Code Support for P4/5A Socket Weld PWHT Exemptions

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ABSTRACT

Significant differences in the Post-weld Heat Treatment (PWHT) requirements exist between several Codes that are commonly used in Fossil and Nuclear Power Plants. One difference is the treatment of the PWHT exemptions for socket welds in P Nos. 4 and 5A materials. In B31.1-2001, these materials require the thickness of both the hub and the pipe to determine the PWHT requirements. Other Codes only consider the throat thickness of the socket weld. The support for issuing a technical revision item within the B31.1 Power Piping Code utilized data provided in the EPRI report *Socket Weld PWHT Exemptions for P NOS. 4 & 5A Materials (1009720).* The investigation reviewed the requirements of the different codes, including the historical requirements in B31.1, and justified a proposal within B31.1 to allow further exemptions for P Nos. 4 and 5A socket welds. The justification was based on several papers and technical data that have studied the effects of PWHT on socket welded joints.

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1
INTRODUCTION

The various codes that are required to be used in power plants have a significant variation in the rules for PWHT. In some cases, these variations may be justified based on service conditions addressed by the applicable code. Minor variations are not generally a safety concern but may be an economic issue. The potential exemption of socket welds in P Nos. 4 & 5A materials is not a significant safety issue, as evidenced by the following information, but it can be an economic concern. Unnecessary PWHT is a cost, both from the direct costs of the process but also from indirect costs associated with outage lengths and plant system availability.

This code support, initiated by The Repair and Replacement Applications Center (RRAC) of the Electric Power Research Institute (EPRI) was aimed at reinstating those socket weld exemptions from PWHT that existed in the B31.1.0-1967 edition. The scope of this effort was to justify and process code changes in B31.1 by recommending appropriate exemptions rules from PWHT for socket welds constructed with these materials. EPRI document 1009720 was intended to support the changes within the B31.1 Code but it may also be used to support changes in other Code Sections.

2
CODE REQUIREMENTS

General

The following discussions do not include those other criteria for PWHT that must also be considered; only those that specifically apply to the thickness and composition requirements for socket welds (including slip-on flanges). Other criteria include the requirements of the welding procedure specification, contract specifications, and preheat requirements.

B31.1.0-1967 through B31.1-current edition - Power Piping Code

USAS B31.1.0-1967 Edition

PWHT was excluded for all socket welds per Note 3)a of Table 131, "Preheat and Post-heat Treatment of Welds", which stated:

> 3)a. Post-heat Treatment is not mandatory for socket welds.

This note applied to all grades of materials covered, including P No. 1 through P No. 5. It should be noted that the P No. 5 materials listed in the allowable stress tables had a maximum chromium content of 5% even though earlier editions of B31.1 (1955) included some 7 Cr and 9Cr materials.

ANSI B31.1-1973 Edition

The 1973 Edition of B31.1 brought in the technical requirements for Boiler External Piping (BEP) from Section I, Power Boilers. As such, there were two tables that applied to PWHT of Power Piping.

Table 131, Preheat and Post heat Treatment of Welds Exclusive of Boiler External Piping, applied to what is now referred to as Non-Boiler External Piping (NBEP). Note (4) of Table 131 excluded most socket welds (although not all) since the minimum thickness was based on the throat thickness of the fillet weld. In addition, the maximum size permitted for socket welds was NPS 3. Table 131 Note (4) applied to the column labeled "Min. Wall & Other In." and stated:

> *4. The thickness of socket, fillet, and seal welds is defined as the throat thickness for pressure and nonpressure retaining welds.*

For both P No. 4 and P No. 5 materials, Note (4) applied to:

"Over ½ in. or over 4 in. nominal size or over 0.15%C. Max"

Table 133, Mandatory Requirements for Post-weld Heat Treatment of Welds for Boiler External Piping, applied to Boiler External Piping (BEP). Strict interpretation of the requirements for BEP would result in all P No. 4 and P No. 5 socket welds requiring PWHT. This is because Para. 133 stated "Except as otherwise specifically provided in the notes to Table 133, all welded pressure piping shall be given a post-weld heat treatment at a temperature not less than specified in Table 133." The notes to Table 133 did not address socket welds however.

ANSI B31.1-1977 Edition with winter 1978 Addenda

There were no changes to the PWHT requirements in B31.1 between the 1973 Edition and the winter 1978 Addenda to the 1977 Edition. However, with the Winter 1978 Addenda, major changes were made to the PWHT requirements. The goal of these changes was to combine the PWHT requirements for BEP and NBEP. In making these changes however, the technical requirements were modified to a center ground, also with some consideration of other related codes and standards. There were also some technical issues related to low vs. high hardenability materials that were incorporated as a result of the consensus proceedings of the B31.1 Code Committee.

The exemption thicknesses for P No. 1 and P No. 3 materials were based on new criteria in B31.1-1977 w/ W78A. These criteria are detailed in Para. 132.4.1, which states:

"132.4.1 The term 'Nominal Thickness' as used in Table 132 and notes is the lesser thickness of A. or B. as follows:

A. The thickness of the weld

B. The thicker of the materials being joined at the weld."

Para. 132.4.2 defines the thickness of the weld for the user. For fillet welds, the thickness of the weld is defined as the throat thickness of the weld. Again, this in effect resulted in the exemption of socket welds from required PWHT for P No. 1 and P No. 3 materials.

The exemption thickness for P No. 4 and P No. 5 materials was not based on the same criteria however. These exemption thicknesses were based on the "maximum material thickness" (Note I.A.2 for both P No. 4 and P No. 5 materials in Table 132, Post-weld Heat Treatment). In addition, Note I.A.3 of Table 132 also maintained the requirement for a maximum of 0.15% C in order to exempt PWHT. This results in a PWHT requirement for some socket welds where the hub thickness of the socket is greater than ½ in., which often occurs with heavy wall sockets and flanges from NPS 1½ and above. The fact that many of the P No. 4 materials for forged fittings have a maximum carbon content in excess of 0.15% also requires additional PWHT, even if the exemption thickness requirements were met.

ASME B31.1-2001 Edition

No significant changes have been made to the exemption thickness and the carbon content criteria for PWHT exemptions from the B31.1-1977 w/ W78A Edition. Other changes have

occurred, most notably the diameter limitation of NPS 4 for exemption in P Nos. 4 and 5A materials and the holding temperature change for P No. 4 from 1300-1375°F to 1200-1300°F (the balloting has been completed in B31 for the change to the holding temperature and should appear in the 2004 edition).

B31.3 – Process Piping Code

ASME B31.3-2002 Edition

The B31.3 Code for Process Piping, Table 331.1.1 requires post weld heat treatment of socket welds but Para. 331.1.3, Governing Thickness, subparagraph (b), allows the exemption of PWHT for NPS 2 and smaller if the weld throat thickness is ≤ 5/8 in. for P No. 1 material or ≤ 1/2 in. for P Nos. 3, 4, and 5 materials. This effectively eliminates PWHT for NPS 2 and smaller but still requires PWHT for larger socket welds.

Section I – Power Boilers

ASME Section I-2001 Edition with 2002 Addenda

ASME Section I, Power Boilers, Table PW-39, contains specific exemptions for socket welds in P Nos. 1, 3, 4, 5A, & 5B. For all of these materials, the exemption may be allowed if the throat thickness of the fillet weld does not exceed ½ in. Additional applicable criteria are applied to P Nos. 3, 4, 5A, and 5B materials. These include the carbon content of the materials; ≤0.25% for P No. 3, ≤0.15% for P Nos. 4, 5A, and 5B. In addition, there is a limit of ≤3% chromium for P Nos. 5A and 5B materials (which eliminates P No. 5B material from the PWHT exemption). Again, unless the alloy content requires the PWHT, the use of the throat thickness of the socket weld effectively allows them to be exempted from PWHT, except where the carbon content limitation would apply (similar to the current B31.1, this is most likely to apply to P No. 4 materials used for the forged fittings).

Section III, Div 1 – Rules for Construction of Nuclear Facility Components

ASME Section III-2001 Edition with 2002 Addenda

The rules for PWHT in ASME Section III, Div. 1 for Component Classes 1, 2, and 3 are very similar, but not identical, particularly when socket welds are being considered. With regard to the thickness limitations for exemption from PWHT, the thickness used for all materials is the least thickness of the materials or of the weld. The weld thickness for socket welds is considered to be the throat thickness. PWHT is required by all three component classes (per Subsections NB, NC, and ND) when the throat thickness for the socket weld exceeds ½ in. in P Nos. 3, 4, 5A, & 5B materials. For P No. 1 materials, socket welds are not specifically addressed, which results in the limit of 1½ in. being the effective limit for the throat thickness exemption. The same carbon and chromium limits are applied to Section III as detailed in the Section I requirements.

3 CONCLUSIONS & PROPOSED REVISION

The results of the EPRI-RRAC study showed that the properties of the weldment are satisfactory in the as welded condition even though there are some overall improvements in the properties of socket welds in hardenable materials as a result of PWHT. However, these improvements do not appear to be significantly related to the thickness or to a marginal increase in the hardenability of the coupling side of the socket welds. As a result, some relaxation in the requirements for PWHT in P Nos. 4 and 5A materials is justified, as those requirements relate to the hub side of the socket. On the pipe side of the socket however, since high stresses were determined to be potentially present at the toe of the fillet weld on the pipe side, a concern remained that the benefits of PWHT may still be needed in some cases. A relaxation to allow fitting to pipe socket welds to be exempted based on the throat thickness of the weld would include a limitation on the nominal thickness of the pipe (since the weld size is based on the pipe nominal wall thickness). Very few socket weld joints would require PWHT in P Nos. 4 and 5A materials if the exemption is based on the throat thickness of the weld (≤ ½ in.), even if the additional limitation of the carbon content of a maximum of 0.15% is applied to the pipe material.

The following proposal was submitted to the B31.1 section committee for considration.

ITEM 03-00190

ASME B31.1-2001

Table 132

01
A02

TABLE 132
POSTWELD HEAT TREATMENT (CONT'D)

P-Number from Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 4 Gr. Nos. 1, 2	1300 (700) to 1375 (750)	1 hr/in. (25 mm) 15 min minimum	2 hr plus 15 min for each additional inch over 2 in. (50 mm)

GENERAL NOTE:

(A) PWHT is not mandatory for P-No. 4 material under the following conditions:

(1) welds in pipe or attachment welds to pipe complying with all of the following conditions:

(A) a nominal material thickness of ½ in. (13.0 mm) or less;

(B) a specified carbon content of the material to be welded of 0.15% or less;

~~(C) application of 250°F (120°C) minimum preheat during welding.~~

(2) for seal welding of threaded or other mechanical joints provided:

(A) the seal weld has a throat thickness of ⅜ in. (9.0 mm) or less;

~~(B) a minimum preheat of 250°F (120°C) is maintained during welding.~~

(3) attachment welds for non-load-carrying attachments provided in addition to (1)(B) and (1)(C) above:

(A) stud welds or fillet welds made by the SMAW or GTAW process shall be used;

(B) the hardened portion of the heat affected zone (HAZ) shall not encroach on the minimum wall thickness of the pipe, as determined by welding procedure qualification using the maximum welding heat input. The depth of the HAZ shall be taken as the point where the HAZ hardness does not exceed the average unaffected base metal hardness by more than 10%.

(C) if SMAW is used, the electrode shall be the low hydrogen type;

(D) the thickness of the test plate used in making the welding procedure qualification of Section IX shall not be less than that of the material to be welded;

(E) the attachment weld has a throat thickness of $^{3}/_{16}$ in. or less.

(4)

INSERT A

B31.1 Proposal – Item 03-00190

Insert A (Table 132, P No. 4, General Note (A)(4))

(4) for socket welded components and slip-on flange welds provided:
(A) the throat thickness is ½ in. (13 mm) or less;
(B) the wall thickness of the pipe is ½ in. (13 mm) or less;
(C) the specified carbon content of the pipe is 0.15% or less.

P-Number from Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 5A Gr. No. 1	1300 (700) to 1400 (760)	1 hr/in. (25 mm) 15 min minimum	2 hr plus 15 min for each additional inch over 2 in. (50 mm)

GENERAL NOTE:
(A) PWHT is not mandatory for P-No. 5A material under the following conditions:
(1) welds in pipe or attachment welds to pipe complying with all of the following conditions:
(A) a nominal material thickness of ½ in. (13.0 mm) or less;
(B) a specified carbon content of the material to be welded of 0.15% or less;
~~(C) a minimum preheat of 300°F (150°C) is maintained during welding.~~
(2) attachment welds for non-load-carrying attachments provided in addition to (1)(B) and (1)(C) above:
(A) stud welds or fillet welds made by the SMAW or GTAW process shall be used;
(B) the hardened portion of the heat affected zone (HAZ) shall not encroach on the minimum wall thickness of the pipe, as determined by welding procedure qualification using the maximum welding heat input. The depth of the HAZ shall be taken as the point where the HAZ hardness does not exceed the average unaffected base metal hardness by more than 10%.
(C) if SMAW is used, the electrode shall be the low hydrogen type;
(D) the thickness of the test plate used in making the welding procedure qualification of Section IX shall not be less than that of the material to be welded;
(E) the attachment weld has a throat thickness of 5/16 in. or less.
(3) ← INSERT B

B31.1 Proposal Item 03-00190

Insert B (Table 132, P No 5A, General Note (A)(3))

(3) for socket welded components and slip-flange welds provided:

(A) the throat thickness is ½ in. (13mm) or less;

(B) the wall thickness of the pipe is ½ in. (13mm) or less;

(C) the specified carbon content of the pipe is 0.15% or less.

4 STATUS

Just prior to the writing of this report the B31.1 standards committee approved the revision item for incorporation into the next addenda package. This change should provide significant cost savings for repair or replacement of BOP socket welded connections utilizing these materials.

This document does not provide, nor represent, an approved ASME Code or Standard and should not be used or referred to as an ASME Code or Standard. It is intended only to describe work that has been conducted in support of efforts for technical revision items initiated in the code.

5 REFERENCES

1. *Reinstatement of Post-Weld Heat Treatment (PWHT) Exemptions for P Nos. 4 and 5A Socket Welds,* EPRI, Palo Alto, CA: 2004. 1009720.

2. ASME Technical Revision Item 03-00190. Phil Flenner. Flenner Engineering Services. November 30, 2003.

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