GM	WORLDWIDE ENGINEERING STANDARDS	Material Specification	GMW3399

Multi-Phase and Ultra-High Strength Sheet Steel

1 Scope

This specification covers the requirements for continuous cast, hot rolled or cold rolled sheet steel with specified tensile strengths from 450 MPa through 1700 MPa.

1.1 Material Description. This specification applies to uncoated and coated, Dual Phase (ferrite + martensite) (DP), ferrite bainite with high hole expansion (FB), Multi-phase (ferrite + martensite + bainite + precipitation hardening) (MP), and Martensitic (MS) materials. These products shall be supplied as coils or sheets. Hot rolled flat products are usually supplied in thicknesses greater than 1.80 mm. Cold and hot rolled flat products with the appropriate surface type and surface finish are suitable for the application of surface coatings, metallic hot dipping, electrolytic plating, hot spray painting, organic coatings and/or other coatings. This specification does not apply to steel for case hardening and cold reduced, work hardened strips. Additional requirements or agreements have to be specified by local business units, e.g., North America (NA), Europe (E), Latin America (LA), and Asia Pacific (AP).

Multi-phase (MP) and martensitic (MS) steels shall only be used for roll forming, simple bending/flange applications, and targeted stamping applications as approved by GM Materials and Manufacturing Engineering.

1.2 Symbols. Not applicable.

1.3 Applicability. Typical applications include body panels, body structure members, chassis components and bumpers.

2 References

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

2.1 External Standards/Specifications.

ASTM A751	ISO 6892	ISO/TS 16630	SAE/USCAR-5
ASTM E45	ISO 7438	ISO/TS 16949	SAE/USCAR-7
ASTM E112	ISO 10275	JIS Z 2241	

2.2 GM Standards/Specifications.

GMW8	GMW3335	GMW14729	GMW16066
GMW11	GMW14057	GMW14829	GMW16170
GMW3011	GMW14058	GMW14872	GMW16546
GMW3059	GMW14699	GMW15056	GMW16549
GMW3221	GMW14700	GMW15282	GMW16656
GMW3224	GMW14704	GMW15425	GMW16823

2.3 Additional References.

- GWS-5A
- SEP 1970 (Available at http://www.stahleisen.de → Go to Products → Bookshop)

3 Requirements

The following 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.

3.1 Requirements on Delivery.

3.1.1 Chemical Requirements.

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3.1.1.1 Base Metal. Base metal composition based on product (coil or sheet/blanks) analysis determined per ASTM A751 shall conform to the grade specific requirements in Appendix A, Table A1. When end-product (coil/blank) test results are not available, heat analysis may be used. Chemical composition on the end product is the referee method.

3.1.1.2 Surface Treatment. Products coated with a designated lubricant (e.g., mill oil or pre-lube) shall comply with GMW16546 and GMW16656 and/or be approved by the local business unit.

3.1.2 Mechanical Requirements. The steel products shall meet the mechanical properties as specified in Appendix A, Tables A2 thru A7. The 0.2% Offset Yield Strength, Tensile Strength, Elongations (Uniform and Total) and bake hardening indices (BH_2) 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 JIS Z 2241 (No. 5). Both test methodology and results shall be reported accordingly per GMW3335. Strain hardening exponent *n* and *K* values shall be determined per ISO 10275. The specific strain level shall be reported with all test results.

Strain hardening exponent *n* and *K* value shall be determined at 10% to 20% strain, or at 10% to end of uniform elongation when uniform elongation is less than 20%, but greater than 12%. If the maximum uniform elongation is less than 12%, the strain hardening exponent shall be reported as the true strain at the end of uniform elongation ($n_{U.E.} = \varepsilon_{U.E.}$) Dual Phase grades require an additional determination of n value at 4% to 6% strain. The specific strain range shall be reported with all test results.

3.1.2.1 Mechanical Property Requirements of Dual Phase (DP), Ferrite Bainite (FB), Multi-phase (MP) and Martensitic (MS) grades of hot rolled, cold reduced, uncoated and coated sheet steel grades are based on the minimum as-received tensile strength.

Some steels (DP and MP) have the additional requirement of a **Bake Hardening Index** (BHI). Where required, the material shall attain an increase in lower yield strength as specified in the appropriate table after 2% tensile strain and baking at 170 °C for 20 minutes. Figure B1 in Appendix B defines Bake Hardening and Work Hardening Indexes.

Note: The bake hardening index in this specification is a parameter that characterizes the general bake hardening response of steel. The actual or measured bake hardening response for production parts depends on a number of factors that must be considered. The amount of strain, the direction of strain relative to the test direction, the actual part temperature/time in the paint bake ovens, etc., may all impact the observed bake hardening response.

3.1.2.2 Bend Test Requirements for Martensitic (MS) and Multi-phase (MP) Grades. Testing shall be performed according to ISO 7438, by utilizing a bending device consisting of a V-block and a former or two low friction mounted test rollers and a former. Martensitic steels (MS) and Multi-phase steels (MP) must meet the bending radii as specified in the Appendices, Tables A2, A4, A6 and D1 for a bending angle of 90°. A minimum of three (3) tested samples shall not exhibit cracking when viewed at 10x to 20x magnification.

3.1.2.3 Mechanical Property Requirements of Ferrite Bainite (FB) Grades. Ferrite Bainite grades must meet the requirements of the hole expansion test as shown in Appendix A, Table A7. Testing shall be performed per ISO/TS 16630.

3.1.3 Physical Requirements.

3.1.3.1 Material Thickness and Tolerance. The detailed engineering part drawing or electronic math file will specify the material thickness and tolerance. The tolerance requirements for various thicknesses and strength levels are listed in GMW3224.

3.1.3.2 Surface Requirements.

3.1.3.2.1 Surface Texture. Specific requirements for the texture for each region are detailed in GMW16823.

3.1.3.2.2 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.

3.1.3.2.3 Additional Surface Requirements of Hot Rolled Products. Uncoated hot rolled products shall be supplied in a pickled (de-scaled) and oiled condition to ensure an adequate processability and a good adhesion of applied coatings, as required by the appropriate specifications.

Hot rolled steels may be slightly skin-passed at the discretion of the supplier or with agreement by General Motors.

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3.1.3.2.4 Pre-Treatment Compatibility/Paint Adhesion (Qualification Testing). 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). When tested with approved thin film pre-treatments, the requirements of GMW16170 (coating weight and thickness) must be fulfilled. Steels with thin organic pre-coatings per GMW15056 are excluded from these requirements; as a pre-treatment will not be deposited. However, the additional requirements below must be met for thin film organic pre-coating qualification.

After application of production representative pre-treatment and paint, the steel shall meet the following requirements:

1. Adhesion of the E-coat shall fulfill test requirements of the crosshatch test according to GMW14829:
   - For samples that are phosphated: rating 0 as-received and after 120 h humidity exposure per GMW14729.
   - For samples with thin film pre-treatment, requirements according to GMW16170 must be met.
2. 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).
3. For fully painted applications on exposed (E) surfaces, 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.
4. 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. The creep back shall be evaluated per GMW15282 and meet the requirements stated in the following specifications:
   - GMW3011 for samples that are phosphated.
   - GMW16170 for samples with thin film pre-treatment.
   - GMW15056 for samples with thin organic pre-coating (applicable to thin film organic coating qualification only).

3.1.3.2.5 Adhesive Compatibility (Qualification Testing). Uncoated or zinc-based coated steels supplied to this specification shall be capable of being bonded with GM approved adhesives when tested according GMW16549. Testing to this specification will evaluate bonding characteristics to the metal surface.

3.1.3.2.6 Coating Requirements. Refer to coating requirements in GMW8 for hot dipped coatings, GMW11 for electrogalvanized coatings, GMW16066 for aluminized coatings, and GMW15056 for thin organic pre-coatings. Coating requirements include, but are not limited to coating composition, coating mass, and coating adhesion.

3.1.3.3 Microstructure.

3.1.3.3.1 Grain Size. During steel qualification, grain size shall be tested to ASTM E112 and shall be consistent throughout the thickness of the sheet.

3.1.3.3.2 Segregations and Material Inhomogeneities and Cleanliness. Inhomogeneities (e.g., martensite lines, slag inclusions, segregations) in the steel shall be minimized and should not affect cold forming properties.

3.1.3.3.3 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 2.0 for thin and 2.0 for heavy.

3.1.3.4 Marking. If required, marking shall be carried out on the unexposed surface of full finish coils for outer panels and on the outer side of the coils for inner panels. The marking must be agreed upon between the supplier and purchaser. The purchaser must release the marking ink.

3.1.3.5 Other Requirements. Requirements such as tolerances on product shape and dimensions, inspections units, number of tests, sampling, test conditions, retests, inspection documents, packing, and handling of disputes shall be agreed upon between supplier and the local business unit.

3.2 Processing Requirements.

3.2.1 Additional Requirements.

3.2.1.1 Weld Seams in Coils. If weld seams in cold rolled material are allowed by Global Manufacturing Engineering Department, the following restrictions have to be considered:

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For cold reduced coils, pickling weld seams from the manufacturing process of hot rolled coils is permissible without restriction. Punch holes may be used for cold reduced coils to detect weld seams, but must be avoided in stamped parts. For cold reduced coils with exposed (E) or semi-exposed (Z) surfaces, weld seams are permissible, but must be indicated by perforation. For cold reduced coils with unexposed (U) surfaces, weld seams are not permissible unless special exceptions are made by the local organization. For hot rolled coils, weld seams are not permissible.

3.2.1.2 Welding. Sheet steel supplied to this standard shall be weldable with standard GM Weld Practices and meet spot weld, arc weld, or laser fillet weld acceptance criteria per GMW14057, GMW14058, or GMW15425, respectively. When required for qualification, testing for spot weldability shall be performed per GWS-5A and approved by the ME-Weld Department of GM Manufacturing Engineering. Contact the GM Weld Council for specific information regarding weldability at weld.council@gm.com.

Note: The standard weld test methods are intended for **yield** strength levels up to 420 MPa. Modifications to these methods may be required for higher strength levels. Due to unique properties of multi-phase and ultra-high strength steels, selection of the weld process parameters should be determined in consultation with the steel supplier.

3.2.1.3 Stretcher Strains. All steel used for exposed (E) surfaces and secondary exposed surfaces shall be free from stretcher strains for six months.

3.3 Performance Requirements. Not applicable.

3.4 Requirements on Other Stages during Life Cycle.

3.4.1 Chemical Requirements. Provisions must be made to prevent the addition of such elements (see 5.3) from scrap or other materials used in the manufacturing process which would impair the recyclability of the finished components.

3.4.2 Mechanical Requirements. The mechanical property requirements shown in the Appendices, Tables A2 thru A7 and D1 shall be guaranteed for a minimum of 3 months after delivery to the manufacturing plant. For material qualification, required mechanical properties shall be guaranteed for a minimum of 6 months after coil finishing.

3.4.2.1 Hydrogen Embrittlement Sensitivity. During source approval/qualification of materials with a tensile strength level ≥ 980 MPa, the supplier must demonstrate the steel is be free of hydrogen embrittlement according to SEP 1970 (U-bend 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)) under typical steel processing conditions.

Following GM-qualified steelmaking and/or electro-coating processes, subsequent hydrogen generating processes including, but not limited to, acid cleaning, phosphating, electroplating, etc., shall not be performed with GM Materials Engineering approval for high strength steels and/or parts consisting of ≥ 980 MPa tensile strength steel or exhibiting hardness ≥ 353 HV (36 HRC), including in high strain/cold worked areas (i.e., on part bend radii, features/depressions, sheared edges, etc.) 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 and be free of hydrogen embrittlement per SEP 1970 or SAE/USCAR-7 in the same manner as the preceding.

3.5 Requirements on Test Specimens. Reference GMW3221.

4 Manufacturing Process

Not applicable.

5 Rules and Regulations

5.1 Legal Regulations. All materials must satisfy applicable laws, rules, regulations and recommendations valid in the country of usage.

5.2 Language. In the event of conflict between the English and domestic language, the English language shall take precedence.

5.3 Inspection and Rejection. Samples of components or materials released to a GM material specification shall be tested for conformity with the requirements of this material specification and approved by the responsible Engineering department prior to commencement of delivery of bulk supplies.

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A new approval must be received for any changes, e.g., properties, manufacturing process, location of manufacture, etc. If not otherwise agreed, all testing and documentation normally required for initial release must be completed.

It is the responsibility of the supplier to inform the customer in a timely manner, without solicitation, and to include documentation of all modifications of materials and/or processes and to apply for a new release.

All shipments of materials or parts under contract or purchase order manufactured to this standard shall be equivalent in every respect to the initial samples approved by engineering. There shall be no major changes in formulation or manufacturing process permitted without prior notification and approval by engineering. Lack of notification by the supplier constitutes grounds for rejection of any shipment. While samples may be taken from incoming shipments and checked for conformance to this specification, the supplier shall accept the responsibility for incoming shipments meeting this standard without dependence upon purchaser's inspection.

5.4 Material Safety Data Sheets/Safety Data Sheets (MSDS/SDS). For new product submissions, or when a change in chemical composition of an existing product has occurred, a complete copy of the Material Safety Data Sheet/Safety Data Sheet must be submitted in compliance with the Globally Harmonized System of Classification and Labeling of Chemicals (GHS) requirements or other country-specific MSDS/SDS requirements.

5.5 All materials supplied to this standard must comply with the requirements of the International Material Data System (IMDS) and GMW3059, **Restricted and Reportable Substances.**

5.6 Initial Source Approval. No shipments shall be made by any supplier until preliminary technical approval (inclusive material tests at supplier and/or GM) has been obtained. Requirements for steel qualification may be found in GMW14699.

5.7 Quality Requirements. The supplier shall have quality process control procedures compliant with ISO/TS 16949 or as required by GM Global Purchasing and Supply Chain (GPSC) demonstrating that the product will conform to all specification requirements. The data required to be submitted for this specification for each shipment will be determined by the regional manufacturing location.

6 Approved Sources

Materials supplied to this specification must be approved by General Motors.

A list of approved materials can be found in the sheet metal approved source list in GM SupplyPower (Document Library » Engineering » GM North America » Product Design). This GM Material File is provided to third parties to reduce redundant testing of materials. If approved material already listed is used, the part supplier can use GM Material File reference for Production Part Approval Process (PPAP) material approval. If the decision is made to use a not yet approved material, contact the GM Materials Engineering for details on the approval process. The material approval process must be completed prior to PPAP start date of the part supplied to General Motors.

7 Notes

7.1 Glossary.

MATSPC: Global repository of GM approved materials for corresponding GM Engineering Standards.

7.2 Acronyms, Abbreviations, and Symbols.

AP	Asia Pacific
ASTM	ASTM International
BHI	Bake Hardening Index
CR	Cold Rolled
DO	Distinction of Image
DP	Dual Phase
E	Europe
E	Exposed (surfaces)
EG	Electrogalvanized (Coating)
ELPO	Electrodeposition Primer
EN	European Norm

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FB	Ferrite Bainite
GHS	Globally Harmonized System of Classification and Labeling of Chemicals
GME	General Motors Europe
GMW	General Motors Worldwide
GPSC	Global Purchasing and Supply Chain
HD	Hot-Dipped (Galvanized Coating)
HR	Hot Rolled
IMDS	International Material Data System
ISO	International Organization for Standardization
JIS	Japanese Industrial Standards
L	Longitudinal
LA	Latin America
LCE	Low Carbon Equivalent
Max.	Maximum
Min.	Minimum
MP	Multi-phase
MPa	Megapascals
MPS	Material Parts Specification
MS	Martensitic
MSDS	Material Safety Data Sheet
N/A	Not applicable
NA	North America
PPAP	Production Part Approval Process
QP	Quenched-and-Partitioned
SDS	Safety Data Sheet
SOR	Statement of Requirements
SWE	Secondary Work Embrittlement
T	Temper Rolled (surfaces)
U	Unexposed (surfaces)
UTS	Ultimate Tensile Strength
VDA	German Association of the Automotive Industry (Verband der Automobilindustrie)
WH	Work Hardening
WHI	Work Hardening Index
YS	Yield Strength
Z	Semi-exposed (surfaces)

8 Coding System

The coding system for General Motors Worldwide (GMW) sheet steel specifications on engineering part drawings and manufacturing engineering documents shall use a nomenclature consisting of the material designation, steel product type, minimum tensile/minimum yield strength, and surface quality or coating designation. The material designation is defined by the applicable GMW base metal material specification that follows the GMW specification number system. The minimum tensile strength and minimum yield strength is specified in megapascals (MPa) by a numerical designation.

The Surface Quality is designated as either E for exposed, Z for semi-exposed, T for temper rolled, or U for unexposed applications. For coated applications, refer to GMW8 for hot dip zinc coatings, GMW11 for electrogalvanized coatings, and GMW16066 for aluminized coatings. The GMW sheet steel specification shall be called out on engineering drawings and manufacturing engineering documents as follows:

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