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Third Charpy Interlaboratory Comparison Between NIST and Anand Testing Machine Services LLP

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Abstract

This document reports the results of the third Charpy Interlaboratory Comparison between NIST (National Institute of Standards and Technology, Boulder, Colorado, USA) and ATMS (Anand Testing Machine Services LLP, Kabnur, India). The first and second comparisons were run in 2022 and 2024, respectively. Each laboratory tested Charpy reference specimens that were produced and certified at different energy levels by the two institutions. Test results obtained at NIST and ATMS were compared using the same machine configuration (C-type hammer) and striker type (2 mm), and statistical methods (unpaired two-sample *t*-test) were employed to assess the significance of interlaboratory differences. Unlike the two previous comparisons, where some statistical differences were between ATMS and NIST were detected, the test results obtained in 2026 and the outcome of the corresponding statistical analyses demonstrated excellent agreement between the two institutes.

Keywords

Absorbed energy; certified Charpy reference specimens; interlaboratory comparison; unpaired two-sample *t*-test.

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1. Introduction

During the period September/October 2022, Anand Testing Machine Services LLP (ATMS, Kabnur, India) and the National Institute of Standards and Technology (NIST, Boulder, Colorado, USA) conducted a peer (interlaboratory) comparison, consisting of testing Charpy reference specimens produced and certified by both institutes at different energy levels. Charpy impact tests were conducted at room temperature (21 °C) using C-type hammers and 2 mm strikers. Additional tests were performed at NIST on a U-type machine equipped with an 8 mm striker. The activity was detailed in a NIST Technical Note [1], which also included considerations on the influence of hammer type (C-type vs. U-type) and striker type (2 mm vs 8 mm) on test results.

Between June and July 2024, a second intercomparison exercise was conducted between NIST and ATMS, following a similar pattern as the first one. The results were documented in a second NIST Technical Note [2].

In both the first and second intercomparison exercises, statistically significant differences were found between ATMS and NIST for some specimen groups.

A third peer comparison, similar to the previous two, between NIST and ATMS was proposed to Enrico Lucon (Project Leader of NIST Charpy Machine Verification Program) on January 2nd, 2026 by Mr. Shital Anandache (Quality Manager of Anand Testing Machine Services LLP). After the proposal was accepted, ATMS sent to NIST twenty certified reference specimens, ten from each of two nominal absorbed energy levels (40 J and 150 J). In turn, NIST shipped to ATMS thirty-two certified reference specimens, ten from a low-energy lot (LL-206), twelve from a high-energy lot (HH-206), and ten from a super-high energy lot (SH-73). Additionally, NIST received from ATMS twenty Quality Control (QCM) specimens of EN353, to be used for investigating the effect of Charpy striker edge radius (8 mm vs. 2 mm) on Charpy absorbed energy.

Reference and quality control specimens were tested at room temperature (20 °C – 21 °C) at both institutes during the months of January and February 2026, using Charpy machines equipped with the same hammer type (C-type) and of similar capacity (400 J for ATMS, 357 J for NIST). The C-type machine used at NIST is shown in **Figure 1**. All reference specimens (ATMS and NIST) were tested using 2 mm strikers, while the ATMS Quality Control specimens were tested with both 2 mm and 8 mm strikers in both laboratories.

This report presents a detailed comparison of test results obtained from both laboratories, and includes basic statistical analyses.

Anand Testing Machine Services LLP (ATMS) are accredited as a Reference Material Producer in accordance with ISO 17034:2016 [3]. Their Charpy specimens are produced in accordance with ISO 148-3 [4], and can be used for the indirect verification of Charpy machines according to ISO 148-2 [5].

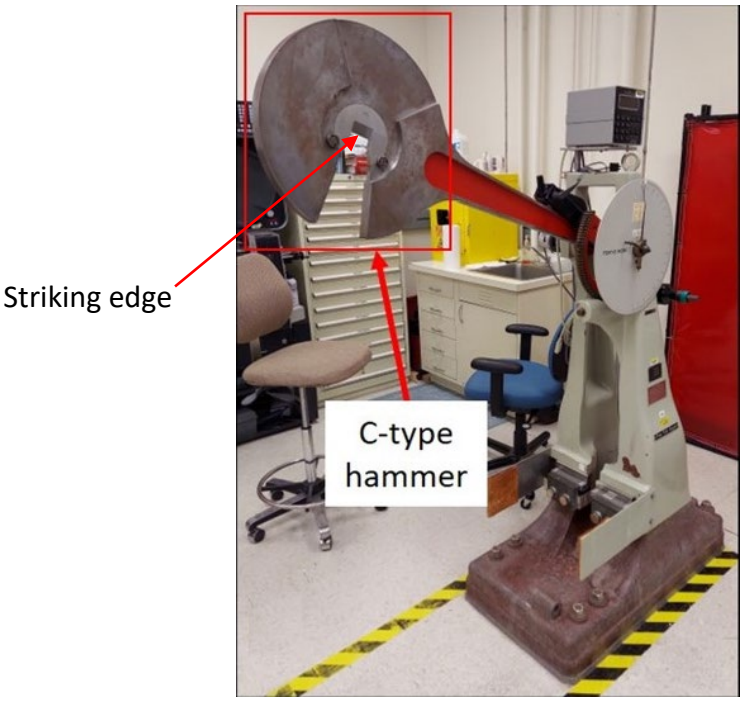

Figure 1. Charpy machine used for the tests at NIST, equipped with with a 2 mm striker.

2. Specimens and Test Matrix

The following certified reference Charpy specimens were tested in this intercomparison.

- Certified Reference Specimens produced by ATMS
  - Low-energy specimens, batch ATMS-40J-M-34 (certified absorbed energy at 20 °C with 2 mm striker: KV_R = 44.6 J).
  - High-energy specimens, batch ATMS-150J-26A-M41 (certified absorbed energy at 20 °C with 2 mm striker: KV_R = 143.6 J).
- Certified Reference Specimens produced by NIST
  - Low-energy specimens, lot LL-206 (certified absorbed energy at 21 °C with 2 mm striker: KV_R = 18.3 J).
  - High-energy specimens, lot HH-206 (reference absorbed energy at 21 °C with 2 mm striker: KV_R = 117.4 J).
  - Super-high energy specimens, lot SH-73 (reference absorbed energy at 21 °C with 2 mm striker: KV_R = 212.2 J).
- Quality Control Specimens produced by ATMS: Batch G-120.

For each of the certified reference lots/batches listed above, ten specimens were tested by each institute at 21 °C, with the exception of HH-206 (twelve tests at each location).

For the Quality Control specimens, ten specimens per lab were tested with 2 mm strikers, and the same number with 8 mm strikers.

The test matrix of this interlaboratory comparison is shown in **Table 1**. Overall, 144 room temperature Charpy impact tests were performed (72 at ATMS and 72 at NIST).

Table 1. Test matrix for the third interlaboratory comparison between ATMS and NIST.

Specimen producer	Testing institute	Lot/batch id	Type of specimen	Type of striker	Number of specimens tested
ATMS	NIST	M-34	Reference	2 mm	10
		26A-M41			10
	ATMS	M-34	Reference	2 mm	10
		26A-M41			10
	NIST	G-120	Quality Control	2 mm	10
				8 mm	10
	ATMS	G-120	Quality Control	2 mm	10
				8 mm	10
NIST	NIST	LL-206	Reference	2 mm	10
		HH-206			12
		SH-73			10
	ATMS	LL-206	Reference	2 mm	10
		HH-206			12
		SH-73			10

3. Tests Performed at ATMS in Kabnur (India)

3.1. Tests on NIST Reference Specimens

Three sets of ten specimens from LL-206 (low energy), twelve specimens from HH-206 (high energy), and ten specimens from SH-73 (super-high energy) were tested on January 30th, 2026. The Charpy machine used (ITM-2) had a capacity of 400 J and was equipped with a C-type hammer and a 2 mm striker.

Before testing, ATMS dimensionally checked all NIST reference specimens for compliance with ASTM E23-25 [6]. The measurements are collected in Appendix A, and were all found to be acceptable, with one exception (super-high energy specimen #65). This specimen was also tested, and its absorbed energy was consistent with the results obtained from the remaining samples (**Table 2**).

The values of absorbed energy obtained are provided in **Table 2**. The detailed test reports are reproduced in Appendix B.

Table 2. Results of the Charpy tests performed at ATMS on NIST reference specimens. The result highlighted in yellow corresponds to the only dimensionally non-compliant specimen (#65, see Appendix A).

Specimen Lot	*KV* (J)	Specimen Lot	*KV* (J)	Specimen Lot	*KV* (J)
LL-206	17.6	**HH-206**	116.0	**SH-73**	204.0
	18.0		122.0		202.0
	18.0		120.0		202.4
	18.4		110.0		206.0
	Jammed		113.2		208.0
	17.6		122.4		200.0
	18.0		122.8		205.6
	18.4		124.0		200.0
	17.6		114.4		206.4
	18.4		109.6		198.4
			113.2		
			113.2		
$\overline{KV}$ (J)	**18.0**		**116.7**		**203.3**
SD (J)	**0.35**		**5.22**		**3.22**
CV	**1.9 %**		**4.5%**		**1.6 %**
KV_R (J)	**18.3**		**118.5**		**212.2**
$\lvert\Delta KV\rvert$ (J or %)	**0.3**		**1.5 %**		**4.4 %**
Repeatability (J or %)	**0.8**		**12.2 %**		**4.5 %**

Legend

KV = absorbed energy; $\overline{KV}$ = mean absorbed energy; SD = standard deviation; CV = coefficient of variation, $\frac{\mathrm{SD}}{\overline{KV}}$; KV_R = reference absorbed energy (certified value); $|\Delta KV|$ = absolute difference between $\overline{KV}$ and KV_R (absolute or relative to KV_R); repeatability = difference between largest and smallest test result (absolute or relative to KV_R).

At all energy levels, the average absorbed energy reported by ATMS was within the larger of 1.4 J and 5 % of KV_R (ASTM E23 requirement), as well as within the larger of 4 J and 10 % of KV_R (ISO 148-2 requirement), with respect to the corresponding NIST certified values.

The repeatability of the test results was also acceptable at all energy levels according to ISO 148-2 (within the larger of 6 J and 15 % of KV_R).

One of the tested low-energy specimens experienced jamming, and the corresponding value of absorbed energy was removed from the results and subsequent analyses.

3.2. Tests on ATMS Reference Specimens

Two sets of ten specimens from batches M-34 and 26A-M41 were tested on January 30th, 2026, using the same C-type machine (Anand make) and striker (2 mm) mentioned above.

The values of absorbed energy obtained are provided in **Table 3**. The detailed test reports are reproduced in Appendix C.

Table 3. Results of the Charpy tests performed at ATMS on ATMS reference specimens.

Specimen Lot	*KV* (J)	Specimen Lot	*KV* (J)
M-34	47.4	**26A-M41**	134.8
	44.8		133.2
	44.4		133.2
	42.8		138.4
	44.4		137.6
	44.0		144.4
	48.8		144.0
	46.4		146.4
	46.0		138.8
	43.6		136.0
$\overline{KV}$ (J)	**45.3**		**138.7**
SD (J)	**1.86**		**4.76**
CV	**4.1 %**		**3.4 %**
KV_R (J)	**44.6**		**143.6**
$\lvert\Delta KV\rvert$	**1.5 %**		**3.4 %**
Repeatability	**13.5 %**		**9.2 %**

For both M-34 and 26A-M41, the average absorbed energy was within the larger of 4 J and 10 % of KV_R (ISO 148-2 requirement) with respect to the reference values. The repeatability also fulfilled the requirements of ISO 148-2 (lower than the larger of 6 J and 15 % of KV_R). The deviations between mean and reference values would also be acceptable as per ASTM E23 for both M-34 and 26A-M41.

3.3. Tests on ATMS Quality Control Specimens

Two sets of ten specimens from Quality Control batch G-120 were tested on January 30th, 2026, using the ITM-2 C-type machine (ITM-2). One set was tested with a 2 mm striker, and one with an 8 mm striker.

The values of absorbed energy obtained are provided in **Table 4**. The detailed test reports are reproduced in Appendix D.

Table 4. Results of the Charpy tests performed at ATMS on ATMS Quality Control specimens.

Specimen batch	**Striker type**	***KV* (J)**	**Striker type**	***KV* (J)**
G-120	2 mm	115.6	8 mm	84.4
		121.6		88.0
		120.0		86.4
		117.2		87.2
		110.0		81.2
		112.4		77.6
		112.0		89.2
		120.4		88.4
		115.6		99.6
		108.4		84.0
$\overline{KV}$ (J)		**115.3**		**86.6**
SD (J)		**4.55**		**5.80**
CV		**3.9 %**		**6.7 %**
KV_R (J)		**113.6**		**113.6**
$\lvert\Delta KV\rvert$		**1.5 %**		**23.8 %**
Repeatability		**11.6 %**		**19.4 %**

An obvious influence of striker type on absorbed energy can be remarked in Table 4, with the 2 mm striker yielding significantly higher absorbed energy ($\overline{KV}_{2mm} - \overline{KV}_{8mm}$ = 28.7 J). This was eventually confirmed by the statistical analyses detailed in 5.3.

4. Tests Performed at NIST in Boulder (Colorado, US)

4.1. Tests on NIST Reference Specimens

Three sets of ten specimens from LL-206 (low energy), twelve specimens from HH-206 (high energy), and ten specimens from SH-73 (super-high energy) were tested on January 14th, 2026. The Charpy machine used (Tokyo-Koki) had a capacity of 357 J and was equipped with a C-type hammer and a 2 mm striker.

The values of absorbed energy obtained are provided in Table 5, with associated statistical parameters.

At all energy levels, the average absorbed energy reported obtained by NIST was within the larger of 1.4 J and 5 % of KV_R (ASTM E23 requirement), as well as within the larger of 4 J and 10 % of KV_R (ISO 148-2 requirement), with respect to the corresponding NIST certified values. The repeatability of the test results was also acceptable at all energy levels according to ISO 148-2 (within the larger of 6 J and 15 % of KV_R).

Table 5. Results of the Charpy tests performed at NIST on NIST reference specimens.

Specimen Lot	*KV* (J)	Specimen Lot	*KV* (J)	Specimen Lot	*KV* (J)
LL-206	16.3	**HH-206**	112.1	**SH-73**	200.5
	17.6		112.7		201.8
	18.4		120.0		204.3
	17.1		113.8		205.9
	18.2		113.5		204.3
	16.3		117.0		202.3
	17.9		119.5		200.6
	16.4		107.2		205.3
	18.2		110.9		203.9
	18.3		119.1		202.8
			122.3		
			115.9		
$\overline{KV}$ (J)	**17.5**		**115.3**		**203.2**
SD (J)	**0.87**		**4.41**		**1.87**
CV	**5.0 %**		**3.8 %**		**0.9 %**
KV_R (J)	**18.3**		**118.5**		**212.2**
$\lvert\Delta KV\rvert$ (J or %)	**0.8**		**2.7 %**		**4.4 %**
Repeatability (J or %)	**2.1**		**12.7 %**		**2.5 %**

4.2. Tests on ATMS Reference Specimens

Two sets of ten specimens from batches M-34 and 26A-M41 were tested on February 30th, 2026, using the same C-type machine (Tokyo-Koki) and striker (2 mm) mentioned above. The specimens were dimensionally checked, and all dimensions satisfy the requirements of ISO 148-2 (Appendix E).

The values of absorbed energy obtained are provided in Table 6, with associated statistical parameters.

Table 6. Results of the Charpy tests performed at NIST on ATMS reference specimens.

Specimen Lot	*KV* (J)	Specimen Lot	*KV* (J)
M-34	44.7	**26A-M41**	134.3
	46.7		137.4
	47.8		143.9
	45.6		135.1
	42.9		132.6
	46.9		136.3
	46.4		141.0
	43.4		136.5
	43.2		144.5
	45.0		140.5
$\overline{KV}$ (J)	**45.2**		**138.2**
SD (J)	**1.71**		**4.08**
CV	**3.8 %**		**2.9 %**
KV_R (J)	**44.6**		**143.6**
$\lvert\Delta KV\rvert$	**1.5 %**		**3.7 %**
Repeatability	**11.1 %**		**8.3 %**

For both specimen batches, the average absorbed energy is within the larger of 4 J and 10 % of KV_R (ISO 148-2 requirement) with respect to the reference values. The repeatability also fulfilled the requirements of ISO 148-2 (lower than the larger of 6 J and 15 % of KV_R). The deviations between mean and reference values would also be acceptable as per ASTM E23 for both M-34 and 26A-M41.

4.3. Tests on ATMS Quality Control Specimens

Two sets of ten specimens from Quality Control batch G-120 were tested on February 6th, 2026, using the Tokyo-Koki C-type machine. One set was tested with a 2 mm striker and one with an 8 mm striker.

The values of absorbed energy obtained are provided in Table 7, with associated statistical parameters. An apparent outlier (highlighted in yellow in Table 7) was recorded, and could not be explained.

A significant influence of striker type can be observed on the test results reported in Table 7, with the 2 mm striker yielding significantly higher absorbed energy ($\overline{KV}_{2mm} - \overline{KV}_{8mm}$ = 23.8 J). If the apparent outlier is excluded, the difference between mean absorbed energies (26.7 J) is closer to that recorded by ATMS (28.7 J).

Table 7. Results of the Charpy tests performed at NIST on ATMS Quality Control specimens.

Specimen batch	Striker type	*KV* (J)	Striker type	*KV* (J)
G-120	2 mm	106.5	8 mm	79.3
		109.7		84.0
		105.0		93.2
		109.6		76.9
		111.8		79.1
		106.6		78.4
		115.2		73.1
		79.6		92.9
		105.0		74.7
		107.8		87.8
$\overline{KV}$ (J)		**105.7**		**81.9**
SD (J)		**9.68**		**7.21**
CV		**9.2 %**		**8.8 %**
KV_R (J)		**113.6**		**113.6**
$\lvert\Delta KV\rvert$		**7.0 %**		**27.9 %**
Repeatability		**31.3 %**		**17.7 %**

5. Statistical Comparisons Between ATMS and NIST Test Results

5.1. NIST Reference Specimens

The results obtained at ATMS on specimens from lots LL-206, HH-206, and SH-73 (Table 2) were statistically compared to the absorbed energy values obtained at NIST on the same three lots. Average values of absorbed energy and corresponding standard deviations are summarized in Table 8 for the three lots and the two institutes. Absorbed energy values are also illustrated in the form of box-and-whiskers plots[1] in Figure 2 (LL-206), Figure 5 (HH-206), and Figure 6 (SH-73).

Table 8. Sample sizes, means, and standard deviations for ATMS and NIST tests on NIST reference specimens.

Institute	LL-206			HH-206			SH-73		
	N	$\overline{KV}$ (J)	SD (J)	*N*	$\overline{KV}$ (J)	SD (J)	*N*	$\overline{KV}$ (J)	SD (J)
ATMS	10	18.0	0.35	12	116.7	5.22	10	203.3	3.22
NIST	10	17.5	0.87	12	115.3	4.41	10	203.2	1.87

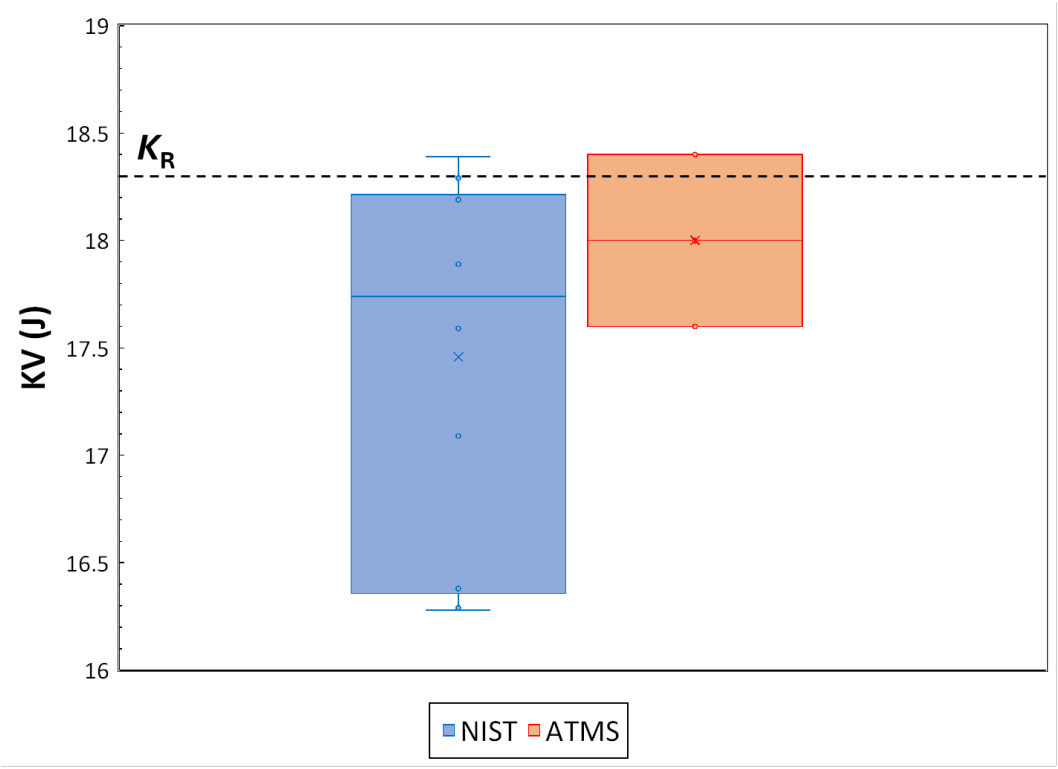

Figure 2 – Comparison between ATMS and NIST test results on LL-206 specimens.

[1] The bottom and top edges of the boxes respectively indicate the 25th and 75th percentiles. The whiskers (when visible) extend to the most extreme data points not considered outliers. An outlier is defined as a value that exceeds three scaled median absolute deviations from the median.

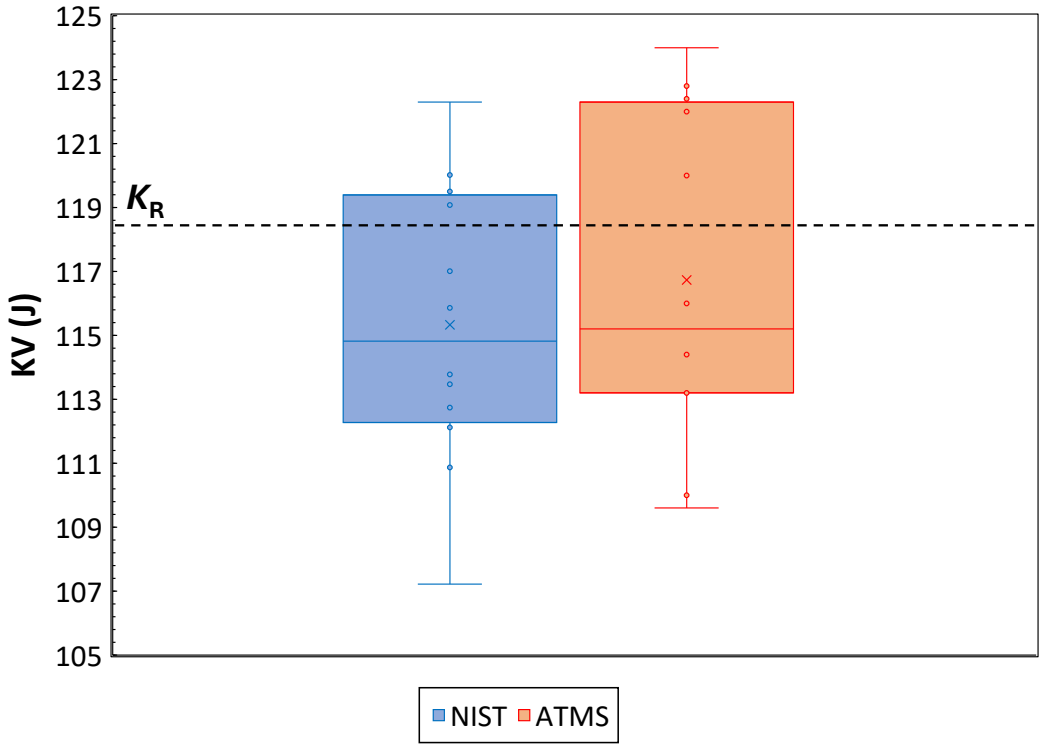

Figure 3 - Comparison between ATMS and NIST test results on HH-206 specimens.

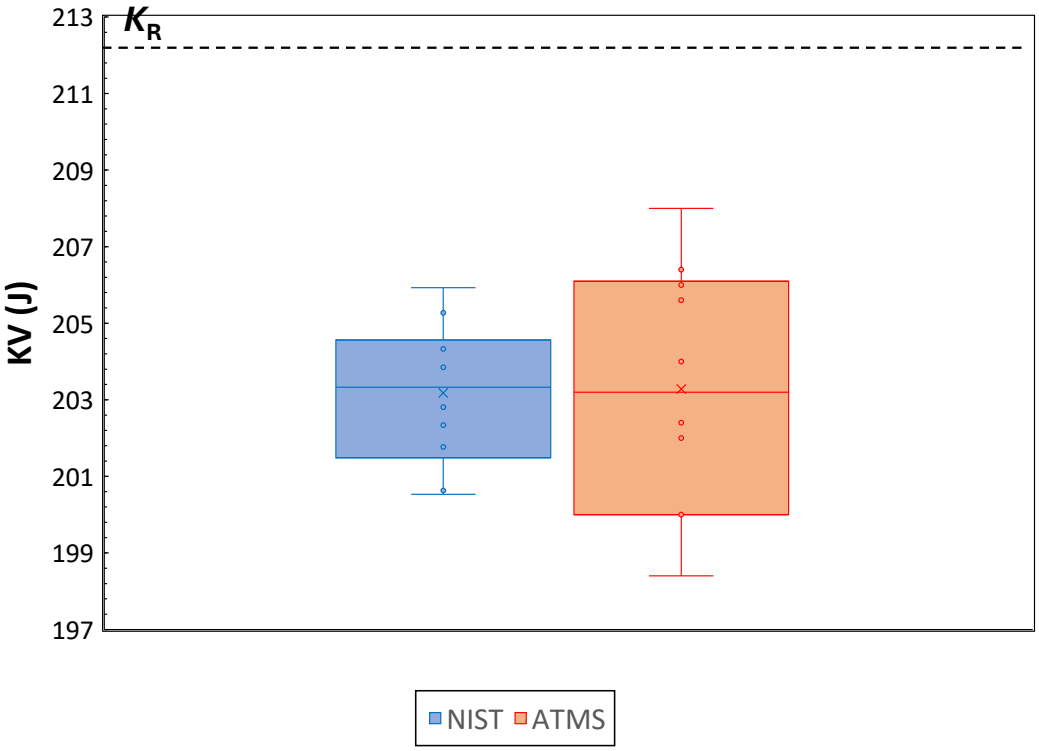

Figure 4 - Comparison between ATMS and NIST test results on SH-73 specimens.

Statistical comparisons consisted of running unpaired two-sample *t*-tests on mean values and standard deviations. The tests assumed equal or unequal variances for the samples, based on the outcome of two-sample *F*-tests for variances. For the data in Table 8, the calculated *p*-values for the *t*-tests and their interpretation are shown in Table 9. The difference between the means is considered statistically significant if $p < 0.05$.

Table 9. Calculated probability values from *t*-tests for the Charpy tests on NIST reference specimens.

Specimen lot	Equal/unequal variances	*t*-test *p-value*	Interpretation
LL-206	Unequal	0.0957	Difference between means is not significant
HH-206	Equal	0.4845	Difference between means is not significant
SH-73	Equal	0.9325	Difference between means is not significant

Based on the calculated *p*-values, differences between mean absorbed energies obtained by ATMS and NIST on NIST reference specimens are not statistically different at all three energy levels.

This outcome is more favorable than the statistical results that emerged from the first [1] and second [2] ATMS/NIST intercomparisons, when differences between means were found statistically significant at the low-energy level (first intercomparison) and at both low- and super-high energy level (second intercomparison).

5.2. ATMS Reference Specimens

The results obtained on specimens from batches M-34 and 26A-M41 at ATMS (January 30th, 2026 – Table 3)and at NIST (February 6th, 2026 – Table 6) were statistically compared.

Average values of absorbed energy and corresponding standard deviations are summarized in Table 10 for the two batches and the two institutes. Absorbed energy values are also illustrated in the form of box-and-whiskers plots in Figure 5 (M-34) and Figure 6 (26A-M41).

Table 10. Sample sizes, means, and standard deviations for ATMS and NIST tests on ATMS reference specimens.

Institute	M-34			26A-M41		
	N	$\overline{KV}$ **(J)**	**SD (J)**	***N***	$\overline{KV}$ **(J)**	**SD (J)**
ATMS	10	45.3	1.86	10	138.7	4.76
NIST	10	45.2	1.71	10	138.2	4.08

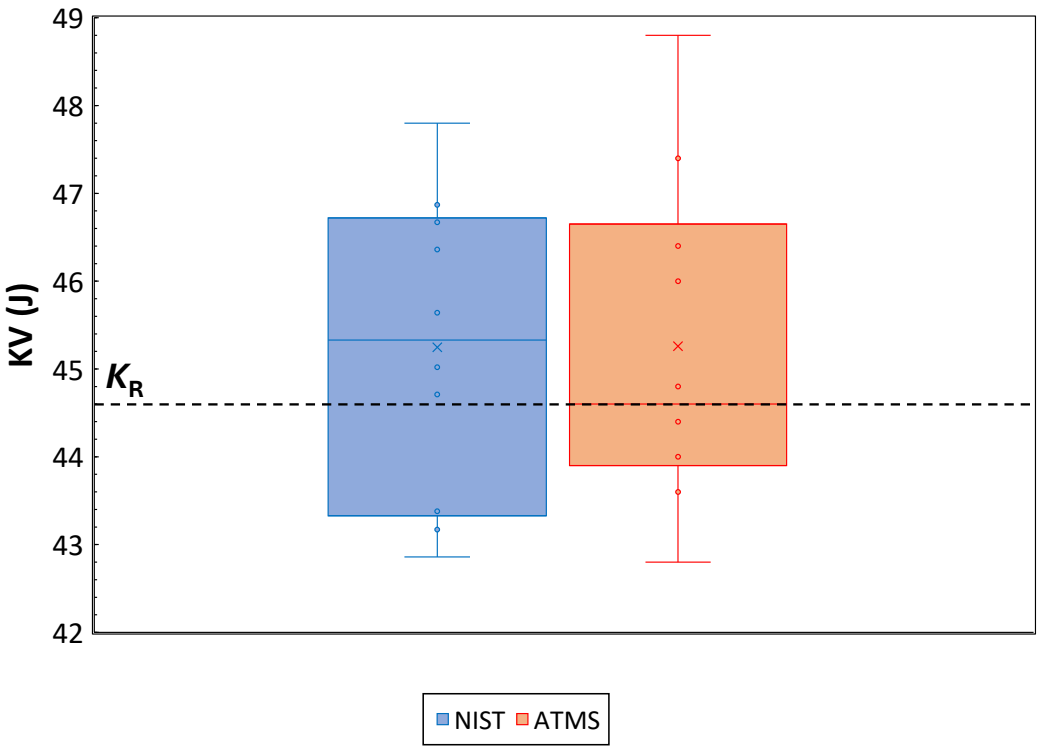

Figure 5 – Comparison between ATMS and NIST test results on M-34 specimens.

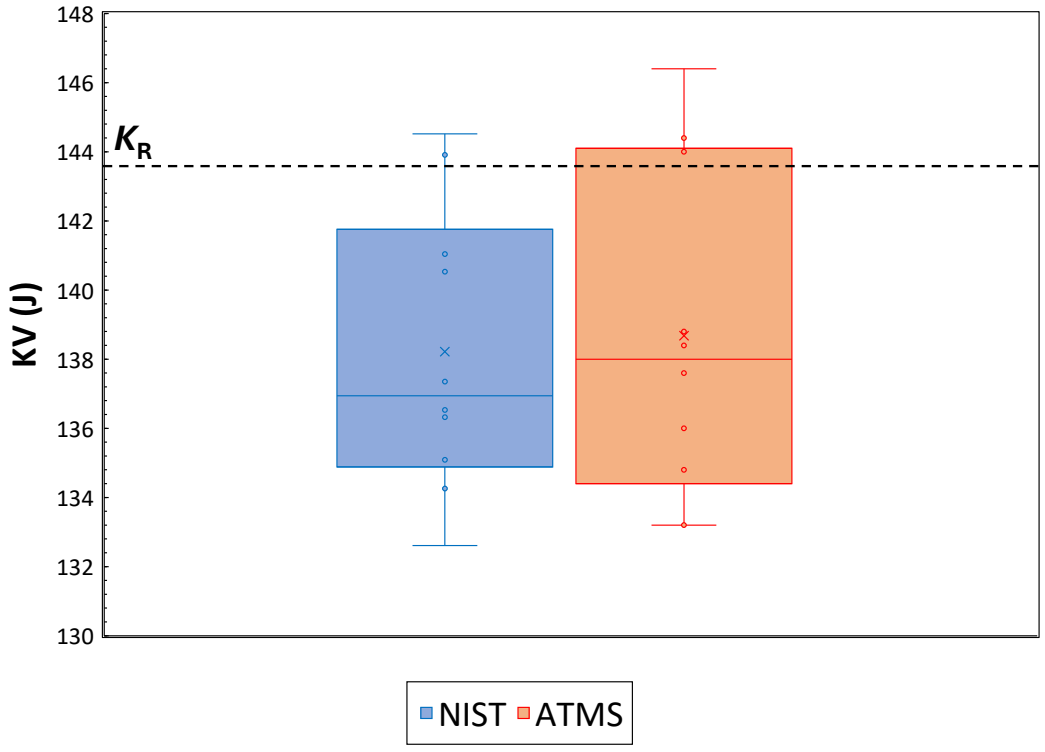

Figure 6 – Comparison between ATMS and NIST test results on 26A-M41 specimens.

Statistical comparisons were performed by means of unpaired two-sample *t*-tests on mean values and standard deviations. The tests assumed equal or unequal variances for the samples, based on the outcome of two-sample *F*-tests for variances. For the data in Table 10, the calculated *p*-values for the *t*-tests and their interpretation are provided in Table 11.

Table 11. Calculated probability values from *t*-tests for the Charpy tests on NIST reference specimens.

Specimen lot	Equal/unequal variances	*t*-test *p-value*	Interpretation
M-34	Equal	0.9882	Difference between means is not significant
26A-M41	Equal	0.8176	Difference between means is not significant

Based on the calculated *p*-values, differences between mean absorbed energies obtained by ATMS and NIST on ATMS reference specimens are not statistically different at both energy levels.

This outcome is similar to the one from the second [2] ATMS/NIST intercomparison (no statistical differences at both energy levels), but different from the outcome of the first intercomparison [1], where results at the lower energy (60 J) were found to be statistically different.

5.3. ATMS Quality Control Specimens

ATMS provided NIST with twenty Quality Control specimens (batch G120), to be tested with the same C-type machine used for testing reference specimens, ten with a 2 mm striker and ten with an 8 mm striker. Tests were conducted at NIST on February 6th, 2026 (2 mm striker) and February 8th, 2026 (8 mm striker). The same number of tests were performed at ATMS on January 30th, 2026. The results obtained by NIST and ATMS are reported in Table 4 and Table 7, respectively.

The Quality Control specimens are made of EN 353 steel, a Ni-Cr-Mo alloy case-hardenable steel suitable for high-stress, heavy-duty applications, and equivalent to AISI 8620. It had been observed that these specimens yield significantly different absorbed energies when tested with 2 mm and 8 mm strikers, and this was confirmed by the results of both NIST and ATMS tests, which are summarized in Table 12 (differences between 20 J and 30 J).

Table 12. Sample sizes, means, and standard deviations for ATMS and NIST tests on ATMS Quality Control specimens.

Institute	Striker	*N*	$\overline{KV}$ (J)	SD (J)
ATMS	2 mm	10	115.3	4.55
	8 mm	10	86.6	5.80
NIST	2 mm	10	105.7	9.68
	8 mm	10	81.9	7.21

Based on two-sample *t*-tests, the statistical differences between 2 mm and 8 mm striker tests are extremely significant for both ATMS tests (*p*-value = 3.33×10^{-10}) and NIST tests (*p*-value = 7.27×10^{-6}).

6. Conclusions

In January and February 2026, Anand Testing Machine Services LLP (ATMS, India) and the National Institute of Standards and Technology (NIST, USA) conducted their third interlaboratory comparison of Charpy tests on reference specimens produced by both Institutes, as a follow-up of two similar intercomparison exercises conducted in 2022 and 2024.

The mean values of absorbed energy obtained by ATMS and NIST in the framework of this intercomparison exercise were found not statistically different, at all energy levels, for the reference Charpy specimens produced by both institutes. Therefore, the agreement between ATMS and NIST was better than in the two previous exercises, when statistically significant differences were observed for:

- First intercomparison exercise (2022): lower energy ATMS specimens (M-20, KV_{ref} = 62.5 J) and low-energy NIST specimens (LL-189, KV_{ref} = 15.6 J at -40 °C for 8 mm strikers).
- Second intercomparison exercise (2024): low-energy NIST specimens (LL-198, KV_{ref} = 19.1 J) and super-high-energy NIST specimens (SH-67, KV_{ref} = 206.3 J).

Given the similarity of the test matrixes for the three intercomparison exercises, no apparent cause can be identified for the improved agreement observed in the third exercise with respect to the first two.

Furthermore, all ATMS and NIST tests on ATMS and NIST reference specimens were found to fulfil the requirements of both ASTM E23 and ISO 148-2 test standards.

Finally, Quality Control specimens produced by ATMS were also tested by both institutes, and the results confirmed the expected strong influence of the striker edge radius, with 2 mm strikers providing significantly higher absorbed energies (between 20 J and 30 J) than 8 mm strikers.

References

[1] E. Lucon and R. L. Santoyo, “Charpy Interlaboratory Comparison Between NIST and Anand Testing Machine Services,” 2022. doi: 10.6028/NIST.TN.2243.

[2] E. Lucon, A. C. Eckhardt, and R. L. Santoyo, “Second Charpy Interlaboratory Comparison Between NIST and Anand Testing Machine Services LLP,” 2024. doi: 10.6028/NIST.TN.2301.

[3] International Standards Organization, “ISO 17034:2016 -- General requirements for the competence of reference material producers,” 2016, [Online]. Available: www.iso.org.

[4] International Standards Organization, “ISO 148-3:2016, Metallic materials — Charpy pendulum impact test — Part 3: Preparation and characterization of Charpy V-notch test pieces for indirect verification of pendulum impact machines,” 2016. [Online]. Available: www.iso.org

[5] International Standards Organization, “ISO 148-2:2016, Metallic materials — Charpy pendulum impact test — Part 2: Verification of testing machines,” 2016. [Online]. Available: www.iso.org

[6] ASTM International, “E23 − 25, Standard Test Methods for Notched Bar Impact Testing of Metallic Materials,” 2024. doi: 10.1520/E0023-24.

Appendix A. Dimensional measurements performed by ATMS on NIST reference specimens

ANAND TESTING MACHINE SERVICES LLP, RMP DIVISION						
No.	RMP-7.3 / QR - 20	Revision No.	00	Revision Date	09.04.2024	Page 1 of 1

Lot No. : LL - 206

MEASUREMENT OF FINAL DIMENSIONS

Date : 29 JAN 2026

ATMS Tolerance	54.7 to 55.0 mm	± 0.2 mm	9.97 - 10.03 mm	9.97 - 10.03 mm	0.225 to 0.275 mm		44.00 to 46.00 deg		7.975 to 8.025 mm		89.85 to 90.15 deg			
TP No. / Accepted Yes / No.	Length in mm, L	Centring in mm, 27.5 mm	Width in mm, W	Thickness in mm, B	Radius in mm		Angle in degrees		Ligament Length in mm, 8.00 mm		Angle Adjacent Sides in degree			
					1	2	1	2	1	2	A	B	C	D
179	54.96	0.003	10.004	10.004	0.2481	0.2470	44.38	44.54	8.017	8.022	89.97	90.03	89.97	90.03
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
475	54.95	0.018	10.010	10.01	0.2448	0.2447	44.31	44.50	8.022	8.024	89.98	90.05	89.98	89.97
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
589	54.93	0.006	10.002	10.011	0.2456	0.2458	44.47	44.84	8.021	8.022	89.98	89.97	89.98	89.95
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
907	54.94	0.000	10.010	10.002	0.2464	0.2474	44.32	44.47	8.019	8.021	90.05	89.93	90.03	89.97
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1294	54.96	0.008	10.011	10.008	0.249	0.2408	44.36	44.64	8.023	8.024	90.03	89.97	90.05	89.93
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
149	54.93	0.019	10.010	10.002	0.2451	0.2455	44.31	44.61	8.017	8.02	89.97	90.03	89.95	89.97
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
291	54.91	0.006	10.002	10.011	0.2487	0.2457	44.52	44.56	8.004	8.016	90.07	89.92	90.08	89.92
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
757	54.91	0.015	10.011	10.002	0.2464	0.2475	44.31	44.52	8.017	8.008	90.02	89.95	90.02	89.95
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1082	54.94	0.023	10.003	10.009	0.2478	0.2488	44.46	44.59	8.021	8.012	90.07	89.97	90.07	89.92
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1695	54.87	0.037	10.004	10.005	0.2503	0.2525	44.51	44.33	8.022	8.018	90.02	89.97	90.03	89.97
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

ANAND TESTING MACHINE SERVICES LLP, RMP DIVISION						
No.	RMP-7.3 / QR - 20	Revision No.	01	Revision Date	09.04.2024	Page 1 of 1

Lot No. : HH - 206

MEASUREMENT OF FINAL DIMENSIONS

Date : 29 JAN 2026

ATMS Tolerance	54.7 to 55.0 mm	± 0.2 mm	9.97 - 10.03 mm	9.97 - 10.03 mm	0.225 to 0.275 mm		44.00 to 46.00 deg		7.975 to 8.025 mm		89.85 to 90.15 deg			
TP No. / Accepted Yes / No.	Length in mm, L	Centring in mm, 27.5 mm	Width in mm, W	Thickness in mm, B	Radius in mm		Angle in degrees		Ligament Length in mm, 8.00 mm		Angle Adjacent Sides in degree			
					1	2	1	2	1	2	A	B	C	D
1321	54.91	0.064	10.020	10.012	0.2496	0.2451	44.21	44.14	8.016	8.017	90.02	89.98	90.02	89.98
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1322	54.91	0.003	10.010	10.018	0.2511	0.2501	45.29	45.37	8.017	8.01	89.92	90.08	89.98	90.05
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1359	54.92	0.038	10.015	10.015	0.2504	0.251	45.17	45.25	8.022	8.019	90.03	90.02	90.02	90.03
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1360	54.92	0.052	10.019	10.004	0.25	0.2507	44.20	44.24	8.019	8.017	90.03	90.03	90.02	90.02
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1419	54.86	0.013	10.017	10.02	0.2539	0.2517	44.23	45.29	8.017	8.019	90.05	89.97	90.03	89.98
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1420	54.9	0.015	10.015	10.012	0.2411	0.2485	44.17	45.15	8.021	8.016	89.98	90.02	89.97	90.02
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1527	54.87	0.002	10.007	10.015	0.2537	0.2464	45.19	45.18	8.017	8.018	90.03	89.98	90.02	89.98
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1528	54.86	0.020	10.017	10.013	0.2519	0.251	45.00	44.12	8.022	8.022	90.02	89.93	89.93	89.98
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1529	54.9	0.049	10.014	10.018	0.2559	0.254	45.24	45.29	8.016	8.018	89.97	90.05	89.98	89.93
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1530	54.9	0.014	10.014	10.012	0.2531	0.251	45.29	45.26	8.02	8.02	90.08	89.97	90.02	89.98
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1531	54.87	0.036	10.005	10.018	0.2467	0.2488	44.07	44.15	8.022	8.017	90.02	90.03	89.98	90.02
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1532	54.9	0.007	10.012	10.008	0.2538	0.2504	44.20	44.31	8.015	8.018	89.98	90.07	89.98	90.07
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

	ANAND TESTING MACHINE SERVICES LLP, RMP DIVISION						
	No.	RMP-7.3 / QR - 20	Revision No.	01	Revision Date	09.04.2024	Page 1 of 1

Lot No. : SH - 73

MEASUREMENT OF FINAL DIMENSIONS

Date : 29 JAN 2026

ATMS Tolerance	54.7 to 55.0 mm	± 0.2 mm	9.97 - 10.03 mm	9.97 - 10.03 mm	0.225 to 0.275 mm		44.00 to 46.00 deg		7.975 to 8.025 mm		89.85 to 90.15 deg			
TP No. / Accepted Yes / No.	Length in mm, L	Centring in mm, 27.5 mm	Width in mm, W	Thickness in mm, B	Radius in mm		Angle in degrees		Ligament Length in mm, 8.00 mm		Angle Adjacent Sides in degree			
					1	2	1	2	1	2	A	B	C	D
0005	54.91	0.023	10.010	10.012	0.2625	0.2419	44.12	44.34	7.998	7.997	89.98	90.02	89.98	89.95
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
0009	54.91	0.032	10.008	10.012	0.2601	0.2641	44.22	44.42	7.995	7.996	89.98	89.98	89.98	89.98
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
0019	54.89	0.007	10.008	10.018	0.2578	0.2591	44.03	44.01	7.994	7.991	89.98	90.02	90.03	89.98
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
0065	54.89	0.011	10.010	10.018	0.256	0.2575	43.99	44.09	8.002	7.994	89.98	90.02	90.02	89.98
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
0089	54.89	0.020	10.010	10.190	0.257	0.241	44.03	44.07	7.995	7.996	89.97	89.98	90.02	90.03
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
0014	54.89	0.008	10.050	10.011	0.2593	0.2513	44.85	44.41	7.994	7.995	89.98	89.97	90.03	89.98
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
0025	54.9	0.001	10.008	10.010	0.2549	0.2519	44.09	44.12	7.994	7.993	89.98	90.02	89.98	89.98
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
0040	54.89	0.026	10.008	10.010	0.2604	0.259	44.04	44.09	7.996	7.992	89.97	90.05	90.03	89.97
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
0055	54.91	0.001	10.008	10.007	0.2569	0.2545	44.09	44.14	7.992	7.992	89.95	90.03	89.97	90.03
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
0080	54.89	0.003	10.010	10.015	0.2521	0.251	44.66	44.67	7.991	7.992	89.98	90.02	89.98	90.02
Accetable (Yes / No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Appendix B. Results of Charpy tests performed at ATMS on NIST reference specimens

ANAND TESTS (JAN 30, 2026)

Test Machine : ITM-2 (400 J)
Striker Type : 2 mm
Temperature : 21°C

Lot	Specimen No.	KV (J)	B / NB / FB	A / S
LL - 206	179	17.6	B	S
	475	18.0	B	S
	589	18.0	B	A
	907	18.4	B	A
	1294	jammed		
	149	17.6	B	S
	291	18.0	B	S
	757	18.4	B	A
	1082	17.6	B	A
	1695	18.4	B	S
	Reference Absorbed Energy	=	18.3	
	Average Absorbed Energy	=	18.0	
	Standard Deviation	=	0.35	
	Coefficient of Variation	=	0.019	

Lot	Specimen No.	KV (J)	B / NB / FB	A / S
HH - 206	1321	116.0	B	S
	1322	122.0	FB	A
	1359	120.0	B	S
	1360	110.0	B	S
	1419	113.2	B	S
	1420	122.4	B	A
	1527	122.8	B	A
	1528	124.0	FB	A
	1528	114.4	B	A
	1529	109.6	B	S
	1530	113.2	FB	S
	1531	113.2	FB	S
	Reference Absorbed Energy	=	117.4	
	Average Absorbed Energy	=	116.7	
	Standard Deviation	=	5.22	
	Coefficient of Variation	=	0.045	

Lot	Specimen No.	KV (J)	B / NB / FB	A / S
SH - 73	5	204.0	NB	- - - - -
	9	202.0	NB	- - - - -
	19	202.4	NB	- - - - -
	65	206.0	NB	- - - - -
	89	208.0	NB	- - - - -
	14	200.0	NB	- - - - -
	25	205.6	NB	- - - - -
	40	200.0	NB	- - - - -
	55	206.4	NB	- - - - -
	80	198.4	NB	- - - - -
	Reference Absorbed Energy	=	212.2	
	Average Absorbed Energy	=	203.28	
	Standard Deviation	=	3.22	
	Coefficient of Variation	=	0.016	

Appendix C. Results of Charpy tests performed at ATMS on ATMS reference specimens

ANAND TESTS (JAN 30, 2026)

Test Machine : ITM-2 (400 J)
Striker Type : 2 mm
Temperature : +20°C

Lot	Specimen No.	KV (J)	B / NB / FB	A / S
M 34	151	47.4	B	S
	152	44.8	B	A
	153	44.4	B	S
	154	42.8	B	A
	155	44.4	B	A
	156	44.0	B	S
	157	48.8	B	A
	158	46.4	B	A
	159	46.0	B	S
	160	43.6	B	S
	Reference Absorbed Energy	=	44.6	
	Average Absorbed Energy	=	45.3	
	Standard Deviation	=	1.86	
	Coefficient of Variation	=	0.041	

Lot	Specimen No.	KV (J)	B / NB / FB	A / S
26A - M 41	066	134.8	B	S
	067	133.2	B	S
	068	133.2	B	S
	069	138.4	B	S
	070	137.6	B	S
	071	144.4	FB	A
	072	144.0	FB	A
	073	146.4	FB	A
	074	138.8	B	S
	075	136.0	B	S
	Reference Absorbed Energy	=	143.6	
	Average Absorbed Energy	=	138.7	
	Standard Deviation	=	4.76	
	Coefficient of Variation	=	0.034	

Appendix D. Results of Charpy tests performed at ATMS on ATMS Quality Control specimens

ANAND TESTS (JAN 30, 2026)

Test Machine : ITM-2 (400 J)
Striker Type : 2 mm
Temperature : +20°C

Lot	Specimen No.	KV (J)	B / NB / FB	A / S
G-120	176	115.6	B	S
	177	121.6	B	S
	178	120.0	B	S
	179	117.2	B	A
	180	110.0	B	S
	218	112.4	B	S
	220	112.0	B	S
	221	120.4	B	S
	222	115.6	B	A
	223	108.4	B	A
	Average Absorbed Energy	=	115.3	
	Standard Deviation	=	4.55	
	Coefficient of Variation	=	0.039	

ANAND TESTS (JAN 30, 2026)

Test Machine : ITM-2 (400 J)
Striker Type : 8 mm
Temperature : +20°C

Lot	Specimen No.	KV (J)	B / NB / FB	A / S
G-120	011	84.4	B	A
	012	88.0	B	A
	013	86.4	B	A
	014	87.2	B	S
	015	81.2	B	A
	072	77.6	B	A
	073	89.2	B	S
	075	88.4	B	A
	076	99.6	B	A
	077	84.0	B	S
	Average Absorbed Energy	=	86.6	
	Standard Deviation	=	5.80	
	Coefficient of Variation	=	0.067	

Appendix E. Dimensional measurements performed by NIST on ATMS reference specimens

M34 23-24

Specimen number	*W* (mm)	*B* (mm)	Centering (mm)	*L* (mm)	α (°)	ρ (mm)	*b* (mm)
111	10.018	10.009	0.007	54.907	45.14	0.240	7.990
112	10.012	10.007	0.067	54.894	45.29	0.228	7.987
113	10.020	10.009	0.088	54.852	45.06	0.229	7.993
114	10.022	10.007	0.016	54.895	45.44	0.245	8.005
115	10.016	10.009	0.020	54.903	45.34	0.249	8.003
116	10.020	10.005	0.099	54.888	45.36	0.234	7.996
117	10.022	10.006	0.011	54.899	45.29	0.233	7.991
118	10.017	10.015	0.080	54.846	45.20	0.230	7.993
119	10.019	10.009	0.099	54.878	45.31	0.235	7.993
120	10.023	10.010	0.055	54.831	44.77	0.233	7.987

26A-M41 011-091

Specimen number	*W* (mm)	*B* (mm)	Centering (mm)	*L* (mm)	α (°)	ρ (mm)	*b* (mm)
51	9.999	10.016	0.061	54.867	44.65	0.249	7.995
52	9.984	10.013	0.050	54.862	44.95	0.239	7.991
53	9.981	10.011	0.063	54.859	45.59	0.251	7.991
54	9.987	10.011	0.116	54.846	44.43	0.253	7.992
55	9.989	9.991	0.039	54.899	44.97	0.247	7.994
451	10.004	10.018	0.019	54.941	45.46	0.240	7.996
452	10.003	10.024	0.053	54.953	44.72	0.227	7.997
453	10.006	10.019	0.024	54.950	45.13	0.246	8.000
454	10.006	10.022	0.049	54.948	44.64	0.246	8.000
455	10.007	10.020	0.043	54.947	45.13	0.246	8.000