

THOR-05F Durability Report

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Vehicle Research and Test Center

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1 BACKGROUND & OBJECTIVE

The National Highway Traffic Safety Administration (NHTSA) has actively supported the development of an advanced 5th percentile female dummy for frontal impacts. The THOR-05F (Test Device for Human Occupant Restraint) frontal crash test dummy incorporates improved biofidelic features and significantly expanded instrumentation over previous small female frontal crash test dummies. The primary design objectives for the THOR-05F included:

- a) Biofidelity in mass, size, surface geometry, and dynamic response;
- b) Repeatability and reproducibility of performance;
- c) Durability - minimization of damage in severe test environments; and
- d) Incorporation of specific instrumentation relevant to injury assessment.

The design approach included a systematic evaluation of design requirements for each of these objectives. The objective of this study is to specifically address the durability design objective.

2 DURABILITY EVALUATION METHODOLOGY

The durability of the THOR-05F was evaluated in elevated-energy qualification tests. Baseline tests for each body region were performed according to the qualification test procedures specified in the *THOR 5th Percentile Female (THOR-05F) Qualification Procedures and Requirements* (NHTSA, In Process) at the speeds specified for qualification tests. The durability tests were performed at speeds corresponding to energy level increases of approximately 10 percent, 20 percent, and 30 percent above the baseline qualification test energy.

The THOR-05F neck, knee, and ankle durability was evaluated using component-level qualification test procedures and head, face, thorax, abdomen, and upper leg durability was evaluated in full-body qualification test procedures. A final baseline test was performed for each body region at the prescribed standard qualification test speed to confirm the tested components still met qualification requirements after higher-energy testing. Failure to meet qualification requirements in the final baseline test could indicate deterioration or damage to the tested components. All components were also inspected for damage following testing.

To allow for recovery of parts after impacts, the minimum wait time between tests followed the prescribed allowance in the qualification procedures. For body regions where only one side was tested, all testing was performed on the left side of the dummy.

3 DURABILITY IN ELEVATED-ENERGY QUALIFICATION TESTS

3.1 HEAD

3.1.1 Methodology

Durability tests were performed using the head qualification procedures described in the *THOR-05F Qualification Procedures and Requirements*. The head qualification test is a dynamic test performed to examine the force-time and acceleration-time response of the head when impacted on the forehead with a 19.2 kg rigid impactor at 2.00 ± 0.05 m/s (Figure 3-1). For durability tests on the head, the test energy was elevated from the qualification baseline by approximately 10, 20, and 30 percent, by increasing the test velocity (Table 3-1). After the three increased-energy tests, another baseline test was run to confirm that the higher-energy tests did not change the head's baseline response. THOR-05F dummy serial number EU3430 was used for this durability series.

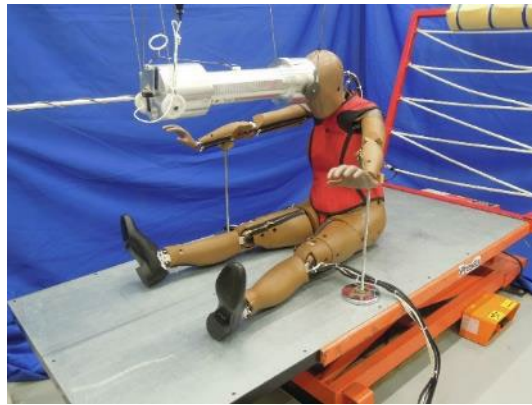


Figure 3-1. Head durability test setup

Table 3-1. Target Test Velocities for Head Durability Tests

Test Severity	Target Velocity (m/s)
Initial Baseline	2.00
10% Energy Increase	2.10
20% Energy Increase	2.19
30% Energy Increase	2.28
Final Baseline	2.00

3.1.2 Results

For the baseline THOR-05F head qualification tests, the maximum probe force and the maximum head center of gravity (CG) resultant acceleration must be within the ranges provided in Table 3-2. Table 3-3, along with Figure 3-2 and Figure 3-3, illustrates the results of the durability tests along with the qualification corridors for baseline tests.

Table 3-2. Head Qualification Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	1.95	2.05
Maximum Probe Force	N	4566	5581
Maximum Head CG Resultant Acceleration	g	140	171

Table 3-3. Head Durability Results (THOR-05F EU3430)

Date	Test Number	Test Severity	Actual Velocity (m/s)	Maximum Probe Force (N)	Maximum Head CG Resultant Acceleration (g)
08/07/24	240807-2	Initial Baseline	2.00	5,267	157
08/07/24	240807-8	10% Energy Increase	2.09	5,534	167
08/07/24	240807-9	20% Energy Increase	2.22	5,959	184
08/07/24	240807-14	30% Energy Increase	2.27	6,058	189
08/08/24	240808-3	Final Baseline	2.01	5,242	154

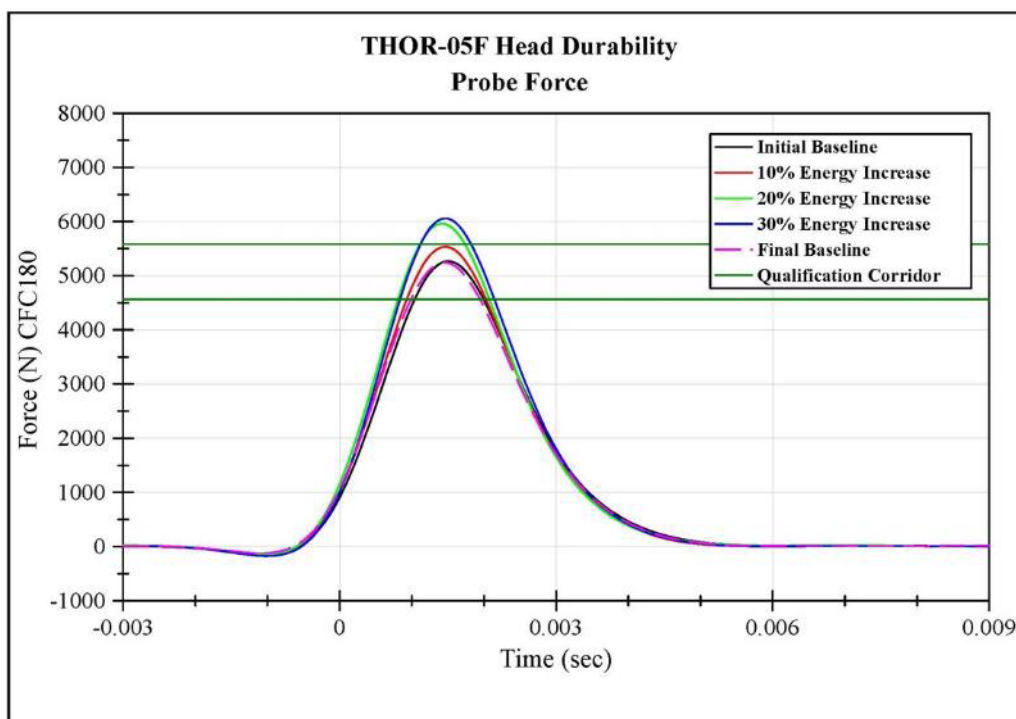


Figure 3-2. Probe force in head durability tests

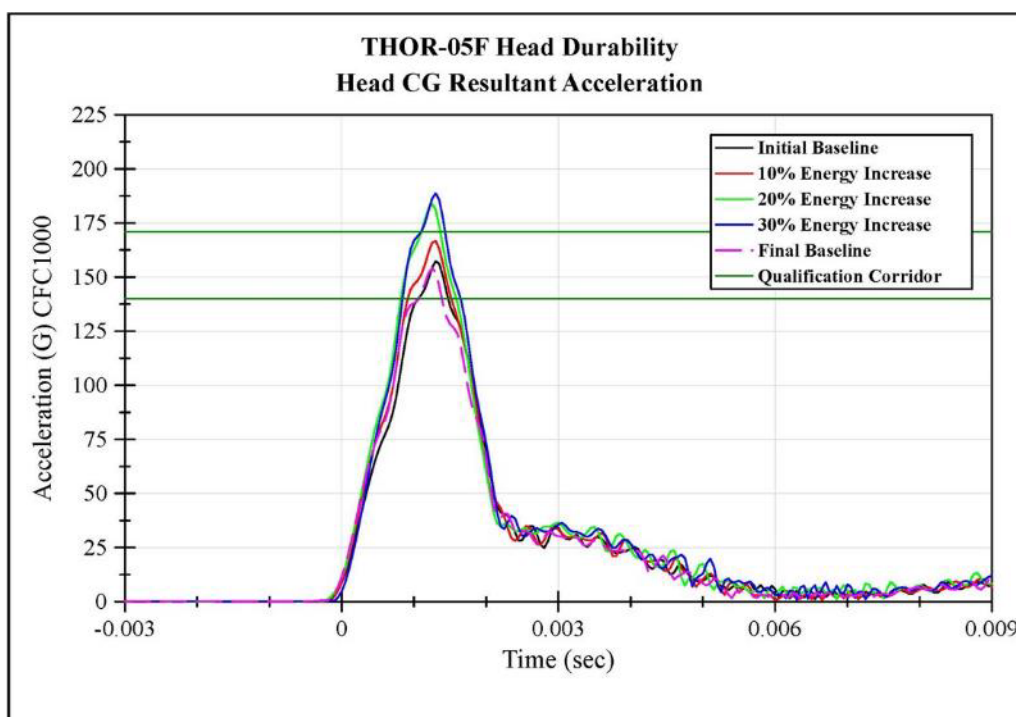


Figure 3-3. Head CG resultant acceleration in head durability tests

3.1.3 Discussion

Both the initial and final baseline head responses were within the specified qualification corridors for probe force and maximum head CG resultant acceleration, confirming that the head still met qualification requirements after the increased-energy tests. No visible damage to the head was observed post-test. These results indicate that the head displays acceptable durability.

3.2 FACE

3.2.1 Methodology

Durability tests were performed using the face qualification procedures described in the *THOR-05F Qualification Procedures and Requirements*. The rigid-disk qualification test evaluates facial impact response to loading by a 10.70 kg impactor with a rigid circular face (diameter=152.4 mm) at a velocity of 6.73 ± 0.05 m/s (Figure 3-4). For the face durability tests, the test energy was elevated from the qualification baseline by approximately 10, 20, and 30 percent (Table 3-4). After the three increased-energy tests, another baseline test was run to confirm that the higher-energy tests did not change the face's baseline response. THOR-05F dummy serial number EU3430 and face insert EU2582 were used for this durability series.

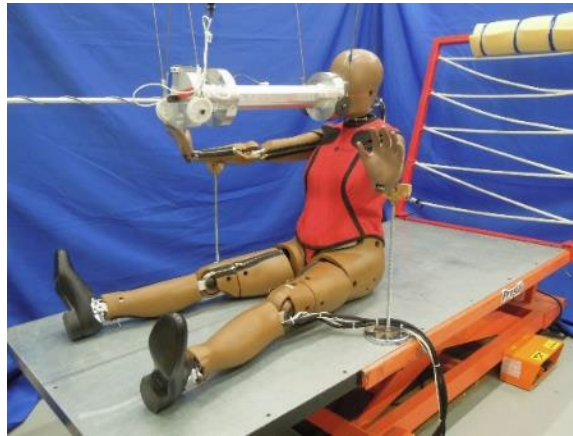


Figure 3-4. Face durability test setup

Table 3-4. Target Test Velocities for Face Durability Tests

Test Severity	Target Velocity (m/s)
Initial Baseline	6.73
10% Energy Increase	7.06
20% Energy Increase	7.37
30% Energy Increase	7.67
Final Baseline	6.73

3.2.2 Results

For the baseline THOR-05F face qualification tests, the maximum probe force must be within the ranges provided in Table 3-5. Table 3-6, along with Figure 3-5 and Figure 3-6, illustrates the results of the durability tests along with the qualification corridors for baseline tests.

Table 3-5. Face Rigid Disk Qualification Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	6.68	6.78
Maximum Probe Force	N	5,469	6,684

Table 3-6. Face Durability Results (THOR-05F EU3430 Face Insert EU2582)

Date	Test Number	Test Severity	Actual Velocity (m/s)	Maximum Probe Force (N)
08/08/25	250808-3	Initial Baseline	6.69	5,987
08/08/25	250808-5	10% Energy Increase	7.03	6,258
08/08/25	250808-6	20% Energy Increase	7.33	6,831
08/11/25	250811-2	30% Energy Increase	7.62	7,321
08/11/25	250811-3	Final Baseline	6.70	5,554

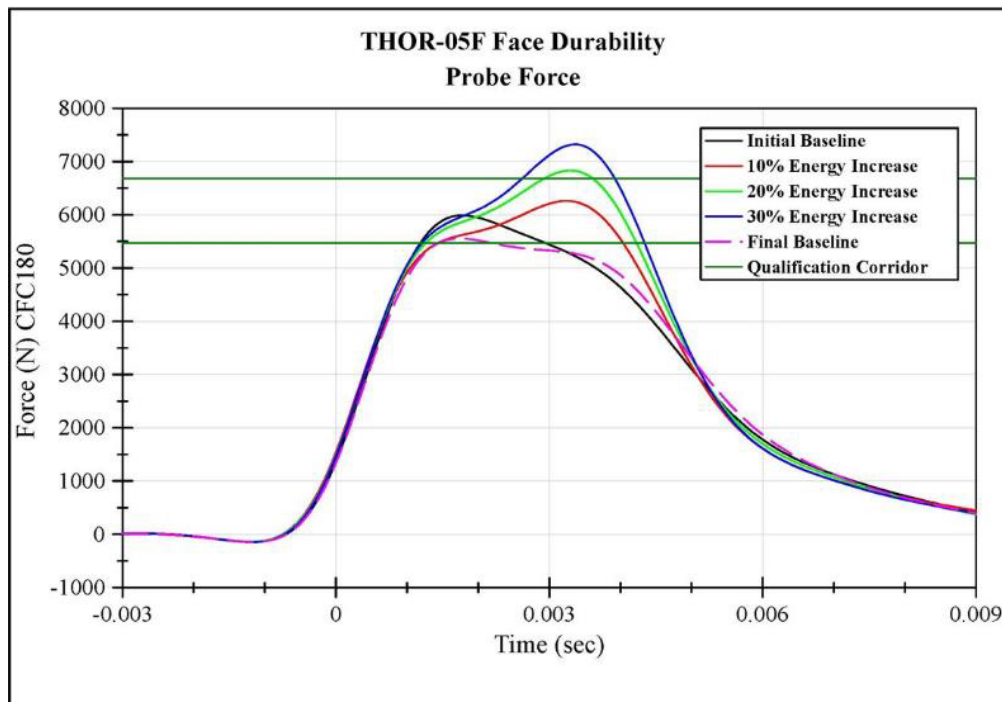


Figure 3-5. Probe force in face durability tests

3.2.3 Discussion

Both the initial and final baseline face responses were within the specified qualification corridors for probe force, confirming that the face still met qualification requirements after the increased-energy tests. No visible damage to the face was observed post-test. These results indicate that the head displays acceptable durability.

3.3 NECK FLEXION

3.3.1 Methodology

Durability tests were performed using the neck flexion qualification procedures described in the *THOR-05F Qualification Procedures and Requirements*. In the flexion tests qualification procedures, aluminum honeycomb is used to decelerate the pendulum from an impact velocity of 5.00 ± 0.05 m/s (Figure 3-7). For durability tests on the neck in flexion, the test energy was elevated from the qualification baseline by approximately 10, 20, and 30 percent (Table 3-7). After the three increased-energy tests, another baseline test was run to confirm that the higher-energy tests did not change the neck's baseline response. Neck EU0311 was used for this durability series.

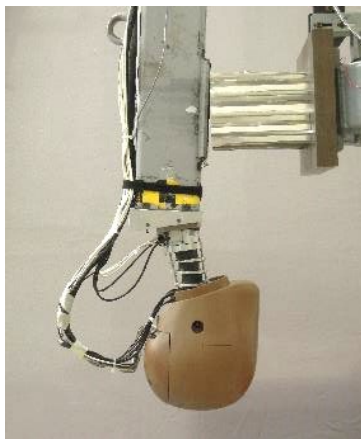


Figure 3-6. Neck flexion test setup

Table 3-7. Target Test Velocities for Neck Flexion Durability Tests

Test Severity	Target Velocity (m/s)
Initial Baseline	5.00
10% Energy Increase	5.24
20% Energy Increase	5.48
30% Energy Increase	5.70
Final Baseline	5.00

3.3.2 Results

For the THOR-05F neck flexion baseline qualification tests, the neck flexion responses must be within the ranges provided in Table 3-8. Table 3-9, along with Figure 3-8 through Figure 3-11, illustrates the durability test results along with the qualification corridor for baseline tests.

Table 3-8. Neck Flexion Qualification Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	4.95	5.05
Maximum Upper Neck Moment M_Y	N-m	16.0	19.5
Maximum Upper Neck Force F_Z prior to 40 ms	N	693	847
Minimum Head Angular Velocity ω_Y (relative to earth)	deg/s	-2,350	-1,923
Minimum Head Rotation Angle θ_Y (relative to pendulum)	deg	-86.1	-70.4

Table 3-9. Neck Flexion Durability Results (Neck EU0311)

Date	Test Number	Test Severity	Actual Velocity (m/s)	Maximum Upper Neck M_Y (Nm)	Maximum Upper Neck F_Z prior to 40 ms (N)	Minimum Head ω_Y (deg/s)	Minimum Head θ_Y (deg)
06/26/24	240626-4	Initial Baseline	5.00	18.2	681	-2,079	-76.9
06/26/24	240626-5	10% Energy Increase	5.25	18.0	759	-2,134	-80.9
06/27/24	240627-1	20% Energy Increase	5.50	18.2	807	-2,117	-81.7
06/27/24	240627-2	30% Energy Increase	5.71	18.2	858	-2,187	-84.8
06/27/24	240627-3	Final Baseline	4.99	17.9	699	-2,096	-76.8

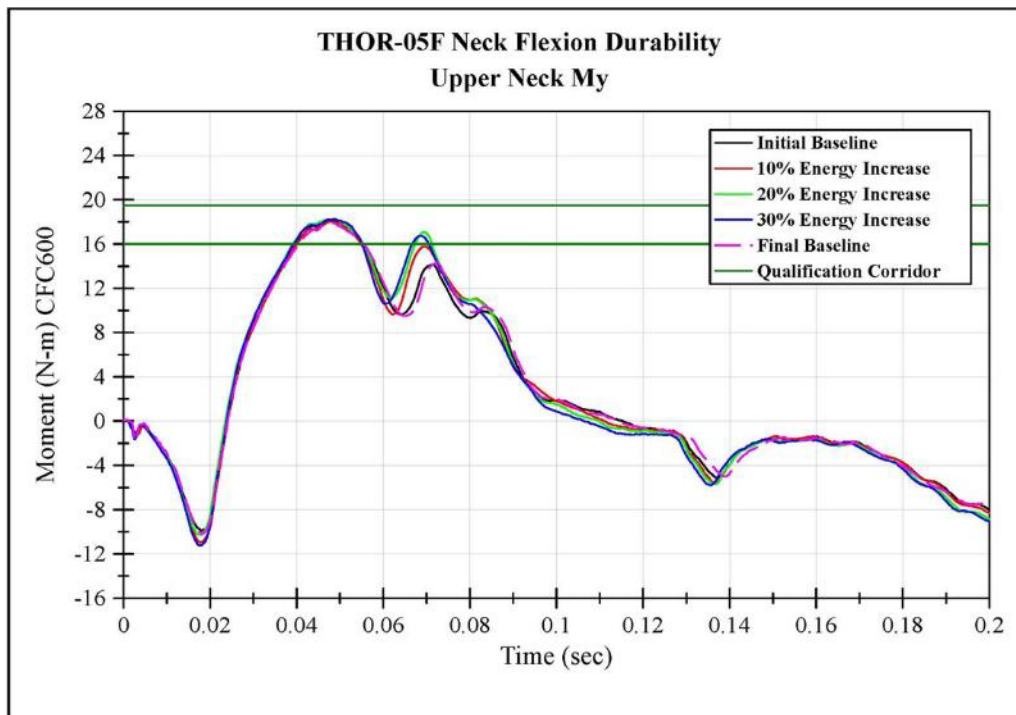


Figure 3-7. Upper neck moment M_y in neck flexion durability tests

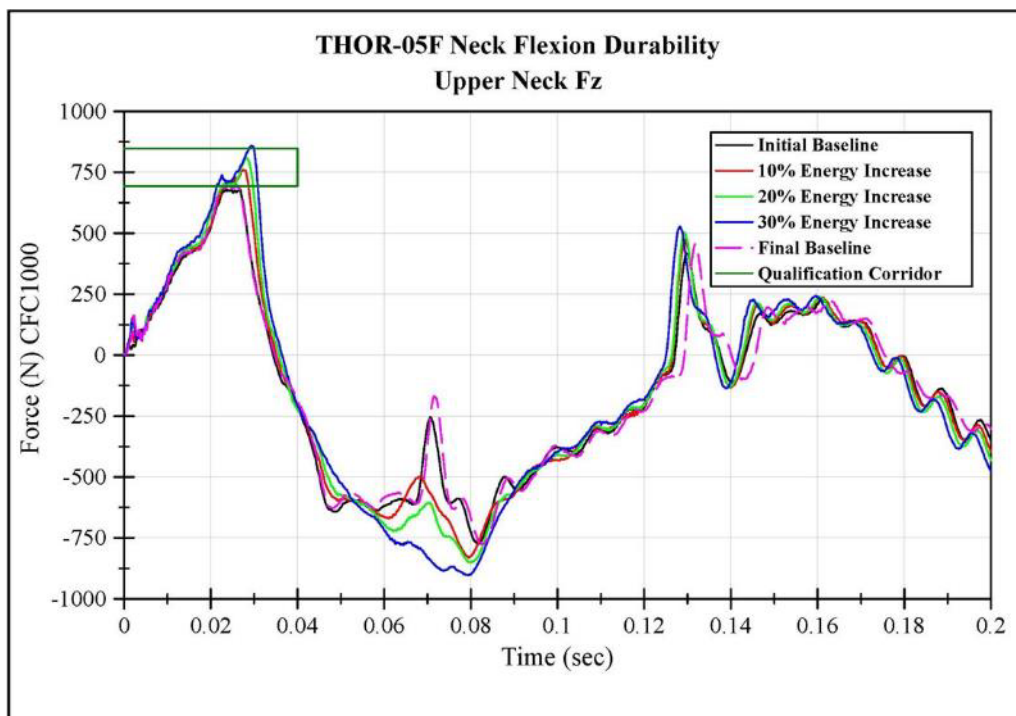


Figure 3-8. Upper neck force F_z prior to 40 ms in neck flexion durability tests

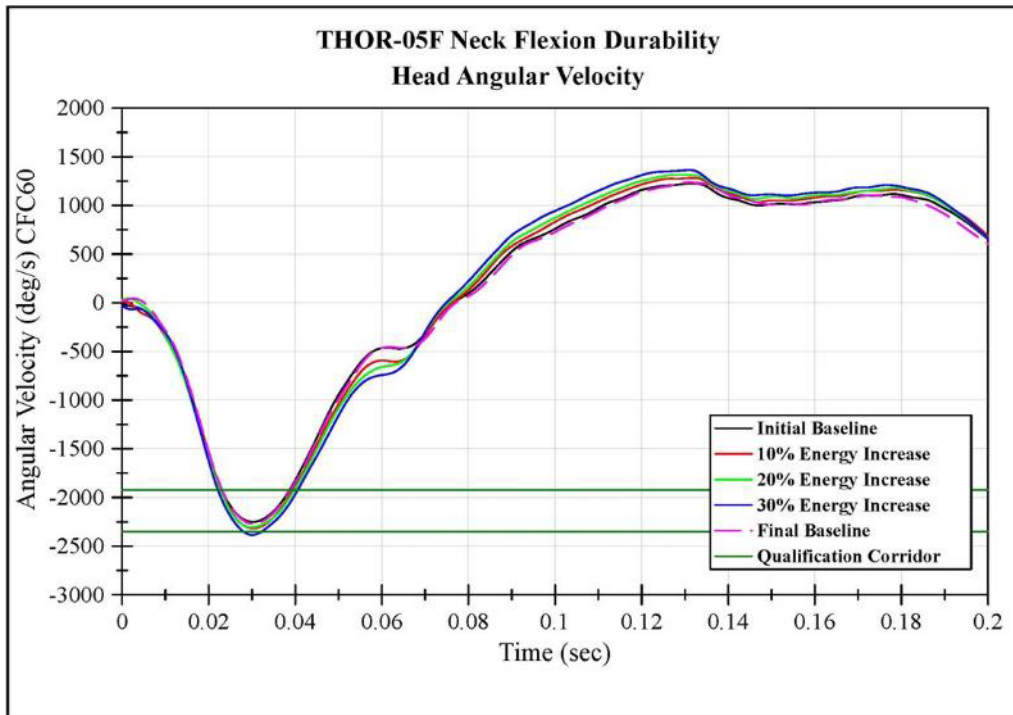


Figure 3-9. Head angular velocity $\dot{\theta}_Y$ in neck flexion durability tests

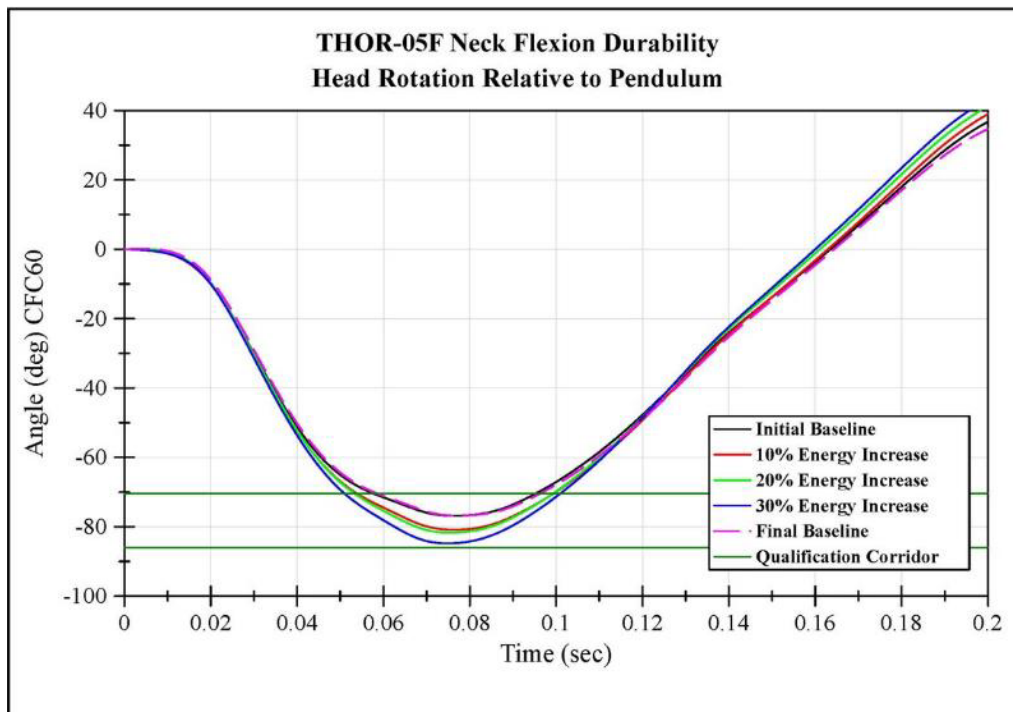


Figure 3-10. Head rotation angle θ_Y in neck flexion durability tests

3.3.3 Discussion

Both the initial and final baseline neck flexion responses were within the specified qualification corridors for upper neck moment and force, head angular rate, and head rotation angle, confirming that the neck still met qualification requirements with respect to flexion after the increased-energy tests. It was noted for some measures that the portion of the response curve most sensitive to the changes in energy was not the peak used for qualification. In these cases, the initial and final baseline responses were qualitatively compared and there was no concern for durability. No visible damage to the neck was observed post-test. These results indicate that the neck displays acceptable durability.

3.4 NECK EXTENSION

3.4.1 Methodology

Durability tests were performed using the neck extension qualification procedures described in the *THOR-05F Qualification Procedures and Requirements*. In the neck extension qualification tests, the lower neck load cell is attached rigidly to the bottom of the head-neck pendulum that is decelerated from an impact velocity of 5.00 ± 0.05 m/s by aluminum honeycomb (Figure 3-12). For durability tests on the neck in extension, the test energy was elevated from the qualification baseline by approximately 10, 20, and 30 percent (Table 3-10). After the three increased-energy tests, another baseline test was run to confirm that the higher-energy tests did not change the neck's baseline response. Neck EU0311 was used for this durability series.

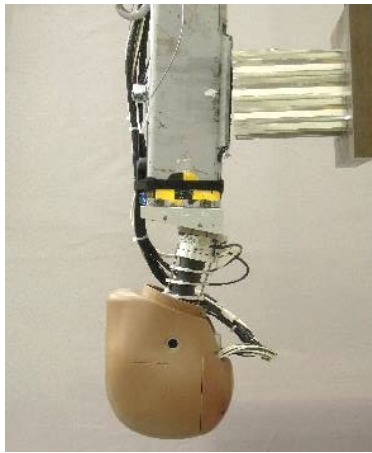


Figure 3-11. Neck extension test setup

Table 3-10. Target Test Velocities for Neck Extension Durability Tests (EU0311)

Test Severity	Target Velocity (m/s)
Initial Baseline	5.00
10% Energy Increase	5.24
20% Energy Increase	5.48
30% Energy Increase	5.70
Final Baseline	5.00

3.4.2 Results

For the THOR-05F neck extension baseline qualification tests, the neck extension responses must be within the ranges provided in Table 3-11. Table 3-12, along with Figure 3-13 through Figure 3-16, illustrates the durability test results along with the qualification corridor for baseline tests.

Table 3-11. Neck Extension Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	4.95	5.05
Minimum Upper Neck Moment M_y	N-m	-20.8	-17.0
Minimum Upper Neck Force F_z	N	-1,469	-1,202
Maximum Head Angular Velocity ω_y (relative to earth)	deg/s	2,154	2,632
Maximum Head Rotation Angle θ_y (relative to pendulum)	deg	79.1	96.7

Table 3-12. Neck Extension Durability Results (Neck EU0311)

Date	Test Number	Test Severity	Actual Velocity (m/s)	Minimum Upper Neck M_y (Nm)	Minimum Upper Neck F_z prior to 40 ms (N)	Maximum Head ω_y (deg/s)	Maximum Head θ_y (deg)
06/27/24	240627-4	Initial Baseline	5.00	-19.1	-1,208	2,358	86.7
06/27/24	240627-5	10% Energy Increase	5.26	-18.0	-1,302	2,408	90.3
06/27/24	240627-6	20% Energy Increase	5.49	-18.8	-1,488	2,453	92.4
06/27/24	240627-7	30% Energy Increase	5.71	-29.9	-1,853	2,512	94.9
06/27/24	240627-8	Final Baseline	5.00	-17.4	-1,261	2,360	86.4

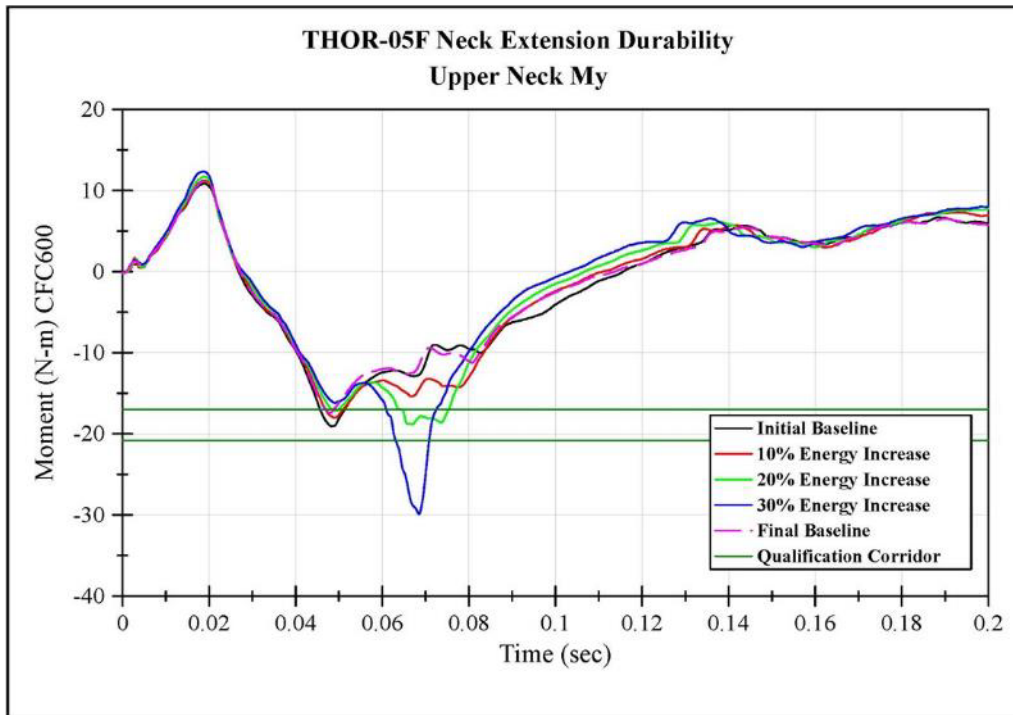


Figure 3-12. Upper neck moment My in neck extension durability tests

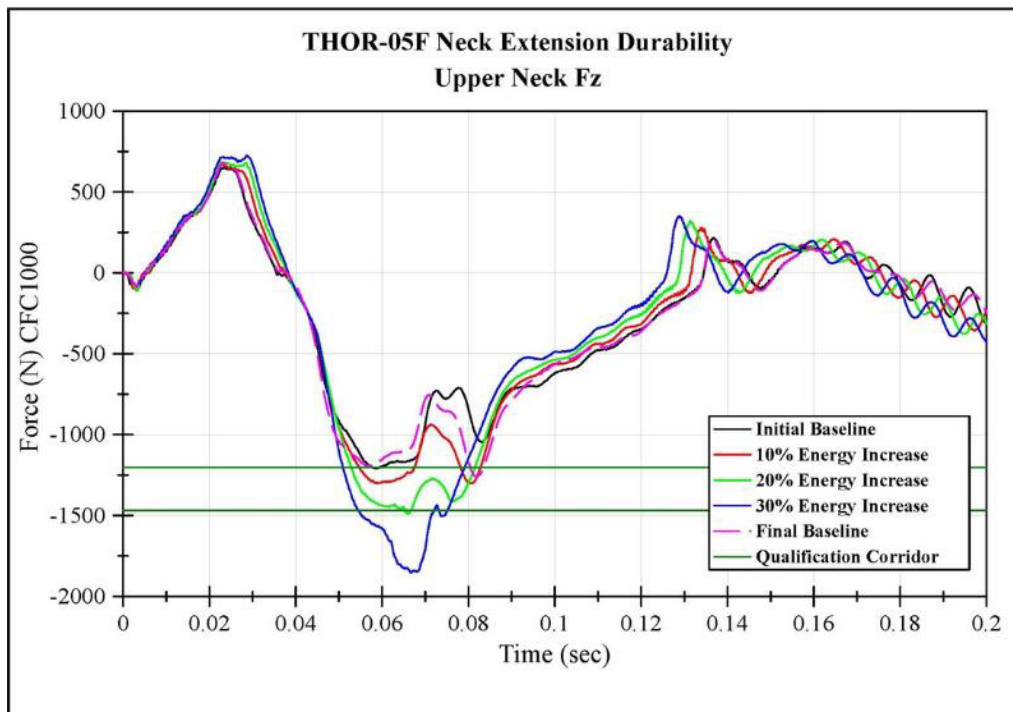


Figure 3-13. Upper neck force Fz in neck extension durability tests

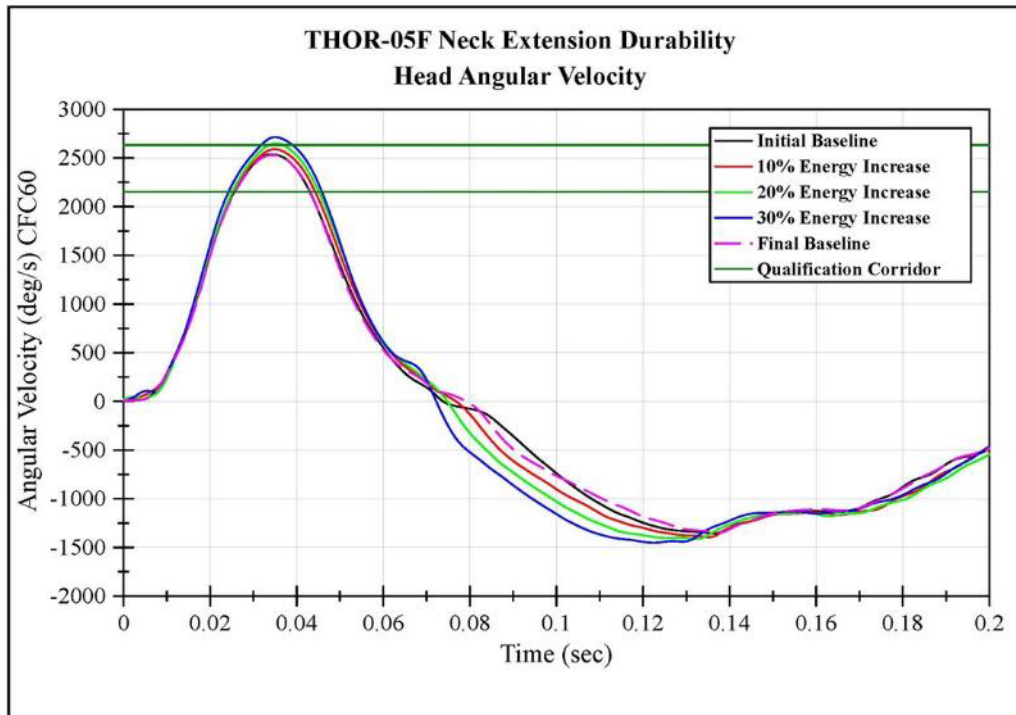


Figure 3-14. Head angular velocity ω_v in neck extension durability tests

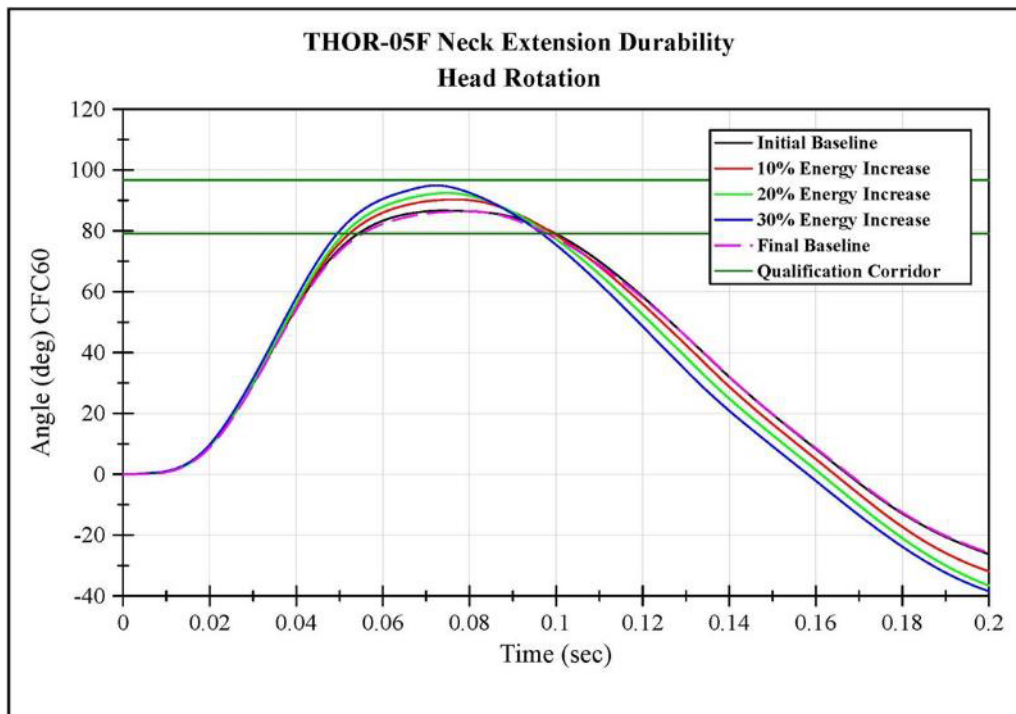


Figure 3-15. Head rotation angle θ_v in neck extension durability tests

3.4.3 Discussion

Both the initial and final baseline neck extension responses were within the specified qualification corridors for upper neck moment and force, head angular velocity, and head rotation angle, confirming that the neck still met qualification requirements with respect to extension after the increased-energy tests. It was noted for some measures that the portion of the response curve most sensitive to the changes in energy was not the peak used for qualification. In these cases, the initial and final baseline responses were qualitatively compared and there was no concern for durability. No visible damage to the neck was observed post-test. These results indicate that the neck displays acceptable durability.

3.5 NECK LATERAL FLEXION

3.5.1 Methodology

Durability tests were performed using the neck lateral flexion qualification procedures described in the *THOR-05F Qualification Procedures and Requirements*. In the lateral flexion qualification tests, the lower neck load cell is attached rigidly to the bottom of the head-neck pendulum and decelerated from an impact velocity of 5.00 ± 0.05 m/s by aluminum honeycomb (Figure 3-17). For lateral flexion durability tests on the neck, the test energy was elevated from the qualification baseline by approximately 10, 20, and 30 percent (Table 3-13). After the three increased-energy tests, another baseline test was run to confirm that the higher-energy tests did not change the neck's baseline response. Neck EU0311 was used for this durability series.

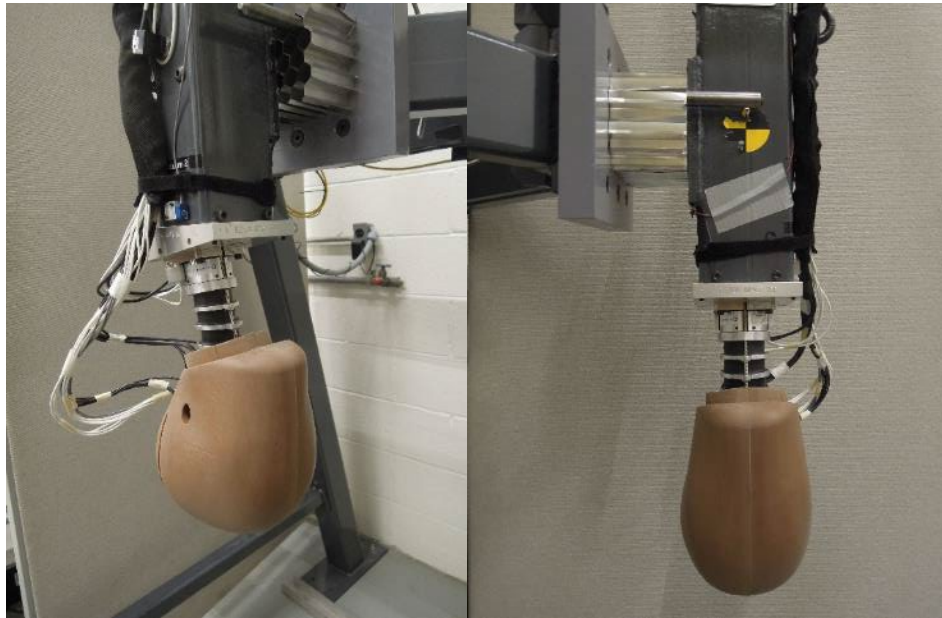


Figure 3-16. Neck lateral flexion test setup

Table 3-13. Target Test Velocities for Lateral Flexion Neck Durability Tests

Test Severity	Target Velocity (m/s)
Initial Baseline	3.40
10% Energy Increase	3.57
20% Energy Increase	3.72
30% Energy Increase	3.88
Final Baseline	3.40

3.5.2 Results

For the THOR-05F neck lateral flexion baseline qualification tests, the neck lateral flexion responses must be within the ranges provided in Table 3-14 and Table 3-15. Table 3-16 and Table 3-17, along with Figure 3-18 through Figure 3-20, illustrate the neck lateral flexion durability test results along with the qualification corridor for baseline tests.

Table 3-14. Neck Left Lateral Flexion Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	3.35	3.45
Maximum Upper Neck Moment M_x after 40 ms	N-m	27.6	33.7
Minimum Head Angular Velocity ω_x (relative to earth)	deg/s	-1,495	-1,223
Minimum Head Rotation Angle θ_x (relative to pendulum)	deg	-54.2	-44.4

Table 3-15. Neck Right Lateral Flexion Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	3.35	3.45
Minimum Upper Neck Moment M_x after 40 ms	N-m	-33.7	-27.6
Maximum Head Angular Velocity ω_x (relative to earth)	deg/s	1,223	1,495
Maximum Head Rotation Angle θ_x (relative to pendulum)	deg	44.4	54.2

Table 3-16. Neck Left Lateral Flexion Durability Results (Neck EU0311)

Date	Test Number	Test Severity	Actual Velocity (m/s)	Maximum Upper Neck M_x after 40 ms (Nm)	Minimum Head ω_x (deg/s)	Minimum Head θ_x (deg)
06/25/24	240625-6	Initial Baseline	3.41	31.6	-1,294	-48.3
06/25/24	240625-7	10% Energy Increase	3.57	32.0	-1,341	-51.7
06/26/24	240626-1	20% Energy Increase	3.72	33.0	-1,367	-53.2
06/26/24	240626-2	30% Energy Increase	3.88	34.8	-1,428	-57.3
06/26/24	240626-3	Final Baseline	3.41	30.0	-1,313	-49.5

Table 3-17. Neck Right Lateral Flexion Durability Results (Neck EU0311)

Date	Test Number	Test Severity	Actual Velocity (m/s)	Minimum Upper Neck M_x after 40 ms (Nm)	Maximum Head ω_x (deg/s)	Maximum Head θ_x (deg)
06/25/24	240625-1	Initial Baseline	3.41	-31.9	1,263	47.3
06/25/24	240625-2	10% Energy Increase	3.58	-33.4	1,337	51.3
06/25/24	240625-3	20% Energy Increase	3.74	-33.7	1,381	54.1
06/25/24	240625-4	30% Energy Increase	3.90	-34.6	1,398	56.6
06/25/24	240625-5	Final Baseline	3.41	-29.9	1,282	49.7

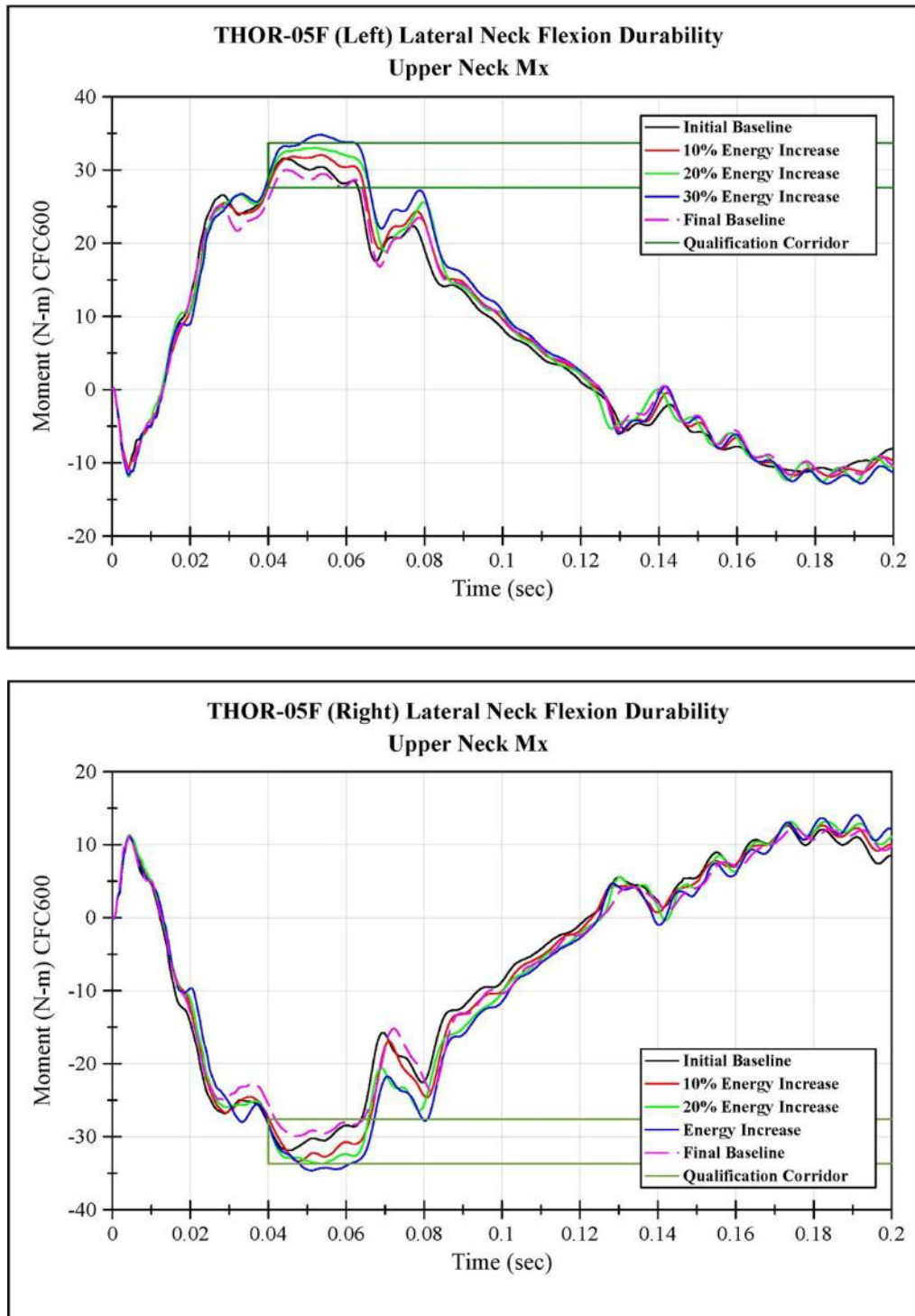


Figure 3-17. Left (top) and right (bottom) upper neck moment M_x in neck lateral flexion durability tests

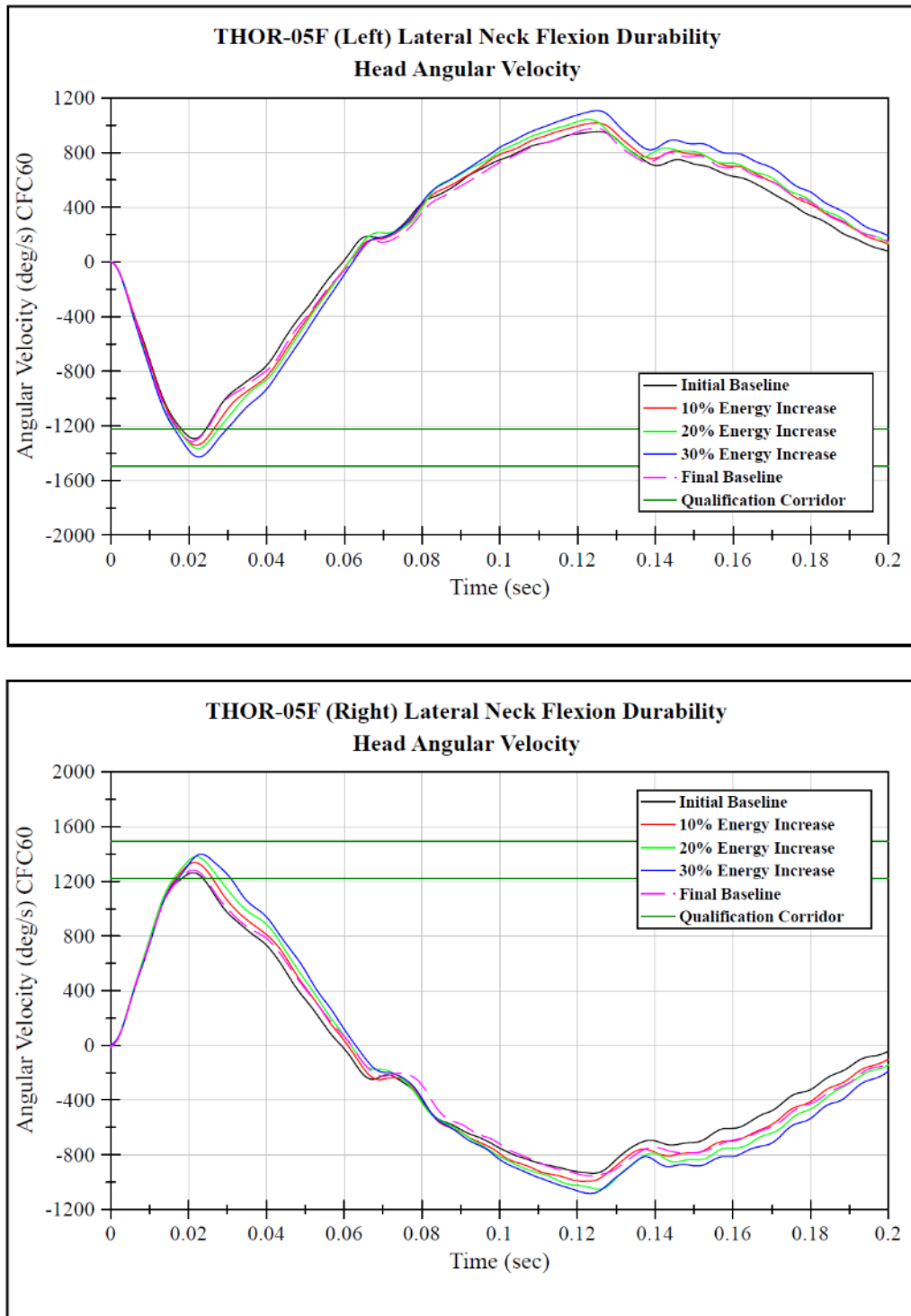


Figure 3-18. Left (top) and right (bottom) head angular velocity ω_x in neck lateral flexion durability tests

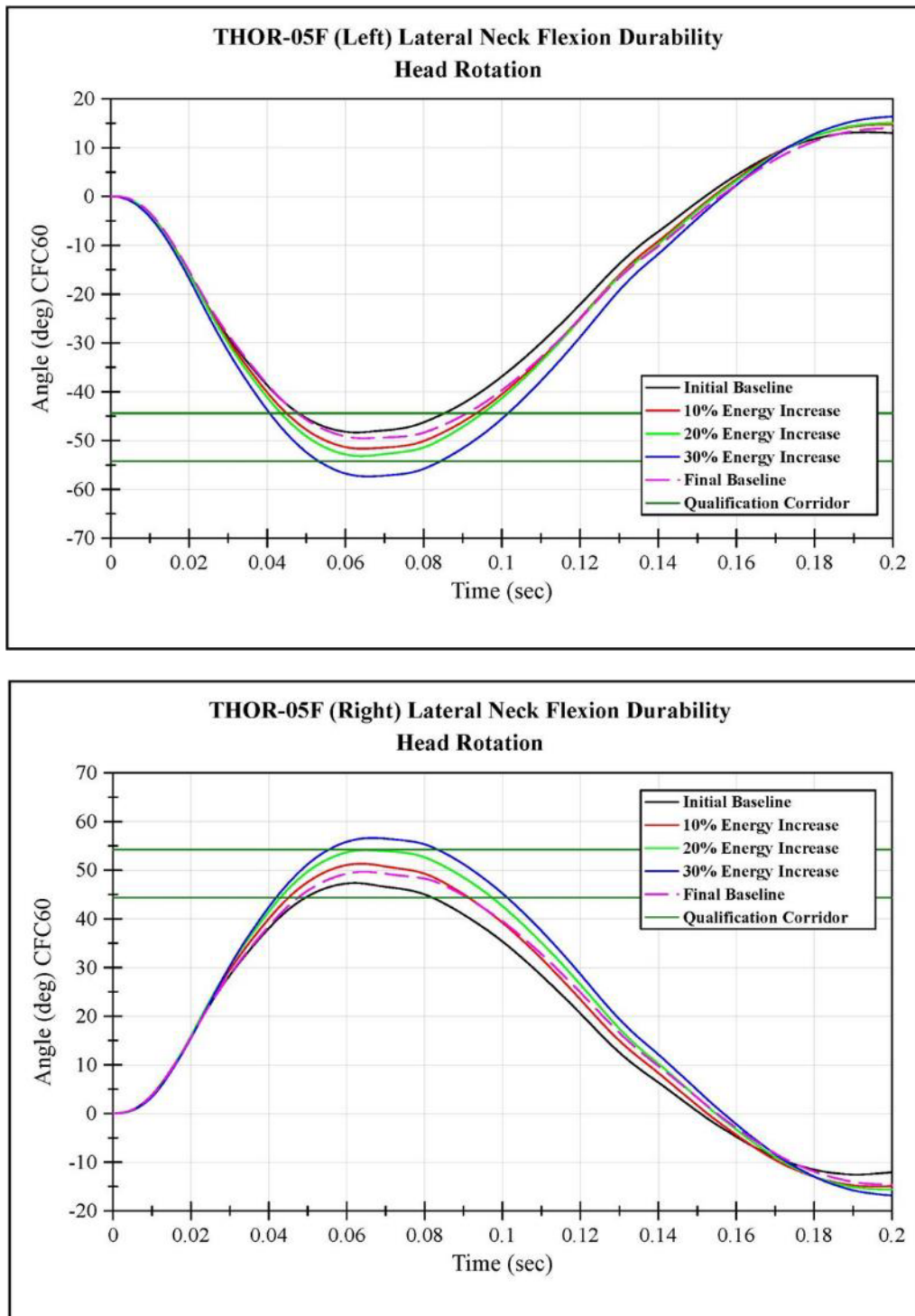


Figure 3-19. Left (top) and right (bottom) head rotation angle ω_x in neck lateral flexion durability tests

3.5.3 Discussion

Both the initial and final baseline neck lateral flexion responses were within the specified qualification corridors for upper neck moment, head angular velocity, and head rotation angle, confirming that the neck still met qualification requirements with respect to lateral flexion after the increased-energy tests. No visible damage to the neck was observed post-test. These results indicate that the neck displays acceptable durability.

3.6 NECK TORSION

3.6.1 Methodology

Durability tests were performed using the neck torsion qualification procedures described in the *THOR-05F Qualification Procedures and Requirements*. The neck torsion qualification test assesses the response of the neck to rotation about the Z axis. In this test, a neck torsion fixture (drawing DL474-1000) is fixed to the pendulum that is also used in neck flexion and extension qualification tests (Figure 3-21). As in other neck qualification tests, the pendulum is decelerated from 5.00 ± 0.05 m/s by aluminum honeycomb. On impact, the lower neck load-cell remains rigidly coupled with the torsion fixture while the momentum of the 1.5 ± 0.05 kg pendulum weight rotates the upper neck about the neck's Z-axis.

For torsion durability tests on the neck, the test energy was elevated from the qualification baseline by approximately 10, 20, and 30 percent (Table 3-17). After the three increased-energy tests, another baseline test was run to confirm that the higher-energy tests did not change the neck's baseline response. Neck EU0311 was used for this durability series.

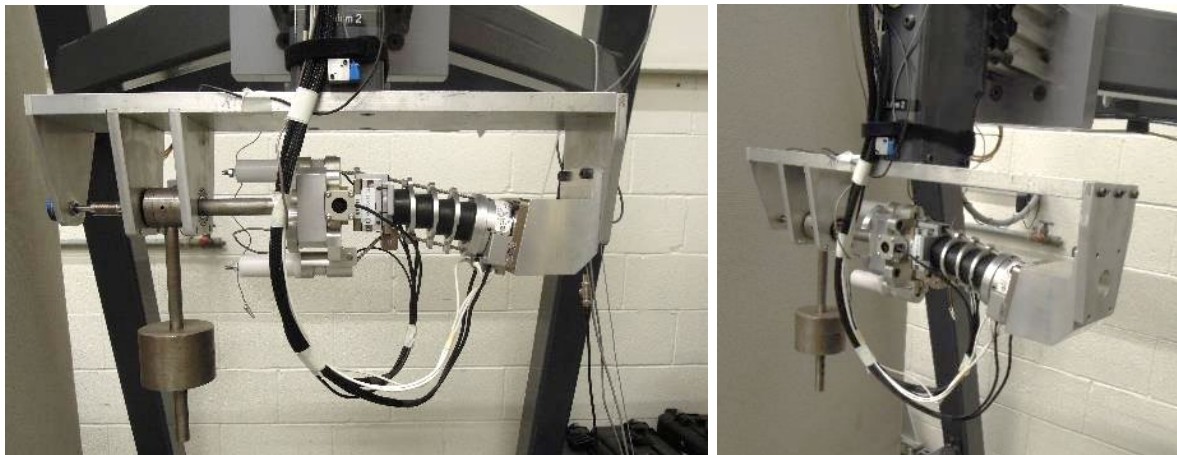


Figure 3-20. Neck torsion test setup

Table 3-18. Target Test Velocities for Neck Torsion Durability Tests

Test Severity	Target Velocity (m/s)
Initial Baseline	3.40
10% Energy Increase	3.57
20% Energy Increase	3.72
30% Energy Increase	3.88
Final Baseline	3.40

3.6.2 Results

For the THOR-05F neck torsion baseline qualification tests, the neck torsion responses must be within the ranges provided in Table 3-19 and Table 20. Table 3-21 and Figure 3-22 through Figure 3-24, illustrate the neck torsion durability test results along with the qualification corridors for baseline tests.

Table 3-19. Neck Left Torsion Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	3.35	3.45
Maximum Upper Neck Moment M_z	N-m	18.3	22.4
Minimum Neck Fixture Rotation Angle θ_z	deg	-56.2	-46.0
Minimum Upper Neck Angular Velocity ω_z (relative to earth)	deg/s	-1,419	-1,161

Table 3-20. Neck Right Torsion Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	3.35	3.45
Minimum Upper Neck Moment M_z	N-m	-22.4	-18.3
Maximum Neck Fixture Rotation Angle θ_z	deg	46.0	56.2
Maximum Upper Neck Angular Velocity ω_z	deg/s	1,161	1,419

Table 3-21. Neck Left Torsion Durability Results (Neck EU0311)

Date	Test Number	Test Severity	Actual Velocity (m/s)	Maximum Upper Neck M_z (Nm)	Minimum Neck Fixture θ_z (deg)	Minimum Upper Neck ω_z (deg/s)
06/18/24	240618-10	Initial Baseline	3.40	21.6	-47.4	-1,205
06/18/24	240618-11	10% Energy Increase	3.56	22.8	-50.0	-1,280
06/24/24	240624-2	20% Energy Increase	3.73	23.5	-51.7	-1,316
06/24/24	240624-3	30% Energy Increase	3.90	24.9	-56.0	-1,383
06/24/24	240624-5	Final Baseline	3.40	21.2	-48.1	-1,224

Table 3-22. Neck Right Torsion Durability Results (Neck EU0311)

Date	Test Number	Test Severity	Actual Velocity (m/s)	Minimum Upper Neck M_z (Nm)	Maximum Neck Fixture θ_z (deg)	Maximum Upper Neck ω_z (deg/s)
06/24/24	240624-7	Initial Baseline	3.40	-21.4	48.8	1,242
06/24/24	240624-8	10% Energy Increase	3.57	-22.5	51.4	1,293
06/24/24	240624-9	20% Energy Increase	3.73	-23.3	54.1	1,342
06/24/24	240624-11	30% Energy Increase	3.91	-23.9	57.4	1,388
06/24/24	240624-16	Final Baseline	3.40	-20.9	49.8	1,247

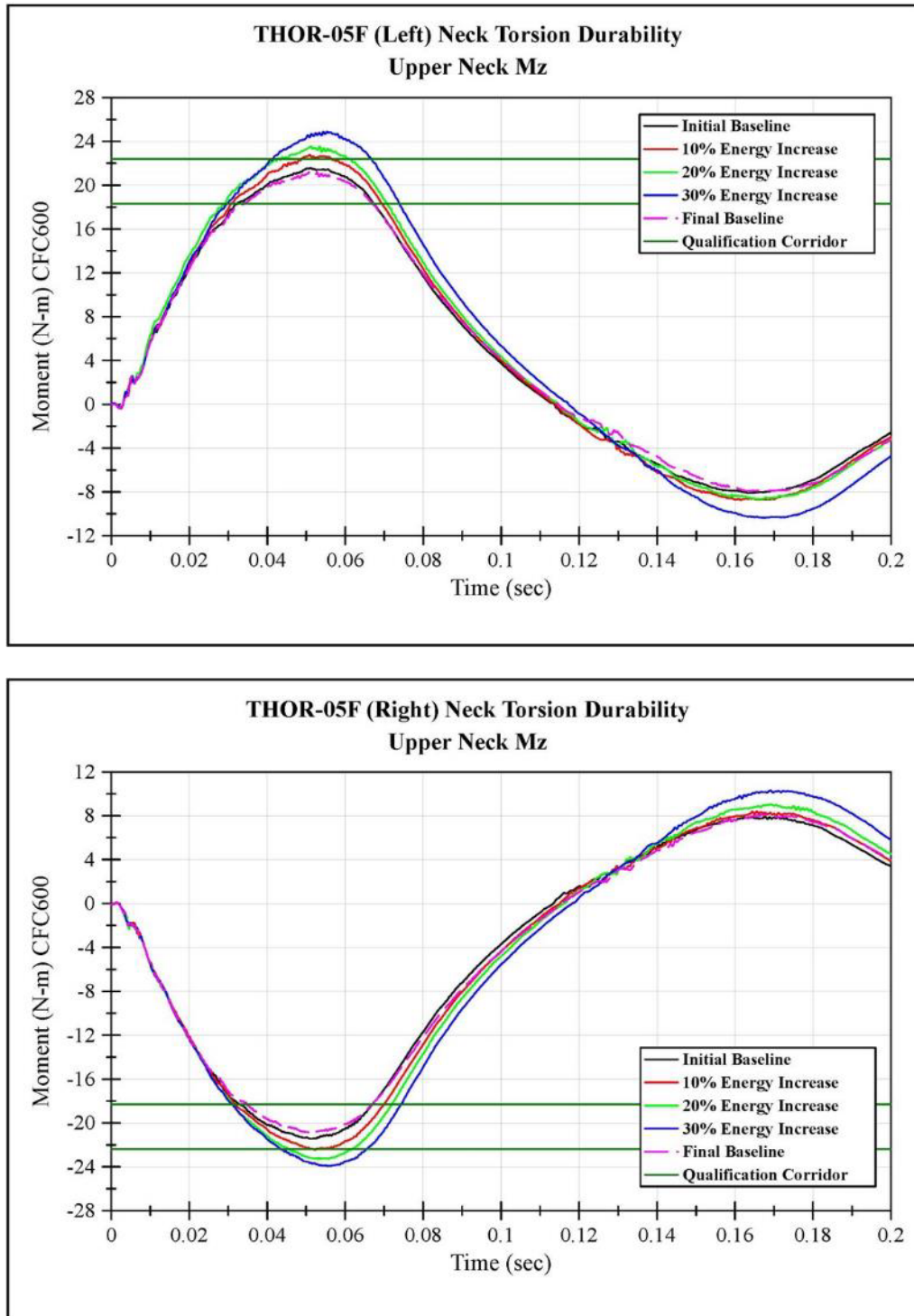


Figure 3-21. Left (top) and right (bottom) upper neck moment Mz in neck torsion durability tests

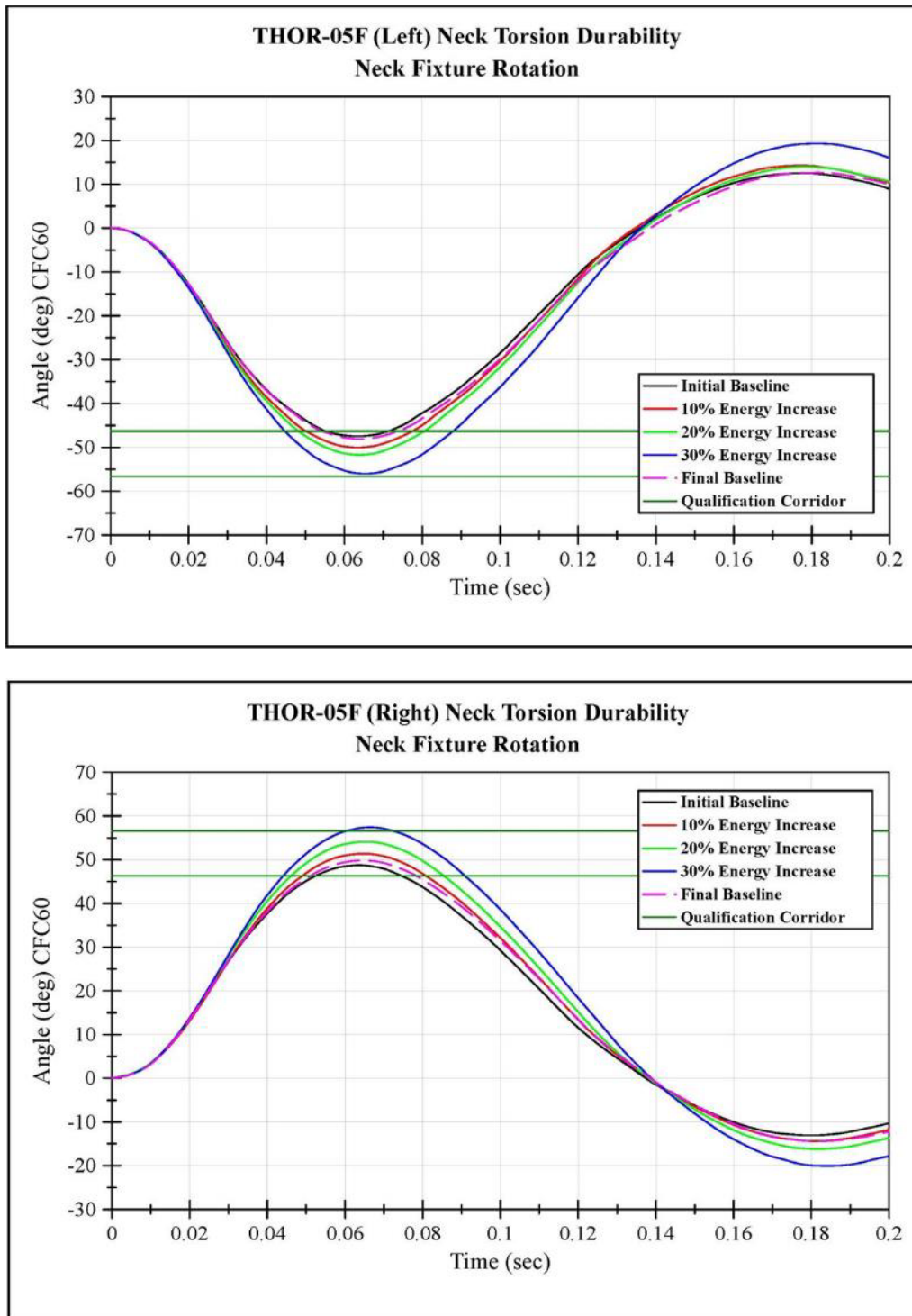


Figure 3-22. Left (top) and right (bottom) neck torsion fixture rotation angle θ_z in neck torsion durability tests

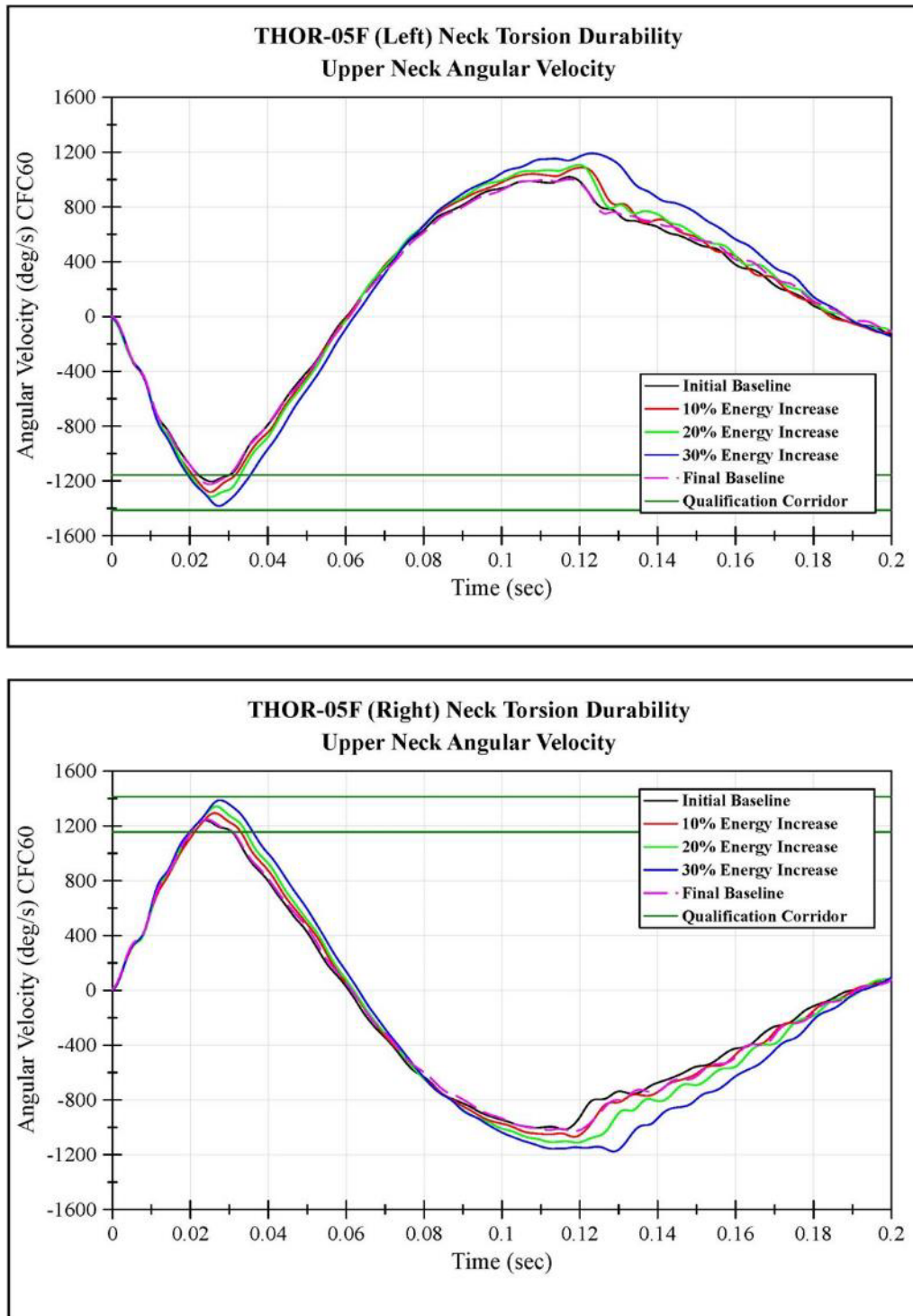


Figure 3-23. Left (top) and right (bottom) neck angular velocity ω_z in neck torsion durability tests

3.6.3 Discussion

Both the initial and final baseline neck torsion responses were within the specified qualification corridors for upper neck moment, neck angular velocity, and neck fixture rotation angle, confirming that the neck still met qualification requirements with respect to torsion after the increased-energy tests. No visible damage to the neck was observed post-test. These results indicate that the neck displays acceptable durability.

3.7 UPPER THORAX

3.7.1 Methodology

Upper thorax durability tests followed the qualification procedures described in the *THOR-05F Qualification Procedures and Requirements*. The qualification test is a blunt impact to the sternum at 4.30 m/s $\pm$ 0.05 m/s (Figure 3-25). In this test, an impactor with a rigid disk face with a diameter of 152.4 mm and a mass of 13.97 kg contacts the ATD at mid-sternum level. For durability tests on the upper thorax, the test energy was elevated from the qualification baseline by approximately 10, 20, and 30 percent (Table 3-23). After the three increased-energy tests, another baseline test was run to confirm that the higher-energy tests did not change the thorax's baseline response. THOR-05F EU9863 was used for this durability series.

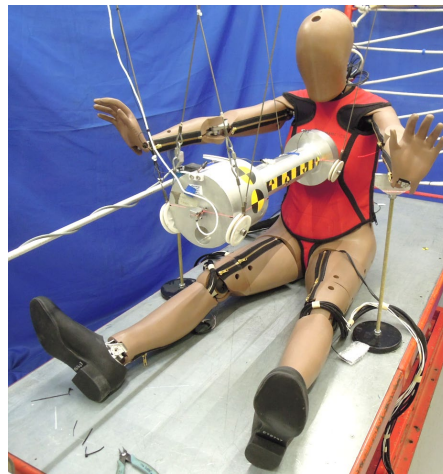


Figure 3-24. Upper thorax impact test setup

Table 3-23. Target Velocities for Upper Thorax Durability Tests

Test Severity	Target Velocity (m/s)
Initial Baseline	4.30
10% Energy Increase	4.51
20% Energy Increase	4.71
30% Energy Increase	4.90
Final Baseline	4.30

3.7.2 Results

For the baseline THOR-05F upper thorax qualification tests, the upper thorax responses must be within the ranges provided in Table 3-24. Table 3-25, along with Figure 3-26 through Figure 3-28, illustrates the durability test results along with the qualification corridors for baseline tests.

The primary response specifications for the upper thorax qualification test are the resultant deflections of the left and right upper ribs in the local spine coordinate system, as measured by the InfraRed Telescoping Rod for Assessment of Chest Compression (IR-TRACC) assemblies, and the reaction force calculated using the pendulum acceleration and probe mass. The resultant deflections of the left and right IR-TRACCs are assessed individually.

Table 3-24. Upper Thorax Qualification Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	4.25	4.35
Maximum Probe Force	N	1,796	2,195
Maximum Upper Left Resultant Deflection	mm	31.7	38.8
Maximum Upper Right Resultant Deflection	mm		
Difference Between Maximum Left & Right Resultant Deflections	mm		< 5.0
Force at Left & Right Maximum Resultant Deflection	N	1,616	1,976

Table 3-25. Upper Thorax Durability Results (THOR-05F EU9863)

Date	Test Number	Test Severity	Actual Velocity (m/s)	Maximum Probe Force (N)	Maximum Upper Left Resultant Deflection (mm)	Maximum Upper Right Resultant Deflection (mm)	Absolute Diff Between Left & Right Resultant Deflection (mm)	Force at Left Maximum Resultant Deflection (N)	Force at Right Maximum Resultant Deflection (N)
02/12/24	240212-1	Initial Baseline	4.30	1,905	32.6	36.8	4.2	1,881	1,868
02/12/24	240212-2	10% Energy Increase	4.50	2,177	36.0	35.9	0.1	2,009	2,036
02/12/14	240212-3	20% Energy Increase	4.70	2,330	35.6	37.6	2.1	2,081	2,126
02/12/24	240212-4	30% Energy Increase	4.89	2,337	37.8	38.5	0.8	2,212	2,149
02/12/24	240212-6	Final Baseline	4.29	1,986	34.2	35.5	1.3	1,803	1,795

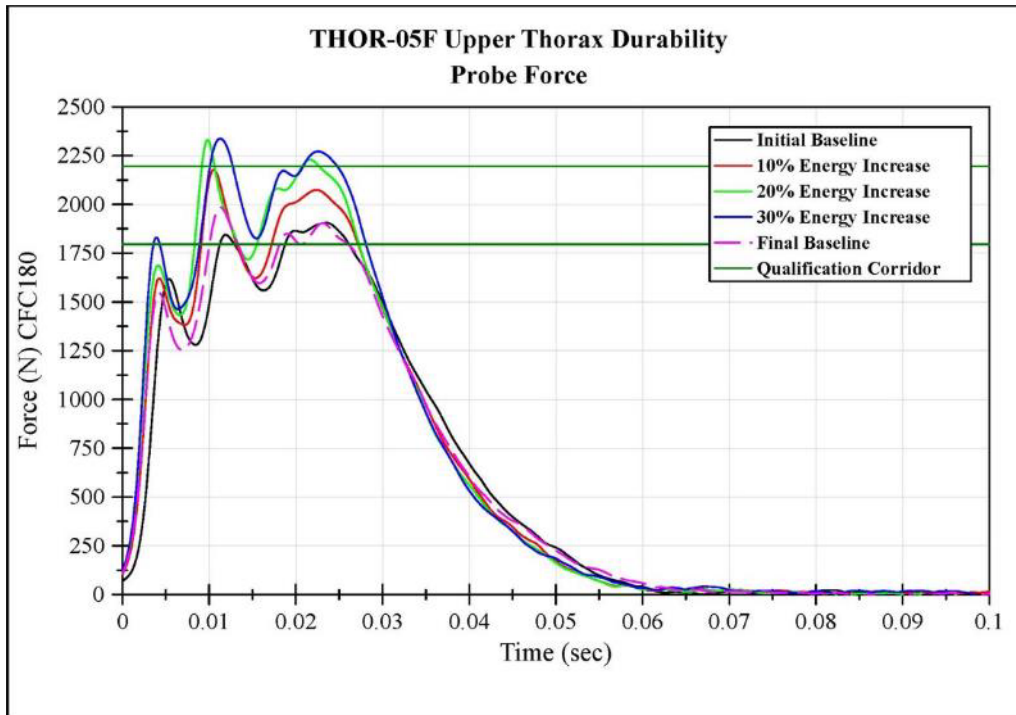


Figure 3-25. Probe force in upper thorax durability tests

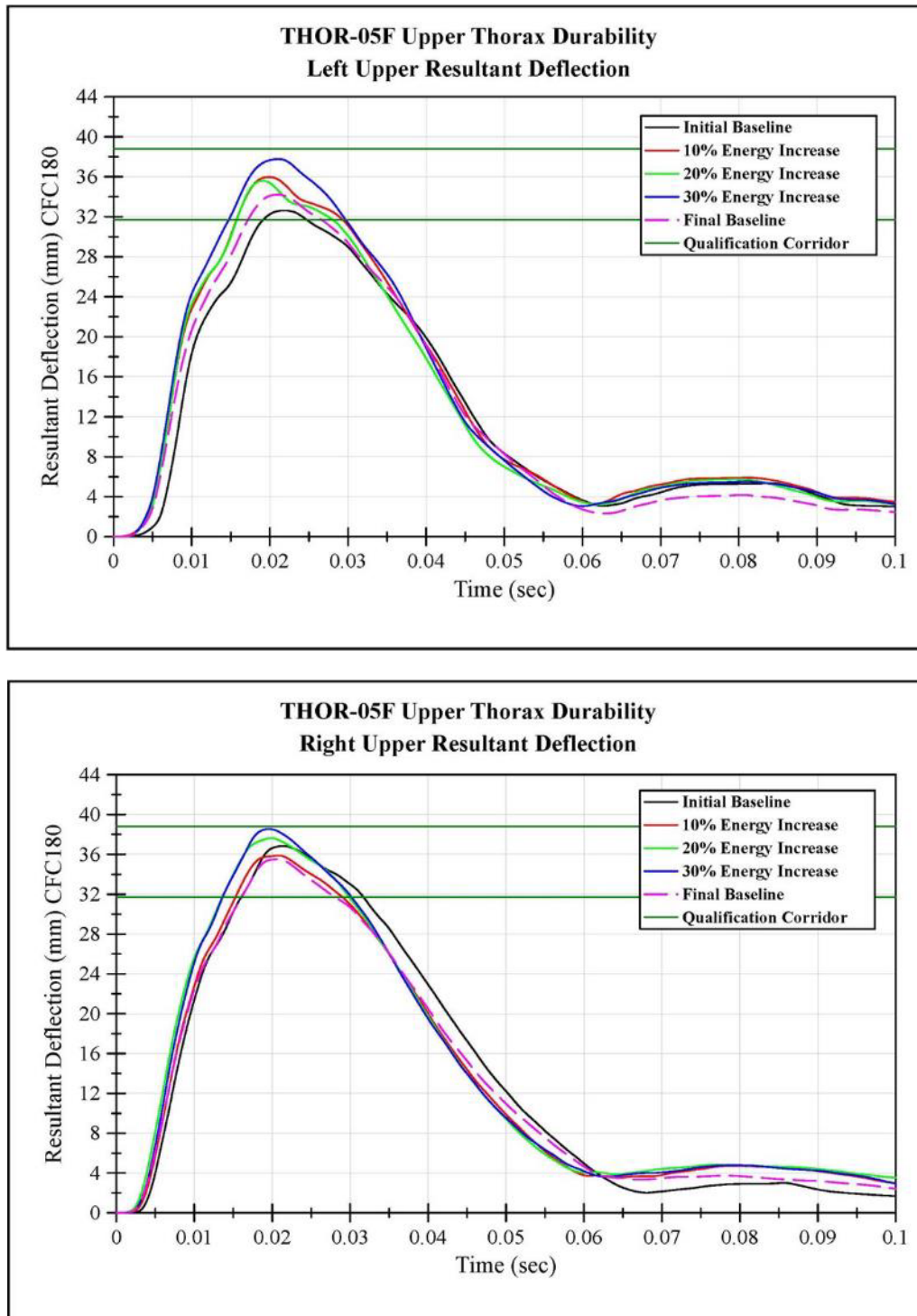


Figure 3-26. Left (top) and right (bottom) upper thorax resultant deflection in upper thorax durability tests

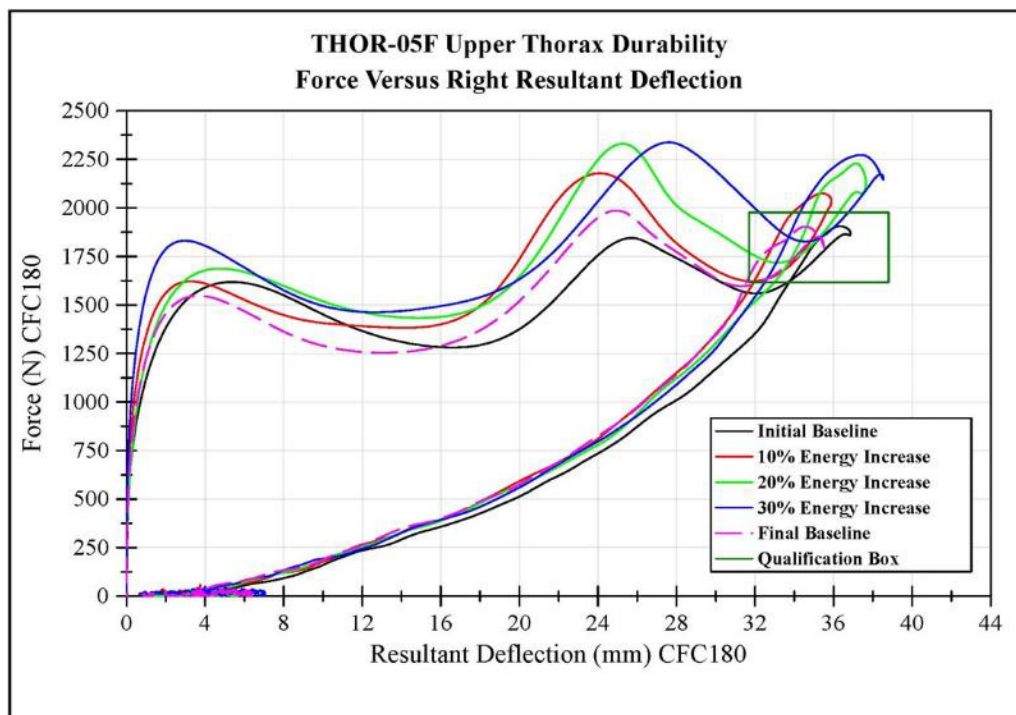
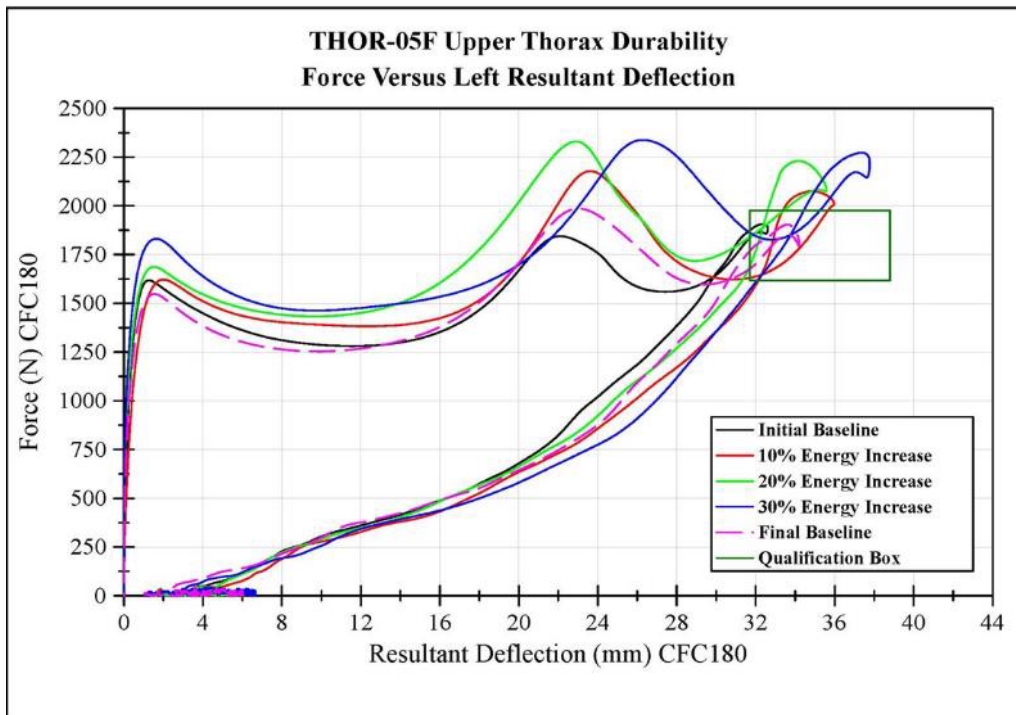


Figure 3-27. Force-deflection in left (top) and right (bottom) upper thorax durability tests

3.7.3 Discussion

Both the initial and final baseline upper thorax responses were within the specified qualification corridors for probe force, resultant upper deflections, and force at maximum deflection, confirming that the upper thorax still met qualification requirements after the increased-energy tests. No visible damage to the thorax was observed post-test. These results indicate that the upper thorax displays acceptable durability.

3.8 LOWER THORAX

3.8.1 Methodology

Lower thorax durability tests followed the qualification procedures described in the *THOR-05F Qualification Procedures and Requirements*. The impactor, also used in the upper thorax test (Figure 3-29), has a mass of 13.97 kg and a 152.40 mm diameter rigid disk impact surface. Impact speed in qualification tests is 4.30 ± 0.05 m/s. The impact is centered over the lower left or right thorax IR-TRACC's attachment to the chest flesh, with the line of impact horizontal and parallel to the dummy's sagittal plane. The resultant deflection of the lower thorax IR-TRACC (on the impacted side) is calculated in the local spine coordinate system. For durability tests on the lower thorax, the test energy was elevated from the qualification baseline by approximately 10, 20, and 30 percent (Table 3-26). After the three increased-energy tests, another baseline test was run to confirm that the higher-energy tests did not change the thorax's baseline response. THOR-05F EU9863 was used for this durability series.



Figure 3-28. Lower thorax durability test setup

Table 3-26. Target Velocities in Lower Thorax Durability Tests

Test Severity	Target Velocity (m/s)
Initial Baseline	4.30
10% Energy Increase	4.51
20% Energy Increase	4.71
30% Energy Increase	4.90
Final Baseline	4.30

3.8.2 Results

For the baseline THOR-05F lower thorax qualification tests, the lower thorax responses must be within the ranges provided in Table 3-27. Table 3-28, along with Figure 3-30 and Figure 3-31, illustrates the durability test results along with the qualification corridors for the baseline tests.

Table 3-27. Lower Thorax Qualification Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	4.25	4.35
Maximum Probe Force	N	1,807	2,209
Left or Right Resultant Deflection at Max Force	mm	38.4	46.9

Table 3-28. Lower Thorax Durability Results (THOR-05F EU9863)

Date	Test Number	Test Severity	Impact Velocity (m/s)	Maximum Probe Force (N)	Resultant Deflection at Max Force (mm)
Left Side					
8/11/25	250811-4	Initial Baseline	4.30	1,997	42.3
8/11/25	250811-6	10% Energy Increase	4.52	2,230	43.6
8/11/25	250811-7	20% Energy Increase	4.72	2,375	43.8
8/11/25	250811-9	30% Energy Increase	4.90	2,608	44.3
8/11/25	250811-11	Final Baseline	4.31	2,024	41.8
Right Side					
02/16/24	240216-3	Initial Baseline	4.29	1,937	45.3
02/16/24	240216-4	10% Energy Increase	4.49	2,222	46.3
02/16/24	240216-5	20% Energy Increase	4.70	2,246	48.1
02/22/24	240222-1	30% Energy Increase	4.89	2,444	48.3
02/22/24	240222-2	Final Baseline	4.29	1,959	45.8

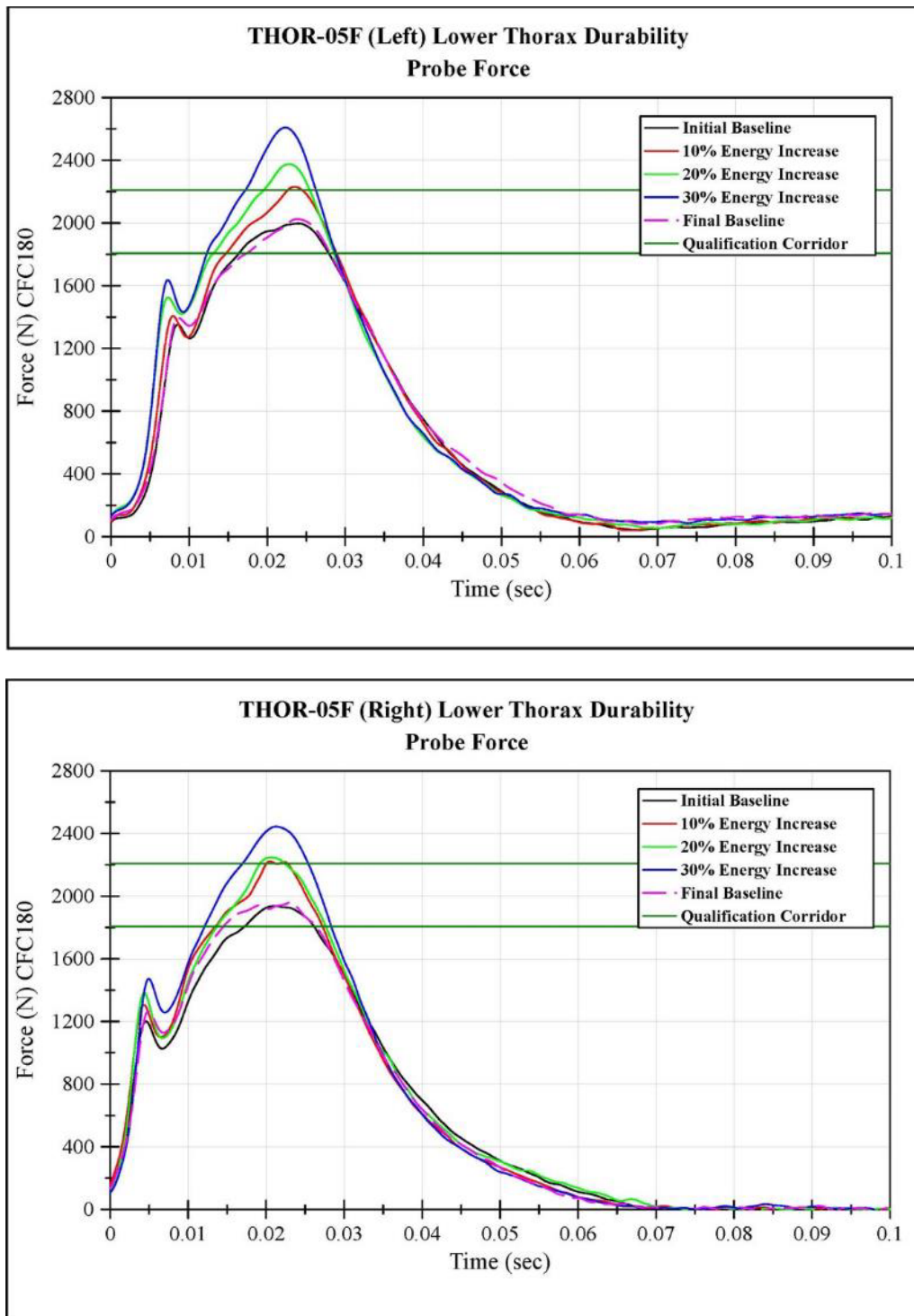


Figure 3-29. Probe force in left (top) and right (bottom) lower thorax durability tests

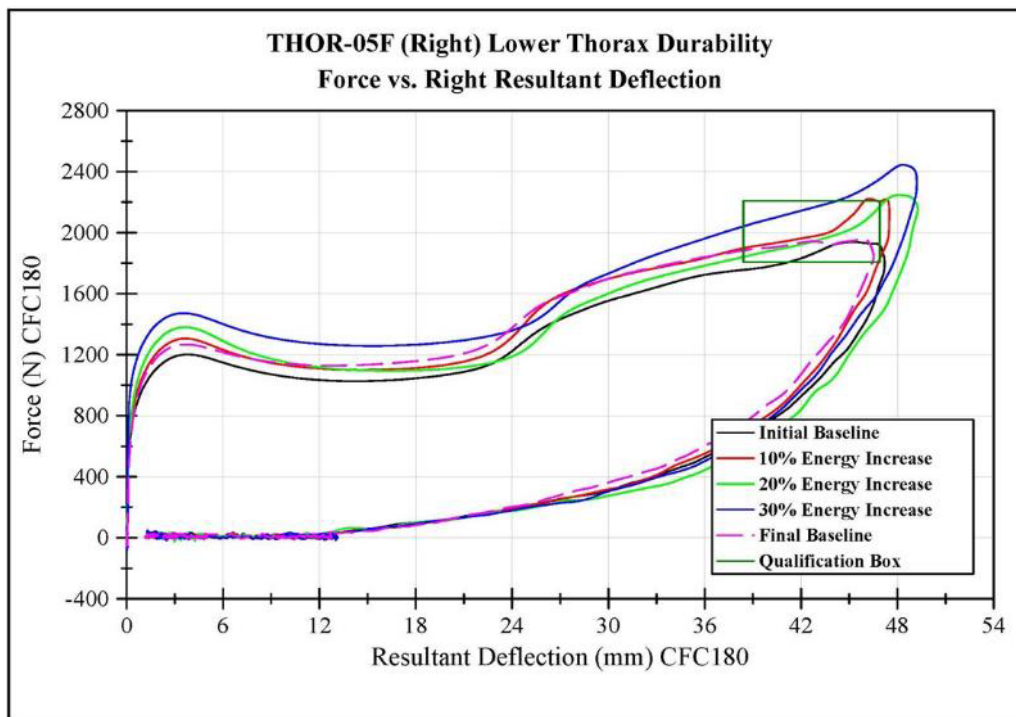
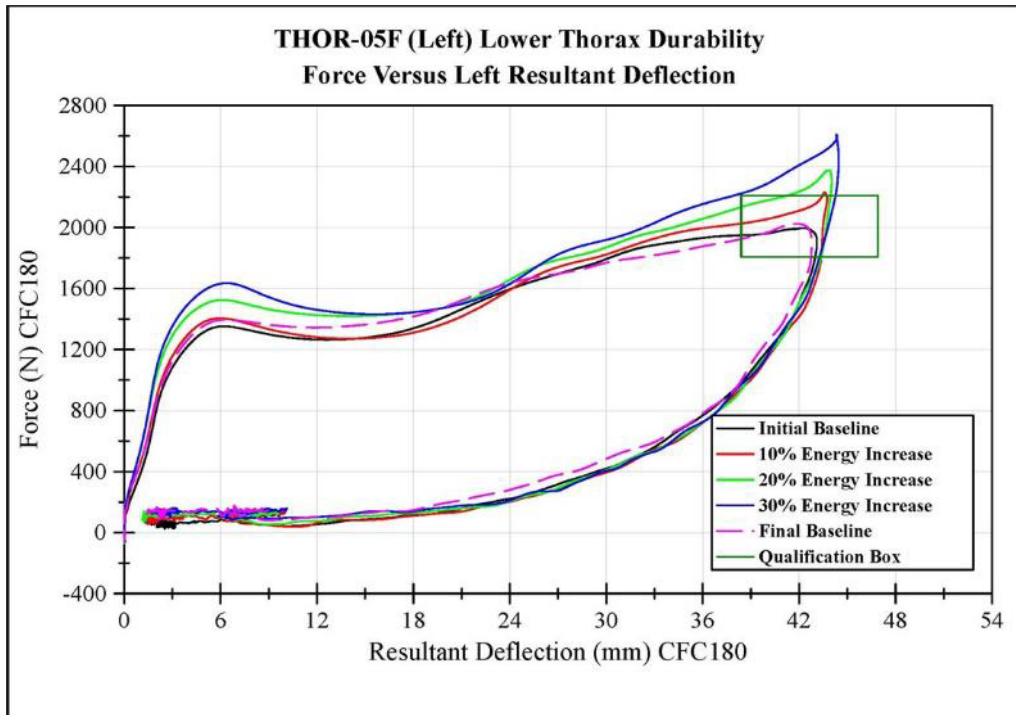


Figure 3-30. Force-deflection in left (top) and right (bottom) lower thorax durability tests

3.8.3 Discussion

Between testing the left and right lower thorax for durability, this ATD was used in a sled test series and minor cosmetic damage to the ribs was observed. However, the damage did not affect qualification results so the durability series was continued. Both the initial and final baseline lower thorax responses were within the specified qualification corridors for probe force and resultant deflection, confirming that the lower thorax still met qualification requirements after the increased-energy tests. No additional visible damage to the thorax was observed post-test. These results indicate that the lower thorax displays acceptable durability.

3.9 ABDOMEN

3.9.1 Methodology

Abdomen durability tests followed the qualification procedures described in the *THOR-05F Qualification Procedures and Requirements*. These qualification tests use a 16.00 kg impactor with a rectangular, horizontal rigid bar to impact the lower abdomen of the THOR-05F at 6.10 ± 0.05 m/s (Figure 3-32). The center of the rigid bar impacts the abdomen 20.7 mm below the umbilicus landmark on the abdomen. For durability tests on the abdomen, the test energy was elevated from the qualification baseline by approximately 10, 20, and 30 percent (Table 3-29). After the three increased-energy tests, another baseline test was run to confirm that the higher-energy tests did not change the abdomen's baseline response. THOR-05F EU9863 was used for this durability series.

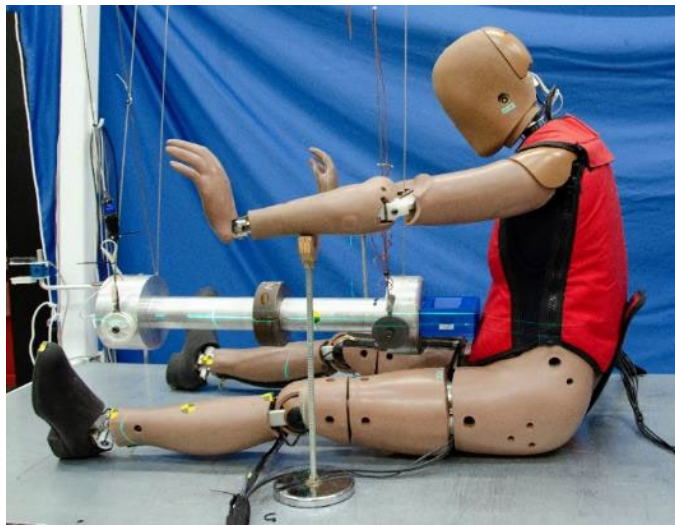


Figure 3-31. Abdomen durability test setup

Table 3-29. Target Test Velocities for Abdomen Durability Tests

Test Severity	Target Velocity (m/s)
Initial Baseline	6.10
10% Energy Increase	6.40
20% Energy Increase	6.68
30% Energy Increase	6.96
Final Baseline	6.10

3.9.2 Results

For the THOR-05F abdomen baseline qualification tests, the abdomen responses must be within the ranges provided in Table 3-30. Table 3-31, along with Figure 3-33 and Figure 3-34, illustrates the durability test results along with the qualification corridors for the baseline tests.

Table 3-30. Abdomen Qualification Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	6.05	6.15
Maximum Probe Force	N	4,052	4,952
Lower Left Abdomen Maximum Pressure	kPa	189	231
Lower Right Abdomen Maximum Pressure			
Difference Between Peak Left & Right Maximum Pressures	kPa		< 15

Table 3-31. Abdomen Durability Results (THOR-05F EU9863)

Date	Test Number	Test Severity	Actual Velocity (m/s)	Maximum Probe Force (N)	Lower Left Abdomen Maximum Pressure (kPa)	Lower Right Abdomen Maximum Pressure (kPa)	Absolute Diff Between Left & Right Abdomen Pressure (kPa)
08/19/24	240819-9	Initial Baseline	6.10	4,508	211	199	11
08/19/24	240819-10	10% Energy Increase	6.39	5,015	224	214	10
08/20/24	240820-4	20% Energy Increase	6.68	5,325	225	225	0
08/20/24	240820-5	30% Energy Increase	6.95	5,862	230	239	9
08/20/24	240820-6	Final Baseline	6.09	4,540	199	213	13

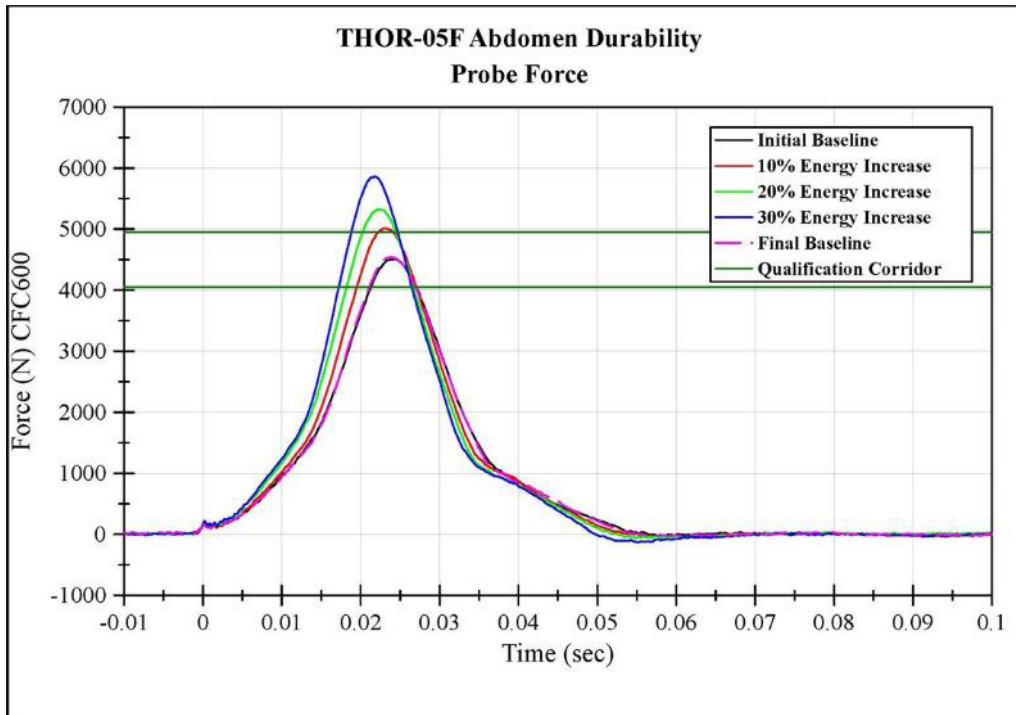


Figure 3-32. Probe force in abdomen durability tests

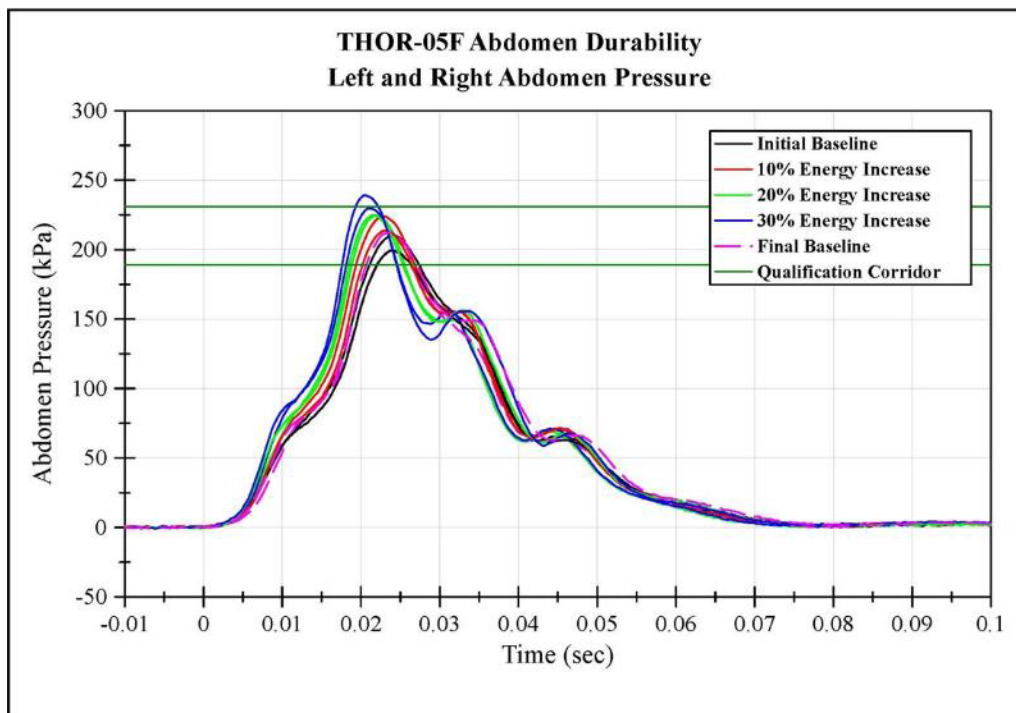


Figure 3-33. Left and right abdomen pressure in abdomen durability tests

3.9.3 Discussion

Both the initial and final baseline abdomen responses were within the specified qualification corridors for probe force and abdomen pressure, confirming that the abdomen still met qualification requirements after the increased-energy tests. No visible damage to the abdomen was observed post-test. These results indicate that the abdomen displays acceptable durability.

3.10 UPPER LEG

3.10.1 Methodology

Upper leg durability tests followed the qualification procedures described in the *THOR-05F Qualification Procedures and Requirements*. This qualification test measures the response of the femur to axial impacts at the knee using a 7.26 kg impactor with a 76.2 mm diameter rigid circular impact surface at 3.65 ± 0.05 m/s (Figure 3-35). For durability tests on the upper leg, the test energy was elevated from the qualification baseline by approximately 10, 20, and 30 percent (Table 3-32). After the three increased-energy tests, another baseline test was run to confirm the higher-energy tests did not change the upper leg's baseline response. THOR-05F EU9863 was used for this durability series.



Figure 3-34. Upper leg durability test setup

Table 3-32. Target Test Velocities for Upper Leg Durability Tests

Test Severity	Target Velocity (m/s)
Initial Baseline	3.65
Energy Increase (10%)	3.83
Energy Increase (20%)	4.00
Energy Increase (30%)	4.16
Final Baseline	3.65

3.10.2 Results

For the baseline THOR-05F upper leg qualification tests, the upper leg responses must be within the ranges provided in Table 3-33. Table 3-34 and Table 3-35, along with Figure 3-36 through Figure 3-38, illustrate the durability test results along with the qualification corridors for the baseline tests.

Table 3-33. Upper Leg Qualification Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	3.60	3.70
Maximum Probe Force	N	7,105	8,684
Minimum Femur Force Fz	N	-4,535	-3,711
Maximum Resultant Acetabulum Force	N	1,829	2,236

Table 3-34. Left Upper Leg Durability Results (THOR-05F EU9863)

Date	Test Number	Test Severity	Actual Velocity (m/s)	Maximum Probe Force (N)	Minimum Femur Fz (N)	Maximum Resultant Acetabulum Force (N)
08/14/25	250814-2	Initial Baseline	3.63	7,381	-4,039	1,847
08/14/25	250814-3	10% Energy Increase	3.83	8,841	-4,770	2,023
08/14/25	250814-4	20% Energy Increase	3.99	9,199	-4,938	2,029
08/14/25	250814-5	30% Energy Increase	4.15	9,843	-5,226	2,015
08/14/25	250814-7	Final Baseline	3.61	8,086	-4,262	1,928

Table 3-35. Right Upper Leg Durability Results (THOR-05F EU9863)

Date	Test Number	Test Severity	Actual Velocity (m/s)	Maximum Probe Force (N)	Minimum Femur Fz (N)	Maximum Resultant Acetabulum Force (N)
08/13/25	250813-5	Initial Baseline	3.62	8,315	-4,138	1,854
08/13/25	250813-6	10% Energy Increase	3.82	9,032	-4,404	2,001
08/13/25	250813-7	20% Energy Increase	4.00	9,828	-4,759	2,005
08/13/25	250813-8	30% Energy Increase	4.15	10,420	-5,014	2,158
08/13/25	250813-9	Final Baseline	3.63	8,322	-4,128	1,833

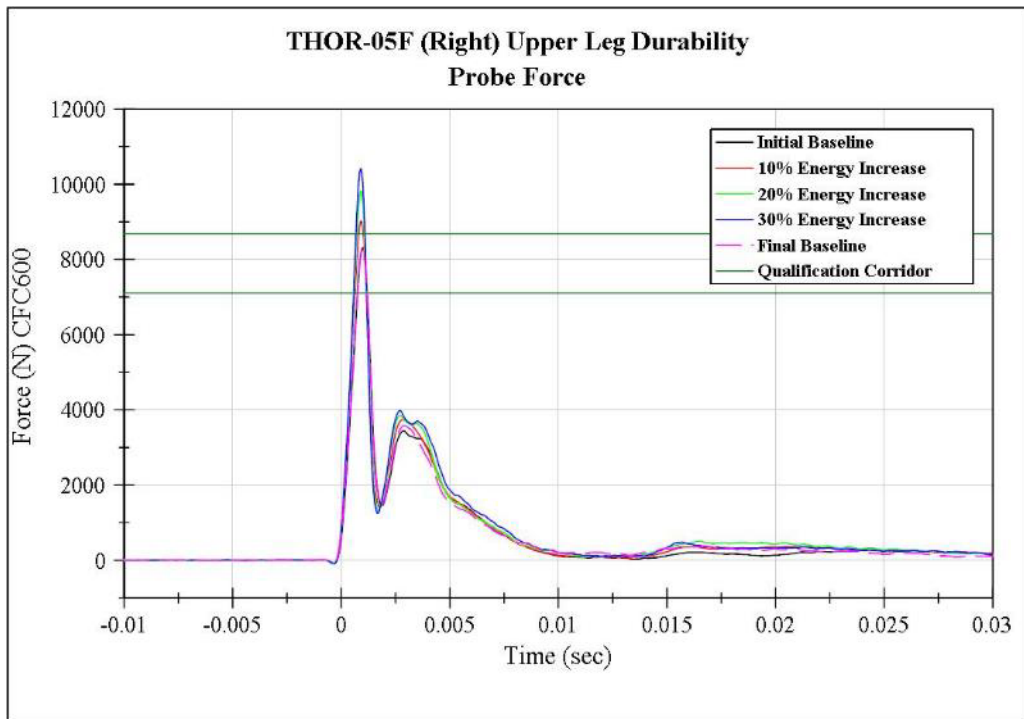
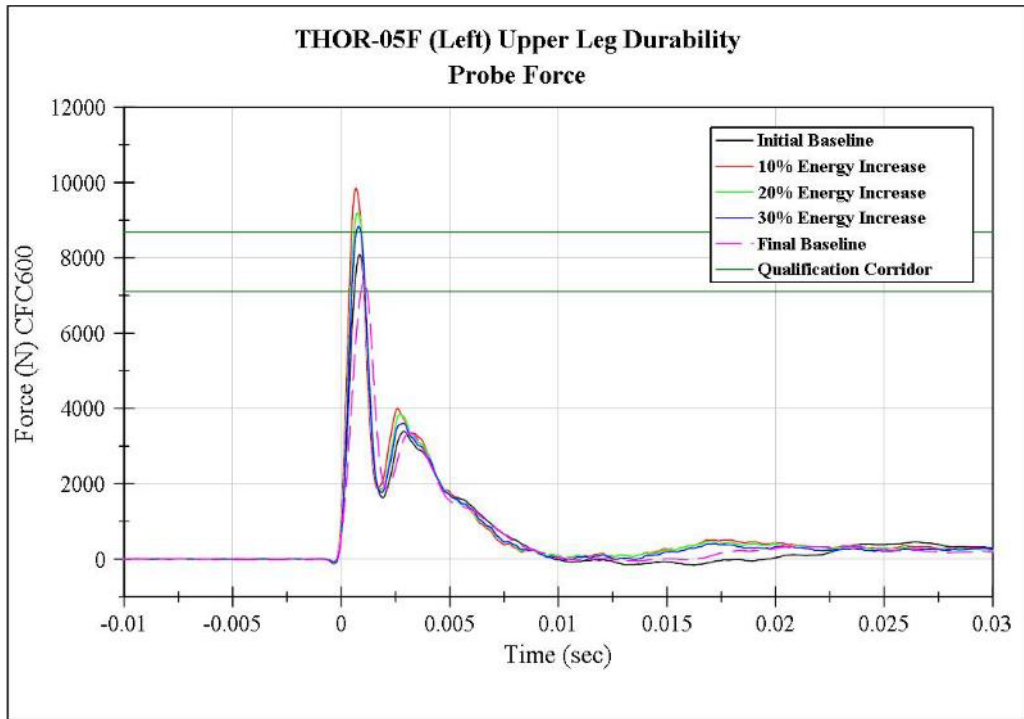


Figure 3-35. Probe force in left (top) and right (bottom) upper leg durability tests

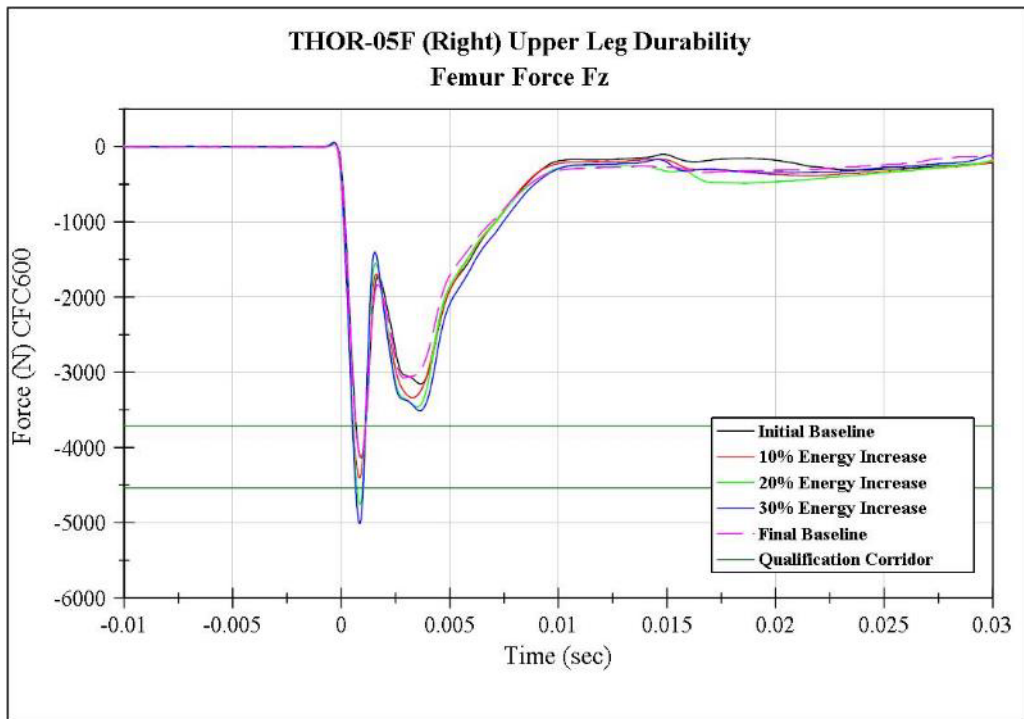
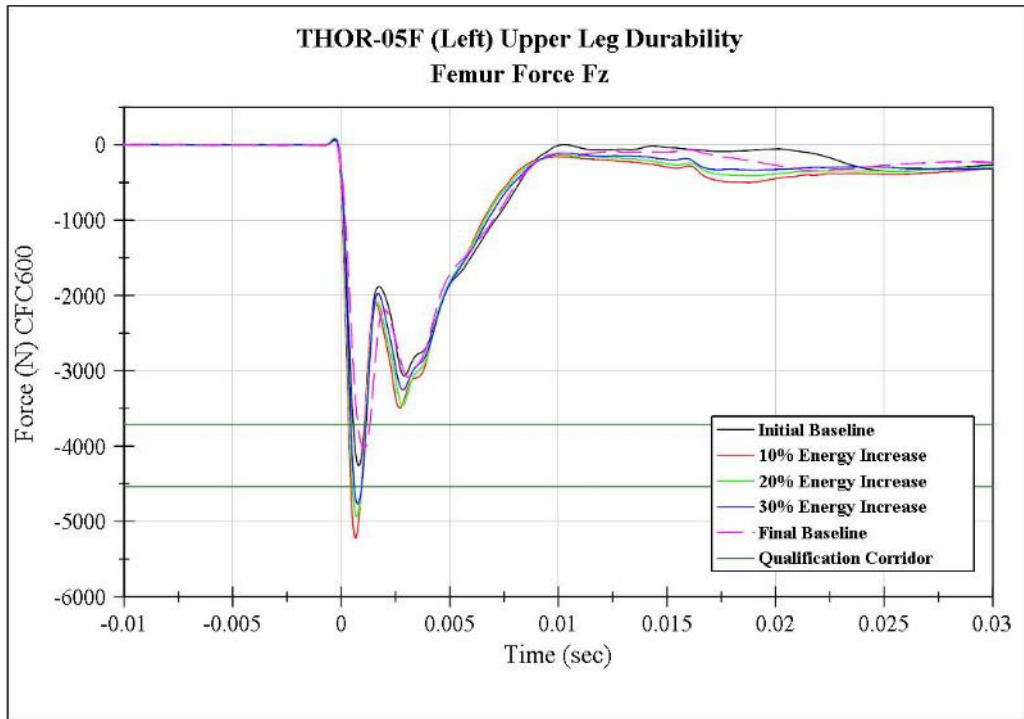


Figure 3-36. Femur force Fz in left (top) and right (bottom) upper leg durability tests

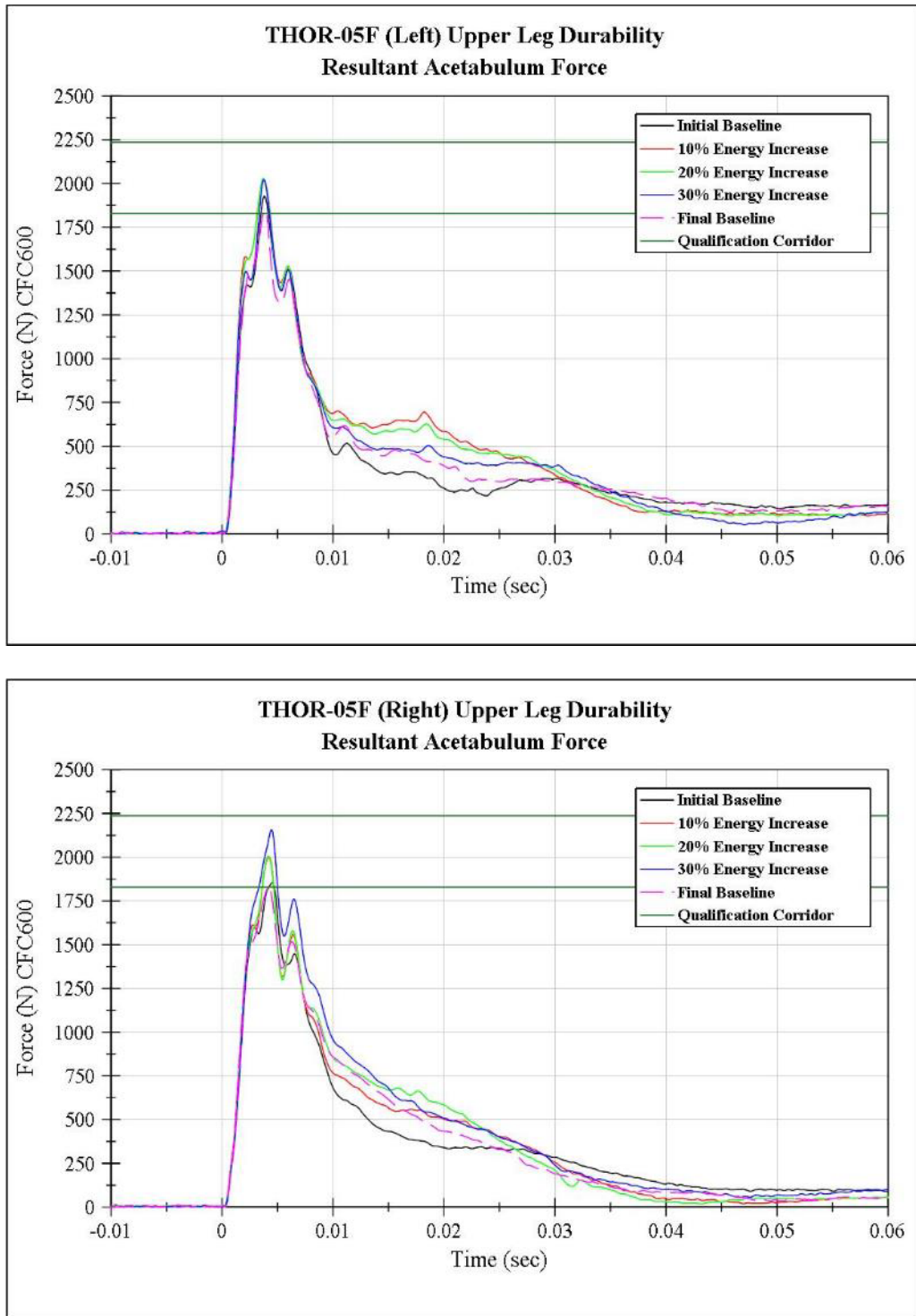


Figure 3-37. Resultant acetabulum force in left (top) and right (bottom) upper leg durability tests

3.10.3 Discussion

Both the initial and final baseline upper leg responses were within the specified qualification corridors for probe force, femur force, and resultant acetabular force, confirming that the upper leg still met qualification requirements after the increased-energy tests. No visible damage to the upper leg was observed post-test. These results indicate that the upper leg displays acceptable durability.

3.11 KNEE

3.11.1 Methodology

Knee durability tests followed the qualification procedures described in the *THOR-05F Qualification Procedures and Requirements*. This qualification test measures the anterior-posterior translation of the tibia with respect to the femur at the knee joint. A 7.26 kg impactor with a 76.2 mm diameter rigid circular impact surface impacts a load distribution bracket attached at the knee slider at 2.15 ± 0.05 m/s (Figure 3-39). For durability tests on the knee, the test energy was elevated from the qualification baseline by approximately 10, 20, and 30 percent (Table 3-36). After the three increased-energy tests, another baseline test was run to confirm that the higher-energy tests did not change the knee's baseline response. Knee slider FB5964 was used for this durability series.

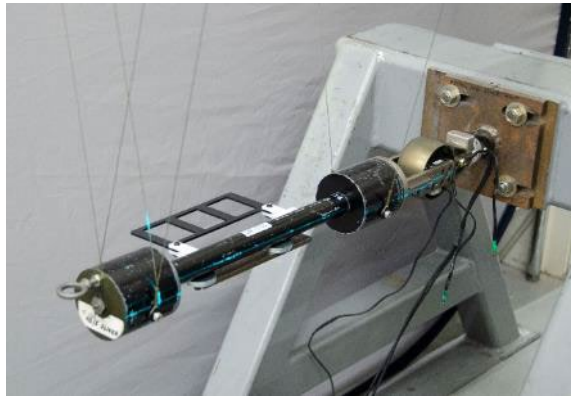


Figure 3-38. Knee slider durability test setup

Table 3-36. Target Test Velocities for Knee Slider Durability Tests

Test Severity	Target Velocity (m/s)
Initial Baseline	2.15
10% Energy Increase	2.25
20% Energy Increase	2.36
30% Energy Increase	2.45
Final Baseline	2.15

3.11.2 Results

For the baseline THOR-05F knee qualification tests, the knee slider responses must be within the ranges provided in Table 3-37. Table 3-38, along with Figure 3-42 and Figure 3-43, illustrates the durability test results along with the qualification corridors for the baseline tests.

Table 3-37. Knee Qualification Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	2.10	2.20
Minimum Femur Force F _z	N	-4,194	-3,431
Knee Deflection at Min Femur Force F _z	mm	-15.2	-12.4

Table 3-38. Knee Slider Durability Results (Knee Slider FB5964)

Date	Test Number	Test Severity	Impact Velocity (m/s)	Minimum Femur F _z (N)	Knee Deflection at Minimum Femur F _z (mm)
8/12/25	250812-2	Initial Baseline	2.17	-3,553	-13.6
8/12/25	250812-4	10% Energy Increase	2.28	-4,829	-14.3
8/12/25	250812-5	20% Energy Increase	2.37	-5,636	-14.5
8/12/25	250812-6	30% Energy Increase	2.47	-6,457	-14.6
8/12/25	250812-7	Final Baseline	2.15	-3,895	-14.0

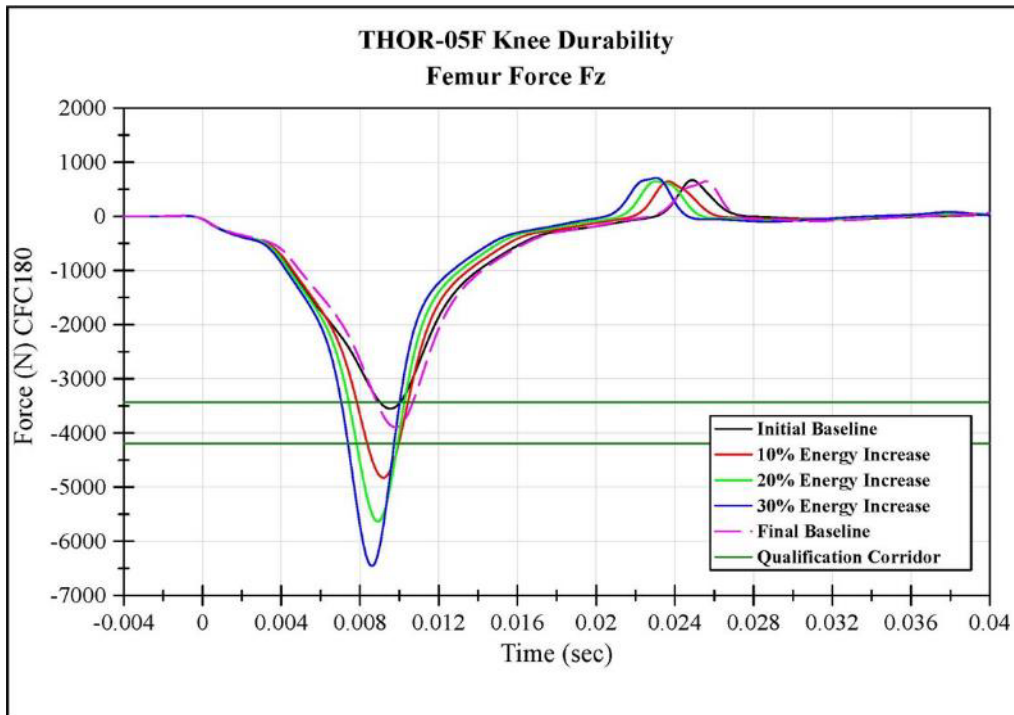


Figure 3-39. Femur Fz in knee slider durability tests

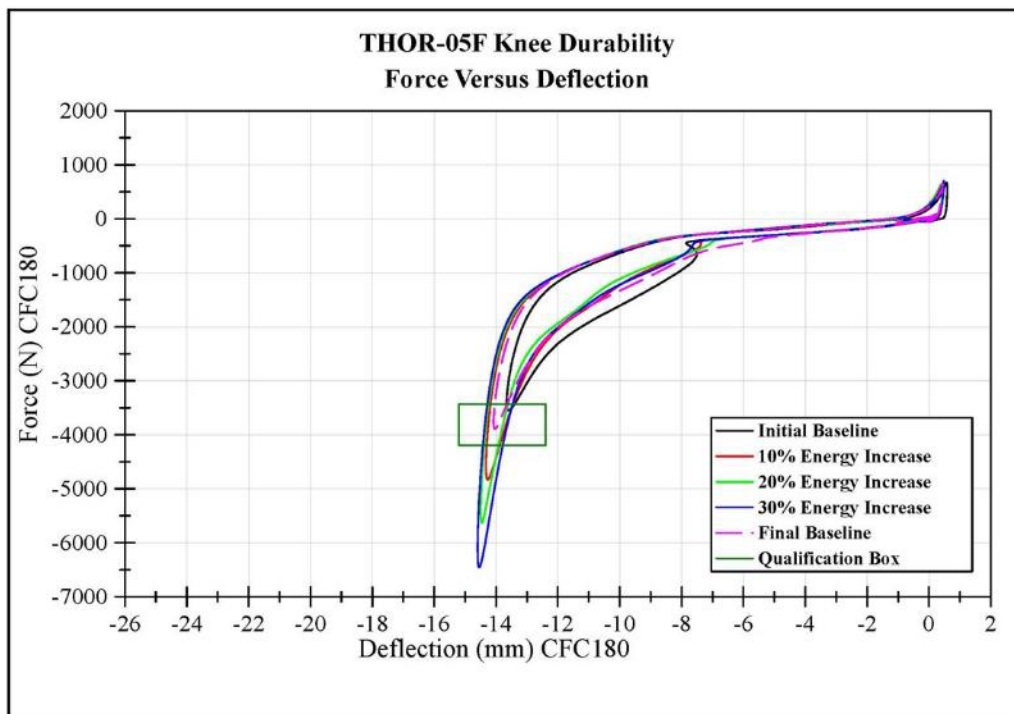


Figure 3-40. Force-deflection in knee slider durability tests

3.11.3 Discussion

Both the initial and final baseline knee responses were within the specified qualification corridors for knee deflection and femur force, confirming that the knee still met qualification requirements after the increased-energy tests. No visible damage to the knee was observed post-test. These results indicate that the knee displays acceptable durability.

3.12 ANKLE INVERSION

3.12.1 Methodology

Durability tests were performed using the ankle inversion qualification procedures described in the *THOR-05F Qualification Procedures and Requirements*. In the ankle inversion qualification test, a 3.00 kg rigid impactor contacts a padded bracket that is temporarily secured to the sole plate of the foot at 2.00 ± 0.05 m/s (Figure 3-42). The bracket is positioned so the line of impact is offset from the longitudinal axis of the tibia, resulting in inversion of the ankle assembly. For durability tests, the test energy was elevated from the qualification baseline by approximately 10, 20, and 30 percent (Table 3-39). After the three increased-energy tests, another baseline test was run to confirm that the higher-energy tests did not change the ankle's baseline response. Ankle EV2720 was used for this durability series.

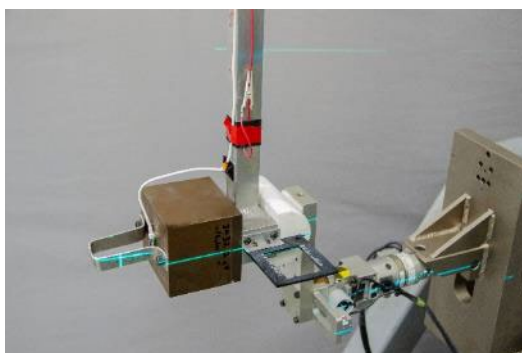


Figure 3-41. Ankle inversion durability test setup

Table 3-39. Target Test Velocities for Ankle Inversion Durability Tests

Test Severity	Target Velocity (m/s)
Initial Baseline	2.00
10% Energy Increase	2.10
20% Energy Increase	2.19
30% Energy Increase	2.28
Final Baseline	2.00

3.12.2 Results

For the baseline THOR-05F ankle inversion qualification tests, the responses must be within the ranges provided in Table 3-40. Table 3-41, along with Figure 3-43 through Figure 3-45, illustrates the durability test results along with the qualification corridors for the baseline tests.

Table 3-40. Left Ankle Inversion Qualification Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	1.95	2.05
Minimum Lower Tibia Force F_z	N	-349	-286
Minimum Ankle Moment M_x	Nm	-31.4	-25.7
Minimum Ankle Rotation Angle θ_x	deg	-30.6	-25.0

Table 3-41. Left Ankle Inversion Durability Results (Ankle EV2720)

Date	Test Number	Test Severity	Actual Velocity (m/s)	Minimum Lower Tibia F_z (N)	Minimum Ankle M_x (Nm)	Minimum Ankle θ_x (deg)
09/10/24	240910-15	Initial Baseline	2.01	-295	-28.6	-28.6
09/10/24	240910-17	10% Energy Increase	2.10	-326	-31.9	-29.5
09/11/24	240911-1	20% Energy Increase	2.19	-344	-34.0	-30.0
09/11/24	240911-4	30% Energy Increase	2.32	-395	-39.6	-31.3
09/11/24	240911-5	Final Baseline	2.00	-288	-27.7	-28.7

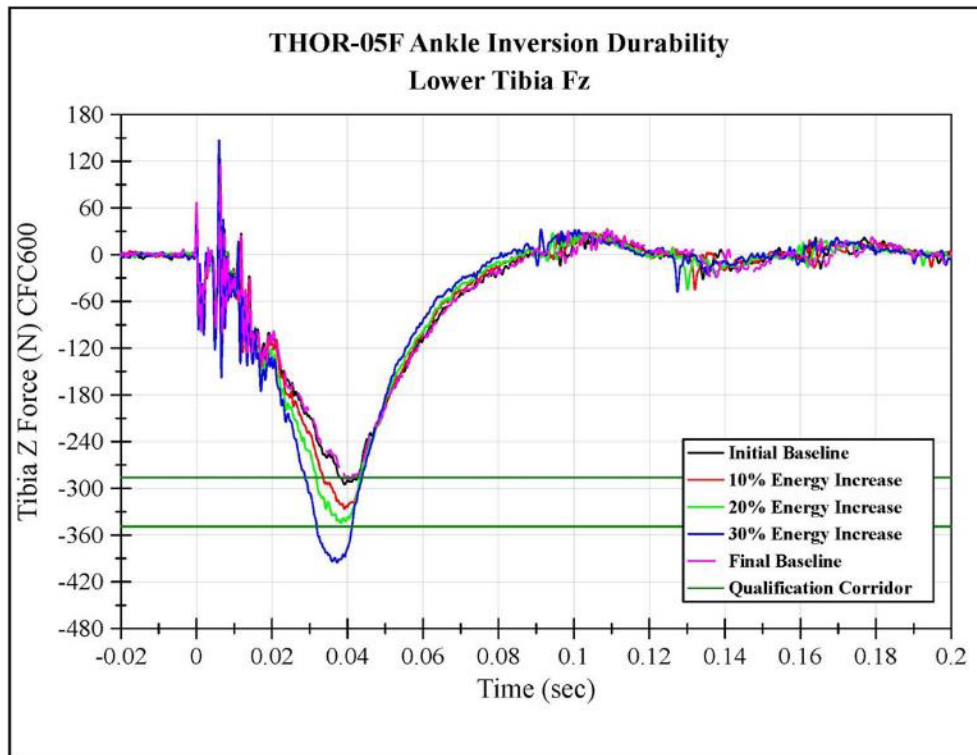


Figure 3-42. Lower tibia force Fz in foot inversion durability tests

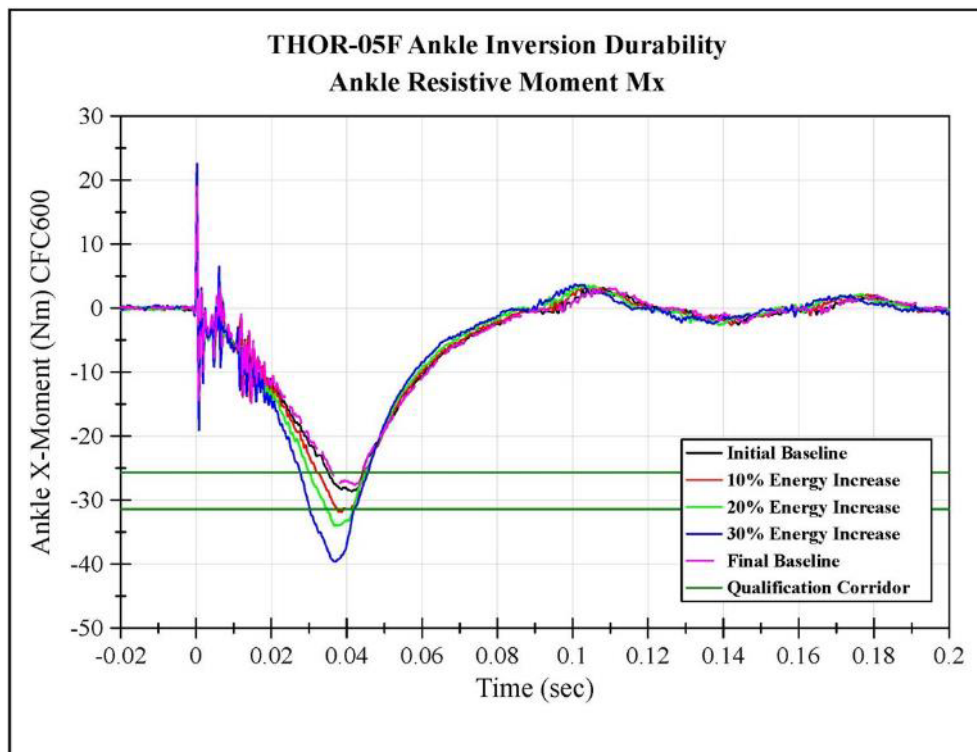


Figure 3-43. Ankle moment Mx in foot inversion durability tests

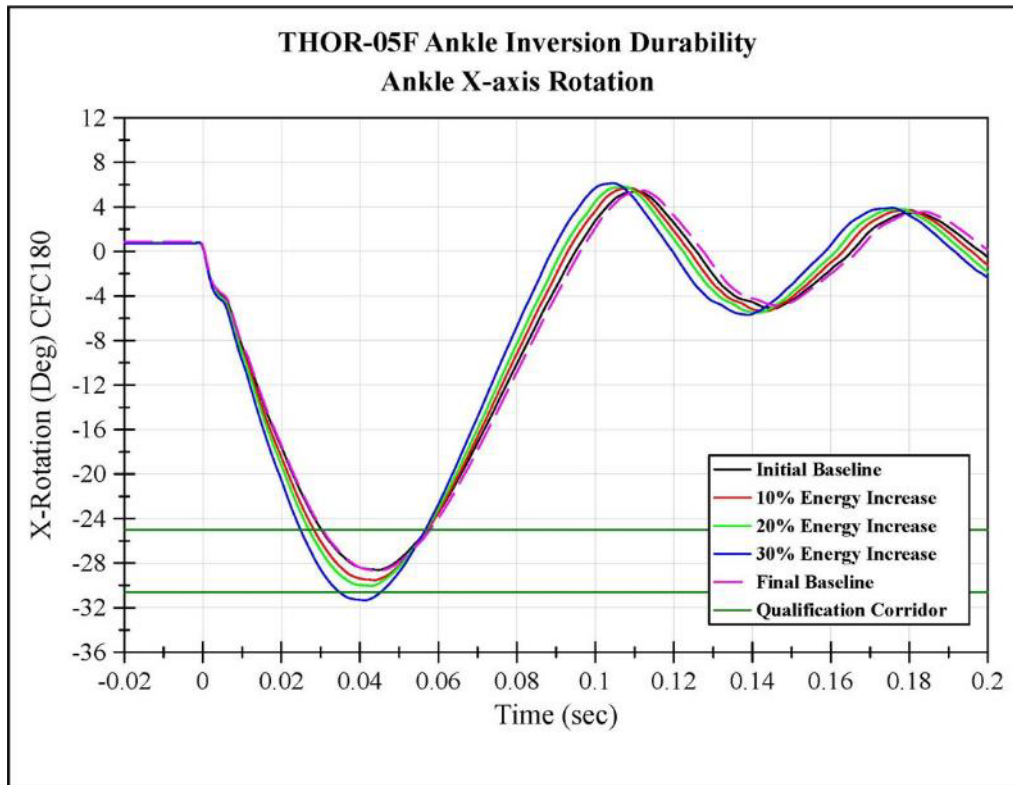


Figure 3-44. Ankle rotation angle θ_x in foot inversion durability tests

3.12.3 Discussion

Both the initial and final baseline ankle inversion responses were within the specified qualification corridors for lower tibia force, ankle moment, and ankle rotation angle, confirming that the ankle still met qualification requirements with respect to inversion after the increased-energy tests. No visible damage to the ankle was observed post-test. These results indicate that the ankle displays acceptable durability in inversion.

3.13 ANKLE EVERSION

3.13.1 Methodology

Durability tests were performed using the ankle eversion qualification procedures described in the *THOR-05F Qualification Procedures and Requirements*. In the ankle eversion qualification test, a 3.00 kg rigid impactor at 2.00 ± 0.05 m/s contacts a padded bracket that is temporarily attached to the sole plate of the foot. The bracket is positioned so the line of impact is offset from the longitudinal axis of the tibia, resulting in eversion of the ankle (Figure 3-46). For durability tests, the test energy was elevated from the qualification baseline by approximately 10, 20, and 30 percent (Table 3-42). After the three increased-energy tests, another baseline test was run to confirm that the higher-energy tests did not change the ankle's baseline response. Ankle EV2720 was used for this durability series.

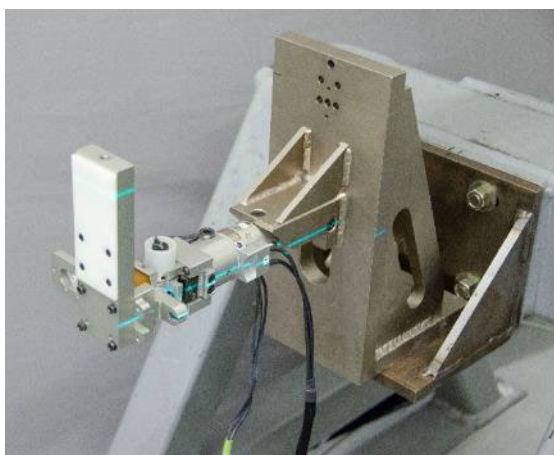


Figure 3-45. Ankle eversion durability test setup

Table 3-42. Target Test Velocities for Ankle Eversion Durability Tests

Test Severity	Target Velocity (m/s)
Initial Baseline	2.00
10% Energy Increase	2.10
20% Energy Increase	2.19
30% Energy Increase	2.28
Final Baseline	2.00

3.13.2 Results

For the baseline THOR-05F ankle eversion qualification tests, the responses must be within the ranges provided in Table 3-43. Table 3-44, along with Figure 3-47 through Figure 3-49, illustrates the durability test results along with the qualification corridors for the baseline tests.

Table 3-43. Ankle Eversion Qualification Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	1.95	2.05
Minimum Lower Tibia Fz	N	-353	-289
Maximum Ankle Moment M _x	Nm	26.2	32.0
Maximum Ankle Eversion Rotation Angle θ_x	deg	24.8	30.3

Table 3-44. Ankle Eversion Durability Results (Ankle EV2720)

Date	Test Number	Test Severity	Actual Velocity (m/s)	Minimum Lower Tibia Fz (N)	Maximum Ankle M _x (Nm)	Maximum Ankle θ_x (deg)
09/11/24	240911-12	Initial Baseline	2.01	-312	28.4	28.2
09/12/24	240912-3	10% Energy Increase	2.09	-330	30.5	28.7
09/12/24	240912-4	20% Energy Increase	2.18	-357	33.5	29.8
09/12/24	240912-5	30% Energy Increase	2.33	-399	38.6	31.0
09/12/24	240912-6	Final Baseline	2.00	-301	28.2	28.4

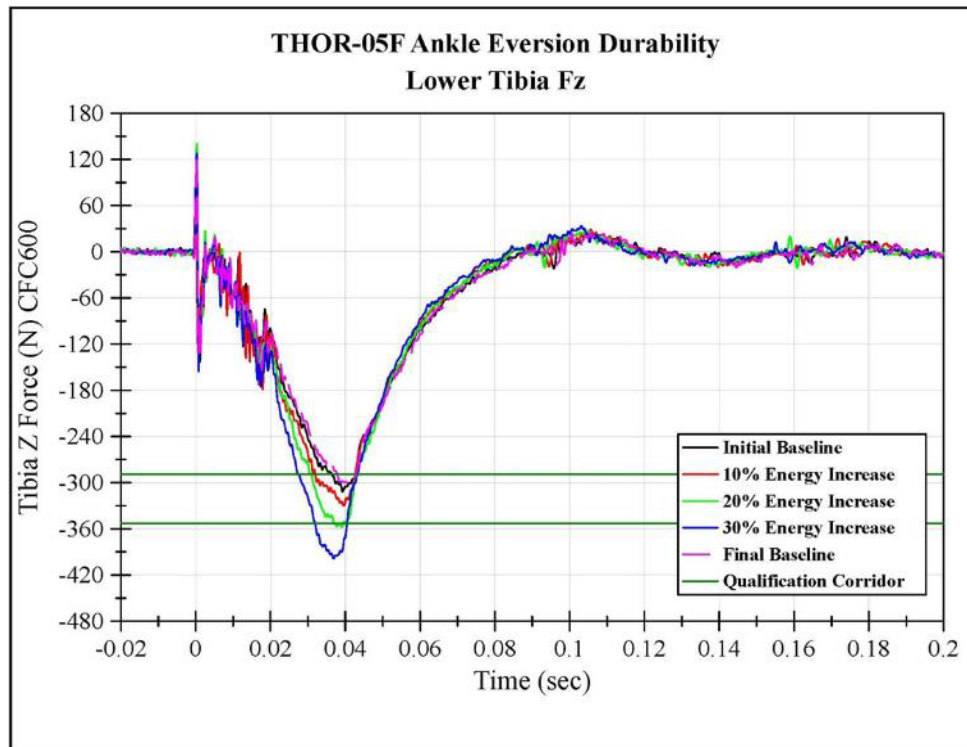


Figure 3-46. Lower tibia force Fz in ankle eversion durability tests

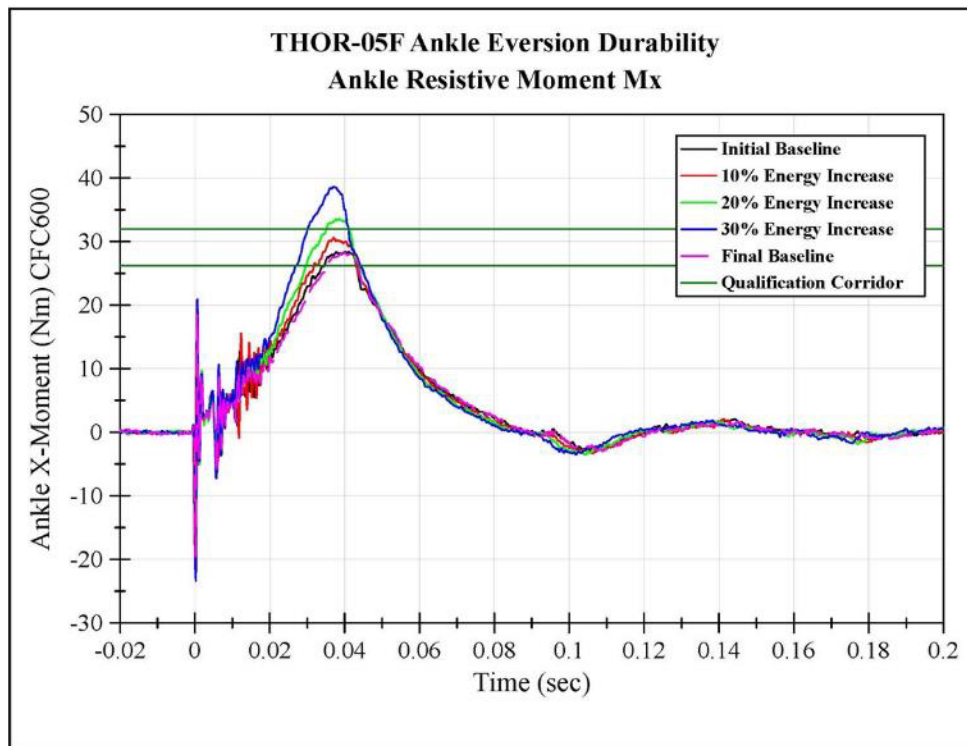


Figure 3-47. Ankle moment Mx in ankle eversion durability tests

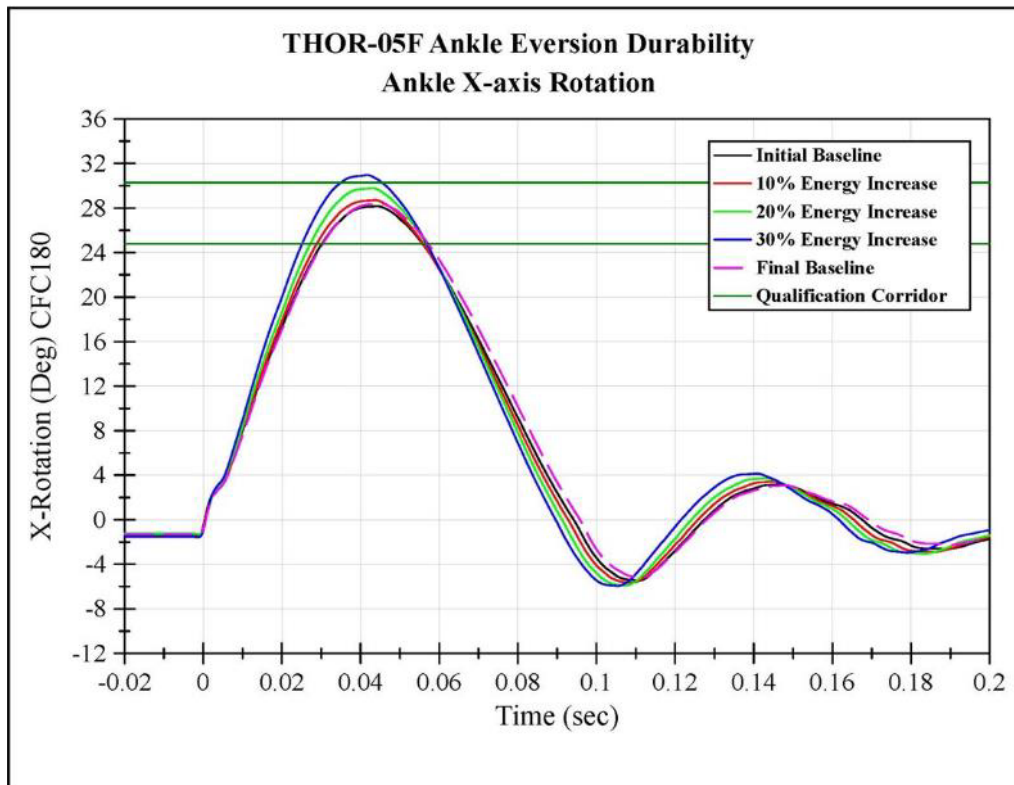


Figure 3-48. Ankle rotation angle θ_x in ankle eversion durability tests

3.13.1 Discussion

Both the initial and final baseline ankle eversion responses were within the specified qualification corridors for lower tibia force, ankle moment, and ankle rotation angle, confirming that the ankle still met qualification requirements with respect to eversion after the increased-energy tests. No visible damage to the ankle was observed post-test. These results indicate that the ankle displays acceptable durability in eversion.

3.14 BALL OF FOOT

3.14.1 Methodology

Durability tests were performed using the ball of foot impact qualification procedures described in the *THOR-05F Qualification Procedures and Requirements*. This qualification test measures the dynamic impact response of the ball of the foot. The leg is held rigidly with the tibia horizontal (Figure 3-50). The test uses the NHTSA Dynamic Impactor (TLX-9000-006, TLX-9000-007) with an effective mass of 8.52 kg. The pendulum arm is mounted to a rigid shaft that pivots on low-friction ball bearings. The impact surface is a horizontal rigid semi-cylinder 63.5 mm in diameter. The pendulum impacts the ball of the foot at a velocity of 2.00 ± 0.05 m/s in qualification tests. For durability tests, the test energy was elevated from the qualification baseline by approximately 10, 20, and 30 percent (Table 3-45). After the three increased-energy tests, another baseline test was run to confirm that the higher-energy tests did not change the foot's baseline response. Ankle EV2720 was used for this durability series.

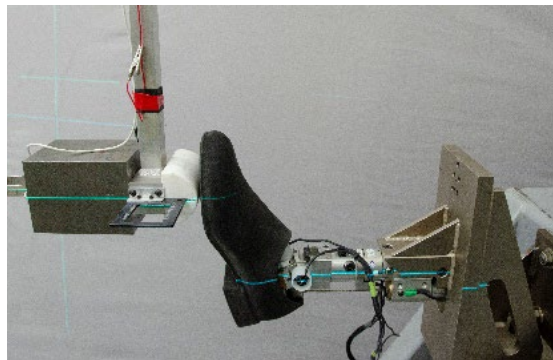


Figure 3-49. Ball of foot durability test setup

Table 3-45. Target Velocities for Ball of Foot Durability Tests

Test Severity	Target Velocity (m/s)
Initial Baseline	2.00
10% Energy Increase	2.10
20% Energy Increase	2.19
30% Energy Increase	2.28
Final Baseline	2.00

3.14.2 Results

For the baseline THOR-05F ball of foot qualification tests, the responses must be within the ranges provided in Table 3-46. Table 3-47, along with Figure 3-51 through Figure 3-53, illustrates the durability test results along with the qualification corridors for the baseline tests.

Table 3-46. Ball of Foot Qualification Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	1.95	2.05
Minimum Lower Tibia F _z after 10ms	N	-1,020	-835
Maximum Ankle Moment M _Y	Nm	42.9	52.4
Minimum Ankle Rotation Angle θ_Y	deg	30.6	37.3

Table 3-47. Ball of Foot Durability Results (Ankle EV2720)

Date	Test Number	Test Severity	Actual Velocity (m/s)	Minimum Lower Tibia F _z after 10 ms (N)	Maximum Ankle M _Y (Nm)	Minimum Ankle θ_Y (deg)
08/07/25	250807-1	Initial Baseline	1.99	-994	50.6	31.0
08/07/25	250807-2	10% Energy Increase	2.10	-1,113	60.6	32.0
08/07/25	250807-3	20% Energy Increase	2.20	-1,230	68.7	32.8
08/07/25	250807-4	30% Energy Increase	2.30	-1,327	77.3	33.5
08/07/25	250807-5	Final Baseline	1.99	-991	49.8	31.5

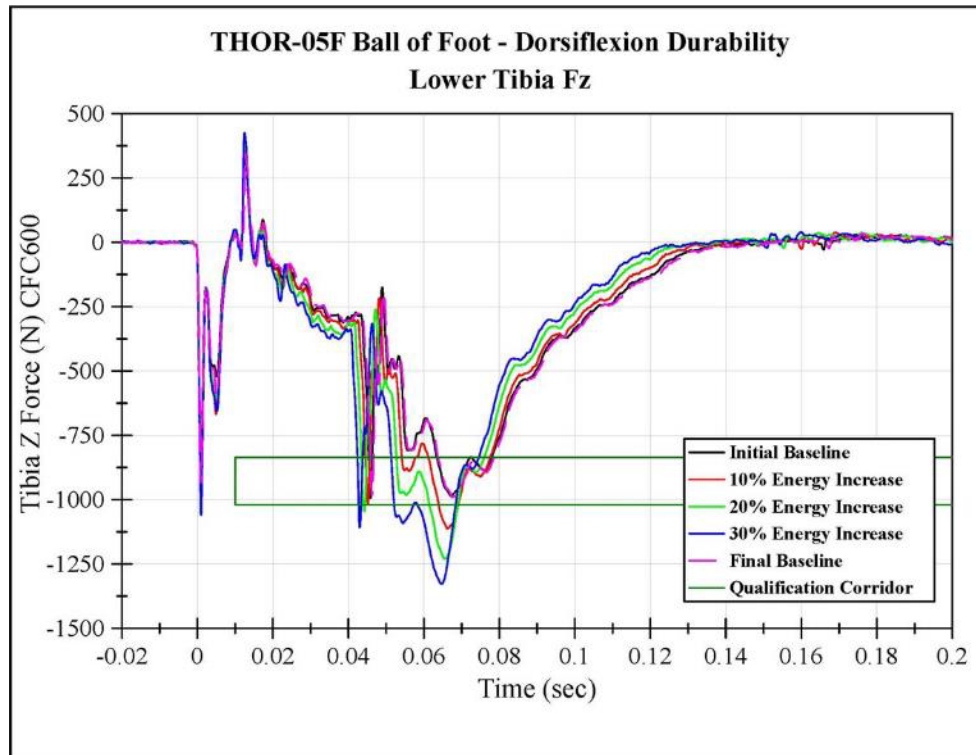


Figure 3-50. Lower tibia force Fz after 10ms for ball of foot durability tests

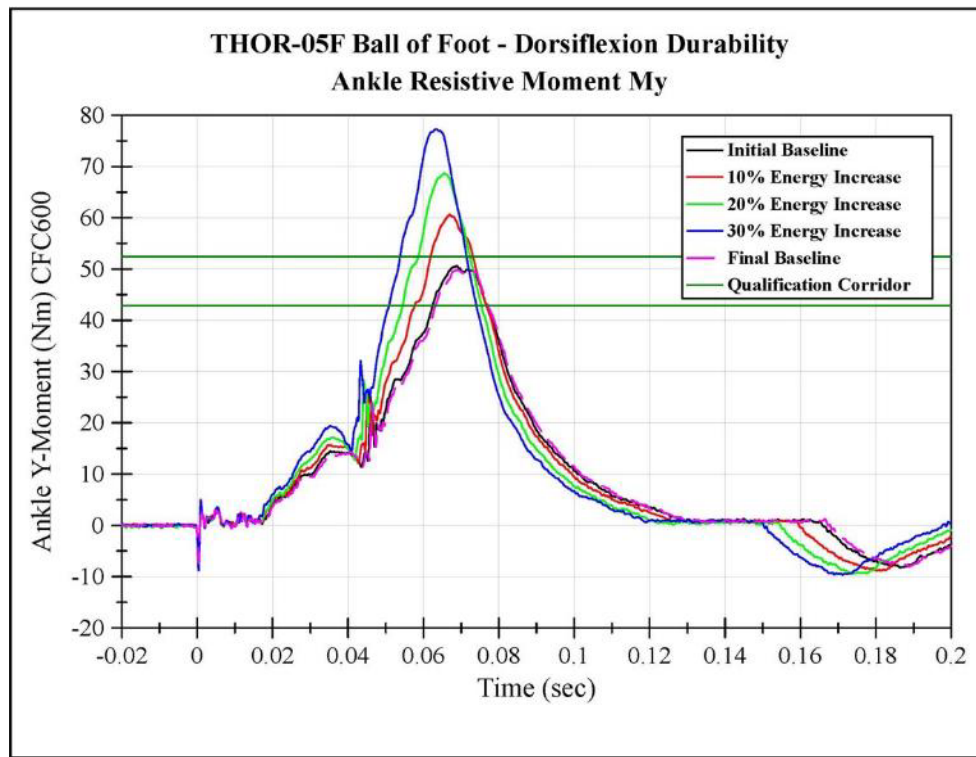


Figure 3-51. Ankle moment Mx in ball of foot durability tests

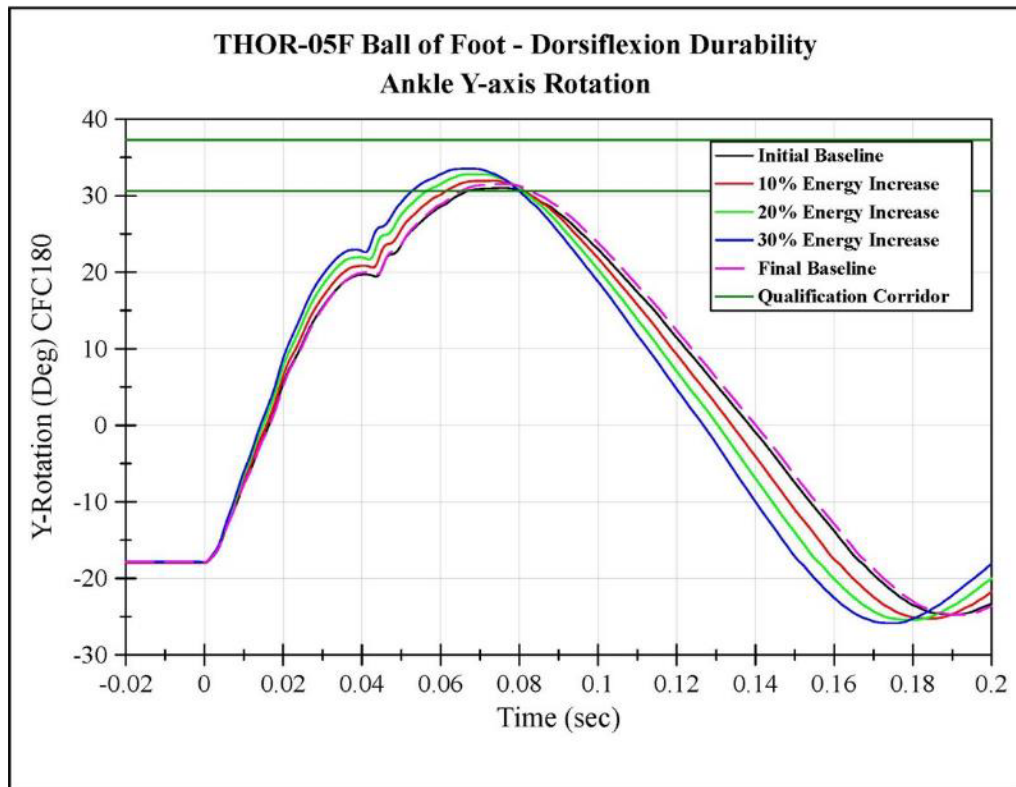


Figure 3-52. Ankle rotation angle θ_y in ball of foot durability tests

3.14.3 Discussion

Both the initial and final baseline ball of foot responses were within the specified qualification corridors for lower tibia force, ankle moment, and ankle rotation angle, confirming that the components still met qualification requirements with respect to ball of foot loading after the increased-energy tests. No visible damage to the foot or ankle was observed post-test. These results indicate that the lower extremity components displayed acceptable durability in ball of foot loading.

3.15 HEEL

3.15.1 Methodology

Durability tests were performed using the heel impact qualification procedures described in the *THOR-05F Qualification Procedures and Requirements*. This qualification test evaluates the dynamic impact response of the heel of the foot. The leg is held rigidly with the tibia horizontal (Figure 3-54). The test uses the NHTSA Dynamic Impactor (TLX-9000-007, TLX-9000-006) with an effective mass of 3.00 kg. The rigid, horizontal semi-cylinder impact surface is 63.5 mm in diameter and impacts the heel at a velocity of 4.0 ± 0.05 m/s. The test energy was elevated from the qualification baseline by approximately 10, 20, and 30 percent (Table 3-48). After the three increased-energy tests, another baseline test was run to confirm that the higher-energy tests did not change the heel's baseline response. Ankle EV2720 was used for this durability series.

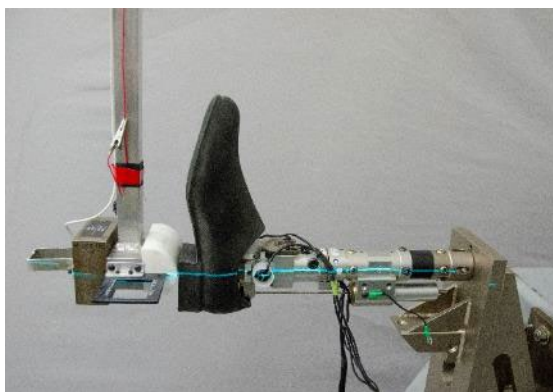


Figure 3-53. Heel durability test setup

Table 3-48. Target Velocities for Heel Durability Tests

Test Severity	Target Velocity (m/s)
Initial Baseline	4.00
10% Energy Increase	4.20
20% Energy Increase	4.38
30% Energy Increase	4.56
Final Baseline	4.00

3.15.2 Results

For the baseline THOR-05F heel qualification tests, the responses must be within the ranges provided in Table 3-49. Table 3-50, along with Figure 3-55 and Figure 3-56, illustrates the durability test results for tests conducted at increased-energy levels, along with the qualification corridors for the baseline tests.

Table 3-49. Heel Qualification Response Requirements

Parameter	Units	Specification	
		Min.	Max.
Impact Velocity	m/s	3.95	4.05
Maximum Probe Force	N	3,447	4,212
Minimum Lower Tibia Force Fz	N	-2,220	-1,816

Table 3-50. Heel Durability Results (Ankle EV2720)

Date	Test Number	Test Severity	Actual Velocity (m/s)	Maximum Probe Force (N)	Minimum Lower Tibia Fz (N)
09/12/24	240912-24	Initial Baseline	4.00	3,824	-2,054
09/12/24	240912-25	10% Energy Increase	4.22	4,065	-2,172
09/12/24	240912-28	20% Energy Increase	4.40	4,233	-2,259
09/12/24	240912-30	30% Energy Increase	4.58	4,395	-2,333
09/12/24	240912-32	Final Baseline	3.98	3,736	-1,965

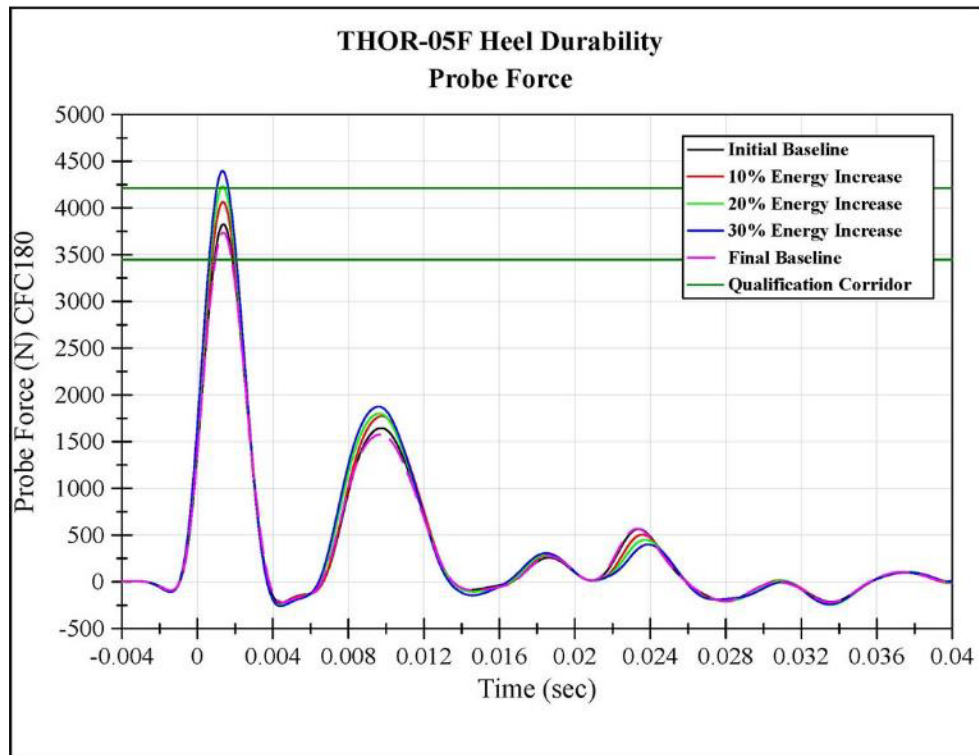


Figure 3-54. Probe force in heel durability tests

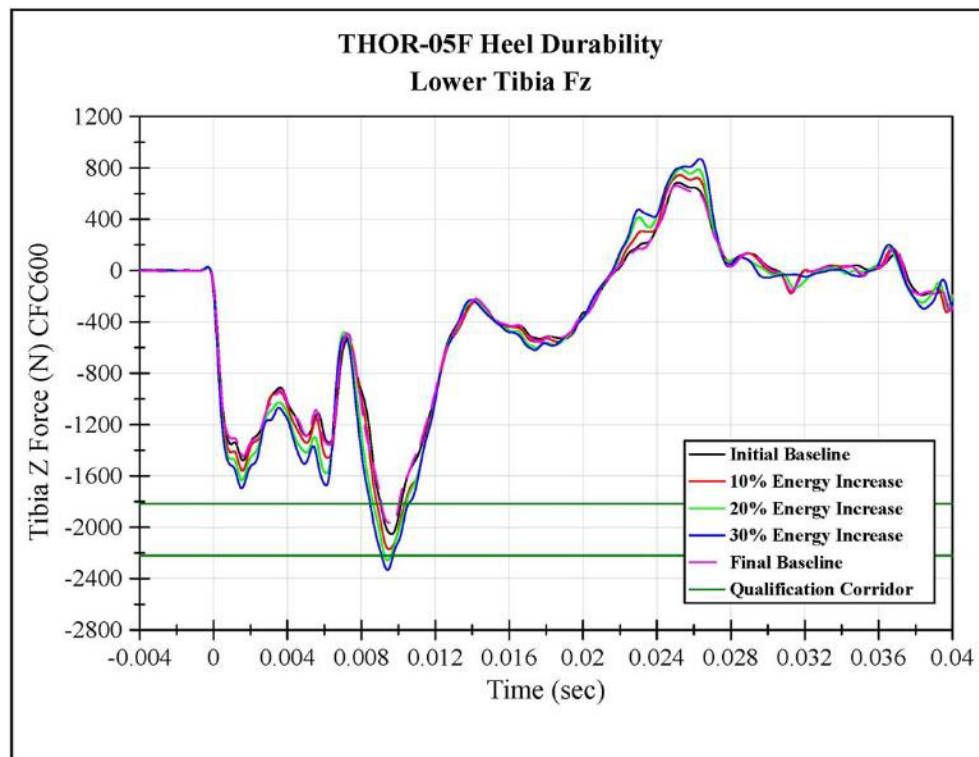


Figure 3-55. Lower tibia force Fz in heel durability tests

3.15.3 Discussion

Both the initial and final heel test responses were within the specified qualification corridors for probe force and lower tibia force, confirming that the components still met qualification requirements with respect to heel loading after the increased-energy tests. No visible damage to the tested components was observed post-test. These results indicate that the lower extremity components displayed acceptable durability in heel loading.

4 SUMMARY

Durability of the THOR-05F was assessed by conducting the test procedures specified in the *THOR-05F Qualification Procedures and Requirements* at energy levels elevated beyond the qualification test specifications. The baseline qualification tests are designed to replicate crash-level loading, so this durability test series is intended to ensure additional robustness of the ATD design. The results of each test condition were considered to show acceptable durability if a) final baseline testing confirmed that the tested components still met qualification requirements after the elevated-energy tests were conducted, and b) no damage was found in visual inspection of the parts involved in the test. Overall, the THOR-05F demonstrated acceptable durability in all qualification test conditions.

5 REFERENCES

NHTSA. (In Process). *THOR 5th Percentile Female (THOR-05F) Qualification Procedures and Requirements*.