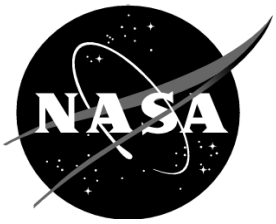
Process Specification for the Semi-Automatic and Machine Stud Welding of Non-Flight Hardware

Engineering Directorate

Structural Engineering Division

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	REVISIONS	
VERSION	**CHANGES**	**DATE**
Baseline	Original version	11/9/99
A	Periodic review. Few editorial changes.	01/26/04
B	Periodic review. Few editorial changes. Added Definitions section. Reformatted to match new formatting requirements. Peer reviewed amongst ES and NT.	06/02/20
C	Periodic review. Updated signatures and date. Minor rewording of various sections for clarity. Reformatted section numbering.	03/31/26

1.0 SCOPE

This process specification provides the requirements that govern the semi-automatic and machine stud welding of non-flight hardware. Procedural and quality assurance requirements are given. All work instructions and Weld Procedure Specifications (WPS) used during welding shall satisfy the requirements of this process specification and its applicable documents.

2.0 APPLICABILITY

This process specification applies to the stud welding of non-flight hardware fabricated under the control of the NASA/Johnson Space Center (JSC) and which utilizes welding equipment that automatically controls the weld timing, power and/or application pressure. Stud welding by capacitor discharge methods (CDSW) as well as by the drawn arc methods (DASW) is covered by this specification.

The term "non-flight hardware" refers to any hardware made for facilities structures and equipment, ground support equipment, training, mock-up mission equipment, engineering prototype, development hardware, ground-based structures, and/or test equipment. Furthermore, stud welding performed under this specification shall only be used for components that are minimally loaded and fail-safe attachments that are not man-rated.

2.1 Deviations and Waivers

Any deviations or waivers regarding the use of this process specification shall be requested in writing by the outside vendor. This request shall be directed to the responsible M&P organization with the appropriate justification and rationale. A written response will be provided upon such a request.

3.0 USAGE

This process specification shall be called out on the engineering drawing by a drawing note with the following general format:

WELD AND INSPECT PER NASA/JSC PRC-0011

3.1 DESIGN REQUIREMENTS

a) All engineering drawings shall depict welded joints using the applicable symbols described in AWS A2.4.

b) The parts list (bill of materials) shall contain the stud material, material specification, stud length, configuration (i.e., threaded, flanged or non-flanged, etc.), thread size and pitch, metallurgical condition (e.g., ¼ hard, ½ hard, etc.) if applicable, and surface finish (if applicable).

3.2 WORK INSTRUCTIONS

Work instructions shall be generated for implementing this process specification. The work instructions shall contain sufficient detail to ensure that the manufacturing process produces consistent, repeatable products that comply with this specification. At JSC, these work instructions are approved as Detailed Process Instructions (DPI) that describe in a detailed, step-by-step format the required procedures, equipment, and materials to be used for conducting a given process.

If this manufacturing process is to be performed by an outside vendor, work instruction development shall be the responsibility of the vendor. The contractor shall ensure that the work instructions meet the requirements of this process specification.

4.0 REFERENCES

The standards listed below shall be considered a part of this specification to the extent specified herein. Unless otherwise indicated, the revision that is in effect on the date of invitation for bids or the date of request for proposals shall apply.

a. American Welding Society (AWS) Standards

ANSI/AWS A2.4	Standard Symbols for Welding, Brazing and Nondestructive Testing
ANSI/AWS A3.0	Standard Welding Terms and Definitions
ANSI/AWS B2.1	Specification for Welding Procedure and Performance Qualification
ANSI/AWS QC-1	Standard for AWS Certification of Welding Inspectors

b. NASA/JSC Documents

JPG 1700.1G	NASA/JSC Requirements Handbook for Safety, Health And Environmental Protection
JPR 8500.4	Engineering Drawing System Requirements
SOP-007.1	Preparation and Revision of Process Specifications

5.0 MATERIAL REQUIREMENTS

All base materials used in the welding of hardware per this process specification, shall meet the requirements of an applicable commercial specification (e.g., ASTM, AMS, etc.). Alternatively, a manufacturer's specification may be used but it must be approved by the responsible M&P organization.

5.1 EQUIPMENT

The equipment used to produce the welds shall consist of an electrical energy source (i.e., power supply), welding gun and cables, controller and grounding cables.

5.1.1 Power Supply

The power supply shall have an adequate means of controlling the energy applied to the weld zone. The primary AC power line source shall be regulated, or the power supply shall have means for internal voltage regulation. Regulation shall be within ± 2 percent for line voltage variations of ± 10 percent. Energy source indication meters shall have a minimum accuracy of ± 0.5 percent.

5.1.2 Welding Gun

The welding gun shall be designed for being held manually and shall provide for readily adjusting the force applied to the stud. The gun's pressure applying mechanism (e.g., spring assembly, etc.) shall be designed such that it can provide adequate repeatability demonstrable via weld procedure qualification.

5.1.3 Tooling and Fixtures

Tooling required to locate or assist in the assembly of hardware to be welded shall be designed to preclude any secondary current path that will allow current to be shunted away from the gun, stud, or substrate.

5.1.4 Welding Equipment

The welding equipment shall be qualified as a system that includes at a minimum, the power supply, welding gun, controller and all interconnecting cables.

6.0 PROCESS REQUIREMENTS

All weldments shall be fabricated according to the requirements of this process specification. The requirements of the applicable codes and standards listed in section 4.0 shall be met as specified by this PRC based on the design and intended function of the hardware. Certain paragraphs of this process specification may be abbreviated restatements taken from the applicable standards and are included here for clarification. The remaining paragraphs of this process specification may represent requirements imposed in addition to the basic requirements of the applicable codes and standards.

All stud welding shall be performed using Welding Procedure Specifications (WPS) that have been qualified in accordance with the requirements of section 7.1.

6.1 PROCESS-SPECIFIC REQUIREMENTS

6.1.1 Weld Circuit Interconnection

Prior to the start of each qualification, preproduction, production, and/or requalification welding, the weld circuit interconnections shall be inspected to ensure that they are tight, clean, and corrosion free.

6.1.2 Gun Setup and Alignment

Prior to the start of each qualification, preproduction, production, and/or requalification welding, the gun chuck, spark shield, lifting mechanism (as applicable) and all related essential components shall be checked per the WPS requirements, and adjusted as necessary.

6.1.3 Gun Inspection and Alignment

Chucks, spark shields, and all related essential components shall be inspected before the start of each qualification, preproduction, production, and/or requalification welding. They shall also be continuously monitored for conditions that may impede welding techniques and/or weld quality. Upon discovery of any undesirable condition, the component(s) shall be cleaned, dressed, or replaced, as required.

6.1.4 Gun Force

Gun force shall be set to per the WPS assigned. Gun force shall be verified by making test welds on non-production material, and adjusted if necessary, prior to the start of every shift, or prior to every different production or lot/batch run, and at any interval(s) deemed necessary by the operator or responsible engineering personnel.

7.0 PROCESS VERIFICATION

A Welding Procedure Specification (WPS) shall be qualified for each unique weld type to be produced, by conforming to the requirements below before the production welds are made. An existing qualified WPS for one unique weld type may be used for a new engineering drawing, provided that the essential weld variables are met.

7.1 QUALIFICATION OF WPS

The actual welding variables, methods, practices, specific tooling requirements, and test results used during WPS qualification shall be recorded on a Procedure Qualification Record (PQR). Welding procedures shall be qualified to the requirements of AWS B2.1 at a minimum, with the exception that only one stud weld

cross section is required for conditions where metallurgical examination is necessary.

7.2 REQUALIFICATION OF WPS

Requalification of the WPS shall be required when any of the following conditions exist:

a) The weld system has been placed on a different external power source except when the power supply has a means for internal power regulation,
b) A WPS is proposed to be used on a different model or make of weld system or systems other than that used for the initial qualification,
c) Major maintenance has been performed on the weld system. Major maintenance includes replacement of the power supply, major repair of the power supply requiring entrance into the controller or transformer cabinet, replacement of the weld head, or replacement or change in length of any of the interconnecting cables,
d) Preproduction weld samples do not meet requirements and no assignable cause for the failure can be determined.

Requalification may be performed with fewer total test sample requirements than that required for an initial qualification for a unique weld type. For requalification, 3 total weld samples shall be produced and submitted as a lot. All 3 samples shall be subjected to visual inspection and destructive bend or torque testing and shall meet the applicable requirements specified herein. No requalification specimens from the 3 submitted shall fail any of the requirements as stated herein. Requalification results shall be documented on a PQR with a specific notation made indicating “requalification”. If the requalification activities result in any welding parameter deviations that exceed the range specified in Table 1 for that parameter, then the level of testing in 7.1 shall be required.

7.2.1 Essential Variables

All essential variables (as determined applicable by the responsible M&P engineering organization) shall be addressed and identified on a qualified WPS and the supporting PQR. These essential variables are listed in Table 1 (as applicable).

7.3 QUALIFICATION SAMPLES

7.3.1 General

The manufacturing organization is responsible for qualifying the welding process. Actual studs that will be used in production shall be used as qualification and preproduction control samples except that the length may vary to accommodate the required testing. Substrate base metal of the same material and surface condition

of the actual components used in the design shall also be used.

TABLE 1 -- ESSENTIAL WELDING VARIABLES

NUMBER	ESSENTIAL VARIABLES	VARIABLE RANGE
1	Primary Power Source for System	NONE
2	Power Supply - Make and Model	NONE
3	Weld Gun - Make and Model	NONE
4	Interconnecting Cable Size	NO DECREASE
5	Interconnecting Cable Length	NO INCREASE
6	Stud Material Type	NONE
7	Stud Material Metallurgical Condition	NONE
8	Stud Nominal Cross-Sectional Thickness	± 10 percent
9	Stud Surface Finish	NONE
10	Stud Contact Surface Nominal Shape	NONE
11	Substrate Material Type	NONE
12	Substrate Metallurgical Condition	NONE
13	Surface(s) Condition of Base Materials	NONE
14	Chuck Material Type	NONE
15	Weld % Power (or Stored Voltage)	± 10 percent
16	Number of Weld Pulses	NONE
17	Weld Pulse Width	NONE
18	Force Applied to Stud	± 10 percent
19	Current Type (AC or DC)	NONE
20	Addition or Deletion of a Ferrule	NONE
21	Process Type (Capacitor Discharge or Drawn Arc)	NONE

7.4 QUALIFICATION MATERIALS

For each unique type of weld to be produced, a minimum of 10 sample welded studs shall be produced for an initial procedure qualification and submitted as a lot. Weld control settings shall not be varied nor shall any maintenance other than weld gun component cleaning be performed on the equipment during the production of the qualification samples. The qualification sample set shall be acceptable to all of the following 3 levels of quality control for successful qualification: 1) visual inspection, 2) destructive bend testing, and 3) destructive torque or tensile testing. For weld types where the stud and the substrate material are different alloys (or where the stud and/or the substrate are plated with a different alloy), metallurgical examination shall be required. In such cases, a total of 11 samples shall be submitted as a set, and one (1) of these samples shall be subjected to metallurgical/metallographic examination.

7.5 VISUAL INSPECTION

All stud weld specimens shall be visually inspected per section 7.4. If any of the individual samples from the set fail to pass the visual inspection requirements, an additional sample shall be allowed to be welded and submitted to replace it, one time only. If more than 2 of the original samples fail the visual inspection requirements, further weld parameter development or process analysis to determine the cause for the rejection is required prior to submitting another set of samples for testing to the requirements of this specification.

7.6 DESTRUCTIVE BEND TESTING

Five (5) weld samples from the set submitted shall be bend tested per AWS B2.1. Acceptance shall be based on that given in AWS B2.1.

If any of the individual samples from the 5 bend tests fails, 2 additional stud samples may be welded and submitted for inspection and testing as part of the initial sample set, one time only. If more than 1 of the original 5 samples fails the bend test described above, further weld parameter development or process analysis to determine the failure cause is required prior to submitting another set of samples for testing to the requirements of this specification.

7.7 DESTRUCTIVE TORQUE TESTING

Five (5) weld samples shall be torque tested per AWS B2.1 from the set submitted. Acceptance shall be based on that given in AWS B2.1.

If any of the individual samples from the 5 torque tests fails, 2 additional stud samples may be welded and submitted for inspection and testing as part of the initial sample set, one time only. If more than 1 of the original 5 samples fails the torque test described above, further weld parameter development or process analysis to determine the failure cause is required prior to submitting another set of samples for testing to the requirements of this specification.

7.8 DESTRUCTIVE TENSILE TESTING

As an alternative to torque testing, five (5) weld samples shall be tensile tested per AWS B2.1 from the set submitted. Acceptance shall be based on that given in AWS B2.1.

If any of the individual samples from the 5 tensile tests fails, 2 additional stud samples may be welded and submitted for inspection and testing as part of the initial sample set, one time only. If more than 1 of the original 5 samples fails the tensile test described above, further weld parameter development or process analysis to determine the failure cause is required prior to submitting another set of samples for testing to the requirements of this specification.

7.9 METALLURGICAL EXAMINATION

As required for dissimilar welds, one (1) of the 11 samples shall be sectioned, mounted, polished, and etched for metallurgical examination. The weld shall be examined and interpreted by a metallurgist qualified to interpret weld metallographs. Acceptance shall be based on that given in AWS B2.1. If these criteria cannot be met, further weld parameter development or process analysis to determine the cause for the rejectable condition is required prior to submitting another 11 samples for testing to the requirements of this specification. Photomicrographs of the prepared samples shall be taken and retained with the PQR.

7.10 PROCESS DOCUMENTATION REQUIREMENTS

The WPS, PQR, and WOPQ shall be prepared and retained as a permanent record and made available upon request to the responsible M&P organization for review**.** These procedures must contain, at a minimum, all of the essential welding parameters, an identification of the welding equipment, and include any pertinent tooling information. One copy of the WPS shall be maintained in the vicinity of the welding station and shall be readily accessible by the welders, inspectors, supervision, and engineering.

7.11 WELDING PROCEDURE SPECIFICATION

A Welding Procedure Specification (WPS) is a qualified written working procedure that must be developed before beginning production for each unique weld type to be produced. Qualification support documentation in the form of a Procedure Qualification Record (PQR) shall be maintained on file to show proof of process/procedure capability using the WPS. The WPS shall be traceable by means of serialized nomenclature and shall show traceability to the applicable PQR(s). The WPS used for production welding shall meet the requirements of AWS B2.1 except as specified herein and shall be certified by the responsible M&P organization at the operating facility, prior to use in production. If a qualified WPS does not exist prior to welding of production parts, one shall be qualified according to the requirements stated herein. Any appropriate WPS format may be used.

7.12 PROCEDURE QUALIFICATION RECORD

A Procedure Qualification Record (PQR) is documentation to support the welding procedure specification to show proof of process/procedure capability. A PQR shall be unique and traceable, by means of serialized nomenclature. The PQR shall be process-specific and specific to a unique weld type. Data required in the PQR shall include detailed descriptions of the test coupon configurations and joint designs, all pertinent material specifications, all pertinent essential process variables used, all destructive and nondestructive test results from the qualification sample set, and all required certifications from the approving organization. The PQR shall be approved

by the responsible M&P organization at the operating facility. Any appropriate PQR format may be used.

7.13 WELDING OPERATOR PERFORMANCE QUALIFICATION

A Welding Operator Performance Qualification (WOPQ) is documentation that shows that a welder has been tested in accordance with NASA/JSC PRC-0011 and shown competent to produce a sound weld for a specific welding process/base material combination/equipment/system.

8.0 PROCESS QUALIFICATION

Process verification shall consist of visual inspection as described further in section 7.0. In special cases, in process testing (IPT) may be used where visual inspection of the stud welds are not possible. IPT shall consist of at least one test weld after every 50th production weld (or more frequent as determined by the responsible M&P organization). The test weld shall be visually examined by the operator and then bend tested. The stud shall be bent a minimum of 90° and no failure of the weld shall be allowed. Alternatively, the stud shall be torque tested to failure. No failure of the weld shall be allowed and the failure shall be in the stud shank or the base substrate.

8.1 PREPRODUCTION WELDING VERIFICATION

One (1) preproduction weld sample shall be prepared for each unique type of weld using the appropriate qualified WPS. The sample shall be visually inspected, in accordance with section 7.3, and bend tested, in accordance with section 7.6 (as an alternate to bend testing, torque testing may be performed in accordance with section 7.7). The preproduction sample shall be made and tested before the welding of the production welds and under the following conditions:

a) At the start of a production shift or the change of production shifts,
b) Upon replacement of the gun chuck or any component of the pressure (force) mechanism,
c) Following evidence of severe metal expulsion,
d) Following a weld misfire or no weld condition where a weld has been attempted but not made and no assignable cause can be determined,
e) Where a different operator was assigned to the workstation to continue a job,
f) After every 50^{th} weld made for applications where visual inspection of the final weld is not possible,
g) If an inspector requests to halt production to sample the process output by bend, torque or tensile testing.

A different WPS may be alternated within a production welding session provided the above requirements are met.

8.2 WELD VERIFICATION

Prior to any process which would preclude inspection of the final production welds, all preproduction test welds and workmanship shall be inspected for conformance to the requirements of this standard and the engineering drawing. If a nonconformance is identified, the process shall be halted and dedicated process analysis efforts shall be made to determine the cause for the nonconformance (or possible nonconformance).

8.3 VISUAL INSPECTION

All welds (where possible) shall be inspected visually by an AWS Certified Welding Inspector (CWI) qualified to AWS QC-1 and documented accordingly for engineering disposition. The welds shall conform to the following visual inspection criteria:

a) **Cracked Weld** - Any weld that exhibits a crack in the weldment shall be rejected.
b) **Flash** – There shall be evidence of weld flash around the circumference of the stud at the weld interface. However, non-fusion on the legs of the flash and small voids as described in c) below shall be acceptable.
c) **Blow Holes, Pits, and Voids** - Any weld that exhibits pits or related voids at the weld interface that exceeds 20% of the circumference of the weld shall be rejected. This includes pits and voids caused by metal expulsion.
d) **Open Weld** - An open weld shall be rejected. An open weld is one in which a weld has been attempted but little or no bonding has occurred.
e) **Missed Weld** - Any weld that has been specified on the drawings but has been overlooked by the welding operator shall be identified and welded to meet the drawing requirements.

If a weld is rejectable per the above criteria but intact, further testing as described below may be applied to validate the weld integrity. The stud may be bent at an approximate 15° angle away from the visible defect. If no failure occurs, the stud shall be bent back straight and shall be considered acceptable. As an alternate, the stud may be torque tested to the requirements of AWS B2.1, without exhibiting failure. The stud shall then be considered acceptable.

8.4 WELD REPAIRS AND REWORK

Any stud weld that has been indicated as having a defect (with the exception of an Open Weld or a Missed Weld) as listed in 7.3, or as not meeting the requirements specified on the drawing, may be removed and rewelded at the same location where the original weld was attempted. However, all rewelding shall be performed with a new stud. Studs shall be removed by mechanical means and the surface dressed by grinding and/or sanding to provide a clean, void free surface for rewelding. An Open or Missed Weld shall be reworked to provide an initial weld per the engineering drawing. If a reweld attempt is unsuccessful, the process shall be halted and

dedicated process analysis efforts shall be made to determine the cause for the nonconformance (or possible nonconformance). All rewelds shall be performed using the WPS used for the original weld or a specific qualified WPS for that repair and shall meet all of the requirements of the original drawing and any additional requirements that are documented in the WPS.

9.0 TRAINING AND CERTIFICATION OF PERSONNEL

9.1 TRAINING

If welding operator training is considered necessary prior to qualification/requalification training (when necessary) should consist of practice using the facility welding equipment and a specific WPS to demonstrate proficiency, under the supervision of a qualified/certified welding operator.

Electric stud welding is a potentially hazardous joining process because of the high energies involved. Training shall include adequate exposure to all stud welding equipment manufacturer's instructions and applicable industry standards relating to safety.

Safety related documents listed in section 4.0 of this PRC form a part of these safety precautions and notes to the extent specified herein. The latest revision of these documents at the time of invitation for bid from the procuring agency shall always apply.

9.2 WELDING OPERATOR QUALIFICATION

Stud welding of non-flight hardware to this specification shall be performed by a welding operator qualified and certified in accordance with NASA JSC PRC-0011. Sufficiently detailed records shall be maintained by the manufacturing organization executing the process(es). These records shall be made available to the responsible M&P organization upon request.

Welding operator qualification tests may be executed in any position and the qualification is valid for welding in all positions.

Minimum requirements for qualification/certification shall be demonstrated by any of the following:

a) The operator must have successfully performed a PQR qualification or requalification to a written WPS per this specification, or
b) The operator must have been judged competent in the process and use of the equipment, by the responsible M&P organization, by successfully demonstrating the application of a qualified WPS. This shall include demonstration to the certifying representative, machine operation, schedule/parameter setup/selection, gun setup, and weld cycle execution.

10.0 DEFINITIONS

The following definitions (and associated acronyms) shall apply to this entire document:

1. **Capacitor Discharge Stud Welding (CDSW)** – A welding process which generates the required heat for melting of the substrate and stud materials by producing a very short duration electric arc (e.g., 3 to 6 ms) from the rapid discharge of electrical energy stored in a bank of capacitors. Stud welding by this process does not usually require that a protective ferrule be used.

2. **Drawn Arc Stud Welding (DASW)** – A welding process which generates the required heat for melting of the substrate and stud materials by producing a relatively long duration arc (e.g., greater than 6 months) produced from a precisely timed discharge of direct current (DC) energy. Stud welding by this process usually requires that a protective ferrule be used to contain the molten metal and shield the arc.

3. **Essential Variable** - A variable in the welding process that must be controlled to ensure repeatable weld quality.

4. **Procedure Qualification Record (PQR)** – a detailed written record of the process that has been qualified. The record shall include all the applicable inspection and tests that were conducted and a record of the results of those tests. The PQR shall be signed (certified) by the responsible organization overseeing the welding operations.

5. **Repair** – an action taken to correct a production deficiency in the hardware that results in the hardware not meeting the original design but is fully functional and serviceable as intended by the design.

6. **Rework** – an action taken to correct a production deficiency in the hardware that results in the hardware meeting the original design and is fully functional and serviceable as intended by the design.

7. **Unique Weld Type** - Those weld joint configurations that differ from one another in any of the following respects:

    1. Stud Material Type
    2. Stud Material Metallurgical Condition
    3. Stud Nominal Cross-sectional Thickness
    4. Stud Surface Finish
    5. Stud Contact Surface Nominal Shape
    6. Substrate Material Type

7. Substrate Metallurgical Condition
8. Surface(s) Condition of Base Materials

9. **Welding Operator Performance Qualification (WOPQ)** – a detailed written record which provides proof that a process operator (welding operator) has been tested and certified to be competent and capable of executing the process per a written welding procedure specification. The WOPQ shall be formally approved (certified) by the engineering or inspection authority from the facility carrying out the process.

10. **Welding Procedure Specification (WPS)** – a detailed written procedure that is used by a welder to ensure that the execution of the qualified process is carried out as intended.