



**WORLDWIDE
ENGINEERING
STANDARDS**

**Material Specification
Metals**

GMW14400

Low Carbon, Heat-Treatable Boron Steel – Uncoated or Aluminized Pre-Coated

1 Scope

This specification covers the requirements for low carbon, heat-treatable boron steel used in the manufacture of structural parts requiring heat treatments to achieve high strength. Press-hardened steel can be pre-formed and subsequently hot-stamped and die quenched, but post-forming should not be the scope for this type of steel. Typical applications include door impact beams, bumper impact beams, and reinforcements for impact structures.

1.1 Material Description. The particular application shall determine the pre- or post- forming operations to produce the finished product.

1.1.1 Resistance Welded Mechanical Tubing. Tubes supplied to this specification are roll formed from 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 a coil blank in the as-rolled condition. The raw stamping can be selectively coil induction hardened to achieve the required strength requirements. Aluminized, pre-coated products are not to be used in these applications.

1.1.3 Hot-Stamped/Die-Quenched Steel.

1.1.3.1 Uncoated Products. Part sections formed with this operation and supplied under this standard shall be made by austenitizing a pre cut blank or pre-stamped part, hot stamping the heated

blank or pre-stamped part, and rapid cooling (quenching) the stamped part in the die. The cooled part may be subsequently shot blasted to remove oxide from the surface. The microstructure of the finished parts shall consist of martensite and bainite.

1.1.3.2 Pre-Coated Products. Part sections formed with this operation and supplied under this standard 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. Parts shall not be pre-stamped prior to the hot stamping operation, but slight roll-forming operations may be allowable if the coating is not damaged. Shot blasting the cooled part is not permitted for pre-coated parts due to damage to the coating. The microstructure of the finished parts shall consist of martensite and bainite.

1.2 Material Identification. The GMW base metal specification number defines the material designation, steel product type, grade, and finish type. The steel product type is "CR" for cold rolled products, or "HR" for hot rolled products. The steel grades will correspond to the chemical and mechanical requirements as shown in Tables 1 through 4. The finish type, an alpha character, will be designated with the finish U (unexposed). The above 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 paragraph 8.

1.2.1 Material Identification.

GM WORLDWIDE	NORTH AMERICA	EUROPE	LATIN AMERICA	ASIA PACIFIC
GMW14400M-ST-T HT1475T/1170Y MS	GM4396M Type 1 (tubes)			
GMW14400M-ST-S HT1475T/1170Y MS	GMN7486			
GMW14400M-ST-S HS1300T/950Y MS	GM6429M			

1.3 Symbols. Not applicable.

1.4 Typical Applications. Typical applications are uncoated or pre-coated sheet metal and thin gauge tubular structural parts requiring yield and tensile strengths exceeding 950 MPa and 1250 MPa, respectively.

1.5 Remarks. Not applicable.

2 References

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

2.1 External Standards/Specifications.

AS 1391	ISO 6892
ASTM A370	ISO 10275
ASTM A513	ISO 11014-1
ASTM A751	JFS A101
ASTM E45	JIS B0610
ASTM E646	JIS B0651
ASTM E1077	JIS Z2201
ISO 898-1	QS9000
ISO 1460	SAE J419

2.2 GM Standards/Specifications.

9984001	GMW3001
B0401270	GMW3011
B0401271	GMW3059
EMS.9310015	GMW3355
EMS.ME.1508	OPEL 105
GM6180M	QT 001130
GM9769P	STD 2240
GME 8689	STD 3966
GME 00007	TB6909196
EN 10327	OPEL L 000 0726

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 Deviations at the end of this document.

Parts supplied according to this specification must 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 re-validated with the new process.

3.1 Requirements on Delivery.

3.1.1 Chemical Requirements. Base metal composition based on product (ladle, coil, or sheet/blanks) analysis determined per ASTM A751 shall conform to the requirements of Table 1 and/or shall be agreed upon between supplier and purchaser. Additional demands and restrictions may be imposed by local Materials Engineering organizations depending on the application.

Table 1: Chemical Composition

Carbon	0.20 to 0.25%
Manganese	1.00 to 1.35%
Aluminum	0.010 min. %
Silicon	0.15 to 0.35%
Phosphorous	0.025 max. %
Sulfur	0.010 max. %
Chromium	0.11 to 0.35%
Nitrogen	0.010 max. % (100 ppm)
Boron ^{Note 1}	0.0005 to 0.003 %

Note 1: For die quenched steel, boron is permissible in the range of 0.0015 to 0.005 wt. %

3.1.1.1 Surface Treatment. Products coated with a designated lubricant (i.e., mill oil or prelube) shall comply with GM-North America specification 9984001, GM-Latin America specification EMS.9310015, GM-Europe specifications B0401270/B0401271 (oil) respective with GME 8689.

3.1.2 Mechanical Requirements. The steel products shall meet the mechanical property requirements depending on the specific application. Tubular products, post-form induction heat treated products, and hot stamped products shall adhere to the requirements in Table 2, Table 3, and Table 4, respectively. The 0.2% Offset Yield Strength, Tensile Strength and Percent Total Elongation shall be determined in the longitudinal direction per GMW3335 for cold-formed parts. The test direction is not critical for finished, hot-formed parts. 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 2201 (#5).

When specified, the strain hardening exponent **n** value shall be determined per ISO 10275. The specific strain level shall be reported with all test results. The strain hardening exponent **n** value shall be determined at 10 to 20% strain, or at 10% to end of uniform elongation when uniform elongation is less than 20% unless the specified minimum **n**-value is less than 0.12. In these cases, the

strain-hardening exponent must be determined at 6% to end of uniform elongation. The specific strain range shall be reported with all test results. The determination of strain hardening exponent n value does not apply to heat treated parts or for parts that are hot-formed.

3.1.3 Additional Pre-Coated Product Requirements for Hot-Stamping Applications.

3.1.3.1 Aluminized Sheet. The following requirements shall be met by the supplier for aluminized boron steel used in hot-stamping applications, in addition to chemical and mechanical requirements in Table 1 and Table 4.

3.1.3.1.1 Al-Si Coating Bath Analysis. The continuous coating shall adhere to the composition requirements in Table 5 and shall meet the requirements of GMW3059. The coating shall not contain trace elements that are detrimental to adhesive bondability, phosphatability, or paintability.

3.1.3.1.2 Coating Mass. ASTM A428 or DIN EN 10327- Appendix B shall be used for determination of coating mass for aluminized coatings. The test sample size shall be 2000 mm² minimum, with a preferred sample size of 3330 mm² (57.7 ± 0.1 mm square or 65.1 ± 0.1 mm in diameter). Coating mass shall be measured by triple spot test, and must conform to values in Table 6. The mass shall be an average of three measurements taken across the width of the strip at least 25 mm from the edge. In no case shall the lowest value of the three samples fall below the minimum individual requirement in Table 6. Each side should be measured separately (e.g. by masking the coating from one side) to ensure the requirements of Table 6 are met.

3.1.3.1.3 Coating Thickness. For conversion of coating thickness to coating mass, a density factor of 3.0 g/cm³ shall be used for Al-Si alloy coatings. Coating measurements may be used for routine quality control evaluations. Coating thickness shall be measured using a suitable layer thickness gauge, on-line x-ray gauge, or from a specimen cut perpendicular to the panel surface. Suitable instruments for evaluation of coating thickness on the as-received pre-coated sheet (eg. eddy current, ferromagnetic, or metallurgical microscope) shall have a capability of ± 1.0 μm 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, standard mounting practices shall be used and thickness shall be measured at 1000x magnification. The referee method for determining coating thickness shall be coating mass, as specified by paragraph 3.1.3.1.2.

3.1.3.1.4 Coating Designation. The type of coating and coating mass is specified by a suffix added to the basic specification number. The first two letters **AI** will designate a continuous aluminized coating. The coating mass prior to hot stamping for each side is designated in g/m². Only a minimum specified coating mass of 60 g/m² (triple spot test) 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 the example in section 8.3.2.

3.1.3.1.5 Coating Surface 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 coloring are permissible if they do not affect corrosion resistance, formability, or the application of any other surface coating. Regulations in detail will be issued by the responsible formability analysis organization (e.g., NAO Manufacturing Engineering Metal Parts Specification (MPS) sheet, GMIO responsibly manufacturing or metallurgical engineering document).

3.1.4 Physical Requirements.

3.1.4.1 Material Thickness and Tolerances. The detailed engineering part drawing or electronic math data file will specify the material thickness and tolerance. For post formed induction heat treat applications, the product thickness range is 1.9 to 6.0 mm nominal hot rolled and 1.0 to 1.8 mm nominal cold rolled. Tolerances for electric resistance welded tubes not specified on drawings shall follow ASTM A513.

3.1.4.2 Surface Requirements.

3.1.4.2.1 Surface Texture.

3.1.4.2.2 Phosphatability/Paintability. For painted applications of bare parts, the surface shall be capable of achieving a high quality zinc phosphate conversion coating according to GMW3011. Special requirements for aluminized pre-coated parts may be agreed upon between the part supplier and purchaser. All parts supplied to this specification must meet tape adhesion requirements as stated in GMW3011 (Table 1).

For GM North America applications, steel supplied to this specification must be capable of meeting 9984001 and be qualified according to GM9769P. For GME applications, phosphatability and paintability are required to meet GME 00007 for organic coated parts.

3.1.4.2.3 Adhesive Bondability. For bonded applications, the surface of the flat products furnished to this specification shall be capable of adhering to

surfaces bonded with GM qualified and approved adhesives.

3.1.4.3 Microstructure.

3.1.4.3.1 Inclusions. Two (2) optional methods for analysis are available. There should be an agreement with the local business unit which of the two following methods has to be performed:

Method A: ASTM E45 Method D, Plate III, by analysis @ 100X inclusion content shall not exceed a rating of 2.0 for thin and 2.0 for heavy.

Method B: Opel 105 (DIN 50602) technique M: by analysis, inclusions shall not exceed size index 3; in case of diameters smaller than 20 mm, they shall not exceed size index 2.

3.1.4.3.2 Surface Decarburization. Total (complete) surface decarburization exceeding 0.05 mm is prohibited as defined by ISO 898-1, ASTM E1077, or SAE J419 Type 1.

3.1.4.4 Quality. Electrical resistance welded tubes shall be free of laps, cracks, seams, or other defects which could be detrimental to the fabricated part. The weld shall be uniform, metallurgically sound, and free from defects such as voids or foreign material which could be detrimental to the final product. All as-received tubes and sheet products shall have a smooth finish and shall be coated with a designated lubricant (ie. mill oil or prelube) and shall comply with GM-NAO specification 9984001, GMB specification EMS.9310015, or GME-ME specification B 0401270/B 0401271 respective with GME 8689. All sheet product surfaces must be free of heavy oxides, scale, etc. which may contaminate paint systems or affect subsequent manufacturing operations.

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

3.1.4.6 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 Welding. The steel substrates supplied to this standard shall be approved for welding by the GM Conveyors, Controls, Robotics and Welding (CCRW) Department of GM Manufacturing Engineering. Contact the GM Weld Council for specific information regarding weldability at weld.council@gm.com.

Note that 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 ultra high strength steels, selection of the weld process parameters should be determined in consultation with the steel supplier.

3.2.2 Weld Seams in Coils. If the local business unit allows weld seams in cold rolled material, the following restrictions have to be considered:

For cold reduced coils, pickling weld seams from the manufacturing process of hot rolled coils are permissible without any restriction. Welding seams in cold reduced coils are allowed in combination with punch holes to detect the welds and remove them before stamping; they have to be avoided in parts. For cold reduced coils with unexposed (U) surfaces, the welding seams are not permissible unless special exceptions are allowed by the local business unit. For hot rolled coils weld seams are not permissible.

3.2.3 Stretcher Strains. All unexposed (U) products shall be free of stretcher strains as agreed upon between purchaser and supplier.

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 paragraph 5.2) from scrap or other materials used in the manufacturing process which would impair the recycleability of the finished components.

3.4.2 Mechanical Requirements. Not applicable.

3.4.3 Physical Requirements. Not applicable.

3.4.4 Additional Requirements. Not applicable.

4 Manufacturing Process

Not applicable.

5 Rules and Regulations

5.1 All materials supplied to this specification must comply with the requirements of GMW3001, **Rules and Regulations for Material Specifications.**

5.2 All materials supplied to this specification must comply with the requirements of GMW3059, **Restricted and Reportable Substances for Parts.**

6 Approved Sources

The approval of suppliers to this specification will be executed by the authorized Materials Engineering departments. Approved suppliers names for GM North America are available on the on-line

MATSPC System and for the other regions by the responsible central formability analysis organization or Purchasing Departments.

7 Notes

7.1 Glossary. Not applicable.

7.2 Acronyms, Abbreviations, and Symbols. Not applicable.

8 Coding System

The coding system for 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 U for unexposed applications. For aluminized pre-coated applications, refer to section 3.1.3.1.5 in this specification. The GMW sheet steel specification shall be called out on engineering drawings and manufacturing engineering documents as follows:

8.1 Example of coding for heat treated, low carbon boron steel for tubular applications:

8.1.1 Example of engineering part drawing and manufacturing coding for uncoated high strength steel:

GMW14400M-ST-T HT1475T/1170Y MS UNCOATED U

Where:

GMW14400M =Continuous Number
ST =Materials Type (**STeel**)
T =Materials Category (**Tube**)
HT =Post-Form **Heat Treated**
1475T =Minimum Tensile Strength (MPa)
1170Y =Minimum Yield Strength (MPa)
MS =Steel Type (MS)
UNCOATED =Coating Designation
U =Surface Quality

GMW14400M-ST-T =Base Metal Specification

8.2 Example of coding for low carbon, heat treatable boron steel for post-form induction heat treat applications:

8.2.1 Example of engineering part drawing and manufacturing coding for uncoated high strength steel:

GMW14400M-ST-S HT1475T/1170Y MS UNCOATED U

Where:

GMW14400M =Continuous Number
ST =Materials Type (**STeel**)
S =Materials Category (**Sheet**)
HT =Post-Form **Heat Treated**
1475T =Minimum Tensile Strength (MPa)
1170Y =Minimum Yield Strength (MPa)
MS =Steel Type (MS)
UNCOATED =Coating Designation
U =Surface Quality

GMW14400M-ST-S =Base Metal Specification

8.3 Example of coding for low carbon, heat treatable boron steel for hot-stamped applications:

8.3.1 Example of engineering part drawing and manufacturing coding for uncoated high strength steel:

GMW14400M-ST-S HS1300T/950Y MS UNCOATED U

Where:

GMW14400M =Continuous Number
ST =Materials Type (**STeel**)
S =Materials Category (**Sheet**)
HS =**Hot-Stamped**
1300T =Minimum Tensile Strength (MPa)
950Y =Minimum Yield Strength (MPa)
MS =Steel Type (MS)
UNCOATED =Coating Designation
U =Surface Quality

GMW14400M-ST-S =Base Metal Specification

8.3.2 Example of engineering part drawing and manufacturing coding for aluminized high strength steel:

GMW14400M-ST-S HS1300T/950Y MS Al60Al60U

Where:

GMW14400M =Continuous Number
ST =Materials Type (**STeel**)
S =Materials Category (**Sheet**)
HS =**Hot-Stamped**
1300T =Minimum Tensile Strength (MPa)
950Y =Minimum Yield Strength (MPa)
MS =Steel Type (MS)
Al60Al60 =Coating Designation
U =Surface Quality

GMW14400M-ST-S =Base Metal Specification

GMW14400**GM WORLDWIDE ENGINEERING STANDARDS****Table 2: Welded and Heat Treated Tubular Product Mechanical Properties**^{Note 1, Note 2}

Condition	Designation	Yield Strength at 0.2% offset (MPa)	Tensile Strength (MPa)	Total Elongation
As-Received	GMW14400M-ST-T HT1475T/1170Y MS	min. 1170	min. 1475	min. 10 %

Note 1: Additional demands can be specified by the local business units.

Note 2: Mechanical properties are to be measured on the full the tubular product, per ASTM A370.

Table 3: Post-Form Induction Heat Treated Product Mechanical Requirements^{Note 1}

		Yield Strength at 0.2% offset (MPa)	Tensile Strength (MPa)	Total Elong. in 50 mm (min. %)		Total Elong. in 80 mm (min. %)	R-bar	n-value
Condition	Designation	min.	min.	ISO 1	JIS	ISO II	Typical	min.
As-Rolled ^{Note 2}	GMW14400M-ST-S HT1475T/1170Y MS	300	500	15	17	14	0.8-1.0	0.13
Finished Part ³		1170	1475	5	6	4.5	N/A	N/A

Note 1: Additional demands can be specified by the local business units.

Note 2: Both CR and HR must meet the mechanical property requirements in Table 3. As-rolled mechanical properties only apply to parts formed by the local manufacturing groups at GM.

Note 3: If a standard tensile specimen may not be obtained from a finished part, microhardness in the core (HV1, 10, or 30 kg = 425 min.) and macrohardness on the surface (44 HRC min.) requirements must be met.

Table 4: Hot-Stamped Product Mechanical Requirements^{Note 1, 2, 3}

		Yield Strength at 0.2% offset (MPa)		Tensile Strength (MPa)		Total Elong. in 50 mm (min. %)		Total Elong. in 80 mm (min. %)
Condition	Designation	min.	max.	min.	max.	ISO 1	JIS	ISO II
Finished Part	GMW14400M-ST-S HS1300T/950Y MS	950	1250	1300	1700	5	6	4.5

Note 1: Additional demands can be specified by the local business units.

Note 2: Mechanical properties valid on flat areas where, thinning < 10% (after hot-stamping).

Note 3: If a standard tensile specimen may not be obtained, microhardness in the core (HV1, 10, or 30 kg = 400-550) and macrohardness on the surface (41-50 HRC) requirements must be met.

Table 5: Al-Si Coating Bath Analysis (wt. %)

Aluminum	85 to 95%
Silicon	5 to 11%

Table 6: Al-Si Coating Requirements^{Note 1}

Condition	Coating Mass (g/m ²)	Coating Thickness (μm) ^{Note 2}
Prior to hot-stamping	60 to 100	20 to 33
Following hot-stamping	N/A	>35

Note 1: Additional demands can be specified by the local business units.

Note 2: Prior to hot-stamping, suitable evaluation instruments to measure coating thickness on the as-received sheet include eddy current, ferromagnetic, or microscopy. Magnetic inductive measurements are not recommended following the hot-stamping operation without proper calibration.

9 Release and Revisions

9.1 Release. This standard originated in September 2005. It was first approved by the Global Steel Team in November 2005. It was first published in November 2005.

Deviations

Deviations on requirements for local business units.

3.1 Requirements on Delivery.

3.1.1 Chemical Requirements.

GMNA and GM-Europe: Only coil or sheet/blank analysis is permitted.

3.1.1.1 Base Metal.

GMAO-Latin America: Refer to EMS.ME.1508.

GMAO-Asia Pacific and GMAO-Europe: Steel products shall have chemical composition that is agreed between purchaser and supplier that is capable of achieving the desired mechanical properties specified in GMW14400M.

3.1.2 Mechanical Requirements.

GMNA: 4-6% n-value testing not required. All specified values must be met in the longitudinal (L) direction.

GMAO-Europe and GMAO-Latin America: Designation of carry over parts to be used on global platform vehicles must be changed into the new GMW Material Description System.

GMAO-Asia Pacific: Australian and Japanese Steel Suppliers for Holden shall perform tensile testing to Australian Standard AS 1391, and to Japanese Industrial Standard JIS Z 2201 (No. 5 test piece), respectively.

GM-Europe: All specified values must be met in the longitudinal (L) direction.

Axle tubes may be specified with the following final part requirements:

GMW14400M-ST-T HT1200T/950Y MS

YS: 950 – 1050 MPa

TS: 1200 MPa min

A5: 6%min

3.1.4 Physical Requirements.

3.1.4.2 Surface Requirements.

3.1.4.2.3 Adhesive Bondability.

GM Europe – For measurement of the combined tension and shear resistance with beading adhesive (eg. Opel L 000 0726 (09274295)), and in accordance to specification L 000 0726, paragraph

3.9.1 and 3.9.4 the tensile shear strength shall be ≥ 9 MPa. A cohesive failure in the adhesive with coating separation ≤ 50 % is permissible. For adhesives with special properties (shear strength and tenacity) an agreement between design, steel, and adhesive experts must be reached before using the material relevant for structures with higher demands.

3.1.4.3 Microstructure.

3.1.4.3.1 Inclusions.

GMAO-Asia Pacific (Isuzu) - Inclusions refer to sub-clause 14.2 of JFS A 1001.

3.1.4.4 Quality.

GM Europe – The semi-exposed (Z) surface is not to be specified. Exposed (E) and unexposed (U) cold rolled and coated products are to be temper rolled.

GMAO-Latin America: Refer to EMS.ME.1508.

GMAO-Asia Pacific: All products shall be free from stretcher strains for six (6) months unless otherwise agreed upon between purchaser and supplier. Surface finish and quality should be negotiated between the steel mills and parts manufacturer to be appropriate to the final use of the part. In all cases the supplied steel and the parts made from that steel shall be clean and free of scale, stains, corrosion, debris or any other defects which would be objectionable on the finished part.

3.2 Processing Requirements.

GMAO-Latin America: Cold Bending for Part Design Purpose. Ultra high strength steels are frequently fabricated for cold bending. Many interrelated factors affect the ability of given piece of steel to form over any given radius in shop practice. These factors include thickness, strength level, degree of restraint in bending, relationship to rolling direction, chemical composition and microstructure.

5.4 Inspection and Rejection.

GMNA – Further information can be found in the GMNA sheet steel qualification standard (GM9769P) or from GM Worldwide Purchasing – Supplier Quality.