



Laser Lap Welding Acceptance and Repair Procedure

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.

1.1 Purpose. The purpose of this specification is to provide acceptance criteria for laser lap welds in automotive products for which General Motors is responsible for establishing or approving product design.

1.2 Applicability. The criteria established in this standard becomes mandatory when referenced on a product design document. Deviations from the acceptance criteria provided in this standard must be identified on a weld design document, an approved Product Quality Standard (PQS) or specific product/program deviation.

Note: See Deviations section for product/programs; A2LL, A2XX, C1YB, C1YC, O1SL, and T1XX.

1.3 Remarks. Welds are considered satisfactory when weldments carry the intended or expected 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 specification; therefore, while the weld quality criteria of this specification are consistent with service loading requirements, weldments have been established based on the use of 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 laser welds often retain some of their engineering properties and may contribute to the integrity of the assembly.

1.3.1 Clarification. For clarification of this standard or editorial comments, e-mail the GM Weld Council at weld.council@gm.com.

Proposed changes to this standard must be presented to the Weld Council. To suggest a change to this standard, reference the "Procedure for Weld Standard Changes" on the Global Weld Council's web page.

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	GMW14058	GMW15563	GMW16435
GMW14057	GMW14085	GMW16383	GMW16804

2.3 Additional References.

- BOAPQ-7 Body Opening Appearance Perceived Quality – Joining (for visual acceptance)
- GM Global Customer Audit Procedure – Appearance Zones
- GM Global Manufacturing Systems (GMS) Operating Guidelines and Global Launch Manual
- GM Global Quality Requirements for Corrective Action and Nonconforming Material
- GM Information Lifecycle Management (ILM) Policy
- Midwest Thermal Spray CBF-100 available at www.midwestthermal.com/cbf100.html

3 Requirements

3.1 General Acceptance Criteria.

3.1.1 Individual Laser Lap Weld Criteria. There are multiple visual and measurable attributes that are used to evaluate laser lap weld quality. These attributes are divided into two categories: attributes that affect conformance and attributes that are undesirable for appearance or processing.

3.1.2 Weld Surface Perceptual Quality. Product and Manufacturing Engineering jointly must identify and approve weld surface cosmetic appearance criteria for those welds deemed necessary to satisfy the GM Global Customer Audit. Laser welds visible to the customer in strategic areas of the body are considered Perceptual Quality welds (reference the GM Global Customer Audit Procedure – Appearance Zones) and Body Opening and Perceptual Quality (BOAPQ)-7. Product Quality Standards shall be utilized to document the appearance acceptance standards addressing the desired weld precision (alignment, spacing, and concentricity) and prominence (undercut, burn-through, and spatter). Laser welds not meeting appearance standards should have the process adjusted to the qualified setup to eliminate the undesirable condition.

3.1.3 Structural Categories of Laser Lap Welds. There are two categories of laser lap welds: structural and process.

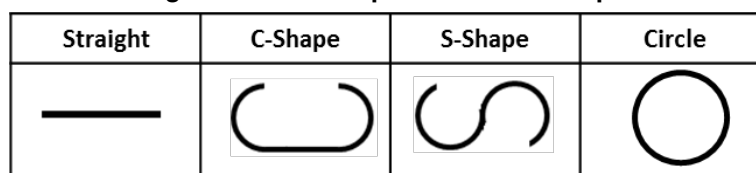
3.1.3.1 Structural Laser Lap Welds. Structural welds are installed for performance of the welded product. All laser lap welds are structural unless specifically noted as process welds on the weld design document.

3.1.3.2 Process Laser Lap Welds. Process welds are installed to facilitate in-process assembly, but are not required for structural performance of the product. Process laser welds must be identified by Product and Manufacturing Engineering and shown on the weld design document.

3.1.4 Laser Lap Weld General Acceptance by Type of Joint. Laser lap welds are further classified into three groups: Stitch Welds, Continuous Seams, and Laser Spot Welds (LSW). These groups of laser lap welds are defined in following content.

3.1.4.1 Laser Lap Weld Stitch Shapes. Laser lap welds may be made into various forms of stitch shapes. These forms include (but are not limited to) a Straight Stitch (50 mm or shorter), a C-Shape, an S-Shape, or a Circle (as defined in the product design document). See Figure 1.

Figure 1: Laser Lap Weld Stitch Shapes



3.1.4.2 Laser Lap Weld Continuous Seams. Laser lap welds that are longer than 50 mm are defined as continuous seam laser lap welds.

3.1.4.3 Laser Spot Welds (LSW). An LSW is a unique stitch shape, which is in the form of a spiral. The molten pool created by the laser beam in conjunction with the close spacing of the spiral path, forms a continuous cylindrical fusion zone, similar to a resistance spot weld. See Figure 2.

Figure 2: Laser Spot Weld (LSW)



3.2 Visual Acceptance Criteria. The visual acceptance criteria for the three basic shapes of laser welds (Lap Stitch Welds, Continuous Seams, and LSWs) are defined in following content.

3.2.1 Visual Acceptance Criteria for Laser Lap Stitch Welds.

3.2.1.1 Stitch Welds – Visual Attributes – Discrepant and Non-Conforming Welds. Welds that exhibit any of the following attributes are discrepant and may cause the patterns to be non-conforming.

3.2.1.1.1 Stitch Welds – Weld Shape and Orientation. Laser lap stitch welds can be installed in various shapes and configurations (linear stitch, staple, circle, S, etc.) A laser lap weld that is installed with a shape or orientation that differs from the product design, is discrepant.

3.2.1.1.2 Stitch Welds – Missing Welds. When fewer welds exist than are specified on the weld design document, the omitted weld(s) are discrepant.

3.2.1.2 Stitch Welds – Visual Attributes – Appearance and Processing Considerations. Stitch 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.

3.2.1.2.1 Stitch Welds – Spatter. Weld spatter that collects on a surface that is visible to the customer shall be removed. Spatter shall also be removed if it negatively effects a subsequent process. Spatter does not make the weld discrepant and does not affect structural conformance. Product Quality Standards shall be used to determine when process adjustments are required. Product Quality Standards shall be used to determine when process adjustments are required. See BOAPQ-7.

3.2.1.2.2 Stitch Welds – Surface Porosity and Top-Surface Expulsion. When excessive surface porosity or top-surface expulsion is present (see Figure 18), the process shall be adjusted to its qualified setup to eliminate the condition. Product Quality Standards shall be used to determine when process adjustments are required. Product Quality Standards shall be used to determine when process adjustments are required. See BOAPQ-7.

3.2.1.2.3 Stitch Welds – Crater Cracks. Crater cracks that are fully contained in the crater do not cause the weld to be discrepant. When crater cracks are present, the process shall be adjusted to its qualified setup to eliminate the condition (see Figure 17). Product Quality Standards shall be used to determine when process adjustments are required. See BOAPQ-7.

3.2.2 Visual Acceptance Criteria for Laser Lap Weld Continuous Seams.

3.2.2.1 Continuous Seam Visual Attributes – Discrepant and Nonconforming Welds. Continuous seam laser lap welds that exhibit any of the following attributes may affect conformance.

3.2.2.1.1 Continuous Seam – Weld Shape. Continuous seam laser lap welds that are installed with a shape that is different than the product design (outside 5 mm band width tolerance), do not conform.

3.2.2.1.2 Continuous Seam – Missing Welds. When fewer continuous seam laser lap welds exist than are specified on the weld design document, the omitted weld(s) do not conform.

3.2.2.2 Continuous Seam Visual Attributes – Appearance and Processing Considerations. Continuous seam laser lap welds that exhibit the following attributes are undesirable either from an appearance or processing viewpoint. These attributes are not used in determining weld conformance.

3.2.2.2.1 Continuous Seam – Spatter. Weld spatter that collects on a surface that is visible to the customer shall be removed. Spatter shall also be removed if it negatively effects a subsequent process. Spatter does not make the weld discrepant and does not affect structural conformance. Product Quality Standards shall be used to determine when process adjustments are required. Product Quality Standards shall be used to determine when process adjustments are required. See BOAPQ-7.

3.2.2.2.2 Continuous Seam – Surface Porosity and Top-Surface Expulsion. Surface porosity does not affect weld or pattern conformance. When excessive surface porosity or top-surface expulsion is present (see Figure 18), the process shall be adjusted to its qualified setup to eliminate the condition. Product Quality Standards shall be used to determine when process adjustments are required. See BOAPQ-7.

3.2.2.2.3 Continuous Seam – Crater Cracks. Crater cracks that are fully contained in the crater do not affect weld or pattern conformance. When crater cracks are present, the process shall be adjusted to its qualified setup to eliminate the condition (see Figure 3). Product Quality Standards shall be used to determine when process adjustments are required. See BOAPQ-7.

3.2.3 Visual Acceptance Criteria for LSWs.

3.2.3.1 Laser Spot Visual Attributes – Discrepant and Nonconforming Welds. Welds that exhibit any of the following attributes are discrepant and may cause the patterns to be non-conforming.

3.2.3.1.1 Laser Spot – Weld Shape. LSWs installed with a shape that is different than the product design are discrepant.

3.2.3.1.2 Laser Spot – Missing Welds. When fewer LSWs exist than are specified on the weld design document, the omitted weld(s) are discrepant. LSWs replaced with resistance spot welds or other approved discrete joining methods are not considered missing.

3.2.3.1.3 Laser Spot – Burn-Through. LSWs that exhibit burn-through must be repaired due to leaks. LSWs having burn-through are discrepant. The repair methods for a single burn-through and non-conforming pattern are different. See 3.4 and Appendix A, Table A3.

The acceptance criteria for burn-through in aluminum laser lap welds shall be documented utilizing PQS or deviation specific to each program/product.

3.2.3.1.4 Laser Spot – Edge Welds. LSWs that are not contained within all edges of the sheet metal being welded are discrepant, see Figure 3.

Figure 3: Edge Welds



3.2.3.1.5 Laser Spot – Surface Concavity. Visible surface concavity is expected. LSWs that do not exhibit concavity shall be further evaluated with non-destructive testing to ensure fusion.

3.2.3.2 Laser Spot – 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 used in determining weld pattern conformance.

3.2.3.2.1 Laser Spot – Spatter. Weld spatter that collects on a surface that is visible to the customer shall be removed. Spatter shall also be removed if it negatively effects a subsequent process. Spatter does not make the weld discrepant and does not affect structural conformance. PQS shall be used to determine when process adjustments are required. See BOAPQ-7.

3.2.3.2.2 Laser Spot – Center Pore. A center pore does not make the weld discrepant, see Figure 16.

3.3 Measurable Acceptance Criteria. The measurable acceptance criteria for the three basic shapes of laser welds (Lap Stitch Welds, Continuous Seams, and LSWs) are defined in following content.

3.3.1 Measurable Acceptance Criteria for Laser Lap Stitch Welds.

3.3.1.1 Stitch Welds – Location. Laser lap stitch welds must be properly located relative to design location as indicated on the weld design document, visual aid or weld template and to each other as follows:

- A laser stitch weld installed > 10 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 > 10 mm, the weld furthest from the design location is discrepant.

3.3.1.2 Stitch Welds – Adjacent, Missing, Cold Welds or Discrete Joints. Product detected with two or more adjacent structural welds or discrete joints that are not installed (missing), or not fused (cold welds) must be repaired regardless of the pattern tolerance.

3.3.1.3 Stitch Welds – Weld Size. The effective size of a laser lap stitch (L_e) is determined by measuring the actual fused length of the weld (L_a) and then subtracting the length of any portions of the weld that have discontinuities (L_d). Discontinuities are defined as surface cracks, burn-through, top-surface cut-through, or skips, see 3.3.1.3.1 thru 3.3.1.3.4. A weld whose effective length ($L_e = L_a - \sum L_d$) is shorter than shown in Table 1 is discrepant.

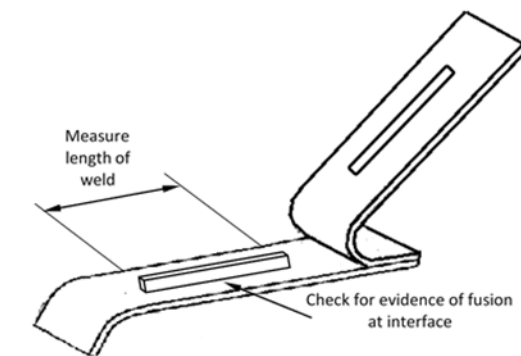
Table 1: Laser Lap Weld Stitch Length Requirements

Design Weld Length (mm) L_w	<i>Measured from Top Sheet</i> Maximum Allowable Length (mm) for the Total of All Discontinuities
≤ 50 (Stitch)	10% of the Design Weld Length

Note: mm = millimeter(s).

Actual fused weld length may be determined by either peel testing (see Figure 4) or by using a nondestructive method that clearly demonstrates fusion along the length of the stitch (e.g., ultrasonic or x-ray testing).

Figure 4: Laser Lap Stitch Weld by a Destructive Peel Test



3.3.1.3.1 Stitch Welds – Surface Cracks. A surface cracks (see Figure 5) that is visible without the aid of magnification, is a discontinuity whose length cannot be counted in the effective weld length. Welds having individual surface cracks longer than the maximum allowed discontinuity length contained in Table 1 are discrepant.

Figure 5: Surface Crack Example

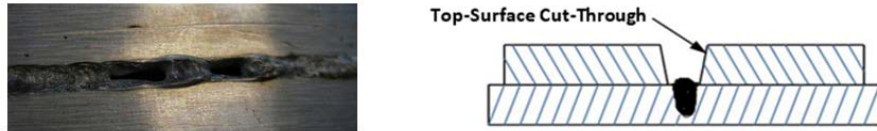


3.3.1.3.2 Stitch Welds – Burn-Through. Burn-through is not only a non-conformity due to leakage (3.4.1.2) but is also a structural discontinuity whose length cannot be counted in the effective weld length. Stitch welds having burn-through longer than the maximum allowed discontinuity length contained in Table 1 are discrepant and

requires structural repair if the pattern tolerance is exceeded. The repair methods for a single burn-through and non-conforming pattern are different, see 3.4 and Appendix A, Table A2.

3.3.1.3.3 Stitch Welds – Top-Surface Cut-Through. Top-surface cut-through is a discontinuity whose length cannot be counted in the effective weld length, see Figure 6. Stich welds having top-surface cut-through longer than the maximum allowed discontinuity length contained in Table 1 are discrepant.

Figure 6: Top-Surface Cut-Through Examples



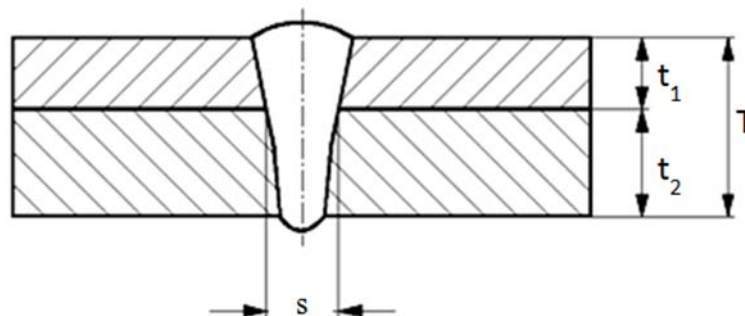
3.3.1.3.4 Stitch Welds – Skip. A skip is a discontinuity and the length of a skip cannot be counted in the effective weld length. Laser stitch welds having skips longer than the maximum allowed discontinuity length contained in Table 1 are discrepant.

3.3.1.4 Stitch Welds – Measurements on Cross-Section. The bead width, depth of fusion, concavity, convexity, porosity, and internal cracks of laser lap stitch welds are measured on metallographic cross-sections. The specific criteria for these follows.

3.3.1.4.1 Stitch Welds – Bead (Weld) Width at the Faying Surface. The bead width “s” is fused width at the faying surface, see Figure 7. The bead width “s” shall be equal to or greater than the thickness of the thinner sheet (t_1) at the interface being evaluated. A laser lap stitch weld whose bead width is less than this minimum bead width size is discrepant.

The acceptance criteria for bead width in aluminum laser lap welds shall be documented utilizing PQS or deviation specific to each program/product.

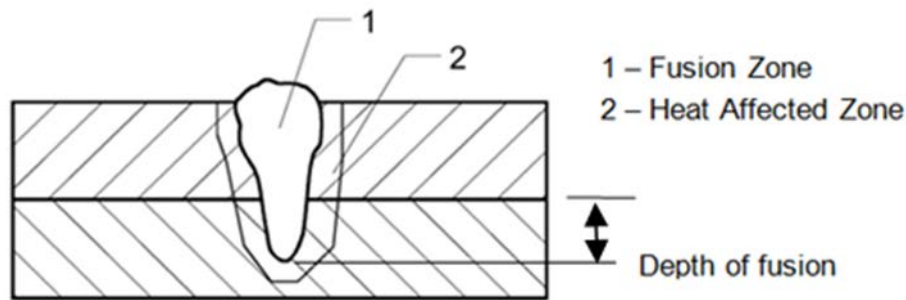
Figure 7: Bead Width (s) Measurement Example



3.3.1.4.2 Stitch Welds – Depth of Fusion. The maximum distance that fusion extends into the bottom sheet (sheet away from the laser) of a laser lap stitch weld is the depth of fusion, see Figure 8. The target depth of fusion in a continuous seam lap weld is 100% penetration into the bottom sheet. A laser lap stitch weld whose depth of fusion is < 30% penetration into the bottom sheet is discrepant.

The acceptance criteria for depth of fusion in aluminum laser lap welds shall be documented utilizing PQS or deviation specific to each program/product.

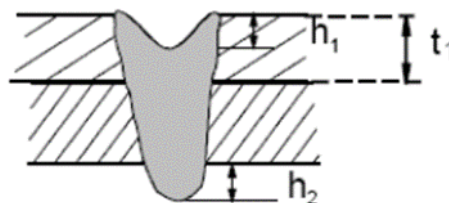
Figure 8: Depth of Fusion Example



3.3.1.4.3 Stitch Welds – Top-Sheet Concavity. Top-sheet concavity (h_1) for laser lap stitch welding shall be $< 30\%$ of the thickness of the top-sheet (t_1). A laser lap stitch weld whose top-sheet concavity is $> 30\%$ of the top sheet thickness is discrepant, see Figure 9.

The acceptance criteria for top-sheet concavity in aluminum laser lap welds shall be documented utilizing PQS or deviation specific to each program/product.

Figure 9: Concavity and Root Convexity Example



3.3.1.4.4 Continuous Seam – Root-Convexity. A laser lap stitch weld whose root-convexity (h_2) is > 0.2 mm shall have its process adjusted to the qualified setup, see Figure 9. Root convexity does not affect weld or pattern conformance.

3.3.1.4.5 Continuous Seam – Internal Porosity. When excessive internal porosity and/or voids and cavities are present in a laser lap stitch weld, the process shall be adjusted to its qualified setup. PQS specific to each program/product shall be used to determine when process adjustments are required. Internal porosity does not affect weld or pattern conformance.

3.3.1.4.6 Continuous Seam – Internal Cracks. The weld cross-section of a laser lap stitch weld should not contain any cracks that are visible at 15x magnification or less. PQS specific to each program/product shall be used to determine when process adjustments are required. Internal cracks do not affect weld or pattern conformance.

3.3.2 Measurable Acceptance Criteria for Laser Lap Weld Continuous Seams.

3.3.2.1 Continuous Seam – Weld Start and Stop Location. Welds are properly located when installed within 3 mm from the start and stop locations indicated on the weld design document, visual aid, or weld template. Continuous weld seams not correctly located, require that the welding process be adjusted to the qualified setup. An improperly located weld seam conforms provided the effective weld length requirement is met.

3.3.2.2 Continuous Seam – Excessive Actual Weld Length (L_a). The actual weld length is the measured length along the weld centerline from the weld start to weld end, see Figure 10. A weld whose actual length exceeds the design weld length should have its process adjusted to the qualified setup.