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Saltstone Paddles and Augers Materials of Construction Study

Chris Rasmussen

Brinley Swanson

September 2024

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September 2024

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EXECUTIVE SUMMARY

The Saltstone Production Facility (SPF) uses a 10-inch READCO continuous, co-rotating twin-screw mixer to mix the dry premix with the low-level radioactive waste (LLW) salt solution to produce fresh saltstone grout. The paddles and augers within the mixer degrade via erosion in the region where the salt solution is introduced into the mixer. After the paddles/augers erode to a point where the throughput impacts operations, the mixer is disassembled, the effected paddles/augers are replaced, and the mixer is reassembled. Saltstone Engineering indicated that this effort requires an approximately three-week outage. The objective of this task is to assess alternative materials of construction (MOCs) that will provide better erosion characteristics and decrease the frequency in which the paddles and augers need replacement. Previous Astralloy V studies looked only at Charpy Impact and Rockwell Hardness Testing. Each of these will be examined for different alloys as well as Miller Testing (abrasion to determine wear) which will provide a good assessment of an alloy's erosion/wear characteristics.

The following facts concerning the current and proposed alloys for Saltstone Paddles and Augers are provided in this report.

- Current Astralloy V material and alloy E52100 had the most favorable Miller Testing Results.
- Charpy Impact Testing did not correlate with Miller Testing Results.
- Hardness Testing correlated with Miller Testing results meaning that higher hardness will provide more favorable wear resistance.
- Further investigation of E52100 and various tool grade steels is recommended for achieving wear resistant properties.

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LIST OF ABBREVIATIONS

Al	Aluminum
ASTM	American Society for Testing and Materials
C	Carbon
DI	Deionized Water
EDM	Electrodischarge Machining
ELN	Electronic Laboratory Notebook
H	Hydrogen
HIP	Hot Isostatic Pressing
HT	Heat Treated
HRb	Rockwell Hardness "B" Scale
HRc	Rockwell Hardness "C" Scale
LLW	Low Level Radioactive Waste
ksi	Kilopounds per Square Inch
MOC	Material of Construction
N	Nitrogen
Na	Sodium
O	Oxygen
P	Phosphorous
RPM	Revolutions Per Minute
S	Sulfur
SAR	Slurry Abrasive Response
SPF	Saltstone Production Facility
SRNL	Savannah River National Laboratory
TTQAP	Task Technical Quality Assurance Plan
TTR	Technical Task Request
W/P	Water to Premix
wt%	Weight Percent

1.0 Introduction

The Saltstone Production Facility (SPF) uses a 10-inch READCO continuous, co-rotating twin-screw mixer to mix the dry premix with the low-level radioactive waste (LLW) salt solution to produce fresh saltstone grout. The paddles and augers internal to the mixer degrade via erosion in the region where the salt solution is introduced into the mixer. After the paddles/augers erode to a point where the throughput impacts operations, the mixer is disassembled, the effected paddles/augers are replaced, and the mixer is reassembled. Saltstone Engineering indicated that this effort requires an approximately three-week outage.

Extending Paddle and Auger life on the Saltstone 10-inch READCO mixer may be achieved through finding alternate materials of construction (MOC) for each of these components. The paddles are currently made from Astralloy V and the Auger screws are a 316L stainless steel alloy that is stellite coated. Several hardenable steel alloys will be considered as well as an alternative processing of Astralloy V alloy. Each alloy was subject to Charpy Impact testing and the best candidates were Hardness and Miller tested (abrasion) [1].

2.0 Experimental Procedure

2.1 Alloy Selection

Several alloys were selected based on application (wear), ability to be hardened through heat treatment, and commercial availability. The current MOC for the paddles, Astralloy V, is a non-ASTM standard material produced by one supplier [2]. The alloys that were evaluated are listed in Table 2-1 below. Steel grades 4140, 4340 and 8620 are commercially available, hardenable alloys that provide good combinations of hardness, toughness, and wear resistance [3]. A high-hardness, high-wear resistant alloy, E52100 was also evaluated [3]. Each alloy was sent to Pinson Valley Heat Treatment in AL to be heat treated to 45-50 HRc (Rockwell Hardness "C" scale) [3].

Table 2-1. Alloys to be evaluated

Sample	Uses
E52100	High wear grade steel used for bearing races (high surface wear resistance)
Astralloy V HT	Current material used in applications where high wear resistance is desired
HIP Astralloy V HT	Alternate processing (HIP_ of current material, heat treated
HIP Astralloy V	Alternate processing (HIP) of current material
4140	Good structural strength
4340	High surface wear resistance used for gear sets
8620	High surface wear resistance used for gear sets

Hot Isostatic Pressing (HIP) was evaluated as an alternate process for Astralloy V in effort to achieve isotropic charpy impact properties (i.e. charpy impact values that are uniform in x, y and z directions [2]). HIP requires an alloy be atomized into powder form, placed in a can, heated and pressed using high pressure into a solid form. HIP was recommended as a possible process in a previous report [2] to achieve isotropic properties. An as received HIP sample and a HIP sample with further heat treatment (HT) after HIP were evaluated.

For this study, Astralloy V sections from the same lot as previously studied [2] were powderized using an atomizer by Surface Engineering in Tampa, FL. After this, the powder was HIPed by Exothermics in

Nashua, NH at 2000 °F under a pressure of 25 ksi for 180 minutes. One section of the billet was sent to Applied Technical Services in Marietta, GA for Charpy impact specimen creation. Another section of this billet was sent to Pinson Valley Heat Treatment in AL to be normalized at 1650˚F for one hour and air cooled as per recommendation in the Astralloy V Technical Guide [4] and then sent onto ATS for Charpy sample creation.

2.2 Charpy Impact and Hardness Testing

Each alloy sample was machined (via Electro Discharge Machining, EDM) into Charpy impact bars for Charpy impact testing to determine the toughness of materials. The recommended toughness values were previously established as 25-35 ft*lbs in "Recommended Acceptance Criteria for Mixer Paddles" [5]. This Acceptance Criteria also included a recommended hardness range of 51-54 HRc [5]. Achieving both high impact strength and hardness is challenging as these properties are shown to be inversely related [2,3,4]. Toughness was used to screen MOC with only those with the desired toughness values based on the Acceptance Criteria [5] selected for further hardness and Miller Testing. All HIPed materials were subject to Miller and Hardness testing.

2.3 Abrasion Testing

2.3.1 Simulant Selection

Abrasion testing was performed using a slurry that best simulates the current process variables in the Saltstone Process Facility (SPF). Premix materials – blast furnace slag (slag) and flyash – were obtained directly from SPF from the most recent lot being used in production (April 2024) to prepare the April 2024 Toxicity Characteristic Leaching Procedure (TCLP) sample. The ratio currently used at SPF (60:40 wt% slag:fly ash) was used for testing. Materials were weighed separately and then mixed before combining with salt solution simulant to create a slurry for testing.

Salt solution composition was from SRNL-STI-2023-00389 [6]. Toxic and radioactive materials were omitted from this testing to minimize hazards as they are not expected to be significant contributors to the wear of the test materials. Simulant targets are listed in Table 2-2 below for 2 liter batch.

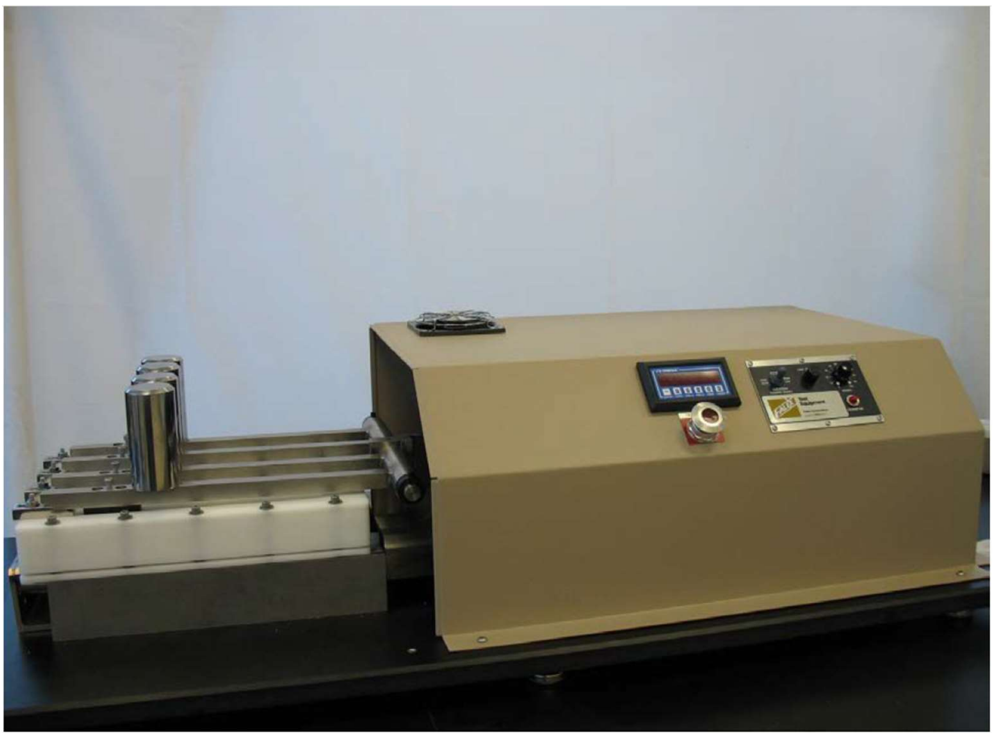
Table 2-2. Simulant targets

Chemical	Chemical Formula	Target [g]
DI Water	H_2O	1114.80
Sodium Hydroxide	NaOH, 50 wt%	458.37
Sodium Nitrate	$NaNO_3$	172.79
Aluminum Nitrate	$Al(NO_3)_3 \cdot 9H_2O$	136.11
Sodium Nitrite	$NaNO_2$	64.68
Sodium Carbonate	Na_2CO_3	52.70
Sodium Sulfate	Na_2SO_4	25.51
Sodium Phosphate	$Na_3PO_4 \cdot 12H_2O$	2.20

2.3.2 Abrasion Testing

The *Falex* Miller Machine was selected for abrasion testing to best mimic the abrasive wear seen in the SPF process (Figure 2-1 below). The test consists of a reciprocating arm to which the test coupons are affixed in a mount and where each coupon is placed into a slurry filled trough. In accordance with ASTM G75 [7], the arm moves back and forth at a rate of approximately 48 RPM and runs in 2-hour increments for a total test time of 6 hours. Each arm has a 5-pound weight affixed to the top to apply even pressure as the arm travels in the slurry trough. Before the test and after each 2-hour period, each coupon is cleaned and weighed to determine weight loss. This weight loss is used to calculate a slurry abrasivity resistance (SAR) number to define how each material endures the trial period. The Miller Machine test produces quality comparative results but does not define a quantitative weight loss rate for the SPF process. Nonetheless, materials with a lower SAR number – better abrasion resistance – should perform better in the SPF process.

Figure 2-1. Miller testing machine



2.3.3 Simulant W/P Ratio Testing

The water to premix (W/P) ratio used in the SPF is 0.59. However, lower W/P are expected to provide higher wear characteristics, amplifying any difference in the wear for each material in a shorter period of time. W/P ratios of 0.3, 0.37, 0.45, 0.59 were tested for set time to ensure that the slurry would not set during the abrasion testing. The test was performed using a Vicat testing apparatus [8]. All slurries did not set before 8 hours so each of them would not present an issue during abrasion testing for the aspect of setting. The different W/P ratio slurries were also prepared and bagged to determine flowability and consistency prior to any abrasion testing. The 0.3 W/P ratio did not wet well and was ruled out for further evaluation.

W/P ratios of 0.37, 0.45, and 0.59 were selected for an initial abrasion test run in the Miller Machine. Miller machine tests were performed using standard coupons to evaluate the flowability of the slurries during the test as well as the differences in wear generated between the 3 W/P ratios. The results are in Table 2-3 below.

Table 2-3. W/P ratio slurries

Coupon #	438	439	440
W/P	0.59	0.45	0.37
Mass Loss [g]	$2.6x10^{-3}$	$2.5x10^{-3}$	$5.6x10^{-3}$

0.37 W/P did produce about twice the wear of 0.45 and 0.59 W/P samples. However, it was noted that visually the slurry was not properly flowing underneath the sample during the test. The 0.59 and 0.45 W/P ratio slurries produced nearly identical results so 0.59 W/P was selected to match the SPF process.

2.4 Quality Assurance

Quality Assurance requirements for performing reviews of technical reports and the extent of review are established in manual E7 2.60 [9]. SRNL documents the extent and type of review using the SRNL Technical Report Design Checklist contained in WSRC-IM-2002-00011, Rev. 2 [10]. The customer requested that a Functional Classification of Production Support apply to this work [11], therefore a Design Verification technical review according to section 5.3.2 of E7 2.60 will apply [9]. Data collection and analysis methods used in this work comply with this requirement as detailed in the TTQAP [1]. All data collected as part of this study is maintained or referenced in the SRNL Electronic Laboratory Notebook system in experiments K9637-00509-21 [12] and M8433-00697-01 [13].

3.0 Results and Discussion

3.1 Charpy Impact and Hardness Testing

Each alloy was sent to Applied Technical Services in Marietta, GA (similar to previous testing of Astralloy V alloys [2]) for creation of Charpy Impact specimens (via EDM) and then Charpy impact testing per ASTM A370 [14]. Results from Applied Technical Services are in Appendix A. Alloys 4140 and 4340 had the lowest Charpy Impact values (with the exception of HIPed material) and were not continued to hardness and Miller testing. Hardness testing per ASTM E18 [15] was performed on select samples. The results are summarized in Table 3-1 below with standard deviations reported.

Table 3-1. Charpy impact and hardness testing results.

		Charpy, ft-lbs						Hardness
Sample	**ATS Test Report**	x av	σx	y av	σy	z av	σz	Average ± σ, scale
E52100	409321-4	15	±0.6	6	±0.6	6	±1.0	44.8 ± 4.1 HRc
Astralloy V HT	355249-2	29	±1.0	26	±1.0	8	±4.0	47.2 ± 0.8 HRc
HIP Astralloy V HT	409321-5	2	±0	2	±0	2	±0	94 ± 3 HRb
HIP Astralloy V	425216	2	±0	2	±0	2	±0	93.2 ± 1.8 HRb
4140	409321-2	6	±1.2	7	±1.0	4	±1.5	-
4340	409321-3	9	±0.6	9	±0.6	6	±1.5	-
8620	409321-1	36	±8.4	31	±9.6	17	±1.7	61.3 ± 18.0 HRb

Red values denote hardness values below recommended HRc scale

Charpy and Hardness Acceptance Criterion for SPF are 25-35 ft-lbs and Rockwell C hardness of 51-54, respectively [5]. Achieving both of these criteria is challenging as increases in Charpy Impact Strength often result in decreases in Hardness, exemplified by results seen for the 8620 alloy, where this alloy had good Charpy Impact values but very low hardness values (results were in Rockwell hardness "B" scale (uses steel ball indenter) whereas desired hardnesses are in Rockwell "C" scale (uses diamond indenter), as the B scale is lower than the C scale [15]). Previously studied rolled Astralloy V material met the Charpy requirements in the x and y directions (fell short in z directions, non-isotropic) however fell short of the recommended hardness requirements.

Of note, both Astralloy V HIP samples (HT and non-HT) had low Charpy and Hardness. This configuration of Astralloy V had not been previously investigated and there is no ASTM standard or other information documented on this alloy and process. The E52100 had higher Charpy than the HIP samples (as well as the 4140 and 4340) however hardness was much higher (45 HRc vs 94 HRb) than the HIP sample and closer to the previously studied rolled Astralloy V (47 HRc).

3.2 Miller Testing

The auger section of the SPF mixer consists of 316L stainless steel with stellite coated tips. The 316L stainless steel coupons were run in this test as a baseline set of samples in order to discern the wear on the material after the stellite coating is worn from the tips of the auger. As expected, the 316L stainless steel performed poorly compared to other material selections, with significant mass loss during the 6-hour period. Astralloy V is used downstream in the SPF mixer for the paddle mixing section and provides a significant improvement over the 316L material for wear resistance (Table 3-2).

Table 3-2. SAR number and average mass loss per alloy tested

Material	SAR Number	Average Cumulative Mass Loss %
E52100	250	0.52%
Astralloy V	307	0.80%
HIP Astralloy V HT	632	1.94%
HIP Astralloy V	844	1.62%
8620	1020	1.93%
316L	1247	2.37%

Of the new materials tested, the E52100 showed the greatest abrasion resistance with a SAR number of 250 in the simulant slurry over the 6-hour test. This material is among the hardest of the materials tested and shows the importance of hardness on abrasion resistance. 8620 material was selected for having an improved toughness over the 316L material, with the idea that foreign objects passing through the mixer in the process could break more hardened materials, causing an abrupt shutdown to the process. However, the material's lack of hardness lowers its value to the process when trying to improve the life of the auger section of the mixer, especially when coupled with the understanding from discussions with SPF that foreign object contamination is now being caught earlier in the process and no longer disrupts mixer operation as frequently [16].

The Astralloy V normally used in the process is cold rolled which increases the hardness of the rolled surface [4]. This working process does create anisotropic hardness and the non-work hardened surface is exposed on the tips of the paddles for the SPF mixer. HIP Astralloy V materials were intended to create isotropic properties (same properties in x, y and z directions) of the parts. Both the initial coupons and secondary heat-treated coupons had significantly worse abrasion resistance than the traditional Astralloy V material. The hardness value of the material without rolling is too low to provide a significant improvement in material performance versus the cost of the added processing.

4.0 Conclusions

The most favorable results from the Miller Testing were for E52100 and current rolled Astralloy V. The E52100 did not have a high Charpy impact value but had a high resistance to abrasion. The Astralloy V had higher Charpy impact strength values than the E52100 while it performed slightly worse in the Miller Testing. Each sample had hardness within HRc 40's, which is close to ideal hardness ranges for wear surfaces (typical range of 50-63 HRc [3]). Based on these results, hardness is established as the most suitable acceptance criteria for favorable wear surfaces, followed up with Miller Testing for both paddle and auger materials. The samples created (HIP Astralloy V and HIP Astralloy V HT) using Hot Isostaic Pressing did not produce favorable results for impact strength and hardness.

5.0 Recommendations, Path Forward or Future Work

Further investigation of the wear properties E52100 and/or any other suitable, commercially available wear resistant materials, such as various grades of tool steels, with the supplier READCO is recommended. Additive Manufacturing techniques can also be investigated to supplement the proposed future work. Due to the low wear resistance (high SAR number) and hardness values of the HIP samples, it is recommended to cease any further development at this time due to high processing costs. Additionally, a new acceptance criterion could be specified to only Hardness and SAR number targets.

6.0 References

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6. SRNL-STI-2023-00389, Results for the January 2023 Semiannual Tank 50 Salt Solution Sample, Revision 0, October 2023.

7. ASTM G75, Standard Test Method for Determination of Slurry Abrasivity (Miller Number) and Slurry Abrasion Response of Materials (SAR Number).

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9. “Technical Reviews”, Savannah River Site, Manual E7, Procedure 2.60, Latest Revision.

10. “Savannah River National Laboratory Technical Report Design Check Guidelines”, Westinghouse Savannah River Company, WSRC-IM2002-00011, Rev. 2, August 2004.

11. Jezewski, A., “Evaluation of Alternative Saltstone Mixer Flush Strategies”, Savannah River Mission Completion, X-TTR-Z-00028, Rev. 0, November 2023.

12. Rasmussen, C., “Saltstone Paddles and Augers”, K9637-00509-21, SRNL E-Notebook (Production), Savannah River National Laboratory, September 2024.

13. Swanson, B., “Miller Machine Testing”, M8433-00697-01, SRNL E-Notebook (Production), Savannah River National Laboratory, September 2024.

14. ASTM A370, Standard Test Methods and Definitions for Mechanical Testing of Steel Products.

15. ASTM E18, Standard Test Method for Rockwell Hardness of Metallic Materials.

16. M-DCF-Z-00436, Magnetic Separator for Bulk Material Unloading System, 3/12/2004.

Appendix A. Charpy Impact Test Reports from ATS E52100

Applied Technical Services

We Take A Closer Look
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TEST REPORT 409321-4

Contact: Chris Rasmussen
Customer: Battelle Savannah River Alliance
Savannah River Site
Aiken, SC 29808

Date: November 02, 2023
Purchase Order: Subcontract No. 000063345

Summary

Charpy impact testing performed using ASTM A370-22, and the customer provided instructions in Subcontract # 000063345. The client requested impact specimens to be machined completely using the wire EDM process. Testing in accordance with ATS QA Manual Rev. 21 dated 06/01/2023.

Sample Table

ATS#	P/N	Description	Pass/Fail
See Table 1	Sample E	Bar 52100	N/A

Reviewed by 2023.11.02 19:01:58 -04'00'
D. Johnson, Group Manager

Reviewed by Rodney Allen Digitally signed by Rodney Allen Date: 2023.11.02 19:06:37 -04'00'
W. R. Allen, Mechanical Testing

ISO 9001

ATS 075, 6/2021 Page 1 of 2 ATS # 409321-4

Applied Technical Services | +1(888) 287-5227 | www.atslab.com

Table 1: Charpy V-Notch, Performed at 32° Fahrenheit

Sample ID	Absorbed Energy (ft-lbs)	Lateral Exp. (mils)	% Shear	Remarks
37	15	4	5	Full size (0.394" x 0.394") impact specimens were tested per ASTM A370-22 at 32° Fahrenheit.
38	15	4	5	
39	14	3	5	
40	5	2	0	
41	6	3	0	
42	6	3	0	
43	6	1	0	
44	5	2	0	
45	7	3	0	

Astralloy V (2018 lot)[2]

APPLIED TECHNICAL SERVICES

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MATERIALS TEST REPORT

Ref. 355249-2 **Date** June 10, 2021 **Page** 1 **of** 2

Christopher Rasmussen
Savanah River Nuclear Solutions
999-W Room 390
Aiken, SC 29803

Purchase Order #: SRNS-0000519841

Test Procedure

- Shear ☐
- Load ☐
- Impact ☒
- Density ☐
- Bend ☐
- Other ☐
- Shear ☐

Material: Astralloy Heat-treated Block #1 (Heat D3298)

Requirements: None reported

.

Test Results

Part Identification	Quantity	Absorbed Energy (ft-lbs)	Lateral Exp.(mils)	% Shear	Remarks
1L-L0	1	28	9	0	Full size (0.394" x 0.394") charpy V-notch samples were tested per ASTM A370-20 at +32°F. The specimens were sectioned using the Wire EDM method per the customers request and in accordance with contract No. 0000519741.
2L-L0	1	27	9	0	
3L-L0	1	28	7	0	
1L-L90	1	30	9	0	
2L-L90	1	29	9	0	
3L-L90	1	30	9	0	

ACCREDITED
MECHANICAL TESTING CERT #1888.01

Prepared by: Dennis Johnson, Materials Testing

Reviewed by: Rodney Allen — W. R. Allen, Materials Testing

ATS 904, 01/2010

APPLIED TECHNICAL SERVICES

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MATERIALS TEST REPORT

Ref. 355249-2 **Date** June 10, 2021 **Page** 2 **of** 2

Christopher Rasmussen
Savanah River Nuclear Solutions
999-W Room 390
Aiken, SC 29803

Purchase Order #: SRNS-0000519841

Test Results Continued

Part Identification	Quantity	Absorbed Energy (ft-lbs)	Lateral Exp.(mils)	% Shear	Remarks
1T-T0	1	26	8	0	Full size (0.394" x 0.394") charpy V-notch samples were tested per ASTM A370-20 at +32°F. The specimens were sectioned using the Wire EDM method per the customers request and in accordance with contract No. 0000519741.
2T-T0	1	26	8	0	
3T-T0	1	27	8	0	
1T-T90	1	28	9	0	
2T-T90	1	23	6	0	
3T-T90	1	26	8	0	
1ZT ①	1	5	2	0	Full size (0.394" x 0.394") charpy V-notch samples were tested per ASTM A370-20 at +32°F. The specimens were sectioned using the Wire EDM method per the customers request and in accordance with contract No. 0000519741.
2ZT ①	1	4	2	0	
3ZT ①	1	5	1	0	
1ZL ①	1	2 ②	2	0	
2ZL ①	1	2 ②	2	0	
3ZL ①	1	2 ②	2	0	

① Sample broke outside of notch.
② Value outside of calibrated range and is reported as approximate.

HIPAstralloy V

TEST REPORT 425216

Contact: Chris Rasmussen
Customer: Battelle Savannah River Alliance
Savannah River Site
Aiken, SC 29808

Date: May 29, 2024
Purchase Order: BSRA-0000669100

Summary

Charpy impact testing was performed using **ASTM A370-24.** Specimens were machined in the orientation provided by the client. Testing in accordance with ATS QA Manual Rev. 22 dated 01/02/2024.

Sample Table

ATS#	P/N	Description	Pass/Fail
See Table 1	Sample A	Astralloy V (45HRC) Block	None Provided

Reviewed by Chris Henry 2024.05.29 15:13:12 -04'00'
C. Henry, Mechanical Supervisor

Reviewed by Rodney Allen Digitally signed by Rodney Allen Date: 2024.05.29 15:48:49 -04'00'
W. R. Allen, Mechanical Testing

ISO 9001

Table 1: Charpy V-Notch, Performed at 32° Fahrenheit

Sample ID	Absorbed Energy (ft-lbs)	Lateral Exp. (mils)	% Shear	Remarks
X1	2	1	0	Full size (0.394" x 0.394") impact specimens were tested per ASTM A370-24 at 32° Fahrenheit.
X2	2	1	0	
X3	2	1	0	
Y1	2	1	0	
Y2	2	1	0	
Y3	2	2	0	
Z1	2	0	0	
Z2	2	5	0	
Z3	2	1	0	

(1) Absorbed energy values are below the calibrate range of the equipment and are reported "as a guide".

HIP Astralloy V HT

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TEST REPORT 409321-5

Contact: Chris Rasmussen
Customer: Battelle Savannah River Alliance
Savannah River Site
Aiken, SC 29808

Date: March 28, 2024
Purchase Order: Subcontract No. 000063345

Summary

Charpy impact testing performed using ASTM A370-23, and the customer provided instructions in Subcontract # 000063345. Due to the unexpectedly low hardness of the material, conventional machining methods were used in place of the requested Wire EDM method. Testing in accordance with ATS QA Manual Rev. 22 dated 1/2/2024.

Sample Table

ATS#	P/N	Description	Pass/Fail
See Table 1	Astralloy	Astralloy V 60/35 Billet HIP	N/A

Table 1: Charpy V-Notch, Performed at 32° Fahrenheit

Sample ID	Absorbed Energy (ft-lbs)	Lateral Exp. (mils)	% Shear	Remarks
1, A1L	2*	2	0	Full size (0.394" x 0.394") impact specimens were tested per ASTM A370-23 at 32° Fahrenheit.
2, A2L	2*	4	0	
3, A3L	2*	2	0	
4, A1T	2*	2	0	
5, A2T	2*	2	0	
6, A3T	2*	2	0	
7, A1Z	2*	2	0	
8, A2Z	2*	1	0	
9, A3Z	2*	4	0	

*Absorbed Energy value is outside of calibrated range of equipment.

Reviewed by 2024.03.28 11:31:34 -04'00'
D. Johnson, Group Manager

Reviewed by Chris Henry 2024.03.28 12:18:05 -04'00'
C. Henry, Mechanical Supervisor

ISO 9001

4140

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TEST REPORT 409321-2

Contact:	Chris Rasmussen	**Date:**	November 02, 2023
Customer:	Battelle Savannah River Alliance Savannah River Site Aiken, SC 29808	**Purchase Order:**	Subcontract No. 000063345

Summary

Charpy impact testing performed using **ASTM A370-22**, and the customer provided instructions in Subcontract # 000063345. The client requested impact specimens to be machined completely using the wire EDM process Testing in accordance with ATS QA Manual Rev. 21 dated 06/01/2023.

Sample Table

ATS#	P/N	Description	Pass/Fail
See Table 1	Sample B	Plate 4140	N/A

Reviewed by 2023.11.02 18:53:32 -04'00'
D. Johnson, Group Manager

Reviewed by Rodney Allen
W. R. Allen, Mechanical Testing

ISO 9001

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ATS 075, 6/2021 Page 1 of 2 ATS #409321-2

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Table 1: Charpy V-Notch, Performed at 32° Fahrenheit

Sample ID	Absorbed Energy (ft-lbs)	Lateral Exp. (mils)	% Shear	Remarks
10	7	4	0	Full size (0.394" x 0.394") impact specimens were tested per ASTM A370-22 at 32° Fahrenheit.
11	5	2	0	
12	7	2	0	
13	7	10	0	
14	6	4	0	
15	8	4	0	
16	2	4	0	
17	5	2	0	
18	3	2	0	

4340

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TEST REPORT 409321-3

Contact:	Chris Rasmussen	**Date:**	November 02, 2023
Customer:	Battelle Savannah River Alliance Savannah River Site Aiken, SC 29808	**Purchase Order:**	Subcontract No. 000063345

Summary

Charpy impact testing performed using ASTM A370-22, and the customer provided instructions in Subcontract # 000063345. The client requested impact specimens to be machined completely using the wire EDM process. Testing in accordance with ATS QA Manual Rev. 21 dated 06/01/2023.

Sample Table

ATS#	P/N	Description	Pass/Fail
See Table 1	Sample C	4340 Plate	N/A

Reviewed by 2023.11.02 18:58:19 -04'00'
D. Johnson, Group Manager

Reviewed by Rodney Allen Digitally signed by Rodney Allen Date: 2023.11.02 19:06:35 -04'00'
W. R. Allen, Mechanical Testing

ISO 9001

Table 1: Charpy V-Notch, Performed at 32° Fahrenheit

Sample ID	Absorbed Energy (ft-lbs)	Lateral Exp. (mils)	% Shear	Remarks
19	10	2	0	Full size (0.394" x 0.394") impact specimens were tested per ASTM A370-22 at 32° Fahrenheit.
20	9	3	0	
21	9	2	0	
22	10	4	0	
23	9	3	0	
24	9	2	0	
25	5	2	0	
26	6	2	0	
27	8	2	0	

8620

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TEST REPORT 409321-1

Contact: Chris Rasmussen
Customer: Battelle Savannah River Alliance
Savannah River Site
Aiken, SC 29808

Date: Nov 02, 2023
Purchase Order: Subcontract No. 000063345

Summary

Charpy impact testing performed using **ASTM A370-22**, and the customer provided instructions in Subcontract # 000063345. The client requested impact specimens to be machined completely using the wire EDM process. Testing in accordance with ATS QA Manual Rev. 21 dated 06/01/2023.

Sample Table

ATS#	P/N	Description	Pass/Fail
See Table 1	Sample D	2.5" x 5" x 5" ASTM A829 Grade 860 Steel Block	N/A

Reviewed by 2023.11.02 18:48:10 -04'00'
D. Johnson, Group Manager

Reviewed by Rodney Allen Digitally signed by Rodney Allen Date: 2023.11.02 19:06:31 -04'00'
W. R. Allen, Mechanical Testing

ISO 9001

ATS 075, 6/2021 Page 1 of 2 ATS # 409321-1

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Table 1: Charpy V-Notch, Performed at 32° Fahrenheit

Sample ID	Absorbed Energy (ft-lbs)	Lateral Exp. (mils)	% Shear	Remarks
28	40	34	10	Full size (0.394" x 0.394") impact specimens were tested per ASTM A370-22 at 32° Fahrenheit.
29	41	33	10	
30	26	23	5	
31	20	20	0	
32	35	34	10	
33	38	31	10	
34	15	11	0	
35	18	14	0	
36	18	15	0	

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