



Pre-Coated or Uncoated Heat-Treatable Sheet Steel

1 Scope

This specification covers the requirements for heat-treatable boron steel used in the manufacture of structural parts to manage very high tensile loads without significant deformation as required in safety and occupant protection. This material is heat treated, formed and simultaneously quenched in a water-cooled die in a process referred to as hot stamping, hot press forming or press hardening. Material produced by this process is generally referred to as Press Hardened Steel (PHS). This process produces parts with varied microstructures consisting of combinations of tempered martensite and non-martensitic transformation products. PHS parts may be specified to contain soft zones, which are lower strength than the surrounding metal and may contain reduced amounts of martensite relative to the surrounding metal.

1.1 Material Description. The material designation is defined by the GMW material specification number, material category (Sheet or Tubular product), steel product type, grade, and finish type. The substrates used in these applications may be cold rolled or hot rolled, but the product type is designated as heat treated (HT) or hot stamped (HS), as appropriate. The steel grades will correspond to the chemical and mechanical requirements as shown in Appendix A, Table A1 through Table A5. Only the surface quality designation of U, representing an unexposed application, shall be used unless otherwise approved by Materials Engineering. The preceding descriptive items are used together to form the coding system. Examples of the coding system for engineering part drawings, electronic math data files and/or manufacturing engineering documents are shown in Section 8.

1.1.1 Resistance Welded Mechanical Tubing. Tubes supplied to this specification are formed from a steel strip to the desired shape and dimension, electrical resistance welded into a tube, and then heat treated to achieve the final mechanical property requirements.

1.1.2 Induction Heat Treated Steel. Part sections formed with this operation and supplied under this standard shall be made by stamping in the as-rolled condition. The raw stamping can be selectively induction hardened to achieve the required strength requirements. Al-Si, Zn, Zn-Fe, or Zn-Ni pre-coated products shall not be used in these applications.

1.1.3 Hot Stamped Die Quenched Steel. Parts shall be made by austenitizing a pre-cut blank, hot stamping the heated blank and rapid cooling (quenching) the stamped part in the die or via water quenching. Press hardened steel (PHS) can be formed by either direct or indirect stamping processes. The direct process is considered as main-stream for all usages (except tubes).

Note: The indirect stamping process is not a globally available manufacturing process and must not be used (or parts designed to require its use) without the prior authorization of the GM Global Functional Lead (GFL). Use of the indirect process implies that affected parts cannot be used globally without driving excessive cost to ship stamped parts globally. Exception: For tubular products such as axle tubes, the indirect process is globally available and can be used without prior approval.

1.1.3.1 Uncoated Products. Parts formed with uncoated steel and supplied under this standard shall be subsequently cleaned (also referred to as "blasting") to mechanically remove oxide from the surface as described in 3.3.3.2.

1.1.3.2 Pre-Coated Products. Parts formed with a hot stamping operation may also utilize pre-coated steels furnished according to this specification to eliminate the need for cleaning/blasting and/or to improve corrosion performance.

1.1.3.2.1 Aluminum-Silicon (Al-Si) Pre-Coatings. Al-Si coated parts shall not be cold-stamped prior to the hot stamping operation, but roll-forming or variable thickness rolling operations may be allowable if the coating is not significantly damaged and approved by GM Materials Engineering. As noted in GMW15619, variable thickness rolled blanks are restricted to non-corrosion-critical areas, and use in corrosion critical areas must be approved by GM Materials Engineering.

Cleaning/blasting is not permitted for Al-Si pre-coated parts to prevent damage of the coating.

1.1.3.2.2 Zinc Based Pre-Coatings. The preferred manufacturing process for zinc or zinc alloy coated parts is direct hot stamping. Parts shall be cleaned (blasted) to remove any oxide layer from the surface as described in 3.3.3.2.

1.1.4 Material Callouts. The list of material and coating designations shown in Table 1 are the only approved material callouts that can be released unless GM Materials Engineering and the appropriate Global Subsystem Leadership Team approves.

Table 1: Approved Material Call-Outs

Material Call-Out	Coating System	Material Description
GMW14400M-ST-S-HS1300T/950Y-MS-UNCOATED-U	Uncoated	Uncoated press hardened steel stampings
GMW14400M-ST-S-HS1300T/950Y-MS-IB-UNCOATED-U	Uncoated	Uncoated press hardened steel stampings
GMW14400M-ST-S-HT1475T/1170Y-MS-UNCOATED-U	Uncoated	Uncoated induction heat treated products
GMW14400M-ST-T-HT1475T/1170Y-MS-UNCOATED-U	Uncoated	Uncoated welded and heat treatable tubular product
GMW14400M-ST-S-HS550T/370Y-MP-AS60G60G-U	Al-Si	Al-Si coated press hardened steel stampings
GMW14400M-ST-S-HS1000T/800Y-MP-AS60G60G-U	Al-Si	Al-Si coated press hardened steel stampings
GMW14400M-ST-S-HS1300T/950Y-MS-AS60G60G-U	Al-Si	Al-Si coated press hardened steel stampings
GMW14400M-ST-S-HS1300T/950Y-MS-AS35G35G-U	Al-Si	Al-Si coated press hardened steel stampings
GMW14400M-ST-S-HS1300T/950Y-MS-IB-AS60G60G-U	Al-Si	Al-Si coated press hardened steel stampings
GMW14400M-ST-S-HS1800T/1200Y-MS-AS60G60G-U	Al-Si	Al-Si coated press hardened steel stampings
GMW14400M-ST-T-HT1475T/1170Y-MS-AS60G60G-U	Al-Si	Al-Si coated welded and heat treatable tubular product
GMW14400M-ST-S-HS1300T/950Y-MS-EG60N60N-U	Zn-Ni	Zn-Ni coated press hardened steel stampings
GMW14400M-ST-S-HS1300T/950Y-MS-HD90A90A-U	Zn-Fe	Hot dip Zn-Fe coated press hardened steel stampings

1.2 Symbols. Not applicable.

1.3 Applicability. Typical applications are uncoated or pre-coated sheet metal stampings and thin gauge tubular structural parts requiring tensile strength minima ranging from 550 MPa to 1800 MPa. Typical applications include door impact beams, bumper impact beams and structural reinforcements for side impact, roof strength, and impact energy management.

1.4 Remarks. See the table in Section 9 for a cross reference of replaced specifications.

2 References

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

2.1 External Standards/Specifications.

ASTM A370	ASTM E45	ISO 1460	SAE J419
ASTM A428	ASTM E112	ISO 3887	SAE/USCAR-5
ASTM A513	ASTM E1077	ISO 4287	SAE/USCAR-7
ASTM A751	EN 10346	ISO 6892	
ASTM B487	IATF 16949	ISO 18594	

2.2 GM Standards/Specifications.

GMW8	GMW14057	GMW14872	GMW16170
GMW11	GMW14058	GMW15200	GMW16549
GMW3011	GMW14700	GMW15282	GMW16579
GMW3059	GMW14704	GMW15425	GMW16823
GMW3224	GMW14729	GMW15619	

© Copyright 2019 General Motors Company All Rights Reserved

GMW3335

GMW14829

GMW16066

2.3 Additional References.

- GWS-5A
- SEP 1160 (Available at <http://www.stahleisen.de> → Go to Products → Bookshop)
- SEP 1970 (Available at <http://www.stahleisen.de> → Go to Products → Bookshop)
- VDA 238-100 (Available at <http://www.vda.de/en> → Services → Publications)

3 Requirements

This section defines specific requirements for material on delivery, processing, performance and other stages during life cycle. Deviations required for individual GM business units are listed in the Deviations at the end of this document.

Parts supplied according to this specification shall undergo successful trials that fully meet end product requirements. In the event of any changes to the heat treatment and/or manufacturing process to which the part was successfully validated, the appropriate engineering group must be notified, and the part must be tested and requalified to the proper Production Part Approval Process (PPAP) level as determined by GM.

Hot stampers are required to maintain a consistent source of steel supply and to use GM approved suppliers listed in GM's Approved Source List.

3.1 Sample Requirements for Qualification. For initial steel supplier qualification, test samples shall be removed from production representative coils and heat treated in a production representative manner. If the samples are either zinc coated or uncoated, the surfaces shall be media blasted in a production representative process to remove surface oxides.

3.2 Engineering Requirements.

3.2.1 Chemistry. Base metal composition based on product (coil, sheet/blanks, or tube) analysis determined per ASTM A751 shall conform to the requirements of Table A1 and/or shall be agreed upon between supplier and purchaser. When end product test results are not available, ladle analysis may be used. Chemical composition on the end product is the referee method.

3.2.2 Applied Process Coatings.

3.2.2.1 Corrosion Preventatives. Temporary/transit corrosion protection, such as oils, paper, or containerization, etc., may be used to protect the coils or blanks from in-transit corrosion that may result in detrimental impact to subsequent manufacturing processes. Rust preventatives applied to finished parts shall be chosen to prevent contamination to paint systems or negative effects to subsequent manufacturing operations. Zn-based coatings shall not be oiled prior to the press hardening process.

3.2.2.2 Forming Lubricants. If coil or blank lubricants are applied, supplier shall ensure that all downstream operations, manufacturing processes and part performance requirements are not negatively affected. Lubricants shall not be a source of diffusible hydrogen into the steel when burned during austenitization. Any lubricant applied must pass all qualification tests outlined in this specification.

3.2.3 Mechanical Property Requirements. The 0.2% Offset Yield Strength, Tensile Strength and Percent Total Elongation shall be determined in the longitudinal direction per GMW3335. Tests shall be performed using samples per ISO 6892 Type I (50 mm gage length ASTM type sample), ISO 6892 Type II (80 mm gage length DIN type sample), or ISO 6892 Type III (50 mm gage length JIS type sample). See Note 6 and Note 7 in Table A4 for requirement modifications for the testing of standard tensile bars with material gauges/thicknesses < 1 mm and subsize tensile bars with specimen gauge lengths < 50 mm.

3.2.3.1 Base Metal Mechanical Property Requirements. Uncoated cold rolled steel supplied to this specification for direct hot stamping operations shall be in the "full hard" or non-annealed condition and hot rolled steel shall be supplied with "as rolled" mechanical properties unless otherwise agreed upon. Coated cold rolled and hot rolled steel supplied to this specification for direct hot stamping operations shall be in the annealed condition. Steel supplied for induction heat treating after forming shall conform to the pre-heat treat requirements in Table A3.

3.2.3.2 Finished Part Mechanical Property Requirements. All finished parts shall meet the mechanical property requirements shown in Tables A2, A3 or A4 depending on the specific application and manufacturing process. Suppliers are responsible to ensure that the method used to cut and prepare tensile specimens for evaluation shall be appropriate for the strength of the material.

© Copyright 2019 General Motors Company All Rights Reserved

June 2019

Page 3 of 23

If a part is to contain soft zones or purposeful regions of non-martensitic transformation products, e.g., toy-tabs, all pertinent control parameters for the soft zone shall be specified in the part math file or equivalent location and shall contain the locations, size/transitions and mechanical properties (hardness and uniaxial tensile properties) of the soft zone(s) with appropriate tolerancing.

3.2.3.2.1 Post-Stamping Heat Treatment. Parts produced to GMW14400M-ST-S-HS1800T/1200Y-MS require a post-stamping bake at 170 °C for 20 minutes; baking must be performed prior to determining specification conformance and prior to any appreciable stressing of the component due to shipping or sub-assembly.

3.2.4 Bend Test Requirements. Bend testing is required for steel supplier qualification. Samples shall be taken from production representative coils and heat treated in a production representative process.

Bend testing shall be performed according to VDA 238-100. The material shall be capable of being bent without pre-strain, both longitudinally and transverse to the rolling direction, through the bend angle, α , as shown in Table A5 on a three-point free bend with the ends unrestricted with the specified bending radii.

3.2.4.1 Bend Test for Heat Treated Parts. Heat treated parts shall meet the bend test requirements as described in 3.2.4 as part of the prototype part validation and initial part production verification by saleable PPAP. Samples shall be removed from finished parts using laser, water jet cutting, or electrical discharge machining (EDM). If a suitably sized sample for bend testing per VDA 238-100 cannot be removed from the part, flat samples from the production material may be heat treated and die quenched in the production representative process according to the supplier's process control plan, or waived by GM Engineering or GM Supplier Quality.

3.2.4.2 Hydrogen Embrittlement Sensitivity. For material qualification, all materials supplied to this specification must be demonstrated free of hydrogen embrittlement according to SEP 1970 (U-bend test or tensile specimen with notched hole loaded to 100% yield strength (YS)) or SAE/USCAR-7 (standard tensile specimen loaded to 80% ultimate tensile strength (UTS)). Hydrogen generating processes including, but not limited to, acid cleaning, phosphating, electroplating, etc., shall be avoided whenever possible. In the case where hydrogen generating processes cannot be avoided for steel and/or part processing, suppliers shall follow the de-embrittlement requirements per SAE/USCAR-5 followed by verification that parts are free of hydrogen embrittlement per SEP 1970 or (SAE/USCAR-7) in the preceding manner. For direct water part processing (quenching), suppliers shall follow the de-embrittlement requirements per SAE/USCAR-5 and verify parts are free of hydrogen embrittlement per SEP 1970 (tensile specimen with notched hole loaded to 100% YS) or SAE/USCAR-7 (standard tensile specimen loaded to 80% UTS).

3.2.5 Additional Requirements for Pre-Coated Steels for Hot Stamping. The following requirements shall be met by steel suppliers and stampers of pre-coated boron steels used in hot-stamping applications. These requirements are in addition to the chemical and mechanical requirements in Table A1, Table A4, and Table A5.

3.2.5.1 Coating Analysis Prior to Heat Treatment. The continuous coating shall meet the composition requirements in Table A6 or Table A7 and shall also meet the requirements of GMW3059. The coating shall not contain trace elements that are detrimental to adhesive bonding, phosphate or other conversion coatings applied to promote paint adhesion, or paintability.

3.2.5.2 Coating Mass Prior to Heat Treatment. ASTM A428, ISO 1460 or EN 10346 shall be used for determination of coating mass for coatings. The test sample size shall be 2000 mm² minimum, with a preferred sample size of 3330 mm² (57.7 mm $\pm$ 0.1 mm or 65.1 mm $\pm$ 0.1 mm in diameter). Coating mass shall be measured by triple spot and single spot testing, and shall conform to values in Table A6 or Table A7. The triple spot coating mass shall be an average of three measurements taken across the width of the strip at least 25 mm from the edge. In no instance shall the coating weight of any of these samples fall below the minimum single spot test requirement in Table A6 or Table A7. Each side shall be measured separately (e.g., by masking the coating from one side) to ensure the requirements of Table A6 or Table A7 are met.

3.2.5.3 Coating Analysis After Heat Treatment. For zinc-based coatings, a Glow Discharge Optical Emission Spectroscopy (GD-OES) analysis, or equivalent, must be performed through the coating thickness for both steel supplier qualification and initial part production verification by saleable PPAP. The coating composition, including the elements iron, zinc, nickel, aluminum and manganese shall be reported along with photomicrographs at 500x from both sides of the steel sheet.

For Al-Si coatings, a Glow Discharge Optical Emission Spectroscopy (GD-OES) analysis, or equivalent, must be performed through the coating thickness for steel supplier qualification. The coating composition, including the elements iron, aluminum, silicon, and manganese shall be reported along with photomicrographs at 500x from both sides of the steel sheet.

Processing and handling of the coated product during heat treatment and any other processes shall not contaminate the coating. See GMW16579 for process related contamination of the coating.

3.2.5.4 Coating Thickness After Heat Treatment. Coating thickness requirements are shown in Table A6 and Table A7. Photomicrographs of Al-Si coating cross sections following heat treatment are shown in Figure A1. Interdiffusion layers are identified in Figure A1 to outline the measurement method. Coating thickness may also be used for routine quality control evaluations. Coating thickness is measured using a suitable layer thickness gauge, on-line x-ray gauge, or from a specimen cut perpendicular to the panel surface per ASTM B487. Suitable instruments for evaluation of coating thickness on the as-received pre-coated sheet (e.g., eddy current, ferromagnetic, or metallurgical microscope) shall have a capability of $\pm 1.0 \mu\text{m}$ accuracy. Magnetic inductive measurements are not recommended on the finished hot-stamped part without proper calibration due to the alloy reaction which occurs during hot stamping. When using a metallurgical microscope to examine the coating layers, standard mounting practices shall be used and thickness shall be measured after 2% to 4% nital etching followed by examination at 500x to 1000x magnification.

3.2.6 Cyclic Corrosion Lab Test in Flanges. For material qualification, samples for corrosion testing shall be prepared according to SEP 1160, part 1, glass flange type II "Evaluation of Weldable Corrosion Protection Primers for the Automotive Industry – Corrosion Performance" and as shown in Figure 1. No paint is allowed on the flanged surfaces. The paint used to coat the surface outside of the flange (non-test surfaces of the panels) is not required to meet original equipment manufacturer (OEM) specifications, however, the applied paint must remain fully adherent during corrosion testing and prevent corrosion of the painted surfaces.

Three samples representing each side of the material shall be prepared with simulated glass flanges for a total of six samples. In addition, three reference samples with coatings HD60G60G or EG60G60G shall be prepared and evaluated in the same way. The samples shall then be exposed to accelerated laboratory corrosion testing according to GMW14872 (UB), All, 4sp, Method 1/2, Exposure D. Maximum pit depth shall be determined by microscopic cross section of the flange section, taking care to examine the entire area under the flange.

Assembly of Glass Flanges for Corrosion Tests

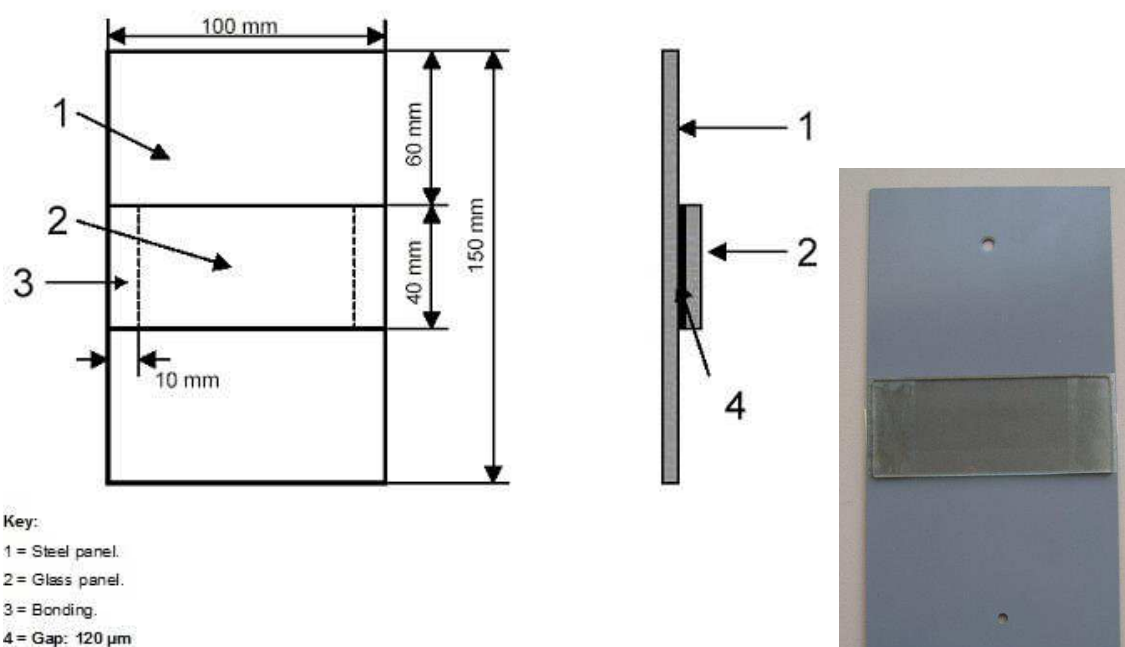


Figure 1: Sample Setup for Corrosion Test with Flanges

3.2.7 Coating Adhesion. For material qualification, coating adhesion shall be evaluated on degreased samples that have been adhesively bonded and subsequently evaluated by lap shear strength testing as described in GMW15200-HS-IR-FS with a GM-approved high strength impact resistant full spectrum adhesive. Samples shall

© Copyright 2019 General Motors Company All Rights Reserved

be prepared and evaluated to represent standard cure condition (25 minutes at $175\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$). The bond strength and fracture mode of the samples shall be reported.

Cohesive separation within the adhesive (preferred) or delamination of the coating to the steel substrate that occurs above the specified minimum strength level of $\geq 16\text{ MPa}$ at room temperature and $\geq 8\text{ MPa}$ at $-40\text{ }^{\circ}\text{C}$, are considered acceptable.

3.2.8 Microstructure.

3.2.8.1 Inclusions. For material qualification, non-metallic inclusions in the steel substrate shall be quantified according to ASTM E45 Method D, Plate I-r, by analysis at 100x; inclusion content shall not exceed a rating of 2 for thin and 2 for heavy. Manganese sulfide (MnS) stringers shall not exceed $500\text{ }\mu\text{m}$ in length as measured along the steel rolling direction.

3.2.8.2 Prior Austenite Grain Size. For both coated and uncoated steel, a prior austenite grain size rating ($16\text{ }\mu\text{m}$ – rating of ASTM 9 or finer per ASTM E112) may be specified for impact critical hot-stamped components as determined by GM Materials and Product Engineering.

3.2.9 Material Thickness and Tolerances. The detailed engineering part drawing or electronic math data file will specify the material thickness. Thickness tolerances shall be per GMW3224. Tolerances for electric resistance welded tubes not specified on drawings shall follow ASTM A513.

3.2.10 Coating Designation. The type of coating and coating mass is specified by a suffix added to the basic specification number. The first two letters AS will designate a continuous Al-Si pre-coating. The letters HD will designate a continuous hot-dipped zinc (with suffix G after coating mass callout) or zinc-iron alloy (with suffix A after coating mass callout) pre-coating. The letters EG will designate a continuous electrolytically-applied zinc (with suffix G after coating mass callout) or zinc-nickel (with suffix N after coating mass callout) pre-coating. The coating mass prior to hot stamping for each side is designated in grams per square meter (g/m^2). Only the specified coating masses of Table A6 or Table A7 (triple spot and single spot) may be used unless the appropriate engineering group is consulted. The letter U follows the coating and mass designation to specify an unexposed surface finish. See examples of nomenclature in Table 1 and Section 8.

3.2.11 Coating Quality. The steel shall be free from surface defects as negotiated between purchaser and supplier. For unexposed (U) surfaces, defects such as slight indentations, small marks, minor scratches, and slight discoloration are permissible if they do not affect corrosion resistance, formability, or the application of any other surface coating.

Break-offs or burn-offs of zinc based coatings caused by the stamping process are not allowed. If cracks occur in zinc based coatings, crack width shall be less than the coating thickness and shall not affect corrosion protection.

For Al-Si coatings, bare spots, break-offs, burn-offs, and cracks due to stamping shall not exceed 1 mm in width or be detrimental to the barrier protection inherent in the coating. Cracks shall not penetrate into the steel substrate. Examples of coating defects that can occur from hot stamping are shown in the appendices of GMW16579. Surface scratches or gouges shall not adversely affect part performance through introduction of deep surface flaws resulting in loss of sufficient quench rate or geometric stress concentrations. Suppliers of hot stamped parts are responsible to ensure that their heat treatment process does not negatively affect corrosion protection as required in 3.2.6.

3.3 Manufacturing Requirements.

3.3.1 Pre-Treatment/Paint Adhesion of Heat Treated Parts. For material qualification and when tested with approved phosphate systems, uncoated or zinc-based coated steels shall be capable of achieving a high quality zinc phosphate conversion coating according to GMW3011 (crystal size and coating weight). Parts produced from pre-coated Al-Si steel must meet the overall corrosion requirements of these specifications, but are excluded from the phosphate conversion coating weight and thickness requirements since they generally are not phosphateable and instead rely on surface micro-discontinuities for adhesion of subsequent primers and paints.

When tested with approved thin film pre-treatments, the requirements of GMW16170 (coating weight and thickness) shall be met. After application of production representative pre-treatment and paint, the steel shall meet the following requirements:

- a. Adhesion of the E-coat shall fulfill test requirements of the crosshatch test according to GMW14829:
 1. For samples that are phosphated: a rating of "0" as-received and after 120 h humidity exposure per GMW14729.

2. For samples with thin film pre-treatment: requirements according to GMW16170 shall be met.
- b. Pretreated (zinc Phosphate or thin film) and E-coated samples must meet delamination test requirements according to GMW14704 (rating 0 or 1 after 48 h test duration).
- c. For underbody applications, the material shall also meet the requirements of the stone chip resistance test according to GMW14700, Method A (or B) and Method C, with a minimum stone impact rating of 8.
- d. Creep-back resistance shall be inspected on E-coated samples. The samples shall be scribed per GMW15282 and tested according to GMW14872, EXT, All, 4 salt spray per cycle, Method 1/2, exposure C. Creep-back shall be tested according to GMW15282 and meet the following requirements:
 1. For samples that are phosphated: 6 mm maximum (uncoated), 4 mm maximum (pre-coated) creep-back.
 2. For samples with thin film pre-treatment: 6 mm maximum (uncoated), 4 mm maximum (pre-coated) creep-back.

3.3.2 Adhesive Compatibility. For material qualification, metallic surfaces supplied to this specification shall be demonstrated capable of bonding with GM approved adhesives when tested according GMW16549. Testing to this specification will evaluate bonding characteristics to the metal surface.

3.3.3 Surface Requirements.

3.3.3.1 Surface Texture. Heat treated parts furnished with an aluminum-silicon coating, shall exhibit a roughness average (R_a) of 1.8 μm minimum and profile peak to valley height (R_t) of 12 μm minimum, as defined in ISO 4287. The R_a and R_t shall be measured using a sampling length/cutoff wavelength, λ_c , of 2.5 mm and evaluation length of 12.5 mm.

Surface defects such as slivers, laminations, scratches in the coated and/or in the uncoated substrate that may be detrimental to the finished part performance are not allowed.

3.3.3.2 Surface Quality. The surface condition shall meet the requirements of GMW16823. The steel shall be free from surface defects as negotiated between purchaser and supplier. Only unexposed (U) surfaces may be specified for materials subject to GMW14400.

3.3.3.3 Surface Oxides.

- **Uncoated Parts:** After hot stamping, the steel surface shall be cleaned/blasted such that subsequent operations such as phosphating/painting, bonding and welding are not adversely affected.
- The application of a corrosion preventative oil may be required in order to ensure that parts do not develop surface oxides/rust during shipment and storage. Any applied oils must meet the requirements shown in 3.2.2.1.
- **Aluminum-Silicon (Al-Si) Pre-Coated Parts:** Cleaning/blasting of the surface is not permitted.
- **Zinc Based Pre-Coated Parts:** Cleaning/blasting of the surface is required to remove visible red/brown oxides produced during hot stamping that would otherwise negatively affect subsequent processes such as adhesive bonding, painting and welding. The cleaning/blasting process used by the supplier, such as dry ice, steel shot, airless blasting, etc., shall be selected such that it removes the surface oxide layer, but does not remove or damage the corrosion protective coating, and it does not negatively affect dimensional tolerances. The cleaning/blasting medium shall not contaminate the coating, introduce coating inclusions, or leave any residues on the coating that may be detrimental to part performance. The application of corrosion preventative oils may be required in order to ensure that parts do not develop surface oxides/rust during shipment and storage. Any applied oils must meet the requirements shown in 3.2.2.1.
- Surfaces that have been cleaned/blasted shall consist of a uniform, homogeneous appearance. Hot stampers shall verify adequate oxide coating removal by one of the following two methods:
 - a. **Method One:** Application of drops prepared from a test solution of 50 g of copper (II) sulfate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, 98%) and 20 mL of sulfuric acid (H_2SO_4 , 95%) in 2 L of distilled water to a stamped part that is clean and free of oil. The test solution shall only be applied when the solution and part temperature are at ($23^\circ\text{C} \pm 2^\circ\text{C}$) or false results may occur. Areas that exhibit complete oxide removal will react almost immediately to drops of the test solution on the panel as demonstrated by the formation of gas bubbles in the solution. A successful test will result in bubble formation in < 2 s of application. Excessive oxides that are not removed from the coating will cause delays in the formation of bubbles in the test solution.