Rolled Shapes with Improved Notch Toughness

API SPECIFICATION 2MT2
FIRST EDITION, JUNE 2002

EFFECTIVE DATE: DECEMBER 1, 2002

REAFFIRMED, JUNE 2015

AMERICAN PETROLEUM INSTITUTE

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Upstream Segment

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Suggested revisions are invited and should be submitted to the standardization manager, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005.

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Rolled Shapes with Improved Notch Toughness

1 Scope

1.1 This specification covers rolled shapes (wide flange shapes, angles, etc.), having a specified minimum yield strength of 50 ksi (345 Mpa), intended for use in offshore structures. Commonly available Class A, Class B, and Class C beams refer to degrees of fracture criticality as described in section 8.1.3 of API RP 2A, with Class C being for the least critical applications. For special critical applications, Class AAZ shapes may be specified, by agreement, using supplement S101.

1.2 Supplementary requirements are provided for use where additional testing or additional restrictions are required by the purchaser. Such requirements apply only when specified in the purchase order.

1.3 When the steel is to be welded, a welding procedure suitable for the grade of steel and intended use or service is to be utilized. For the purposes of welding procedure qualification under AWS D1.1, until AWS cites this specification, use the following:

a. Matching filler metals (AWS D1.1, Table 3.1) shall be as for Group II.

b. Preheats (AWS D1.1, Table 3.2) shall be as for Category B (or Category D for class A-QST herein).

c. Matching weld toughness (AWS D1.1, Tables C4.2 and C4.3) shall correspond to Class A, B, or C herein.

Alternative preheats (AWS D1.1, Annex XI) may also be used to advantage.

1.4 When heat straightening, hot or warm forming, or post-weld heat treatment above 1050°F (565°C) is anticipated for Class A shapes produced by methods other than hot rolling, controlled rolling, normalized rolling, or normalizing, supplement S9 should be invoked.

1.5 By agreement, this specification may be used as a supplement to purchase rolled shapes to other international standards, e.g., Euronorm, ISO, or JIS, in which case references to ASTM A6 may be replaced by the comparable international standard. Users should note that dimensions and design properties might not be the same as A6 shape designations, and that “equivalent” sections could be heavier.

2 Referenced Documents

2.1 NORMATIVE

ASTM A6/A6M, *Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling*

ASTM A370/A370M, *Test Methods and Definitions for Mechanical Testing of Steel Products*

ASTM A673/A673M, *Specification for Sampling Procedure for Impact Testing of Structural Steel*

ASTM A898/A898M, *Specification of Straight Beam Ultrasonic Inspection of Rolled Steel Structural Shapes*

2.2 INFORMATIVE

API RP2A-WSD, 21st Edition, *Recommended Practice for Planning, Designing, and Constructing Fixed Offshore Platforms*

API Spec 2B, *Specification for the Fabrication of Structural Steel Pipe*

API Spec 2W, *Specification for Steel Plates for Offshore Structures, Produced by Thermo-Mechanical Control Processing (TMCP)*

ASTM A913/A913M, *High-Strength Low-Allow Shapes of Structural Quality, Produced by Quenching and Self-Tempering Process (QST)*

ASTM A992/A992M, *Standard Specification for Steel for Structural Shapes*

AWS D1.1-2000, *Structural Welding Code—Steel*

Heat Straightening Repairs of Damaged Steel Bridges: A Technical Guide and Manual of Practice (with CD), U.S. Dept. of Transportation Rep. No. FHWA-IF-99-004.

3 General Requirements for Delivery

3.1 Material furnished to this specification shall conform to ASTM A6/A6M, except as provided otherwise herein.

3.2 Visual examination for defects shall be performed on all surfaces.

4 Manufacturing

4.1 The steel shall be made by basic oxygen or electric furnace process. Additional refining by electroslag remelting, vacuum arc remelting, or ladle metallurgy furnace is permitted.

4.2 The steel shall be killed. Killed steel is confirmed by a statement of “killed steel” on the test report, or by reporting strong deoxidizers.

4.3 The steel shall be made to fine grain practice. For Class A and B, the fine grain definition in Section 8.3 of ASTM A6 shall apply.

4.4 Steel may be cast in ingots or may be strand cast. When steels of different specifications are sequentially strand cast, the producer shall identify and remove the transition material.

4.5 Class A shapes shall be produced by any of the following processes. The process used shall be identified on the mill certificate.

a. AR: as-rolled (hot rolled).
b. CR: controlled rolling, with final rolling at a reduced temperature.
c. NR: normalized rolling, with final rolling of the shape performed in the upper recrystallization range, without the extra cycle of cooling and reheating.
d. N: normalizing, with reheating and cooling performed off line (see 4.7).
e. QST: quenching and self-tempering process, as described in Appendix X1 of ASTM A913. Self-tempering temperature shall be a minimum of 1100°F (600°C), and the self-tempering temperature for the material represented shall be reported on the mill certificate.
f. QT: conventional quenching and tempering, off line (see 4.7).
g. TMCP: thermo-mechanical control processing, by agreement. TMCP is defined in Appendix B of API Spec 2W. The manufacturer's process shall be identified with a code number or designation for ready reference, sufficient to provide traceability of process variables.

4.6 Class B and Class C shapes may be produced by AR, CR, or NR. Shapes which fail to meet the minimum specified mechanical requirements in the as-produced condition may be heat treated by normalizing, provided the delivered beams meet the grain size, tensile, and impact mechanical properties of this specification, and dimensional tolerances and surface finish requirements of ASTM A6 (see 4.7). Test frequency shall be per heat, per heat treat batch. Heat treatment shall be noted on the mill certificate.

4.7 By agreement, straightening and surface dressing to meet the dimensional tolerances and surface finish requirements of ASTM A6 may be performed by a third party remediation shop or fabricator. Heat straightening, if used, shall conform to agreed procedures. Reference may be made to the principles and precautions described in U.S. Dept. of Transportation Report No. FHWA-IF-99-004, *Heat Straightening Repairs of Damaged Steel Bridges:* A Technical Guide and Manual of Practice.

5 Chemical Composition

5.1 Chemical analysis shall be performed in accordance with ASTM A6, and comply with the heat requirements prescribed in Table 1. Elements shown without a range are maxima. Any element knowingly added shall be reported.

5.2 The carbon equivalents CE and PCM on heat analysis shall not exceed the limits prescribed in Table 1, using the following formulae:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Cu + Ni)/15$$

$$PCM = C + Si/30 + (Mn + Cu + Cr)/20 + Ni/60 + Mo/15 + V/10 + 5B$$

The chemical analysis (heat analysis) of all the elements that appear in the carbon equivalent formulae shall be reported. For thickness over 1.5-in. (38-mm), the CE may be 0.02 higher, and the PCM may be 0.01 higher.

6 Mechanical Properties

6.1 Tensile properties of the steel as represented by test specimens taken according to ASTM A6 shall meet the following requirements:

- yield strength 50 ksi (345 MPa) min.
- tensile strength 65-90 ksi (450-620 MPa)
- elongation 18% in 8-in. (200 mm) gage length
  21% in 2-in. (50 mm) gage length

6.2 Charpy V-Notch (CVN) tests shall be made in accordance with ASTM A673, Frequency H (i.e., 50 tons per section, footweight and grade, continuously produced). Specimens with orientation L-T shall be removed from the flange or thickest outstand as shown in Figure 2 of ASTM A673. Test temperature and minimum average energy value for full size specimens shall be as prescribed in Table 2.

Table 1—Chemical Requirements (Heat Analysis %)

Element	Class A	Class B	Class C
Carbon	0.14	0.16	0.23
Manganese	1.60	1.60	0.50 – 1.50
Phosphorus	0.025	0.025	0.035
Sulfur	0.025	0.025	0.045
Silicon	0.50	0.50	0.50
Copper	0.35	0.35	0.60
Nickel	0.50	0.50	0.45
Chromium	0.25	0.30	0.35
Molybdenum	0.05	0.10	0.15
Columbium (Nb)	0.05	0.05	0.05
Vanadium	0.05	0.08	0.11
Nitrogen	0.012	0.012	0.015
Titanium	0.025	0.025	*
Boron	0.0005	0.0005	*
CE	0.38	0.42	0.45
PCM	0.22	0.24	–
* This element shall not be added.			

Table 2—Charpy Test Requirements

	Class A	Class B	Class C
Test temperature, °F	– 4°F	32°F	70°F
°C	(– 20°C)	(0°C)	(21°C)
Impact energy, ft.-lb.	30	20	20
Joules	(41)	(27)	(27)

6.3 At the option of the manufacturer, retests may be made on material which fails the heat lot CVN test; in this case each beam or column as rolled must be tested. Acceptance or rejection of each piece as rolled shall be based on the result of its own CVN test set.

7 Marking

7.1 Shapes furnished to this specification shall be marked by the manufacturer in accordance with ASTM A6 and the following:

- Class A shall be marked as API 2MT2 Class A, and may also be marked as ASTM A913 Grade 50 if it meets the requirements of both specifications.
- Class B shall be marked as API 2MT2 Class B.
- Class C shall be marked as API 2MT2 Class C, and may also be marked as ASTM A992 if it meets the requirements of both specifications.

7.2 The API monogram may be applied to products complying with the requirements of the specification and only by authorized users.

7.3 Class B and Class C shapes furnished in the as rolled or controlled rolled condition require no additional marking; shapes furnished in the normalizing rolled or normalized condition shall be marked with the suffix “-NR” or “-N”.

7.4 Class A shapes shall be marked with the suffix AR, CR, NR, N, QST, QT, or TMCP, as defined in 4.5.

8 Supplementary Requirements

8.1 S1—VACUUM TREATMENT

The steel shall be made by a process which includes vacuum degassing while molten. Unless otherwise agreed upon with the purchaser, it is the responsibility of the manufacturer to select suitable process procedures.

8.2 S2—PRODUCT ANALYSIS

Product analysis shall be made for those elements listed in the material specification. Test frequency shall be as specified on the order, but no less frequent than once per heat. Specimens for analysis shall be taken adjacent to or from the tension test specimens, or from a sample taken from the same relative location as that from which the tension test specimen was taken.

8.3 S3—IMPACT TESTS AT LOWER TEMPERATURE

Impact tests may be made at temperatures lower than those specified in Table 2. The testing temperature shall be specified by the purchaser and agreed to by the manufacturer.

8.4 S4—ADDITIONAL TENSION TESTS

By agreement, at least one tension test shall be made per production lot. Production lot is defined as for frequency H Charpy tests (i.e., 50 tons per section, footweight and grade, continuously produced). The results obtained (and the actual self-tempering temperature for QST) shall be reported on the mill report.

8.5 S8—ULTRASONIC EXAMINATION

Ultrasonic examination shall be performed in accordance with ASTM A898, Level I.

8.6 S9—SIMULATION OF THERMAL TREATMENT

Where heat straightening, hot or warm forming, or post weld heat treatment is anticipated, it is advisable to notify the manufacturer of any intended fabrication heat treatment. When S9 is invoked, a second set of mechanical test specimens shall be subjected to a simulated thermal treatment cycle (provided by the purchaser) that is representative of the thermal treatment to which the material will be subjected during fabrication. The temperature range, time at temperature, and cooling rate shall be as specified on the order.

8.7 S19—ADDITIONAL QUALITY CONTROL REQUIREMENTS

8.7.1 A quality system shall be implemented, and quality plan shall be developed by the manufacturer prior to the commencement of manufacturing operations.

8.7.1.1 The quality system shall be certified by a third party agency, or otherwise accepted by the purchaser, to be in compliance with any one of the following standards:

a. API Q1.
b. ISO 9001 or ISO 9002.
c. ANSI/ASQC Q91 or Q92.
d. ASME Sec VIII Div 1 App 10, Sec VIII Div 2 App 18, or Sec III NCA 3800.
e. MIL-Q-9858.

8.7.1.2 The quality plan, consisting of a process control plan (i.e., manufacturing procedures) and an inspection and test plan, shall be written specifically for the work, and be approved by the purchaser prior to the commencement of manufacturing. By agreement, the quality plan shall comply with ISO 10005.

8.7.1.3 The process control plan shall include the following:

a. The steel making process and refining sequence.
b. Rolling practices and heat treatment procedures.
c. The minimum allowable rolling reduction.
d. Specific details of surface conditioning and heat straightening (if used).
e. The specific manufacturing facilities and remediation shops to be used.

8.7.1.4 By agreement, the draft inspection and test plan shall provide spaces for the purchaser to indicate involvement, i.e., hold points, witness points, monitor points, document review points, etc., of purchaser's representatives, third party inspection personnel, or certifying agencies, as applicable.

8.7.2 Traceability of each rolled shape shall be maintained with respect to heat, heat treat sequence, production lot, and batch, as applicable.

8.8 S20—ADDITIONAL SURFACE REQUIREMENTS AND WELD REPAIR

8.8.1 Each rolled shape shall be visually inspected with the surfaces in a condition such that they can readily be examined for defects. Coverage for visual examinations shall be 100% of all surfaces, without exception.

8.8.1.1 Surfaces shall be free of tears, scabs, blisters, laps, cracks, or other similar surface imperfections. The maximum depth of other localized discontinuities (e.g., rolled-in scale, gouges, seams, or pits) shall not exceed the following values:

NOMINAL THICKNESS OF PRODUCT	MAX. PERMISSIBLE DEPTH OF DISCONTINUITY
up to 0.75 in. (20 mm)	0.047 in. (1.2 mm) or 25% of thickness, whichever is less
over 0.75 in. to 1.5 in. (40 mm)	0.067 in. (1.7 mm)
over 1.5 in. to 3 in. (75 mm)	0.098 in. (2.5 mm)
over 3 in.	0.118 in. (3 mm)

8.8.1.2 Imperfections or discontinuities exceeding the foregoing limits shall be removed by grinding, or chipping and grinding, provided the ground area is well faired and the resulting depression does not exceed the limits of ASTM A6, Section 9.2.1.

8.8.2 Repair welding by the manufacturer shall not be allowed.

8.8.3 Imperfections or discontinuities which cannot be corrected within the limitations of 8.8.1.2 shall be removed by the manufacturer by grinding, chipping and grinding, or other mechanical means, which will leave an excavation suitable for subsequent repair welding by the purchaser or an agreed remediation contractor.

8.8.3.1 The total area of repair-weld excavations on any one piece shall not exceed an agreed percentage (1% or 2%) of the surface area. Additional limitations on remaining material and the depth of repair-weld excavations shall be as stipulated by ASTM A6, Sections 9.3.2.2 and 9.3.2.3.

8.8.3.2 Pieces requiring subsequent weld repair shall be identified as follows:

a. Each repair weld excavation shall be circled with white or yellow paint.
b. Each piece requiring weld repair shall be marked with an agreed special color code on or adjacent to one end.

8.9 S44—THROUGH THICKNESS (Z-DIRECTION) TESTING

8.9.1 General

This Supplementary Requirement covers the procedure and acceptance standards for the determination of reduction-of-area using a tension test specimen whose axis is normal to the surfaces of steel sections with nominal thickness 0.75 in. (19 mm) and greater. Definitions shall be in accordance with ASTM A370.

8.9.2 Number and Location of Test Specimens

Tests shall be taken with the same frequency as and adjacent flange location to sets of Charpy V-notch tests, as defined in 6.2.

8.9.3 Orientation of Test Specimens

The longitudinal axis of the test specimen shall be perpendicular to the outer surface of the flange or outstand.

8.9.4 Preparation of Test Specimens

Specimens shall be prepared as follows:

a. Prolongations shall be joined to opposite surfaces of the coupon being tested, with their axes coincident. The joining method used should be one which results in a minimal heat-affected-zone in the portion of the coupon being tested. Friction (inertial), stud, electron beam, or shielded metal-arc welding methods have proven to be suitable. Prolongation materials shall be selected so that failure shall occur in the sample portion of the specimen.
b. Specimens shall be machined to the form and dimensions of the 0.500 in. (12.5 mm) round specimen of Figure 5 of ASTM Methods and Definitions A370, except for thicknesses less than $1^1/4$ in. (32 mm) where the 0.350 in. (8.75 mm) test specimen may be used.
c. The full thickness shall be contained within the uniform section with no taper permitted. The length ("G" in Figure 5 of ASTM A370) of the cylindrical section of the test piece

shall be adjusted as necessary to contain the section thickness within a uniform diameter throughout the section.

8.9.5 Testing

Tensile testing shall be conducted in accordance with the requirements of ASTM A370.

8.9.6 Acceptance Standards

Standards for the acceptance of through-thickness testing shall be as follows:

a. Each tension test specimen shall exhibit a minimum reduction of area of 30%. If one specimen is below 30%, but not below 25%, a retest of two additional specimens from a location adjacent to the failed specimen shall be made, and both of these additional determinations shall equal or exceed 30%.
b. Minimum reduction-of-area limits higher than stated in 8.9.6a may be specified subject to agreement between the material manufacturer and the purchaser.

8.9.7 Marking

Material accepted in accordance with this procedure for through-thickness testing shall be identified by stamping or stenciling "Z" adjacent to marking otherwise required (e.g., API 2MT2-AZ).

8.10 S75—MAXIMUM YIELD AND YIELD/TENSILE RATIO

8.10.1 The maximum yield strength shall be 65 ksi.

8.10.2 The maximum yield strength to tensile strength ratio shall be 0.85.

8.11 S76—CORE REGION CHARPY TESTS (FOR "W" SHAPES ONLY)

For flange thickness of 1.5 inches or greater, an additional set of Charpy specimens shall be removed from the core region of the web-to-flange intersection, as defined in ASTM A913, Figure S00001 or ASTM A992 Figure XY1. Test temperature and energy requirements shall be subject to agreement.

8.12 S77—REDUCED SULFUR

Maximum sulfur shall be 0.010%.

8.13 S78—50% SHEAR FRACTURE APPEARANCE

By agreement, the broken Charpy specimens shall exhibit 50% shear fracture appearance, in addition to meeting the specified energy, at the specified test temperature in Table 2 or 8.3 (S3), as applicable.

8.14 S101—CLASS AAZ SHAPES

8.14.1 When specified and agreed, Class AAZ shapes shall conform to the requirements for Class A, plus the following supplementary requirements:

a. 8.3: S3—Charpy test at – 40°F (– 40°C)
b. 8.4: S4—production lot tensile tests
c. 8.5: S8—ultrasonic exam
d. 8.7: S19—additional quality control requirements
e. 8.8: S20—additional surface requirements and weld repair
f. 8.9: S44—Z-tested
g. 8.10: S75—max. yield and yield/tensile
h. 8.12: S77—reduced sulfur
i. 8.13: S78—50% shear fracture appearance

8.14.2 Class AAZ shapes shall be marked API 2MT2 Class AAZ, with suffix per 7.4.

8.15 S102—PRODUCT ANALYSIS WITHOUT TOLERANCE

By agreement, the chemical analysis of the product shall conform to the requirements prescribed in Section 5 and Table 1 herein, without further tolerances.

APPENDIX A—SUGGESTIONS FOR ORDERING API 2MT2 SHAPES

A.1 Placing Orders

In placing orders for steel shapes to be manufactured in accordance with API Spec 2MT2, the purchaser should specify the following on the purchase order (parenthetical remarks are commentary for the user, and need not appear on the order):

Specification	API Spec 2MT2
Grade	(all are 50 ksi yield, group II in AWS D1.1 and API RP 2A)
Class*	C (ordinary chemistry and toughness)
	B (improved chemistry and toughness)
	A (superior chemistry and toughness)
	AAZ (invoking extras in 8.14: S101)
Quantity/Size	As required
Mill inspection by purchaser	State if required, and any advance notice requirements
Items only “by agreement”	Section 1.5: other international standards
	Section 4.7: third party remediation shop
	Section 8.1: S1—prescribed steelmaking methods
	Section 8.3: S3—lower impact test temperature
	Section 8.4: S4—production lot tension tests
	Section 8.7: S19—ISO 10005; hold points
	Section 8.8: S20—surface defect percentage
	Section 8.9: S44—min RA > 30%
	Section 8.11: S76—core Charpy criteria
	Section 8.13: S78—Charpy 50% shear
	Section 8.14: S101—Class AAZ
	Section 8.15: S102—no tolerance on chemistry
Intended fabrication heat treatment	For manufacturer’s information, even if no 8.6: S9
Delivery date, shipping instructions	As required
Supplementary requirements	As required
*Classes C, B, and A are intended to correspond to API RP 2A (steel classes described in Section 8.1.3 and weld impact requirements of Section 10.2.2). Class AAZ is intended for exceptionally critical applications.	

A.2 Commentary on Supplementary Requirements

The purchaser should state on the purchase order the requirements concerning the following Supplementary Requirements, which are optional with the purchaser. However, not all options are available from all producers, and some require specific agreement.

A.2.1 S1—VACUUM TREATMENT

(Common prescriptive supplement from ASTM beam specs, but rarely found in API node steel specs, which are performance based.)

A.2.2 S2—PRODUCT ANALYSIS WITHOUT TOLERANCE

(Chemistry from the finished product, rather than from the heat’s ladle sample, eliminating the tolerances allowed by ASTM A6.)

A.2.3 S3—IMPACT TESTS AT LOWER TEMPERATURE

(The following targets have been suggested as being possible in some cases, and more compatible with the usage of plate specifications in offshore structures:

Class C	20 ft.-lb. at 32ºF	27J at 0ºC
Class B	20 ft.-lb. at – 4ºF	27J at – 20ºC
Class A	30 ft.-lb. at – 40ºF	41J at – 40ºF required for Class AAZ

Users are cautioned that, for heavy section beam and column sections having flange thickness greater than 1.5 inches, meeting the foregoing toughness requirements may have progressively more limited availability with the usual production methods, and may require time consuming and costly extra processing. For these applications, consideration should be given to fabricating members by welding together 50 ksi plates of appropriate chemistry and Charpy toughness, in which case the provisions of AWS D1.1 apply; or beams of a higher performance class may be substituted.)

A.2.4 S4—ADDITIONAL TENSION TESTS

Testing production lot rather than heat lot, required for Class AAZ.

A.2.5 S8—ULTRASONIC EXAMINATION

Recommended to avoid pre-existing laminations in the through member of truss connections or nodes; alternatively, this inspection may be performed on a spot basis at the fabrication site, and the member re-orientated to avoid laminations at nodes.

A.2.6 S9—SIMULATION OF THERMAL TREATMENT

Checks for loss of strength or toughness if the steel is to be heated during fabrication above 1050°F (565°C), beyond the usual heat affected zone from welding.

A.2.7 S19—ADDITIONAL QUALITY CONTROL REQUIREMENTS

Quality system, quality plan, process control plan, and traceability, for Class AAZ.

A.2.8 S20—ADDITIONAL SURFACE REQUIREMENTS AND WELD REPAIR

(Surface defects marked by steelmaker and weld repaired by qualified fabricator. Part of Class AAZ.)

A.2.9 S44—THROUGHTHICKNESS (Z-DIRECTION) TESTING

Recommended to avoid laminar tearing in the through member of truss connections or nodes. Passing the test may require further processing beyond 8.12: S77, reduced sulfur. Appropriate supplement for Class A. Required part of Class AAZ. If a reduction of area greater than the standard 30% is required, this must be stated, subject to agreement.

A.2.10 S75—MAXIMUM YIELD AND YIELD/ TENSILE RATIO

Part of Class AAZ.

A.2.11 S76—CORE REGION CHARPY TESTS

Results are typically less favorable than samples from the flange, but research is mixed on the significance of this.

A.2.12 S77—REDUCED SULFUR

May be used to achieve the goals of 8.9: S44 without the extra cost of Z-direction testing.

A.2.13 S78—50% SHEAR FRACTURE APPEARANCE

Often a better indicator of the brittle fracture transition temperature than a modest impact energy requirement, for modern low sulfur steels. Also may be more difficult for steelmakers to meet. Part of Class AAZ.

A.2.14 S101—CLASS AAZ SHAPES

Collects various Supplementary Requirements for critical applications, including Charpy tests at – 40ºF (40ºC).

A.2.15 S102—PRODUCT ANALYSIS WITHOUT TOLERANCE

Available by special agreement only.

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