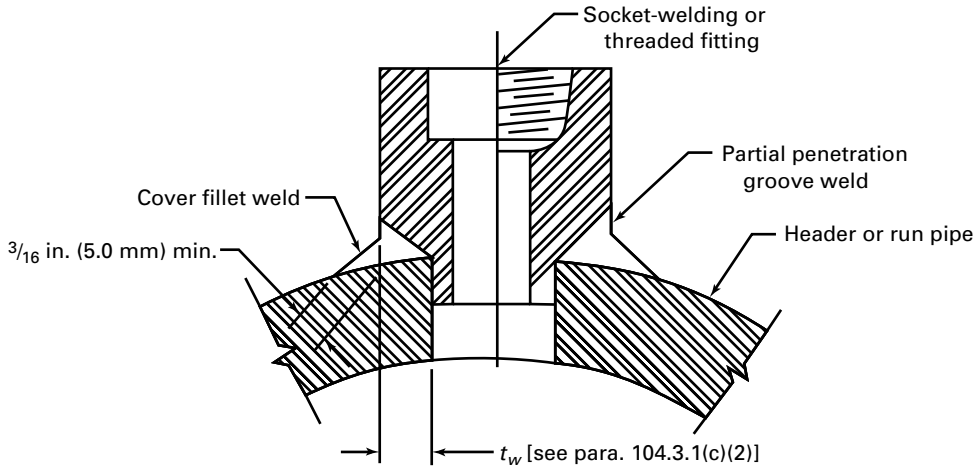
Figure 127.4.8-7 Typical Partial Penetration Weld Branch Connection for NPS 2 (DN 50) and Smaller Fittings



required in para. 128.6 accepting responsibility for the ability of the brazer or brazing operator.

128.6 Brazing Records

The employer shall maintain a record signed by him/her and available to the purchaser or his/her agent and the inspector, showing the date and results of procedure and performance qualification.

The BPQ shall also show the identification symbol assigned to the brazer or brazing operator employed by him/her, and the employer shall use this symbol to identify the brazing performed by the brazer or brazing operator. This may be accomplished by the application of the symbol on the braze joint in a manner specified by the employer. Alternatively, the employer shall maintain records that identify the braze joint(s) made by the brazer or brazing operator.

Table 129.3.1-1 Approximate Lower Critical Temperatures

Material	Approximate Lower Critical Temperature, °F (°C) [Note (1)]
Carbon steel (P-No. 1)	1,340 (725)
Carbon–molybdenum steel (P-No. 3)	1,350 (730)
1Cr–½Mo (P-No. 4, Group No. 1)	1,375 (745)
1¼Cr–½Mo (P-No. 4, Group No. 1)	1,430 (775)
2¼Cr–1Mo, 3Cr–1Mo (P-No. 5A)	1,480 (805)
5Cr–½Mo (P-No. 5B, Group No. 1)	1,505 (820)
9Cr	1,475 (800)
9Cr–1Mo–V, 9Cr–2W (P-No. 15E)	1,470 (800)

NOTE: (1) These values are intended for guidance only. The user may apply values obtained for the specific material in lieu of these values.

129 BENDING AND FORMING

129.1 Bending

Pipe may be bent by any hot or cold method and to any radius that will result in a bend surface free of cracks. Such bends shall meet the design requirements of para. 102.4.5 with regard to minimum wall thickness. Where limits on flattening and buckling are not specified by design, as delineated in para. 104.2.1, manufacturing limits of PFI ES-24 shall be met. When defaulting to PFI ES-24, mutual agreement between purchaser and fabricator beyond the stated manufacturing limits shall not be allowed without the approval of the designer.

The use of bends designed as creased or corrugated is not prohibited.

129.2 Forming

Piping components may be formed (swedging, lapping, or upsetting of pipe ends, extrusion of necks, etc.) by any suitable hot or cold working method, provided such processes result in formed surfaces that are uniform and free of cracks or other defects, as determined by method of inspection specified in the design.

129.3 Heat Treatment of Bends and Formed Components

129.3.1 Except for creep strength enhanced ferritic steels (P-No. 15E), hot bending or hot forming is performed at a temperature equal to or above T_{crit} − 100°F (56°C), where T_{crit} is the lower critical temperature of the material. Cold bending or cold forming is performed at a temperature below T_{crit} − 100°F (56°C). (See Table 129.3.1-1 for lower critical temperatures.) For creep strength enhanced ferritic steels (P-No. 15E), hot bending or hot forming is performed at a temperature equal to or above 1,300°F (705°C). Cold bending or

(18)

Table 132.1.1-1 Postweld Heat Treatment

P-Number and Group Number (ASME BPV Code, Section IX, QW/QB-420)	Holding Temperature Range, °F (°C) [Note (1)]	Minimum Holding Time at Temperature for Control Thickness [Note (2)]	
		≤2 in. (50 mm)	>2 in. (50 mm)
P-No. 1, Groups 1–3	1,100 to 1,200 (595 to 650)	1 hr/in. (25 mm), 15 min minimum	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (50 mm)
P-No. 3, Groups 1 and 2	1,100 to 1,200 (595 to 650)		
P-No. 4, Groups 1 and 2	1,200 to 1,300 (650 to 705)		
P-No. 5A, Group 1	1,250 to 1,400 (675 to 760)		
P-No. 5B, Group 1	1,250 to 1,400 (675 to 760)		
P-No. 6, Groups 1–3	1,400 to 1,475 (760 to 800)		
P-No. 7, Groups 1 and 2 [Note (3)]	1,350 to 1,425 (730 to 775)		
P-No. 8, Groups 1–4	PWHT not required unless required by WPS		
P-No. 9A, Group 1	1,100 to 1,200 (595 to 650)		
P-No. 9B, Group 1	1,100 to 1,175 (595 to 630)		
P-No. 10H, Group 1	PWHT not required unless required by WPS. If done, see Note (4).		
P-No. 10I, Group 1 [Note (3)]	1,350 to 1,500 (730 to 815)		
P-No. 15E, Group 1 [Note (5)]	1,300 to 1,425 (705 to 775) [Notes (6), (7)]	1 hr/in. (25 mm), 30 min minimum	1 hr/in. (25 mm) up to 5 in. (125 mm) plus 15 min for each additional inch (25 mm) over 5 in. (125 mm)
All other materials	PWHT as required by WPS	Per WPS	Per WPS

GENERAL NOTE: The exemptions for mandatory PWHT are defined in Table 132.2-1.

NOTES:
(1) The holding temperature range is further defined in paras. 132.1.1 and 132.2.
(2) The control thickness is defined in para. 132.4.1.
(3) Cooling rate shall not be greater than 100°F (55°C) per hour in the range above 1,200°F (650°C), after which the cooling rate shall be sufficiently rapid to prevent embrittlement.
(4) If PWHT is performed after bending, forming, or welding, it shall be within the following temperature ranges for the specific alloy, followed by rapid cooling:
Alloys S31803 and S32205 — 1,870°F to 2,010°F (1 020°C to 1 100°C)
Alloy S32550 — 1,900°F to 2,050°F (1 040°C to 1 120°C)
Alloy S32750 — 1,880°F to 2,060°F (1 025°C to 1 125°C)
All others — 1,800°F to 1,900°F (980°C to 1 040°C)
(5) See para. 125.1.2(c) for hardness requirements for ASTM A217, Grade C12A and A1091, Grade C91 castings after PWHT.
(6) The minimum PWHT holding temperature may be 1,250°F (675°C) for nominal material thicknesses (see para. 132.4.3) ≤½ in. (13 mm).
(7) The Ni+Mn content of the filler metal shall not exceed 1.2% unless specified by the designer, in which case the maximum temperature to be reached during PWHT shall be the A_1 (lower transformation or lower critical temperature) of the filler metal, as determined by analysis and calculation or by test, but not exceeding 1,470°F (800°C). If the 1,470°F (800°C) was not exceeded but the A_1 of the filler metal was exceeded or if the composition of the filler metal is unknown, the weld must be removed and replaced. It shall then be rewelded with compliant filler metal and subjected to a compliant PWHT. If the 1,470°F (800°C) limit was exceeded, the weld and the entire area affected by the PWHT will be removed and, if reused, shall be renormalized and tempered prior to reinstallation.

Table 132.1.1-2 Alternate Postweld Heat Treatment Requirements for Carbon and Low Alloy Steels, P-Nos. 1 and 3

Decrease in Specified Minimum Temperature, °F (°C)	Minimum Holding Time at Decreased Temperature, hr [Note (1)]
50 (30)	2
100 (55)	4
150 (85) [Note (2)]	10
200 (110) [Note (2)]	20

NOTES:
(1) Times shown apply to thicknesses ≤1 in. (25 mm). Add 15 min/in. (25 mm) of thickness for control thicknesses >1 in. (25 mm) (see para. 132.4).
(2) A decrease >100°F (55°C) below the minimum specified temperature is allowable only for P-No. 1, Groups 1 and 2 materials.

132.2 Mandatory PWHT Requirements

Heat treatment may be accomplished by a suitable heating method that will provide the desired heating and cooling rates, the required metal temperature, temperature uniformity, and temperature control.

(a) The upper limit of the PWHT temperature range in Table 132.1.1-1 is a recommended value that may be exceeded provided the actual temperature does not exceed the lower critical temperature of either material (see Table 129.3.1-1).

(b) When parts of two different P-Numbers are joined by welding, the postweld heat treatment shall be that specified for the material requiring the higher PWHT temperature. When a nonpressure part is welded to a pressure part and PWHT is required for either part, the maximum PWHT temperature shall not exceed the maximum temperature acceptable for the pressure retaining part.

(c) Caution is necessary to preclude metallurgical damage to some materials or welds not intended or qualified to withstand the PWHT temperatures required. The use of material transition joint designs may be required.

(d) The designer may require PWHT even if not mandatory per Table 132.1.1-1 or Table 132.2-1.

Table 132.1.3-1 Postweld Heat Treatment of P36/F36

Class	Holding Temperature, °F (°C)	Holding Time
1	1,100–1,200 (595-650)	2 in. (50 mm) and less thickness: 1 hr/in. (25 mm), 15 min minimum Over 2 in. (50 mm): add 15 min for each additional 1 in. (25 mm) of thickness
2	1,000–1,150 (540–620)	1 hr/in. (25 mm), ½ hr minimum

132.3 Exemptions to Mandatory PWHT Requirements

132.3.1 Postweld heat treatment is not required for the following conditions unless required by the qualified WPS or the designer:

(a) welds in nonferrous materials

(b) welds exempted in Table 132.1.1-1 or Table 132.2-1

(c) welds subject to temperatures above the lower critical temperature (see Table 129.3.1-1) during fabrication provided the WPS has been qualified with PWHT (see para. 132.1) at the temperature range to be reached during fabrication

132.3.2 The postweld heat treatment exemptions of Table 132.2-1 may be based on the actual chemical composition as determined by a ladle or product analysis in accordance with the material specification in lieu of the specified or maximum specified chemical composition limits.

132.3.3 Thermocouples may be temporarily attached directly to pressure-containing parts using the capacitor discharge method of welding in accordance with the requirements of para. 127.4.9(a).

132.4 Definition of Thicknesses Controlling PWHT (18)

132.4.1 The term *control thicknesses* as used in Table 132.1.1-1, Table 132.2-1, 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 or the thickness of the pressure-containing material if the weld is attaching a nonpressure-containing material to a pressure-containing material

132.4.2 Thickness of the weld, which is a factor in determining the control thickness, is defined as follows:

(a) groove welds (girth and longitudinal) — the thicker of the two abutting ends after weld preparation, including I.D. machining

(b) fillet welds — the throat thickness of the weld

(c) partial penetration welds — the depth of the weld groove

(d) material repair welds — the depth of the cavity to be repaired

(e) branch welds — the weld thickness is the dimension existing in the plane intersecting the longitudinal axes and is calculated as indicated for each detail using

$$t_c = \text{the smaller of } {}^1/_4 \text{ in. } (6\,\text{mm}) \text{ or } 0.7t_{nb}$$

(1) for welds described in Figure 127.4.8-4:

Detail (a)

$$\text{weld thickness} = t_{nb} + t_c$$

Detail (b)