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Ultimately Reliable Pyrotechnic Systems

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Abstract

1. Objectives/Scope:
   This paper presents the methods by which NASA has designed, built, tested, and certified pyrotechnic devices for high reliability operation in extreme environments and illustrates the potential applications in the oil and gas industry.

2. Methods, Procedures, Process
   NASA's extremely successful application of pyrotechnics is built upon documented procedures and test methods that have been maintained and developed since the Apollo Program. Standards are managed and rigorously enforced for performance margins, redundancy, lot sampling, and personnel safety. The pyrotechnics utilized in spacecraft include such devices as small initiators and detonators with the power of a shotgun shell, detonating cord systems for explosive energy transfer across many feet, precision linear shaped charges for breaking structural membranes, and booster charges to actuate valves and pistons.

3. Results, Observations, Conclusions
   NASA's pyrotechnics program is one of the more successful in the history of Human Spaceflight. No pyrotechnic device developed in accordance with NASA's Human Spaceflight standards has ever failed in flight use. NASA's pyrotechnic initiators work reliably in temperatures as low as -420 ^{o}F. Each of the 135 Space Shuttle flights fired 102 of these initiators, some setting off multiple pyrotechnic devices, with never a failure. The recent landing on Mars of the Opportunity rover fired 174 of NASA's pyrotechnic initiators to complete the famous "7 minutes of terror." Even after traveling through extreme radiation and thermal environments on the way to Mars, every one of them worked. These initiators have fired on the surface of Titan.

4. Novel/Additive Information
   NASA's design controls, procedures, and processes produce the most reliable pyrotechnics in the world. Application of pyrotechnics designed and procured in this manner could enable the energy industry's emergency equipment, such as shutoff valves and deepsea blowout preventers, to be left in place for years in extreme environments and still be relied upon to function when needed, thus greatly enhancing safety and operational availability.

Introduction

NASA has directly provided pyrotechnic devices for all human-rated spaceflight programs from the Apollo effort forward. The pyrotechnics utilized in spacecraft include such devices as small initiators and detonators, detonating cord systems for explosive energy transfer across many feet, precision linear shaped charges for breaking structural membranes, and booster charges to actuate valves and pistons. The majority of these devices have been installed for highly critical applications where a failure to function, or premature function, would

result in mission loss and, potentially, loss of human life. Over the course of the previous five decades, NASA has developed a protocol for designing, manufacturing, testing, qualifying, and accepting these critical components to ensure the best possible chance for mission success. These methods were established because there were no military or industry standards then available to meet the stringent needs of human-rated spaceflight in extreme operational environments. The information is captured as NASA standards, is comprised of best engineering practices and lessons learned, and also serves as the only accepted requirements documentation suitable for applications where human lives are at stake. To date there have been zero flight failures of NASA pyrotechnic hardware. This paper will present a brief synopsis of the methods NASA employs to take a design concept from inception to final acceptance with confidence in its ultimate reliability.

Design Philosophy

Every successful design must start with a well-established set of requirements. These requirements must cover reliability, safety, and quality assurance measures, as well as performance. Other critical parameters are configuration control, device traceability, material selection and control, considerations of service life, and a thorough understanding of the expected operational environment. Finally, a robust suite of non-destructive and destructive verification tests is needed to fully vet the design.

Redundancy is the fundamental means of mitigating single point failures when designing against the fails-to-operate failure mode for must-work applications. This includes redundancy down to, and including, the final explosive charge. This design requirement is paramount, and compliance must be verified by test.

Configuration Control & Traceability

Highly disciplined configuration control is at the heart of the NASA pyrotechnics process. Any documentation used in the manufacturing and testing of pyrotechnic hardware is captured in a configuration control baseline before the start of fabrication. This includes all component and tooling drawings, component inspection and acceptance sheets, and manufacturing and testing paperwork. These documents are recorded by number and revision. An example is shown in Appendix A. The use of alternate or redlined paperwork is strictly forbidden.

The NASA production process is broken down into a series of Phase Reviews that must be conducted by NASA's experienced pyrotechnic engineers and completed prior to acceptance of any lot of pyrotechnics. These Reviews are generally held at the vendor's facility and include participation of the vendor Engineering and Quality personnel, as well as of NASA Engineering and Quality representatives.

A Phase I Review specifically focuses on component drawings. Phase I is concluded by completing all action items generated during the Review. At that point, the design configuration is locked down with required drawings, inspection sheets, and the document revision levels. This allows the vendors to start procuring device components that may have long lead times.

A Phase II Review establishes configuration of the remaining documentation, such as assembly and test procedures. Again, this paperwork is locked down by document number and revision. Phase II is complete when all Review action items are closed. Completion of this Phase enables the vendor to start the manufacturing process and to proceed through final testing.

The last stage, a Phase III Review, occurs when all manufacturing steps and all testing has been successfully completed. These Reviews are always conducted at the vendor facility. The product acceptance data packs (ADPs) are reviewed at this time and are evaluated for compliance, completeness, and accuracy. The ADP consists of all component receiving inspection data, manufacturing and testing information, and discrepancy reports. Visual inspection of the deliverable units is also performed. The Phase III Review concludes when all action items and discrepancies are resolved. A Flight Certificate, refer to Appendix F for an example, is then generated which provides lot pertinent information, such as part number and name, lot number, serial numbers, energetic material batch numbers, and an expiration date for age-sensitive devices. NASA then takes official ownership and deems the hardware as flightworthy.

Traceability is also enforced during the manufacturing and test process to ensure that all units fabricated during a production run are identical. This traceability requires part marking with both lot and serial numbers. This aids in segregating hardware built at different times and also helps to separate units within each lot. Traceability requirements are also flowed down to the component level. NASA employs single lot control for all parts determined to be critical. This includes both structural and energetic materials. For human spaceflight, the Johnson Space Center (JSC) takes that requirement a step further by establishing single lot control for all

pyrotechnic devices (i.e. each component must also come from single lots). This greatly simplifies component tracking, eliminates device variability, and also serves to facilitate investigation efforts when anomalies occur. Component traceability requires that certificates of conformance (C of C) be provided for all parts and that manufacturing dates be provided for age sensitive materials. The documentation must show compliance to all drawing requirements with a C of C for each operation conducted by sub-vendors. Refer to Appendices B & C for C of C examples.

Material selection is driven by the end function performance requirements. Issues of structural integrity, age sensitivity, compatibility, operational environment, and energy output must be considered. Only designated, well-understood secondary explosives are to be used, and the use of vendor-proprietary blends is highly discouraged. Periodic surveillance sampling is also mandated for energetic materials in order to verify that the output characteristics have not degraded prior to loading. NASA's pyrotechnic discipline experts must evaluate and approve any deviations from the established material requirements.

Development, Qualification, & Acceptance

As mentioned above, a robust verification process is needed to show compliance with the design requirements. Thorough development testing is required prior to a device entering the qualification cycle. These tests are used to determine that the design is acceptable for the intended function, and that success will be maintained with both positive, and negative, margins on the pyrotechnic device. The positive margin tests are conducted to show that structural integrity is sustained when there is excessive explosive output. The negative margin tests are used to show that function is not compromised if the explosive material degrades over time. These tests also factor in the effects of other "unknown unknowns".

Qualification testing can begin once the development testing is completed and the operational margins are determined to be sufficient. Full Quality Assurance oversight is used during the manufacturing and testing of the the qualification lot. All anomalies are fully documented. Any disposition other than scrap for a defective unit must be accepted through the established quality system and must have NASA expert concurrence. The quantities tested must represent a sample size that is statistically significant and can meet the predetermined values for reliability and confidence. The qualifying environmental conditions are established to provide significant margin over those predicted when in actual use. A failure experienced during a non-destructive test results in loss of that unit, which may be replaced with another representative part. However, a single failure during a destructive test can lead to rejection of the entire lot.

Once a design has been fully qualified, subsequent lot builds go through a series of acceptance tests. Quality Assurance oversight is the same as used during the qualification effort. NASA mandates that the number of units expended during this process be 10% of the manufactured quantity, or 10 units, whichever is greater. The acceptance tests may expose the units to environments that are less harsh than those assessed during qualification. Any failure during destructive acceptance testing may also lead to a lot rejection. Refer to Appendix D.

Age Surveillance

Age surveillance is maintained for all pyrotechnic hardware containing energetic material. A small number of units are tested at predetermined intervals to extend the expiration date of the hardware lot. This periodic inspection determines whether or not performance has degraded over time.

Conclusion

NASA's pyrotechnics program is one of the more successful in the history of Human Spaceflight. For example, the pyrotechnic initiators NASA provide work reliably in temperatures as low as -420 ^{o}F. Each of the 135 Space Shuttle flights fired 102 of these initiators, some setting off multiple pyrotechnic devices, with no device failures. During its recent landing on Mars, the Opportunity rover fired 152 of these pyrotechnic initiators to complete the famous "7 minutes of terror." Even after traveling through extreme radiation and thermal environments on the way to Mars, every one of them worked. These initiators have even fired on the surface of Titan.

The NASA hardware design and acceptance process is extremely thorough when practiced in its entirety. Manufacturing hardware for Human Spaceflight results in a substantial amount of documentation produced and test data collected, and is a process that requires a significant amount of manpower for reviews. This investment, however, has paid huge dividends considering the flawless flight record of pyrotechnic hardware built according to these standards. This equates to tens of thousands of units successfully fired. The upfront investment of this review process is low when compared to the loss of a mission, or worse yet, a human life.

Appendix A: Example of Configuration Baseline Document

LTR	ZONE	REVISION
D		Revised Table with updated revision letters.

NEXT ASSEMBLY	SIGNATURES	DATE	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION			
N/A	DR M. W. Maples	04/11/2013	LYNDON B. JOHNSON SPACE CENTER HOUSTON, TEXAS			
	ENG M.W. Maples	04/11/2013				
	CH T. Rohloff	04/11/2013	PRODUCT BASELINE RECORD, 1.375 FRANGIBLE NUT AND BOOSTER			
DRAWING TYPE	APP M. MAPLES	04/11/13				
Non-Flight Other	QE					
	MATL		PROJECT 02241			
	STRESS		CAGE CODE	SIZE	DWG NO.	REV.
	AUTH		21356	A	SKH26152333	D
	FINAL APP	4/11/13	SCALE NA	ORG. EP2	SHEET 1 OF 3	

STATUS: Check for DCNs against the drawing.

Appendix A (Cont)

PRODUCT BASELINE RECORD
1.375 FRANGIBLE NUT AND BOOSTER
PTRS JSC 66437 Revision B
PMP JSC 66479 Revision A
CDR & Phase II Review

Description	Part Number	Lot Number
Frangible Nut	SEH26152322-301	DDB/ DDC
Booster	SEH26152324-301	DDE

Item	Document	Dash	Rev.	Description	Comments
Assembly Piece Parts					
1	SDH26152321	-003	E	Frangible Nut, 1.375 Inch	Released
2	SEH26152322	-301	A	EFT-1 Frangible Nut, 1.375 Inch	Released
3	SEH26152324	-301	NC	Booster Assembly, EFT-1 Frangible	Released
4	SEH26152101	-303	D	Booster Assembly, Frangible Nut	Released
5	SDH26152109	-006	F	Booster Housing, Frangible Nut	Released
6	SDH26152117	-001	A	Closure Disk, Booster, 1.5 Inch Frangible Nut	Released
7	SDH26152117	-002	A	Closure Disk, Booster, 1.5 Inch Frangible Nut	Released
8	SDH26152119	-001	A	Isomica Disk, Booster 1.5 Inch Frangible Nut	Released
9	SDH26152120	-001	A	PTFE Plug, Booster 1.5 Inch Frangible Nut	Released
Energy Systems Test Area (Standard) Operating Checklists					
1	ESTA-OC-2-031		F	Helium Leak Check for Explosive Components	Active
2	ESTA-OC-2-080		A	Pyrotechnic Resistance Welder Operating Procedure	Active
3	ESTA-OC-2-083		A	Operating Checklist for Pneumatic Press System 213	Active
4	ESTA-OC-2-085		C	Operating Checklist for Propellant Drying	Active
5	ESTA-OC-2-101		NC	Procedure for Operation of Low Pressure Panel, System 944	Active
6	ESTA-OC-2-106		A	Telesis Laser Marker Operating Checklist	Active
7	ESTA-OC-2-107		NEW	Operation of Vacuum Bell Jar, System 204	Active
8	ESTA-OC-2-218		A	Operation of Cincinnati Sub-Zero with LN2 Boost, System 218	Active
9	ESTA-OC-352-01200		NC	Operation of 1 Cubic Foot Cincinnati Sub-Zero with Humidity Control	Active
10	ESTA-OC-352-01807		NC	Shock Tube Detonator Initiation	Active
11	ESTA-OP-2-104		A	Operating Procedure for Hydraulic Loading and Firing Fixture	Active
Procedures					
1	SKG26152325		C	Acceptance Test Procedure, 1.375 Inch Frangible Nut and Booster Assembly	Released

DWG NO. **SKH26152333**		
CAGE CODE **21356**	SHEET 2 OF 3	REV **D**

Appendix A (Cont)

2	SKG26152326		B	Assembly Procedure, Booster Assembly, 1.375 Inch Nut	Released
3	SKG26152327		D	Frangible Nut 1.375 Inch Receiving and Inspection Plan	Released
4	SKG26152328		B	Booster Housing, Frangible Nut Booster Assembly Receiving and Inspection Plan	Released
5	SKG26152329		NC	Isomica Disk, 1.5 Inch Frangible Nut Booster Receiving and Inspection Plan	Released
6	SKG26152330		NC	Closure Disk, 1.5 Inch Frangible Nut Booster, Receiving and Inspection Plan	Released
7	SKG26152331		NC	RDX Receiving and Inspection Plan	Released
8	SKG26152332		NC	PTFE Plug, Frangible Nut Booster Receiving and Inspection Plan	Released
Test Equipment and Tooling Drawings					
1	SDH26152111		B	Zero Load Bolt	Released
2	SDH26152112		C	Washer, 1.5 Frangible Nut	Released
3	SEH26152113		D	Load Bolt, Frangible Nut	Released
4	SDH26152114		NC	Base Plate, 1.5 Frangible Nut	Released
5	Dwg# 352-015		A	Hydraulic Loading Fixture	Released
6	Dwg# 352-043		NC	Hydraulic Test Stand, 2.5" Frangible Nut	Released
7	Dwg# 352-048		E	Vacuum Cup, Helium Leak Detector	Released
8	Dwg# 352-101		A	Weld Fixture 1.5 Inch Nut Booster	Released
9	Dwg# 352-102		NC	Electrode, Spot Welding 1.5 Inch Nut Booster	Released
10	Dwg# 352-103		NC	Load Test Stand, 1.5” Frangible Nut	Released
11	Dwg# 352-105		NC	Spherical Washer Set, Hydraulic Test Stand	Released
12	Dwg# 352-106		NC	Loading Fixture, 1.5 Inch Nut Booster	Released
13	Dwg# 352-108		NC	Funnel, 1.5 Inch Frangible Nut Booster	Released
14	Dwg# 352-109		NC	Ram Guide, 1.5 Inch Frangible Nut Booster	Released
15	Dwg# 352-110		NC	PTFE Plug Reaming Tool, 1.5 Inch Frangible Nut Booster	Released
16	Dwg# 352-113		NC	Zero Load Test Fixture	Released
17	Dwg# 352-117		NC	Plug Guide, 1.5” Frangible Nut Booster	Released
18	Dwg# 352-118		NC	Vibration Fixture 1.5 Inch Frangible Nut Booster	Released
19	Dwg# 352-122		NC	Loading Ram, 1.5” Frangible Nut Booster	Released
20	Dwg# 352-124		NC	Swell Sleeve, 1.5 Frangible Nut Booster	Released
21	Dwg# 352-178		A	Washer, 1.375 Inch Frangible Nut	Released
22	Dwg# 352-180		A	Base Plate, 1.375 Frangible Nut	Released
23	Dwg# 352-185		NC	Tapered Washer Set, 1.375 Frangible Nut	Released
24	Dwg# 352-186		NC	Nut Spacer, 1.375 Inch Nut	Released
25	Dwg# 352-187		NC	Load Test Stand 1.5” Frangible Nut	Released
26	Dwg# 352-188		A	Box, Assembly	Released
27	Dwg# 352-210		C	2-1/2" Nut Loading Fixture System 210	Released
28	Dwg# 352-212		NC	Helium Leak Can System 212	Released
29	Dwg# 352-213		A	Pneumatic Press System 213	Released
30	Dwg# 352-944		A	Low Pressure Panel System 944	Released

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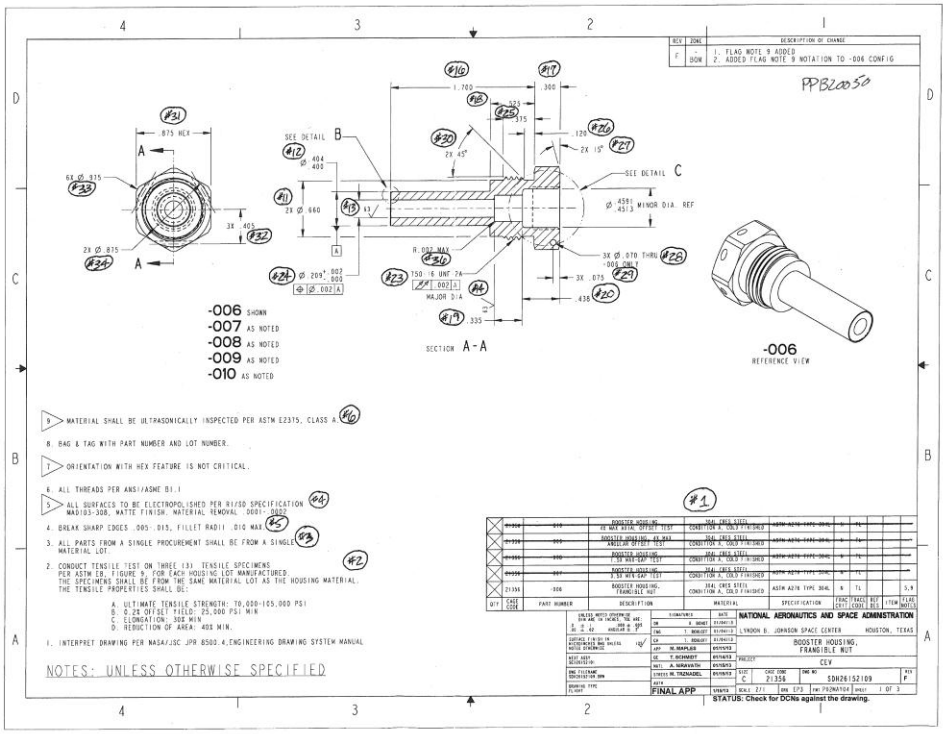
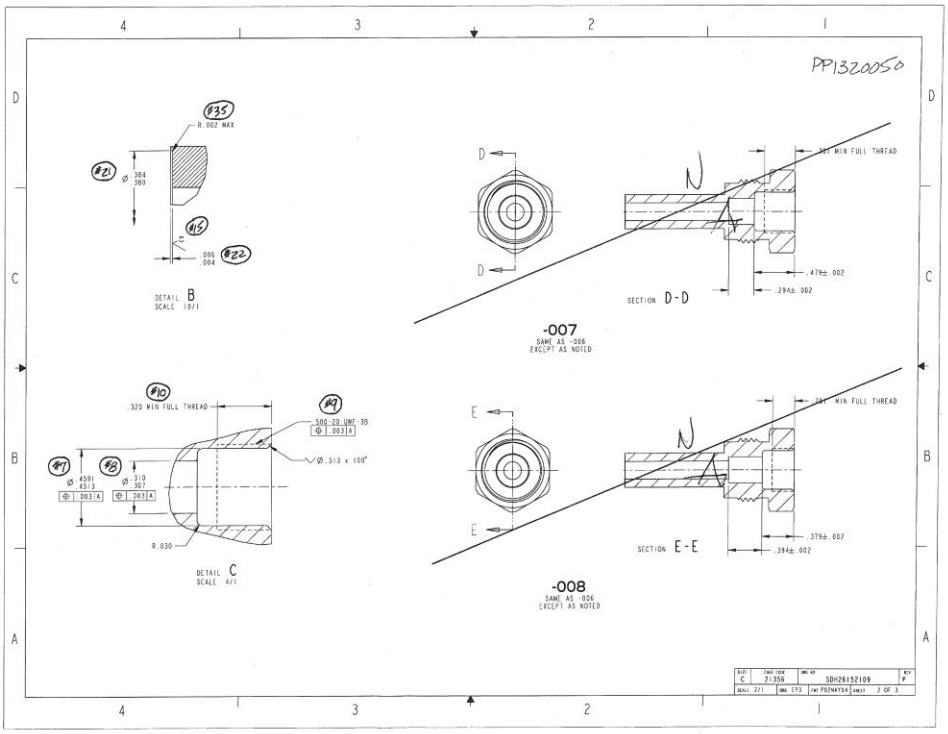
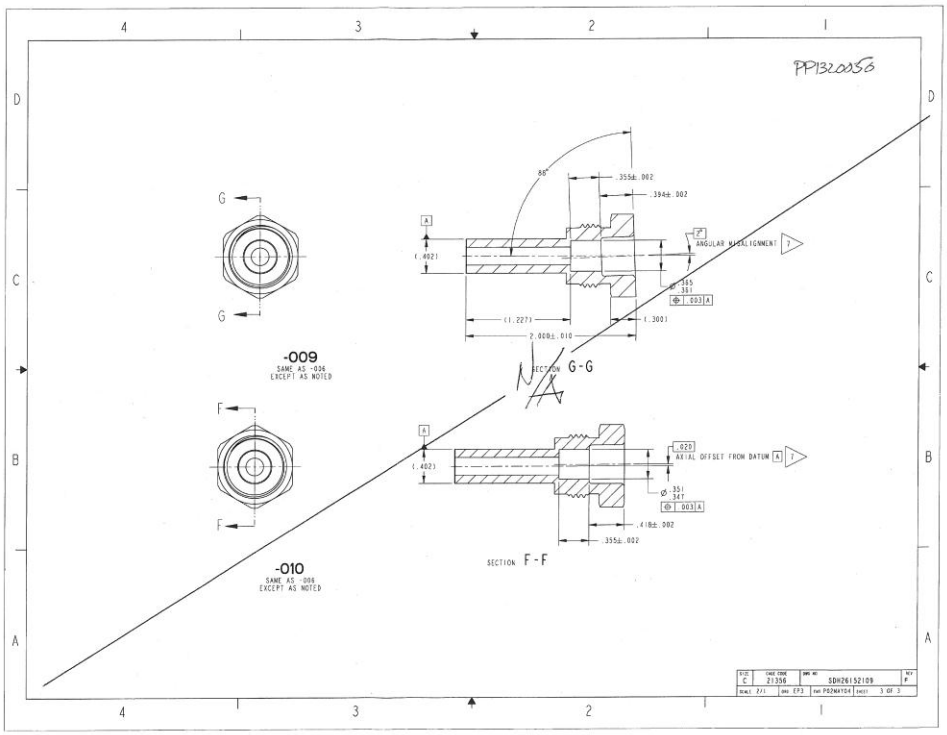
Appendix B: Example of Component Receiveing Inspection Documentation



Appendix B (Cont)



Appendix B (Cont)



Appendix B (Cont)

PP13L0050

LTR	ZONE	REVISION
B	All	Changed SDH26152109 revision from "E" to "F" in header. Inserted MIP 6 and renumbered following MIPs.

NEXT ASSEMBLY	SIGNATURES	DATE	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION			
SEH26152101	DR S. Hacker	01/16/2013	LYNDON B. JOHNSON SPACE CENTER HOUSTON, TEXAS			
	ENG N. Augustine	01/16/2013				
	CH R. Dean	01/16/2013	BOOSTER HOUSING, FRANGIBLE NUT BOOSTER ASSEMBLY RECEIVING AND INSPECTION PLAN			
DRAWING TYPE	APP S. HACKER	01/16/13				
Non-Flight Other	QE					
	MATL		PROJECT 02241			
	STRESS		CAGE CODE	SIZE	DWG NO.	REV.
	AUTH		21356	A	SKG26152328	B
	FINAL APP	1/16/13	SCALE NA	ORG. EP3	SHEET 1 OF 3	

STATUS: Check for DCNs against the drawing.

Appendix B (Cont)

PP132005 0

PART NAME: BOOSTER HOUSING, 1.5 FRANGIBLE NUT
P/N: SDH26152109-006
L/N: NUJ13HR83P
DRAWING: SDH26152109 REV F
QTY: 100

Sample for MIPs per ANSI/ASQ Z1.4-2008
General Inspection Level = II
Lot Size = 100
Sample Size Code Letter = F
Sample Size From Table II-A = 20
AQL = 0.010

Sample for MIPs per ANSI/ASQ Z1.4-2008
General Inspection Level = S-2
Lot Size = 100
Sample Size Code Letter = B
Sample Size From Table II-A = 3
AQL = 0.010

MIP #	FEATURE	ZONE	INSPECT LEVEL	QTY INSP	QTY ACC	QTY REJ	INSPECT METHOD	QA STAMP & DATE
1	304L CRES Steel Condition A Cold Finished per ASTM A276 Type 304L	A1	100%	100	100	0	CERT	SAIC 52 4/15/13
2	GENERAL NOTE 2	A4	100%	100	100	0	CERT	SAIC 52
3	GENERAL NOTE 3	B4	100%	100	100	0	REG CERT	SAIC 52
4	FLAG NOTE 5	B4	100%	100	100	0	CERT	SAIC 52
5	GENERAL NOTE 4	B4	100%	100	100	0	VISUAL	SAIC 52
6	FLAG NOTE 9	B4	100%	100	100	0	CERT	SAIC 52
7	Ø .4513 - .4591 ⊕ .003 A	2-B4	100%	100	100	0	CMM	SAIC 52
8	Ø .307 - .310 ⊕ .003 A	2-B4	100%	100	100	0	CMM	SAIC 52
9	.500-20 UNF-3B ⊕ .003 A	2-B3	100%	100	99	1	GO-NOGO GAGES	52 SAIC 4/15/13
10	.320 Min Full Thread	2-B4	100%	100	99	1	" "	PP133004 52 SAIC 4/15/13
11	2 X Ø .660	C3	100%	100	100	0	CMM	SAIC 52
12	Ø .400 - .404	C3	100%	100	100	0	CMM	SAIC 52
13	Surface Finish ≤ 63	C3	100%	100	100	0	VISUAL/ SCOPE	SAIC 52
14	Surface Finish ≤ 63	C2	100%	100	100	0	"	SAIC 52
15	Surface Finish ≤ 63	2-C4	100%	100	100	0	"	SAIC 52
16	1.700	D3	100%	100	100	0	CMM	SAIC 52
17	0.300	D2	100%	100	100	0	CMM	SAIC 52
18	0.525	D2	100%	100	100	0	CMM	SAIC 52
19	0.335	C3	100%	100	100	0	CMM	SAIC 52 4/15/13

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PP132005 2

MIP #	FEATURE	ZONE	INSPECT LEVEL	QTY INSP	QTY ACC	QTY REJ	INSPECT METHOD	QA STAMP & DATE
20	0.438	C2	100%	100	100	0	CMM	SAIC 52 4/15/13
21	Ø .380 - .384	2-D4	100%	100	100	0	GAGE PINS	SAIC 52
22	.004 - .006	2-C4	100%	100	100	0	DEPTH MIC.	SAIC 52
23	.750-16 UNF-2A ↗↗ .002 A MAJOR DIA	C3	100%	100	100	0	OPTIC. COMP.	SAIC 52 4/6/13
24	Ø .209 +.002 / -.000 ⊕ Ø .002 A	C3	100%	100	93	7	CMM	52 SAIC 4/15/13 PP130041
25	0.375	D2	II	20	20	0	GAGE PIN	SAIC 52
26	0.120	D2	II	20	20	0	GAGE PIN	SAIC 52
27	2 X 15°	C2	II	20	20	0	OPTIC. COMP.	SAIC 52
28	3 X Ø .070 THRU	C2	II	20	20	0	GAGE PINS	SAIC 52
29	3 X Ø .075	C2	II	20	20	0	OPTIC. COMP.	SAIC 52
30	2 X 45°	C3	II	20	20	0	OPTIC. COMP.	SAIC 52
31	.875 HEX	D4	S-2	3	3	0	CALIPER	SAIC 52
32	3 X .405	C3	S-2	3	3	0	OPTIC. COMP.	SAIC 52
33	6 X Ø .975	C4	S-2	3	3	0	CALIPER	SAIC 52
34	2 X Ø .875	C4	S-2	3	3	0	"	SAIC 52
35	R .002 MAX	2-D4	S-2	3	3	0	VISUAL	SAIC 52
36	R .002 MAX	C3	S-2	3	3	0	VISUAL	SAIC 52 4/15/13

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Appendix B (Cont)

BOOSTER BODY SDH26152109-006 "ACTUALS"
ON-SHORE L/N: NNJ12HB83P

I.D#	MIP #12 Ø .400-.404	MIP #24 Ø .209 -.000/+.002	MIP #16 + MIP#17 2.000 ± .010	MIP #19 + MIP #20 .773 ± .010	MIP #22 .004-.006
1	.4019	.2093	1.9977	.7716	.0056
2	.4018	.2095	1.9974	.7721	.0050
3	.4015	.2102	1.9982	.7717	.0049
4	.4016	.2110	1.9975	.7720	.0050
5	.4013	.2102	2.0003	.7720	.0050
6	.4014	.2095	1.9974	.7724	.0050
7	.4017	.2106	1.9974	.7718	.0050
8	.4017	.2101	1.9987	.7727	.0056
9	.4013	.2102	1.9980	.7715	.0053
10	.4015	.2102	1.9981	.7720	.0049
11	4012	.2103	1.9977	.7716	.0045
12	.4015	.2102	1.9977	.7715	.0045
13	.4012	.2101	1.9978	.7714	.0052
14	.4013	.2100	1.9980	.7716	.0055
15	.4015	.2094	1.9977	.7719	.0055
16	.4017	.2105	1.9979	.7711	.0051
17	.4019	.2103	1.9983	.7718	.0051
18	.4019	.2098	1.9975	.7723	.0050
19	.4018	.2101	1.9987	.7718	.0050
20	.4013	.2104	1.9977	.7714	.0049
21	.4014	.2102	1.9977	.7719	.0050
22	.4014	.2100	1.9987	.7723	.0056
23	.4014	.2101	1.9978	.7715	.0055
24	.4015	.2101	1.9980	.7718	.0049
25	.4105	.2096	1.9973	.7723	.0055

I.D#	MIP #12 Ø .400-.404	MIP #24 Ø .209 -.000/+.002	MIP #16 + MIP#17 2.000 ± .010	MIP #19 + MIP #20 .773 ± .010	MIP #22 .004-.006
26	.4015	.2102	1.9982	.7722	.0060
27	.4014	.2102	1.9981	.7716	.0050
28	.4017	.2094	1.9977	.7721	.0052
29	.4014	.2101	1.9983	.7717	.0056
30	.4015	.2101	1.9974	.7716	.0049
31	.4012	.2103	1.9979	.7713	.0050
32	.4017	.2095	1.9981	.7715	.0051
33	.4015	.2101	1.9977	.7714	.0050
34	.4015	.2103	1.9981	.7718	.0058
35	.4012	.2106	1.9976	.7719	.0050
36	.4014	.2105	1.9979	.7715	.0060
37	.4010	.2103	1.9980	.7716	.0055
38	.4018	.2107	1.9973	.7717	.0055
39	.4018	.2104	1.9989	.7719	.0058
40	.4015	.2095	1.9975	.7717	.0055
41	.4014	.2105	1.9973	.7714	.0048
42	.4007	.2103	1.9975	.7716	.0058
43	.4016	.2096	1.9972	.7719	.0057
44	.4011	.2102	1.9983	.7716	.0055
45	.4011	.2102	1.9981	.7717	.0057
46	.4013	.2102	1.9990	.7720	.0056
47	.4013	.2106	1.9977	.7717	.0052
48	.4012	.2104	1.9975	.7712	.0054
49	.4015	.2101	1.9983	.7716	.0060
50	.4015	.2095	1.9970	.7722	.0051

PP13.0055

Appendix B (Cont)

BOOSTER BODY SDH26152109-006 "ACTUALS"
ON-SHORE L/N: NNJ13HB83P

I.D#	MIP #12 Ø .400-.404	MIP #24 Ø .209 -.0004.002	MIP #16 + MIP#17 2.000 ± .010	MIP #19 + MIP #20 .773 ± .010	MIP #22 .004-.006
51	.4015	.2108	1.9980	.7719	.0050
52	.4012	.2104	1.9966	.7714	.0051
53	.4010	.2102	1.9971	.7717	.0050
54	.4016	.2102	1.9976	.7719	.0052
55	.4016	.2105	1.9980	.7712	.0052
56	.4015	.2103	1.9981	.7722	.0050
57	.4016	.2095	1.9977	.7717	.0059
58	.4012	.2104	1.9968	.7716	.0049
59	.4011	.2103	1.9963	.7711	.0042
60	.4014	.2107	1.9976	.7720	.0059
61	.4011	.2103	1.9980	.7717	.0052
62	.4014	.2104	1.9983	.7718	.0056
63	.4016	.2095	1.9979	.7721	.0050
64	.4014	.2103	1.9978	.7717	.0045
65	.4016	.2104	1.9981	.7723	.0060
66	.4013	.2101	1.9974	.7713	.0050
67	.4015	.2104	1.9975	.7715	.0053
68	.4014	.2104	1.9975	.7716	.0048
69	.4013	.2108	1.9973	.7720	.0059
70	.4015	.2103	1.9976	.7717	.0053
71	.4013	.2104	1.9974	.7717	.0048
72	.4013	.2103	1.9973	.7714	.0051
73	.4014	.2102	1.9979	.7715	.0053
74	.4014	.2105	1.9980	.7724	.0058
75	.4015	.2104	1.9974	.7715	.0055

I.D#	MIP #12 Ø .400-.404	MIP #24 Ø .209 -.0004.002	MIP #16 + MIP#17 2.000 ± .010	MIP #19 + MIP #20 .773 ± .010	MIP #22 .004-.006
76	.4014	.2103	1.9980	.7715	.0060
77	.4015	.2101	1.9966	.7711	.0053
78	.4016	.2095	1.9980	.7728	.0048
79	.4015	.2104	1.9977	.7721	.0055
80	.4013	.2103	1.9978	.7719	.0058
81	.4015	.2104	1.9981	.7723	.0059
82	.4012	.2102	1.9979	.7723	.0048
83	.4014	.2101	1.9976	.7716	.0040
84	.4015	.2101	1.9977	.7713	.0053
85	.4013	.2103	1.9983	.7720	.0050
86	.4014	.2103	1.9982	.7719	.0059
87	.4013	.2100	1.9982	.7725	.0055
88	.4016	.2101	1.9980	.7718	.0052
89	.4015	.2101	1.9987	.7717	.0054
90	.4014	.2104	1.9972	.7716	.0049
91	.4017	.2100	1.9990	.7723	.0053
92	.4021	.2095	1.9984	.7724	.0055
93	.4016	.2105	1.9981	.7715	.0053
94	.4015	.2102	1.9987	.7716	.0048
95	.4014	.2101	1.9988	.7720	.0055
96	.4002	.2103	1.9974	.7714	.0050
97	.4013	.2103	1.9982	.7718	.0051
98	.4016	.2095	1.9976	.7722	.0055
99	.4013	.2100	1.9983	.7722	.0056
100	.4012	.2103	1.9980	.7720	.0049

Appendix C: Example of Component Process Certification Documentation

PP12200B / PP13200S0

ORDER FOR SUPPLIES OR SERVICES

PAGE 1 OF PAGES 18

IMPORTANT: Mark all packages and papers with contract and/or order numbers.

1. DATE OF ORDER: 07/03/2012	2. CONTRACT NO. (If any):
3. ORDER NO.: NNJ12HD87P	4. REQUISITION/REFERENCE NO.: 4200442020
5. ISSUING OFFICE (Address correspondence to): NASA/Johnson Space Center Attn: Rochelle Overstreet/BH4 2101 NASA Parkway Houston TX 77058-3696	
6. SHIP TO: a. NAME OF CONSIGNEE: NASA/ Johnson Space Center b. STREET ADDRESS: NASA/ Johnson Space Center Attn: Rick Dean Transportation Officer, Bldg 421 2101 NASA Parkway c. CITY: Houston d. STATE: Tx e. ZIP CODE: 77058 f. SHIP VIA: Ground	
7. TO: a. NAME OF CONTRACTOR: R & G STEEL, INC. b. COMPANY NAME: c. STREET ADDRESS: 320 BROOKES DR STE 201 d. CITY: HAZELWOOD e. STATE: MO f. ZIP CODE: 63042-2744	8. TYPE OF ORDER [X] a. PURCHASE [ ] b. DELIVERY REFERENCE YOUR: Quote No. NNJ12487836Q Please furnish the following on the terms and conditions specified on both sides of this order and on the attached sheet, if any, including delivery as indicated. Except for billing instructions on the reverse, this delivery order is subject to instructions contained on this side only of this form and is issued subject to the terms and conditions of the above-numbered contract.
9. ACCOUNTING AND APPROPRIATION DATA: See Schedule	10. REQUISITIONING OFFICE: NASA/Johnson Space Center
11. BUSINESS CLASSIFICATION (Check appropriate box(es)) [X] a. SMALL [ ] b. OTHER THAN SMALL [ ] c. DISADVANTAGED [ ] d. WOMEN-OWNED [ ] e. HUBZone [ ] f. SERVICE-DISABLED VETERAN-OWNED [ ] g. WOMEN-OWNED SMALL BUSINESS (WOSB) ELIGIBLE UNDER THE WOSB PROGRAM [ ] h. EDWOSB	12. F.O.B. POINT: Destination
13. PLACE OF a. INSPECTION: Destination b. ACCEPTANCE: Destination	14. GOVERNMENT B/L NO. 15. DELIVER TO F.O.B. POINT ON OR BEFORE (Date): 08/01/2012 16. DISCOUNT TERMS: Net 30 days

17. SCHEDULE (See reverse for Rejections)

ITEM NO. (a)	SUPPLIES OR SERVICES (b)	QUANTITY ORDERED (c)	UNIT (d)	UNIT PRICE (e)	AMOUNT (f)	QUANTITY ACCEPTED (g)
	INCO TERMS 1: FOB INCO TERMS 2: Destination Accounting Info: 72EP11/6100.2615/72/FC000000/747797.06.13.13.01.1/0/000/2600/72/EXPX22012D/201E/1 Cost Center: 72EP11 GI Account: 6100.2615 Order: FC000000 WBS Element1: 747797.06.13.13.01.1 Continued ...					

18. SHIPPING POINT	19. GROSS SHIPPING WEIGHT	20. INVOICE NO.	17(h) TOTAL (Cont. pages)
21. MAIL INVOICE TO:			
a. NAME: NASA/Shared Services Center			$69,395.00
SEE BILLING INSTRUCTIONS ON REVERSE b. STREET ADDRESS (or P.O. Box): Financial Management Division (FMD) Accounts Payable Bldg 1111, C Road NSSC-AccountsPayable@nasa.gov			17(i) GRAND TOTAL $69,395.00
c. CITY: Stennis Space Center d. STATE: MS e. ZIP CODE: 39529-6000			

22. UNITED STATES OF AMERICA BY (Signature): LaToy J. Jones 7/3/12

23. NAME (Typed): LaToy J. Jones
TITLE: CONTRACTING/ORDERING OFFICER

AUTHORIZED FOR LOCAL REPRODUCTION
PREVIOUS EDITION NOT USABLE

OPTIONAL FORM 347 (Rev. 2/2012)
Prescribed by GSA/FAR 48 CFR 53.213(f)

Appendix C (Cont)

PP12200008/PP13200050

ORDER FOR SUPPLIES OR SERVICES
SCHEDULE - CONTINUATION

PAGE NO 2

IMPORTANT: Mark all packages and papers with contract and/or order numbers.

DATE OF ORDER	CONTRACT NO.	ORDER NO.
07/03/2012		NNJ12HD87P

ITEM NO. (a)	SUPPLIES/SERVICES (b)	QUANTITY ORDERED (c)	UNIT (d)	UNIT PRICE (e)	AMOUNT (f)	QUANTITY ACCEPTED (g)
	WBS Element2: 0 Item Number: 000 Commitment Item: 2600 Funds Center: 72 Fund: EXPX22012D Functional Area: 201E					
001	Inconel 718 per AMS 5662 @ 3.75" diamete	40	EA	1,688.00	67,520.00	
002	304L per ASTM A276@1.125"	30	EA	62.50	1,875.00	
	TOTAL CARRIED FORWARD TO 1ST PAGE (ITEM 17(H))				$69,395.00	

AUTHORIZED FOR LOCAL REPRODUCTION
PREVIOUS EDITION NOT USABLE

OPTIONAL FORM 348 (Rev. 4/2006)
Prescribed by GSA FAR (48 CFR) 53.213(f)

Appendix C (Cont)

PP13200050

Certificate of Conformance

I certify that on April 2, 2013, On-Shore USA furnished the supplies or services called for by Contract No. NNJ13HB83P via UPS on our packing slip 776, in accordance with all applicable requirements. I further certify that the supplies or services are of the quality specified and conform in all respects with the contract requirements including specifications, drawings, preservation, packaging, packing, marking requirements, and physical item identification (part number), and are in the quantity shown on this or on the attached acceptance document.

Date of Execution: April 2, 2013

Signature:

Title: President
On-Shore USA, LLC
1011 Sesame St.
Franklin Park, IL 60131

Appendix C (Cont)

07/23/2012 09:59 5555555555 RG STEEL PAGE 14

PP1220068 / PP1320050

OUTOKUMPU

Certificate of Test

HEAT E111656 ORDER 625846/ 03 BOL 0214497 • CERTIFICATION • 10/27/11

HOUSTON 770860000

---------- YOUR ORDER & DATE ----------
10/27/11 CUST# 1126001 CUST TAG#11101123

---------- ITEM DESCRIPTION ----------
GRADE 304L/304 Ship Condition CONDA
Size 304L RND CPA CONDA 1.1250 x 144.000 RL
Country of Melt: UNITED KINGDOM Country of Mfg.: UNITED STATES
NAFTA Country of Origin is Country of Melt

No weld repair
Free of mercury contamination, Free of radiation contamination
No WEEE relevant substances; Meets EU electrical ROHS

Total Bundles 1 Total Weight 1086

WO 2026293 Bundles: 1D

---------- SPECIFICATIONS ----------
MFG TO FINISHED BAR IN THE USA FROM BILLETS IMPORTED UNITED KINGDOM
AMS 5639M, 5647J
ASME SA182 E07-E10, Add. 11a
ASME SA479 E07-E10 A11
ASTM A182 10a
ASTM A276 10
ASTM A479/A479M 11
ASTM E112 96
ASTM A193 11 B8
Solution Annealed Condition
NACE MR0175-03, ISO 15156:03
DFARS 225.7002-2(B)(1)
UNS S30400/S30403,AISI304/30
ESP SS1 Rev 4 w/ exception
SAE AMS-QQ-S-763B
ASME SA193 E10 A11a
ASME SA320 B8 CL1 E10 A11a
ASTM A262 98 Practice E
ASTM A314 97
ASTM A484 11
ASTM A320 11 B8 Class 1
DIN 50049/EN 10204 3.1
Sol Anneal @ 1900F min/WQ
DFARS 252.225.7014 6/05
Federal Spec QQ-S-763F
Prodec Quality
NACE MR0103/mid-rad hardness

---------- MECHANICAL & OTHER TESTS ----------

Hardness as shipped	167 HB		
Hardness as shipped	(84 HRB)		
Grain size	8.0	Tensile strength,KSI (MPa)	92.3 (636)
Micro	OK	0.2% Yield Strngth,KSI(MPa)	41.0 (283)
Intergranular corrosion	OK		
		Elongation % in 4D	54.8
		Reduction of area %	76.3
		Charpy (ft lb)	0 0 0 Avg 102

---------- CHEMICAL COMPOSITION ----------

Carbon	(C)	.024	Manganese	(Mn)	1.390
Phosphorus	(P)	.031	Sulphur	(S)	.025
Silicon	(Si)	.268	Chromium	(Cr)	18.340
Nickel	(Ni)	8.140	Cobalt	(Co)	.169
Copper	(Cu)	.514	Moly	(Mo)	.300
Nitrogen	(N)	.087	Columbium	(Cb)	.015
Titanium	(Ti)	.002	Aluminum	(Al)	.004
Tin	(Sn)	.017	Vanadium	(V)	.060
Columbium/ Tantalum	(Cb+Ta)	.015			
Iron	(Fe)	Balance			
Melt Practice		EAF			
Refining Practice		AOD			
De-long Ferrite					

Knowingly & willfully falsifying or concealing a material act on this form, or making false, fictitious or fraudulent statements or representations herein could constitute a felony punishable under federal statutes. We hereby certify that the test results shown in this report are correct and accurate as contained in the records of the company and are in compliance with the specifications, codes, and standards listed above.

Outokumpu Stainless Bar, Inc.
2040 Greenbrier Pkwy.
Florence, SC 29726

M.F. Marcenio, Quality Manager MF Marcenio

Appendix C (Cont)

PP1220068/
PP1320050

Customer:
NASA/ ESTA
Houston, Tx
Requester/Phone:
Rick Dean
(281) 483-4572
Fax Number:

Cust. Control No.:
TPS#: PP1220068
Date Received:
7/25/2012
Date Completed:
7/31/2012

RITF Material Test Report

JSC Receiving Inspection and Test Facility
Johnson Space Center - Building 15 Hibay - M/S NT315
Houston, Texas 77058
Fax 281-483-0355 Voice 281-483-0366

Report Number:
120409
Description:
Inconel 718 Round Bar
Part Number:
Unknown
Part Size:
3.75" Dia. x 1" Thick
Manufacturer:
UNKNOWN
Distributor:
R&G Steel
Lot Number:
16LB
Quantity Tested:
1

Mechanical Properties

Hardness Test Results Low Limit(NA) High Limit(29 HRC) **Test Procedure -** ASTM E18

Sample ID	Pass/Fail	Scale	High Value	Low Value	Mean Value	Comments
120409-001	Pass	HRBW	100	98	99	P/F based on customer supplied specifications

Measurement of uncertainty: +/- 1

Material: Inconel 718

Chemical Properties (%)

Sample ID	Pass/Fail	Al	B	C	Co	Cr	Cu	Fe	Mn	Mo	Nb	Ni	P	S	Si	Ti	Comments
120409-001	Pass	0.460	0.003	0.028	0.21	17.98	0.041	18.01	0.079	2.91	5.15	52.62	0.004	0.001	0.06	0.99	None

Chemical analysis performed using OES and verified within 2 sigma using certified reference materials.

SPECIAL NOTES: The material was assessed to the customer supplied specification of SAE AMS 5662 with a defined maximum hardness requirement of 277 HB which converts to 29 HRC on the Rockwell Hardness scale per ASTM E140.

REPORT APPROVED BY: M. McGuire **DATE:** 7/31/2012
TITLE: Engineer

THESE TEST RESULTS RELATE ONLY TO THE SAMPLES TESTED. THIS REPORT SHALL NOT BE REPRODUCED. EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY.

Appendix C (Cont)

PP1220068 / PP1320050

Customer:
NASA/ ESTA
Houston, Tx
Requester/Phone:
Rick Dean
(281) 483-4572
Fax Number:

Cust. Control No.:
TPS#: PP1220068
Date Received:
7/25/2012
Date Completed:
7/31/2012

RITF Material Test Report

JSC Receiving Inspection and Test Facility
Johnson Space Center - Building 15 Hibay - M/S NT315
Houston, Texas 77058
Fax 281-483-0355 Voice 281-483-0366

Report Number:
120404
Description:
304L Round Bar
Part Number:
Unknown
Part Size:
1.125" Dia. x 1" Thick
Manufacturer:
UNKNOWN
Distributor:
R&G Steel
Lot Number:
E111656
Quantity Tested:
1

Mechanical Properties

Hardness Test Results Low Limit(NA) High Limit(NA) Test Procedure - ASTM E18

Sample ID	Pass/Fail	Scale	High Value	Low Value	Mean Value	Comments
120404-001	NA	HRBW	90	89	89	P/F indeterminable - no requirements specified

Measurement of uncertainty: +/- 1

Material: 304L SS

Chemical Properties (%)

Sample ID	Pass/Fail	C	Co	Cr	Cu	Fe	Mn	Mo	Ni	P	S	Si	V	W	Comments
120404-001	Pass	0.027	0.14	18.45	0.500	70.61	1.330	0.31	8.10	0.031	0.018	0.26	0.06	0.040	None

Chemical analysis performed using OES and verified within 2 sigma using certified reference materials.

SPECIAL NOTES: The material was assessed to the customer supplied specification of ASTM A276.

REPORT APPROVED BY: M. McGuire **DATE:** 7/31/2012
TITLE: Engineer

THESE TEST RESULTS RELATE ONLY TO THE SAMPLES TESTED. THIS REPORT SHALL NOT BE REPRODUCED. EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY.

Appendix C (Cont)

4-0113
PP1320050

ABLE® Electropolishing
Advanced Metal Improvement Technologies

March 28, 2013

On-Shore USA
1011 Sesame Street
Franklin Park, IL 60131

This is to certify that the following parts were processed according to standard process and your purchase order specifications:

PART NO.	SDH26152109-006 (REV F)
PART DESCRIPTION	Booster Housing
PURCHASE ORDER NO.	18365
QUANTITY SHIPPED	113 PCS.
OPERATION PERFORMED	Electropolish
PACKING LIST NO.	431903-00
LOT NUMBER	
SPEC NUMBER	
REMARKS	

CERT DESCRIPTION	EP Per RI/SD Spec MA0103-308 Type 1 .0001 - .0002 Stock Removal

ABLE ELECTROPOLISHING COMPANY

Thomas Glass
President
tomg@ableelectropolishing.com

Marcia

Phone: 1.888.868.2900 • Fax: 773.277.1655 • www.ableelectropolishing.com
CHICAGO Corporate Headquarters Production Facility: 2001 S. Kilbourn Ave. • Chicago, IL 60623

Appendix C (Cont)

P01220122 / PP1320050

WEST PENN TESTING GROUP

1010 Industrial Blvd.
New Kensington, PA 15068
Ph 724-334-1900
Fax 724-334-9785
info@westpenntesting.com

Ultrasonic Inspection Report

NASA - Johnson Space Center
2101 NASA Parkway
Houston, TX 77058

Report 10000
WO 55629
1/4/2013
Revision 1 (1-7-13)

PO PC11105848
1.125 304L-SS
Heat # E111656

Net Weight 600

Type of Test: UT Immersion
Specifications: ASTM E2375-08 Class A
Procedure: CLI-1061 Rev 12
Acceptance: CLI-1061 Rev 12 Class A

23 pieces of 304L, heat lot number E111656 were ultrasonically tested per ASTM E2375 Class A to meet requirements of drawing SDH26152109 Rev F general flag note 9.

Total Pieces Inspected	Pieces Accepted	Pieces Rejected	Reason for Rejection
23	23	0	-

The recording of false, fictitious or fraudulent statements or entries on this document may be punishable as a felony under Federal Statutes including Federal Law, Title 18, Chapter 47.
During the test and inspections, the products furnished against this order have not come in direct contact with mercury or any of its compound nor with any mercury-containing devices employing a single boundary of containment.

Inspector: ABerry UT Level 1, THenderson UT Level 2
Inspection Date(s): 1/2/2013

Respectfully submitted,

James Neidorfer, NDT Level III Operations Manager
WEST PENN TESTING GROUP, INC.

Appendix C (Cont)

EP 02241

The P-Card Web Solution - 1/11/2013

1688623

NASA

Order Report

Orders where Log No = PC11105848

Log No / Category	Order Date / Qty Ord	Ref No / Qty Rcvd	Supplier Name / UOM	Unit Price	Item Description	Total Amount	Tax Paid	Freight Paid / Charge Code	Date Promised	Date Received / Trans Amt
Cardholder: GLENN, MARTHA A										
PC11105848	12/26/2012		WEST PENN TESTING GROUP			$1,281.87	$0.00	$0.00	1/6/2012	
13	11	11	EA	$47.45	Ultrasonic testing-Inconel 718			EXPX22013D/72EP1/747797		$521.95
13	23	23	EA	$33.04	Ultrasonic testing-304L			EXPX22013D/72EP1/747797		$759.92

Comments: Requestor: Rick Dean

DELIVER TO B350/110
1/11/2013 GOODS RECEIPT ACCEPTED BY LMILES 13010078 M GLENN (C/O RICK DEAN) 352/102

1 Orders	$1,281.87	$0.00	$0.00	$1,281.87

REC'D INSPECTION BY QAD — DATE 4/15/13

*** End of Report *** — RECEIVED IN BOND — DATE 4/15/13

Copyright © 1999-2000
Credit Card Solutions, Inc.
Version 1.00 - Revision 0.00

Appendix C (Cont)

PP13200050

Certificate of Conformance

I certify that on April 2, 2013, On-Shore USA furnished the supplies or services called for by Contract No. NNJ13HB83P via UPS on our packing slip 776, in accordance with all applicable requirements. I further certify that the supplies or services are of the quality specified and conform in all respects with the contract requirements including specifications, drawings, preservation, packaging, packing, marking requirements, and physical item identification (part number), and are in the quantity shown on this or on the attached acceptance document.

Date of Execution: April 2, 2013

Signature:

Title: President
On-Shore USA, LLC
1011 Sesame St.
Franklin Park, IL 60131

Appendix C (Cont)

PP1320050

CERTIFICATE OF COMPLIANCE

Vendor: **On-Shore USA, LLC**
1011 Sesame St.
Franklin Park, IL 60131

Customer's Order number:	**NNJ13HB83P**
Line number:	**001**
Part Number:	**SDH26152109-006**
Drawing Number:	**SDH26152109 rev. F**
Quantity:	**100 each**
Raw Material Origin:	**NASA supplied**
Heat Number:	**E111656**

EXCEPTIONS TO DRAWING: Parts supplied less Note 2 (Tensile Test), and flag note 9 (Ultrasonic Inspection).

Parts furnished with this CERTIFICATE OF COMPLIANCE have been manufactured in accordance with the requirements of the above referenced drawing number and meet all requirements therein except as noted above.

Approved by Kenneth J Kosowski

Kenneth J. Kosowski
President
On-Shore USA

Appendix D: Typical Destructive & Non-Destructive Acceptance Testing

7.7 NONDESTRUCTIVE ACCEPTANCE TEST MATRIX

Table 7 - Nondestructive Acceptance Test Matrix

Test	Test Requirement	Quantity for Test
Product Examination		
Visual Inspection	4.3.1.1	100%
Weight	4.3.1.2	100%
Dimension	4.3.1.3	100%
Identification	4.3.1.4	100%
Proof Load	4.3.1.9	100%
Leakage	4.3.1.5	100%
X-ray	4.3.1.7	100%
N-ray	4.3.1.8	100%

Table 8 - In-Process Acceptance Tests

Test	Test Requirement	Quantity for Test
Explosive Load Weight	4.3.2.1	100%
Tensile Coupon Testing		
Ultimate Strength	4.3.2.2.a	3
0.2% Offset Yield	4.3.2.2.b	3
Elongation	4.3.2.2.c	3
Reduction of Area	4.3.2.2.d	3

Appendix D (Cont)

7.8 DESTRUCTIVE LOT ACCEPTANCE TEST MATRIX

Table 9 - Destructive Lot Acceptance Test Matrix

Test	Test Requirement	Booster Qty	Frangible Nut Qty
Nondestructive Acceptance Tests	4.2.3.1	100% of Lot	100% of Lot
High Temperature Storage	4.3.3.9	Lot Sample	-
Thermal Cycle	4.3.3.10	Lot Sample	9
Shock*	4.3.3.11	Lot Sample	9
Random Vibration*	4.3.3.12	Lot Sample	9
Nondestructive Acceptance Tests**	4.2.3.1**	Lot Sample	-
Electrical Bonding	4.3.1.6	Lot Sample	Lot Sample
Functional/Load Tests****	-	Lot Sample***	Lot Sample***
Margin Web Nut, Min Preload, Single Booster, Cold	4.3.5.6	1	1
Nominal Web Nut, Zero Preload, Single Booster, Cold	4.3.5.6	1	1
Nominal Web Nut, Limit Preload, Single Booster, Cold	4.3.4.1	1	1
Margin Web Nut, Min Preload, Single Booster, Hot	4.3.5.6	1	1
Nominal Web Nut, Zero Preload, Single Booster, Hot	4.3.5.6	1	1
Nominal Web Nut, Limit Preload, Single Booster, Hot	4.3.4.1	1	1
Margin Web Nut, Min Preload, Single Booster, Ambient	4.3.5.6	1	1
Nominal Web Nut, Zero Preload, Single Booster, Ambient	4.3.5.6	1	1
Nominal Web Nut, Limit Preload, Single Booster, Ambient	4.3.4.1	1	1
Nominal Web Nut, Limit Preload, Dual Booster, Cold	4.3.4.1	2	1
Nominal Web Nut, Limit Preload, Dual Booster, Hot	4.3.4.1	2	1
Nominal Web Nut, Limit Preload, Dual Booster, Ambient	4.3.4.1	2	1
Nominal Web Nut - Ultimate Static Load	4.3.5.4	-	2
Post-Fire Integrity Examination	4.3.4.2	Lot Sample	Lot Sample

* Random Vibration and Shock tests may be performed in any order.
** Post Environment NDE is for information only, and will include the following tests: Visual, Dimensional, Leakage, and X-ray.
*** Lot sample is equal to 10% of Lot or 14 nuts / 15 boosters, whichever is greater. Additional lot sample units above 14 nuts / 15 boosters (if any) shall be allocated to the functional tests in the order listed above.
**** All functional/load tests shall be configured with 12% density aluminum foam.

7.9 QUALIFICATION TEST MATRIX

Omitted

Table 10 - Reserved

Appendix E: Serial Number Traceability

Booster Assembly Serial Number Listing

P/N	L/N	S/N	Description	Status
SEH26152324-301	DDE	00001	Booster Asembly, EFT-1 Frangible Nut	Available
SEH26152324-301	DDE	00002	Booster Asembly, EFT-1 Frangible Nut	Available
SEH26152324-301	DDE	00003	Booster Asembly, EFT-1 Frangible Nut	Available
SEH26152324-301	DDE	00004	Booster Asembly, EFT-1 Frangible Nut	Available
SEH26152324-301	DDE	00005	Booster Asembly, EFT-1 Frangible Nut	Available
SEH26152324-301	DDE	00006	Booster Asembly, EFT-1 Frangible Nut	Available
SEH26152324-301	DDE	00007	Booster Asembly, EFT-1 Frangible Nut	Delivered to Lockheed
SEH26152324-301	DDE	00008	Booster Asembly, EFT-1 Frangible Nut	DLAT Unit
SEH26152324-301	DDE	00009	Booster Asembly, EFT-1 Frangible Nut	Delivered to Lockheed
SEH26152324-301	DDE	00010	Booster Asembly, EFT-1 Frangible Nut	DLAT Unit
SEH26152324-301	DDE	00011	Booster Asembly, EFT-1 Frangible Nut	Delivered to Lockheed
SEH26152324-301	DDE	00012	Booster Asembly, EFT-1 Frangible Nut	Available
SEH26152324-301	DDE	00013	Booster Asembly, EFT-1 Frangible Nut	DLAT Unit
SEH26152324-301	DDE	00014	Booster Asembly, EFT-1 Frangible Nut	DLAT Unit
SEH26152324-301	DDE	00015	Booster Asembly, EFT-1 Frangible Nut	Delivered to Lockheed
SEH26152324-301	DDE	00016	Booster Asembly, EFT-1 Frangible Nut	DLAT Unit
SEH26152324-301	DDE	00017	Booster Asembly, EFT-1 Frangible Nut	Delivered to Lockheed
SEH26152324-301	DDE	00018	Booster Asembly, EFT-1 Frangible Nut	DLAT Unit
SEH26152324-301	DDE	00019	Booster Asembly, EFT-1 Frangible Nut	DLAT Unit
SEH26152324-301	DDE	00020	Booster Asembly, EFT-1 Frangible Nut	Delivered to Lockheed
SEH26152324-301	DDE	00021	Booster Asembly, EFT-1 Frangible Nut	Available
SEH26152324-301	DDE	00022	Booster Asembly, EFT-1 Frangible Nut	DLAT Unit
SEH26152324-301	DDE	00023	Booster Asembly, EFT-1 Frangible Nut	DLAT Unit
SEH26152324-301	DDE	00024	Booster Asembly, EFT-1 Frangible Nut	DLAT Unit
SEH26152324-301	DDE	00025	Booster Asembly, EFT-1 Frangible Nut	Available
SEH26152324-301	DDE	00026	Booster Asembly, EFT-1 Frangible Nut	Available
SEH26152324-301	DDE	00027	Booster Asembly, EFT-1 Frangible Nut	Delivered to Lockheed
SEH26152324-301	DDE	00028	Booster Asembly, EFT-1 Frangible Nut	Delivered to Lockheed
SEH26152324-301	DDE	00029	Booster Asembly, EFT-1 Frangible Nut	DLAT Unit
SEH26152324-301	DDE	00030	Booster Asembly, EFT-1 Frangible Nut	Available
SEH26152324-301	DDE	00031	Booster Asembly, EFT-1 Frangible Nut	Available
SEH26152324-301	DDE	00032	Booster Asembly, EFT-1 Frangible Nut	Available
SEH26152324-301	DDE	00033	Booster Asembly, EFT-1 Frangible Nut	Available
SEH26152324-301	DDE	00034	Booster Asembly, EFT-1 Frangible Nut	Available
SEH26152324-301	DDE	00035	Booster Asembly, EFT-1 Frangible Nut	Available
SEH26152324-301	DDE	00036	Booster Asembly, EFT-1 Frangible Nut	Available
SEH26152324-301	DDE	00037	Booster Asembly, EFT-1 Frangible Nut	Available
SEH26152324-301	DDE	00038	Booster Asembly, EFT-1 Frangible Nut	DLAT Unit
SEH26152324-301	DDE	00039	Booster Asembly, EFT-1 Frangible Nut	DLAT Unit
SEH26152324-301	DDE	00040	Booster Asembly, EFT-1 Frangible Nut	Delivered to Lockheed
SEH26152324-301	DDE	00041	Booster Asembly, EFT-1 Frangible Nut	DLAT Unit
SEH26152324-301	DDE	00042	Booster Asembly, EFT-1 Frangible Nut	Available
SEH26152324-301	DDE	00043	Booster Asembly, EFT-1 Frangible Nut	DLAT Unit
SEH26152324-301	DDE	00044	Booster Asembly, EFT-1 Frangible Nut	Delivered to Lockheed
SDH26152109-006	NNJ13HB83P	45	Booster Housing, Frangible Nut	Downgraded prior to assembly (PP1330041)

Appendix E (Cont)

Booster Assembly Serial Number Listing

P/N	L/N	S/N	Description	Status
SEH26152324-301	DDE	00046	Booster Asembly, EFT-1 Frangible Nut	Delivered to Lockheed
SEH26152324-301	DDE	00047	Booster Asembly, EFT-1 Frangible Nut	Available
SDH26152109-006	NNJ13HB83P	48	Booster Housing, Frangible Nut	Downgraded prior to assembly (PP1330041)
SEH26152324-301	DDE	00049	Booster Asembly, EFT-1 Frangible Nut	Delivered to Lockheed
SEH26152324-301	DDE	00050	Booster Asembly, EFT-1 Frangible Nut	Available
SEH26152324-301	DDE	00051	Booster Asembly, EFT-1 Frangible Nut	DLAT Unit
SEH26152324-301	DDE	00052	Booster Asembly, EFT-1 Frangible Nut	DLAT Unit

Appendix F: Sample Flight Certification

National Aeronautics and Space Administration

Lyndon B. Johnson Space Center
2101 NASA Road 1
Houston, Texas 77058-3696

21 August 2014

Pyrotechnic Hardware EFT-1 Certification Record

This record is to certify that NASA-JSC representatives have reviewed all manufacturing and lot acceptance test data pertaining to the following lot of pyrotechnic hardware. Based on this review the hardware listed below is certified as acceptable for Orion Exploration Flight Test #1 (EFT-1) use. No scheduled maintenance is required for this hardware.

Part Name:	EFT-1 Frangible Nut Booster Assembly
Part Number:	SEH26152324-301
Lot Number:	DDE
Expiration Date:	7-31-2017
Explosive Mix:	BAE12F029-088
Serial Numbers:	00007, 00009, 00011, 00015, 00017, 00020, 00027, 00028, 00040, 00044, 00046, 00049

22AUG2014
Technical Monitor

08/22/14
System Manager, Orion Pyrotechnics

8/22/14
NASA Quality Engineering