



Performance Assessment of the HGU-84/P Navy Helicopter Pilot Helmet

By

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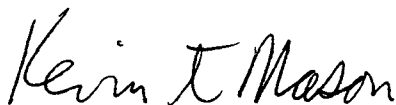
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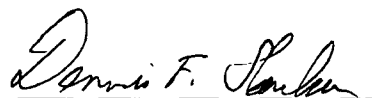


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Table of contents

| | |
|------------------------------|----|
| List of figures | 2 |
| List of tables | 2 |
| Introduction | 3 |
| Background | 3 |
| Materials | 3 |
| Head supported mass | 5 |
| Apparatus and method | 5 |
| Results and discussion | 5 |
| Center of mass | 7 |
| Apparatus and method | 7 |
| Results and discussion | 8 |
| Impact protection | 9 |
| Apparatus and method | 9 |
| Results and discussion | 10 |
| Chinstrap strength | 12 |
| Apparatus and method | 12 |
| Results and discussion | 13 |
| Dynamic retention | 14 |
| Apparatus and method | 14 |
| Results and discussion | 14 |
| Shell tear resistance | 15 |
| Apparatus and method | 15 |
| Results and discussion | 17 |
| Sound attenuation | 17 |
| Apparatus and method | 17 |
| Results and discussion | 17 |
| Evaluation summary | 19 |
| References | 20 |

List of figures

| | |
|---|----|
| 1. HGU-84/P helmet front view | 4 |
| 2. HGU-84/P helmet side view | 4 |
| 3. HGU-84/P helmet component weight breakdown | 7 |
| 4. Head anatomical coordinate system | 8 |
| 5. Impact locations | 11 |
| 6. Chinstrap strength test setup | 13 |
| 7. Dynamic retention test comparative results | 15 |
| 8. Tear resistance test impact anvil | 16 |
| 9. Tear resistance test setup | 16 |
| 10. Physical ear attenuation of the HGU-84/P helmet | 18 |

List of tables

| | |
|--|----|
| 1. Head supported mass results | 6 |
| 2. Mass property determination results | 9 |
| 3. Helmet impact test requirements | 10 |
| 4. Helmet impact test results | 12 |
| 5. Chinstrap strength test results | 14 |
| 6. Shell tear resistance test results | 17 |
| 7. HGU-84/P sound attenuation characteristics (dB) measured with ANSI S12.6 | 18 |
| 8. Estimates of the effective exposure in dBA of the HGU-84/P, HGU-56/P and the SPH-4B for Army noise environments | 19 |

Introduction

In its search for a SPH-3C replacement helmet, the U.S. Navy selected the Head Gear Unit No. 84 (HGU-84/P) helmet for use by the U.S. Navy and Marine Corps helicopter aviators. Concurrent with the Navy's HGU-84/P acquisition process, the U.S. Army was developing a new aviator helmet named the Aircrew Integrated Helmet System (AIHS), designated the Head Gear Unit No. 56 (HGU-56/P). These two aviator helmets were procured and developed to different performance specifications. It is feasible that one helmet assembly may satisfy the performance requirements of the other. The intent of this study was to evaluate the Navy's HGU-84/P against the Army's HGU-56/P performance requirements.

Background

The SPH-4 aviator helmet has been the primary helmet for Army aviators since its inception in the 1970s. Improvements and variations to the SPH-4, such as the SPH-4B and the AH-1 Cobra's helmet targeting system, have increased its applicability in the Army aviation environment. The one Army community not wearing the SPH-4 helmet is the AH-64 Apache aviator. This helmet, designated as the Integrated Helmet and Display Sighting System (IHADSS), possesses a targeting and helmet-mounted display capability unique and integral to the AH-64.

The HGU-56/P is the common replacement helmet for the SPH-4 variants and the IHADSS. The HGU-56/P helmet incorporates improved impact and acoustic protection and is compatible with the M-43 aircrew chemical protective mask.

The U.S. Army Aviation and Troop Command (ATCOM), Program Manager for Aviation Life Support Equipment (PM-ALSE), funded the U.S. Army Aeromedical Research Laboratory (USAARL) to procure and evaluate the Navy HGU-84/P against the U.S. Army HGU-56/P performance requirements. The performance areas evaluated include: impact protection, weight, center of mass, chinstrap strength, shell tear resistance, dynamic retention, and sound attenuation.

Materials

The HGU-84/P aviator helmet, manufactured by Gentex Corporation, is available in four sizes: medium, large, extra-large, and large-wide. Each helmet assembly consists of a shell, polystyrene liner, thermoplastic liner (TPL™), integrated chin- and nape straps, earcups, communication system, leather covered edge-roll, a night vision goggle (NVG) interface mount, and dual snap-on visors with a soft visor cover. The helmet is illustrated in Figures 1 and 2.

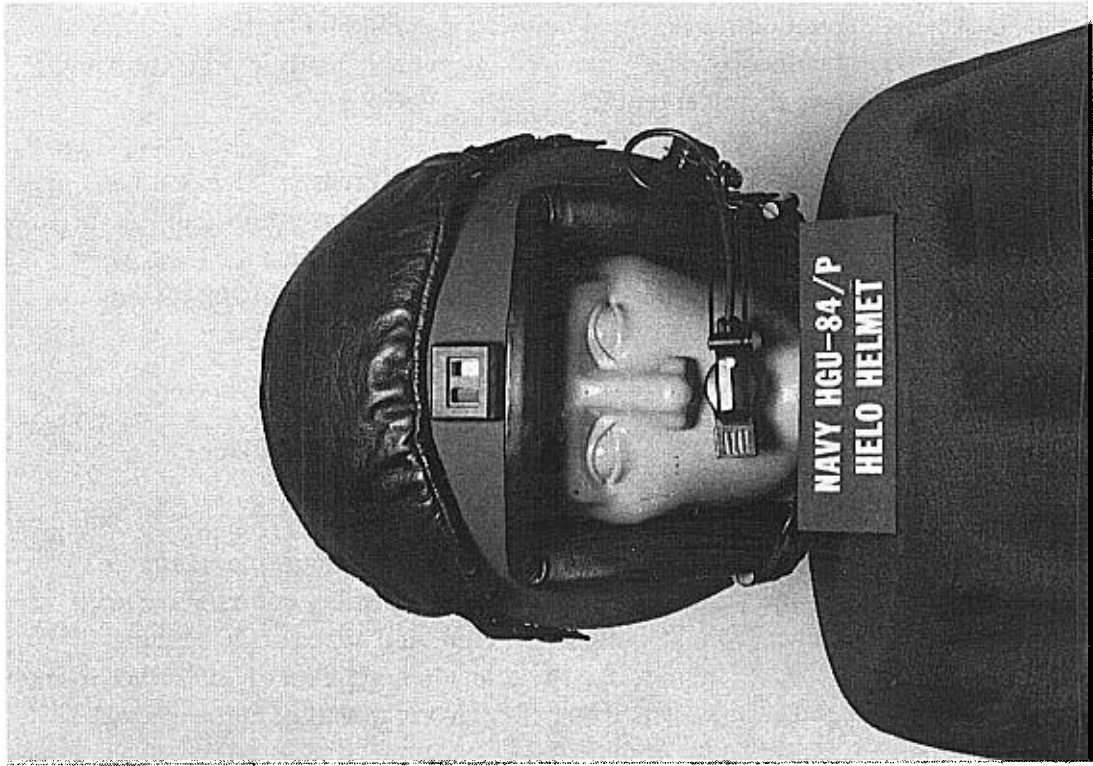


Figure 1. HGU-84/P helmet front view.



Figure 2. HGU-84/P helmet side view.

The helmet shell is constructed of epoxy impregnated nylon and graphite cloth, painted a lusterless flat black. A polystyrene liner, approximately 1.27 cm thick and 0.112 grams per milliliter (7 pounds per cubic foot) density, provides impact protection. Individual fitting is accomplished with a preformed TPL™ which may be custom fitted.

Head supported mass

Apparatus and method

The helmet's mass determination required weighing each helmet on a digital scale accurate to 0.1 gram. One of each size helmet was placed on the scale and its weight recorded. The helmet configuration included shell, energy-absorbing liner, (TPL™), communication system, snap-on dual visor system including visor cover, and integrated chin- and nape straps. No earcup spacing pads were used.

A size large HGU-84/P helmet assembly was completely disassembled for a detailed component weight breakdown assessment. The components were assembled into the following categories: shell, edge roll (consisting of foam, leather, and thread), retention assembly (including screws), communications, earcup fitting pads, visor pad, NVG mount, visor snap, styrofoam liner, TPL™, and the single clear visor.

Results and discussion

The masses of the helmets are provided in Table 1. The HGU-56/P mass requirement is not to exceed 1.3 kilograms. None of the HGU-84/P helmet assemblies meet this requirement. Removal of the soft visor cover brought the size medium within 10 grams of meeting this requirement.

Table 1.
Head supported mass results.

| Size | Visor cover included | Mass (kg) |
|--------------|----------------------|-----------|
| Medium | yes | 1.3517 |
| | no | 1.3109 |
| Large | yes | 1.4016 |
| | no | 1.3608 |
| X-Large | yes | 1.4515 |
| | no | 1.4107 |
| X-Large wide | yes | 1.6148 |
| | no | 1.5740 |

The results of the component weight breakdown are provided in Figure 3. It is easily seen that the communication system and the helmet shell are the two heaviest components contributing over 50 percent to the HGU-84/P helmet's weight. The polystyrene liner is the third heaviest component, contributing 10 percent. This high component weight can be attributed to the high density liner (approximately 7 pounds per cubic foot) which is more than twice the density of the polystyrene liner used in the HGU-56/P helmet (approximated 2 to 2.5 pounds per cubic foot).

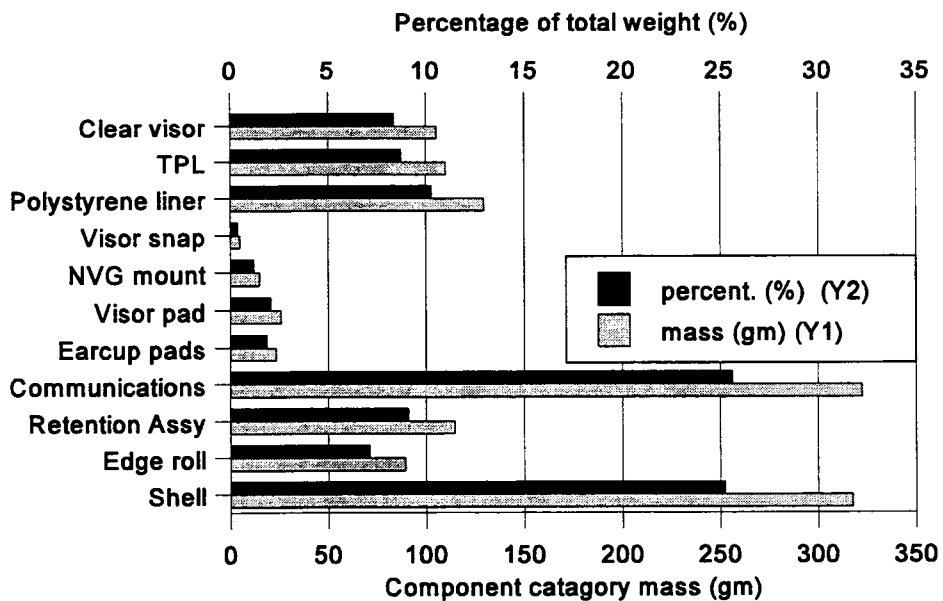


Figure 3. HGU-84/P helmet component weight breakdown.

Center of mass

Apparatus and method

The helmet's center of mass (CM) was measured on a mass properties instrument as described by Deavers and McEntire (1992). The CM location is referenced to the head's anatomical coordinate system illustrated in Figure 4. The helmets were fitted onto a 50th percentile military aviator headform for the determination.

The center of mass was measured by determining the moment applied by the helmet to an instrumented beam after the beam was balanced with the headform mounted on it. The moment of inertia was measured by determining the change in the period of a torsional pendulum before and after the helmet was mounted on the headform.

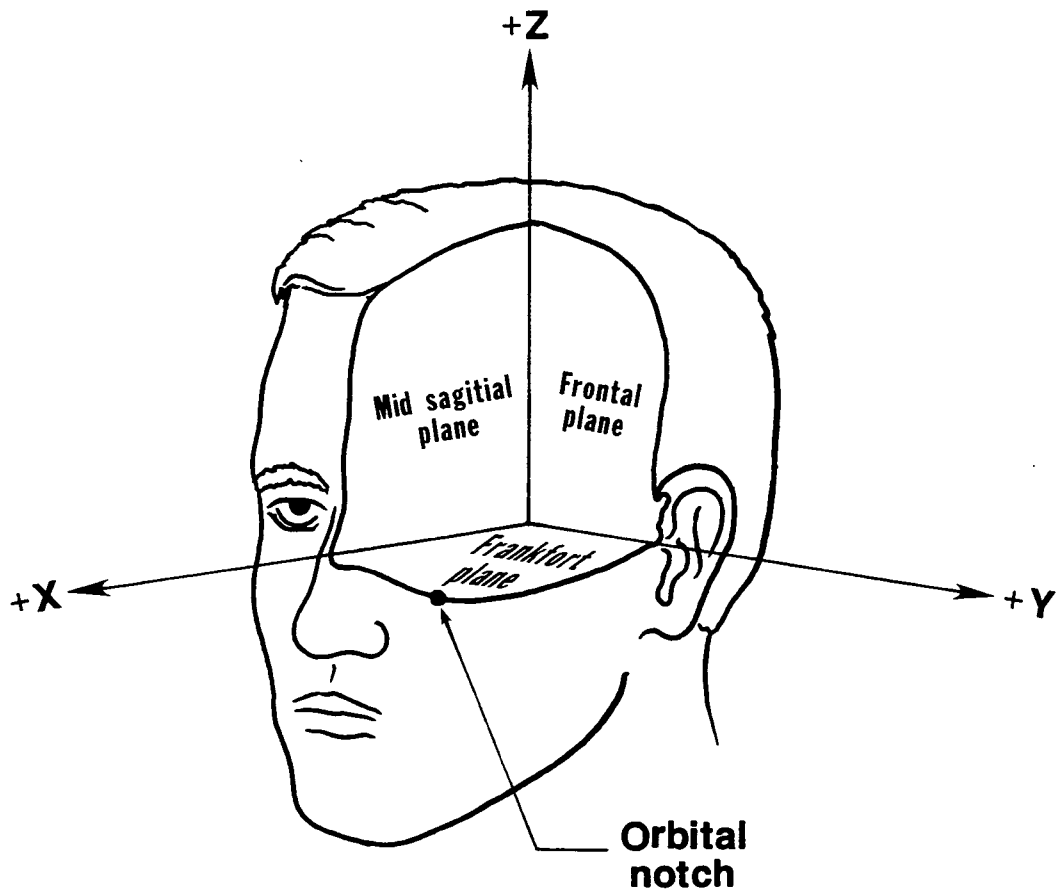


Figure 4. Head anatomical coordinate system.

Each size helmet was tested in two configurations. Based on the fitting literature received with the HGU-84/P helmets, the clear visor is worn as the inner visor and the neutral (or smoked) visor is worn as the outer visor. Two visor configurations were described in the fitting literature. These two configurations were one visor down, or both visors down for a stacked configuration. If either visor was up, the soft visor cover was to be placed on the unused visor. If both visors were deployed, the soft visor cover would be removed from the helmet completely. These were the two configurations tested: (1) the inner clear visor deployed, with the outer neutral visor protected with the soft visor cover; (2) both visors deployed and the soft visor cover removed from the helmet, and not included in the determination.

Results and discussion

The results of the mass property determinations are provided in Table 2. The HGU-56/P requirement is that the helmet CM be located "as close as possible" to the combined head and neck CM. Based on the data recorded, the helmet CM is considered acceptable.

The helmet mass moment of inertia values are provided for reference only and were not used in the evaluation process. Note that the mass moment of inertia values are based on the headform axis system and are not the principal moments of inertia.

Table 2.
Mass property determination results.

| Helmet size | Visor configuration | Mass (kg) | Center of mass (mm) | | | Moment of inertia (kg-cm ²) | | |
|-------------|---------------------|-----------|---------------------|------|-------|---|----------------|----------------|
| | | | x | y | z | I _x | I _y | I _z |
| Medium | 1 | 1.35 | -0.14 | 7.23 | 57.94 | 127.80 | 115.79 | 132.69 |
| | 2 | 1.31 | 0.01 | 6.86 | 50.79 | 137.47 | 121.54 | 133.14 |
| Large | 1 | 1.40 | 0.45 | 5.04 | 51.93 | 149.50 | 135.84 | 150.56 |
| | 2 | 1.36 | 0.32 | 5.42 | 45.62 | 140.13 | 130.11 | 148.41 |
| X-large | 1 | 1.45 | 9.87 | 4.96 | 51.78 | 156.83 | 153.10 | 164.93 |
| | 2 | 1.41 | 10.44 | 5.41 | 43.90 | 148.72 | 148.00 | 163.85 |
| Large/wide | 1 | 1.61 | 2.76 | 4.60 | 50.48 | 177.42 | 177.43 | 193.89 |
| | 2 | 1.57 | 2.14 | 5.60 | 44.96 | 168.57 | 172.11 | 191.74 |

Impact protection

Apparatus and method

Helmet impact protection testing was performed on a monorail guided impact tester. The test setup conformed to ANSI Z90.1-1971 requirements. A medium sized magnesium headform containing an accelerometer located near the head's center of mass was used. The headform was attached by a rod to a lightweight drop cage which, in turn, was attached to a monorail rod through two linear ball bearings. Only two helmets were tested, a size medium and a size large. The two larger sizes were too large to obtain an adequate fit on the test headform.

The required impact velocity and maximum allowable headform acceleration for each impact site is provided in Table 3. The various impact sites are illustrated in Figure 5.

Table 3.
Helmet impact test requirements.

| Impact site | Impact velocity (m/s) | Headform deceleration (G) |
|--------------|-----------------------|---------------------------|
| Front | 6.0 | 175 |
| Rear | 6.0 | 175 |
| Left side | 6.0 | 175 |
| Right side | 6.0 | 175 |
| Crown | 4.88 | 150 |
| Left earcup | 6.0 | 150 |
| Right earcup | 6.0 | 150 |

Results and discussion

The impact test results are provided in Table 4. Only the crown impact site consistently met the Army requirement. Probably, this is a result of the HGU-84/P helmet shell contour in the crown region when compared to the test headform. The test headform is relatively flat in the crown region while the HGU-84/P helmet is spherical. This creates two contact points between the headform and the energy-absorbing (polystyrene) liner when viewed laterally. These two points then received high contact pressures since the loading points are concentrated, resulting in a lower headform acceleration level. Also, the increased standoff distance created by the helmet's spherical shape aid in the impact energy absorption by allowing the helmet and liner to deform under impact without loading the headform directly.

The headband region failed to meet the Army requirements in all instances. This can be attributed to the energy liner's high density and the typically high contact areas between the headform and energy-absorbing liner in the headband region.

The lateral earcup impact test results were encouraging. Only one test resulted in a pass. Yet, the highest reading was a peak of 167 G. The Army requirement for the HGU-56/P is 150 G in the earcup region.

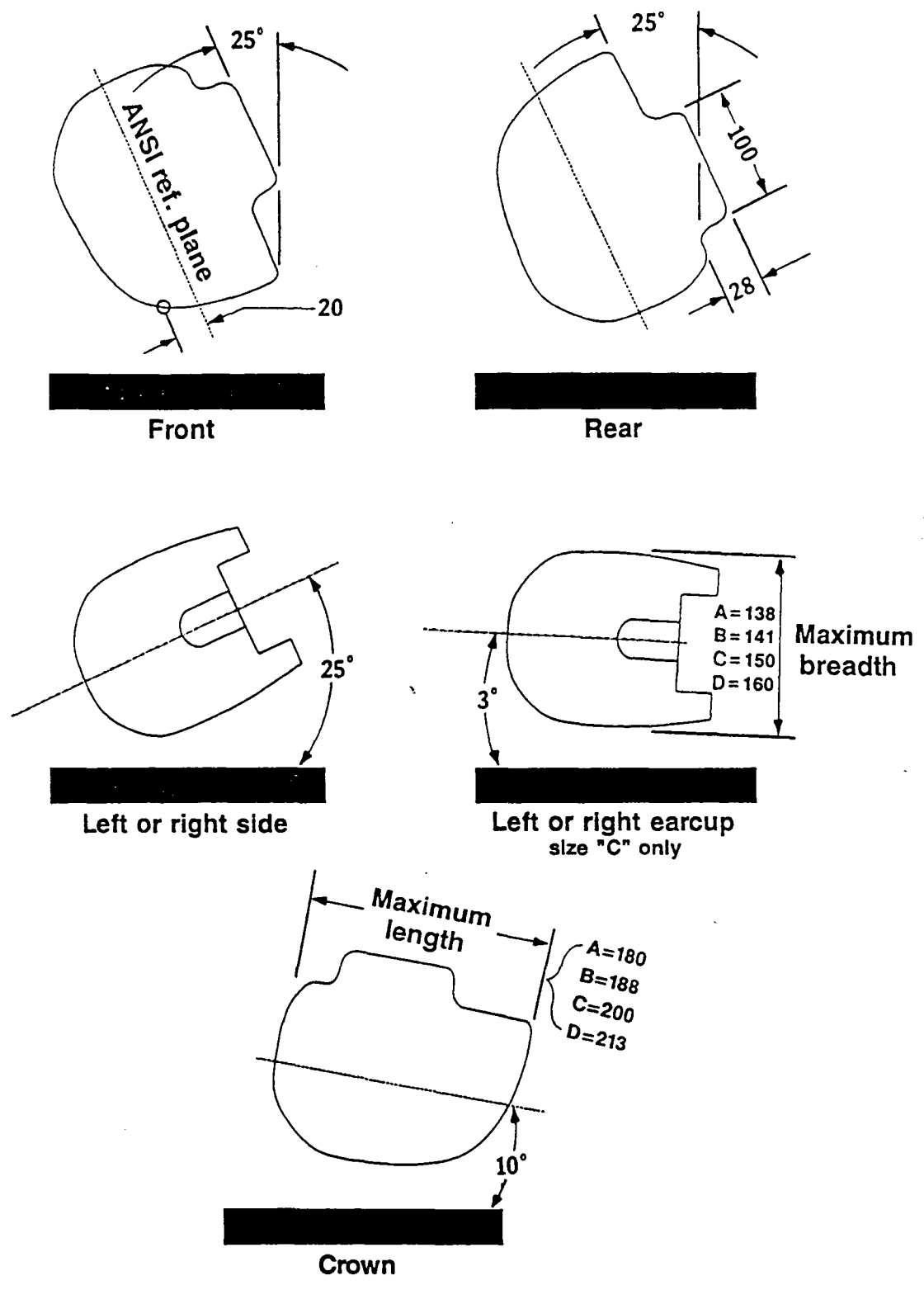


Figure 5. Impact locations.

Table 4.
Helmet impact test results.

| Helmet size | Impact site | Impact velocity (m/s) | Peak acceleration (G) | Result |
|-------------|--------------|-----------------------|-----------------------|---------|
| Medium | front | 6.00 | 196 | fail |
| | rear | * | * | no data |
| | left side | 5.99 | 223 | fail |
| | right side | 6.00 | 267 | fail |
| | left earcup | 6.00 | 123 | pass |
| | right earcup | 6.00 | 167 | fail |
| | crown | 4.96 | 115 | pass |
| Large | front | 5.81 | 313 | fail |
| | rear | 6.00 | 284 | fail |
| | left side | 5.99 | 254 | fail |
| | right side | 5.99 | 255 | fail |
| | left earcup | 5.99 | 165 | fail |
| | right earcup | * | 165 | fail |
| | crown | 4.92 | 131 | pass |

Notes:

* Instrumentation failure.

Chinstrap strength

Apparatus and method

The chinstrap strength was determined by applying a quasistatic load to the chinstrap. The load was applied by a test machine capable of applying and sustaining a load of 1,950 Newtons (440 pounds). The test setup, illustrated in Figure 6, and procedure was in accordance with DOT FMVSS 218. A pre-load of 110 Newton (N) initially was applied to the chinstrap. The load then was increased to the 1950 N proof load and held at this level for 2 minutes.

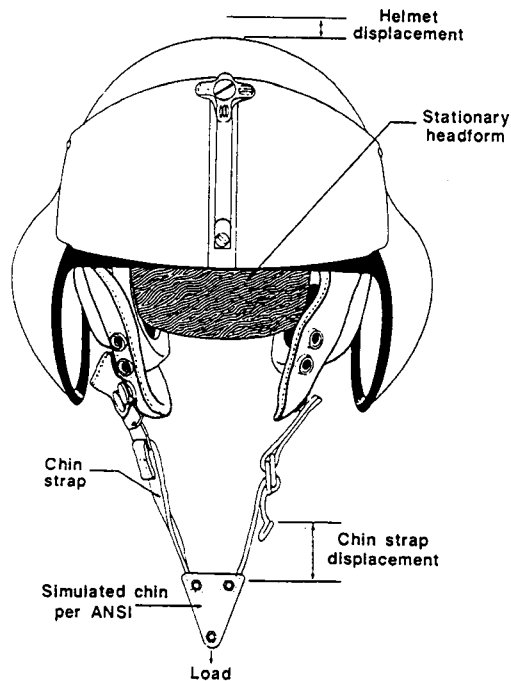


Figure 6. Chinstrap strength test setup.

Chinstrap elongation, determined by measuring the change in simulated chin position between the pre-load and proof-load, shall not exceed 3.8 cm. The helmet's change in vertical position shall be subtracted from the simulated chin position change to calculate the true chinstrap elongation.

Results and discussion

The test results are provided in Table 5. Neither helmet was able to meet the 1950 N load requirement of the HGU-56/P helmet. During each test, the chinstrap webbing slipped through the double D-ring adjustment buckle until a pile fastener portion was reached. The pile fastener material resisted webbing slippage through the D-rings and allowed the load to increase to failure. In each test, the failure point was the snap fastener unfastening. The size large helmet was retested since the first test resulted in such a low failure load.

Chinstrap elongation could not be determined since catastrophic failures were obtained in each test. The chinstrap elongation measure requires the proof-load to be held for a minimum of 2 minutes. During this time, the helmet position normally is recorded since it is common for the helmet fitting system to compress during the chinstrap loading process. This compression contaminates the chin displacement measure and must be corrected. During the catastrophic failures, the helmet's fitting system rebounds, preventing an accurate posttest reading on helmet compression.

Table 5.
Chinstrap strength test results.

| Helmet size | Load (N) | Result |
|----------------|----------|--------|
| Medium | 1516 | Fail |
| Large | 717 | Fail |
| Large (retest) | 1325 | Fail |

Dynamic retention

Apparatus and method

Helmet retention was evaluated dynamically by mounting the helmet onto a pendulum test device and subjecting the Hybrid II headform and Hybrid III neck to a triangular shaped pulse with a peak G level between 23 and 26 G. This test device is described by Gruver and Haley (1988). Helmet rotation was measured by recording the head and helmet reaction to impact with a high speed video recorder. The event was digitized and the angular displacement between the helmet and headform determined.

This test is not a contractual requirement for the HGU-56/P, but comparative data was obtained for the HGU-56/P and the SPH-4B helmets. The Hybrid II head circumference was measured at 59.7 cm (23.5 inches). This head circumference is borderline between the size large and x-large HGU-84/P helmets. Both helmet sizes were included in this evaluation. The appropriate sizes of the HGU-56/P helmet to fit the Hybrid II head were the small and medium which were included in the evaluation. For completeness, a size x-large SPH-4B helmet was included in this evaluation.

The HGU-84/P helmet configuration was the single clear visor in place without the second neutral visor or soft visor cover attached to the helmet. For the HGU-56/P and SPH-4B helmets, the inner clear visor was locked in the down position and the upper neutral visor in its stowed position.

Results and discussion

Comparative helmet rotation time history plots are shown in Figure 7. The worst performing helmet was the SPH-4B which had a maximum forward rotation of 17 degrees and an initial rearward rotation of 4 degrees. The best performing helmet was the HGU-84/P, size large. The two HGU-56/P helmet sizes and the x-large HGU-84/P helmet performed similarly. The

The two HGU-56/P helmet sizes and the x-large HGU-84/P helmet performed similarly. The HGU-84/P performed equally or better than the HGU-56/P helmet. Both, the HGU-84/P and the HGU-56/P helmet configurations performed markedly better than the SPH-4B helmet.

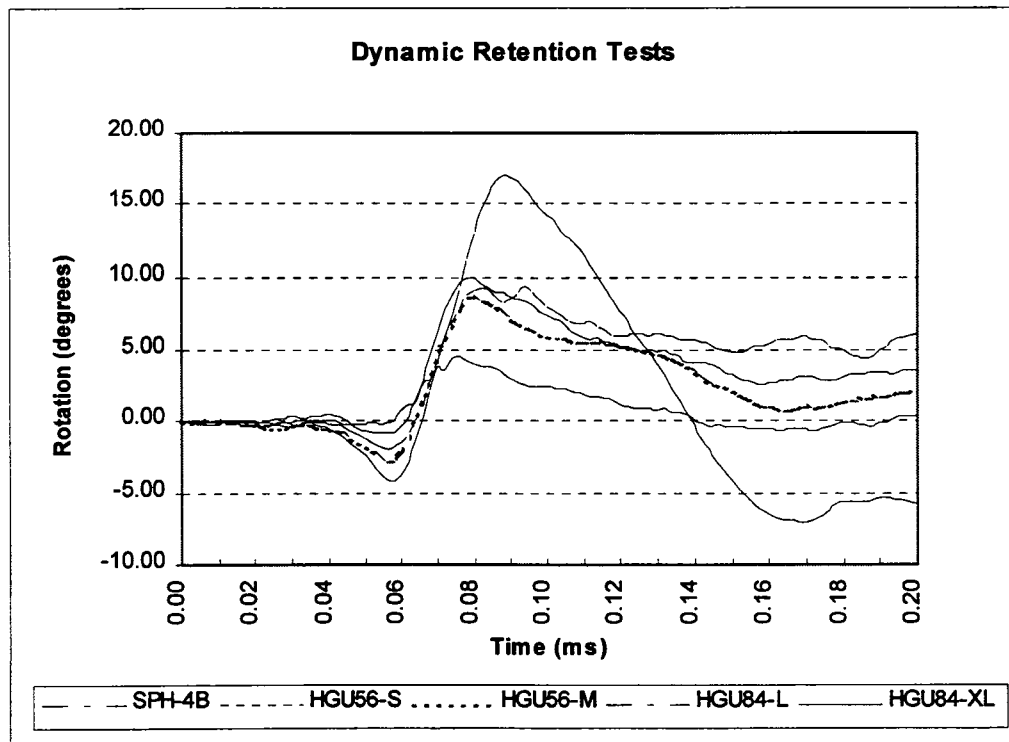


Figure 7. Dynamic retention test comparative results.

Shell tear resistance

Apparatus and method

The ability of the helmet shell to resist foreign object penetration is determined by impacting the shell with a blunt penetration anvil weighing 5 kg. This anvil is required to strike the helmet from a drop height of 1.52 meters. The point of impact on the shell creates a tangent line that is 45 degrees from horizontal. The impact anvil is illustrated in Figure 8. The helmet assembly is required to be disassembled and only the shell included in the test. The tear resistance test setup is illustrated in Figure 9. The maximum allowable tear length, the arc length measured along the shell surface, is 5 cm.

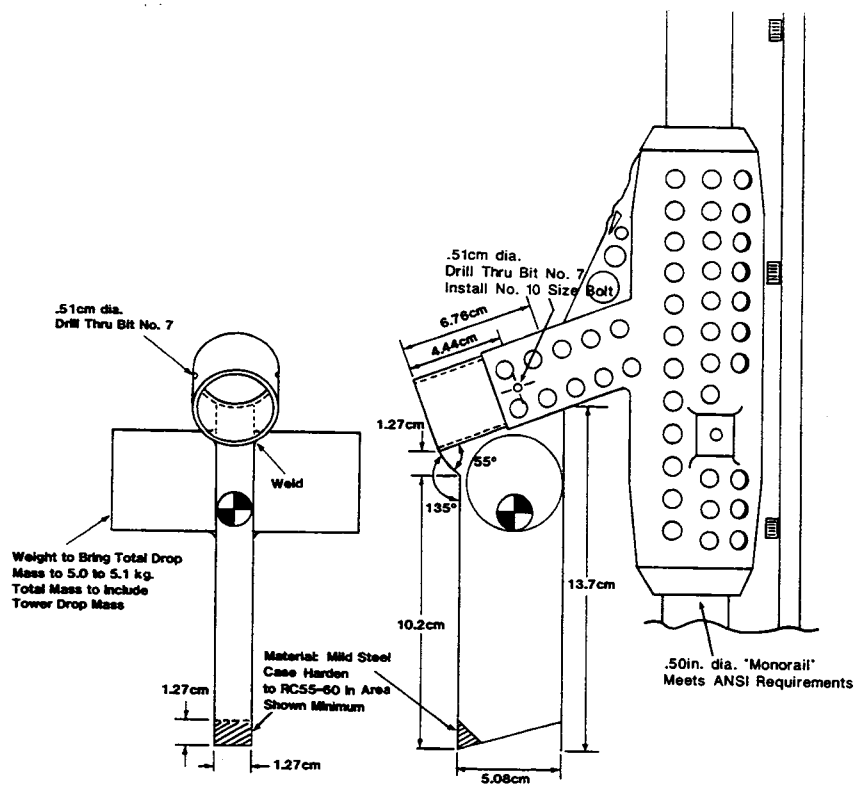


Figure 8. Tear resistance impact anvil.

SET-UP FOR HELMET TEAR TEST

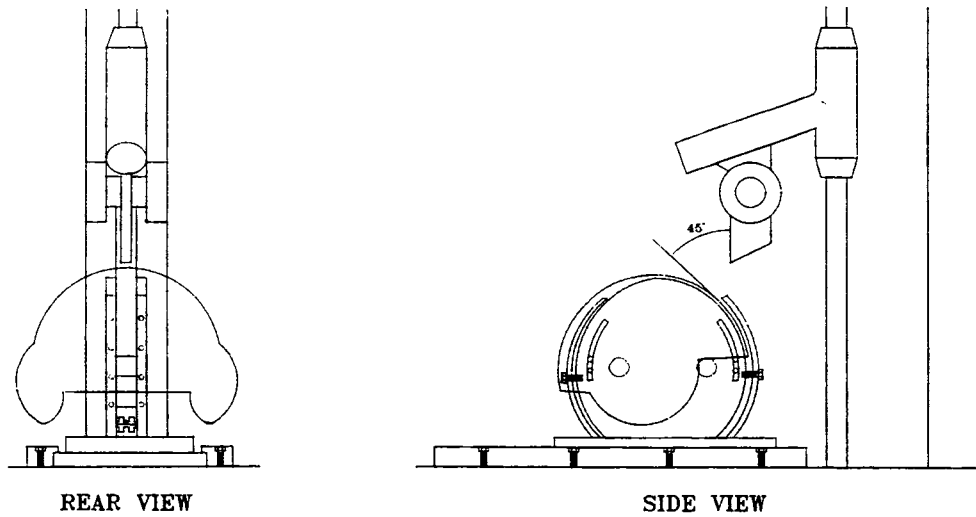


Figure 9. Tear resistance test setup.

Results and discussion

One helmet shell was subjected to the tear test. Five separate penetrations were made to the helmet shell. The results of these tests are provided in Table 6. The HGU-56/P performance level was not met.

Table 6.
Shell tear resistance test results.

| Tear site | Tear length (cm) | Result |
|-------------|------------------|--------|
| Front left | 5.0 | Pass |
| Front right | 4.0 | Pass |
| Rear left | 5.6 | Fail |
| Rear right | 6.5 | Fail |
| Rear center | 3.8 | Pass |

Sound attenuation

Apparatus and method

Sound attenuation characteristics of the HGU-84/P helmet was determined, using American National Standards Institute (ANSI) S12.6 "Method for the measurement of real-ear attenuation of hearing protectors." The facility at USAARL is in compliance with S12.6. Subjects were local college students and Army personnel stationed at USAARL. Subjects were fit with their proper size helmet for the test. The acceptance criteria, using S12.6, for the HGU-56/P Helmet is shown in Table 7 with the HGU-84/P test results.

A second test, MIL-STD-912 "Physical Ear Noise Attenuation Test" (PEAT), also was used to evaluate the sound attenuation characteristics of the helmet. The subjects used in the real-ear test also were used in the PEAT evaluation. While there is no established acceptance criteria using the PEAT procedure, it does provides data for all frequencies from 125 Hertz to 8000 Hertz.

Results and discussion

The mean and standard deviation of the attenuation measurements using the ANSI S12.6 standard are shown in Table 7. These results are from measurements completed on 10 subjects, each fitted with their proper size helmet. The attenuation results indicate the helmet fails to meet the requirements at all frequencies below 1000 Hertz. The earcup used in the HGU-84/P was of low volume relative to the earcup used in the HGU-56/P helmet, which may be the primary factor contributing to the failure. Figure 10 shows the attenuation characteristics using the MIL-STD-912 test procedure. There are no resonance characteristics in the earcup attenuation.

Table 7.
HGU-84/P sound attenuation characteristics (dB) measured with ANSI S12.6.

| | Frequency | | | | | | | | |
|--------------------|-----------|------|------|------|------|-------|------|------|------|
| | 125 | 250 | 500 | 1k | 2k | 3.15k | 4k | 6.3k | 8k |
| Requirement | 17 | 14 | 20 | 21 | 26 | 38 | 37 | 44 | 42 |
| (mean) HGU-84/P | 13.8 | 12.1 | 19.6 | 25.3 | 33.5 | 40.1 | 41.7 | 44.5 | 45.3 |
| (std dev) | 6.9 | 4.9 | 3.7 | 4.1 | 4.4 | 5.9 | 8.3 | 5.8 | 4.1 |

Physical Ear Attenuation of the HGU-84/P Helmet

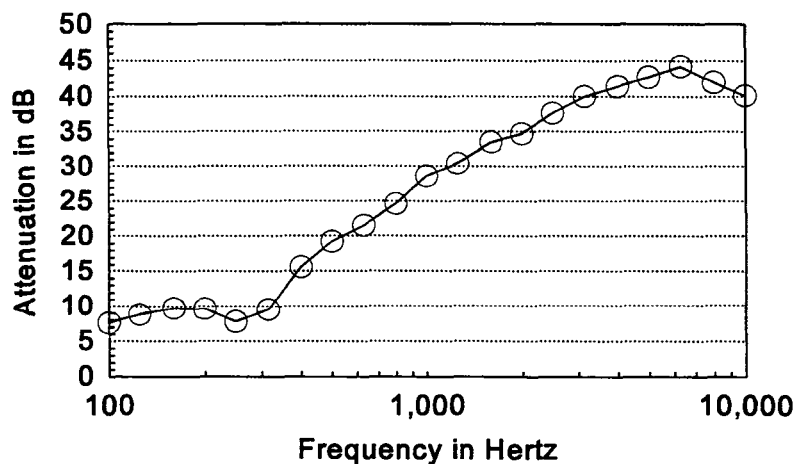


Figure 10. Physical ear attenuation of the HGU-84/P helmet.

Estimates of effective exposure level (EEL) are one way of looking at the effectiveness of a hearing protector in the target noise environment. Table 8 compares the EEL estimates for the HGU-84/P and the HGU-56/P for several aircraft noise environments. The EEL for the HGU-84/P is 4 to 6 dBA more than the HGU-56/P while it is 2 to 4 dBA higher than the SPH-4B. The increase in exposure is significant in that it reduces the exposure time by a factor of two for each three dB increase in accordance with DoDI 6055.12, "Hearing Conservation." For example, the allowable exposure time for the pilot of the CH-47 while wearing the HGU-84/P would be 2.5 hours, but the HGU-56/P would be 6.3 hours.

Table 8.
Estimates of the effective exposure in dBA of the
HGU-84/P, HGU-56/P, and the SPH-4B for Army noise environments.

| | UH-1 pilot 80 kt | UH-60 pilot 100 kt | CH-47 pilot 100 kt |
|----------|---------------------|-----------------------|-----------------------|
| HGU-84/P | 81 | 87 | 90 |
| SPH-4B | 76 | 83 | 88 |
| HGU-56/P | 75 | 82 | 86 |

Evaluation summary

The HGU-84/P helmet assembly was tested for compliance the U.S. Army HGU-56/P helmet requirements. Only the center of mass requirement was met by the HGU-84/P configuration. None of the other HGU-56/P requirements were fully met. The helmet performed equally as well as the HGU-56/P in the dynamic retention evaluation.

References

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