Process Specification for the Resistance Spot Welding of Battery and Electronic Assemblies

Engineering Directorate

Structural Engineering Division

March 2026



National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

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	REVISIONS	
VERSION	**CHANGES**	**DATE**
--	Original version	04/01/1996
A	Expanded content throughout. Re-specify qualification requirements.	10/29/1997
B	Formatting changed process owner, rewrite numerous sections for clarification, deleted requirement for WIR, deleted section 8.2 on audits, and added section 8.3 on WOPQ.	07/22/1999
C	Add tolerance range to base material component thickness(es), remove requirement for certification of welding inspectors by the AWS, remove NASA/MSFC reference documents in 4.0, add item 21 to Table 1, revise 6.1, 7.0, 7.1, 7.3, 8.1, 8.2, and 8.3.	03/24/2000
D	Routine ISO review.	02/17/2004
E	Major revision to the 6.2.4.5 METALLURGICAL EXAMINATION requirements. Added MTR requirement to 5.0. Modified format to SOP-007.1 requirements.	12/12/2019
F	Periodic review. Updated signatures and date. Minor rewording of various sections for clarity.	3/31/2026

1.0 SCOPE

This process specification provides the requirements that govern the Resistance Spot Welding (RSW) of battery tabs and component wires/leads to batteries, battery tabs, or other associated electronic components. Procedural and quality assurance requirements are given. All work instructions and Weld Procedure Specifications (WPSs) used during welding shall satisfy the requirements of this process specification and its applicable documents.

2.0 APPLICABILITY

This process specification applies to the RSW of battery assemblies and associated electronic flight and non-flight hardware fabricated under the control of the NASA/Johnson Space Center (JSC). RSW with opposed electrodes (i.e., referred to herein as "opposed welding") is considered as well as RSW with gapped electrodes (i.e., referred to herein as "series welding"). Battery assemblies are considered to be non-structural with no load carrying capacity and shall be either potted, taped, shrink wrapped, or installed in a rigid containment to preclude stressing the tabs and lead wires.

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-0009

3.1 DESIGN REQUIREMENTS

a) The design of welded joints shall conform to the applicable hardware design handbooks contained in the Engineering Standards Library.

b) All engineering drawings shall depict welded joints using the applicable symbols described in AWS A2.4 Standard Symbols for Welding, Brazing, and Nondestructive Examination**.**

c) As required, all engineering drawings shall specify the minimum number and maximum number of resistance welded spots required for each connection. In any case, there shall be no less than two weld spots per connection. Connections which will accommodate only one spot shall be avoided where possible.

d) As applicable, all engineering drawings shall specify the maximum electrical resistivity allowed for each connection. Where resistivity is not specified, measurements shall not exceed $1.0 m\Omega$.

e) When welding occurs onto battery cells, the parts list shall contain the battery manufacturer, size, model/type number, and voltage rating.

f) The parts list shall contain the tab or contact material, specification, thickness, width, metallurgical condition (e.g., ¼ hard, ½ hard, etc.) and surface finish as applicable.

g) The parts list shall contain component leads (i.e., diode leads) gage, material, and metallurgical condition (e.g., metallurgical, surface finish, etc.) and surface finish as applicable.

h) Stranded wire shall not be resistance spot welded.

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 (DPIs) 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 D17.2	Specification for Resistance Welding for Aerospace Applications

b. NASA/JSC Documents

JPG 1700.1	NASA/JSC Requirements Handbook for Safety, Health and Environmental Protection

SOP-007.1	Preparation and Revision of Process Specifications

c. RWMA Documents

No Document Number	NASA/JSC Requirements Handbook for Safety, Health and Environmental Protection
SOP-007.1	Preparation and Revision of Process Specifications

d. SAE/Aerospace Material Specification (AMS) Documents

AMS 2690	Parallel Gap Welding Microelectronic Interconnections to Thin Film Substrates

5.0 MATERIAL AND EQUIPMENT REQUIREMENTS

Materials used in the welding of electronically related flight hardware should meet the requirements of an applicable material specification unless otherwise specified on a drawing. An applicable commercial material specification or a manufacturer's material specification shall be used. Mills test reports {MTRs) are required when purchasing the nickel battery tab material. The tabs shall be commercially pure nickel alloy made of either nickel 201 (preferred) or nickel 200.

5.1 EQUIPMENT

The equipment used to produce the welds shall consist of an electrical energy source, electrodes, and a means of applying mechanical pressure to the materials to be welded.

5.1.1 POWER SUPPLY

The power supply shall have an adequate means of controlling and indicating the energy applied to the weld zone. The power supply shall have means for internal voltage regulation if there is no such regulation on the primary AC power line source. Regulation shall be within ±2% for line voltage variations of ±10%. Energy source meters shall have a minimum accuracy of ±2%.

5.1.2 WELDING HEAD

The welding head shall be of low-inertia design and provide a means of efficiently controlling electrode force. The electrode force shall be repeatable to within ±5%.

5.1.3 ELECTRODES

The composition of electrodes shall conform to the Resistance Welder Manufacturer's Association (RWMA) alloy classifications or the electrode manufacturer's classifications. Each electrode shall be identified according to the RWMA category or manufacturer's classification, body size, configuration, and tip size. Custom electrodes are allowed,

however, the specific electrode materials and configuration shall be considered an essential variable.

5.1.4 TOOLING AND FIXTURES

Tooling required to locate or assist in the assembly of batteries to be welded shall be designed to preclude any secondary current path that will allow current to be shunted away from the electrodes or through battery cells.

5.1.5 WELDING EQUIPMENT QUALIFICATION

The welding equipment shall be qualified as a system that includes at a minimum, the power supply, weld head, electrodes, and interconnecting cables. Qualification of a Welding Procedure Specification also qualifies the system. Otherwise, qualification of a system shall be per 6.2.2.

5.1.6 FORCE GAUGE

Devices used to determine electrode force shall have a minimum accuracy of ±5%.

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 are abbreviated re-statements taken from the applicable standards and are included here for the 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 resistance welding shall be performed using Welding Procedure Specifications (WPS) that have been qualified in accordance with the requirements of Section 7.0.

6.1 PROCESS-SPECIFIC REQUIREMENTS

6.1.1 WELD SYSTEM INSPECTION AND CHECK OUT

Prior to the start of each qualification, preproduction, production, or requalification lot, and at any interval(s) deemed necessary by the operator or engineering, the following items shall be addressed and any discrepant condition corrected as required. Weld circuit interconnections shall be inspected to ensure that they are tight, clean and corrosion free. Electrode alignment shall be checked per the WPS requirements and adjusted. Electrode tips and contact surface condition shall be inspected and continuously monitored for conditions which may impede welding techniques and/or weld quality. The electrodes and related essential components shall be cleaned, dressed, or replaced. Electrodes shall be dressed with number 600 or finer grit abrasive

paper or equivalent. Electrode force shall be checked quantitatively by a calibrated force gauge and adjusted. For applications where each electrode is controlled individually (e.g., series welding), the force of each electrode shall be determined and adjusted individually.

7.0 PROCESS QUALIFICATION

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 the resistivity determined during qualification meet the requirements of the new drawing as applicable, and it is demonstrated that the essential weld variables will be met. Demonstration shall constitute all the requirements of Section 7.4.2 except that no additional documentation is required (existing PQR and WPS records shall be acceptable documentation).

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).

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 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 by more than 10% 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 less total test sample requirements than that required for an initial qualification for a unique weld type. For requalification, 5 total weld samples shall be produced and submitted as a lot. All 5 samples shall be subjected to visual inspection and conductivity and destructive peel testing and shall meet the applicable requirements specified herein. No requalification specimens from the 5 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 7.4.4 shall be required.

7.3 ESSENTIAL VARIABLES

All essential variables shall be addressed and identified on a qualified WPS and the supporting PQR. These essential variables are listed in Table 1. Other variables determined to be essential to maintaining the quality of the process output may be required to be controlled, as determined by the M&P organization.

TABLE 1: ESSENTIAL WELDING VARIABLES

NUMBER	ESSENTIAL VARIABLES	VARIABLE RANGE
1	A change in the input line voltage source	NONE(1)
2	Power supply - make and model	NONE
3	Weld head - make and model	NONE
4	Interconnecting cable size and length	±10%
5	Tab material type	NONE
6	Tab material metallurgical condition	NONE
7	Tab material thickness	±10%
8	Battery material type	NONE
9	Battery material metallurgical condition	NONE
10	Battery anode thickness	±10%
11	Battery cathode thickness	±10%
12	Component lead material type	NONE
13	Component lead metallurgical condition	NONE
14	Component lead diameter	±10%
15	Surface condition of base materials	NONE
16	Electrode RWMA category or other classification	NONE
17	Electrode configuration & dimensions	NONE
18	Electrode tip spacing	±20%
19	Electrode tip contact surface shape	NONE
20	Electrode tip contact surface area	±10%
21	Process - a change from opposed to series welding or vice versa	NONE
22	Weld% power or watt/sec (all pulses)	±10%
23	Number of weld pulses	NONE
24	Weld pulse width	NONE
25	Electrode tip force (pounds)	±10%
26	Current type (AC or DC)	NONE
27	DC polarity current direction (Opposed Welding only)	NONE

(1) Unless the power supply has internally regulated voltage capability.

7.4 QUALIFICATION SAMPLES

7.4.1 GENERAL

The manufacturing organization is responsible for qualifying the welding process. Actual cathode and anode ends for the same make, size, and model/type battery used in the design shall be obtained for use as qualification and preproduction control samples. Actual batteries may be also used for qualification and/or preproduction control samples. Wire/leads of the same material and construction as component leads, or actual components used in the design, shall also be supplied when appropriate.
The battery cap is typically a low-carbon steel similar to AISI 1018 that is electrolytic nickel plated (pure nickel plate). The presence of the electrolytic nickel plate needs to be verified by a quick energy dispersive spectroscopy (EDS) test prior to weld sample being made. If the presence of electroless nickel plate (nickel-phosphorous alloy plate) is present on the battery caps, the battery cap lot shall be rejected prior to the weld qualification attempt.

7.4.2 QUALIFICATION MATERIALS

For each unique type of weld to be produced, a minimum of 15 sample welded connections shall be produced for an initial procedure qualification and submitted as a lot. For either of the following weld conditions, an additional sample shall be produced and submitted for metallurgical examination bringing the minimum total to 16: 1) the faying surfaces at the weld joint are of essentially different materials, or 2) where it is determined that any of the base materials (plated or not) are known to experience significant degradation or other problems caused by the weld heating. Weld control settings shall not be varied nor shall any maintenance, except cleaning and/or polishing of electrodes, be performed on the equipment during the production of the qualification samples. The number of weld spots on each qualification sample connection shall not exceed the minimum number required per the engineering drawing or if not specified shall be no greater than 2 spots per connection or that planned for production work. The qualification sample set shall be acceptable to all of the following 4 levels of quality control as applicable, for successful qualification: 1) visual inspection, 2) conductivity (resistivity) testing, 3) destructive peel testing, and 4) metallurgical examination (when required).

7.4.3 VISUAL INSPECTION AND ELECTRICAL CONDUCTIVITY TESTING

All weld specimens shall be visually inspected per 8.3 and tested for electrical conductivity (resistivity). The resistivity of each connection shall meet the drawing requirements or if not specified by the drawing, shall measure less than 1.0 $m\Omega$. If any of the individual samples from those submitted fail to pass the visual or resistivity requirements, an additional sample shall be allowed to be welded and submitted to replace it, one time only. If more than 2 samples from the original lot fail the visual or resistivity requirements further weld parameter development or process

analysis to determine the cause for the rejection(s) is required prior to submitting another lot of samples for testing to the requirements of this specification.

7.4.4 DESTRUCTIVE PEEL TESTING

Fifteen (15) weld samples shall be peel tested. The edges of a spot welded sample connection shall be gripped and pulled apart to failure. The welded connection (lap joint) shall be pulled in tension at an approximate 90° angle to the plane of the faying joint surfaces. See Figure 1. The length of the grip sections on the samples shall be long enough to preclude any interference of the gripping hardware with the welded connection. For a procedure qualification or preproduction verification sample set to be considered acceptable, the result of the peel test must be a plug pull-out in a minimum of 75% of the total number of individual spots in the sample set for connections with 4 or more spots, 85% for connections with 3 spots only, and 100% for connections with 2 or less spots. If any of the individual samples from the 15 peel tests fail to result in at least 2 plug pull-outs from the total number of weld spots on the individual connection, 2 additional welded sample connections may be welded and submitted for inspection and testing as part of the initial sample set, one time only. These 2 samples shall then be factored into the above acceptance criteria. If more than 2 samples from the original lot fail the peel test as described above, further weld parameter development or process analysis to determine the cause for the failure(s) is required prior to submitting another 16 samples for testing to the requirements of this specification. If the minimum plug pull-out requirement for the total number of individual spots in the sample set (i.e., 75%, 85%, or 100% for the respective condition) cannot be met as described above, further weld parameter development or process analysis to determine the cause for the failure is required prior to submitting another lot of samples for testing to the requirements of this specification.

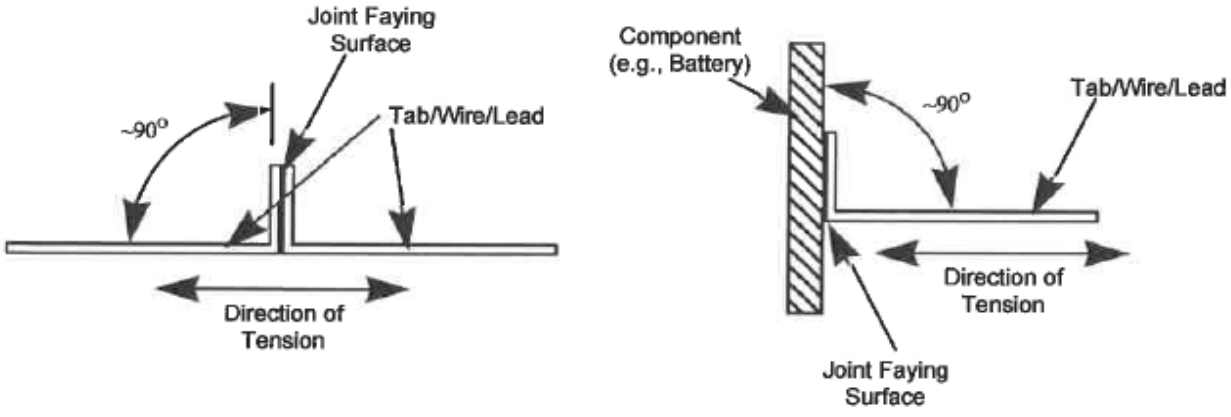


Figure 1 - Peel Test Examples

7.4.5 METALLURGICAL EXAMINATION

Qualifications samples for flight criteria applications shall be cross-sectioned, mounted, polished, and etched for metallurgical examination. See Figures 2 and 3.

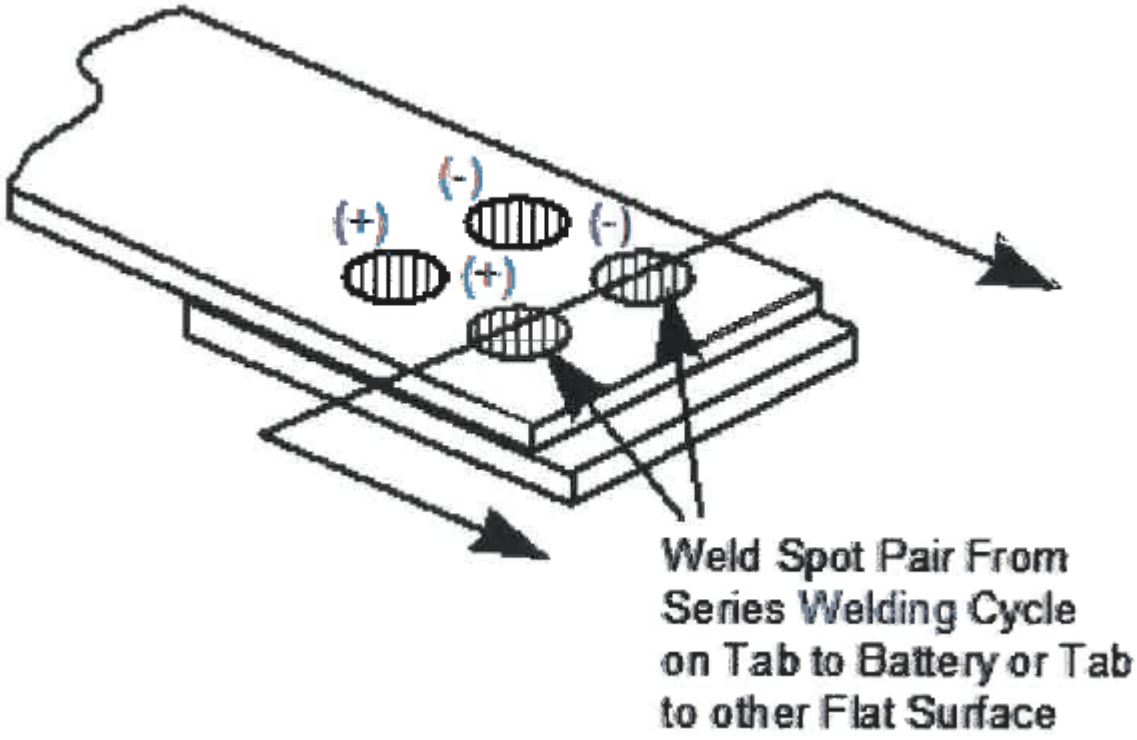


Figure 2: Metallographic Sectioning Requirement

S_M is the minimum nugget size (of the welding schedule certification) & t is the thickness

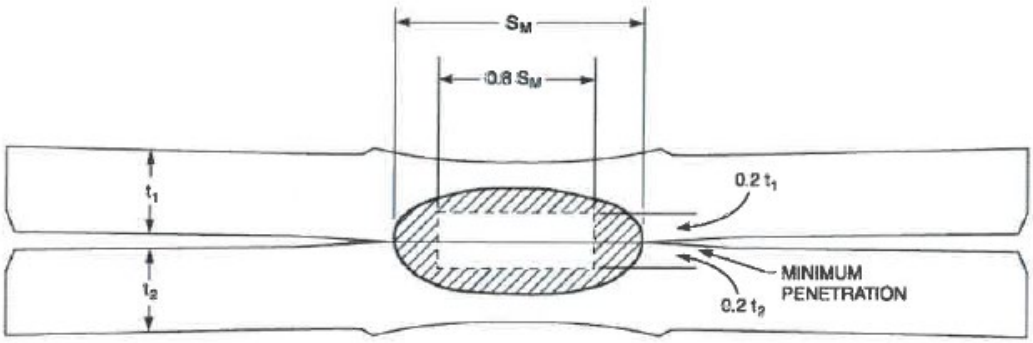


Figure 3: Metallographic Cross-Section after Etching

Note: When $t_1 < t_2$

The metallographic cross-section requirements* are the following:

(1) The welds shall be free of cracks or voids open to any exterior surface.
(2) The penetration shall be 20 - 80 %.
(3) The nugget exhibits no intermittent fusion regions in the weld nugget (regions where the nickel plate is not part of the weld nugget).
(4) Pores and voids in the nugget (away from the nugget edge) shall be no greater than 25% of the thickness of the member.
(5) No sharp, notch-like anomalies shall be present near the edge of the weld nugget. Internal anomalies shall be no closer than 15% of the nugget weld edge radius.
(6) No anomaly or group of internal anomalies shall be greater than 10% of the nugget diameter.
(7) The anode weld nugget size must be consistent and the cathode weld nugget size must be consistent. The weld nugget diameter shall not vary more than 20% in the metallographic samples (smallest anode weld nugget is 100% & largest anode weld nugget is ≤120 %, etc.).
(8) The surface indentation shall be no greater than 30% of the member thickness.

The nugget sizes shall be reported in the metallographic report but acceptance of the nugget size shall be based on the peel tests.

A report with photomicrographs shall be issued at the completion of metallographic examination and retained with the PQR.

*Based on Group 2, Class A Resistance Spot Weld Criteria per AWS D17.2

Please note that:

- The battery cap (t2) is made of AISI 1018 carbon steel that is plated with electrolytic nickel plate (pure nickel). The battery tab (t1) is made of quarter-hard nickel alloy 201 (pure nickel). The battery tab is usually 0.005 inch thick. The combination nickel and steel is difficult to impossible to etch completely. Typically, steel etches easily but nickel resists etching due to galvanic protection.

- The nugget diameter is typically 0.001 to 0.002 inches in diameter and must pass a peel test prior on the same batch prior to sample submittal for metallography. At least 2 samples must be submitted for metallographic qualification. It is preferred that no more than four samples be submitted per qualification attempt due to the time, effort and skill necessary to perform this task in the metallographic lab.

8.0 PROCESS VERIFICATION

Process verification shall consist of visual examination and/or nondestructive inspection, as described further in sections 8.1 to 8.3. In addition, at the appropriate time during the fabrication activities, the manufacturing activity shall assure the following items:

a) The operator is certified for the specific welding operation,
b) A valid WPS exists,
c) The essential variable ranges for the WPS are being adhered to.

8.1 PREPRODUCTION WELDING VERIFICATION

Prior to the start of a production run, a minimum of 1 preproduction weld sample for each unique type of weld shall be prepared using the appropriate qualified WPS. Actual batteries and component leads or simulated ones, as described in section 7.4.1, shall be used for this preproduction weld sample. The sample shall be visually inspected, in accordance with Section 8.3, and peel tested, in accordance with Section 7.4.4. 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 either or both of the welding electrodes,
c) Following metal expulsion or severe metal deposits on the electrode face(s),
d) Following the misfire or no weld condition where a weld has been attempted but not made and no assignable cause can be determined,
e) Following a delay in welding of more than 4 hours and where the welding

system was required to be powered down during this period,
f) Where a different operator was assigned to the workstation to continue a job.

Different WPSs may be alternated within a production welding session provided the above requirements are met.

8.2 WELD VERIFICATION

Prior to encapsulation, potting, or any process which would preclude inspection of the welds, all welds and workmanship shall be inspected for conformance to the requirements of this standard and the engineering drawing. If a nonconformance is identified it shall be documented appropriately. If the welds of a completed welded module or assembly cannot be inspected after the assembly is complete, the module or assembly must be inspected at selected points during assembly to assure inspection of each weld in the module.

8.3 VISUAL INSPECTION

All welds shall be inspected visually at a magnification of 30X. The welds shall conform to the following visual inspection criteria:

a) **Cracked Weld** - Any weld that exhibits a crack in the weld zone shall be rejected.
b) **Pitted/Deformed Weld** - Any weld that exhibits pits, holes or voids open to the surface, in either of the materials shall be rejected. Surface deformation or upset from electrode contact shall not be considered unless the area in question exhibits sharp notch like characteristics, severe oxidation due to overheating, or where either of the elements has been deformed/upset by more than 50% of the material thickness.
c) **Metal Expulsion** - Any weld that exhibits metal expulsion where the molten metal has become separated from the weld area shall be rejected.
d) **Electrode Deposit** - Significant deposits of the electrode tip being left on the weld surface shall be rejected. Topical shallow deposits and superficial marks shall not be considered.
e) **Open Weld** - An open weld shall be rejected. An open weld is one in which a weld has been attempted but no bonding has occurred.
f) **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.

8.4 WELD REPAIRS AND REWORK

Any weld that has been indicated as having a defect (with the exception of an Open Weld or a Missed Weld) as listed in 8.3, or as not meeting the requirements specified on the drawing, may be rewelded no more than 1 time at the same location where the original weld was attempted. An Open or Missed Weld shall be reworked to provide an initial weld

per the engineering drawing. If a reweld attempt is unsuccessful, unless a misfire condition occurs, a discrepancy report shall be generated and shall require dispositioning by the responsible engineering organization. Two unsuccessful reweld attempts shall require dispositioning by the Material Review Board (MRB). The level of documentation of repair welds shall, at a minimum, be consistent with that required for the original production weld. 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.

8.5 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 NASA/JSC M&P organization with the appropriate justification and rationale. A written response will be provided upon such a request.

9.0 TRAINING AND CERTIFICATION OF PERSONNEL

9.1 TRAINING

At JSC, if welding operator training is considered necessary prior to qualification/requalification of existing JSC welding operator personnel or the initial qualification of new hires, it shall be conducted in accordance with ANSI/AWS D17.2. For an outside JSC vendor, welding operator training (when necessary) should consist of practice using the facility welding equipment with a specific WPS to demonstrate proficiency, under the supervision of a qualified/certified welding operator or designated training personnel. Specific development of an appropriate training program shall be the responsibility of the vendor. RSW is a potentially hazardous joining process because of the high energies involved. Training shall include adequate exposure to all spot welding equipment manufacturer's instructions and applicable industry standards relating to safety and where applicable, to the specific hazards related to batteries. All JSC organizations and their contractors who engage in handling batteries shall be trained in all approved guidelines and procedures for working with and handling batteries. 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.

9.2 WELDING OPERATOR QUALIFICATION

Resistance spot welding of battery and related electronic assemblies shall be performed by a welding operator qualified and certified in accordance with NASA/JSC PRC-0009. Sufficiently detailed records shall be maintained by the manufacturing organization executing the process(es). These records shall be made available to the NASA/JSC M&P organization upon request. Minimum requirements for qualification/certification shall be

demonstrated by either 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 engineering representative, by successfully demonstrating the application of a qualified WPS. This shall include demonstration to the qualifier (certifying representative), machine operation, schedule/parameter selection, electrode setup, and weld cycle execution.

10. DEFINITIONS

Process Verification

The WPS, PQR, and WOPQ shall be prepared and retained as a permanent record and made available upon request to the NASA/JSC 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/or engineering.

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 this process specification and shall be certified by the responsible M&P organization at the operating facility, prior to use in production. Appendix B is an example of a Welding Procedure Specification, however, any format is considered acceptable provided all the information and data necessary to successfully perform the welding activity is available and displayed clearly.

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. Appendix A is an example of a Procedure Qualification Record, however, any format is considered acceptable provided all the information and data necessary to accurately document the process is made available and displayed clearly.

Welding Operator Performance Qualification

A Welding Operator Performance Qualification (WOPQ) is documentation that shows that a welder has been tested in accordance with this PRC and shown competent to produce a sound weld for a specific welding process/base material/equipment combination. Any format is considered acceptable provided all the information and data necessary to accurately document the operator's performance qualification is made available and displayed clearly.

Essential Variable - An identified variable in the welding process that must be controlled to ensure repeatable weld quality.

Opposed Welding - RSW which utilizes two electrodes positioned exactly opposite, and in line with each other (electrodes share a common axis). See Figure 5. Each electrode contacts a single piece of base material. Each weld cycle produces only one fused spot.

Series Welding - RSW which utilizes two electrodes positioned adjacent to each other but separated by an air gap or other dielectric. See Figure 5. Each electrode contacts the same surface of base material. This type of welding is utilized where access to both sides of the weld joint is physically restricted or if component damage would result if the welding current were allowed to shunt through the system circuit or electrical component. Support tooling opposing the force of the electrodes is insulated from the welding circuit and therefore does not shunt current from the welding circuit. Each weld cycle produces two fused spots. The electrodes can be positioned parallel or at a fixed angle to each other.

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

1. Battery anode and/or cathode cross sectional thickness (±10%),
2. Anode and/or cathode material, metallurgical condition, and surface finish,
3. Jumper tab cross sectional thickness (±10%),
4. Jumper tab material or metallurgical condition,
5. Component lead/wire material, metallurgical condition, and surface finish,
6. Component lead material/wire cross sectional diameter (±10%).

Peel Test -A mechanical test in which the corners (or sides) of seam or spot welded

foil or sheet members are gripped and pulled apart to determine if the joint fails by delamination, by fracture of a cleaved surface, or by tearing of a button (plug) out of the parent material. Delamination, in contrast to fracture, is a sign of no fusion between the two adjacent members. A button or plug, which is pulled out of the removed member, is not necessarily equal in size to the cast nugget underlying it.

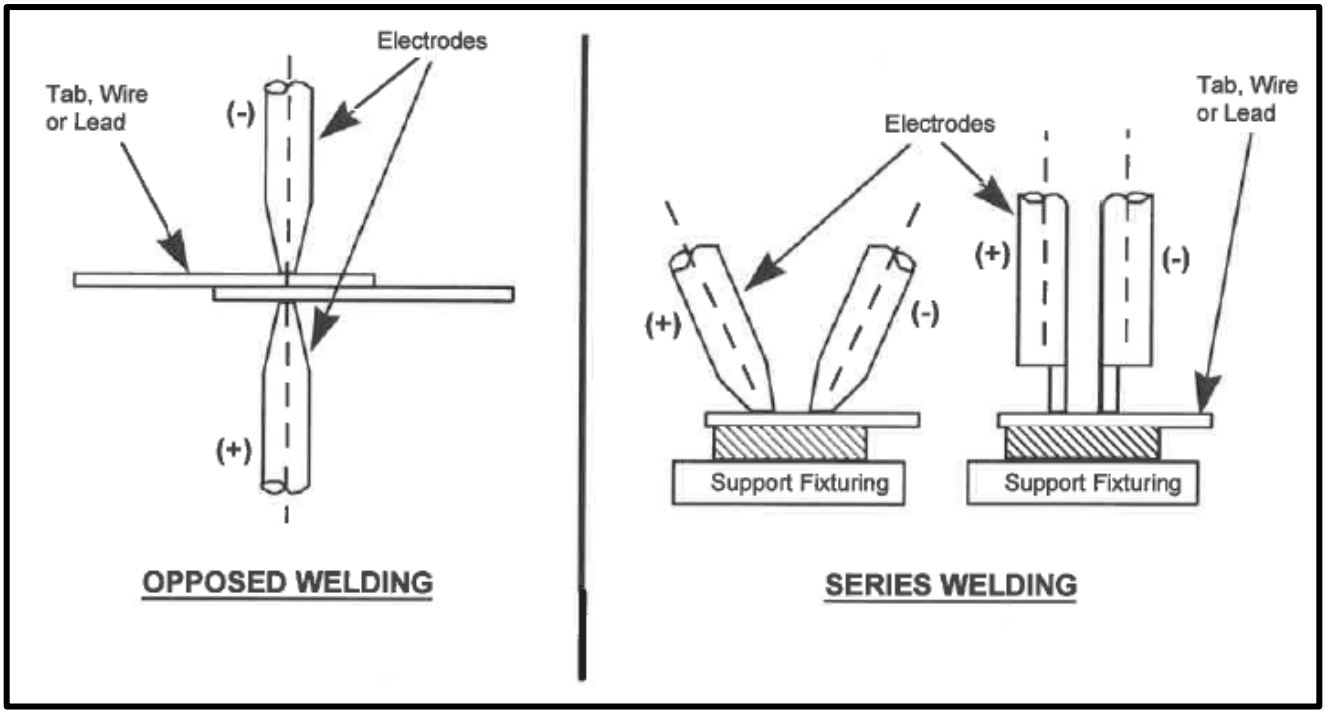


Figure 1: Opposed and Series Welding

Appendix A

Lyndon B. Johnson Space Center

{RESISTANCE SPOT WELDING} PROCEDURE QUALIFICATION RECORD (PQR)

Date:_____ Initial Qualification ☐ Requalification ☐ PQR No. _____

EQUIPMENT IDENTIFICATION

Owner / Location : _____
Power Supply / Model : _____
Serial Number : _____
Weld Head / Model : _____
Serial Number : _____
Interconnecting Cable Size / Length: _____

MATERIALS

BATTERY

Manufacturer : _____
Type / Size : _____
Material Type / Metallurgical Cond : _____
Anode Thickness : _____
Cathode Thickness : _____
Surface Condition : _____

CONNECTING / COMPONENT MATERIALS

Manufacturer : _____
Type / Temper : _____
Heat Number : _____
Thickness / Width : _____
Surface Condition : _____
Component Lead Material : _____
Component Lead Gage : _____

ELECTRODES

RWMA Category : _____
Other Category / Descip : _____
Distance Between Electrode Tips : _____
Elect Tip Config / Size : _____
Contact Tip Surface Shape : _____
Electrode Body Dimensions : _____
Other : _____

ELECTRODE CONFIGURATION AND SETUP

VARIABLES

Pulse 1 : _____ % power or _____ watt seconds
Pulse 2 : _____ % power or _____ watt seconds
No. of Weld Cycles Per Location : _____
Polarity, First Cycle : _____
Polarity, Second Cycle : _____
Pulse Width : _____
Number of Pulses : _____
Total Electrode Tip Force (lbs) : _____
Left Electrode Tip Force (lbs) : _____
Right Electrode Tip Force (lbs) : _____
Firing Force Setting : _____
Approx Avg Peak Amperage Response (reference only) : _____

We certify that the statements and photomicrographs in this data sheet are correct and the test welds were welded and tested in accordance with JSC PRC-0009. The photomicrographs shall form a part of this PQR to the extent specified in JSC PRC-0009, Revision_____.

By:_____ Date: _____

By: _____ Date: _____

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Lyndon B. Johnson Space Center

{RESISTANCE SPOT WELDING} PROCEDURE QUALIFICATION RECORD (PQR)

Date:_____ Initial Qualification ☐ Requalification ☐ PQR No. _____

INSPECTION AND TESTING RESULTS

Sample Number	Cathode or Anode	Visual Results	Resistivity (m-ohms)	Peel Test # Plug Pull Outs / Total	Peel Test UTS (lbs.) (Reference Only)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					

We certify that the statements and photomicrographs in this data sheet are correct and the test welds were welded and tested in accordance with JSC PRC-0009. The photomicrographs shall form a part of this PQR to the extent specified in JSC PRC-0009, Revision_____.

By: _____ Date: _____

By: _____ Date: _____

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Lyndon B. Johnson Space Center

{RESISTANCE SPOT WELDING} PROCEDURE QUALIFICATION RECORD (PQR)

Date:_____ Initial Qualification ☐ Requalification ☐ PQR No. _____

METALLURGICAL TESTING RESULTS

We certify that the statements and photomicrographs in this data sheet are correct and the test welds were welded and tested in accordance with JSC PRC-0009. The photomicrographs shall form a part of this PQR to the extent specified in JSC PRC-0009, Revision_____.

By:_____ Date: _____

By:_____ Date: _____

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Appendix B
Resistance Spot Welding Procedure Qualification Record Page 2
Lyndon B. Johnson Space Center

{RESISTANCE SPOT WELDING} WELDING PROCEDURE SPECIFICATION (WPS)

RSW Procedure Specification Number : _____ Date In Effect: _____
Applicable JSC PQR Number(s) : _____ Revision: _____

EQUIPMENT IDENTIFICATION

Owner / Location : _____
Power Supply / Model : _____
Serial Number : _____
Weld Head / Model : _____
Serial Number : _____

MATERIALS

BATTERY

Manufacturer : _____
Type / Size : _____
Material Type / Metallurgical Cond : _____
_____
Anode Thickness : _____
Cathode Thickness : _____
Surface Condition : _____

CONNECTING / COMPONENT MATERIALS

Manufacturer : _____
Type / Temper : _____
Thickness / Width : _____
Surface Condition : _____
Component Lead Material : _____
Component Lead Gage : _____

ELECTRODES

RWMA Category : _____
Other Category / Comp : _____
Distance Between Electrode Tips : _____
Elect Tip Config / Size : _____
Contact Tip Surface Shape : _____
Electrode Body Dimensions : _____

TESTING

Detailed test results are documented in the following Procedure Qualification Record(s) (PQR): _____
_____

ELECTRODE CONFIGURATION AND SETUP

VARIABLES

Pulse 1 : _____ % power or : _____ watt seconds
Pulse 2 : _____ % power or : _____ watt seconds

No. of Weld Cycles Per Location : _____
Polarity, First Cycle : _____
Polarity, Second Cycle : _____
Pulse Width : _____
Number of Pulses : _____
Total Electrode Tip Force (lbs) : _____
Left Electrode Tip Force (lbs) : _____
Right Electrode Tip Force (lbs) : _____
Firing Force Setting : _____
Approx Avg Peak Amperage Response (reference only): _____

We certify that the statements in this specification sheet are correct and the test welds were welded and tested in accordance with JSC PRC-0009, Revision_____.

By: _____ Date: _____

By: _____ Date: _____

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