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**Noise Attenuation Performance of the Joint
Service Aircrew Mask (JSAM) Fixed Wing (FW) Variant with Flight
Helmets**

**Hilary L. Gallagher
Richard L. McKinley
Battlespace Acoustics Branch
Warfighter Interface Division**

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Interim Report**

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711 HUMAN PERFORMANCE WING,
HUMAN EFFECTIVENESS DIRECTORATE,
WRIGHT-PATTERSON AIR FORCE BASE, OH 45433
AIR FORCE MATERIEL COMMAND
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\\signed\\
Richard L. McKinley
Work Unit Manager
Battlespace Acoustics Branch

\\signed\\
Robert C. McKinley
Chief, Battlespace Acoustics Branch
Warfighter Interface Division

\\signed\\
G. Richard Freeman
Warfighter Interface Division
Human Effectiveness Directorate
711 Human Performance Wing

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EXECUTIVE SUMMARY

Noise attenuation performance measurements were collected on the Joint Service Aircrew Mask (JSAM) Fixed Wing (FW) variant Generation 5 worn in combination with service-specific helmets at the Air Force Research Laboratory's (AFRL) acoustics facilities at Wright-Patterson Air Force Base in March 2011. American National Standards Institute (ANSI) methods were used to measure the passive attenuation performance of the flight helmets with and without the JSAM-FW respirator. Passive attenuation was measured using ANSI S12.6-1997(R2002)¹ Methods for Measuring the Real-Ear Attenuation (REAT) of Hearing Protectors, Method A, while passive insertion loss was measured using ANSI S12.42-1995(R2004)² Microphone-in-Real-Ear (MIRE) and Acoustic Test Fixture Methods for the Measurement of Insertion Loss of Circumaural Hearing Protection Devices. Noise attenuation of the HGU-55/P, HGU-68/P, and HGU-84/P were measured with and without the JSAM-FW respirator to understand the effect the respirator may have on noise attenuation. The JSAM-FW Performance Specification [71] requirement³ defined that when integrated, no more than a 3 dB degradation of the measured one-third octave band hearing attenuation shall result when compared to the original (helmet only) configuration. The results showed that the JSAM-FW system degraded the noise attenuation of the three helmets by more than 3 dB at some but not all frequencies.

1.0 INTRODUCTION

Flight helmets are donned in military jet aircraft for multiple reasons. Combating noise in the cockpit as well as providing satisfactory voice communication capabilities are just two of them. The JSAM-FW respirator is worn in combination with a flight helmet to provide "above-the-shoulder" chemical/biological (CB) protection for the respiratory system in an actual or perceived CB warfare environment. The JSAM-FW system includes a hood assembly and a torso-mounted equipment assembly. The system was designed to be worn with all the current below-the-neck ensembles. Aircrews wear the JSAM-FW based on threat and operational requirements. Aircrews also perform extended ground duties such as pre-flight, post-flight, rearming, refueling and cargo loading of aircraft while wearing the JSAM-FW and emergency actions such as ground escape and evasion. This system was developed to replace the United States Navy (USN) AP-22P aircrew respirator (AR-5), the United States Air Force (USAF) MBU-19/P aircrew mask (AERP) and MCU-2/P, and the USA M45 protective mask.

In March of 2011, AFRL's 711th Human Performance Wing, Human Effectiveness Directorate, Warfighter Interface Division, Battlespace Acoustics Branch (711 HPW/RHCB) received a request to evaluate the noise attenuation performance of the HGU-55/P (Figure 1a), the HGU-68/P (Figure 1b), and the HGU-84/P (Figure 1c) with and without the JSAM-FW respirator. Each helmet system included a service-specific helmet, an Oregon Aero Zetaliner, no visor, standard earcups with speakers, and an oxygen mask with a valve and hose (MBU-20/P with the HGU-55/P and MBU-23/P with the HGU-68/P and the HGU-84/P). When the helmets were worn in combination with the JSAM-FW, the system included a service-specific helmet, a Joint Strike Fighter (JSF)

liner, no visor, standard earcups with speakers, and the JSAM-FW. The objectives were to determine if noise attenuation goals were met for the JSAM-FW when comparing the noise attenuation performance of the helmet with and without the JSAM-FW and to identify any operability shortcomings. The JSAM requirement³ is shown below.

[71] *The JSAM when integrated with existing and developmental head-mounted personal/life support equipment in Appendix E shall result in no more than a 3 dB degradation of the measured one-third octave band hearing attenuation compared to the original (non-JSAM) configuration.*

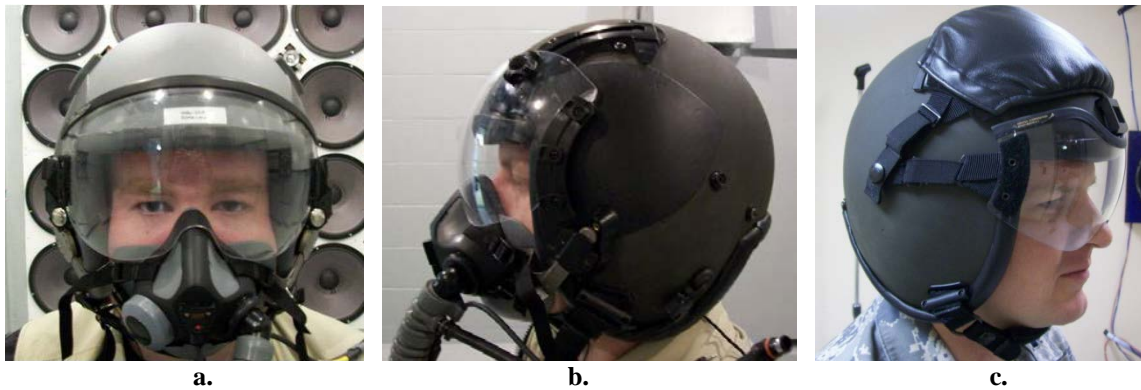


Figure 1. Flight helmets a. HGU-55/P b. HGU-68/P and c. HGU-84/P

2.0 METHODS

2.1 Subjects

Ten paid volunteer subjects (6 male, 4 female) participated in the attenuation measurements on the HGU-55/P, the HGU-68/P, and the HGU-84/P helmets worn with and without the JSAM-FW respirator. All subjects had hearing threshold levels less than or equal to 15 dB hearing level (HL) from 125 to 8000 Hz. The ten subjects ranged in age from 19 to 26 with a mean age of 23 years. Anthropometric head and neck measurements were collected for each subject, as shown in Table 1. All subjects were expertly fitted by a trained program representative.

Table 1. Anthropometric head and neck measurements for participating subjects

Subject ID	Anthropometric Head and Neck Measurements (cm)			
	Head Length	Head Width	Nasal Root to Supramentale	Neck Circumference
1482	20.1	15.2	8.9	38.7
1427	19.2	15.3	9.0	37.3
1379	19.5	15.6	8.2	38.5
1487	19.0	13.9	8.7	33.0
1485	19.7	14.7	8.3	36.0
1447	20.2	15.5	8.5	40.0
1481	19.6	14.8	8.0	40.5
45	19.5	14.7	9.3	43.5
1442	19.0	15.7	9.2	37.5
33	18.5	13.9	8.6	35.7

2.2 REAT

The AFRL REAT facility was used to measure the passive attenuation performance of hearing protectors. The facility was built for the measurement, analysis, and documentation of the sound attenuation properties of passive hearing protection devices. The chamber, its instrumentation, and measurement procedures were in accordance with ANSI S12.6-1997(R2002).¹ The procedures described in ANSI S12.6 consist of measuring the open ear (without the hearing protector, Figure 2) and occluded ear (with the hearing protector) hearing thresholds of human subjects using a von Békésy tracking task. These psychoacoustic thresholds were measured two times for the open condition and two times for the occluded condition. The real-ear attenuation at threshold for each subject was computed at each frequency, 125 to 8000 Hz, by averaging the two trials (the difference between open and occluded ear hearing thresholds). The mean and standard deviation was then calculated across all the subjects.



Figure 2. Female subject in REAT facility, open ear condition

2.3 MIRE

The AFRL MIRE facility was used to measure the passive insertion loss of hearing protectors, Figure 3. Insertion loss was defined as the algebraic difference in dB between the sound pressure levels (SPL) measured at a reference point with and without the hearing protection device in place. The facility and measurements were operated in accordance with ANSI S12.42-1995(R2004).² Miniature microphones (Knowles model BT-1759) were used to simultaneously measure the SPL at the entrance of both ear canals. 105 dB overall SPL was generated and two objective measurements were collected to complete one trial: open ear and occluded ear. Three trials were collected per subject according to the standard. For each subject, the mean of these three measurements was computed for both the open and occluded ear conditions. Average insertion loss for the ten subjects was then calculated for each configuration.

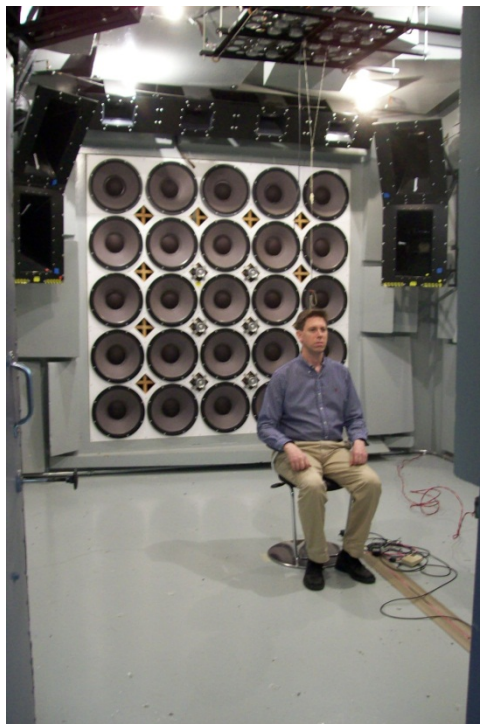


Figure 3. Male subject sitting in test facility at AFRL for MIRE measurement

3.0 RESULTS

The ANSI S12.6 real-ear attenuation (REAT) performance and ANSI S12.42 microphone-in-real-ear (MIRE) measurements of the HGU-55/P, HGU-68/P, and HGU-84/P were measured with and without the JSAM-FW respirator (Figures 4-9, Tables 2-7). The results were analyzed to compare the noise attenuation performance of the flight helmet with and without the JSAM-FW respirator in order to understand the effect the JSAM-FW may have on the system. The JSAM-FW requirement states that the addition of the JSAM-FW respirator shall not degrade the noise attenuation of the flight helmet by more than 3dB.

3.1 REAT – Passive Noise Attenuation

Passive noise attenuation performance was measured on the HGU-55/P with and without the JSAM-FW in AFRL’s REAT facility. Mean and standard deviation results from 125-8000 Hz are shown numerically in Table 2 and the mean results shown graphically in Figure 4. The JSAM-FW degraded the noise attenuation of the HGU-55/P by more than 3 dB at 125 and 250 Hz, but resulted in approximately 6 dB improvement at 4000 Hz.

Table 2. Mean and standard deviation passive attenuation results from REAT measurements comparing the HGU-55/P with and without the JSAM-FW

		Frequency (Hz)						
		125	250	500	1000	2000	4000	8000
HGU-55/P with JSAM-FW	Mean	13.97	9.28	18.06	32.41	38.31	49.26	53.37
	SD	5.98	5.07	2.82	5.38	4.79	10.49	9.10
HGU-55/P	Mean	18.29	13.08	18.78	31.15	32.71	43.69	53.62
	SD	2.93	4.57	5.05	3.20	5.44	7.47	5.14

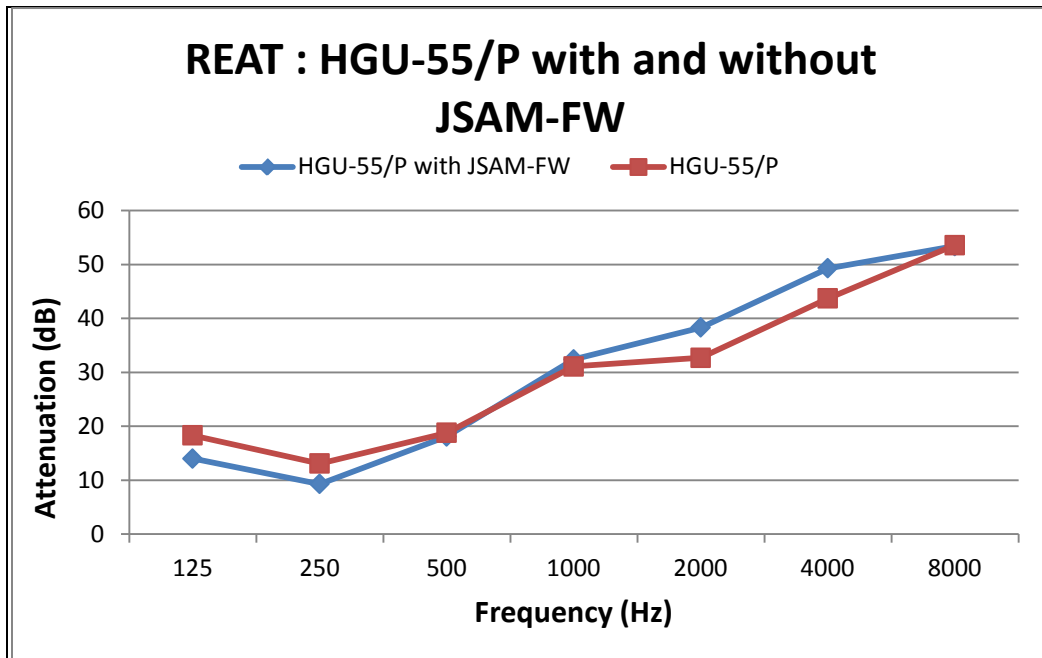


Figure 4. Passive noise attenuation of the HGU-55/P with and without the JSAM-FW

REAT passive noise attenuation performance was also measured on the HGU-68/P with and without the JSAM-FW. Mean and standard deviation data from 125-8000 Hz are shown numerically in Table 3 and the mean results shown graphically in Figure 5. The addition of the JSAM-FW respirator had no negative effect on the flight helmet noise attenuation when comparing the mean noise attenuation of the HGU-68/P with and without the JSAM-FW across all frequencies.

Table 3. Mean and standard deviation passive attenuation results from REAT measurements comparing the HGU-68/P with and without the JSAM-FW

		Frequency (Hz)						
		125	250	500	1000	2000	4000	8000
HGU-68/P with JSAM-FW	Mean	14.52	13.41	17.59	30.10	36.31	49.99	52.93
	SD	3.95	5.23	3.45	2.57	3.46	5.55	4.76
HGU-68/P	Mean	16.28	9.21	16.45	29.95	36.43	45.81	53.81
	SD	5.30	5.72	5.84	4.61	5.72	7.87	5.56

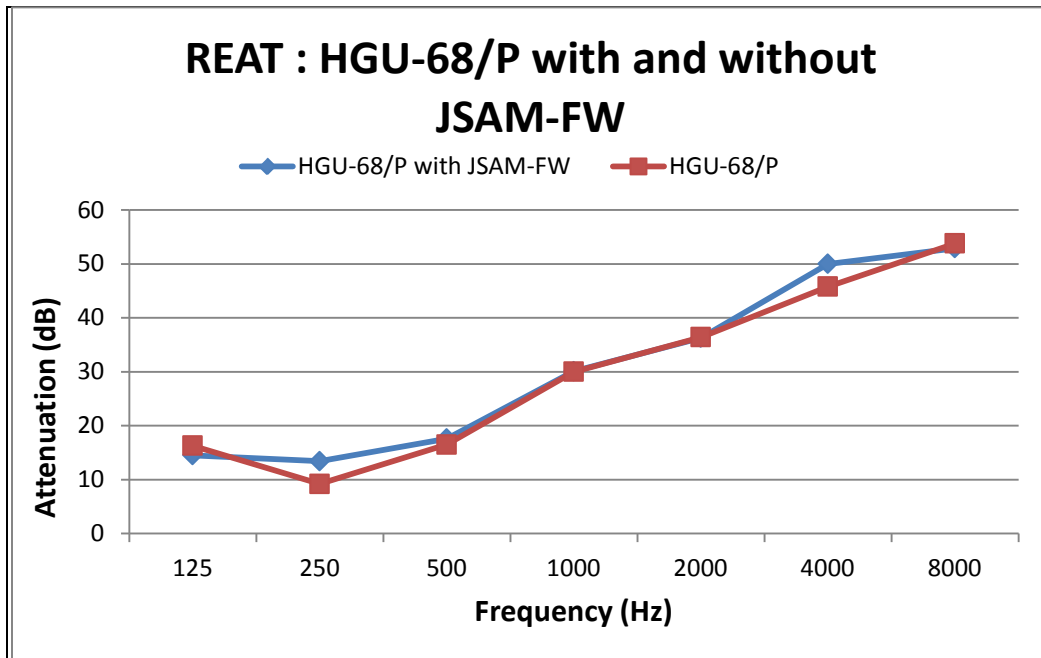


Figure 5. Passive noise attenuation of the HGU-68/P with and without the JSAM-FW

Passive noise attenuation performance on the HGU-84/P with and without the JSAM-FW was measured in the REAT facility at AFRL. Mean and standard deviation data from 125-8000 Hz are shown numerically in Table 4 and the mean results shown graphically in Figure 6. The HGU-84/P worn in combination with the JSAM-FW degrades the noise attenuation performance greater than 3 dB when compared to the HGU-84/P alone at 125 and 250 Hz.

Table 4. Mean and standard deviation passive attenuation results from REAT measurements comparing the HGU-84/P with and without the JSAM-FW

		Frequency (Hz)						
		125	250	500	1000	2000	4000	8000
HGU-84/P with JSAM-FW	Mean	13.62	7.32	16.20	31.27	41.76	53.20	58.67
	SD	5.92	4.49	4.74	5.95	4.55	7.48	6.02
HGU-84/P	Mean	19.78	13.41	15.83	29.39	39.87	47.71	56.39
	SD	3.97	2.67	2.47	2.43	2.97	10.81	4.44

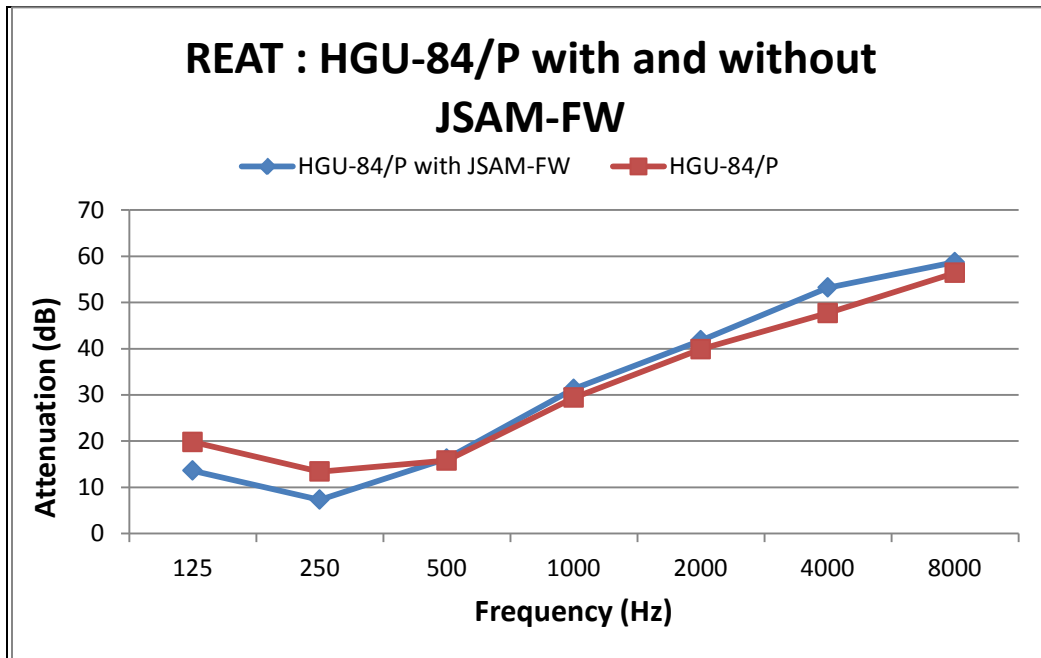


Figure 6. Passive noise attenuation of the HGU-84/P with and without the JSAM-FW

3.2 MIRE – Passive Insertion Loss

Passive insertion loss data were collected in the MIRE facility at AFRL on the HGU-55/P with and without the JSAM-FW. Mean data from 125-8000 Hz are shown numerically in Table 5 and graphically in Figure 7. The addition of the JSAM-FW to the HGU-55/P degraded the noise attenuation greater than 3 dB across all frequencies except 500 and 2000 Hz.

Table 5. Mean passive insertion loss results from MIRE measurements comparing the HGU-55/P with and without the JSAM-FW

	Frequency (Hz)						
	125	250	500	1000	2000	4000	8000
HGU-55/P with JSAM-FW	3.05	2.33	20.17	28.66	34.30	41.49	42.59
HGU-55/P	10.99	10.69	22.66	33.41	35.37	45.40	52.61

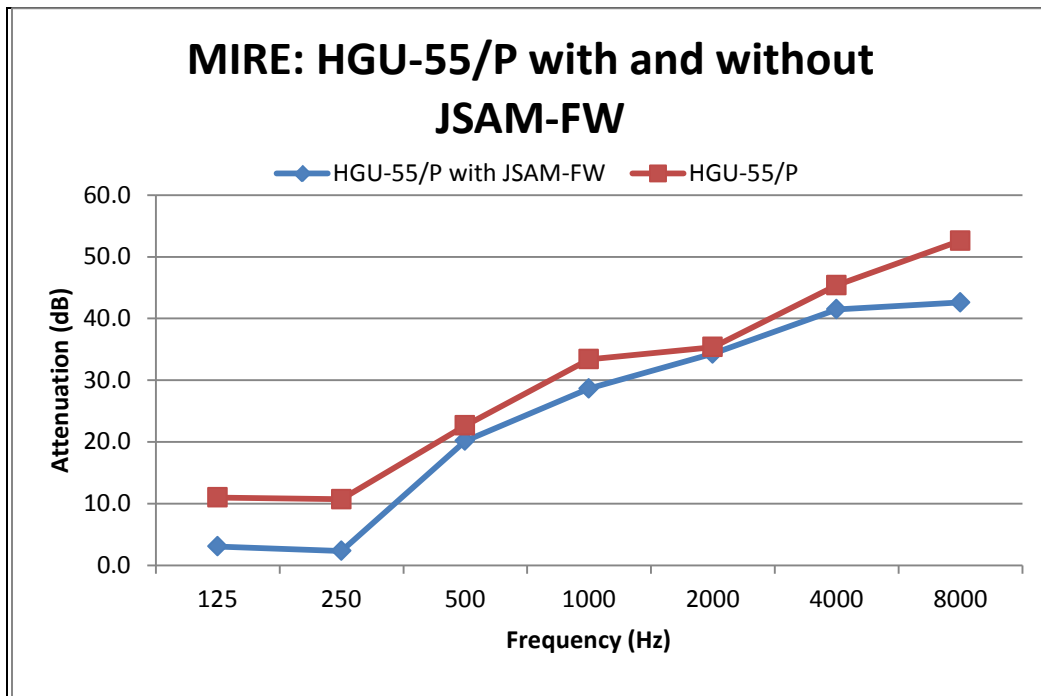


Figure 7. Passive insertion loss of the HGU-55/P with and without the JSAM-FW

Passive insertion loss data were collected on the HGU-68/P with and without the JSAM-FW in the MIRE facility at AFRL. Mean data from 125-8000 Hz are shown numerically in Table 6 and graphically in Figure 8. A degradation greater than 3 dB was found across all frequencies except 500 Hz when comparing the HGU-68/P with and without the JSAM-FW.

Table 6. Mean passive insertion loss results from MIRE measurements comparing the HGU-68/P with and without the JSAM-FW

	Frequency (Hz)						
	125	250	500	1000	2000	4000	8000
HGU-68/P with JSAM-FW	5.11	5.85	18.49	26.67	35.28	38.92	44.44
HGU-68/P	13.76	9.51	21.50	30.54	39.65	49.98	55.67

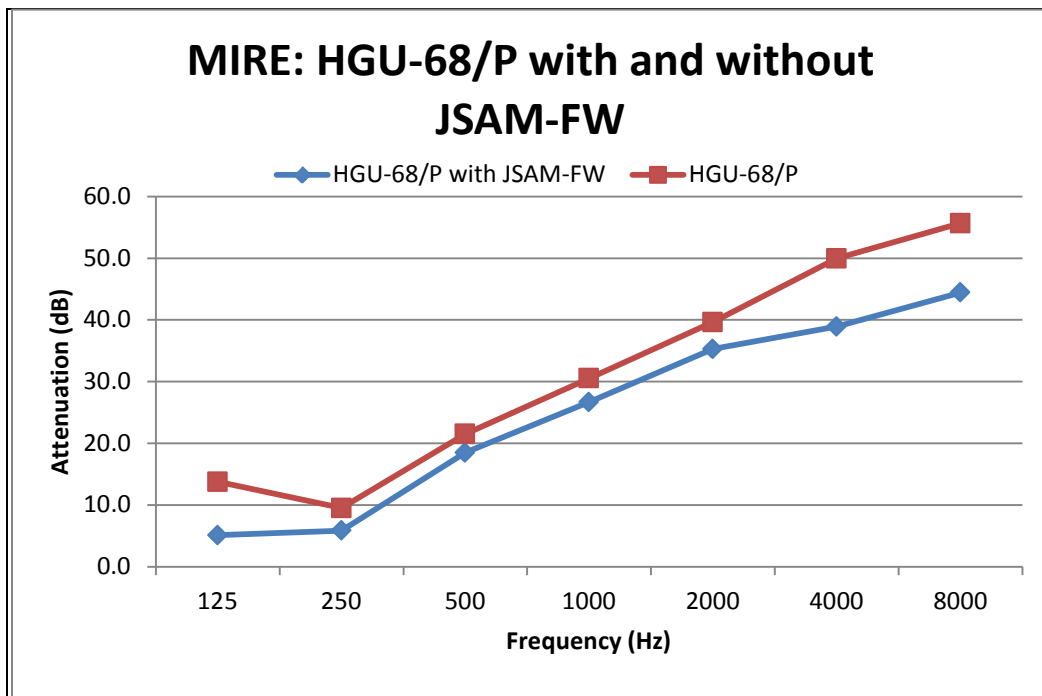


Figure 8. Passive insertion loss of the HGU-68/P with and without the JSAM-FW

MIRE passive insertion loss data were collected on the HGU-84/P with and without the JSAM-FW. Mean data from 125-8000 Hz are shown numerically in Table 7 and graphically in Figure 9. The addition of the JSAM-FW to the HGU-84/P had a negative effect on the passive insertion loss for the helmet alone across all frequencies except 500 and 1000 Hz. This negative effect was greater than 3 dB.

Table 7. Mean passive insertion loss results from MIRE measurements comparing the HGU-84/P with and without the JSAM-FW

	Frequency (Hz)						
	125	250	500	1000	2000	4000	8000
HGU-84/P with JSAM-FW	4.41	4.81	19.18	29.71	38.47	45.08	48.16
HGU-84/P	13.13	13.09	18.89	31.26	44.89	51.01	55.67

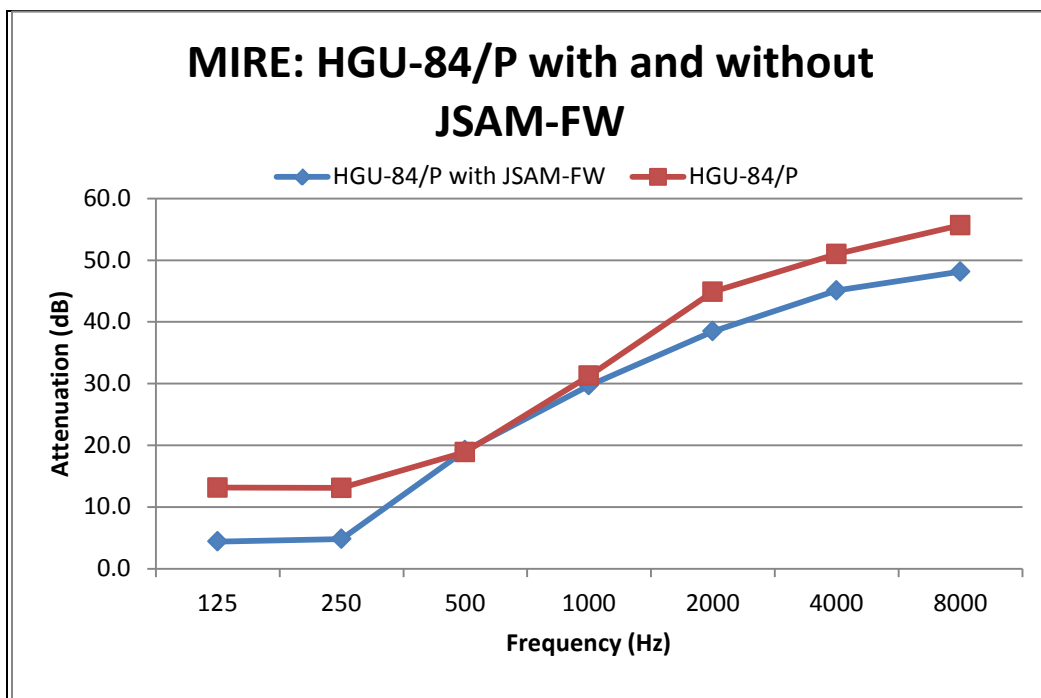


Figure 9. Passive insertion loss of the HGU-84/P with and without the JSAM-FW

4.0 DISCUSSION

It is not surprising that the noise attenuation performance of a flight helmet would be degraded when worn in combination with a CB respirator like the JSAM-FW. Any material or cable that breaks the seal of the earcup in a flight helmet has the ability to cause an acoustic leak. The JSAM-FW requirement was set so that the JSAM-FW, worn in combination with a flight helmet, would degrade the noise attenuation by no more than 3 dB across all frequencies when compared to the flight helmet alone.

Both REAT and MIRE methods were used to collect passive noise attenuation data. REAT methods are psychoacoustic measurements and the data could be used in

conjunction with the applicable service-specific and/or Department of Defense (DoD) hearing conservation program regulations for estimating the noise levels at the ear of the user and, when integrated with the exposure time, to estimate the noise dose. MIRE methods are objective and were developed for engineering controls and product development/assurance. Regardless of the test method, when comparing the noise attenuation of the HGU-55/P, HGU-68/P and the HGU-84/P with and without the JSAM-FW, the JSAM-FW negatively affects the noise attenuation performance at 125 and 250 Hz by more than 3 dB. The exception was the REAT data collected on the HGU-68/P with the JSAM-FW where results showed no degradation of noise attenuation across all frequencies.

The reduction in noise attenuation resulting from the incorporation of the JSAM-FW respirator could potentially be improved by fully integrating the earcups of the flight helmet into the JSAM-FW design. This would eliminate the material passing under the earcup that breaks the seal and adversely affects the noise reduction capability. The addition of communication earplugs could also potentially improve attenuation and voice communications when the JSAM-FW is donned by the aircrew, although aircrew acceptability could become an issue.

5.0 CONCLUSIONS

Passive noise attenuation (REAT) and passive insertion loss (MIRE) data were collected on the HGU-55/P, HGU-68/P and the HGU-84/P with and without the JSAM-FW respirator. When using REAT methods to collect noise attenuation performance data, the JSAM-FW respirator degraded the noise attenuation by more than 3 dB at 125 to 250 Hz for the HGU-55/P and HGU-84/P flight helmets. No degradation was found across all frequencies when comparing the mean noise attenuation of the HGU-68/P with and without the JSAM-FW. When using the MIRE methods to collect passive insertion loss data, the JSAM-FW degraded the attenuation by more than 3 dB across all frequencies except the mid-frequencies (500 to 2000 Hz) for all the flight helmets.

The noise attenuation performances of the flight helmets worn with and without the JSAM-FW were collected in accordance with ANSI S12.6 and ANSI S12.42 for measuring the attenuation of hearing protectors and hearing protection systems. The REAT data presented in this report are suitable for use in noise exposure calculations for the DoD and individual service hearing conservation programs.

6.0 REFERENCES

1. ANSI S12.6-1997(R2002) American National Standard Methods for Measuring the Real-Ear Attenuation of Hearing Protectors.
2. ANSI S12.42-1995(R2004) American National Standard for Microphone-in-real-ear and Acoustic Test Fixture Methods for the Measurement of Insertion Loss of Circumaural Hearing Protection Devices.
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