The Impact Testing Enigma
A Review of ASME Section VIII, Division 1, Subsection C, Part UCS, Impact Testing Requirements

AB-511

Edition 2, Revision 1 – Issued 2017-05-03
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1.0 INTRODUCTION

Manufacturers continuously face the challenge of complying with the impact testing provisions of ASME Section VIII, Division 1.

As Code impact testing rules are quite complex, instances of misconception and/or oversight are not unusual, hence the enigma. The material provided in this document is not intended to replace the Code rules. The intent of this review of impact testing rules and the decision charts provided is to help manufacturers meet Code requirements.

The presentation material consists of a series of impact testing decision charts, and a selection of the most common problems, misconceptions and oversights with regard to impact testing as it applies to pressure vessel construction to the ASME Code, Section VIII, Division 1, CSA B51 Part 1, and the Alberta Safety Codes Act and Pressure Equipment Safety Regulation. The primary focus of the document is on Subsection C, Part UCS impact testing requirements.

This document has been revised to include changes to ASME Section VIII, Division 1, Subsection C, Part UCS up until and including the 2015 Edition and CSA-B51, 2014 Edition.

1 In the Webster's Ninth New Collegiate Dictionary, Enigma is defined as “something hard to understand or explain”.

2.0 IMPACT TESTING DECISION CHARTS

2.1 Impact Testing Requirements (Materials)

Subsection C, Part UCS Carbon and Low Alloy Steel Material

Exempted

If a minimum design metal temperature and thickness combination is on or above the curve, impact testing is not required, except as required by UCS 67(a)(3) for weld metal.

UG-20(f)

Not Exempted

UCS-66(a) Fig. UCS-66

By component, based upon the governing thickness as per UCS-66(a), the applicable material curve and the MDMT.

UCS-66(b) Fig. UCS-66.1

Not Exempted

By component, based upon the ratio of:

\[ \frac{t_{r}}{t_{n}} \]

where:

- \( c \) = corrosion allowance, in.
- \( E^* \) = Fig. UCS-66.2, note 3
- \( t_{r} \) = nominal not-corroded thickness (Fig. UCS-66.2, Note 1)
- \( t_{n} \) = required thickness in corroded condition for all applicable loadings (Fig. UCS-66.2, Note 2), based on the applicable joint efficiency (Fig. UCS-66.2, Note 3)

UCS-66(b)(1)(b) Fig. UCS-66.1 & 2

Components not stressed in the general primary membrane tensile stress. (Flat heads, covers, tubeshells, flanges) MDMT may be reduced as UCS-66.2 step 3 ratio of:

Maximum design pressure at MDMT
Maximum allowable pressure at MDMT

UCS-66(c) Exemption for Carbon and Low Alloy Steel Long Weld Neck Flanges as defined in UCS-66(c)(4) and ferritic steel flanges (ASME B 16.5, B16.47 and split loose flanges as specified in UCS-66(c)(3) with MDMT no colder than -20°F.

UCS-66(d) Exemption for thin UCS materials and thin P-1 material in pipe and tubes less than NPS 4 (Refer to UCS-66(d) for thickness limitations).

UCS-66(g) Exemption for Fig. 84.1, General note(c) materials (at MDMT's not colder than 5°F colder than the test temperature required by the specification).

UCS-66(h) Exemption for metal backing strips of materials assigned to curve 'A' of Fig 66-66 and 1/4 in. or less in thickness which remain in place with MDMT no colder than -20°F.

UCS-66(i) Reduction of MDMT for impacted test components based upon coincident ratio (Fig UCS-66.1).

UCS-66(j) When base metal is exempt from impact testing by UCS-66(g) or by Fig. UCS-66 Curves C or D, -20°F is the coldest MDMT to be assigned for welded components that do not meet UCS-67(a)(3).

Impact Testing Required in accordance with UG-84

See UCS-66(c) for further reduction of 30°F in the MDMT exemption when non-mandatory PWHT is performed for P-No.1 Materials.

Note: CSA B-51, Par. 7.1.3 requires impact testing at MDMT below -50°F

Prepared in accordance with ASME Section VIII, Division 1- 2015 Ed. & CSA B51-14
2.2 Impact Testing Requirements of Welding Procedures with Filler Metal

Subsection C Part UCS Carbon and low Alloy Steel Material
UCS-67(a) Welds made with filler metal

WPQ Weld Metal Impact Testing Required in accordance with UG-84(f)

Yes

UCS-67(a)(1)

Is either base metal required to be impact tested by the rules of Section VIII Division 1

No

WPQ Weld Metal Impact Testing Required in accordance with UG-84(f)

True

UCS-67(a)(2)

When the thickness of any individual weld pass exceeds 1/2" and the MDMT is colder than 70°F

False

WPQ Weld Metal Impact Testing Required in accordance with UG-84(f)

True

UCS-67(a)(3)

When joining base metals exempt from impact testing by UCS-66(g) or Fig. UCS-66, curve C or D and the MDMT is colder than -20°F but not colder than -55°F. Qualification of the welding procedure with impact testing is not required when no individual weld pass in the production weld exceeds 1/4 in. in thickness; and each heat/ or lot of filler metal and batch of flux has been classified by their manufacturer through impact testing per the applicable SFA specification at a temperature not warmer than the MDMT. Additional testing beyond the scope of the SFA specification may be performed by the filler metal and/or flux manufacturer to expand their classification for a broader range of temperatures;

False

WPQ Weld Metal Impact Testing Required in accordance with UG-84(f)

True

UCS-67(a)(4)

When joining base metals exempt from impact testing by UCS-66(g) and the MDMT is colder than -55°F.

False

WPQ Weld Metal Impact Testing not required.

Note: CSA B-51, par. 7.1.3 requires impact testing at MDMT below -50°F.

Prepared in accordance with ASME Section VIII, Division 1- 2015 Ed. & CSA B51-14

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2.3 Impact Testing Requirements of Welding Procedures without Filler Metal

Subsection C Part UCS Carbon and low Alloy Steel Material

UCS-67(b)
Except for welds made as part of the material specification, welds in UCS materials made without filler metal shall be completed using welding procedures qualified with impact testing when:

WPQ Weld Metal Impact Testing Required in accordance with UG-84(f)

True

UCS-67(b)(1)
when either base metal is required to be impact tested by the rules of this division

False

WPQ Weld Metal Impact Testing Required in accordance with UG-84(f)

True

UCS-67(b)(2)
the thickness at the weld exceeds 1/2 in. regardless of the MDMT

False

WPQ Weld Metal Impact Testing Required in accordance with UG-84(f)

True

UCS-67(b)(3)
when the thickness at the weld exceeds 5/16 in. and the MDMT is colder than 50°F

False

WPQ Weld Metal Impact Testing Required in accordance with UG-84(f)

True

UCS-67(b)(4)
¹ When joining base metals exempt from impact testing by UCS-66(g) and the MDMT is colder than -55°F

¹ When joining base metals exempt from impact testing by UCS-66(g) and the MDMT is colder than -55°F

False

WPQ Weld Metal Impact Testing not required.

¹ Note: CSA B-51, Par. 7.1.3 requires impact testing at MDMT below -50°F

Prepared in accordance with ASME Section VIII, Division 1-2015 Ed. & CSA B51-14
2.4 Impact Testing Requirements Vessel [Production] Impact Tests (Page 1)

UG-84(I) Vessel (Production) Impact Test Plates

Required

For each vessel, one test plate shall be made for each welding procedure used for joints of category A and B, unless the vessel is one of several as defined in UG-84(I)(3)(b) or (c).

The vessel impact test plate shall be from one of the heats of steel used for the vessel or groups of vessels. For Category A joints, the test plate shall, where practical, be welded as an extension of a production joint so that the test plate element will represent as nearly as practicable the quality and type of welding in the vessel joint. (Note: additional processes, not included in the category A joint as per UG-84(I)(3)(a)(1) or (2), cannot be added exclusively to the test plate to represent category B welding or repair welding without additional test plates). For category B joints that are welded using a different procedure than used on category A joints, the test plate shall be welded concurrently with (or as close to the start of welding as practicable) production welding, using the same type of equipment and procedure, at the same location.

UG-84(I)(1)

Not Eligible for exemption under UG-84(I)(3)(b) or (c)

For several vessels or parts of vessels, welded within any 3 month period at one location if:
1. The plate thickness does not vary by the greater of 1/4 in. or 25% (25% of the plate tested), and
2. The specification and grade of the material is the same. A test plate shall be made for each 400 ft. of joints welded by the same procedure. (Note: Accurate records of the total weld length represented by the test plate are required)

UG-84(I)(3)(a)

For small vessels meeting U-1(I) volume requirements, made from one heat of material requiring impact tests, one test plate made from the same heat of material and welded with the same electrode and WPS may represent one lot of 100 vessels or less, or each heat treatment furnace which ever is smaller.

UG-84(I)(3)(c)

UG-84(I)(3)(b)

UG-84(I)(3)

OR

Not Eligible for exemption under UG-84(I)(3)(b) or (c)

UG-84(I)(1)

Rejection

If the test plate fails to meet the impact requirements the welds represented by the plate shall be unacceptable. Reheat treatment and retesting or retesting only are permitted.

UG-84(c)

Acceptance

Production impact test results comply with UG-84(c)

Provides acceptance criteria for impact testing results.

1 Note: CSA B-51, par. 7.1.3 requires impact testing at MDMT below -50°F
2 Note: UG-84(I)(3)(a)(1) and (2) Stipulations on test plate weld positions, and if automatic, machine, semi-automatic or manual welding is performed

Prepared in accordance with ASME Section VIII, Division 1- 2015 Ed. & CSA B51-14
2.5 Impact Testing Requirements Vessel [Production] Impact Tests (Page 2)

ASME Section VIII, Division 1, Paragraph UG-84 Vessel (Production) Impact test Plates

Example 1

a) Vessel contains both category A and Category B weld joints.

b) Category A and B joints are welded using the same multi-process (GMAW-SMAW-SAW) WPS

c) The vessel is not one of several per UG-84(j)(3)(b) or (c)

Start

Prepare Category A weld joint test coupon as required. UG-84(i)

Pass Testing per UG-84(c)

YES

NO

Determine if additional test plate(s) required. UG-84(i)(3)(a)

NO

Additional test plate required

YES

Prepare additional test plate(s)

Pass Testing per UG-84(c)

YES

NO

Rejection - See UG-84(j)

UG-84(i)(1)

For Category A joints, the test plate shall, where practicable, be welded as an extension to the end of a production joint so that the test plate weldment will represent as nearly as practicable the quality and type of welding in the vessel joint.

Note: This requires all processes that will be used in the Category A joint to be included in the test plate.

UG-84(j)

Rejection. If the vessel plate fails to meet the impact requirements, the welds represented by the plate shall be unacceptable. Reheat treatment and retesting or retesting only are permitted.

UG-84(i)(3)

In addition, for Category A and B joints the following requirements shall apply:

- (1) If automatic or semiautomatic welding is performed, a test plate shall be made in each position employed in the vessel welding.
- (2) If manual welding is also employed, a test plate shall be made in the flat position only, except if welding is to be performed in other positions a test plate need be made in the vertical position only (where the major portions of the weld layers are deposited in the vertical upward direction). The vertically welded test plate will qualify the manual welding in all positions.

Note:

A long seam with an attached production test plate is welded using only the SAW welding process. The circumferential seams are to be welded using a semiautomatic (GMAW) and manual welding (SMAW) process. Now that these processes have been added as per UG-84(i)(3) above, this would require an additional test plate to represent the addition of other processes. It would not be acceptable to add these additional processes to the test plate for the long seam only and try to cover the manual and semiautomatic processes to be used on the circumferential seams.

END
3.0 MATERIALS & DESIGN

3.1 CSA B51-14, Part 1, Clause 7.1.3

Carbon and low alloy steel used for the construction of pressure vessels at a minimum design metal temperature below –50 °F shall be impact tested at the MDMT or lower temperature with the test results meeting UG-84 of ASME Section VIII Division 1.

3.2 UG-20(f)(1)

To qualify for exemption under UG-20(f) the material shall be limited to P Number 1, Group Number 1 or 2, and the thickness as defined in UCS-66(a) [see also, Note(1) in Fig.UCS-66.2] is limited to ½ inch for curve A materials and 1 inch for curve B, C, or D materials of Figure UCS-66.

3.3 UCS-67(a)(3)

Under the provisions of UCS-67(a)(3), for MDMTs that are colder than –20 °F but not colder than –55 °F, for materials exempt from impact testing by UCS-66(g) or Figure UCS-66, Curves C or D from Figure UCS-66 must be made with welding procedures qualified by impact testing. Qualification of welding procedures with impact testing is not required when no individual weld pass in the production weld exceeds ¼” in thickness and the welding consumables, for each heat and/or lot of filler metal or combination of heat/or lot of filler metal and batch of flux used to joint these base metals has been classified by the consumable manufacturer through impact tests per the applicable SFA specification at a temperature not warmer than the MDMT. The welding procedure qualification shall include impact tests of welds and heat affected zones, as specified by the first paragraph of UCS-67.

3.4 UCS-68(b)

This paragraph requires that welded joints be postweld heat treated when required by other rules of Section VIII-1 or when the MDMT is colder than –55 °F, and the coincident ratio as defined in Fig. UCS-66.1 is 0.35 or greater, except for P-No. 1 materials that are impact tested per UG-84 with energy values specified in UCS-68(b), and Category A & B joints plus fillet weld requirements as per UCS-68(b)(1) & (2) are met.
3.5 Exemption Combinations

3.5.1 Interpretation VIII-1-89-138R

If a vessel is constructed of a combination of P-No. 1 Group No. 1 or 2 materials and other materials listed in Subsection C, the rules of UG-20(f) may be applied to the portion constructed of P-No. 1 Group No. 1 or 2.

3.5.2 Interpretation VIII-1-95-15

The allowable temperature reduction determined from Fig. UCS-66.1 (coincident ratio less than 1) and the temperature reduction permitted by UCS-68(c) (postweld heat treatment when not otherwise a requirement per Code) may be combined.

3.5.3 Interpretation VIII-1-95-160

The additional temperature reduction provided by UCS-68(c) may be applied to the provision of UCS-66(c), which allows ANSI B16.5 and B16.47 flanges and split loose flanges as specified within the Code paragraph, exemption from impact testing when the MDMT is no colder than –20 °F.

3.5.4 UG-20(f) + UCS-66(b)

A temperature reduction determined from Fig. UCS-66.1 (coincident ratio less than 1) may not be applied in addition to an exemption from impact testing under UG-20(f).

3.5.5 UG-20(f) + UCS-68(c)

A temperature reduction permitted by UCS-68(c) may not be applied in addition to an exemption from impact testing under UG-20(f).

3.5.6 Table UCS-56-1 Note (b)(2) + UCS-68(c)

A temperature reduction permitted by UCS-68(c) may not be applied when the provisions of table UCS-56-1, General Note (b)(2) is used to avoid the requirement to postweld heat treat (200 °F preheat for P-No. 1 materials over 1¼ in. nominal thickness through 1½ in. nominal thickness).
4.0 WELDING PROCEDURES

4.1 QW-407.2

This Supplementary Essential Variable requires that the procedure qualification test be subjected to PWHT essentially equivalent to that encountered in the fabrication of production welds, including at least 80% of the aggregate time(s) at temperature(s). For example, to remain within the WPS requirements, the maximum post weld heat treatment time(s) at temperature(s) for the production weld or production test coupons is 1.25 times the time(s) at temperature(s) qualified by the PQR coupon.

4.2 QW-403.6

This Supplementary Essential Variable specifies that the minimum base metal thickness qualified is the thickness of the test coupon T or 5/8" inch, whichever is less. However where T is less than ¼ inch, the minimum thickness qualified is ½T.

4.3 UG-84(h)(2)(-c) and UG-84(g)(5)

Paragraph UG-84(h)(2)(-c) requires that the base material for the weld test coupon meet the minimum notch toughness requirement for the thickest material of the range of base material to be qualified by the procedure. Paragraph UG-84(g)(5) then requires that the weld metal impact test values shall be at least as high as those for the base material. This paragraph may place an additional limit on the qualification thickness of a WPS, for instance when QW-403.7 allows the WPS to qualify to 8 inches. For example, assume a WPS is qualified on a P-No. 1 Group No. 1 base material which has a minimum specified yield strength of 55 ksi. If the test is made on a 1½ inch thick plate and the provisions of QW-403.7 are utilized, the test specimen would normally qualify the WPS for thicknesses up to 8 inches. Fig. UG-84.1 requires that the impact test results must average 30 ft-lbs. or more to qualify for a thickness of 3 inches or more.
5.0  FABRICATION

5.1  UCS-67(a)

This paragraph stipulates that welds made with filler metal shall be deposited using welding procedures qualified with impact testing when any of the following apply:

(1) When either base metal is required to be impact tested,
(2) When the thickness of any individual pass exceeds \( \frac{1}{2} \)" and the MDMT is colder than 70°F,
(3) When joining base metals exempt from impact testing by UCS-66(g) (typically SA-350 LF2 Class 1, SA-333 Grade 6 materials), or above the curves of Figure UCS-66 C or D, and the MDMT is colder than -20°F but no colder than -55°F. Qualification of the welding procedure with impact testing is not required when no individual pass in the production weld exceeds \( \frac{1}{4} \)" in thickness and each heat and/or lot of filler metal or combination or heat and/or lot of filler metal and batch of flux has been classified by impact testing as per the applicable SFA specification by the consumable manufacturer at a temperature not warmer than the MDMT.

5.2  UG-84(i)(1) General (Production Impact Test Plates)

The vessel impact test plate shall be from one of the heats of steel used for the vessel or group of vessels.

For Category A joints, the test plate shall, where practicable, be welded as an extension to the end of a production joint so that the test plate weldment will represent as nearly as practicable the quality and type of welding in the vessel joint. The term practicable has been interpreted different ways. For example, a run-off tab would not be practicable for the Category “A” joint in a sphere made from 2 hemispheres or when a seamless shell is used without a long seam. This should not be interpreted so as to avoid the use of the run-off tab due to other problems (such as not attaching the impact coupon to the long seam because it was not practicable at the time), or welding the test plate after the vessel has been completed because it was forgotten at the start of production and this is considered as close to the start of production as practicable. This is supported by Interpretation VIII-79-16.

For Category B joints that are welded using a different welding procedure than used on Category A joints, a test plate shall be welded under the production welding conditions used for the vessel, using the same type of equipment and at the same location and using the same procedure(s) as used for the joint, and it shall be welded concurrently with the production welds or as close to the start of production welding as practicable.
Under some circumstances when the above requirements have not been met, a test plate removed from the production weld seam has been accepted as meeting the Code provisions, but a production impact test plate cannot be welded after the fact.

5.3 UG-84(i)(3)(a) Number of Vessel Impact Test Plates Required

For each vessel, one test plate shall be made for each welding procedure used for joints of Categories A and B, unless the “vessel” is one of several as defined in UG-84(i)(3)(b) or (c).

A significant problem complying with this paragraph can be created when the possibility of repairs has not been considered before vessel fabrication. To illustrate the problem, consider a 4-inch thick vessel welded primarily with SAW but the WPS includes both the SMAW and SAW processes. If a SMAW repair 2 1/2” in depth is required, will the weld repair depth be qualified under this same WPS as was used for production welding and production impact test plates (in other words does the WPS have adequate SMAW deposited weld metal thickness to conduct the 2 1/2” repair)?

5.4 UG-84(i)(3)(b) Number of Vessel Impact Test Plates required

For several vessels or parts of vessels, welded within any 3 month period at one location (the 3 month period is from when welding has started on the category A & B joints of the first vessel and ends once the last category A & B joints are completed on the last vessel represented) , the plate thickness of which does not vary by more than 1/4 inch or 25%, whichever is greater, and of the same specification and grade of material, a test plate shall be made for each 400 ft of joints welded by the same procedure.

If it is intended to invoke the provisions of this paragraph, accurate records of Category A and B welding footage must be maintained by the manufacturer. The records must be acceptable to the A.I.

When reviewing the applicability of production impact tests that have been performed, against the requirements of UG-84(i)(3)(b), use the thickness of the test plate for determination of the 25% thickness variation provision not the thickness of the thickest part welded.

Questions have arisen as to the applicability of the limitations of UG-84(i)(3)(b) when a vessel has had impact test plates prepared in accordance with UG-84(i)(3)(a). What if the production welding extends beyond a three month time period? The time, thickness and footage limitations do not apply to production impact tests performed in accordance with UG-84(i)(3)(a).
5.5  UG-84(f)(2) Impact Testing of Welds

All test plates (PQR and Production, when not exempted) shall be subjected to heat treatment, including cooling rates and aggregate time(s) at temperature(s) as established by the Manufacturer for use in actual manufacture.

This paragraph can have significant consequences when an exemption under the referenced paragraphs is not available, for instance P-No. 3, Gr. Numbers 1 and 2 materials, reheat treatment of the vessel could lead to unacceptable WPS and production impact tests. **Material impact test results may also be unacceptable** under reheat treatment as provided for in Subsection C. Particular attention should be paid to this paragraph when dealing with UHT materials.

One must remember that irrespective of the Subsection C exemptions to UG-84(f)(2), the WPS(s) may become unacceptable if the vessel itself, or production impact test coupons are subjected to heat treatments that are outside of QW-407.2 requirements for the welding procedure [at least 80% of aggregate time(s) at temperature(s)].

5.6  Location, Orientation, Temperature, and values of Weld Impact tests UG-84(g).

5.7  The 2013 Edition of ASME Section VIII, Division 1, has included requirements for additional HAZ coupons which is dependent on the base metal thickness and joint type.

UG-84(g)(2) illustrates through Figure UG-84.5 and Table UG-84.6 the location of where impact specimens must be taken. The significant change is depending on the type of joint (either a single or two sided welded joint), additional heat affected zone (HAZ) specimens are required. Prior to the change, material under 1 ½” only required one set of impacts in the material and one set in the HAZ, and for materials over 1 ½” two sets were required in the material and one in the HAZ. The table below illustrates the total number of impact test sets and specimens required.

<table>
<thead>
<tr>
<th>Base metal thickness, t</th>
<th>No. of Specimen Sets¹ (HAZ)</th>
<th>No. of Specimen Sets¹ (Weld Metal)</th>
<th>Total # of (sets)¹ (specimens)</th>
<th>No. of Specimen Sets¹ HAZ</th>
<th>No. of Specimen Sets¹ (Weld Metal)</th>
<th>Total # of (sets)¹ (specimens)</th>
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</thead>
<tbody>
<tr>
<td>t ≤ ¾ in.</td>
<td>Single Sided Weld</td>
<td>Single Sided Weld</td>
<td>Two Sided Weld</td>
<td>Two Sided Weld</td>
<td>Two Sided Weld</td>
<td></td>
</tr>
<tr>
<td>t ≤ ¾ in.</td>
<td>one set</td>
<td>one set</td>
<td>(6)</td>
<td>one set</td>
<td>one set</td>
<td>(6)</td>
</tr>
<tr>
<td>¾” &lt; t &lt; 1 ½ in.</td>
<td>one set</td>
<td>one set</td>
<td>(6)</td>
<td>two sets</td>
<td>one set</td>
<td>(9)</td>
</tr>
<tr>
<td>t = 1½ in.</td>
<td>two sets</td>
<td>one set</td>
<td>(9)</td>
<td>two sets</td>
<td>one set</td>
<td>(9)</td>
</tr>
<tr>
<td>t &gt; 1½ in.</td>
<td>two sets</td>
<td>two sets</td>
<td>(12)</td>
<td>two sets</td>
<td>two sets</td>
<td>(12)</td>
</tr>
</tbody>
</table>

**Notes:** 1- As per UG-84(c)(1) a set of impact specimens consists of 3 specimens
6.0 TESTING

6.1 UG-84(j) Rejection

If the vessel test plate fails to meet the impact requirements, the welds represented by the plate shall be unacceptable. Reheat treatment and retesting or retesting only are permitted.

Under the provision for reheat treatment it is necessary to consider the applicability of the welding procedure under QW-407.2, as well as UG-84(f)(2) implications.
### 7.0 REVISION LOG

<table>
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<th>Edition #</th>
<th>Revision #</th>
<th>Date</th>
<th>Description</th>
</tr>
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<td>1st Edition issued 1999-09-20</td>
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<tr>
<td>1</td>
<td>1</td>
<td>1999-10-25</td>
<td>General Updates</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>2016-04-08</td>
<td>General Updates</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>2017-05-03</td>
<td>Added $t=1\frac{1}{2}$ in. row to table in section 5.7 &amp; removed equal to sign in row 4.</td>
</tr>
</tbody>
</table>

Issued 2017-05-03