Report SAM-TR-76-9

NOISE LEVELS MEASURED WITHIN AIRCRAFT DURING TAKEOFF, CLIMB, AND CRUISE (LOW, NORMAL, AND HIGH)

February 1976

Progress Report for Period March-October 1975

USAF SCHOOL OF AEROSPACE MEDICINE
Aerospace Medical Division (AFSC)
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This technical report has been reviewed and is approved for publication.

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Noise measurements obtained within cockpits of 12 groups of fixed- and rotary-wing aircraft during takeoff, climb, and cruise (low, normal, and high) are reported. Mean, variance, and standard deviations are reported for each group. Data include Flat (F) or C-weighted levels, A-weighted levels, and F/C minus A levels.

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NOISE LEVELS MEASURED WITHIN AIRCRAFT DURING TAKEOFF, CLIMB, AND CRUISE (LOW, NORMAL, AND HIGH)

INTRODUCTION

Most aircraft cockpits contain noise that may interfere with communications, result in auditory fatigue, and cause permanent noise-induced hearing loss. Also, noises that require loud vocal effort by crewmembers may contribute to increased general fatigue. Medical personnel in the military services have been concerned about undesirable auditory and nonauditory effects of noise commonly encountered during various phases of flight. This concern has prompted research aimed at identifying, defining, and eventually controlling such undesirable effects. One of the primary undesirable effects of noise found within aircraft is permanent noise-induced hearing loss among personnel who are not adequately protected. Generally, the noise levels found within most aircraft cockpits are of sufficient magnitude to cause permanent threshold shifts among persons who routinely fly without proper personal ear protection.

Personnel at the USAF School of Aerospace Medicine, Brooks Air Force Base, Texas, and the 6570th Aeromedical Research Laboratory, Wright-Patterson Air Force Base, Ohio, have conducted many studies that identify and describe acoustic environments found within aircraft. The author has published several reports (1-19) that deal with noise in aircraft in an attempt to help Air Force medical personnel who are responsible for the health of flying personnel to better understand the nature of the noise found within different types of aircraft during various phases of ground and airborne operation.

The author has taught noise effects and hearing conservation to aeromedical personnel attending formal courses at the USAF School of Aerospace Medicine, and a continuing area of interest expressed by medical personnel is the noise found within aircraft. This report was prepared to provide insight concerning the range of noise levels found within groups of aircraft during five phases of ground and airborne operation. The noise data reported in this study were extracted from a compendium of noise measurements which the author has accumulated over the past 18 years. For this study, only Flat (including C-weighted) and A-weighted levels are reported. Study of the data contained in this report will help interested personnel understand the magnitudes of noise found within cockpits of various types of aircraft during different phases of flight. These data have been categorized so that meaningful generalizations concerning differences in noise levels found within different types of aircraft can be made.

APPROACH

The author selected samples of noise data from measurements obtained within cockpits of many types of aircraft and classified them into five phases of operation: takeoff, climb,and cruise (low, normal, and high). Unfortunately, noise data were not available for all five operational conditions for each aircraft. As a result, the numbers of aircraft reported for each condition of flight were not equal, but since this report deals with generalities, the data do serve the author's intent.

The measurements are arranged into eight subgroups of fixed-wing and four subgroups of rotary-wing aircraft. The type and number of powerplants were used to establish the subgroups for fixed-wing aircraft, and the number and types of powerplants and rotors were used to subgroup data obtained within rotary-wing aircraft. The majority of data in this report had to be converted from octave-band measurements, using a WANG 500 calculator, programmed to read out in dBA and Flat level. Octave-band weightings provided by Peterson and Gross (20) were used. When available, measurements recorded directly in C-weighted and A-weighted noise levels were used. Since the numbers of aircraft included in each subsample varied between different operating conditions, the number included in each sample is identified separately for each subgroup. Mean and standard deviation values are reported for each subgroup.

The groups of aircraft described in this study include:

<u>Fixed-wing aircraft (FW):</u>

FW1R (1 recriprocating engine)
FW2R (2 reciprocating engines)
FW4R (4 reciprocating engines)
FW1TP (1 turboprop engine)
FW2TP (2 turboprop engines)
FW4TP (4 turboprop engines)
FWJint (internally mounted jet engines)
FWJext (externally mounted jet engines)

<u>Rotary-wing aircraft (RW):</u>

RW1RR (1 main rotor and powered by reciprocating engines)

RW2RR (2 main rotors and powered by reciprocating engines)
RW1RTS (1 main rotor and powered by turboshaft engines)
RW2RTS (2 main rotors and powered by turboshaft engines)

RESULTS

Tables 1 and 2 summarize the data derived from this study: Table 1, from fixed-wing aircraft; and Table 2, from rotary-wing aircraft. The mean data reported in both tables were obtained from 1175 sets of noise measurements. These data (Flat or C-weighted and A-weighted levels) were obtained within 195 aircraft during takeoff or liftoff; 119, conditions of climb; 53, low cruise, 579, normal cruise; and 229, high cruise. Differences noted between means for the different subgroups emphasize the value of subclassifying aircraft according to type and number of engines. Inspection of the data reveals that A-levels tend to vary more than Flat or C-levels for given conditions of ground or flight operation.

Generally, cockpit noise levels were highest during takeoff; however, aircraft capable of higher airspeeds, such as turboprop and jet-powered aircraft, demonstrated higher levels during high-cruise flight than during takeoff. This phenomenon has been noted previously and is associated with boundary-layer disturbances created by air friction.

The mean A-levels recorded within fixed-wing aircraft powered by a single reciprocating engine ranged from 99.8 dB during low cruise to 107.7 dB during high cruise; by two reciprocating engines, from 97.1 dB during normal cruise to 105.5 dB during takeoff; and by 4 reciprocating engines, from 90.9 dB during low cruise to 104.1 dB during takeoff.

Turboprop-powered aircraft revealed similar findings. The mean A-levels available for aircraft fitted with a single turboprop engine ranged from 90.5 dB during low cruise to 99.7 dB during takeoff; two turboprop engines, from 93.6 dB during normal cruise to 99.4 dB during takeoff; and 4 turboprop engines, from 87.9 dB during climb to 95.9 dB during high cruise.

Mean A-levels noted within aircraft powered by turbojet or turbofan engines were somewhat different in distribution. Aircraft fitted with internally mounted turbojet or turbofan engines provided mean A-levels that ranged from 101.9 dB during normal cruise to 105.2 dB during takeoff; a relatively small range of levels was noted between different conditions of operation. This range of levels was lower than those noted within aircraft powered by externally mounted turbojet or turbofan engines, which were from 87.5 dB during climb to 96.4 dB during high cruise.

The mean A-levels noted within helicopters (Table 2) were rather high. Single-rotor vehicles powered by reciprocating engines yielded mean A-levels ranging from 102.2 dB during normal cruise to 104.4 dB during liftoff; and levels from those powered by turboshaft engines, from 95.8 dB during liftoff to 100.8 dB during high cruise. Within twin-rotor helicopters powered by turboshaft engines, the mean A-levels ranged from 100.6 dB during high cruise to 103.0 dB during normal cruise.

Tables 3 and 4 summarize the mean A-weighted levels obtained within fixed- and rotary-wing aircraft respectively; the range of levels expected for plus and minus one standard deviation from the mean are also included. This information is also illustrated in Figures 1 and 2. Figure 1 shows mean levels and envelopes that include plus and minus one standard deviation from the mean for cockpits of fixed-wing aircraft. Figure 2 illustrates plottings for rotary-wing vehicles. The current auditory risk limits used by the Air Force, specified in Air Force Regulation 161-35, are shown on each of these figures. The allowable durations, or limits, in minutes represent exposures permitted for unprotected ears. The levels found within many of the aircraft included in this study clearly constitute a potential risk to unprotected ears, especially among persons who fly in these aircraft frequently.

A parameter known as the "harmonic index," obtained by simply subtracting the A-level measurement from the Flat or C-level reading (F/C-A), provides insight concerning the frequency composition of the noise in a given A-weighted level. A small harmonic index, such as -2 to +2, indicates that the frequency composition of the noise that produced the overall level contains a large portion of its amplitude within about 600- through 6000-Hz frequency range. Harmonic index values greater than about 7 to 10 represent spectra that contain dominant acoustic energy in the lower frequency range. For example, an F/C-A of 13 reflects a noise that contains the most intense acoustic energy within the frequency range below about 1000 Hz. The harmonic index also provides insight concerning the amount of attenuation expected from personal ear-protection devices, such as headsets. Since headsets usually provide far less attenuation to noise in the lower frequency range, a large F/C-A value represents a condition for which the headset will reduce the ambient noise less than for noises with small F/C-A values.

Tables 5 and 6 list the F/C-A values noted within the cockpits of the fixed- and rotary-wing aircraft respectively. Generally, vehicles fitted with either propellers or rotors yielded the largest F/C-A values, and the smallest indices were noted within cockpits of aircraft fitted with turbojet or turbofan engines. Figures 3-7 show mean Flat/C-levels, A-levels, and harmonic indices during takeoff (Figure 3), climb (Figure 4), low cruise (Figure 5), normal cruise (Figure 6), and high cruise (Figure 7).

CONCLUSION

The data reported in this study provide the type of generalizations that are most helpful to gain a basic understanding of the overall noise levels found within the cockpits of aircraft during different conditions of ground and airborne operation.

The findings obtained from this study reemphasize the need for concern for the hearing of aircrew members. Obviously, the potential for the occurrence of noise-induced hearing loss among aircrew members is evident. Figure 8 summarizes the mean A-weighted noise levels that evolved from this study. The average noise levels, when compared to the current USAF auditory risk criteria (shown along right side of figure), reflect the presence of ambient noise levels that are great enough to warrant the establishment of close medical monitoring of aircrew members. Fortunately, the U.S. Air Force employs stringent audiometric monitorings of all aircrew members to insure that significant amounts of hearing loss do not develop. Also, the U.S. Air Force expends considerable effort to develop personal ear protection devices, such as headsets used alone or fitted in crash helmets, that provide significant protection against excessive noises found within aircraft.

REFERENCES

1. Gasaway, D. C., and J. L. Hatfield. A survey of internal and external noise environments in U.S. Army aircraft. USAARU Report No. 64-1, Dec 1963 (AD 428 331).

2. Gasaway, D. C. Characteristics of noise associated with operation of military aircraft. Aerosp Med 35:327 (1964).

3. Gasaway, D. C. Noise generated by secondary and auxiliary aircraft systems. SAM-TR-69-83, Dec 1969 (AD 702 101).

4. Gasaway, D. C. Noise encountered in rotary-wing aircraft. SAM-TR-69-87, Dec 1969 (AD 703 422).

5. Gasaway, D. C. Cockpit noise exposures associated with the operation of fixed- and rotary-wing aircraft. SAM-TR-70-21, Apr 1970 (AD 705 964).

6. Gasaway, D. C. Noise environments within multiplace fixed-wing aircraft. SAM-TR-70-26, May 1970 (AD 708 430).

7. Gasaway, D. C. Airspeed influence on noise within fixed- and rotary-wing aircraft. SAM-TR-70-27, June 1970 (AD 711 359).

8. Gasaway, D. C. Noise associated with operation of Air Force OV-10A aircraft. SAM-TR-70-51, Aug 1970 (AD712 667).

9. Gasaway, D. C., and H. C. Sutherland, Jr. Noise problems in aeromedical evacuation operations. SAM Aeromed Rev 2-70, Sept 1970 (AD 713 882).

10. Gasaway, D. C. Noise within the Bell UH-1P helicopter during flight. SAM-TR-70-57, Sept 1970 (AD 713 830).

11. Gasaway, D. C. Noise associated with operation of the C-9A (aeromedical evacuation) aircraft. SAM-TR-70-63, Oct 1970 (AD 715 222).

12. Gasaway, D. C. Noise associated with airborne operation of C-141A aircraft. SAM-TR-70-74, Dec 1970 (AD 718 097).

13. Gasaway, D. C. Cockpit noise within trainer aircraft. SAM-TR-70-95, Dec 1970 (AD 717 852).

14. Gasaway, D. C. Noise within the F-4E during ground and airborne operations. SAM-TR-71-14, May 1971 (AD 731 092).

15. Gasaway, D. C. Noise associated with T-41A and T-41C trainer aircraft. SAM-TR-71-22, Aug 1971 (AD 731 128).

16. Gasaway, D. C. Measurement of noise levels in aircraft. Proceeding of AFSC Science and Engineering Symposium, Vol. II, Dayton, Ohio, 5 Oct 1971.

17. Gasaway, D. C. Bioacoustic noise problems during operation of C-7A Caribou aircraft. SAM-TR-71-12, Dec 1971 (AD 738 627).

18. Gasaway, D. C. Noise within fixed-wing utility aircraft used by the military. SAM-TR-71-43, Dec 1971 (AD 742 972).

19. Gasaway, D. C. A-weighted sound levels in cockpits of fixed- and rotary-wing aircraft. SAM-TR-75-22, July 1975.

20. Peterson, A. P. G., and E. E. Gross, Jr. Handbook of noise measurement. West Concord, Mass.: General Radio Company, 1967.

TABLE 1. SUMMARY OF MEAN AND STANDARD DEVIATION DATA DERIVED FROM STUDY OF NOISE LEVELS (DECIBELS) MEASURED IN COCKPITS OF FIXED-WING AIRCRAFT (NUMBER IN EACH SAMPLE SHOWN IN PARENTHESES)

Type of aircraft		Takeoff		Climb		Cruise					
						Low		Normal		High	
		F/C	A	F/C	A	F/C	A	F/C	A	F/C	A
FW1R	(No.)	(30)		(24)		(21)		(82)		(31)	
	Mean	119.0	104.6	113.2	103.6	110.4	99.8	110.9	100.2	114.7	107.7
	SD	5.2	7.7	4.8	7.0	4.1	5.8	4.9	7.6	5.2	7.3
FW2R	(No.)	(37)		(25)		(14)		(123)		(43)	
	Mean	118.4	105.5	114.0	100.0	110.0	97.7	110.1	97.1	115.1	103.5
	SD	7.2	8.5	6.2	7.7	5.3	4.5	6.8	6.6	6.7	7.6
FW4R	(No.)	(7)		(9)		(8)		(58)		(21)	
	Mean	115.8	104.1	107.3	93.6	103.4	90.9	104.3	92.0	112.1	99.5
	SD	7.9	7.3	4.4	4.7	7.6	8.1	7.4	6.6	8.0	8.8
FW1TP	(No.)	(3)				(4)		(4)			
	Mean	108.3	99.7			99.2	90.5	105.5	96.8		
	SD	2.5	4.0			2.1	2.4	2.9	3.3		
FW2TP	(No.)	(18)		(12)				(43)			
	Mean	113.3	99.4	107.2	97.0			104.3	93.6		
	SD	6.8	9.0	9.7	10.6			5.0	5.6		
FW4TP	(No.)	(6)		(9)				(32)		(10)	
	Mean	110.8	93.8	104.9	87.9			102.4	88.7	108.8	95.9
	SD	9.9	4.2	7.3	5.8			7.2	5.9	5.2	6.0
FWJint	(No.)	(36)		(30)				(89)		(57)	
	Mean	108.6	105.2	106.4	103.8			104.1	101.9	106.3	104.0
	SD	4.3	5.6	3.9	4.9			6.7	7.4	7.1	7.1
FWJext	(No.)	(14)		(10)		(10)		(61)		(24)	
	Mean	100.2	92.9	90.5	87.5	94.1	89.2	94.1	89.5	100.3	96.4
	SD	7.2	7.2	8.1	8.1	8.2	7.0	9.0	8.5	9.4	8.3

TABLE 2. SUMMARY OF MEAN AND STANDARD DEVIATION DATA DERIVED FROM STUDY OF NOISE LEVELS (DECIBELS) MEASURED IN COCKPITS OF ROTARY-WING AIRCRAFT (NUMBER IN EACH SAMPLE SHOWN IN PARENTHESES)

Type of aircraft		Liftoff		Climb		Cruise					
						Low		Normal		High	
		F/C	A	F/C	A	F/C	A	F/C	A	F/C	A
RW1RR	(No.)	(13)						(25)		(18)	
	Mean	112.9	104.4					110.6	102.2	113.0	103.7
	SD	3.1	4.6					3.7	4.0	4.1	4.4
RW2RR	(No.)							(4)			
	Mean							108.5	103.5		
	SD							4.8	5.3		
RW1RTS	(No.)	(24)						(44)		(27)	
	Mean	104.3	95.8					107.0	98.1	109.1	100.8
	SD	7.0	5.0					5.7	4.3	5.0	4.6
RW2RTS	(No.)	(7)						(14)		(8)	
	Mean	108.7	101.9					108.4	103.0	106.9	100.6
	SD	2.3	2.5					4.3	5.4	3.5	3.2

TABLE 3. MEAN A-WEIGHTED LEVELS AND RANGE OF A-LEVELS APPROPRIATE FOR ±1 STANDARD DEVIATION FOR FIXED-WING AIRCRAFT

Type of aircraft		Takeoff	Climb	Cruise		
				Low	Normal	High
FW1R	Mean	104.6	103.6	99.8	100.2	107.7
	Range*	96.9 - 112.3	96.6 - 110.6	94.0 - 105.6	92.6 - 107.8	100.4 - 115.0
FW2R	Mean	105.5	100.0	97.7	97.1	103.5
	Range*	97.0 - 114.0	92.3 - 107.7	93.2 - 102.2	90.5 - 103.7	95.9 - 111.1
FW4R	Mean	104.1	93.6	90.9	92.0	99.5
	Range*	96.8 - 111.4	88.9 - 98.3	82.8 - 99.0	85.4 - 98.6	90.7 - 108.3
FW1TP	Mean	99.7		90.5	96.8	
	Range*	95.7 - 103.7		88.1 - 92.9	93.0 - 100.6	
FW2TP	Mean	99.4	97.0		93.6	
	Range*	90.4 - 108.4	86.4 - 107.6		88.0 - 99.2	
FW4TP	Mean	93.8	87.9		88.7	95.9
	Range*	89.6 - 98.0	82.1 - 93.7		82.8 - 94.6	89.9 - 101.9
FWJint	Mean	105.2	103.8		101.9	104.0
	Range*	99.6 - 110.8	98.9 - 108.7		94.5 - 109.3	96.9 - 111.1
FWJext	Mean	92.9	87.5	89.2	89.5	96.4
	Range*	85.7 - 100.1	79.4 - 95.6	82.2 - 96.2	81.0 - 98.0	88.1 - 104.7

*dBA levels ±1 SD

TABLE 4. MEAN A-WEIGHTED LEVELS AND RANGE OF A-LEVELS APPROPRIATE FOR ±1 STANDARD DEVIATION FOR ROTARY-WING AIRCRAFT

Type of aircraft		Liftoff	Climb	Cruise		
				Low	Normal	High
RW1RR	Mean	104.4			102.2	103.7
	Range*	99.8 - 109.0			98.2 - 106.2	99.3 - 108.1
RW2RR	Mean				103.5	
	Range*				98.2 - 108.8	
RW1RTS	Mean	95.8			98.1	100.8
	Range*	90.8 - 100.8			93.8 - 102.4	96.2 - 105.4
RW2RTS	Mean	101.9			103.0	100.6
	Range*	99.4 - 104.4			97.6 - 108.4	97.4 - 103.8

*dBA levels ±1 SD

TABLE 5. DECIBEL DIFFERENCES NOTED BETWEEN FLAT OR C-WEIGHTINGS (F/C) AND A-LEVELS (A) FOR FIXED-WING AIRCRAFT

Type of aircraft		Takeoff	Climb	Cruise		
				Low	Normal	High
FW1R	F/C	119.0	113.2	110.4	110.9	114.7
	A	104.6	103.6	99.8	100.2	107.7
	F/C-A =	15.4	9.6	10.6	10.7	7.0
FW2R	F/C	118.4	114.0	110.0	110.1	115.1
	A	105.5	100.0	97.7	97.1	103.5
	F/C-A =	12.9	14.0	12.3	13.0	11.6
FW4R	F/C	115.8	107.3	103.4	104.3	112.1
	A	104.1	93.6	90.9	92.0	99.5
	F/C-A =	11.7	13.7	12.5	12.3	12.6
FW1TP	F/C	108.3		99.2	105.5	
	A	99.7		90.5	96.8	
	F/C-A =	8.6		8.7	8.7	
FW2TP	F/C	113.3	107.2		104.3	
	A	99.4	97.0		93.6	
	F/C-A =	13.9	10.2		10.7	
FW4TP	F/C	110.8	104.9		102.4	108.8
	A	93.8	87.9		88.7	95.9
	F/C-A =	17.0	17.0		13.7	12.9
FWJint	F/C	108.6	106.4		104.1	106.3
	A	105.2	103.8		101.9	104.0
	F/C-A =	3.4	2.6		2.2	2.3
FWJext	F/C	100.2	90.5	94.1	94.1	100.3
	A	92.9	87.5	89.2	89.5	96.4
	F/C-A =	7.3	3.0	4.9	4.6	3.9

TABLE 6. DECIBEL DIFFERENCES NOTED BETWEEN FLAT OR C-WEIGHTINGS (F/C) AND A-LEVELS (A) FOR ROTARY-WING AIRCRAFT

Type of aircraft		Liftoff	Climb	Cruise		
				Low	Normal	High
RW1RR	F/C	112.9			110.6	113.0
	A	104.4			102.2	103.7
	F/C-A =	8.5			8.4	9.3
RW2RR	F/C				108.5	
	A				103.5	
	F/C-A =				5.0	
RW1RTS	F/C	104.3			107.0	109.1
	A	95.8			98.1	100.8
	F/C-A =	8.5			8.9	8.3
RW2RTS	F/C	108.7			108.4	106.9
	A	101.9			103.0	100.6
	F/C-A =	6.8			5.4	6.3

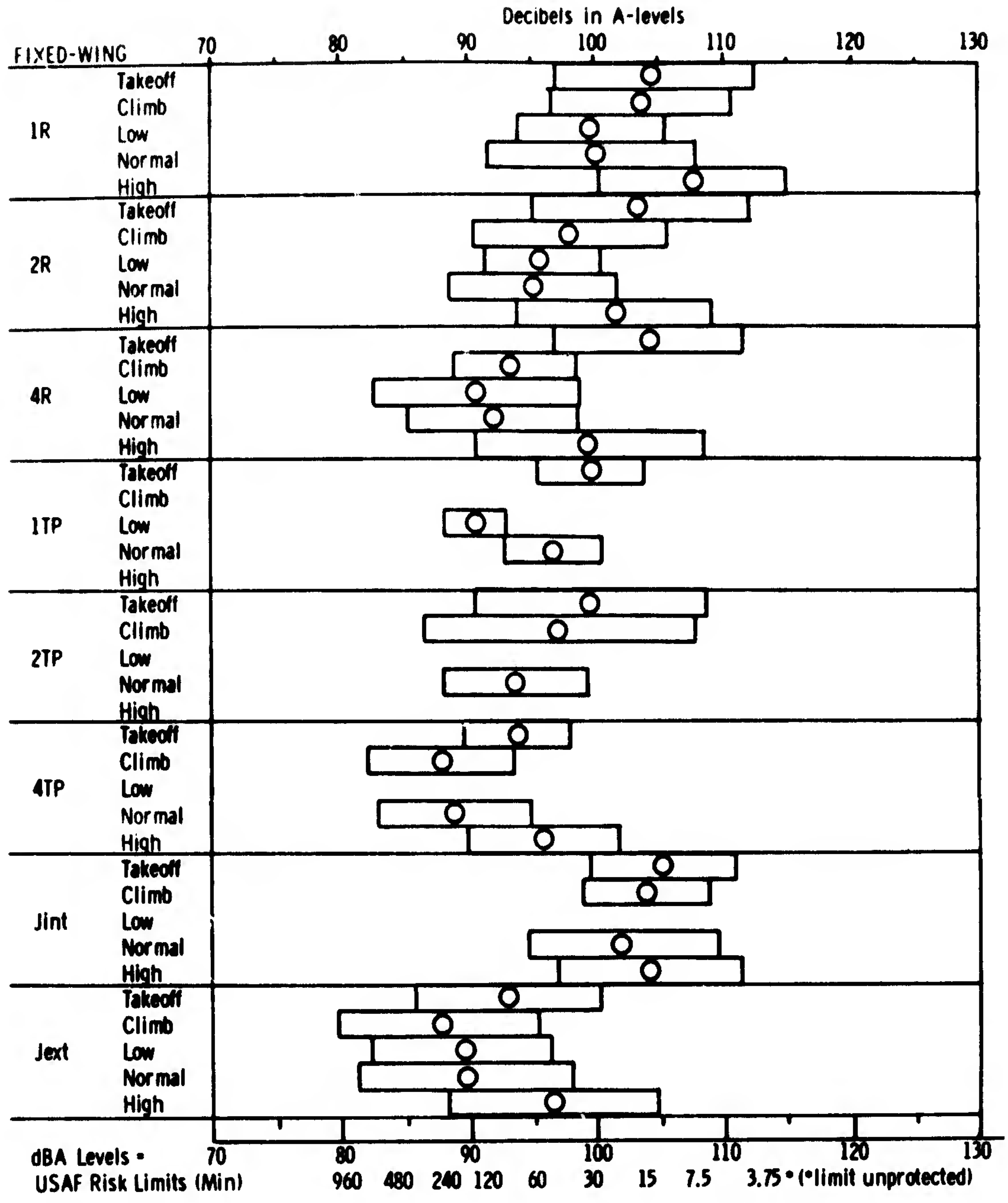

Figure 1. Mean A-levels and envelopes that include one standard deviation from the mean for cockpits of fixed-wing aircraft. Auditory risk limits (in minutes) are shown at bottom of figure.

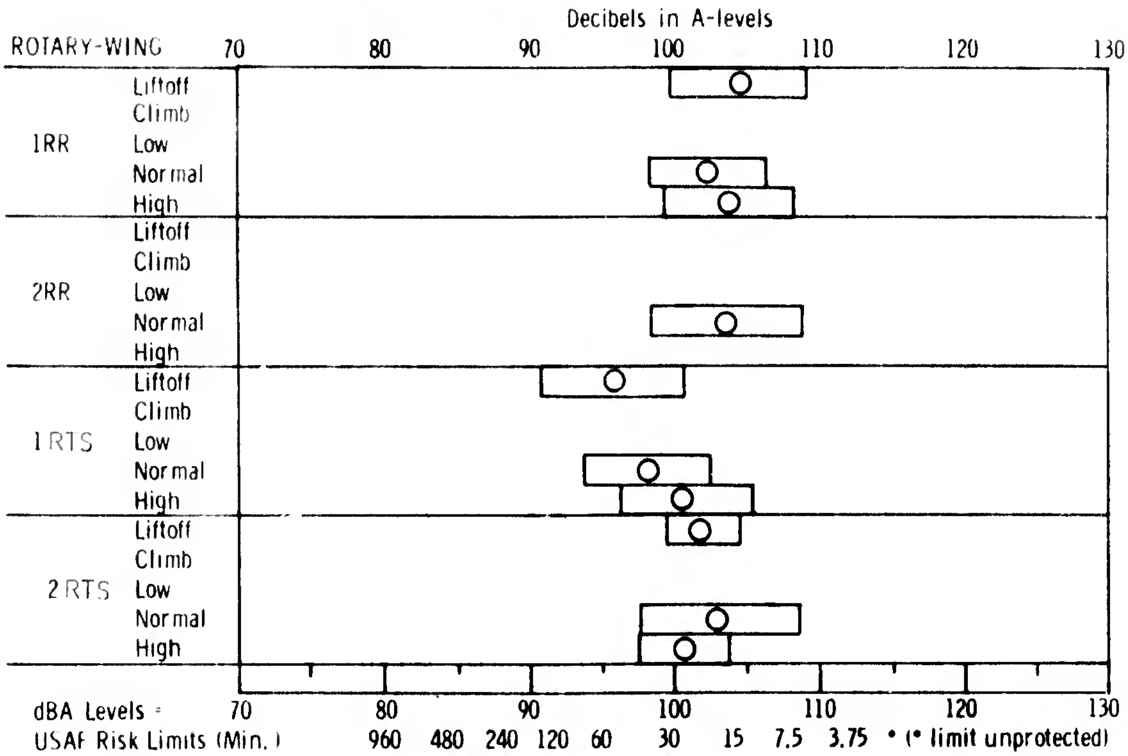

Figure 2. Mean A-levels and envelopes that include one standard deviation from the mean for cockpits of rotary-wing aircraft. Auditory risk limits (in minutes) are shown at bottom of figure.

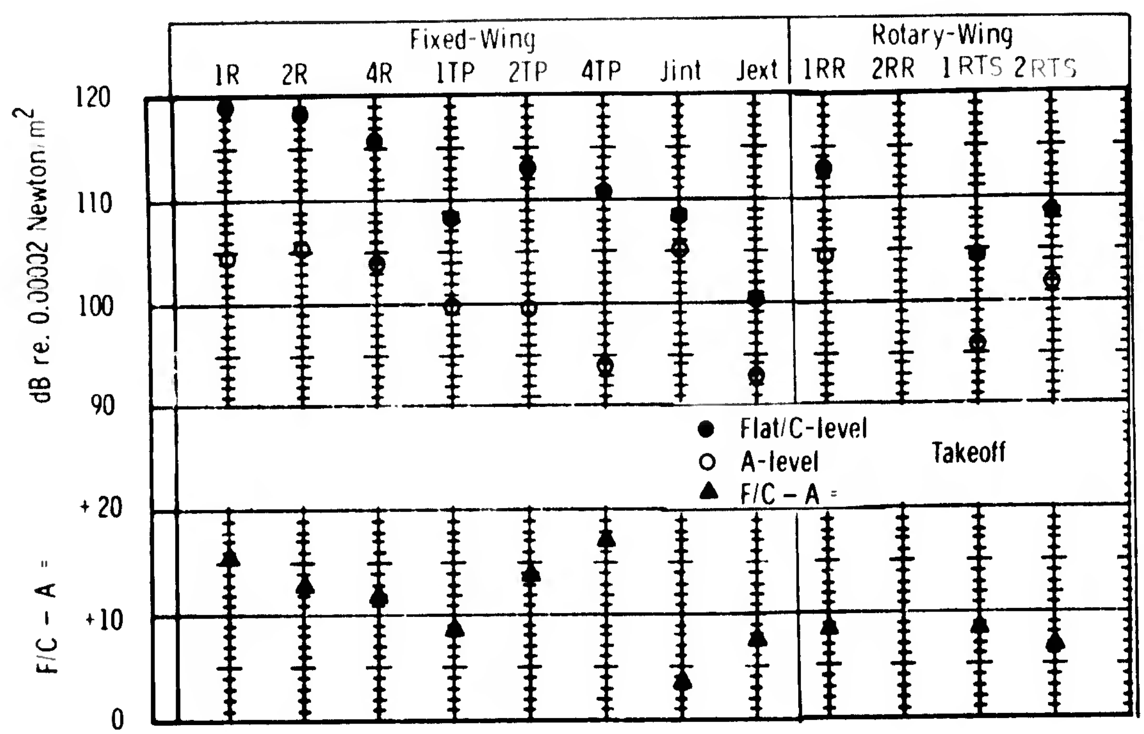

Figure 3. Mean noise levels (F/C level and A-level) and harmonic index (F/C-A =) for cockpits of different aircraft during takeoff (fixed-wing) or liftoff (rotary-wing).

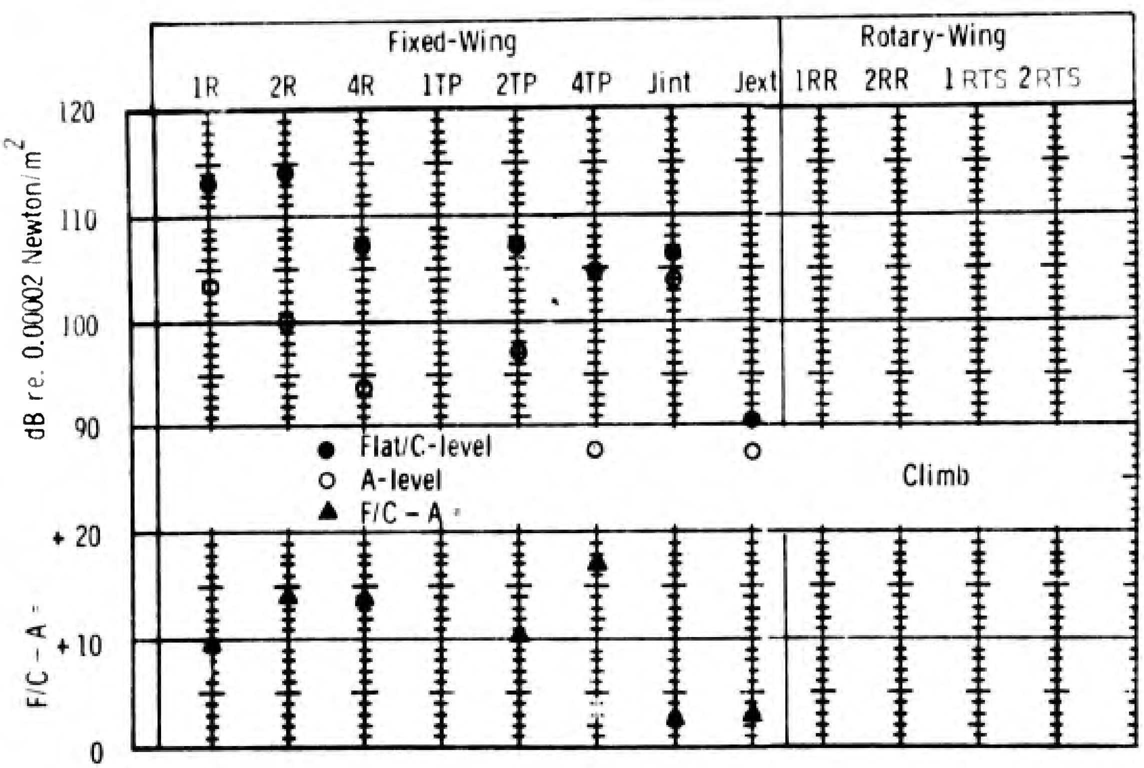

Figure 4. Mean noise levels (F/C level and A-level) and harmonic index (F/C-A =) for cockpits of different aircraft during climb.

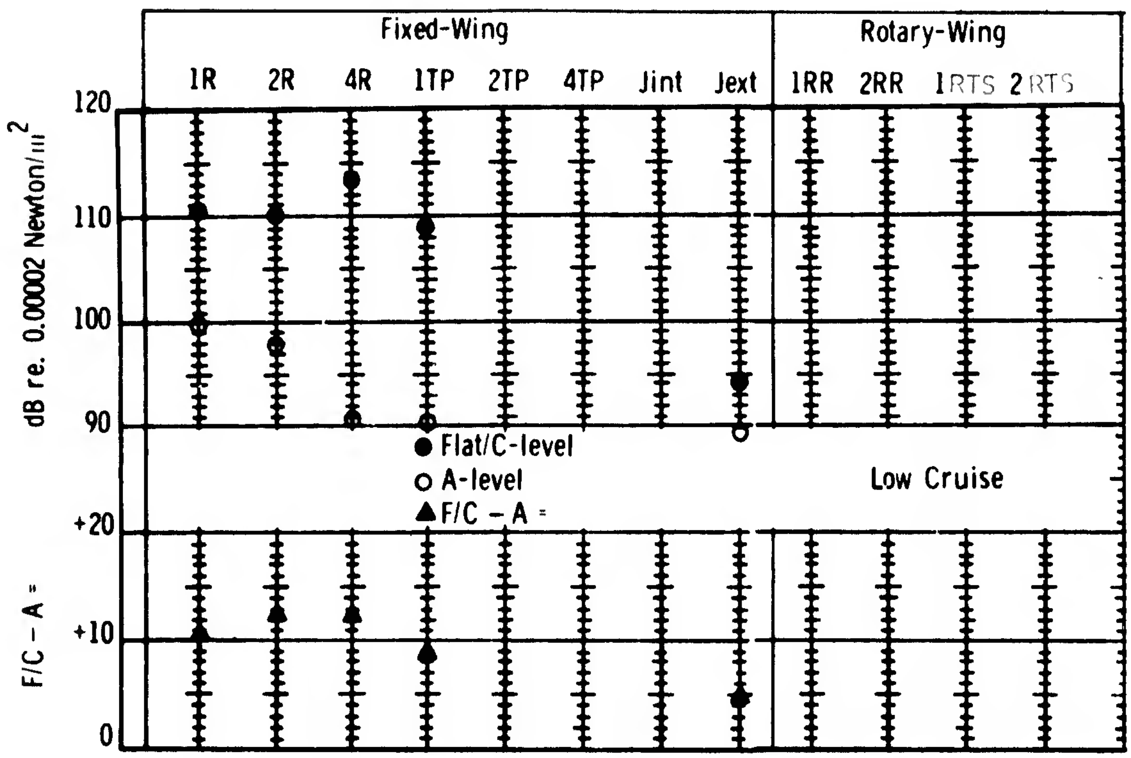

Figure 5. Mean noise levels (F/C level and A-level) and harmonic index (F/C-A =) for cockpits of different aircraft during low cruise.

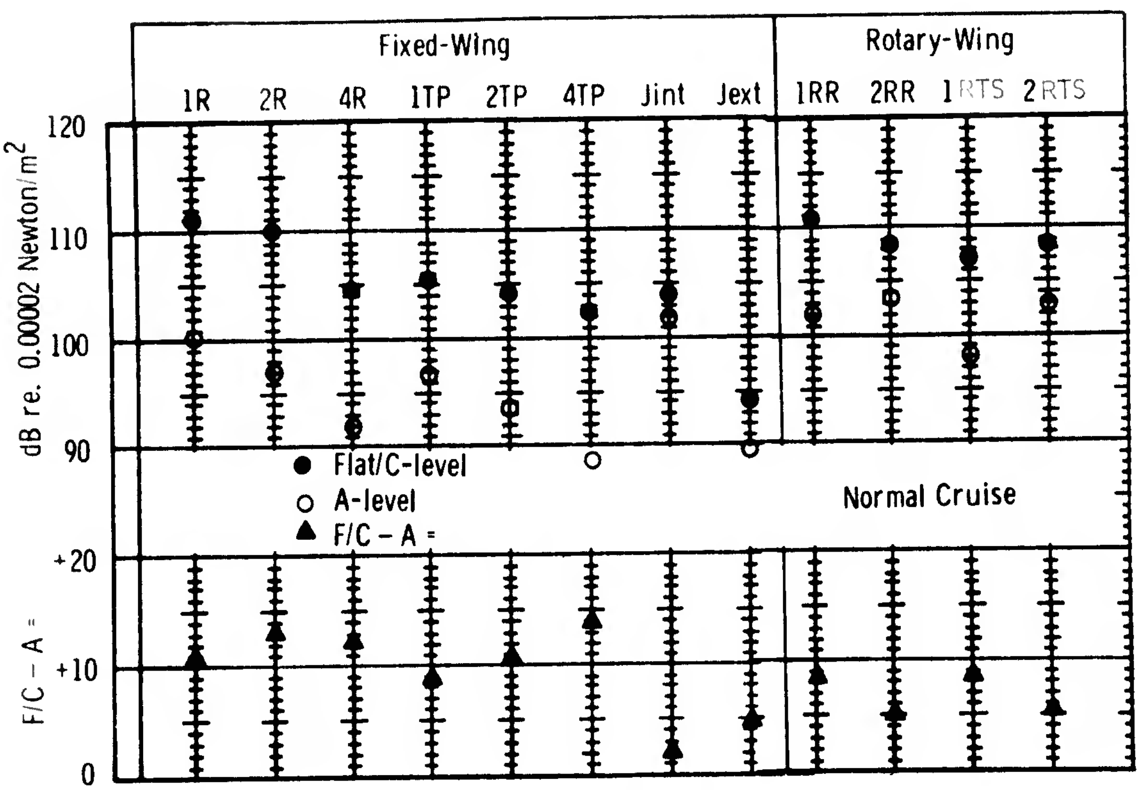

Figure 6. Mean noise levels (F/C level and A-level) and harmonic index (F/C-A =) for cockpits of different aircraft during normal cruise.

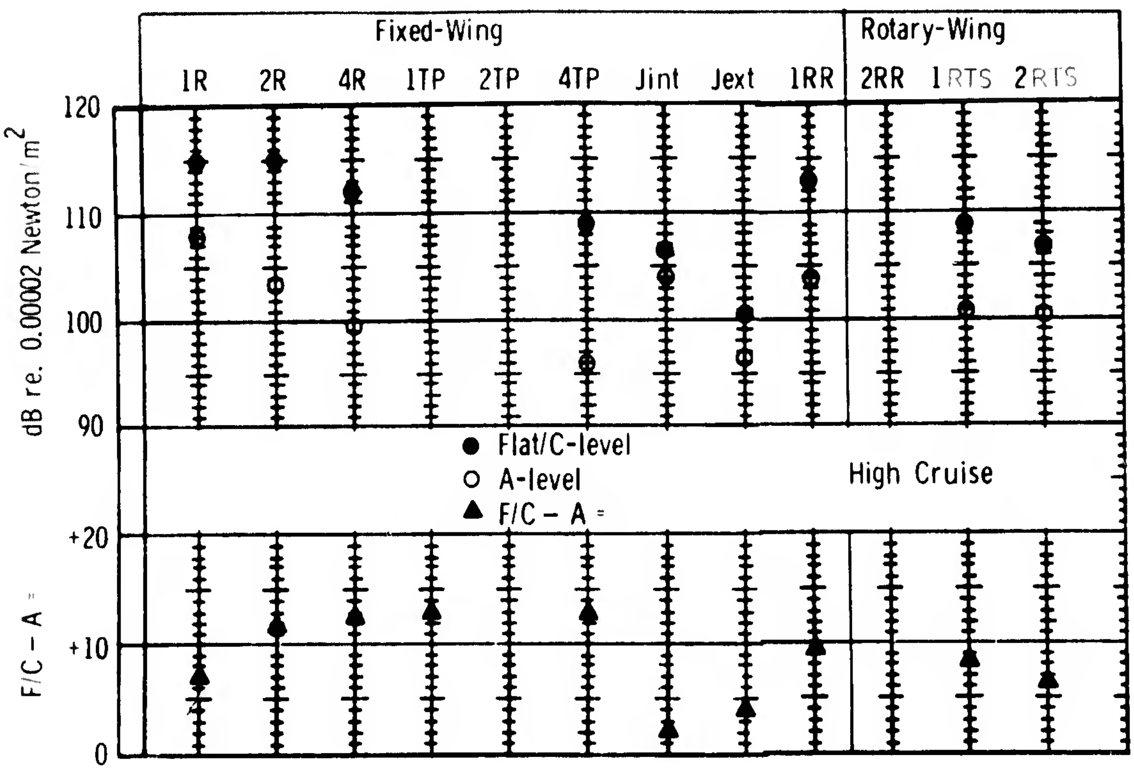

Figure 7. Mean noise levels (F/C level and A-level) and harmonic index (F/C-A =) for cockpits of different aircraft during high cruise.

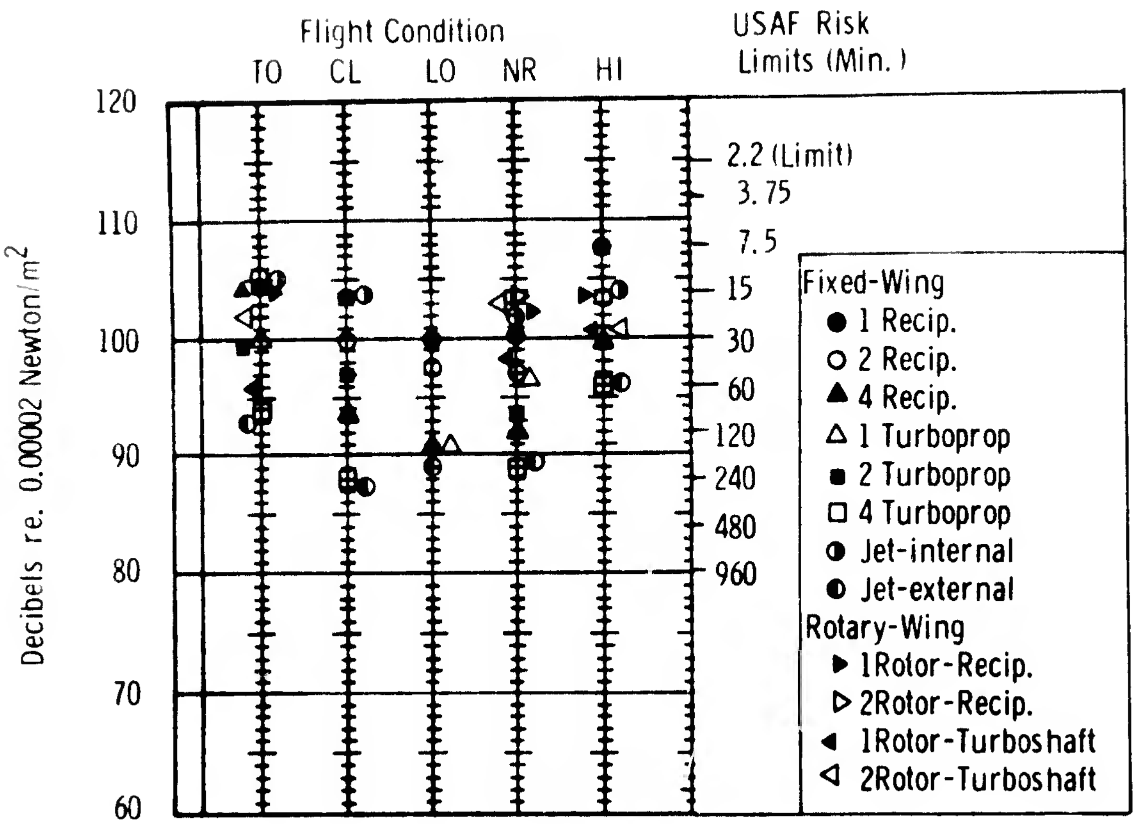

Figure 8. Summary of mean A-levels in cockpits of aircraft compared to USAF auditory risk limits (in minutes) during 5 conditions of flight.