 38 illustrates the interdependency existing between various component vibration specifications as well as the paragraphs within the specification where the requirement is cited.

Current specifications for the acceptance testing of a helicopter component's ability to endure vibration are inadequate. Components are tested according to fixed-wing oriented specifications by employing relatively high frequency vibration (above 25 Hz). By contrast, helicopters are high-amplitude, low-frequency machines, the predominant frequency of excitation being between 10 Hz and 20 Hz. Further, helicopters are developed according to specifications which address the maximum allowable vibration levels in the cockpit and personnel cabin areas only. Lastly, in some cases, inventory helicopters do not conform to the military specification concerning vibration. A model specification is written declaring the higher vibration levels acceptable. Consequently, it is understandable why helicopter components, most of which are installed outside the cockpit and personnel cabin areas, often suffer premature failures. Further, understanding of the influence of excitation frequency on failure rate is needed before more specific recommendation can be made regarding military specification changes.

TABLE XX. APPLICABLE SPECIFICATIONS WITH VIBRATION REQUIREMENTS

Specification	Title
MIL-H-8501(A)1	Helicopter Flying & Ground Handling Qualities General Requirements For
MIL-S-8698(ASG)(1)	Structural Design Requirements, Helicopters
MIL-T-8679	Test Requirements, Ground, Helicopter
MIL-D-23222A(AS)	Demonstration Requirements for Helicopters
MIL-STD-810B(4)	Environmental Test Methods
MIL-W-5013H(1)	Wheel and Brake Assemblies, Aircraft
MIL-B-8584C	Brake System Wheel Design
MIL-T-5041F(1)	Tires, Pneumatic, Aircraft
MIL-L-8552C(2)	Landing Gear Shock Absorbers
MIL-F-18372(Aer)	Flight Control Systems Design Installation & Test
MIL-C-18244A(Wep)	Control & Stabilization Systems, Auto, Piloted Aircraft
MIL-T-6396C(ASG)	Tank, Fuel, Oil
MIL-T-5578C(2)	Tank, Fuel, Aircraft
MIL-F-17874B	Fuel System, Aircraft
MIL-I-18802A(Wep)	Fuel & Oil Lines, Aircraft, Installation of
MIL-T-5955C	Transmission Systems, VTOL-STOL, General
MIL-I-18373A(AS)	Instruments & Navigation Equipment, Installation of
MIL-H-5440E	Hydraulic Systems, Aircraft, Type I & II, Design, Installation
MIL-H-8775C	Hydraulic System Components, Aircraft & Guided Missiles, General
MIL-C-5503C(3)	Cylinders, Aeronautical, Hydraulic Actuating, General
MIL-E-7080B(3)	Electrical Equipment, Aircraft, Selection & Installation
MIL-E-25499C	Electrical Systems, Aircraft, Design & Installation
MIL-L-6723B	Lights, Aircraft, General Specification
MIL-STD-202D(1)	Test Methods for Electronics and Electrical Components
MIL-E-5400M(2)	Electronic Equipment, Airborne, General Spec.
MIL-I-8700A	Installation & Test of Electronics, Aircraft, General
MIL-I-8677(Aer)	Installation Armament Control Systems
MIL-H-18325B(Aer)	Heating & Ventilation System,
MIL-STD-781B	Reliability Tests: Exponential Distribution

Air Vehicle Specs

1	2	3	4	5
Helicopter Flying Qualities, Reqts. for MIL-H-8501A (1): 3.7 Vibration Characteristics	Structural Design Reqts., Helicopters MIL-S-8698 (ASG) (1): 3.6 Mechanical instability, flutter, and vibration 3.6.5 Antivibration provisions (Ref. MIL-H-8501)	Test Reqts., Ground Helicopter MIL-T-8679: 3.2.10.2 Integral tank vibration tests 3.5.1.3 Powerplant antivibration syst. 3.5.2.1.1 Hub vibration tests 3.5.2.1.2 Hydraulic damper tests 3.5.2.1.3 Blade vibration tests 3.6 Tie-down tests 3.6.6.4 T-d test notes	Demonstration Reqts. For Helicopters MIL-D-23222A (AS)	Environmental Test Methods MIL-STD-810B (4) (Superseded MIL-E-5272) 514.1 Vibration categories (a) & (c)

Figure 38. Vibration Specification Tree.

6	7	8	9
Main Rotor Reqts.	Tail Rotor Reqts.	Body Group Reqts.	Alighting Gear Reqts.
NOTE: See columns 1 through 5	NOTE: See columns 1 through 5	NOTE: See columns 1 through 5	NOTE: See columns 1 through 5
			Wheels & Brakes MIL-W-5013H (1): 3.4.3.12 Static Balance See Appendix II
			Brake Syst., Wheel, Dsgn. MIL-B-8584C (No vibration reqts.)
			Tires, Pneum., Aircraft MIL-T-5041F (1) 3.5.6; 3.8.1; 4.4.1; 4.5.2 - Balance
			Shock Absorbers MIL-L-8552C (2): (No vibration reqts.)
			NOTE: See Hydraulic system, Col. 14 , also.

Figure 38. Continued.

10	11	12	13
Flight Control Syst., Dsgn., Install & Test of, Acft. MIL-F-18372 (Aer) 3.1.1.18.3 Tubes (Push-Pull) 3.1.1.19.3 Tubes (Torque systems) 3.5.1 General (Tests and Dsgn. Data Reqts.)	Eng. Sect./Nacelle Reqts. NOTE: See columns 1 through 5	Propulsion Reqts. NOTE: See columns 1 through 5 Tank, Fuel, Acft., SS MIL-T-5578C (2) Tank, Fuel & Oil MIL-T-6396C (ASG)	Instruments and Navigation Equipt., Aircraft; Install of MIL-1-18373A (AS) NOTE: See columns 14, 15, 16 also.
Control & Stabilization Syst., Automatic, Piloted Aircraft; Gen'l. Spec for MIL-C-18244A (WEP)		Fuel Syst. Comp. MIL-F-8615C Fuel Syst.: Acft., Instl. & Test of MIL-F-17874B Fuel & Oil Lines, Acft., Installation of MIL-I-18802A (WEP) See Appendix II Oil Syst., Acft. MIL-D-19838 (No vibration reqts.) Transmission Syst. MIL-T-5955	

NOTES:

(1) See columns 1 through 5

(2) See Hysraulic System also (Col. 14).

Figure 38. Continued.

14	15	16	17
Hydraulic System, Aircraft, Design, Installation, & Data Reqts. MIL-H-5440E: 3.1 Design 3.10.1 Dsgn. practice & installation 3.10.29.6 Vibration 4.2.1 Vibration	Electrical Equip., Aircraft, Selection & Installation of MIL-E-7080B (3)	Electronic Equip., Airborne, Gen'l. Spec MIL-E-5400M (2)	Armament Reqts.
	Electrical Syst., Acft. Design & Install. of MIL-E-25499C	Inst'l. & Test of Electr. Equip. in Aircr. MIL-I-8700A	Instl. of Droppable Stores & Assoc. Rel. Syst. MIL-I-8671
Hydraulic System Components, Aircraft & Missiles, General Specification for MIL-H-8775C	Lights, Aircraft, Gen'l. Spec for MIL-L-6723B	Test Methods for Electronic & Electrical Component Parts MIL-STD-202D (1) (See column 15)	Instl. of Armament Ctrl. Syst. & Assoc. Eqt. MIL-I-8677
Cylinders; Aeronautical, Hydraulic Actuating, General Reqts. for MIL-C-5503C (3)	Test Methods for Electronic & Electrical Component Parts MIL-STD-202D (1)	Enviornmental Test Methods MIL-STD-810B (4) (See column 5)	
	Environmental Test Methods MIL-STD-810B (4) (see column 5)	Standard General Reqts. for Electronic Equipment MIL-STD-454C (No vibration reqts.)	

Figure 38. Continued.

18	19	20	21
Furnishings & Equip. Reqts.	Air Cond. & Anti-Ice Reqts.	Aux. Gear Reqts.	Special Equipt. Reqts. (No vibration reqts)
NOTE: See columns 1 through 5	Heating & Ventilating Systems, Acft. MIL-H-18325B (Aer)	Towing Reqts. & Prov. MIL-T-7935	

Figure 38. Concluded.

The impact of vibration on reliability as an independent influence may cause a failure rate which varies with time rather than one which is constant with time. This is to say that reliability would be expressed as

$$R = e^{-\int_0^t \lambda (t')dt'} \qquad (18)$$

instead of

$$R = e^{-\lambda t} \qquad (19)$$

where
R = reliability
λ = constant failure rate
$\lambda(t)$ = time varying failure rate
t = time

In the reliability test methods of MIL-STD-781B, an attempt is made to not only subject the equipment to vibratory stress at a specified level, 2.2G ±10% peak, but also to include exposure time related to multiples of the specified MTBF. However, close examination of the test requirement shows that an equipment is exposed to the vibratory stress for approximately 1/6 of the total test time (hot/cold cycling occurring at the same time). Thus, MIL-STD-781B test methods also appear to be insufficient in simulating equivalent exposure time to vibratory stress since and equipment when airborne in a helicopter will be subjected to vibratory stress 100% of the time.

Comparisons made between the vibration values cited in MIL-H-8501 (see Appendix II) and MIL-STD-810B or MIL-STD-781B show a difference in value which varies by an order of magnitude; i.e., 0.2g to 0.4g versus 2.0g to 5.0g. It is apparent that general design and test procedures related to vibration are not necessarily designed with reliability in mind. The discrepancy noted in MIL-STD-781B, relative to exposure time, shows up a weakness in the reliability test specification which requires corrective action.

A reading of all the specifications cited in Table XIX, and in particular, those paragraphs called out in Figure 38, will present observations similar to those above with respect to vibratory stress levels and exposure times (other environmental influence notwithstanding).

The above observations suggest that components specifications should relate more closely to the vibration environment that prevails in helicopters. The above observations also suggest that the allowable vibration specification for the helicopter (MIL-H-8501) should deal with the whole aircraft and not just the crew and passenger compartments. By having a more favorable vibration environment throughout the aircraft, component R/M would be improved.

It is suggested that a happy meeting ground exists between making components more tolerant of vibration and making the whole helicopter less of a vibrating machine.

DISCUSSION OF RESULTS

RELIABILITY

On the basis of the data utilized to conduct the study of vibration effects on helicopter reliability, the reliability improves with the reduction of vibratory stress.

In general, a component subjected to a very large number of vibratory stress cycles will require a small percentage improvement in strength or reduction in vibratory stress to go from a severely limited life to an acceptable period of useful life.[4] Many components exhibited a large percentage reduction or zero failures in the absorber-equipped aircraft as compared to a significant number of failures in the nonabsorber aircraft.

Table XXI compares the percentage change in the reliability to the percentage change in the average vibration level for the 13 subsystems considered in the study. The manner in which the one ratio is related to the other is unknown. The overall data presented in Tables V through XI, and Figures 16 through 34 suggest the response of reliability to changes in vibratory stress will possess different slopes for different types of components, dependent upon their construction, material used, method of installation, and location in the aircraft.

Overall changes in the entire aircraft reliability with respect to changes in vibration can be observed from Table IV. There was a 48% reduction in the total aircraft failure rate between the H-3 helicopter without and with the vibration absorber.

The evidence indicates, in all comparisons made, i.e., component level, subsystem level, and aircraft level, a decreasing failure rate with decreasing vibratory stress level.

Several components listed in Tables VI through XI did, however, show a somewhat higher failure rate for aircraft with the absorber. This effect is prevalent primarily in components located in the forward portion of the aircraft. Prior to adding the bifilar absorber to the H-3, a battery absorber, mounted in the forward equipment bay, was used to dampen vibrations in the cockpit area. (The battery absorber is standard equipment in the without-absorber group of aircraft). The vibration amplitude in the nose of the aircraft was nearly the same for both aircraft populations. The battery absorber is very effective in reducing the vibration in the nose of the aircraft but is ineffective throughout the rest of the aircraft. Because the bifilar absorber had a greater overall effect on reducing aircraft vibration, the battery absorber was removed from aircraft having the bifilar absorber.

Vibration data shown in Figure 11 are taken from aircraft equipped with the battery absorber, and the vibration data shown in Figure 12 are taken from aircraft with the bifilar absorber installed and battery absorber removed. (The battery absorber is so called because the aircraft battery, supported in special absorber mount, served to supply the mass needed to

TABLE XXI. RATIO CHANGE IN AVERAGE FAILURE RATE AND RATIO CHANGE IN AVERAGE VIBRATION LEVEL

System	$1 - \frac{\lambda_w}{\lambda_{w/o}}$	$\frac{g_w}{g_{w/o}}$
Airframe	0.52	0.56
Drive	0.56	0.35
Utilities	0.78	0.56
Landing Gear	0.51	0.63
Lights	0.65	0.53
Fuel	0.59	0.60
Flight Controls	0.52	0.42
Cockpit Fuselage	0.70	0.55
Electrical	0.65	0.52
Hydraulic Power	0.54	0.54
Intercommunication	0.46	0.66
Radio Navigation	0.25	0.75
Airconditioning/Heating	0.44	0.40

acquire proper tuning and damping factor).

The heater ignition unit of the absorber equipped aircraft also showed an inordinate increase in failure rate, and it is suggested that the increase was caused by the requirement to use the heater more frequently in the northern latitudes where the absorber-equipped aircraft are located.

The basic objective of showing impact of vibratory stress on the reliability characteristic of airborne equipment has been met and the tabulated and illustrated results strongly suggest that the reliability improves significantly when significant reductions in vibratory stress are achieved.

The data suggest that the useful life of an aircraft can be extended without the need to strengthen or redesign certain airborne components to withstand vibratory stress if adequate methods of damping vibration or isolating equipment from vibratory stress are used. This assumes, however, that adequate testing which simulates the actual vibration environment is also conducted.

MAINTAINABILITY

Corrective maintenance performed on an aircraft is a direct function of the reliability inherent in the design, and it follows that for any improvement made in reliability a proportionate reduction in maintenance should also be achieved. The data analyzed in this study show that in all but a few cases drastic reductions in maintenance were evidenced as a direct result of the reduced vibratory stress and the increased reliability resulting therefrom.

However, the reduction in average failure rate does not fully account for the reduced maintenance because in addition to a lower frequency there is also a lower mean-time-to-repair in some cases. For instance, using data from Table V the average maintenance man-hours per failure expended against the central frames assuming the same size repair crew, is given by

$$\frac{\text{MMH}}{\text{Failure}} = \frac{\text{MMH/1000FH}}{\text{Failures/1000FH}} \qquad (20)$$

For the without absorber case then

$$\frac{\text{MMH}}{\text{Failure}} = \frac{83.2}{5.0} = 16.0 \qquad (21)$$

and for the with absorber case then

$$\frac{\text{MMH}}{\text{Failure}} = \frac{6.1}{2.6} = 2.3 \qquad (22)$$

It appears that the extensiveness of the damage incurred (chargeable as a failure) is less in the with-absorber case than in the without-absorber case, and thus less repair work is required. This also implies, that although airborne components continue to fail or require corrective action, the degree to which a component function is degraded and the extent to which repair time is required to return the component to a functional status are also reduced due to the improved vibration environment. This observation can be borne out by applying equation (20) to the data presented inTables VI through XI.

Table XXII presents the ratio of change in MMH/FH and the ratio of change in average vibration. The manner in which the one ratio is related to the other is unknown. The overall data presented in Table V through XI and Figures 16 through 34 suggest the response of maintenance to changes in vibratory stress will possess different slopes for different types of components, dependent upon their configuration and location in the aircraft.

The study also considered the impact of the reduction in vibration level on the preventive maintenance tasks. There was an increase in frequency and maintenance man-hours for preflight inspection and an increase in maintenance man-hours for postflight inspections in the absorber-equipped aircraft.

The reasons why this should occur in the face of reductions shown for corrective maintenance are unknown, but either local preventive maintenance policies or a more rigorous operational schedule may account for this effect. Table XV shows that although there was an increase in frequency and maintenance man-hours, the average number of maintenance man-hours per preflight inspection are 5.3 MMH in the without-absorber case and 5.0 MMH in the with-absorber case. This implies a greater aircraft operational frequency because preflight inspections are done prior to the start of each flight.

The 50% increase in the maintenance man-hours for postflight inspection in the absorber case is felt to be caused by local maintenance policy which allows portions of the periodic inspection to be performed when a postflight inspection is performed.[5] This accounts, in part, for the significant change in periodic inspection frequency and maintenance in the absorber-equipped aircraft. However, it is also known that the USAF changed the periodic inspection interval from 50 to 100 hours during the time period covered by the data, so a large portion of the reduction in frequency of periodic inspections may be due to this policy change.

It would appear that the ratio of the look-phase time to the fix-phase time would increase because of the decrease in the number of discovered failures; thus, preventive maintenance intervals should be guided by the amount of fixing required subsequent to an inspection. If, in the long term, inspections do not turn up discrepancies, preventive maintenance resources should be conserved by increasing the inspection interval.

TABLE XXII. RATIO CHANGE IN MMH/FH AND RATIO CHANGE IN AVERAGE VIBRATION LEVEL

SYSTEM	$1 - \frac{MMH/FH_w}{MMH/FH_{w/o}}$	$\frac{g_w}{g_{w/o}}$
Airframe	.65	.56
Drive	.42	.35
Utilities	.75	.56
Landing Gear	.71	.63
Lights	.70	.53
Fuel	.57	.60
Flight Controls	.54	.42
Cockpit/Fuselage	.53	.55
Electrical	.67	.52
Hydraulic Power	.74	.54
ICS	.30	.66
Radio Navigation	-.04	.32
Airconditioning/Heating	.63	.40

SPECIFICATION ASSESSMENT

The specifications governing the requirements for designing to a stated vibration environment are suitable in terms of determining resonant responses in an equipment, early fatigue failures, or gross deficiencies in mechanical design, but are lacking in requirements related directly to reliability. This is evident even in the one specification written specifically for reliability testing, MIL-STD-781B.

A more deliberate and well-designed specification along with detailed procedure is necessary such that (1) helicopter vibration levels are specified throughout the aircraft, (2) component specifications are related to the appropriate specified helicopter vibration levels, (3) the nature of the vibration level/endurance characteristics of different types of components are learned, and (4) the statistical variability to be expected among parts is taken into account.

The change in reliability and maintainability under the influence of vibration can be dramatic, as is evidenced by the data presented earlier, and thus, it becomes important that design and testing for the vibration environment be carefully scrutinized prior to planning and performing reliability or maintainability demonstration tests.

Considerable work has been performed and documented relative to developing vibration stress cycling curves for the many materials used in airborne applications. However, except for special programs, little has been accomplished in the reliability area for complete equipment by type, function, or degree of complexity. For example, the difference in the average failure rates as related to difference in vibration level for the types of components shown in Tables VI through XI could not be generalized in a series of curves of mathematical expression because of the lack of data between the recorded points. However, this gap in the data could be filled by subjecting a large group of specimens to a test program which varies the vibratory stress over the range not covered. This kind of program would allow for acquiring the same basic data for components of varying types, functions, and complexities as has been done for base materials.

CONCLUSIONS

Comparison of system and component reliability behavior, as affected by a reduction in vibratory stress, indicates improvements of 48.7% in reliability with a resultant reduction of 38.5% in maintenance due to a 54.3% reduction in vibration level.

The series of bar graphs presented in Figures 16 through 34 show that there are variations in the way in which reliability and maintainability change with respect to change in vibratory stress even within families of similar components. It is concluded that more discrete data, acquired from a closely controlled test program, would be required on each group of components to determine the precise characteristic of the variation of reliability with respect to changes in vibratory stress.

The reduction in the frequency of failure with respect to the improvement in the vibration characteristic suggests that the useful life of aircraft components can be extended without making any design changes in the equipment by reducing the vibration of the helicopter. This statement assumes, in large part, that failures caused by vibration are fatigue related, and according to Heywood[4], small changes in vibratory stress can result in a component's life characteristic being changed from a severely limited life to a reasonable life.

The improved reliability resulting from the reduced vibratory stress environment results in less corrective maintenance being expended on the CH-3 aircraft. This results in less downtime on the aircraft, thereby improving availability and contributing to the reduction in the operating cost of the aircraft.

The life-cycle cost analysis, based upon the data presented, shows that LCC may be reduced by as much as 10% for the 13 aircraft subsystems considered in the study, because of the improved reliability and maintainability brought about by diminishing vibratory stress. The reductions are manifested by lessening the costs of direct maintenance manpower and spares, and by improving helicopter utilization.

Assessment of the various vibration design and test specifications reveal that they are inadequate relative to vibration design requirements and test criteria that can be related to the prediction of actual operational reliability. The inadequacies result from insufficient knowledge of the vibration level/endurance characteristics of various types of aircraft components and from the lack of vibration level requirements for helicopter zones other than the cockpit and personnel cabin areas.

RECOMMENDATIONS

The following recommendations are made based upon the results of this study:

1. Establish a vibration test program such that basic data can be acquired which will eventually allow the formulation of the general relationships between reliability and effect of vibratory stress levels and accumulative cycles on helicopter borne components. A sample group of helicopter components such as lines, hoses, lights, primary and secondary structure could be used in this type of test program to expand the test to more complex or differently configured components.

2. Perform basic research and analyses in order to establish an adequate specification which uniquely relates helicopter component reliability to vibratory stress exposure.

3. Establish a study/test program to research and report upon the various devices, both active and passive, which will reduce the vibratory environment of helicopter components.

4. Expand helicopter vibration specifications to cover all significant areas of the aircraft (not just those occupied by personnel) where component fatigue damage may result.

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APPENDIX I
CLIMATIC BRIEFS

TABLE XXIII. AWS CLIMATIC BRIEF, EGLIN AFB, FLA.

AWS CLIMATIC BRIEF EGLIN AFB, VALPARAISO, FLORIDA — PERIOD [illegible] — WBAN # 13[illegible] — WMO # 72221

Prepared by ETAC ([illegible] 1970) [illegible] — ELEVATION [illegible] ft, STN LTRS [illegible]

MONTH	Temp (°F) Extreme Maximum	Mean Daily Maximum	Mean Daily Minimum	Extreme Minimum	Precip (in) Mean Total	Maximum in 24 Hours	Mean Snowfall	Max Snowfall in 24 Hours	Wind (KT) Prevailing Direction	Mean Speed	Extreme Speed (Peak) (Gusts)	Mean Relative Humidity (%) 0600	1300	Dew Point (°F)	Vapor Pressure (in Hg)	Pressure Altitude	[illegible]	Mean Number of Days: Precip ≥ .01	Precip ≥ 0.5	Snowfall ≥ 0.1	Snowfall ≥ 1.5	Thunderstorms	Fog (≤ 7 Miles)	Temperature (°F) Maximum ≥ [illegible]	Maximum ≥ [illegible]	Minimum ≤ 32	Minimum ≤ 0	Mean Clouds (Tenths)
JAN	7[illegible]	61	[illegible]	11	[illegible]	5.0	∅	∅	[illegible]	7	[illegible]	73	62	[illegible]	[illegible]	400		8	3	0	0	1	17	0	0	7	0	6
FEB	80	[illegible]	45	12	3.7	[illegible]	∅	2	[illegible]	[illegible]	51	[illegible]	[illegible]	[illegible]	.32	450		[illegible]	2	∅	0	2	15	0	∅	[illegible]	0	6
MAR	89	[illegible]	50	2[illegible]	6.2	[illegible]	∅	∅	[illegible]	7	57	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		10	4	0	0	4	15	0	1	1	0	6
APR	92	76	57	29	5.3	6.1	0	0	S	7	52	85	[illegible]	[illegible]	.47	400		6	3	0	0	4	15	∅	[illegible]	∅	0	5
MAY	102	84	65	40	3.2	3.1	0	0	[illegible]	7	48	87	57	[illegible]	.60	300		5	2	0	0	6	12	3	26	0	0	5
JUN	102	89	72	55	5.5	5.8	[illegible]	[illegible]	[illegible]	6	62	[illegible]	62	71	.77	300		10	4	0	0	11	8	12	27	0	0	5
JUL	100	90	74	60	7.6	7.3	0	0	[illegible]	6	58	90	66	73	.81	200		15	5	0	0	16	4	16	31	0	0	6
AUG	104	90	73	64	7.1	5.6	0	0	S	6	70	90	64	73	.81	250		12	4	0	0	14	6	19	[illegible]	0	0	5
SEP	97	87	70	48	7.7	5.6	0	0	SE	6	57	58	62	69	.72	350		10	3	0	0	6	8	9	27	0	0	5
OCT	95	80	59	33	2.6	6.7	0	0	S	6	54	83	[illegible]	58	.43	350		5	1	0	0	2	9	1	10	0	0	4
NOV	89	69	48	17	3.6	3.2	0	0	S	7	54	83	56	49	.35	350		7	2	0	0	2	12	0	2	2	0	5
DEC	79	63	[illegible]	9	4.9	3.8	∅	∅	S	6	[illegible]	83	[illegible]	44	.29	350		9	3	0	0	1	15	0	0	6	0	5
ANN	[illegible]	77	58	[illegible]	61.1	8.[illegible]	∅	1	[illegible]	7	[illegible]	87	[illegible]	58	[illegible]	400		[illegible]	36	∅	0	59	135	60	174	20	0	5
EYR	[illegible]	[illegible]	24	[illegible]	24	[illegible]	19	2[illegible]	25	[illegible]	16	25	[illegible]	25	[illegible]	25		[illegible]	[illegible]	19	19	19	19	24	24	24	24	15

REMARKS

[illegible] POR: Hourly Obs - Jan [illegible] - Nov [illegible]

Daily Obs - Jan [illegible] - May [illegible]

NOTE: [illegible] DATA NOT AVAILABLE. [illegible] LESS THAN 0.5 DAY, 0.5 OR 0.05 INCH, OR 0.5 PERCENT ([illegible]) AS APPLICABLE.

FLYING WEATHER (% FREQ)	HOURS (LST)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	EYR
CIG less than 3000 feet and / or VSBY less than 3 miles	00 - 02	35	3[illegible]	33	30	15	7	5	[illegible]	9	10	2[illegible]	32	19	
	03 - 05	39	37	3[illegible]	34	22	13	13	6	14	23	23	33	24	
	06 - 08	38	40	[illegible]	31	22	17	13	11	19	16	25	35	25	
	09 - 11	33	31	30	25	16	20	20	19	18	14	21	28	[illegible]	
	12 - 14	26	27	25	[illegible]	14	15	17	15	[illegible]	[illegible]	18	[illegible]	[illegible]	
	15 - 17	[illegible]	23	25	[illegible]	[illegible]	[illegible]	11	[illegible]	[illegible]	[illegible]	15	23	[illegible]	
	18 - 20	[illegible]	24	27	20	12	8	7	7	11	9	1[illegible]	25	[illegible]	
	21 - 23	31	25	[illegible]	22	11	9	5	4	10	5	13	[illegible]	[illegible]	
	ALL HOURS	32	30	31	25	16	12	11	10	[illegible]	11	23	27	23	25
CIG less than 1500 feet and / or VSBY less than 3 miles	00 - 02	30	27	29	27	12	[illegible]	2	1	[illegible]	[illegible]	[illegible]	[illegible]	25	
	03 - 05	33	33	31	33	1[illegible]	[illegible]	5	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	06 - 08	31	32	[illegible]	25	25	[illegible]	5	[illegible]	13	12	[illegible]	[illegible]	[illegible]	
	09 - 11	[illegible]	22	[illegible]	[illegible]	[illegible]	6	5	3	8	[illegible]	[illegible]	[illegible]	13	
	12 - 14	[illegible]	26	[illegible]	[illegible]	[illegible]	4	4	3	6	[illegible]	5	[illegible]	[illegible]	
	15 - 17	[illegible]	[illegible]	[illegible]	[illegible]	5	3	2	[illegible]	5	[illegible]	[illegible]	[illegible]	[illegible]	
	18 - 20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	2	[illegible]	4	[illegible]	11	1	[illegible]	
	21 - 23	25	21	25	20	[illegible]	[illegible]	1	[illegible]	2	5	13	[illegible]	[illegible]	
	ALL HOURS	[illegible]	22	[illegible]	[illegible]	12	5	3	3	[illegible]	6	[illegible]	22	[illegible]	25
CIG less than 1000 feet and / or VSBY less than 2 miles	00 - 02	25	22	[illegible]	23	[illegible]	2	[illegible]	1	3	4	12	[illegible]	12	
	03 - 05	27	25	[illegible]	24	13	5	[illegible]	[illegible]	[illegible]	[illegible]	14	[illegible]	[illegible]	
	06 - 08	[illegible]	24	[illegible]	[illegible]	[illegible]	5	[illegible]	3	[illegible]	[illegible]	13	[illegible]	13	
	09 - 11	[illegible]	[illegible]	15	[illegible]	3	2	2	[illegible]	[illegible]	[illegible]	[illegible]	14	[illegible]	
	12 - 14	22	20	11	[illegible]	[illegible]	2	1	1	3	1	5	[illegible]	5	
	15 - 17	13	11	[illegible]	[illegible]	2	1	1	1	3	[illegible]	6	12	[illegible]	
	18 - 20	[illegible]	15	[illegible]	13	[illegible]	1	1	[illegible]	3	2	3	[illegible]	[illegible]	
	21 - 23	21	18	22	17	5	1	∅	1	2	3	10	[illegible]	[illegible]	
	ALL HOURS	20	18	15	15	6	2	1	2	4	4	10	13	[illegible]	25
CIG less than 200 feet and / or VSBY less than ½ mile	00 - 02	11	11	11	7	1	∅	∅	0	∅	1	5	7	5	
	03 - 05	12	11	10	8	4	1	∅	∅	1	1	[illegible]	[illegible]	5	
	06 - 08	10	8	6	4	1	1	∅	∅	1	2	4	6	4	
	09 - 11	3	2	2	[illegible]	0	0	∅	∅	∅	∅	∅	1	1	
	12 - 14	2	1	1	∅	∅	∅	∅	∅	∅	0	∅	∅	∅	
	15 - 17	3	[illegible]	2	1	∅	1	0	0	∅	[illegible]	1	1	[illegible]	
	18 - 20	4	4	5	1	0	∅	0	∅	0	0	1	[illegible]	2	
	21 - 23	9	7	8	3	0	0	0	∅	∅	∅	3	6	3	
	ALL HOURS	[illegible]	6	5	3	1	∅	∅	∅	∅	1	2	4	2	25

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TABLE XXIV. AWS CLIMATIC BRIEF, FORBES AFB, KANSAS

AWS CLIMATIC BRIEF Forbes AFB, Topeka, Kansas — PERIOD 1942-65 — WBAN # [illegible] — AVO #

Prepared by ETAC (Feb 1969) N38 57 W95 40 — ELEVATION 1074 (ft) STN LTRS [illegible]

MONTH	TEMPERATURE (°F) EXTREME MAXIMUM	MEAN DAILY MAXIMUM	MEAN DAILY MINIMUM	EXTREME MINIMUM	PRECIPITATION (in) MEAN TOTAL	MAXIMUM IN 24 HOURS	MEAN SNOWFALL	MAX SNOWFALL IN 24 HOURS	WIND (KT) PREVAILING DIRECTION	MEAN SPEED	EXTREME SPEED (Peak) (Gusts)	MEAN RELATIVE HUMIDITY (%) 0600	1300	DEW POINT (°F)	VAPOR PRESSURE (in Hg)	PRESSURE ALTITUDE 29.95 (ft)	MEAN NUMBER OF DAYS PRECIP ≥ 0.01	PRECIP ≥ 0.5	SNOWFALL ≥ 0.1	SNOWFALL ≥ 1.5	THUNDERSTORMS	FOG (< 7 miles)	TEMPERATURE (°F) MAXIMUM ≥ 90	MAXIMUM ≥ 80	MINIMUM ≤ 32	MINIMUM ≤ 0	MEAN CLOUDS (Tenths)
JAN	69	37	19	-15	1.3	4.4	7	12	N	9	47	79	65	20	.10	1700	6	1	4	2	#	10	0	0	27	2	5
FEB	77	44	24	-3	1.1	1.3	4	6	N	9	64	78	61	24	.12	1800	8	1	3	1	1	11	0	0	22	#	6
MAR	90	51	31	-6	2.8	2.4	6	9	NW	10	50	76	58	30	.16	1800	9	2	3	1	2	10	#	1	17	#	6
APR	95	66	44	24	3.3	3.5	1	6	S	10	54	76	52	41	.26	1800	9	2	1	#	5	8	#	4	4	0	6
MAY	97	75	54	29	4.1	3.1	#	#	S	9	60	82	55	53	.40	1500	11	3	0	0	8	6	1	11	#	0	6
JUN	106	84	64	44	4.6	4.1	0	0	S	9	49	84	57	63	.58	1500	10	3	0	0	9	5	8	22	0	0	5
JUL	111	89	69	53	3.7	4.6	0	0	S	7	51	82	53	66	.64	1350	9	2	0	0	8	4	13	29	0	0	5
AUG	107	89	67	48	3.5	3.3	0	0	S	8	40	81	52	64	.60	1350	7	2	0	0	6	5	15	27	0	0	5
SEP	104	80	58	33	2.8	2.8	#	#	S	9	42	79	50	55	.43	1450	7	2	0	0	5	6	6	16	0	0	4
OCT	96	70	47	24	2.3	4.8	#	#	S	8	47	76	48	44	.29	1550	6	2	#	0	2	6	1	6	2	0	3
NOV	79	54	34	4	1.3	2.3	1	5	S	9	46	76	53	32	.18	1750	6	1	1	#	1	6	0	0	14	0	4
DEC	70	41	23	-9	1.6	3.3	4	4	NW	8	50	79	64	23	.12	1700	5	1	3	1	1	9	0	0	25	1	5
ANN	111	65	45	-15	32.4	4.8	23	12	S	9	64	79	56	43	.28	1650	93	22	15	5	43	36	45	115	111	3	5
EYR	20	20	20	20	20	20	15	15	20	20	10	20	20	20	20	20	20	20	15	15	16	16	20	20	20	20	15

REMARKS

NOSSWO POR: Hourly Obs: Oct 42 - Jun 47, Dec 47 - Nov 49, Feb 52 - Mar 65

Daily Obs: Oct 42 - Jun 47, Dec 47 - Nov 49, Feb 52 - Oct 54

NOTE: [illegible] NOT AVAILABLE. # LESS THAN [illegible] INCH, OR 0.5 PERCENT (%) AS APPLICABLE

FLYING WEATHER (% FREQ)	HOURS (LST)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	EYR
CIG less than 3000 feet and / or VSBY less than 3 miles	00 - 02	27	[illegible]	29	13	14	5	4	5	8	11	17	[illegible]	16	
	03 - 05	23	27	27	21	17	11	8	7	12	13	[illegible]	[illegible]	18	
	06 - 08	32	29	[illegible]	22	22	15	11	13	15	17	[illegible]	[illegible]	[illegible]	
	09 - 11	[illegible]	29	32	23	21	17	9	8	15	[illegible]	[illegible]	27	[illegible]	
	12 - 14	27	26	27	22	19	14	7	7	13	11	19	26	[illegible]	
	15 - 17	24	25	25	18	14	9	4	5	9	[illegible]	17	[illegible]	[illegible]	
	18 - 20	23	24	22	14	12	9	3	[illegible]	7	3	[illegible]	[illegible]	14	
	21 - 23	25	23	22	14	12	7	3	5	5	[illegible]	[illegible]	[illegible]	14	
	ALL HOURS	27	30	25	19	16	11	6	6	11	12	[illegible]	[illegible]	17	[illegible]
CIG less than 1500 feet and / or VSBY less than 3 miles	00 - 02	21	19	17	11	9	4	2	4	6	[illegible]	12	[illegible]	[illegible]	
	03 - 05	[illegible]	[illegible]	[illegible]	[illegible]	11	[illegible]	5	6	9	[illegible]	[illegible]	[illegible]	[illegible]	
	06 - 08	[illegible]	22	21	15	14	[illegible]	9	[illegible]	12	14	[illegible]	22	[illegible]	
	09 - 11	25	21	20	14	12	7	4	6	11	[illegible]	[illegible]	[illegible]	[illegible]	
	12 - 14	22	19	15	10	9	4	2	3	9	[illegible]	[illegible]	[illegible]	[illegible]	
	15 - 17	[illegible]	[illegible]	[illegible]	9	[illegible]	3	1	2	7	[illegible]	[illegible]	[illegible]	[illegible]	
	18 - 20	19	[illegible]	14	8	7	3	1	2	4	[illegible]	[illegible]	[illegible]	[illegible]	
	21 - 23	[illegible]	15	15	8	7	4	1	3	4	[illegible]	11	1	[illegible]	
	ALL HOURS	[illegible]	19	27	[illegible]	9	5	2	4	7	[illegible]	12	[illegible]	12	[illegible]
CIG less than 1000 feet and / or VSBY less than 2 miles	00 - 02	15	14	12	7	5	3	2	3	4	[illegible]	3	[illegible]	[illegible]	
	03 - 05	[illegible]	15	12	[illegible]	[illegible]	[illegible]	4	4	7	7	[illegible]	15	[illegible]	
	06 - 08	[illegible]	17	14	10	9	7	5	6	9	9	10	[illegible]	11	
	09 - 11	[illegible]	15	13	7	7	[illegible]	3	3	7	7	9	[illegible]	[illegible]	
	12 - 14	15	14	11	5	5	2	1	1	4	4	7	13	[illegible]	
	15 - 17	13	12	10	5	4	2	1	1	3	[illegible]	6	12	[illegible]	
	18 - 20	13	12	10	5	4	2	[illegible]	1	2	[illegible]	[illegible]	12	[illegible]	
	21 - 23	14	11	10	4	5	2	3	1	3	5	7	14	[illegible]	
	ALL HOURS	15	15	11	7	6	3	2	2	5	[illegible]	8	13	[illegible]	[illegible]
CIG less than 200 feet and / or VSBY less than 1/2 mile	00 - 02	5	4	2	1	1	#	#	#	1	2	2	5	2	
	03 - 05	6	4	2	2	2	#	1	#	1	2	2	5	2	
	06 - 08	6	5	3	2	1	1	1	1	1	2	2	5	3	
	09 - 11	5	3	2	#	0	0	#	0	#	#	1	4	1	
	12 - 14	3	1	1	#	0	#	0	0	0	0	#	2	1	
	15 - 17	2	1	1	#	#	#	#	#	#	#	#	2	1	
	18 - 20	3	2	1	#	#	#	#	#	#	#	#	2	1	
	21 - 23	3	2	1	#	#	#	1	#	#	1	1	3	1	
	ALL HOURS	4	3	2	1	1	#	#	#	#	1	1	4	1	[illegible]

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TABLE XXV. AWS CLIMATIC BRIEF, PARKS AFB, P.I.

AWS CLIMATIC BRIEF — MANILA INTL/NICHOLS FLD, PHILIPPINES — PERIOD 1949-63 — WBAN # 41204 — WMO # 98429

Prepared by ETAC (OCT 1970) — N 14 31 E 121 01 — ELEVATION: 84 ft — STN LTRS RPMM

MONTH	Temp (°F) Extreme Maximum	Mean Daily Maximum	Mean Daily Minimum	Extreme Minimum	Precip (in) Mean Total	Maximum in 24 Hours	Mean Snowfall	Max Snowfall in 24 Hours	Wind (KT) Prevailing Direction	Mean Speed	Extreme Speed (Max Wind)	Mean Relative Humidity (%) 0000	1300	Dew Point (°F)	Vapor Pressure (in Hg)	Pressure Altitude 99.95% (feet)	Mean No. Days Precip ≥ 0.01	Precip ≥ 0.5	Snowfall ≥ [illegible]	Snowfall ≥ [illegible]	Thunderstorms	Fog (< 7 Miles)	Temp Max ≥ 90	Max ≥ 80	Min ≤ 70	Min ≤ 60	Mean Clouds (Tenths)
JAN	96	87	68	59	0.5	0.7			E	5	27	91	61	68	.68	250	4	#			#	0	3	31	19	#	6
FEB	93	89	69	58	0.3	0.6			E	7	27	88	57	68	.68	250	3	#			#	0	12	28	16	#	6
MAR	97	92	71	61	0.3	1.0			E	8	27	85	53	69	.71	250	3	#			#	0	26	31	11	0	5
APR	98	94	74	62	0.8	2.3			E	8	33	84	53	71	.76	300	3	#			2	0	28	30	1	0	5
MAY	99	94	76	67	3.3	2.3			ESE	7	33	86	55	73	.81	300	8	2			9	0	30	31	#	0	6
JUN	101	91	75	68	10.1	13.9			W	5	33	93	67	75	.87	350	16	5			13	0	21	30	#	0	8
JUL	96	89	75	67	11.2	7.7			W	5	33	95	71	75	.87	350	20	6			13	2	16	31	#	0	8
AUG	94	88	75	68	17.0	9.0			W	5	27	95	74	75	.87	400	23	9			11	2	11	30	#	0	9
SEP	94	88	74	66	12.7	9.0			W	5	27	96	76	75	.87	400	22	7			12	#	10	30	#	0	9
OCT	94	88	73	65	7.4	5.1			E	4	40	95	70	74	.84	350	17	5			9	#	13	31	1	0	7
NOV	93	87	71	62	4.6	4.6			E	4	27	94	68	72	.78	350	12	2			2	#	6	29	6	0	7
DEC	92	86	69	61	2.2	4.4			E	4	27	93	65	70	.73	350	9	1			#	#	2	31	15	0	7
ANN	101	89	73	58	70.4	13.9	*	*	E	6	40	91	64	72	.78	400	140	37	*	*	71	4	178	363	69	#	7
EYR	15	15	15	15	15	15			10	10	10	10	10	10	10	10	15	15			15	15	15	15	15	15	10

REMARKS

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Number Observed Within:		A/B	A/B	A/B	A/B	A/B	A/B	A/B	A/B	A/B	A/B	A/B	A/B	A/B
(POR: 1949-1969)	60 NM	0/0	0/0	0/0	1/1	1/1	2/2	2/2	1/0	2/0	5/1	2/1	1/1	17/9
A) Typhoons/Tropical Storms	120 NM	0/0	0/0	0/4	2/2	2/1	2/2	4/2	4/1	2/0	9/7	9/7	6/6	40/28
B) Typhoons Only	240 NM	1/0	0/0	1/1	4/4	7/3	7/5	12/6	13/7	11/6	18/13	22/16	11/9	107/70

RUSSWO POR: Hrly Obs: Jan54-Dec 63 Daily Obs: Mar 49-Dec 63 (Max wind) refers to highest wind speed interval

NOTE: *DATA NOT AVAILABLE. #LESS THAN 0.5 [illegible], 0.5 OR 0.05 INCH, OR 0.5 PERCENT (%) AS APPLICABLE.

FLYING WEATHER (% FREQ)	HOURS (LST)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	EYR
CIG less than 3000 feet and / or VSBY less than 3 miles	00 - 02	#	1	1	#	2	4	5	4	4	2	5	0	2	
	03 - 05	1	1	1	1	1	3	4	4	3	2	4	1	2	
	06 - 08	1	1	1	#	3	5	5	6	4	3	4	3	3	
	09 - 11	4	5	1	5	6	7	7	12	7	9	7	5	6	
	12 - 14	7	5	3	3	3	7	7	13	8	9	7	5	6	
	15 - 17	4	2	#	4	4	7	8	12	9	6	4	2	5	
	18 - 20	1	#	1	1	7	6	8	12	7	5	4	2	5	
	21 - 23	1	1	1	2	6	5	6	8	5	3	5	1	4	
	ALL HOURS	2	2	1	2	4	6	6	9	6	5	5	3	5	10
CIG less than 1500 feet and / or VSBY less than 3 miles	00 - 02	0	#	0	0	1	2	2	2	2	1	3	0	1	
	03 - 05	1	0	0	0	1	2	2	2	1	1	2	1	1	
	06 - 08	1	1	#	0	1	4	4	2	3	2	3	2	2	
	09 - 11	1	0	#	0	3	3	4	3	3	3	4	2	2	
	12 - 14	1	#	0	#	#	3	4	5	4	2	3	1	2	
	15 - 17	#	0	0	1	1	4	4	5	4	2	3	#	2	
	18 - 20	#	0	0	0	1	2	3	5	3	2	1	0	1	
	21 - 23	#	0	0	1	1	2	3	4	2	1	1	#	1	
	ALL HOURS	1	#	#	#	1	3	3	4	3	2	2	1	2	10
CIG less than 1000 feet and / or VSBY less than 2 miles	00 - 02	0	0	0	0	0	1	1	#	1	0	1	0	#	
	03 - 05	#	0	0	0	0	#	1	1	1	#	1	1	#	
	06 - 08	#	#	0	0	1	3	2	1	1	1	2	1	1	
	09 - 11	#	0	0	0	1	2	3	2	2	2	1	1	1	
	12 - 14	#	0	0	#	0	2	2	2	3	2	2	#	1	
	15 - 17	0	0	0	#	#	2	2	2	2	1	2	#	1	
	18 - 20	#	0	0	0	1	1	1	2	2	1	1	0	1	
	21 - 23	0	0	0	0	#	1	1	1	1	#	#	#	#	
	ALL HOURS	#	#	0	#	1	2	2	1	2	1	1	#	1	10
CIG less than 200 feet and / or VSBY less than ½ mile	00 - 02	0	0	0	0	0	0	0	0	1	0	#	0	#	
	03 - 05	0	0	0	0	0	0	0	#	#	0	1	#	#	
	06 - 08	#	0	0	0	0	1	0	0	#	0	1	#	#	
	09 - 11	#	0	0	0	0	0	#	#	0	0	0	0	#	
	12 - 14	#	0	0	0	0	#	#	#	#	0	0	0	#	
	15 - 17	0	0	0	#	0	#	0	#	0	#	#	0	#	
	18 - 20	0	0	0	0	0	0	0	#	0	#	0	0	#	
	21 - 23	0	0	0	0	0	0	#	#	0	0	#	0	#	
	ALL HOURS	#	0	0	#	0	#	#	#	#	#	#	#	#	10

TABLE XXVI. AWS CLIMATIC BRIEF, SHAW AFB, S. CAROLINA

AWS CLIMATIC BRIEF	SHAW AFB, SUMTER, S. CAROLINA	PERIOD 1942-66	WBAN # 13849 / WMO # 74790
Prepared by ETAC (DEC 1970)	N 33 58 W 80 28	ELEVATION: 262 ft	STN LTRS KSSC

MONTH	TEMPERATURE (°F) Extreme Maximum	Mean Daily Maximum	Mean Daily Minimum	Extreme Minimum	PRECIPITATION (in) Mean Total	Maximum in 24 Hours	Mean Snowfall	Max Snowfall in 24 Hours	WIND (KT) Prevailing Direction	Mean Speed	Extreme Speed (Peak Gust)	MEAN Relative Humidity (%) 0700	Relative Humidity (%) 1300	Dew Point (°F)	Vapor Pressure (In Hg)	Pressure Altitude 99.95% (Feet)	MEAN NUMBER OF DAYS Precip ≥ 0.01 in	Precip ≥ 0.5 in	Snowfall ≥ 0.1 in	Snowfall ≥ 1.5 in	Thunderstorms	Fog (< 7 Miles)	Temperature (°F) Maximum ≥ 90	Maximum ≥ 80	Minimum ≤ 32	Minimum ≤ 0	Mean Clouds (Tenths)
JAN	81	57	38	10	3.0	3.8	*	1	NE	6	48	79	56	36	.21	700	9	2	*	0	*	14	0	*	9	0	6
FEB	82	60	40	9	3.6	2.4	*	3	N	6	50	76	53	37	.22	800	9	2	*	*	1	12	0	*	6	0	6
MAR	89	65	45	20	4.3	2.3	*	4	N	7	58	77	50	41	.26	750	11	3	*	*	2	14	0	3	3	0	6
APR	92	75	54	32	3.6	2.7	0	0	SW	7	50	79	47	49	.35	750	8	3	0	0	4	12	*	11	*	0	5
MAY	99	83	62	40	3.0	4.1	0	0	SW	6	54	84	49	59	.50	600	8	2	0	0	6	13	5	23	0	0	5
JUN	104	89	69	51	4.7	6.3	0	0	SW	5	68	86	52	66	.64	550	9	3	0	0	8	14	15	28	0	0	5
JUL	103	90	72	59	5.7	3.5	0	0	SW	5	55	89	57	70	.74	450	12	4	0	0	11	13	17	30	0	0	6
AUG	102	89	71	56	5.0	3.3	0	0	SW	[illegible]	58	90	57	69	.71	500	10	–	0	0	9	18	16	30	0	0	5
SEP	101	84	66	44	4.1	6.6	0	0	NE	5	47	89	57	64	.60	550	8	2	0	0	4	18	7	22	0	0	5
OCT	99	75	55	30	2.8	3.9	0	0	NNE	5	50	84	51	53	.40	650	6	2	0	0	1	15	1	10	*	0	4
NOV	88	66	45	16	2.5	2.3	*	*	NNE	5	69	81	51	43	.29	[illegible]	7	2	0	0	1	13	0	2	2	0	5
DEC	80	56	38	8	3.1	2.8	*	5	NE	5	[illegible]	78	55	36	.21	650	9	2	*	*	*	14	0	*	10	0	5
ANN	104	74	55	8	45.4	6.6	*	5	SW	6	69	83	53	52	.39	700	106	31	*	*	47	170	61	159	30	0	5
EYR	23	23	23	23	23	23	20	20	25	25	19	25	25	25	25	18	23	23	20	20	20	20	23	23	23	23	21

REMARKS

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Number Observed Within:		A/B	A/B	A/B	A/B	A/B	A/B	A/B	A/B	A/B	A/B	A/B	A/B	A/B
(POR:1900-1969)	60 NM					1/0	2/0	3/2	5/1	8/3	7/0	1/0		27/6
A)Hurricanes/Tropical Storms	120 NM					1/0	6/0	6/3	9/5	16/6	12/4	1/0		51/18
B)Hurricanes Only	240 NM					1/0	10/2	10/4	22/11	34/16	23/7	1/0	1/1	102/41

RUSSWO POR: Hrly Obs: Jan 42 - Dec 66 Daily Obs: Jan 42 - Feb 44, Apr 44 - Jun 65

NOTE: – DATA NOT AVAILABLE. * LESS THAN 0.5 DAY, 0.5 OR 0.05 INCH, OR 0.5 PERCENT (%) AS APPLICABLE.

FLYING WEATHER (% FREQ)	HOURS (LST)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	EYR
CIG less than 3000 feet and / or VSBY less than 3 miles	00 - 02	22	21	19	15	12	11	10	10	18	18	19	21	16	
	03 - 05	27	25	22	20	19	18	18	19	27	23	24	24	22	
	06 - 08	33	31	28	23	25	22	25	27	35	28	29	29	28	
	09 - 11	29	26	24	20	20	20	24	22	29	21	22	26	24	
	12 - 14	24	22	19	15	14	14	18	16	22	15	15	21	19	
	15 - 17	20	19	17	11	9	10	11	10	13	12	12	17	12	
	18 - 20	19	18	16	9	7	8	8	9	12	12	11	17	12	
	21 - 23	19	18	15	10	8	7	8	8	13	13	13	19	13	
	ALL HOURS	24	23	20	15	14	14	15	15	21	15	18	22	13	25
CIG less than 1500 feet and / or VSBY less than 3 miles	00 - 02	17	17	15	11	9	8	8	7	13	13	[illegible]	17	12	
	03 - 05	21	21	18	15	16	16	15	17	23	18	19	20	15	
	06 - 08	27	26	24	18	20	19	22	24	31	25	25	22	22	
	09 - 11	23	22	17	12	11	10	12	11	19	14	18	21	16	
	12 - 14	16	15	12	7	5	4	4	3	8	6	10	15	9	
	15 - 17	14	12	11	5	3	3	4	3	6	6	7	12	7	
	18 - 20	13	13	12	5	3	4	4	5	6	8	7	12	8	
	21 - 23	15	13	12	7	5	4	5	4	8	9	9	13	9	
	ALL HOURS	18	17	15	10	9	8	9	9	14	13	13	17	13	25
CIG less than 1000 feet and / or VSBY less than 2 miles	00 - 02	15	13	12	7	6	6	6	6	11	10	12	13	10	
	03 - 05	17	16	14	11	12	12	12	14	20	15	15	17	15	
	06 - 08	21	20	17	13	15	14	17	18	24	19	19	19	18	
	09 - 11	17	16	13	7	5	4	5	6	11	10	13	16	10	
	12 - 14	12	10	8	4	2	2	2	2	4	5	6	11	6	
	15 - 17	11	8	8	3	2	1	2	2	3	4	9	9	5	
	18 - 20	10	9	8	3	2	2	2	2	4	5	5	9	5	
	21 - 23	12	10	9	4	3	2	3	3	6	7	7	11	6	
	ALL HOURS	14	13	11	7	6	5	6	6	10	9	10	13	9	25
CIG less than 200 feet and / or VSBY less than ½ mile	00 - 02	4	2	3	1	1	*	*	1	2	2	3	5	2	
	03 - 05	4	4	4	2	3	2	2	4	7	4	6	7	4	
	06 - 08	6	5	4	3	3	2	3	5	8	4	7	7	5	
	09 - 11	2	2	1	*	0	0	0	*	*	1	1	3	1	
	12 - 14	1	1	*	0	*	0	*	*	*	0	*	1	*	
	15 - 17	1	[illegible]	*	*	*	*	*	*	*	0	*	1	*	
	18 - 20	1	1	1	0	*	0	0	*	*	*	1	2	1	
	21 - 23	2	2	2	*	*	*	0	0	1	1	1	3	1	
	ALL HOURS	3	2	2	1	1	1	1	1	2	1	2	3	2	25

AWS FORM NOV 67 42 AWSP 105-4, VOL II

TABLE XXVII. AWS CLIMATIC BRIEF, THULE AFB, GREENLAND

AWS CLIMATIC BRIEF — Prepared by ETAC (OCT 1970)

THULE AB/OP SITE, GREENLAND — N 76 32 W 68 45 — PERIOD 1951-65 — ELEVATION: 261 ft — WBAN # 17605 — WMO # 04202 — STN LTRS BGTL

MONTH	Temp (°F) Extreme Maximum	Temp Mean Daily Maximum	Temp Mean Daily Minimum	Temp Extreme Minimum	Precip (in) Mean Total	Precip Maximum in 24 Hours	Precip Mean Snowfall	Precip Max Snowfall in 24 Hours	Wind (KT) Prevailing Direction	Wind Mean Speed	Wind Extreme (Peak) (Gusts) Speed	Mean Relative Humidity (%) 0400	Mean Relative Humidity (%) 1300	Mean Dew Point (°F)	Mean Vapor Pressure (in Hg)	Pressure Altitude 99.95% (Feet)	Mean No. Days Precip ≥0.01	Precip ≥0.5	Snowfall ≥0.1	Snowfall ≥1.5	Thunderstorms	Fog (< 7 miles)	Max Temp ≥60	Max Temp ≥50	Min Temp ≤32	Min Temp ≤0	Mean Clouds (Tenths)
JAN	38	-3	-17	-39	0.5	1.7	5	15	E	8	81	60	61	-21	.01	1850	7	*	7	*	0	5	0	0	31	28	5
FEB	43	-4	-18	-42	0.5	0.9	5	6	E	8	[1]77	59	59	-22	.01	1750	6	*	6	1	0	5	0	0	28	26	5
MAR	34	-8	-22	-44	0.2	0.4	2	4	E	6	90	57	57	-28	.01	1250	4	0	4	*	0	6	0	0	31	31	4
APR	41	8	-8	-36	0.2	0.3	2	3	E	5	84	63	63	-9	.02	1150	4	0	4	*	0	4	0	0	30	24	5
MAY	47	28	17	-11	0.4	1.3	3	3	W	6	68	73	70	15	.08	1050	7	*	7	*	0	8	0	0	30	2	6
JUN	63	41	32	22	0.2	1.1	*	1	W	6	53	75	71	28	.15	950	3	*	1	0	0	11	*	4	17	0	6
JUL	62	46	37	26	0.8	2.0	*	1	W	6	64	77	72	33	.19	1000	5	*	1	0	0	12	*	8	6	0	7
AUG	62	44	36	23	0.7	1.0	*	2	W	5	74	79	72	33	.19	1000	7	*	1	*	0	9	*	5	9	0	7
SEP	49	32	23	-5	0.6	1.3	4	7	E	6	72	74	69	20	.10	1200	8	*	6	1	0	4	0	0	26	*	7
OCT	40	19	7	-24	0.7	0.6	7	7	E	8	51	72	72	6	.05	1400	9	*	10	1	0	2	0	0	31	9	7
NOV	36	6	-7	-28	0.5	0.4	5	4	E	7	65	67	66	-9	.02	1450	8	0	8	1	0	3	0	0	30	22	5
DEC	36	-2	-15	-33	0.2	0.2	3	5	E	7	70	63	62	-18	.01	1550	7	0	7	*	0	5	0	0	31	28	4
ANN	63	17	5	-44	5.5	2.0	36	15	E	7	[1]90	68	66	3	.04	1400	75	*	62	4	0	74	*	17	300	170	6
EYR	13	13	13	13	13	13	13	13	14	14	13	14	14	14	14	14	13		13	13	13	13	13	13	13	13	14

REMARKS

[1]PEAK GUST: FEB 1957-125 KTS ESTIMATED (ANEMOMETER BLOWN AWAY)

RUSSWO POR: Hourly Obs: Nov 51-Oct 65
Daily Obs: Nov 51-May 65

NOTE: *DATA NOT AVAILABLE. *LESS THAN 0.5 DAY, 0.05 OR 0.05 INCH, OR 0.5 PERCENT (*) AS APPLICABLE.

FLYING WEATHER (% FREQ)	HOURS (LST)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	EYR
CIG less than 3000 feet and/or VSBY less than 3 miles	00-02	13	17	8	9	23	28	25	23	15	17	15	10	17	
	03-05	12	16	8	11	23	28	27	20	15	17	17	9	17	
	06-08	13	15	9	9	21	26	26	21	15	18	16	9	17	
	09-11	14	16	10	9	18	24	22	18	15	18	18	10	16	
	12-14	14	16	8	7	19	22	20	18	15	19	19	10	16	
	15-17	15	16	8	6	19	23	20	18	15	21	19	8	16	
	18-20	14	15	8	8	19	24	22	17	16	18	18	9	16	
	21-23	13	15	7	8	21	26	24	22	15	18	18	9	16	
	ALL HOURS	13	15	8	8	21	25	23	20	15	18	18	9	16	14
CIG less than 1500 feet and/or VSBY less than 3 miles	00-02	12	15	7	7	15	22	20	16	7	9	8	7	12	
	03-05	9	14	8	9	15	22	21	14	7	9	9	6	12	
	06-08	11	13	8	7	14	20	19	15	7	6	10	6	12	
	09-11	11	14	9	7	11	17	16	13	7	8	11	7	11	
	12-14	11	13	7	5	10	15	15	12	7	9	11	8	10	
	15-17	12	13	7	5	12	16	13	12	7	10	11	5	10	
	18-20	11	12	6	6	14	18	16	12	6	8	10	6	10	
	21-23	10	14	6	7	15	20	18	15	6	9	10	6	11	
	ALL HOURS	11	14	7	7	13	19	17	13	7	9	10	6	11	14
CIG less than 1000 feet and/or VSBY less than 2 miles	00-02	7	11	5	5	12	19	19	15	5	5	5	[illegible]	9	
	03-05	6	10	5	6	10	21	20	13	5	5	6	4	9	
	06-08	7	10	6	6	10	17	17	13	5	5	6	4	10	
	09-11	8	11	7	4	8	15	14	12	4	4	6	4	8	
	12-14	8	11	5	4	8	13	13	11	5	6	6	4	8	
	15-17	9	10	5	4	9	14	12	10	5	6	6	4	8	
	18-20	9	9	3	5	9	15	14	10	4	4	6	2	8	
	21-23	6	10	4	5	10	17	17	13	4	4	5	3	8	
	ALL HOURS	7	10	5	5	10	16	16	12	4	5	6	4	8	14
CIG less than 200 feet and/or VSBY less than ½ mile	00-02	4	6	2	2	5	7	9	6	2	[illegible]	1	2	4	
	03-05	3	6	3	3	4	6	10	5	2	1	1	2	4	
	06-08	3	6	3	3	2	5	8	4	1	1	2	2	3	
	09-11	4	6	3	2	1	2	5	5	1	1	2	1	3	
	12-14	4	6	2	2	1	1	2	4	1	1	2	2	2	
	15-17	5	6	2	2	1	2	3	3	1	1	1	1	2	
	18-20	4	6	1	2	2	5	5	4	1	*	2	1	3	
	21-23	3	5	1	2	4	7	8	5	1	1	1	1	3	
	ALL HOURS	4	6	2	2	2	4	6	4	1	1	2	1	3	14

TABLE XXVIII. AWS CLIMATIC BRIEF, WOODBRIDGE AERODROME, ENGLAND

AWS CLIMATIC BRIEF WOODBRIDGE (AERODROME), ENGLAND — PERIOD 1952-70B — WBAN # 35051 — WMO # 03595

Prepared by ETAC (JAN 1972) N 52 05 E 01 24 — FIELD ELEVATION: 95 ft — STN LTRS EGVG

MONTH	TEMPERATURE (°F) Extreme Maximum	Mean Daily Maximum	Mean Daily Minimum	Extreme Minimum	PRECIPITATION (in) Mean Total	Maximum in 24 Hours	Mean Snowfall	Max Snowfall in 24 Hours	WIND (KT) Prevailing Direction	Mean Speed	Extreme (Peak) Speed (Gust)	MEAN Relative Humidity (%) 0400	Relative Humidity (%) 1300	Dew Point (°F)	Vapor Pressure (in Hg)	Pressure Altitude 99.95% (feet)	MEAN NUMBER OF DAYS Precip ≥ 0.01	Precip ≥ 0.5	Snowfall ≥ 0.1	Snowfall ≥ 1.5	Thunderstorms	Fog (< 7 miles)	Temperature (°F) Maximum ≥ 90	Maximum ≥ 80	Minimum ≤ 32	Minimum ≤ 0	Mean Clouds (Tenths)
JAN	56	42	34	9	2.1	0.8	4	4	SW	8	49	86	81	34	.20	1350	16	*	4	1	*	19	0	0	13	0	8
FEB	59	43	34	15	1.7	1.3	4	5	W	8	62	85	76	33	.19	1350	14	*	4	1	*	15	0	0	12	0	8
MAR	71	48	36	18	1.5	1.1	1	3	WSW	9	58	85	68	35	.20	1100	11	*	2	*	1	15	0	0	9	0	7
APR	72	53	40	27	1.5	0.7	*	1	SW	8	51	87	65	39	.24	1000	13	*	*	0	1	14	0	0	3	0	7
MAY	76	59	45	29	1.9	1.5	*	*	SSW	7	42	87	64	44	.29	750	13	1	0	0	2	13	0	0	*	0	7
JUN	88	66	50	33	1.7	0.9	0	0	SW	7	35	86	62	49	.35	700	9	1	0	0	2	12	0	*	0	0	7
JUL	86	68	54	40	2.2	1.8	0	0	WSW	7	39	87	63	53	.40	650	11	1	0	0	3	13	0	1	0	0	7
AUG	83	68	54	41	2.5	1.2	0	0	WSW	7	41	87	64	53	.40	750	13	2	0	0	3	14	0	1	0	0	7
SEP	82	65	51	37	2.1	1.7	0	0	WSW	6	45	86	65	51	.38	800	11	1	0	0	2	16	0	*	0	0	7
OCT	76	59	47	31	2.2	2.6	0	0	WSW	7	56	88	72	47	.32	1050	12	1	0	0	1	18	0	0	*	0	7
NOV	65	50	40	25	2.5	1.4	*	3	SW	8	62	85	77	40	.25	1350	16	1	*	*	1	17	0	0	4	0	7
DEC	59	44	36	16	2.2	1.4	1	4	WSW	8	51	85	80	35	.20	1450	16	1	1	*	0	20	0	0	10	0	7
ANN	88	55	43	9	24.1	2.6	10	5	WSW	7	62	86	70	43	.28	1050	155	9	11	2	16	188	0	2	51	0	7
EYR	15	15	15	15	15	15	15	15	16	16	11	16	16	16	16	16	15	15	15	15	15	15	15	15	15	15	16

REMARKS

RUSSWO POR: HRLY OBS: 5210-5212, 5410-5604, 5701-7012;
DAILY OBS: 5210-5212, 5410-5604, 5701-7003.

NOTE: "DATA NOT AVAILABLE. *LESS THAN 0.5 DAY, 0.5 OR 0.05 INCH, OR 0.5 PERCENT (*) AS APPLICABLE.

FLYING WEATHER (% FREQ)	HOURS (LST)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	EYR
CIG less than 3000 feet and/or VSBY less than 3 miles	00-02	58	51	40	35	23	23	20	27	31	40	46	57	38	
	03-05	58	53	44	44	33	33	30	35	37	44	48	56	43	
	06-08	62	55	53	46	35	33	31	37	42	52	52	57	46	
	09-11	62	55	52	42	35	30	36	33	32	41	48	57	44	
	12-14	56	53	46	33	26	24	24	24	26	33	45	52	37	
	15-17	59	48	40	26	19	16	17	16	19	29	45	56	33	
	18-20	60	50	38	26	18	12	13	17	21	35	46	54	33	
	21-23	59	53	39	31	20	16	16	23	25	36	44	54	35	
	ALL HOURS	59	52	44	35	26	23	23	26	29	39	47	55	39	16
CIG less than 1500 feet and/or VSBY less than 3 miles	00-02	48	38	31	28	17	19	16	23	26	32	34	44	30	
	03-05	48	41	35	35	26	28	25	31	32	36	35	45	35	
	06-08	51	42	44	36	25	26	24	32	36	44	41	46	37	
	09-11	49	42	37	24	18	15	15	18	21	33	38	47	30	
	12-14	44	36	25	16	11	10	8	11	12	20	30	41	22	
	15-17	47	34	24	15	8	8	7	10	12	20	31	45	22	
	18-20	49	38	26	19	11	8	8	13	16	28	33	43	24	
	21-23	49	38	28	22	13	14	12	18	21	29	34	44	27	
	ALL HOURS	48	39	31	24	16	16	14	20	22	30	35	44	29	16
CIG less than 1000 feet and/or VSBY less than 2 miles	00-02	31	23	20	17	11	11	8	14	14	20	19	27	18	
	03-05	31	25	22	21	15	17	13	19	21	22	20	28	21	
	06-08	34	27	27	21	14	12	12	20	22	28	24	30	23	
	09-11	33	25	20	14	10	8	7	9	11	16	22	28	17	
	12-14	27	20	13	8	5	5	3	5	6	10	14	23	12	
	15-17	28	17	11	6	3	3	3	4	5	9	15	25	11	
	18-20	30	21	13	9	5	3	3	7	6	13	16	25	13	
	21-23	31	22	15	13	9	7	5	11	9	15	18	27	15	
	ALL HOURS	31	23	17	14	9	8	7	11	12	17	19	27	16	16
CIG less than 200 feet and/or VSBY less than ½ mile	00-02	9	5	4	4	2	1	1	2	3	4	3	6	4	
	03-05	9	6	4	5	3	3	2	4	4	6	4	6	5	
	06-08	10	7	5	4	1	1	1	3	6	6	5	6	5	
	09-11	8	5	2	1	*	0	*	*	1	2	3	6	2	
	12-14	6	2	1	*	0	*	0	0	0	*	1	4	1	
	15-17	6	3	1	*	0	0	0	*	*	1	1	4	1	
	18-20	6	3	1	1	*	1	0	*	1	1	2	5	2	
	21-23	7	3	2	2	1	1	*	1	1	2	2	6	2	
	ALL HOURS	8	4	3	2	1	1	1	1	2	3	3	5	3	16

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TABLE XXIX. CLIMATOLOGICAL DATA FOR ELMENDORF AFB

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
TEMPERATURE (°F)												
Extreme Maximum	49	59	51	63	79	86	83	81	75	63	57	53
Mean Maximum	20	26	32	44	55	63	65	64	55	41	27	20
Mean	13	18	23	36	47	55	58	56	48	35	20	13
Mean Minimum	5	9	14	27	38	47	51	49	41	29	14	6
Extreme Minimum	-36	-42	-24	-20	-1	33	35	29	21	-6	-20	-34
PRECIPITATION (Inches)												
Mean Monthly Total	1.21	1.05	.94	.66	.63	1.18	2.27	2.49	2.40	1.58	1.21	1.56
Mean Number of Days With Precipitation	10	8	8	5	5	8	12	14	14	10	8	11
Mean Monthly Snowfall	12	11	9	6	*	T	-	-	*	7	12	15
Mean Number of Days With Snowfall	9	8	7	4	*	-	-	-	*	4	6	10
SURFACE WINDS (Speed in Knots)												
Prevailing Direction	N	N	N	N	W	W	W	W	N	N	N	N
and Mean Speed	6	7	7	6	7	7	6	6	6	6	7	6
Mean Wind Speed All Directions	4	5	5	5	5	5	4	4	4	4	4	4
10 Knots or Less (Calms Not Included)	66	66	67	71	74	75	74	69	65	69	68	67
Peak Wind Direction	ENE	NNW	SSE	N	SSE	S	WSW	SSE	S	E	N	NNE
and Speed	66	61	47	43	49	43	34	38	42	62	93	45
Percent of Calms	28	24	23	21	17	17	21	26	30	25	25	27
FLYING WEATHER (Percent)												
1500/3	83	88	93	95	98	97	95	96	93	90	86	82
200/1/2	4	2	*	*	*	*	*	*	1	2	3	4

*Less than 1 day, inch or percent as appropriate.

APPENDIX II
EXCERPTS FROM ASSESSED SPECIFICATIONS

MIL-H-8501A(1) Helicopter Flying Qualities, Requirements for

3.7 Vibration Characteristics

3.7.1 In general, throughout the design flight envelope, the helicopter shall be free of objectionable shake, vibration, or roughness. Specifically, the following vibration requirements shall be met:

(a) Vibration accelerations at all controls in any direction shall not exceed 0.4g for frequencies up to 32 cps and a double amplitude of 0.008 inch for frequencies above 32 cps; this requirement shall apply to all steady speeds within the helicopter design flight envelope and in slow and rapid transitions from one speed to another and during transition from one steady acceleration to another.

(b) Vibration accelerations at the pilot, crew, passenger, and litter stations at all steady speeds between 30 knots rearward and V_{Cruise} shall not exceed 0.15g for frequencies up to 32 cps and a double amplitude of 0.003 inch for frequencies greater than 32 cps. From V_{Cruise} to V_{Limit} the maximum vibratory acceleration shall not exceed 0.2g up to 36 cps, and a double amplitude of 0.003 inch for frequencies greater than 36 cps. At all frequencies above 50 cps a constant velocity vibration of 0.039 fps shall not be exceeded.

(c) Vibration characteristics at the pilot, crew, passenger, and litter stations shall not exceed 0.3g up to 44 cps and a double amplitude of 0.003 inch at frequencies greater than 44 cps during slow and rapid linear accelerations or deceleration from any speed within the design flight envelope.

3.7.2 The magnitude of the vibratory force at the controls in any direction during rapid longitudinal or lateral stick deflections shall not exceed 2 pounds. Preferably, these vibratory forces shall be zero.

3.7.3 The helicopter shall be free from mechanical instability, including ground resonance, and from rotor weaving and flutter that influence helicopter handling qualities, during all operating conditions, such as landing, takeoff, and flight.

4.5 Common test techniques.-

4.5.1 Sinusoidal vibration tests. - The vibration shall be applied along each of the three mutually perpendicular axes of the test item. The vibratory acceleration levels or double amplitudes of the specified test curve shall be maintained at the test item mounting points. When specified, for sinusoidal resonance search, resonance dwell, and cycling tests of items weighing more than 80 pounds mounted in airplanes, helicopters, and missiles, the vibratory accelerations shall be reduced +/-1 g for each 20 pound increment over 80 pounds. Acceleration derating shall apply only to the highest test level of the selected curve, but in no case shall the derated test level be less than 50 percent of the selected curve (see note 1 of applicable table 514.1-I through 514.1-V). For equipment weighing over 100 pounds and transported by aircraft, resonance search, resonance dwell, and cycling tests may be frequency and acceleration derated (see notes 1 and 2 of table 514.1-VII). When packaged items are always grouped together on mechanized loading platforms or pallets, acceleration and frequency derating may be based on the total load on the pallet. When the input vibration is measured at more than one control point, the control signal shall be the average of all the accelerometers unless otherwise specified. For massive test items, fixtures and large force exciters, it is recommended that the input control level be an average of at least three or more inputs.

4.5.1.1 Resonance search. - Resonant frequencies of the equipment shall be determined by varying the frequency of applied vibration slowly through the specified range at reduced levels but with sufficient amplitude to excite the item, Sinusoidal resonance search may be performed using the test level and cycling time specified for sinusoidal cycling test, provided the resonance search time is included in the required cycling test time of 4.5.1.3.

4.5.1.2 Resonance dwell - The test item shall be vibrated along each axis at the most severe resonant frequencies determined in 4.5.1.1. Test levels frequency ranges, and test times shall be in accordance with the applicable conditions from tables 514.1-I through 514.1-V figures 514.1 through 514.1-7 for each equipment category. If more than four significant resonant frequencies are found for any one axis, the four most severe resonant frequencies shall be chosen for the dwell test. If a change in the resonant frequency occurs during the test, its time of occurrence shall be recorded and immediately the frequency shall be adjusted to maintain the peak resonance condition. The final resonant frequency shall be recorded.

4.5.1.3 Cycling - The test item shall be vibrated along each axis in accordance with the applicable test levels, frequency range, and times from tables 514.1-I through 514.1-VII and figures 514.1-1 through 514.1-7. The frequency of applied vibration shall be swept over the specified range logarithmically in accordance with figure 514.1-10. The specified sweep time is that of an ascending plus a descending sweep and is twice the ascending sweep time shown on figure 514.1-10 for the specified range. Linear sweep rates may be substituted for the logarithmic sweep rate. When linear sweep rates are used, the total frequency range shall be divided into logarithmic frequency bands having similar time intervals such that each time interval is the time of ascending plus a descending sweep for the corresponding band. The sum of these time intervals shall equal the sweep time specified for the applicable frequency range. The linear sweep rate for each band is then determined by dividing each bandwidth in cps by One-half the sweep time in minutes for each band. The logarithmic frequency bands may be readily determined from figure 514.1-10. The frequency bands and linear sweep rates shown in table 514.1-IX shall be used for the 2 (or 5) to 500 cps and 5 to 2,000 cps frequency ranges. For test frequency ranges of 100 cps or less, no correction of the linear sweep rate is required.