



Weld Acceptance Criteria and Repair Methods Resistance Spot Welds - Steel

1 Introduction

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

Note: For the **stainless steel resistance spot welding in powertrain/propulsion systems applications**, see Deviation Section.

1.1 Purpose. This standard provides the acceptance criteria and repair methods for resistance spot welds in automotive products for which GM is responsible for establishing or approving product design.

Note: This standard applies to steels approved by GM for Resistance Spot Welding (RSW).

1.2 Applicability. The criteria established in this standard become mandatory when referenced on a weld design document. Deviations from any weld criteria provided in this standard must be identified on a weld design document or other product design document.

1.3 Remarks.

1.3.1 Welded structures are considered satisfactory when they carry the intended service loads for a required period. Service loads on weldments in a vehicle are varied in both type and magnitude and cannot be addressed by this standard. Therefore, while the weld quality criteria of this standard are consistent with service loading requirements, they have been established specifically for use in process and product monitoring. Any attempted application of this document to other uses, such as post-crash weld quality assessment, may lead to an erroneous result or conclusion. Discrepant welds by retaining a portion of their engineering properties may still contribute to the integrity of the assembly.

1.3.2 Clarification. For clarification of this specification or editorial comments, email the GM Global Welding and Joining Council at weld.council@gm.com.

1.3.3 Proposed changes to this standard must be presented to the GM Global Welding and Joining Council at weld.council@gm.com

1.3.4 As used in this standard, the words "shall" and "must" denote a requirement; the word "should" denotes a guideline; and the word "may" denotes a choice.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

9984532	GMW14085	GMW16383	GMW16804
GMW14058	GMW15563	GMW16435	GMW17330

2.3 Additional References.

- GM Global Quality Requirements for Corrective Action and Nonconforming Material. GM Plants refer to GM to: https://gmweb.gm.com/quality/oq/QR/IQ_Global/default.aspx (Contact supplier quality for non-GM plants.)

- GM Record Retention Schedule (GMRRS); <https://gmrrs.gm.com/GMRRS/> (Contact supplier quality for non-GM plants.)
- Midwest Thermal Spray CBF100 conductive body filler available at www.midwestthermal.com/cbf100.html

3 Requirements

3.1 General Acceptance Criteria.

3.1.1 Individual Spot Weld Criteria. There are multiple visual and measurable attributes that are used to evaluate spot weld quality. These attributes are divided into two categories:

- a. Attributes that affect conformance (including discrepancies).
- b. Attributes that are undesirable for appearance or processing.

3.1.2 Categories of Spot Welds. There are two categories of spot welds:

- a. Structural welds.
- b. Process welds.

3.1.2.1 Structural Spot Welds. Structural spot welds are installed for performance of the welded product. All spot welds are structural unless specifically noted as process welds on the weld design document.

3.1.2.2 Process Spot Welds. Process spot welds are installed to facilitate in-process assembly, but are not required for structural performance of the product. Process spot welds must be approved by Product and Manufacturing Engineering and shown on the weld design document.

3.2 Visual Acceptance Criteria.

3.2.1 Visual Attributes–Discrepant Welds. Welds that exhibit any of the following attributes are discrepant.

3.2.1.1 Cracks. Spot welds with crack(s) around the circumference that are visible without the aid of magnification, are discrepant. Spot welds with surface cracks confined within the impression left by the electrodes are not discrepant. See Appendix A, Figure A1. The aesthetic appearance criteria for cracks are listed in Appendix A. See also 3.2.3.

3.2.1.2 Holes. All spot welds with holes do not conform and must be repaired. Structural spot welds that contain through-holes that are at least 2 mm in diameter or holes that break the perimeter of the impression left by the electrodes and that are visible without the aid of magnification are discrepant, see 3.4.1. Structural spot welds that contain holes extending through the weld, that are visible without the aid of magnification but smaller than 2 mm and are contained within the impression left by the electrodes, shall have the welding process adjusted to the qualified setup to eliminate the condition causing the hole. Process welds that contain holes extending through the weld shall have the welding process adjusted to the qualified setup to eliminate the condition causing the hole. See Appendix A, Figure A2. The aesthetic appearance criteria for holes are listed in Appendix A. Holes repaired in Zones A, B, and C shall be metal finished to improve appearance. See also 3.2.3.

3.2.1.3 Edge Welds. Welds in which the spot weld impression left by the electrodes, is not contained within all edges of the sheet metal being welded are discrepant. See Appendix A, Figure A3, welds E and F.

3.2.1.4 Missing Welds. When fewer welds exist than are specified on the weld design document, the omitted welds are discrepant. See also note following 3.4.1.

3.2.2 Visual Attributes–Appearance and Processing Considerations. Welds that exhibit the following attributes are undesirable either from an appearance or processing viewpoint. These attributes do not make the weld discrepant and are not used in determining weld pattern conformance.

3.2.2.1 Extra Welds. The number of spot welds installed shall not exceed the number specified on the weld design document, except as required by the repair methods described in 3.4. The welding process shall be adjusted to eliminate extra welds.

3.2.2.2 Whiskers. Welds exhibiting whiskers shall have the welding process adjusted to minimize this condition (Appendix A, Figure A4). The aesthetic appearance criteria for whiskers are listed in Appendix A, Table A1 for whiskers found in special appearance zones A, B, C, and D (Appendix A, Table A2 and Figure A16) and in the Roof Rail Air Bag areas (Appendix A, Figure A17). See Appendix A, Figure A4.

Note: Welds shall be free of whiskers when using ultrasonic inspection equipment to avoid damage to the transducer.

3.2.2.3 Distortion. Spot welds in which the sheet surfaces are distorted > 25 degrees from the normal plane shall have the welding process adjusted to the qualified setup in order to reduce the distortion to < 25 degrees. See Appendix A, Figure A5. The aesthetic appearance criteria for distortion are listed in Appendix A. See also 3.2.3.

3.2.2.4 Thinning and Indentation. Spot welds exhibiting thinning $> 30\%$ of the total metal stack-up shall have the welding process adjusted to the qualified setup in order to reduce the thinning to $< 30\%$. See Appendix A, Figure A6. The aesthetic appearance criteria for indentation are listed in Appendix A. See also 3.2.3.

3.2.2.5 Trim Edge Deformation. Welds in which the original edge of the weld flange is deformed by the electrodes but whose spot weld impression is contained within all edges of the sheet metal being welded are not discrepant. Nonetheless, the process shall be adjusted to the qualified setup to minimize the condition. See Appendix A, Figure A3, welds C and D. The aesthetic appearance criteria for trim edge deformation are listed in Appendix A. See also 3.2.3.

3.2.2.6 Surface Eruption. Surface eruption is an upsurge of the sheet surface adjacent to the electrode impression. See Appendix A, Figure A7. The appearance criteria for surface eruption are listed in Appendix A. See also 3.2.3.

3.2.2.7 Spatter. Spatter is weld metal expulsion that remains attached to surface(s) adjacent to the weld. See Appendix A, Figure A4. The appearance criteria for spatter are listed in Appendix A. See also 3.2.3.

3.2.2.8 Non-Concentric Welds. Weld symmetry is a purely aesthetic criterion that does not affect conformance. The aesthetic appearance criteria for concentric welds are listed in Appendix A. See also 3.2.3.

3.2.3 Perceptual Quality Requirements. Spot welds visible to the customer in strategic areas of the body affect Perceptual Quality (PQ). The special appearance zones (listed in Appendix A, Table A1, Table A2, and Figure A16) are consistent with the GM Global Customer Audit. Spot welds not meeting appearance standards shall have the process adjusted to the qualified setup to minimize the undesirable condition. Moreover, metal finish may be required to meet the aesthetic requirements in these zones.

3.3 Measurable Acceptance Criteria.

3.3.1 Weld Location. Spot welds must be properly located relative to design location as indicated on the weld template and to each other as follows:

- A single in-line grouping or row of welds in which a distinct product feature provides visual reference to the end weld, an end weld installed > 10 mm in radial distance from the design location is a discrepant weld. A distinct product feature is a visible trim edge or other recognizable part feature that is perpendicular or nearly perpendicular to the row of welds and within 30 mm of the end weld.
- For all other welds, a resistance spot weld installed > 20 mm in a radial distance from the design location is a discrepant weld.
- If the spacing between two adjacent welds in a single in-line grouping or row of welds exceeds the design spacing by > 20 mm, the weld furthest from the design location is discrepant.
- The aesthetic appearance criteria for weld location are listed in Appendix A.

3.3.2 Weld Size. The weld size may be measured by either using the weld button (Appendix A, Figure A8), the weld nugget (Appendix A, Figure A9), or the fusion zone. A spot weld is discrepant when the measured weld size at each faying surface is less than the minimum acceptable weld size specified in Table 1.

Table 1: Minimum Acceptable Weld Size

Determining Thickness (DT)	Minimum Acceptable Weld Size
0.60 mm to 0.64 mm	3.0 mm
0.65 mm to 1.29 mm	4.0 mm
1.30 mm to 1.89 mm	5.0 mm
1.90 mm to 2.59 mm	6.0 mm
2.60 mm to 3.25 mm	7.0 mm

3.3.2.1 Two-Thickness Welds. To determine the acceptable weld size for a two-thickness weld (two loose pieces or one loose to two previously welded), use the metal thickness (T) of the thinner of the two layers being welded to determine the weld size as listed in Table 1.

3.3.2.2 Three-Thickness Welds. To determine the acceptable weld size for a three-thickness weld (three loose pieces) use the metal thickness (t) of the thinner of the two layers at each interface to determine the acceptable weld size. However, in the case where the thinnest layer is stacked between two thicker layers use the second thickest piece (t) to determine the acceptable weld size for both welds.

3.3.2.3 Single Fusion Zone (SFZ) Welds. Three-thickness welds designated as SFZ welds (1T to 2T) only require fusion at a single interface of the three layers, see Appendix A, Figure A15. To determine the acceptable weld size at the required interface of the SFZ weld, use the metal thickness (t) of the thinner of the two layers at the required interface.

3.3.2.4 Fusion Mode. There are several different fusion modes that are commonly observed in destructively tested steels. The mode of fracture is not an assessment of the quality of the weld; rather, it is an indication of the weakest fracture path through or around the weld in the context of the strength of the material surrounding the weld.

- Button Pull is common in welds that involve softer, thinner steels. When a rapidly quenched steel spot weld is significantly stronger than the steel surrounding it, the steel tears at the periphery of the nugget. When this tearing propagates to the surface of the base metal substrate, a button results.
- Partial Thickness Fracture is similar to button pull but occurs more often in a thick piece of relatively low strength steel. When the tearing propagates around the periphery of surface of the weld nugget, but does not propagate to the surface, a partial thickness button results.
- Interfacial Fracture is the opposite extreme of button pull. It is most common in joints involving thick, high strength steels. When relatively highly alloyed steel surrounding the rapidly quenched weld nugget is no longer weak in comparison to the weld, the fracture mode switches from fracturing along the weld nugget periphery to a fracturing through the weld. This does not indicate that the weld is weak inasmuch as it indicates that the base metal substrate surrounding the weld is very strong.
- Combinations of button, partial thickness failure, and interfacial fracture are sometimes observed when the random orientation of steel grains together with naturally occurring shrinkage porosity change the localized directional strength within the nugget. The result can be a weld that pulls nuggets (or partial thickness fractures) surrounded by (or next to) areas of interfacial fracture.

In these cases involving interfacial fracture or partial thickness fracture, examination of the fusion zone must be used to determine weld size. When available, cross sectioning can be used to definitively assess the nugget size. Fracture analysis can also be used to differentiate between interfacial fracture and unfused welds. When a product quality standard is released by product engineering, this standard shall be used to evaluate the fusion zone. Welds that exhibit partial thickness fracture or interfacial fracture are fused welds.

3.3.2.5 Unfused Welds. Weld locations that do not produce a weld button after a destruct test and are not interfacial fractures are unfused welds. (Welds with interfacial fractures also demonstrate nuggets upon cross sectional analysis.) Unfused welds are discrepant. See **Note** in 3.4.1 Spot Weld Pattern Conformance Criteria.

3.3.2.6 Laminated Vibration Damping Steel. The minimum weld size specified in Appendix A, Table A1 is required only at the faying surface for laminated steel. There are no minimum weld size requirements for the interface between the layers of the laminated steel.

For purposes of determining the minimum weld size, the laminated steel shall be treated as one sheet whose thickness is equal to the sum of the two outer sheets and the inner viscoelastic layer as shown in Appendix A, Figure A10.

3.4 Disposition/Repair Procedure.

3.4.1 Spot Weld Pattern Conformance Criteria. A pattern is a collection of discrete joints to which a tolerance is applied to meet structural requirements and for determining manufacturing acceptance of the product. The default pattern (when not otherwise stated on the weld design document) is all structural discrete joints on the structure installed at the same manufacturing plant. The quantity tolerance for the single default pattern (when not otherwise stated on the weld design document) is no more than 5% of the total joint/weld count being discrepant. However, any weld pattern may have at least one discrepant weld, regardless of the pattern tolerance percentage. (This affects patterns of fewer than 20 welds where the default percentage of 5% would be less

than one weld.) A joint pattern is conforming when the number of non-discrepant discrete joints/welds (per the requirements of GMW14057, GMW14058, GMW14085, GMW16383, GMW16435, GMW16804, or GMW17330) meets or exceeds the pattern tolerance described in the preceding. Manufacturing acceptance of product is based on all patterns conforming. Disposition of product nonconforming to this standard shall be handled in accord with GM Global Quality Requirements for Corrective Action and Nonconforming Material.

Note: Two or more adjacent missing or unfused welds cause pattern nonconformance regardless of the quantity tolerance. All welds with holes that are visible without the aid of magnification do not conform and require a repair regardless of the quantity tolerance.

3.4.2 Repair Exceptions. An exception to specified product repair requirements may be permitted provided there is documented review and approval by the responsible product engineer allowing the suspect product to deviate from specification and pattern conformance criteria.

3.4.3 Surface Appearance. Spot weld surface appearance criteria are not used in determining weld pattern conformance.

3.4.4 Disposition of Process Spot Welds. Process spot welds are not used in determining weld pattern conformance. Process welds containing holes that are visible without the aid of magnification shall be repaired; see 3.4.5.5.

3.4.5 Repair Methods. When required, weld repairs shall follow the repair method authorized by the responsible product engineer. In the absence of an engineering approved repair methods, the following repair methods shall be used in the following order of preference:

3.4.5.1 Resistance Spot Weld Repair. Spot weld with a weld gun that is qualified for the metal types and thicknesses to be welded. One repair spot weld shall be added for each spot weld being repaired. Repair spot welds must meet the requirements of this standard. Locate repair spot welds as close as possible to the designated weld location without overlapping the existing spot weld.

3.4.5.2 Arc Weld Repair. Arc weld repair of laminated steels is not permitted. Arc weld repair closer than 30 mm of sealer, adhesive, or mastic is not permitted.

3.4.5.3 Arc Spot or Plug Weld Repair. For each spot being repaired, weld using Metal Inert Gas (MIG) plug or Arc spot with steel filler wire. The Arc spot or MIG weld shall conform to the applicable arc spot and plug weld acceptance criteria standard. All repair personnel using this method of repair must be periodically qualified and approved following local procedures/ methods.

3.4.5.4 Arc Fillet Weld Repair. A MIG fillet weld may be used for two metal thickness joints. The MIG repair weld must be located as close as possible to the designated weld location and must be a minimum of 20 mm in length. The repair welds must conform to GMW14058. All repair personnel using this method of repair must be periodically qualified and approved following local procedures/ methods.

3.4.5.5 Welds with Holes. Welds with holes that require repair shall be follow the method called out in Table 2. All repair personnel using MIG repair methods must be periodically qualified and approved following local procedures/ methods. Holes repaired in Zones A, B, and C may also require metal finished to improve appearance. See also 3.2.3.

Table 2: Repairs for Welds with Holes

Weld Type	Hole < 2 mm	Hole Inside Impression Left by Electrode	Hole > 30 mm from Sealer, Mastic, or Adhesive	Repair
Structural Weld	Yes	Yes	Either Yes or No	Use sealer released by responsible product engineer (e.g., Midwest Thermal Spray CBF100 conductive body filler for repairs before paint; 9984532 for repairs after paint)
Structural Weld	Yes	No	Yes	Repair with MIG welding
Structural Weld	Yes	No	No	Contact responsible product engineer for repair/disposition.
Structural Weld	No	Either Yes or No	Yes	Repair with MIG welding
Structural Weld	No	Either Yes or No	No	Contact responsible product engineer for repair/disposition.
Process Weld	Either Yes or No	Either Yes or No	Either Yes or No	Use sealer released by responsible product engineer (e.g., Midwest Thermal Spray CBF100 conductive body filler for repairs before paint; 9984532 for repairs after paint)

4 Manufacturing Process

4.1 Process Control. The welding source is responsible for establishing practices and test methods to assure that the criteria of this standard are met and are consistent with GMW15563 (for non-GM manufacturing facilities) and Process Quality Requirement System (PQRS) process control plans (for GM manufacturing facilities).

4.2 Process Qualification. All welding processes must be qualified (during initial weld verification or subsequent requalification). Process qualification must be documented and retained per the GM Record Retention Schedule (GMRRS).

5 Notes

5.1 Glossary.

Adjacent Welds: Two welds located on the same surface that are laid out in a row, string or geometric arrangement (e.g., square, rectangle, circle, curvilinear path, etc.) If in a geometric arrangement, welds are only adjacent to their immediate neighbors and not welds located diagonally across the geometric arrangement. Same surface with respect to adjacent welds means a surface whose curvature between adjacent welds would allow for welding (ignoring stamped holes). Welds around a corner are not adjacent.

Arc Spot: A weld type which uses a timed arc welding process to penetrate through the surface sheet into adjoining sheets fusing them together.

Base Metal: The metal or alloy being welded.

Crack: A fracture type discontinuity characterized by a sharp tip and high ratio of length to width of opening displacement on the exterior surface. See Appendix A, Figure A1.

Discrete Joint: Discrete joints are non-continuous joints that work together to create the entire joint. These discrete joints include resistance spot welds, arc spot welds, arc plug welds, arc plug brazes, non-fastener