

**STANDARD PNEUMATIC RAM TEST METHOD AND
EQUIPMENT USED IN EVALUATING THE
PERFORMANCE CHARACTERISTICS OF
PROTECTIVE HEADGEAR AND FACEGUARDS**

NOCSAE DOC ND 081 – 23m26

Prepared By

NOCSAE®

**NATIONAL OPERATING COMMITTEE
ON STANDARDS FOR ATHLETIC EQUIPMENT**

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1. Scope

- 1.1. This standard test method describes laboratory equipment and basic requirements pertinent to pneumatic ram testing of protective headgear with face guards. The concept of the pneumatic ram is to deliver an impact to a helmeted, instrumented, headform on a Hybrid III neck that is free to move post impact. This test method has been designed to subject the headgear to both centric and non-centric impacts while capturing both linear and rotational acceleration. It is believed that compliance with this test method will lead to improved headgear performance. Deviations to this test method will be specified in individual standard performance specifications.
- 1.2. ***All testing and requirements of this standard specification must be in accordance with NOCSAE DOC 001 where appropriate.***
- 1.3. This standard test method is limited to use with products associated with specific NOCSAE standards.
- 1.4. *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

- 2.1. NOCSAE DOC (ND) 001: *Standard Test Method and Equipment Used in Evaluating the Performance Characteristics of Headgear/Equipment*
- 2.2. NOCSAE DOC (ND) 101: *Equipment Calibration Procedures.*
- 2.3. User's Manual for the 50th Percentile Hybrid III Dummy
- 2.4. User's Manual for the 5th Percentile Hybrid III Dummy

3. Specific Terminology

- 3.1. Descriptions of terms specific to this standard
 - 3.1.1. Pneumatic Ram: A device that is capable of delivering an impact to the target by moving along a straight line towards the target. The impactor shall be capable of delivering impacts in the range of 3.0 – 9.0 m/s and shall be in guided free flight at the time of impact.
 - 3.1.2. Impactor Rod: The portion of the pneumatic ram system that holds the impactor head and is propelled towards the headform.
 - 3.1.3. Impactor Head: Attached to the end of the impactor rod and contacts the helmet. It is constructed of polyurethane disc in between an engineered aluminum body and an impact face constructed from aluminum or nylon. The face of the impactor head must have a convex face with a radius of 127 mm $\pm$ 3 mm. The MEP disc shall have a thickness of 1.5 inches and a Shore A hardness of 43 $\pm$ 2.

- 3.1.3.1. For youth helmet testing, the face of the impactor head shall be constructed from nylon.
- 3.1.4. Impactor: Impactor rod and impactor head including any additional components required for braking that does not exceed 16.5 kg
- 3.1.5. Rotational Acceleration: A measure of impact severity with respect to the peak acceleration experienced by the headform measured in radians per second squared (rad/s^2). Acceptable rotational acceleration levels measured during impact cannot exceed the limit specified in the appropriate NOCSAE standard performance specification.
- 3.1.6. Linear Bearing Table: A sliding tabletop fitted with the necessary supports to position a headform at various angles and rotations in order to facilitate impacts at the designated locations. This table may be mounted to a separate device that allows for rapid elevation adjustments.
- 3.1.7. Guided Free Flight: Condition in which the impactor is being neither actively propelled nor braked while being guided to the target.

4. Significance and Use

- 4.1. The purpose of this test method is to provide reliable and repeatable measurements for the evaluation of various types of protective headgear. This test method is based on pass/fail criteria for Severity Index (SI), Rotational Acceleration (rad/s^2), and within specified tolerances for other measures.
- 4.2. A passing headgear is able to withstand the impact at an acceptable SI, rad/s^2 , and meets all other requirements of the Performance Specifications when tested in accordance with this test method.
- 4.3. This test method must be used in conjunction with the specified individual standard performance specifications relative to a specific activity.

5. Summary of Test Method

- 5.1. A headgear is positioned on a headform that is mounted onto a Hybrid III neck assembly which is rigidly mounted to a linear bearing table to achieve post impact kinematics. The impactor is propelled at the headgear such that the velocity is within 2% of the specified level when measured over a distance no more than two inches. Impact must occur within one inch of velocity capture. At impact, the resultant peak linear acceleration, Severity Index, and resultant peak rotational acceleration shall be captured.

6. Test Instruments and Equipment

- 6.1. A machine capable of propelling the impactor to the specified velocity $\pm 2\%$. The machine shall have a targeting device able to locate the initial point of contact of the center of the impactor head with the headgear within a $\frac{1}{4}$ " radius within 1 inch of passing through the velocity measuring device. The machine must allow the impactor to make contact with the headgear while in guided free flight for all standard and random impact locations.
- 6.2. An impactor rod that has an outer diameter of nominal 2 inches and inner diameter of nominal 1.25 inches and a weight of 29.25 lbs (13.3 kg) $\pm 3\%$
- 6.3. Impactor Head: Weight shall be 5.05 lbs (2.3 kg) $\pm 3\%$
- 6.4. Hybrid III 50th percentile male neck assembly with titanium nodding joint assembly available from Humanetics Innovative Solutions, Inc. The neck cable shall be tightened to 12 in-lbs (± 1 in-lb) as specified by the Hybrid III user's manual with a calibrated torque wrench.
- 6.5. A linear bearing table that is capable of providing some post impact motion with a weight of 34.65 lbs (15.75 kg) $\pm 5\%$. This mass includes the headform/HIII neck pedestal as well as the α and β angle rotators.
- 6.6. Headform pedestal assembly that allows rotation in both the transverse (Z axis rotation - β angle rotator) and sagittal (Y axis rotation - α angle rotator) planes relative to the headform. The transverse rotation plane must be positioned beneath the sagittal rotation plane.
- 6.7. Recommended Pneumatic Ram including Linear Bearing Table Assembly
- 6.8. Electronic velocity monitor capable of measuring the in-bound velocity of the impactor head within 1 inch of initial contact with the headgear.
- 6.9. Generation II NOCSAE headforms designed to be used with 9 accelerometer systems in sizes small, medium, and large. (See Table 1 and Figure 6 for additional information)
- 6.10. Single axis piezoresistive accelerometers: Endevco 7264-2000B or equivalent
- 6.11. DC amplifier: Endevco Model 136, PCB 482C27, or equivalent.
- 6.12. Impact recording software: BioDAQ version 7.1 or newer - available from Biokinetics and Associates. Other computer-based systems may be used if equivalence to the BioDAQ 7.1 software can be demonstrated.
- 6.13. Data sampling rate shall be a minimum of 10,000 Hz per channel.
- 6.14. Data shall be filtered with a 300 Hz (CFC 180) low pass filter.
- 6.15. Equipment specific to testing youth football helmets to NOCSAE DOC 006: *Standard Performance Specification for Newly Manufactured Youth Football Helmets*
 - 6.15.1. Generation III NOCSAE headforms in sizes small and medium. (See Table 1 and Figure 6 for additional information)
 - 6.15.2. Headform/neck mounting interface: Hybrid III neck transducer structural

replacement available from Humanetics Innovative Solutions, Inc.

- 6.15.3. An impactor rod that has an outer diameter of nominal 2 inches and a wall thickness of 0.095 inches. The weight of the impactor rod and impactor head connector plate shall be 11.6 lbs (5.28 kg) $\pm$ 3%.
- 6.15.4. Impactor Head with Nylon Impactor Face: Weight shall be 3.5 lbs (1.6 kg) $\pm$ 3%
- 6.15.5. Hybrid III 5th percentile neck assembly available from Humanetics Innovative Solutions, Inc. The neck cable shall be tightened to 12 in-lbs ($\pm$ 1 in-lb) as specified by the Hybrid III user's manual.

7. System Check

- 7.1. The system check shall be conducted on the bare headform and consist of three impacts at 3.5 m/s $\pm$ 3% at the following standard impact locations: Side, Rear, and Rear Boss NC.
- 7.2. A system check must be performed just prior to testing and the results maintained as part of the certification test data
- 7.3. A system check must be performed upon the completion of a product testing session and the results maintained as part of the certification test data.
- 7.4. Any variation between the average of the three impacts at each impact location collected in 7.2 and 7.3 must be 7% of less.

8. Impact Locations

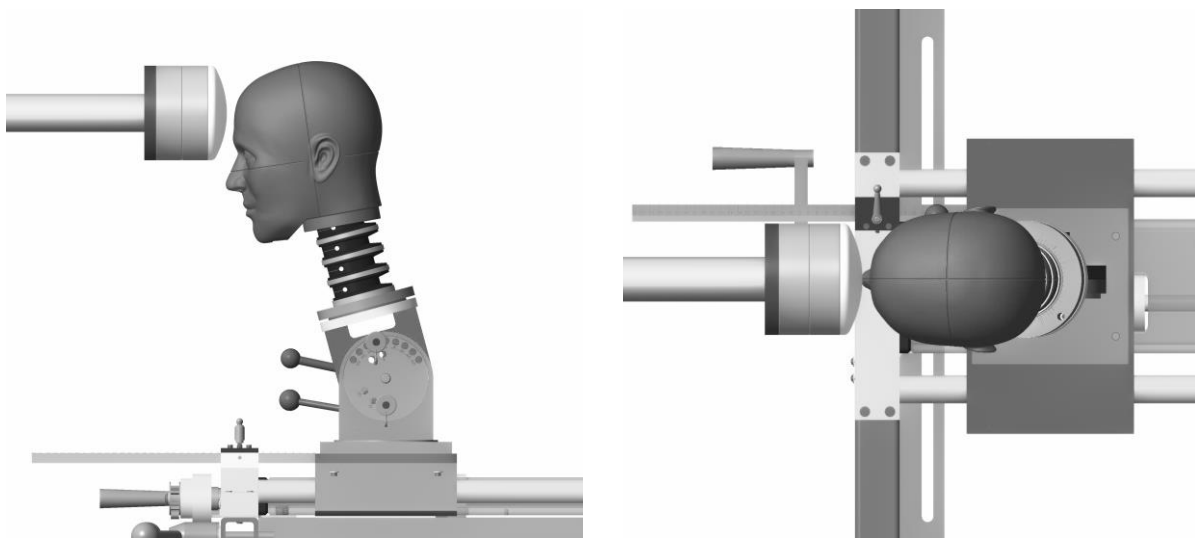


Figure 1: Pneumatic Ram Neutral Headform Position

Note: The starting position should be with the nose of the headform pointing towards the ram and all measurements and angles listed in tables 8.1, 8.2, and 8.3 are relative to this position. The positive direction for α angle is tilting forward towards the ram, and the positive direction for β angle is clockwise. The Z and Y axis measurements are relative to the headform. (All values given in Sections 8.1, 8.2, and 8.3 are $\pm$ 1 degree or $\pm$ 1 mm)

8.1. Small Headform Impact Locations

Impact Location	α	β	Z axis relative to basic plane	Y axis
Side	7 °	-90 °	+54.9 mm	on the coronal plane
Rear Boss NC	7 °	-90 °	+54.9 mm	58.7 mm posterior to coronal plane
Rear Boss CG	7 °	-135 °	+54.9 mm	74.1 mm posterior to coronal plane
Rear	7 °	-180 °	+54.9 mm	on the midsagittal plane
Front Boss	15 °	-60 °	+67 mm	51.4 mm anterior to coronal plane
Front	15 °	0 °	+71.4 mm	on the midsagittal plane

8.2. Medium Headform Impact Locations

Impact Location	α	β	Z axis relative to basic plane	Y axis
Side	7 °	-90 °	+60 mm	on the coronal plane
Rear Boss NC	7 °	-90 °	+60 mm	64 mm posterior coronal plane
Rear Boss CG	7 °	-135 °	+60 mm	81 mm posterior to coronal plane
Rear	7 °	-180 °	+60 mm	on the midsagittal plane
Front Boss	15 °	-60 °	+73 mm	56 mm anterior to coronal plane
Front	15 °	0 °	+78 mm	on the midsagittal plane

8.3. Large Headform Impact Locations

Impact Location	α	β	Z axis relative to basic plane	Y axis
Side	7 °	-90 °	+64 mm	on the coronal plane
Rear Boss NC	7 °	-90 °	+64 mm	67.2 mm posterior coronal plane
Rear Boss CG	7 °	-135 °	+64 mm	85.1 mm posterior to coronal plane
Rear	7 °	-180 °	+64 mm	on the midsagittal plane
Front Boss	15 °	-60 °	+76.7 mm	58.8 mm anterior to coronal plane
Front	15 °	0 °	+81.9 mm	on the midsagittal plane

9. Impact Attenuation Tests

- 9.1. The maximum Severity Index and peak resultant rotational acceleration cannot exceed the limits specified in the appropriate NOCSAE standard performance specification.
- 9.2. Each headgear shall be impacted in accordance with the requirements of the appropriate NOCSAE standard performance specification with respect to impact velocities, impact locations, and test conditions.
- 9.3. Random: Any point located in the impact area.
 - 9.3.1. The α angle shall be positioned at either 7 or 15 degrees.
 - 9.3.2. The β angle shall be positioned between -180 degrees to -60 degrees.
 - 9.3.3. The initial point of contact between the impactor face and the headgear shall not be with any part of the faceguard, including faceguard hardware.
 - 9.3.4. The random impact locations may be selected from any point within the allowed impact area but not closer than 1 inch (25 mm) from the edge of the helmet nor less than 1 inch (25 mm) from any previous impact.

Pneumatic Ram Impactor Head

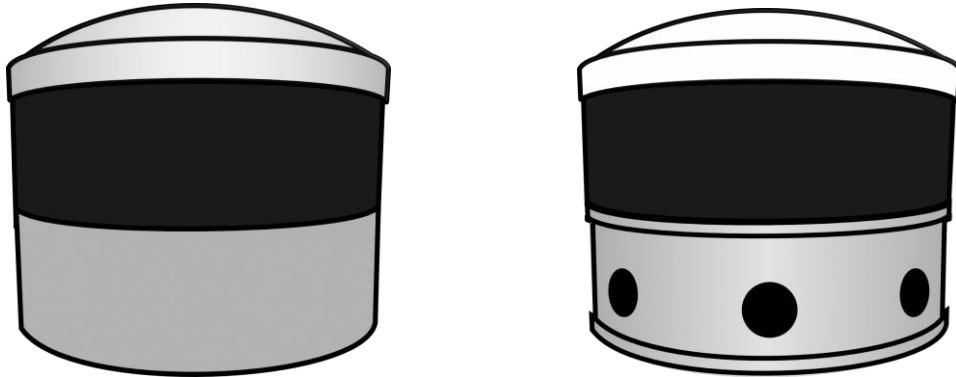


Figure 2: Section 6.3 Impactor Head Unit [left] and ND006 Section 6.15.2 Impactor Head Unit [right]

Pneumatic Ram Test Machine

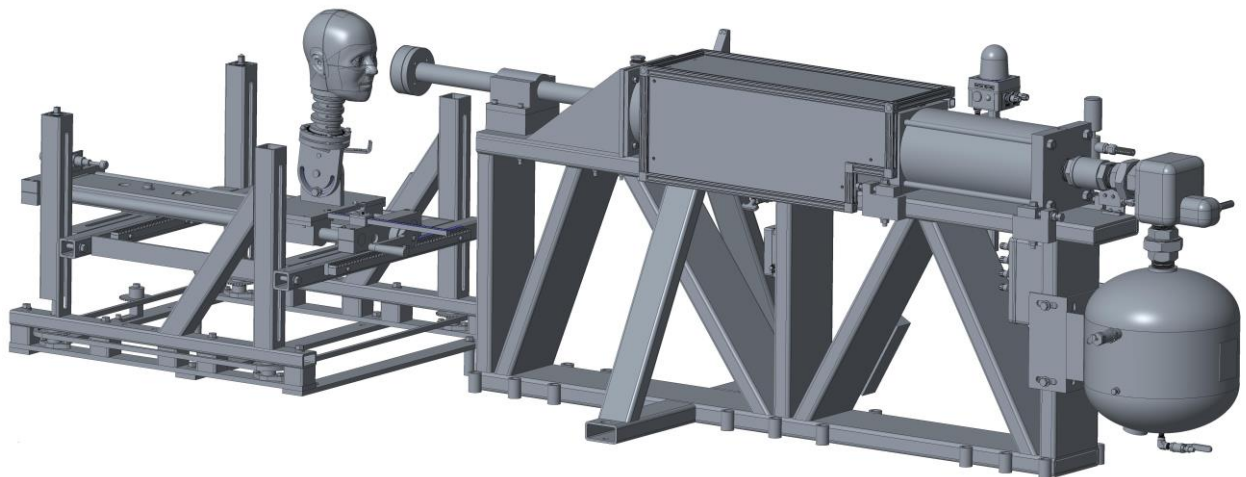
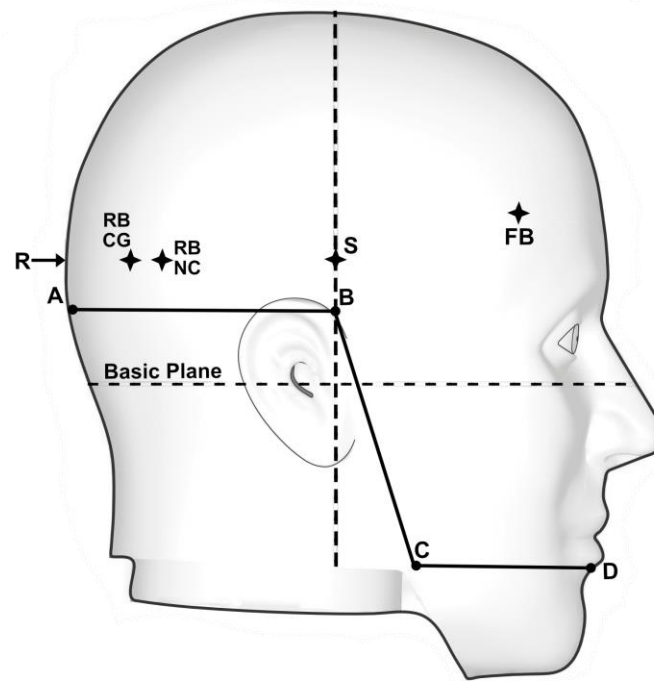


Figure 3

Impact Area

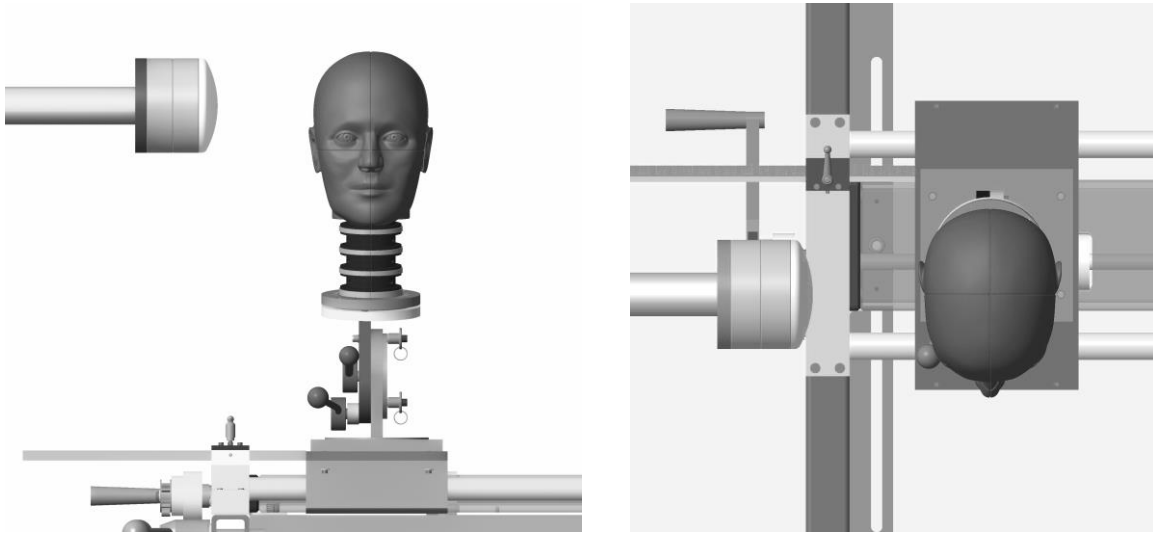


Impact Area – for a headgear that is to be tested on the medium headform*, the impact area must include all locations on the headform which lie on or above a line (AB) 1 $\frac{3}{16}$ inches above and parallel to the BASIC PLANE posterior to the CORONAL PLANE and on or above a line (CD) 2 $\frac{3}{8}$ inches below and parallel to the BASIC PLANE forward of a point 1 $\frac{3}{16}$ inches anterior to the CORONAL PLANE, and forward and above line (BC) which connects these two lines.

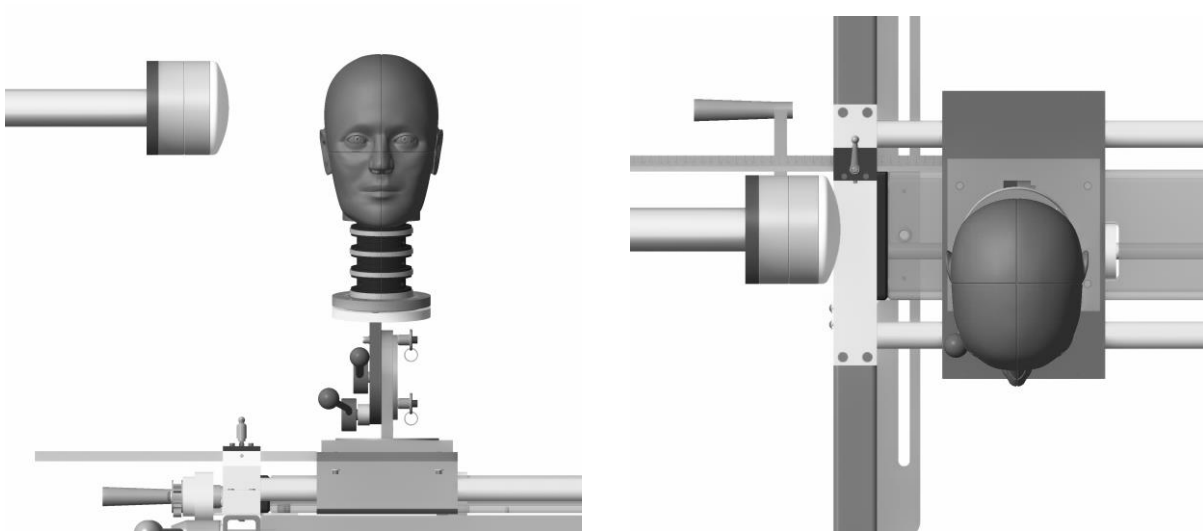
* For the large head forms line AB is 1 $\frac{7}{16}$ " above and line CD is 2 $\frac{5}{8}$ " below the basic plane. For the small headform line AB is $\frac{15}{16}$ " above and line CD is 2 $\frac{1}{8}$ " below the basic plane.

Figure 4

Impact Locations

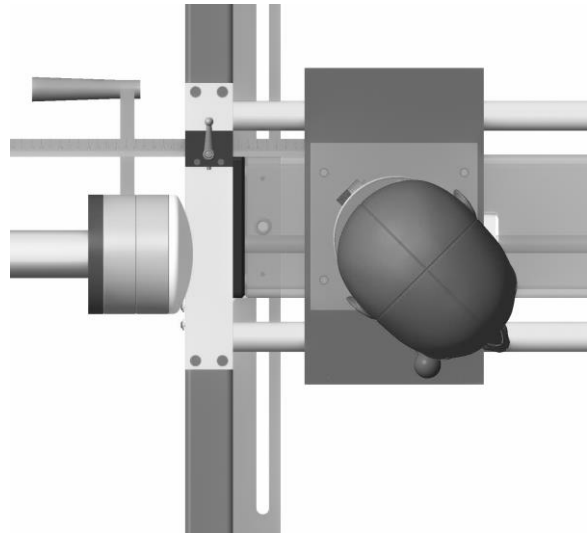
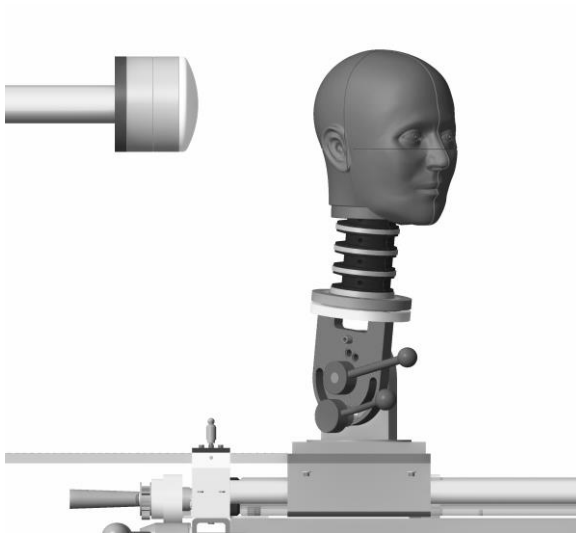


Side

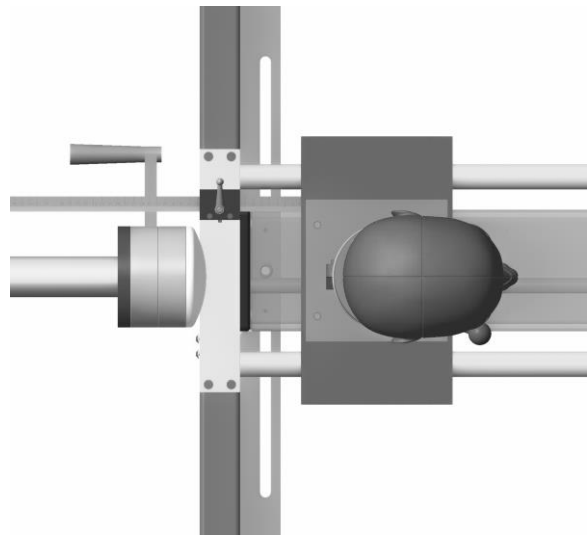
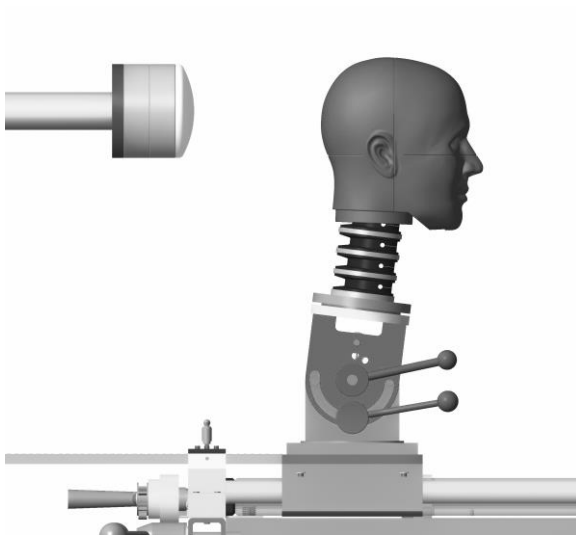


Rear Boss NC

Impact Locations

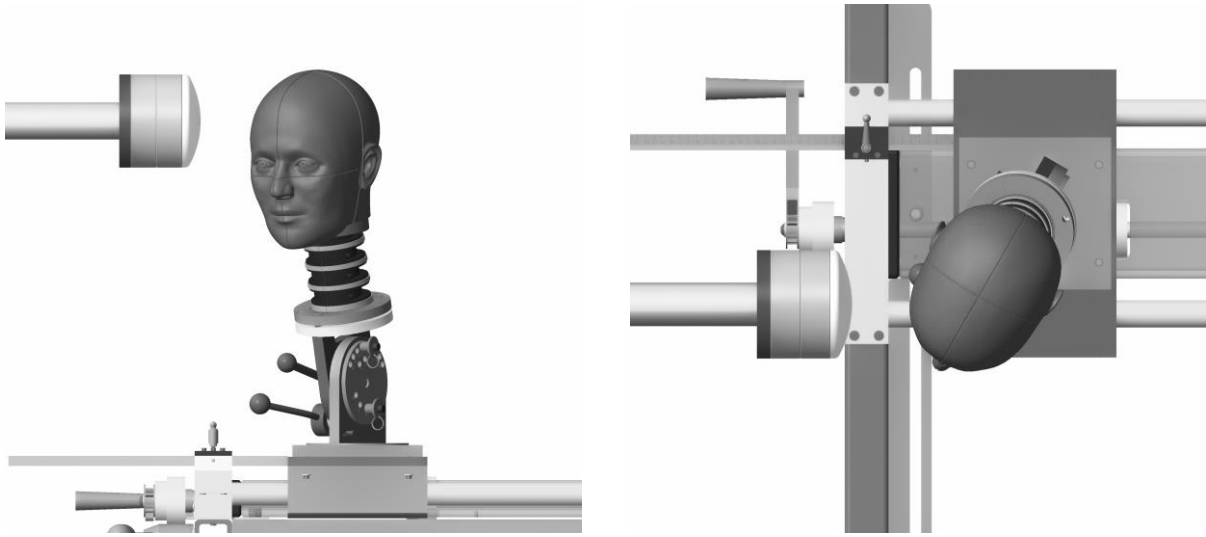


Rear Boss CG



Rear

Impact Locations



Front Boss

Figure 5

TABLE 1
APPROXIMATE MEASUREMENTS OF NOCSAE HEADFORMS †

POINTS OF MEASURE – inches (mm) <i>[See Figure 1 NOCSAE Doc 001]</i>	HEADFORM SIZE		
	Small 6 ⁵ / ₈	Medium 7 ¹ / ₄	Large 7 ⁵ / ₈
1. Head Breadth	5.63 (143)	5.98 (152)	6.46 (164)
2. Maximum brow width (frontal diameter)	4.65 (118)	5.20 (132)	5.52 (140)
3. Ear hole to ear hole (bitracion diameter)	5.24 (133)	5.51 (140)	6.06 (154)
4. Maximum jaw width (bigonial diameter)	4.13 (105)	4.65 (118)	5.08 (129)
5. Head length (glabella landmark to back of head)	7.09 (180)	7.87 (200)	8.15 (207)
6. Outside eye corner (external canthus) to back of head	6.22 (158)	6.81 (173)	7.32 (186)
7. Ear hole (tragion) to back of head	3.50 (89)	3.86 (98)	4.25 (108)
8. Ear hole to outside corner of eye (tragion to ext. canthus)	2.72 (69)	2.95 (75)	3.07 (78)
9. Ear hole to top of head (tragion to vertex)	4.72 (120)	5.24 (133)	5.67 (144)
10. Eye pupil to top of head	4.13 (105)	4.53 (115)	4.96 (126)
11. Ear hole ‡ to jaw angle (tragion to gonion)	3.31 (84)	3.03 (77)	2.84 (72)
12. Bottom of nose to point of chin (subnasal to menton)	2.56 (65)	2.80 (71)	3.03 (77)
13. Top of nose to point of chin (nasion to menton)	4.45 (113)	4.88 (124)	5.39 (137)
14. Head circumference	21.02 (534)	22.68 (576)	24.17 (614)
15. Head weight including neck mounting interface - pounds (kg)			
15.1. Generation II* (NOCSAE neck mounting interface)	7.81 (3.55)	9.60 (4.36)	11.70 lb (5.32)
15.2. Generation III** (HIII neck mounting interface)	7.85 (3.58)	9.85 (4.48)	12.05 lb (5.48)

† The anthropometric measurements are based upon references ND001 2.3 and 2.4.

‡ The right ear of each headform shall be removed flush with the skin surface.

* Generation II headform serial numbers begin with the letters "RM". Weight does not include 9 array accelerometer block.

** Generation III headform serial numbers begin with the letters "EX". Weight does not include instrumentation block.

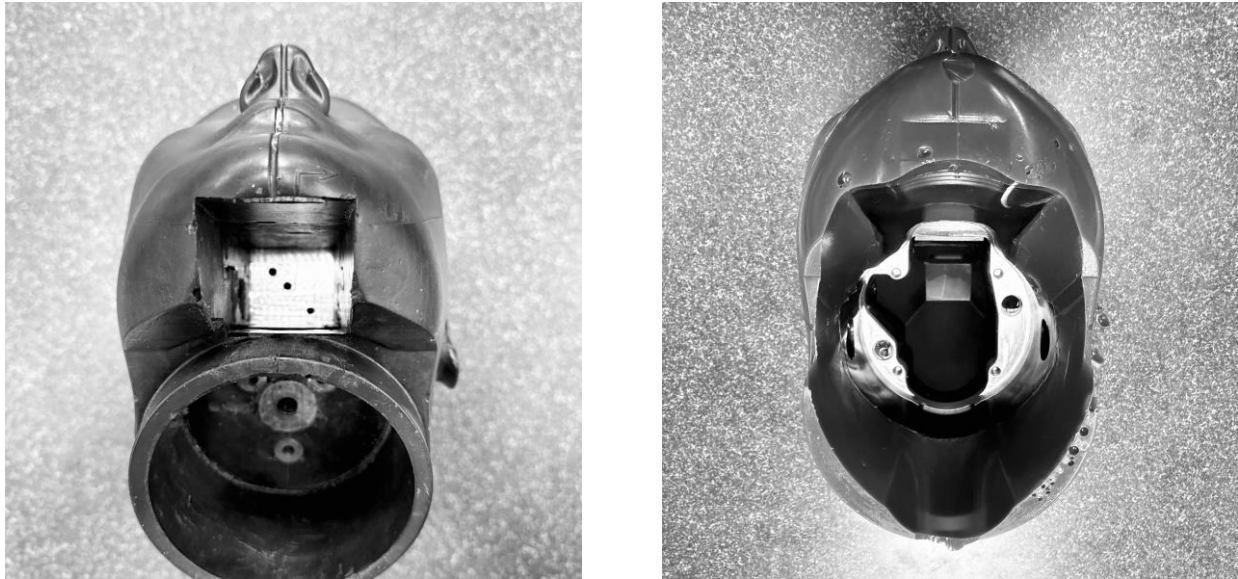


Figure 6: Headform instrumentation channel - Generation II headform [left] and Generation III headform [right]

This test method is subject to revision at any time by the responsible technical authority and must be reviewed every five years and if not revised either reapproved or withdrawn. Your comments are invited either for revision, modification or creation of additional standards and should be addressed to NOCSAE's Executive Director. Check the web at www.nocsae.org to obtain the latest version of a standard.

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MODIFICATIONS/REVISION HISTORY

MAY 2015 MODIFICATIONS/REVISIONS

- Added figures
- Added table
- Clarified numerous sections
- Added dimensions and tolerances

FEBRUARY 2018 MODIFICATIONS/REVISIONS

- REVISION: Added β angle and faceguard contact restrictions for random impact location
- Changed software specification to include newer version of Biokinetics
- Added system check impact location and velocity

MAY 2018 MODIFICATIONS/REVISIONS

- Added Table 1 with headform measurements
- Clarified Linear Bearing Table mass specification

JULY 2018 MODIFICATIONS/REVISIONS

- REVISION: Changed software specification to include newer version of Biokinetics BioDAQ

JANUARY 2019 MODIFICATIONS/REVISIONS

- Added neutral headform position figure
- Added impact location figure
- Added additional impact locations for system check [rear and rear boss nc]
- Corrected neck cable torque typo
- Added reference to Hybrid III 50th Male Dummy User's Manual

SEPTEMBER 2019 MODIFICATIONS/REVISIONS

- Added Section 9.3.4 which states random impact locations may not be closer than 1 inch from any other previous impact location.
- Clarified the α and β angle rotations in Section 6.6

JUNE 2020 MODIFICATIONS/REVISIONS

- Corrected typo in Section 3.1.4 which gave the total impactor mass as 15.5 kg which should have been 16.5 kg.
- Added tolerances for angle and measurement values

JULY 2021 MODIFICATIONS/REVISIONS

- Added specifications for equipment used for youth helmet testing.
- Added reference to 5th Percentile Hybrid III User's Manual

- Updated Pneumatic Ram Figure

DECEMBER 2022 MODIFICATIONS/REVISIONS

- Added sampling rate
- Added filtering specification

DECEMBER 2024 MODIFICATIONS/REVISIONS

- Added sampling rate
- Added filtering specification

MAY 2025 MODIFICATIONS/REVISIONS

- Added additional test equipment information
- Updated Impactor Head Figure
- Added Figure 6

JUNE 2026 MODIFICATIONS/REVISIONS

- Added PCB 482C27 signal conditioner to equipment list