Specification for Steel Plates for Offshore Structures, Produced by Thermo-Mechanical Control Processing (TMCP)

API SPECIFICATION 2W
FOURTH EDITION, AUGUST 1999

EFFECTIVE DATE: FEBRUARY 1, 2000

American
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Upstream Segment

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FOREWORD

This specification is under the jurisdiction of the API Committee on Standardization of Offshore Structures.

The purpose of this specification is to provide standards for the purchase of quenched-and-tempered steel plate suitable for use in welded offshore structures.

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SUGGESTIONS FOR ORDERING API 2W STEEL PLATE

In placing orders for steel plate to be manufactured in accordance with API Spec 2W, the purchaser should specify the following on the purchase order:

Specification	API Spec 2W
Quantity Size	As Required
Grade	42, 50, 50T, or 60
Process of Manufacture	Subsection 3.2.2
Mill Inspection by Purchaser	State advance notice requirements
Delivery Date and Shipping Instructions	As Required
Supplementary Requirements	As Required

The purchaser should state on the purchase order his requirements concerning the following Supplementary Requirements, which are optional with the purchaser.

Note: Section 1 of this specification addresses the purpose/function of several of the supplementary requirements.

S1	Ultrasonic Examination	❑
S2	Notch Toughness at Lower Temperatures	❑
	S2.1 Notch Toughness at – 60°C	❑
	S2.2 Notch Toughness at Other Than – 40°C or – 60°C	❑
	S2.3 Higher Notch Toughness Energy Values	❑
S3	Additional Tension Test	❑
S4	Through-Thickness (Z-Direction) Testing	❑
S5	Low Sulfur Steel for Improved Through-Thickness Properties	❑
S7	Low Nitrogen Content for Improved Notch Toughness in Strain-Aged Condition	❑
S8	Strain-Aged Charpy V-Notch Impact Tests	❑
S9	Simulated Post-Weld Heat Treatment	❑
S10	Hardness Testing	❑
S11	Preproduction Qualification	❑
	S11.3 CTOD testing of weld heat affected zone	❑
	S11.4 Weldability (hydrogen cracking) tests at CP (conventional preheat) level of performance	❑
	MP (modified preheat) level of performance	❑
S12	Notch Toughness Using Drop Weight	❑
S13	Surface Quality	❑
S14	Thickness Tolerance	❑

Special Note:
Nothing in this specification should be interpreted as indicating a preference by the committee for any material or process. In the selection of materials and processes, the purchaser must be guided by his experience and by the service for which the plate is intended.

CONTENTS

Specification for Steel Plates for Offshore Structures, Produced by Thermo-Mechanical Control Processing (TMCP)

1 Scope

1.1 COVERAGE

This specification covers four grades of intermediate strength steel plates for use in welded construction of offshore structures, in selected critical portions which must resist impact, plastic fatigue loading, and lamellar tearing. Grades 42, 50, and 50T are covered in thicknesses up to 6 in. (150 mm) inclusive, and Grade 60 is covered in thicknesses up to 4 in. (100 mm) inclusive.

1.1.1 It is intended that steel produced to Grades 42 and 50T of the basic API Spec 2W, without Supplementary Requirements, although produced in a different manner and of somewhat different chemical compositions, be at least equivalent in minimum performance and, therefore, in service application, to the corresponding grades listed in Sections 4 through 6 of API Spec 2H. Higher performance (i.e., notch toughness at lower temperatures, or enhanced weldability) typically available with TMCP steel may be achieved by specification of Supplementary Requirements.

1.1.2 API 2W steels are intended for fabrication primarily by cold forming and welding. The welding procedure is of fundamental importance and it is presumed that procedures will be suitable for the steels and their intended service. Because of the characteristic high YS/TS ratio of TMCP steels, users may want to consider welding consumables which avoid under-matched weld metal. Conversely, the steels should be amendable to fabrication and welding under shipyard and offshore conditions.

1.2 POST MANUFACTURING HEATING

1.2.1 Due to the inherent characteristics of the TMCP method, plates manufactured to this spec cannot be formed or postweld heat treated at temperatures above 1100°F (595°C) without some risk of sustaining irreversible and significant losses in strength and toughness. If warm-forming is to be required during subsequent fabrication, the tensile and notch toughness properties of the finished component shall be verified and the properties shall conform to the requirements of this specification. The procedure for verification shall be subject to mutual agreement. The plates may be post-weld heat treated at elevated temperatures not exceeding 1100°F (595°C) providing test coupons are subjected to a thermal cycle to stimulate such fabrication operations, as described in S9. Verification or simulation is not necessary for heating at temperatures not exceeding 400°F (205°C).

1.2.2 The primary use of these steels is in tubular joints, stiffened plate construction, and other intersections where portions of the plates will be subject to tension in the thickness direction (Z-direction). Supplementary Requirement S4 provides for through-thickness (Z-direction) testing of plates by the manufacturer and specifies limits for acceptance. Supplementary Requirement S1 provides for ultrasonic examination of the plates by the manufacturer and specifies limits for acceptance.

1.2.3 For applications where through-thickness properties are important but Z-direction testing has not been specified, Supplementary Requirement S5 provides a low-sulfur chemistry intended to reduce the size and number of sulfide inclusions in the plate. Supplement S5 is neither a substitute for S4 Through-Thickness Testing nor a guarantee of a minimum level of through-thickness ductility.

1.2.4 The notch toughness requirements specified in Section 7 are suitable for applications below water, or above water in areas of temperature climate (14°F [– 10°C] minimum service temperature). Cold-formed materials have less toughness due to straining than that of the original flat plates, especially in those areas aged by the attachment welding of stubs and braces. The requirements in Section 7 take into consideration typical losses in toughness due to straining and aging. Supplementary Requirements S7 and S8 deal with the strain-aging problem, and consideration should be given to invoking S1 and/or S8 when the strain exceeds 5% or when (Nitrogen × % strain) exceeds 0.040.

1.2.4.1 For applications with lower service temperatures, lower test temperatures should be considered. Supplementary Requirement S.2 provides for impact tests at temperatures other than specified in Section 7. S2.1 provides for Drop-Weight or Charpy V-notch testing at – 60°C. S2.2 provides for such testing at temperatures less than – 40°C but other than – 60°C.

1.3 PREPRODUCTION QUALIFICATION

Supplementary Requirement S.11 and Section 4 of API RP 2Z, dealing with CTOD testing of the weld heat-affected zone and with resistance to hydrogen cracking, respectively, address problems which are not normally dealt with in a "commodity grade" steel specification. These problems are not unique to TMCP steels, but arise because:

a. Users may be expecting higher performance from TMCP steels than is available with conventional steels (e.g., welding with no preheat, or welding with very high heat inputs while retaining the superior notch toughness), and
b. This is a performance specification which accommodates a variety of different steelmaking practices, rather than a recipe

which completely describes all particulars of chemistry, process, and quality control (essential variables).

It is intended that Supplementary Requirement S11 shall apply only when specified in advance by the purchaser. In many cases it may be possible to rely on prior data assembled by the steelmaker, provided no essential variables of the process have been changed.

2 Referenced Documents

The applicable editions of standards referenced herein are as follows:

API

RP 2A-WSD	*Planning, Designing and Constructing Fixed Offshore Platforms—Working Stress Design*
Spec 2H	*Carbon Manganese Steel Plate for Offshore Platform Tubular Joints*
RP 2Z	*Preproduction Qualification for Steel Plates for Offshore Structures*

ASTM[1]

A6/A6M-98a	*Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes and Sheet Piling*
A370-97a	*Standard Test Methods and Definitions for Mechanical Testing of Steel Products*
A578/A578M-96	*Standard Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications*
E10-98	*Standard Test Method for Brinell Hardness of Metallic Materials*
E23-98	*Standard Test Methods for Notched Bar Impact Testing of Metallic Materials*
E208-95a	*Standard Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels*

3 General Requirements for Delivery

3.1 Material furnished to this specification shall conform to the applicable requirements of ASTM A6/A 6M, as modified herein.

3.2 Plates not ordered to Supplement 11 may be weld repaired in accordance with Section 9.5.2 of ASTM A6/A6M. Separate welding procedure qualifications shall be made for each nominal chemical composition of the plate material and filler metal to be used. Low hydrogen electrodes and welding processes shall be used.

[1]American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959

3.3 Welding procedures for repairing plates ordered to Supplement 11.3, CTOD Testing of Weld Heat Affected Zone, shall be subject to approval by the purchaser.

4 Manufacturing

4.1 MELTING

The steel shall be made by the open hearth, basic oxygen, or electric furnace process.

4.2 ROLLING

The plates shall be produced by thermo-mechanical control processing (TMCP).

4.2.1 TMCP is a rolling method in which both reduction and rolling temperatures are strictly controlled, and accelerated cooling may be carried out through strict control of temperature immediately after the end of rolling in order to provide the specified mechanical properties. A description of the TMCP method is given in Appendix B.

4.2.2 The particular process used shall be identified. The process shall be identified as to whether thermo-mechanical rolling (TMR) alone, or TMR and accelerated cooling (AC) were used. The manufacturer's process shall be identified with a code number or designation for ready reference, sufficient to provide traceability of process variables. It is not the intent, however, to require the disclosure of confidential information.

5 Chemical Requirements

5.1 The steels shall conform to the requirements for chemical composition, as determined by heat analysis, prescribed in Table 1 and to the requirements of 5.2 through 5.5.

5.2 The Carbon Equivalent of (*CE*) the heat analysis shall be calculated by both of the following equations:

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

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

5.3 The maximum Carbon Equivalent shall be as prescribed in Table 2.

5.4 Any element intentionally added or which appears in the carbon equivalent calculation shall be reported.

5.5 Boron, vanadium, zirconium, cerium and other rare earth metals shall not be intentionally added without the specific approval of the purchaser.

5.5.1 If any of the above elements are added, the plate must have additional markings per 8.1.c.

Table 1—Chemical Requirements (Heat Analysis, %)[a]

Element	Grade 42	Grades 50 & 50T	Grade 60
Carbon, max.	0.16	0.16	0.16
Manganese			
to $1^1/_2$ in. incl.	0.90–1.35	1.15–1.60	1.15–1.60
over $1^1/_2$ in.	0.90–1.60	1.15–1.60	1.15–1.60
Phosphorus, max.	0.03	0.03	0.03
Sulfur, max.	0.010	0.010	0.010
Silicon	0.05-0.50	0.05-0.50	0.05-0.50
Nickel, max.	0.75	0.75	1.0
Chromium, max.	0.25	0.25	0.25
Molybdenum, max.	0.08	0.08	0.15
Copper, max.	0.35	0.35	0.35
Titanium			
N ≤ 0.005	0.003–0.02	0.003–0.02	0.003–0.02
N > 0.005	0.007–0.02	0.007–0.02	0.007–0.02
Columbium, max.	0.03	0.03	0.03
Nitrogen, max.[b]	0.012	0.012	0.012
Aluminum			
Acid soluble or	0.015–0.055	0.015–0.055	0.015–0.055
total	0.02–0.06	0.02–0.06	0.02–0.06

[a]See 5.2, 5.3, 5.4, and 5.5.
[b]Nitrogen shall not be intentionally added.

Table 2—Carbon Equivalent Maximums

Grade	Thickness	*CE* Maximum	Pcm Maximum
Grade 42	To $1^1/_2$ in. (40 mm) incl.	0.39	0.22
	Over $1^1/_2$ in. (40 mm) to $3^1/_2$ in. (90 mm) incl.	0.41	0.23
	Over $3^1/_2$ in. (90 mm) to 6 in. (150 mm) incl.	0.43	0.24
Grade 50 and	To $1^1/_2$ in. (40 mm) incl.	0.39	0.22
Grade 50T	Over $1^1/_2$ in. (40 mm) to $3^1/_2$ in. (90 mm) incl.	0.41	0.23
	Over $3^1/_2$ in. (90 mm) to 6 in. (150 mm) incl.	0.43	0.24
Grade 60	To $1^1/_2$ in. (40 mm) incl.	0.42	0.23
	Over $1^1/_2$ in. (40 mm) to 4 in. (100 mm) incl.	0.45	0.25

6 Mechanical Requirements

6.1 The material, as represented by the test specimens, shall conform to the tensile requirements prescribed in Table 1.

6.2 One tensile test shall be taken from one corner of each plate as produced by the TMCP method.

Table 3—Tensile Requirements

Property	Grade 42	Grade 50	Grade 50T	Grade 60
Yield Strength, ksi (MPa)				
t ≤ 1 in. (25 mm)	42–67	50–75	50–80	60–90
	(290–462)	(345–517)	(345–552)	(414–621)
t > 1 in. (25 mm)	42–62	50–70	50–75	60–85
	(290–427)	(345–483)	(345–517)	(414–586)
Tensile Strength, min., ksi (MPa)	62	65	70	75
	(427)	(448)	(483)	(517)
Elongation in 2 in. (50 mm) min., %	24	23	23	22
Elongation in 8 in. (200 mm) min., %	20	18	18	16

7 Notch Toughness Requirements

7.1 One Charpy V-notch impact test, consisting of three transverse specimens, shall be made on each plate as produced by the TMCP Process. The specimens shall be taken from the mid-width and mid-thickness locations of the plate, and tested in accordance with ASTM A 673. Specimen size, test temperature and minimum energy requirements are shown in Table 4.

Due to the low carbon and sulfur contents, the energy of the full-size specimens will often exceed the limit of ASTM E23. To prevent this, the producer has the option of testing subsize specimens to any of the combinations of specimen size, energy requirement, and test temperature of Table 4, as indicated in Options A through E.

7.2 If the average energy value for a set of three specimens is below the average value specified, or if the energy value of one specimen is less than the minimum energy value specified for a single specimen, retests may be made as follows:

a. Retest three additional specimens. The energy value of each specimen must equal or exceed the minimum average energy value specified.
b. If the required energy values are not obtained upon retest, the plate shall not be accepted under this specification.

Table 4—Notch Toughness Requirements, Charpy V-Notch Testing

Grade	Option	Specimen Size mm	Minimum Average Energy ft-lb (J)	Minimum Single Value ft-lb (J)	Test Temperature F (°C)
42	A	10 × 10	25 (34)	20 (27)	– 40 (– 40)
	B	7.5 × 10	25 (34)	20 (27)	– 40 (– 40)
	C	5.0 × 10	25 (34)	20 (27)	– 40 (– 40)
	D	7.5 × 10	19 (26)	15 (20)	– 50 (– 46)
	E	5.0 × 10	13 (18)	10 (14)	– 80 (– 62)
50	A	10 × 10	30 (41)	25 (34)	– 40 (– 40)
	B	7.5 × 10	30 (41)	25 (34)	– 40 (– 40)
	C	5.0 × 10	30 (41)	25 (34)	– 40 (– 40)
	D	7.5 × 10	23 (31)	19 (26)	– 50 (– 46)
	E	5.0 × 10	15 (20)	13 (18)	– 80 (– 62)
60	A	10 × 10	35 (48)	30 (41)	– 40 (– 40)
	B	7.5 × 10	35 (48)	30 (41)	– 40 (– 40)
	C	5.0 × 10	35 (48)	30 (41)	– 40 (– 40)
	D	7.5 × 10	26 (35)	23 (31)	– 50 (– 46)
	E	5.0 × 10	18 (24)	15 (20)	– 80 (– 62)

8 Marking

8.1 Each plate shall be legibly steel die stamped, unless stenciling is specified by the purchaser, with name or brand of the manufacturer, heat and slab (plate) number, and API 2W and grade at one end of the plate not less than 12 in. (300 mm) from any edge. Plates under $^1/_4$ in. (6 mm) in thickness may be stenciled instead of stamped.

The following information shall also be shown as applicable:

a. The API Monogram may be applied to products complying with the requirements of the specification and only by authorized manufacturers.

b. Grade 42 shall be marked API 2W-42.
Grade 50 shall be marked API 2W-50.
Grade 50T shall be marked API 2W-50T.
Grade 60 shall be marked API 2W-60.

c. If any elements previously referenced in 5.5 are added, the plate shall be marked with a “C” adjacent to the “W” in the markings listed in 8.1.b. (e.g., API 2WC-50).

APPENDIX A—SUPPLEMENTARY REQUIREMENTS

By agreement between the purchaser and the material manufacturer, and when specified on the purchase order, the following Supplementary Requirements shall apply.

S1 Ultrasonic Examination

S1.1 Pulse Echo ultrasonic examination shall be performed on each plate in accordance with ASTM Specification A578/A578M, *Standard Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications*—Level II shall be used. Any laminations (defined as complete loss of back reflection) with a dimension greater than 3 in. (75 mm) shall be cause for rejection.

S1.2 Examination reports shall be furnished for each plate, the areas with more than 50% loss of back reflection shall be located on the sketch.

S2 Notch Toughness Test at Lower Temperature

S2.1 Notch toughness tests shall be made in accordance with the requirements of Section 7 or S.12 and shall meet the requirements of Table S2-1 in lieu of the requirements of Table 4 or S12.2.

S2.2 Impact tests may be made at temperatures lower than those specified in Table 3 or S12.2 and other than those specified in Table S2-1. The testing temperature shall be specified by the purchaser and agreed to by the material manufacturer.

S2.3 If the design condition requires a higher energy value, energy values higher than those stated in Table S2.1 may be specified subject to agreement between the purchaser and the material manufacturer.

S3 Additional Tension Test

Two tension tests shall be taken from each plate-as-rolled by the TMCP process (parent plate). The test specimens shall be taken from a corner of the plate at both ends.

S4 Through-Thickness (Z Direction) Testing

S4.1 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 plates with nominal thicknesses $^3/_4$ in. (19 mm) and greater. Definitions shall be in accordance with ASTM A370.

S4.2 *Number of Test Specimens*. Two tests shall be taken from each plate-as-rolled (parent plate).

S4.3 *Orientation of Test Specimens*. The longitudinal axis of the test specimen shall be perpendicular to the surface of the plate.

S4.4 *Location of Test Specimens*. One test specimen shall be taken at the ingot axis or cast slab longitudinal centerline at its intersection with each edge or end of the plate.

S4.5 *Preparation of Test Specimens.* Specimens shall be prepared as follows:

a. Prolongations shall be joined to opposite surfaces of the plate 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 plate 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 plate 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 the plate 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 plate 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 plate thickness within a uniform diameter throughout the section.

Table S2-1—Notch Toughness Requirements at Lower Temperatures Drop-Weight Testing—No-Break at – 67°F (– 55°C), or Charpy Impact Testing

Grade	Specimen Size mm	Minimum Average Energy ft-lb (J)	Minimum Single Value ft-lb (J)	°F (°C)
42	10 × 10	25 (34)	20 (27)	– 76 (– 60)
50 and 50T	10 × 10	30 (41)	25 (34)	– 76 (– 60)
60	10 × 10	35 (48)	30 (41)	– 76 (– 60)

S4.6 *Testing*. Tensile testing shall be conducted in accordance with the requirements of ASTM A370.

S4.7 *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 of the two specimens from a plate 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 S4.7a may be specified subject to agreement between the material manufacturer and the purchaser.

S4.8 *Marking.* Plates accepted in accordance with this procedure for through-thickness testing shall be identified by stamping or stenciling "Z" adjacent to marking otherwise required (i.e., API 2W-50Z).

S5 Low Sulfur Steel for Improved Through-Thickness Properties

S5.1 *Intent.* The intent of this supplementary requirement is to provide, by chemical control, plates with low levels of sulfide inclusions and thereby a reduction of the potential for lamellar tearing of the plate in the area of attachment welds.

S5.2 *Chemistry.* The steels shall conform to the requirements for chemical composition prescribed in Table 1, except that the maximum content of sulfur on heat analysis shall be 0.006%.

S5.3 *Sulfide Shape Control.* If sulfide shape control is ordered or allowed, the method and its control shall be by agreement between the purchaser and the manufacturer.

S5.4 *Through-Thickness Testing*. Through-thickness (Z-direction) tensile testing is not required by this supplementary requirement.

S5.5 *Marking.* Plates accepted in accordance with this supplementary requirement shall be identified by stamping "LS" adjacent to marking otherwise required. (i.e., API 2W-50LS)

S7 Low Nitrogen Content for Improved Notch Toughness in Strain-Aged Condition

S7.1 The nitrogen content shall be 0.009% maximum on heat analysis.

S8 Strain-Aged Charpy V-Notch Impact Tests

S8.1 Charpy V-notch impact test coupons representing the thickest and thinnest plate of each heat shall be uniformly strained 5%, or more if specified, in axial tension and aged at 480°F (250°C) for one hour at temperature prior to cutting the test specimens. The test results shall meet the requirements of Section 7.

S9 Simulation of Postweld Head Treatment

S9.1 Test coupons shall be subjected to a simulated postweld heat treatment provided by the purchaser that is representative of the thermal treatment to which the material will be subjected. The temperature range, time at temperature, and cooling rates shall be as specified on the order.

S10 Hardness Testing

S10.1 This Supplementary Requirement covers the procedure and acceptance standards for surface hardness testing of steel plates furnished under this specification.

S10.2 The hardness test shall be made by the Brinell hardness method as described in ASTM E10-98 using a 3000 kg load. By agreement, other hardness test methods may be used and their measurement converted to Brinell values. The hardness measurement shall be made on both top and bottom surfaces of specimens removed from one corner at each end of the plate-as-rolled. The mill surface and any decarburized layer shall be removed prior to testing. Not less than four hardness measurements shall be made on each plate, all of which must lie within the acceptance limits shown below. If any individual measurement is outside the acceptance limits shown below, two additional measurements may be performed adjacent to the original impression. Both of the new measurements must comply with the acceptance limits in order to invalidate the original measurement.

S10.3 The acceptance limits shall be as follows:

Grade 42	121–192 HBN
Grade 50	131–207 HBN
Grade 50T	137–207 HBN
Grade 60	By agreement.

S11 Preproduction Qualification

S11.1 This Supplementary Requirement provides for prequalification by special welding and mechanical testing of a specific chemical composition range, in combination with specific steelmaking and rolling procedures, from a specific producer. The purpose of this Supplementary Requirement is to minimize the amount of time and testing necessary to prepare and certify welding procedures at the fabrication yard.

S11.2 The specific testing required shall be that contained in Sections 4 and 5 of API RP 2Z, as specified on the purchase order. Prior qualification by a material manufacturer may be accepted for fulfillment of this Supplementary Requirement, if documentation acceptable to the purchaser is provided.

S11.3 Crack tip opening displacement (CTOD) testing of weld heat affected zone shall be performed in accordance with Section 4 of API RP 2Z, which provides for testing over the following range of conditions:

Heat input: 1.5 to 4.5 kJ/mm (38 to 114 kJ/in.)
Preheat: 100° to 250°C (212° to 480°F)

Required CTOD for Grades 42 and 50:
plates 3 in. (75 mm) and under in thickness:
0.25 mm at –10°C (0.010 in. at 14°F).
plates over 3 in. (75 mm) in thickness:
0.38 mm at –10°C (0.015 in. at 14°F).

Testing to a wider range of heat input, wider range of preheats, higher CTOD values, or lower test temperatures, is permitted at the option of the material manufacturer or when specified by the purchaser, and shall be deemed to satisfy the minimum requirements of this Supplement.

S11.4 Weldability testing shall be conducted in accordance with Section 4 of API RP 2Z using two types of tests representing different levels of restraint; the Controlled Thermal Severity (CTS) test for moderate restraint, and the V-Groove test for high restraint.

S12 Notch Toughness Using Drop-Weight

S12.1 Drop-Weight tests shall be conducted. One plate per 50 ton lot or part thereof of the plates in each heat $^{5}/_{8}$ in. (16 mm) or more in thickness shall be tested. The plate tested shall be the thickest gage in each 50 ton lot.

S12.2 Drop-Weight tests shall be in accordance with ASTM E208 on two P-3 specimens from the selected plate(s). The specimens shall be taken adjacent to the tensile test coupons and tested at – 30°F (– 35°C). Both specimens shall meet the "no break" criteria at the test temperature and the results shall be reported.

S12.3 If one specimen fails ("Breaks") on any plate tested, retests may be made as follows:

a. Retest two additional specimens from each plate for which a specimen failed. Each of these two retest specimens must pass ("No Break").
b. If any of the specimens fail upon retest, the heat shall not be accepted.

S13 Surface Quality

For applications where surface quality is considered critical, plates are to be furnished in the blasted and inspected conditions. The depth of rolled-in scale or clusters of pits shall not exceed 0.015 in. and shall not result in an undergage condition. However, isolated individual pits not over 0.030 in. deep are acceptable provided that the plate thickness is not reduced below the specified minimum. Other surface imperfections such as tears, seams, snakes, blisters, scabs, etc. are not acceptable and must be conditioned without reducing the thickness below minimum. The surface imperfections may be removed by grinding provided each ground area is well faired and grinding does not reduce the thickness of the plate below minimum.

S14 Thickness Tolerance

By agreement between purchaser and supplier, plates can be ordered to $^{1}/_{2}$ standard over tolerance for thickness shown in ASTM A6.

APPENDIX B—DESCRIPTION OF THERMO-MECHANICAL CONTROL PROCESS (TMCP)

B.1 Introduction

The Thermo-Mechanical Control Process, commonly referred to as TMCP, has evolved from the controlled rolling processes which have been known and used for a number of years. TMCP produces fine-grained steel by a combination of chemical composition and integrated controls of manufacturing processes from slab reheating to post-rolling cooling, thereby achieving the specified mechanical properties in the required plate thicknesses. TMCP requires accurate control of both steel temperatures and rolling reductions. See "A Synopsis of High Tensile Hull Structural Steels Through the Thermo-Mechanical Control Process (TMCP) in Japan," by Kenji Yasuda, in *HK Tech Bulletin 1983* for a discussion of the various TMCP in use at that time.

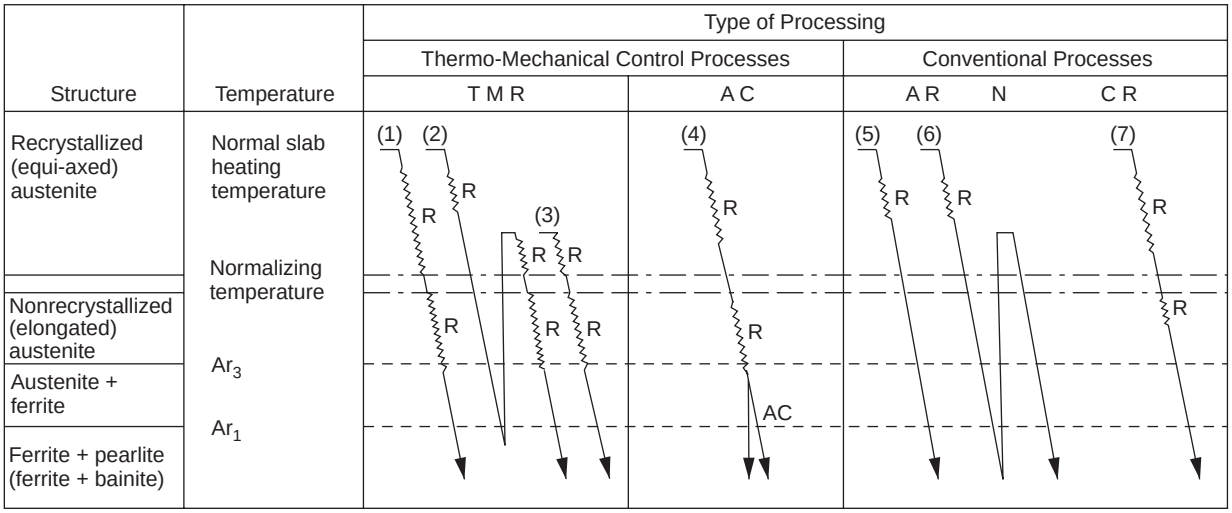
B.2 Outline of TMCP

As shown in Figure B-1, TMCP may incorporate two processes, as follows:

a. Thermo-Mechanical Rolling (TMR), in which steels of fine grain size are produced by rolling in the recrystallization and the non-recrystallization regions of austenite, and sometimes in the dual-phase temperature region of austenite and ferrite. Generally, a high proportion of the rolling reduction is performed close to, or below, the temperature at which austenite begins to transform to ferrite during cooling (AR_3) and may involve rolling in the lower portion of the temperature range of the intercritical duplex phase region.

b. Accelerated Cooling (AC), in which steels meeting the specified requirements are produced by promoting grain refinement and increasing the pearlite and/or bainite volume fraction through controlled cooling (accelerated cooling and air cooling) immediately after the final controlled rolling (CR) or TMR operation.

The selection, from the above, of the method to be used is made by the plate producer depending upon the chemical composition, the plate thickness, and the required properties.



Note:
THR — Thermo-mechanical rolling
AC — Accelerated cooling process
AR — As rolled
N — Normalized
CR — Controlled rolling
R — Reduction

(1), (2), and (3) show three different TMR rolling processes.
(4) shows a TMR process followed by an AC process.
(5) shows the conventional AR process.
(6) shows the conventional AR process followed by normalizing (N).
(7) shows a common controlled rolling (CR) process.

Figure B-1—Schematic Diagrams of Conventional and Thermo-Mechanical Control Process of Steel Plate

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