Table PW-39-14
Mandatory Requirements for Postweld Heat Treatment of Pressure Parts and Attachments — P-No. 51

<table>
<thead>
<tr>
<th>Minimum Holding Time at Normal Temperature for Weld Thickness (Nominal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>P-No. 51</td>
</tr>
</tbody>
</table>

GENERAL NOTE: Postweld heat treatment is neither required nor prohibited for joints between materials of the P-No. 51 group.

PW-40 REPAIR OF DEFECTS

PW-40.1 Weld imperfections, such as cracks, pinholes, and incomplete fusion, detected visually or by leakage tests or by the examinations described in PW-11 and found to be rejectable, shall be removed by mechanical means or by thermal grooving processes, after which the joint shall be rewelded and reexamined.

PW-40.2 When tube-to-header or tube-to-drum welded joints have already received the postweld heat treatment required by PWT-11 and PW-39, minor local additional welding for rework of the joint or to improve the fillet weld contour may be performed on the materials listed in (b) without repeating the postweld heat treatment, subject to all the following limitations:

(a) The depth of any rework welding below the surface shall not exceed the smaller of 10% of the thickness of the drum or header, or 50% of the wall thickness of the tube.

(b) The area to be rework welded shall be preheated to at least the minimum temperatures as indicated below for the material.

<table>
<thead>
<tr>
<th>Material</th>
<th>Welding P-Number Group</th>
<th>Minimum Preheat, °F (°C) for Rework Welding</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-No. 3, Groups 1 and 2</td>
<td>200 (95)</td>
<td></td>
</tr>
<tr>
<td>P-No. 4</td>
<td>250 (120)</td>
<td></td>
</tr>
<tr>
<td>P-No. 5A</td>
<td>300 (150)</td>
<td></td>
</tr>
</tbody>
</table>

(c) The tubes shall not exceed 4 in. (100 mm) O.D., except for P-No. 1 material, which shall not exceed 6 7/8 in. (170 mm) O.D.

(d) The welding procedure used for the rework welding shall have been qualified to the requirements of Section IX for the thickness of rework welding to be performed and for the omission of postweld heat treatment.

PW-40.3 Defects in P-No. 1, all groups (if not otherwise exempted by Table PW-39-1), and P-No. 3 Group Nos. 1 and 2 materials, and in the welds joining these materials, may be weld repaired after the final PWHT but prior to the final hydrostatic test. The welded repairs shall meet the requirements below.

PW-40.3.1 Defect Removal for Base Materials.

The defect shall be removed or reduced to an acceptable size. Before repair welding, the groove shall be examined to verify that the defect has been reduced to an acceptable size, using either the magnetic particle or the liquid penetrant examination methods. When the material is non-ferromagnetic, only the liquid penetrant method shall be used. Methods for magnetic particle examination and liquid penetrant examination shall be in accordance with A-260 and A-270, respectively; however, the acceptance standards for the examination shall be in accordance with the requirements of the original base material specification.


NOTES:

(1) Minimum holding time per inch (25 mm) for thickness up to and including 2 in. (50 mm). Add 15 min per inch (75 mm) of thickness for thickness greater than 2 in. (50 mm).

(2) These lower postweld heat treatment temperatures permitted only for P-No. 1, Group 1 and 2 materials.

(3) For interpolation only

GENERAL NOTES:


(2) Interpolation may be used between temperature values listed in the above table to arrive at minimum holding time at the decreased temperature.
Question: May a vessel which is not part of rotating or reciprocating equipment, used to contain two liquids under a differential pressure, separated by a floating piston be considered to be within the Scope of Section VIII, Division 1?

Reply: Yes.

**Interpretation:** VIII-1-89-232 (Voir, see VIII-1-89-232R)
Subject: Section VIII, Division 1 (1989 Edition), Table UCS-56.1
Date Issued: September 27, 1990
File: BC90-481

Question: May interpolation be used between temperature values listed in Table UCS-56.1 in Section VIII, Division 1 to arrive at minimum holding time at the decreased temperature?

Reply: No.

**Interpretation:** VIII-1-89-232R (See errata on page 500)
Subject: Section VIII, Division 1 (1989 Edition), Table UCS-56.1
Date Issued: September 27, 1990 (January 3, 1991)
File: BC90-481*

Question: May interpolation be used between temperature values listed in Table UCS-56.1 in Section VIII, Division 1 to arrive at minimum holding time at the decreased temperature?

Reply: Yes.

**Errata**
Volume 28
Interpretation
VIII-1-89-232R Correct Date Issued to read January 3, 1991

**Interpretation:** VIII-1-89-233
Subject: Section VIII, Division 1 (1989 Edition), UG-37
Date Issued: September 27, 1990
File: BC90-490

Question: Is it permissible under the requirements of UG-37 in Section VIII, Division 1 to use a nominal head thickness \( t \) when calculating \( A \) (A1 By errata, page 670) for openings in heads?

Reply: Yes.

**Errata**
Volume 28
Interpretation
VIII-1-89-233 In the second line of the Question, correct \( A \) to read \( A1 \)
Table UCS-56.1
Alternative Postweld Heat Treatment Requirements for Carbon and Low Alloy Steels

<table>
<thead>
<tr>
<th>Temperature Below Minimum Holding Time</th>
<th>Decreased Temperature, °F (°C)</th>
<th>Temperature, hr</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 (28)</td>
<td>2</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>160 (88)</td>
<td>4</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>159 (83)</td>
<td>10</td>
<td>(3)</td>
<td></td>
</tr>
<tr>
<td>200 (111)</td>
<td>20</td>
<td>(3)</td>
<td></td>
</tr>
</tbody>
</table>

GENERAL NOTE: Applicable only when permitted in Tables UCS-56-1 through UCS-56-11.

NOTES:
(1) Minimum holding time for 1 in. (25 mm) thickness or less. Add 15 min per inch (25 mm) of thickness for thicknesses greater than 1 in. (25 mm).
(2) These lower postweld heat treatment temperatures permitted only for P-No. 1 Gr. Nos. 1 and 2 materials.

LOW TEMPERATURE OPERATION

UCS-65 SCOPE

The following paragraphs contain requirements for vessels and vessel parts constructed of carbon and low alloy steels with respect to minimum design metal temperatures.

Table UCS-57
Thicknes Above Which Full Radiographic Examination of Butt-Welded Joints Is Mandatory

<table>
<thead>
<tr>
<th>P-No. and Group</th>
<th>Nominal Thickness Above Which Butt-Welded Joints Shall Be Fully Radiographed, ln. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gr. 1, 2, 3</td>
<td>1/8 (3)</td>
</tr>
<tr>
<td>3 Gr. 1, 2, 3</td>
<td>7/32 (19)</td>
</tr>
<tr>
<td>4 Gr. 1, 2</td>
<td>7/32 (16)</td>
</tr>
<tr>
<td>5A Gr. 1, 2</td>
<td>0 (8)</td>
</tr>
<tr>
<td>5B Gr. 1</td>
<td>0 (8)</td>
</tr>
<tr>
<td>5C Gr. 1</td>
<td>0 (8)</td>
</tr>
<tr>
<td>15 % Gr. 1</td>
<td>0 (8)</td>
</tr>
<tr>
<td>9A Gr. 1</td>
<td>9/64 (16)</td>
</tr>
<tr>
<td>9B Gr. 1</td>
<td>7/128 (16)</td>
</tr>
<tr>
<td>10A Gr. 1</td>
<td>7/128 (16)</td>
</tr>
<tr>
<td>10B Gr. 1</td>
<td>7/128 (16)</td>
</tr>
<tr>
<td>10C Gr. 1</td>
<td>7/128 (16)</td>
</tr>
</tbody>
</table>

UCS-66 MATERIALS

(a) Unless exempted by the rules of UG-20(f) or other rules of this Division, Figure UCS-66 shall be used to establish impact testing exemptions for steels listed in Part UCS. When Figure UCS-66 is used, impact testing is required for a combination of minimum design metal temperature (see UG-20) and governing thickness (as defined below) that is below the curve assigned to the subject material. If a minimum design metal temperature and governing thickness combination is on or above the curve, impact testing is not required by the rules of this Division, except as required by (1) below and UCS-67(a)(3) for weld metal. Components, such as shells, heads, nozzles, manways, reinforcing pads, flanges, tubesheets, flat cover plates, backing strips which remain in place, and attachments which are essential to the structural integrity of the vessel when welded to pressure-retaining components, shall be treated as separate components. Each component shall be evaluated for impact test requirements based on its individual material classification, governing thickness as defined in (1) and (2) below, and the minimum design metal temperature.

(1) The following governing thickness definitions apply when using Figure UCS-66:

(a) Excluding castings, the governing thickness t_g of a welded part is as follows:

(-1) for butt joints except those in flat heads and tubesheets, the nominal thickness of the thinnest welded joint [see Figure UCS-66.3 sketch (a)];

(-2) for corner, fillet, or lap-welded joints, including attachments as defined above, the thinner of the two parts joined.

(-3) for flat heads or tubesheets, the larger of

(-2) above or the flat component thickness divided by 4.

(-4) for welded assemblies comprised of more than two components (e.g., nozzle-to-shell joint with reinforcing pad), the governing thickness and permissible minimum design metal temperature of each of the individual welded joints of the assembly shall be determined, and the warmest of the minimum design metal temperatures shall be used as the permissible minimum design metal temperature of the welded assembly. [See Figure UCS-66.3 sketch (b)].

(-5) if the governing thickness at any welded joint exceeds 4 in. (100 mm) and the minimum design metal temperature is colder than 120°F (50°C), impact tested material shall be used.

(b) The governing thickness of a casting shall be its largest nominal thickness.

(c) The governing thickness of flat nonwelded parts, such as bolted flanges, tubesheets, and flat heads, is the flat component thickness divided by 4.

(d) The governing thickness of a nonwelded dished head [see Figure 1-6 sketch (c)] is the greater of the flat flange thickness divided by 4 or the minimum thickness of the dished portion.
NB-4622  PWHT Time and Temperature Requirements

NB-4622.1 General Requirements. Except as otherwise permitted in NB-4622.7, all welds, including repair welds, shall be postweld heat treated. During postweld heat treatment, the metal temperature shall be maintained within the temperature range and for the minimum holding time specified in Table NB-4622.1-1, except as otherwise permitted in NB-4622.4(c). P-Number groups in Table NB-4622.1-1 are in accordance with Section IX, QW-420. Except as provided in NB-4624.3, PWHT shall be performed in temperature-surveyed and -calibrated furnaces, or PWHT shall be performed with thermocouples in contact with the material or attached to blocks in contact with the material. In addition, the requirements of the following subparagraphs shall apply.

NB-4622.2 Time-Temperature Recordings. Time-temperature recordings of all postweld heat treatments shall be made available for review by the Inspector. Identification on the time-temperature recording shall be to the weld, part, or component, as applicable. A summary of the time-temperature recording may be provided for permanent records in accordance with NCA-4134.17.

NB-4622.3 Definition of Nominal Thickness Governing PWHT. Nominal thickness in Table NB-4622.7(b)-1 is the thickness of the weld, the pressure-retaining material for structural attachment welds or the thinner of the pressure-retaining materials being joined, whichever is least. It is not intended that nominal thickness include material provided for forming allowance, thinning, or mill overrun when the excess material does not exceed $\frac{1}{8}$ in. (3 mm). For fillet welds the nominal thickness is the throat thickness, and for partial penetration and material repair welds the nominal thickness is the depth of the weld groove or preparation.

NB-4622.4 Holding Times at Temperature.

(a) The holding time at temperature as specified in Table NB-4622.1-1 shall be based on the nominal thickness of the weld. The holding time need not be continuous. It may be an accumulation of the times of multiple postweld heat treat cycles.

(b) Holding time at temperature in excess of the minimum requirements of Table NB-4622.1-1 may be used, provided that specimens so heat treated are tested in accordance with NB-2200, NB-2400, and NB-4300.

(c) Alternatively, when it is impractical to postweld heat treat at the temperature range specified in Table NB-4622.1-1, it is permissible to perform the postweld heat treatment of certain materials at lower temperatures for longer periods of time in accordance with Table NB-4622.4(c)-1 and (1), (2), and (3) below.

(1) Except for P-No. 1 materials, when welds in the materials listed in Table NB-4622.4(c)-1 are to be postweld heat treated at the lower minimum temperatures, the impact test specimens for the welding procedure qualification required by NB-4300 shall be made using the same minimum temperatures and increased minimum holding time. Welding procedures, qualified at the temperature range and minimum holding time specified in Table NB-4622.1-1 and at the lower temperature and increased minimum holding time permitted by Table NB-4622.4(c)-1, are also qualified for any temperature in between. When such an in-between temperature is used, the minimum holding time shall be interpolated from Table NB-4622.1-1 and the alternative requirements from Table NB-4622.4(c)-1.

(2) Except for P-No. 1 materials, when welds in the materials listed in Table NB-4622.4(c)-1 are to be postweld heat treated at these lower minimum temperatures, the welding material certification required by NB-2400 shall be made using the same minimum temperature and increased minimum holding time. Welding material certified at the temperature range and minimum holding time specified in Table NB-4622.1-1 and at the lower minimum temperatures and increased minimum holding time permitted by Table NB-4622.4(c)-1 are also certified for any temperature in between.

(3) Base material certified in accordance with NB-2200 may be postweld heat treated at the lower minimum temperature ranges and increased minimum holding times without recertification. Postweld heat treatment at these lower minimum temperatures and increased minimum holding times may also be the tempering operation provided a higher tempering temperature is not required by the material specification.

NB-4622.5 PWHT Requirements When Different P-Number Materials Are Joined. When materials of two different P-Number groups are joined by welding, the applicable postweld heat treatment shall be that specified in Table NB-4622.1-1 for the material requiring the higher PWHT temperature range.

NB-4622.6 PWHT Requirements for Non-Pressure-Retaining Parts. When non-pressure-retaining material is welded to pressure-retaining material, the postweld heat treatment temperature range of the pressure-retaining material shall control.

NB-4622.7 Exemptions to Mandatory Requirements. Postweld heat treatment in accordance with this subarticle is not required for:

(a) nonferrous material;
(b) welds exempted in Table NB-4622.7(b)-1;
(c) welds subjected to temperatures above the PWHT temperature range specified in Table NB-4622.1-1, provided the Welding Procedure Specification is qualified in accordance with Section IX and the base material and the deposited weld filler material have been heat treated at the higher temperature;
(d) welds connecting nozzles to components or branch to run piping provided the requirements in NB-4622.8 are met.
Table NB-4622.4(c)-1
Alternative Holding Temperatures and Times

<table>
<thead>
<tr>
<th>Material P-No.</th>
<th>Alternative Minimum Holding Temperatures, °F (°C)</th>
<th>Alternative Minimum Holding Times</th>
<th>[Note (1)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 3, 9A Gr. 1, 9B Gr.</td>
<td>1,050 (565)</td>
<td>2 hr/in. (4 min/mm)</td>
<td>thick</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1, 3, 9A Gr. 1, 9B Gr.</td>
<td>1,000 (540)</td>
<td>4 hr/in. (8 min/mm)</td>
<td>thick</td>
</tr>
</tbody>
</table>

NOTE:
[1] All other requirements of NB-4622 shall apply.

(e) Weld repairs to base metal, weld repairs to cladding after final postweld heat treatment, and weld repairs to dissimilar metal welds, provided the requirements of NB-4622.9 are met.

NB-4622.8 Requirements for Exempting PWHT of Nozzles to Component Welds and Branch to Run Piping Welds. Welds connecting nozzles or branch piping of P-No. 1 materials to components or run piping of P-No. 1 or P-No. 3 materials that are not exempted from PWHT in Table NB-4622.7(b)-1 need not be given a postweld heat treatment if the requirements of (a) below are met for partial penetration and (b) below are met for full penetration welds.

(a) The partial penetration welds are made with A-No. 8 or non-air-hardening nickel-chromium-iron weld metal after:

(1) the ferritic materials to be joined are butt joint or built-up with A-No. 8 or non-air-hardening nickel-chromium-iron weld metal having a minimum thickness of 7/8 in. (6 mm), and

(2) the heat-affected zones of the butt joint or built-up ferritic materials are postweld heat treated in accordance with NB-4620, without the PWHT exemptions being applied, prior to making the final welds.

(b) The full penetration welds are made with A-No. 1 or A-No. 2 weld metal provided that:

(1) the component or run pipe is built-up or butt joint in the area of the attachment with A-No. 1 or A-No. 2 metal having a minimum thickness of 7/8 in. (6 mm);

(2) the A-No. 1 or A-No. 2 weld metal buildup or but joint is postweld heat treated in accordance with NB-4620 for P-No. 1 or P-No. 3 materials without the PWHT exemptions being applied;

(3) the welds do not penetrate through the component or run pipe thickness;

(4) weld metal with A-No. 1 or A-No. 2 analysis is used to join the nozzle or branch pipe of P-No. 1 material to the weld buildup or butt joint;

(5) the nominal thickness of the weld joining the nozzle or branch pipe to the component or run pipe does not exceed 1 1/2 in. (38 mm) and the maximum reported carbon content of the nozzle or branch piping connection does not exceed 0.30%;

(6) a 200°F (95°C) minimum preheat is maintained during welding whenever the nominal thickness of the weld exceeds:

(a) 1/4 in. (32 mm) and the maximum reported carbon content of the material of the nozzle or branch pipe is 0.30% or less, or

(b) 5/32 in. (19 mm) and the maximum reported carbon content of material of the nozzle or branch pipe connection exceeds 0.30%.

NB-4622.9 Temper Bead Weld Repair. Repairs may be made without PWHT or after the final PWHT under the conditions listed below provided it is impractical to postweld heat treat the area after repair. References in the following paragraphs to "P-No." are to Section IX, Table QW/QB-422; to "F-No." are to Section IX, Table QW-432; and to "A-No." are to Section IX, Table QW-442.

(a) General Requirements.

(1) Repair Welding Procedure. The WPS shall be prepared and qualified in accordance with Section IX, QW-290 following the impact testing option with the testing performed in accordance with the requirements of NB-4334 and NB-4335.

(2) Welding Procedure Qualification Test Plate. The test assembly materials for the welding procedure qualification shall be subjected to heat treatment that is at least equivalent to the time and temperature applied to the material being repaired.

(3) Neutron Fluence. If the repair area is to be subjected to a significant fast neutron fluence greater than 10¹⁸ nvt E > 1 MeV, the weld metal Cu content shall not exceed 0.10%.

(4) Nondestructive Examination Methods. All nondestructive examination shall be in accordance with Article NB-5000. Final nondestructive examination of completed weld repairs shall be performed after the weld has been at ambient temperature for a minimum period of 48 hr.

(5) Preparation of Repair Cavity. The maximum area of an individual repair based on the finished surface shall be 500 in.² (3,230 cm²) and the depth of repair shall not be greater than one-third of the base material thickness. The area to be repaired shall be suitably prepared for welding in accordance with a written procedure. Before repair, the surface to be repaired shall be examined by either the magnetic particle or liquid penetrant method.

(6) Documentation of Weld Repairs. Documentation of weld repairs shall be in accordance with NB-4130 exclusive of the size requirements.

(7) Performance Qualifications. If the repair weld is to be performed where physical obstructions impair the welder's ability to perform, the welder shall also
**Consideration**

Tempering Parameter (Hollomon-Jaffe Parameter) is generally used to control PWHT effect, and which is described by the equation (1) below, where \( T \) is heat treatment temperature (kilo Rankine), \( t \) is holding time (hour), and \( C \) is the constant.

\[
H = T \cdot (C + \log t)  \tag{1}
\]

For carbon steels, the value 20 is generally used for constant \( C \). According to Table PW-39-1, the minimum holding temperature \( T \) is substituted for 1.55967 k\(^\circ\)R (1100\(^\circ\)F), and the minimum holding time \( t \) is substituted for 1 hr, \( H \) is estimated to be 31.1934.

\[
H = 1.55967 \cdot (20 + \log 1) = 31.1934
\]

Hollomon-Jaffe equation (1) can be changed into as below.

\[
t = 10^{\left(\frac{H-20}{T}\right)} = 10^{\left(\frac{31.1934-20}{T}\right)}, \tag{2}
\]

Namely, the relationship between holding time and temperature can be described by the exponential function. When the exponent of equation (2) is multiplied by the factor 0.4343 for the purpose of adjustment of the time effect, the calculated values are approximately same with the holding time listed in Table PW-39.1 (see the table below).

<table>
<thead>
<tr>
<th>Decreased Temperature [Table PW-39.1] °F (°C)</th>
<th>0 (0)</th>
<th>50 (28)</th>
<th>100 (56)</th>
<th>150 (83)</th>
<th>200 (111)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PWHT Temperature [Table PW-39-1] °F (°C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( T ): PWHT Temperature (kilo Rankine)</td>
<td>1100 (595)</td>
<td>1050 (567)</td>
<td>1000 (539)</td>
<td>950 (512)</td>
<td>900 (484)</td>
</tr>
<tr>
<td>( t ): ( 10^{\left(\frac{H}{T-20}\right)} )</td>
<td>1</td>
<td>4.60</td>
<td>23.45</td>
<td>134.33</td>
<td>874.76</td>
</tr>
<tr>
<td>( t ): ( \exp\left(\frac{H}{T-20}\right) ) ※</td>
<td>1</td>
<td>1.94</td>
<td>3.94</td>
<td>8.40</td>
<td>18.95</td>
</tr>
<tr>
<td>Minimum Holding Time [Table PW-39.1]</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>10</td>
<td>20</td>
</tr>
</tbody>
</table>

※ \( t = 10^{0.4343\left(\frac{H}{T-20}\right)} \approx e^{\left(\frac{H}{T-20}\right)} \)

Minimum holding time of alternate PWHT (specified in Table PW-39.1) increases exponentially with decreased temperature, and it describes concave curve. Therefore, linear interpolation can be applied.
Figure: Minimum Holding Time by the Linear Interpolation of Table PW-39.1