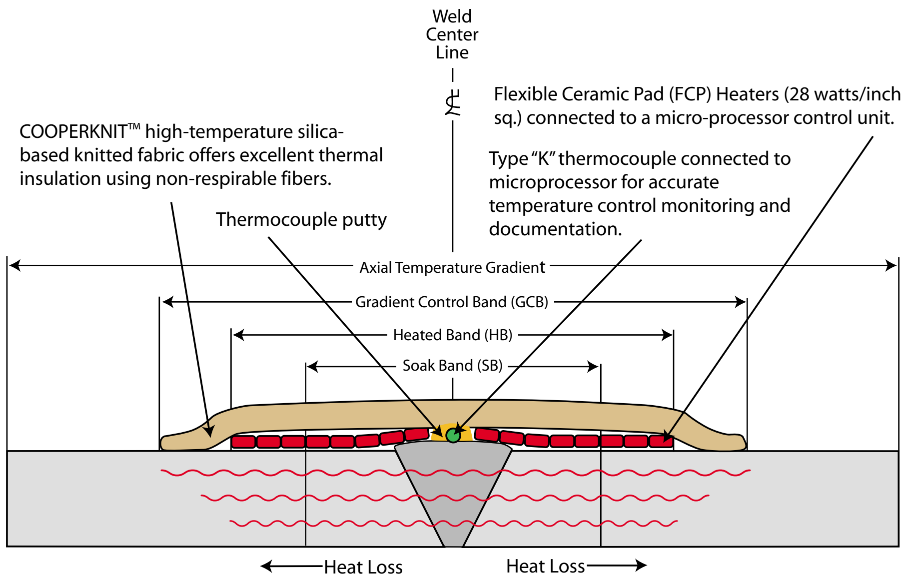
Why Postweld Heat Treat?

- **Alters Hardness and Residual Stresses**
- **Tempers Carbon and Low-Alloy Steels**

Cross-Sectional View

Typical Postheat (stress relief) Setup



(Minimum recommended heat bank $2\sqrt{Rt}$ beyond soak band. R=inside radius of pipe or vessel t=thickness)

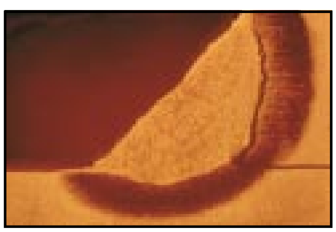
Soak Band (SB). The volume of metal that must be heated to and held within the required temperature range for a specified time. It should consist of the weld metal, heat-affected zone (HAZ) and sufficient base metal adjacent to the weld.

Heated Band (HB). The surface area over which the heat source is applied to achieve the required temperature in the soak band and limited induced stresses in the vicinity of the weld. It should consist of the soak band plus adjacent base metal necessary to control the temperature within the soak band and limit induced stress.

Gradient Control Band (GCB). The surface area over which insulation and/or additional heat source(s) are placed. It should encompass the soak band, heated bank, and sufficient adjacent base metal such that the maximum axial temperature gradient is not exceeded.

Axial Temperature Gradient. The reduction in temperature moving away from the soak band in a direction parallel to the axis of the pipe or pressure vessel. It is frequently specified as a minimum distance, L, over which the temperature may drop to a percentage of that at the edge of the soak band.

Common Causes of Weld Failure



Cracked welds pose danger. This weld joint in low-alloy steel cracked because it did not cool properly.

Weld failures can result from the presence of residual stresses, poor material properties, or hydrogen.

Stress-corrosion cracking and caustic embrittlement can occur when exposed to certain environments, such as hydroxides, nitrates, and hydrogen sulfides.

Carbon steel weldments (weld metal, heat-affected zone [HAZ], and adjacent base metal) may be vulnerable to cracking because of environmental conditions, especially wet H_2S, amine, and other caustic substances.

Certain forms of weld cracking are specifically caused by high hardness (in the weld metal or HAZ) and/or tensile residual stress. Hydrogen introduced into the weld from electrode coatings, fluxes, base metal contamination, or the atmosphere greatly increases the possibility of HAZ and/or weld metal cracking, particularly in hardenable steels.

Weld Properties Improved

Cooperheat-MQS postweld heat treatment (PWHT) can help improve weld integrity, minimize the need for rework, and alter both hardness and residual stress, thereby reducing the potential for cracking.

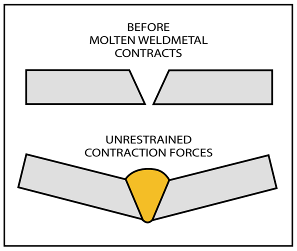
PWHT typically lowers the tensile and yield strength of carbon steel and alloy steel weld metals because the materials soften during the PWHT process. The resulting material is formed more readily and resists impact loading. PWHT also increases hydrogen diffusion, removing the potentially-damaging element from the weld.

Cooperheat-MQS: A Trusted Resource

Because Cooperheat-MQS has extensive experience in PWHT technologies, we can also help you meet the postweld heat treatment requirements recommended by the American Society of Mechanical Engineers (ASME), American Welding Society (AWS), American Institute of Steel Construction (AISC), and other organizations that provide input or regulation to the welding industry.

Improved Machining Stability

Complex fabrications can result in locked-in stresses. If the stresses remain unrelieved, distortion after machining can result because the metal helping to balance the tension and compression forces is removed.



Sometimes, intermediate heating is conducted as the weldment is fabricated, thus reducing excessive build-up of stresses. A final postweld enables the weldment to be machined after welding, without distortion.

(continued on page 4)

Postweld Heat Treatment Requirements for ASME B31.1 – 1998 Edition, Updated to 1999 Addenda

Process Piping — Table 132

Important Note: For information only. Always refer to the actual code.

P-No. Gr. Nos.	Holding Temperature Range, °F (°C)	Holding Time Based On Nominal Thickness Up to 2 in. (50 mm)	Over 2 in. (50 mm)
1 1,2,3	1100 (600) to 1200 (650)	1 hr/in. (25 mm) 15 min. minimum	2 hr plus 15 min. for each additional inch over 2 in. (50 mm)
3 1,2	1100 (600) to 1200 (650)	1 hr/in. (25 mm) 15 min. minimum	2 hr plus 15 min. for each additional inch over 2 in. (50 mm)
4 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)
5 1, 2	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)
6 1,2,3	1400 (760) to 1475 (800)	1 hr/in. (25 mm) 15 min. minimum	2 hr plus 15 min. for each additional inch over 2 in. (50 mm)
7 1, 2	1350 (730) to 1425 (775)	1 hr/in. (25 mm) 15 min. minimum	2 hr plus 15 min. for each additional inch over 2 in. (50 mm)
8 1, 2, 3	None[1]	None[1]	None[1]
9A 1	1100 (600) to 1200 (650)	1 hr/in. (25 mm) 15 min. minimum	2 hr plus 15 min. for each additional inch over 2 in. (50 mm)
9B 1	1100 (600) to 1175 (630)	1 hr/in (25 mm) 15 min. minimum	2 hr plus 15 min. for each additional inch over 2 in. (50 mm)
10H 1	None[1]	None[1]	None[1]
10I 1	1350 (730) to 1500 (815)	1 hr/in. (25 mm) 15 min. minimum	1 hr/in. (25 mm)

Notes: [1]*Postweld heat treatment is neither required nor prohibited. SEE ACTUAL CODE FOR NOTES AND EXEMPTIONS.*

Postweld Heat Treatment Requirements for ASME B31.3 – 1999 Edition, Updated to 2000 Addenda Process Piping — Table 331.1.1

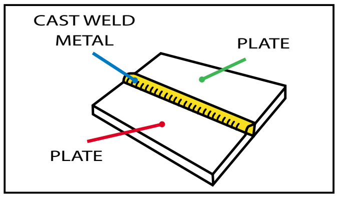
Important Note: For information only. Always refer to the actual code.

Base Metal P-No. or S-No. [Note (1)]	Weld Metal Analysis A-Number [Note (2)]	Base Metal Group	Nominal Wall Thickness		Specified Min. Tensile Strength, Base Metal		Metal Temperature Range		Holding Time		Brinell Hardness [Note (4)] Max.
			in.	mm	ksi	MPa	°F	°C	Nominal Wall [Note (3)] hr/in.	Min. Time, hr	
1	1	Carbon Steel	≥3/4	≥19	All	All	None	None			
			>3/4	>19	All	All	1100-1200	593-649	1	1	
3	2, 11	Alloy steels	≥3/4	≥19	≥71	≥490	None	None			
		Cr ≥ 1/2%	>3/4	>19	All	All	1100-1325	593-718	1	1	225
			All	All	>71	>490	1100-1325	593-718	1	1	225
4[10]	3	Alloy steels,	≥1/2	≥12.7	≥71	≥490	None	None			
		1/2%< Cr ≥2%	>1/2	>12.7	All	All	1300-1375	704-746	1	2	225
			All	All	>71	>490	1300-1375	704-746	1	2	225
5A[10]	4, 5	Alloy steels, (2 1/4% ≥ Cr ≥ 10%)									
5B[10]		≥3% Cr and ≥0.15% C	≥1/2	≥13	All	All	None	None			
5C[10]		≥3% Cr and ≥0.15% C	≥1/2	≥13	All	All	1300-1400	704-760	1	2	241
		>3% Cr or >0.15% C	All	All	All	All	1300-1400	704-760	1	2	241
6	6	High alloy steels	All	All	All	All	1350-1450	732-788	1	2	241
		martensitic									
		A 240 Gr. 429	All	All	All	All	1150-1225	621-663	1	2	241
7	7	High alloy steels, ferritic	All	All	All	All	None	None			
8	8, 9	High alloy steels, austenitic	All	All	All	All	None	None			
9A,	10	Nickel alloy steels	≥3/4	≥19	All	All	None	None			
9B			>3/4	>19	All	All	1100-1175	593-635	1/2	1	
10		Cr-Cu steel	All	All	All	All	1400-1500 [Note (5)]	760-816 [Note (5)]	1/2	1/2	
10A		Mn-V steel	≥3/4	≥19	>71	>490	None	None			
			>3/4	>19	All	All	1100-1300	593-704	1	1	225
			All	All	>71	>490	1100-1300	593-704	1	1	225
10H		Duplex stainless steel	All	All	All	All	[Note (7)]	[Note (7)]	1/2	1/2	
10I		27Cr steel	All	All	All	All	1225-1300 [Note (6)]	663-704 [Note (6)]	1	1	
11A		8 Ni, 9Ni steel	≥2	≥51	All	All	None	None			
SG1			≥2	≥51	All	All	1025-1085 [Note (8)]	552-585 [Note (8)]	1	1	
11A SG2		5Ni steel	>2	>51	All	All	1025-1085[5] [Note (8)]	552-585[5] [Note (8)]	1	1	
62		Zr R60705	All	All	All	All	1000-1100 [Note (9)]	538-593 [Note (9)]	Note [Note (9)]	1	

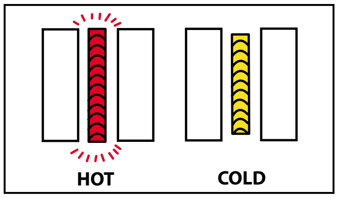
Notes:

1. ***P-Number or S-Number from BPV Code, Section IX, QW/QB-422***
2. ***A-Number from Section IX, QW-442***
3. ***For holding time in U.S. units, use hr/in. thickness; for SI metric units use min/mm (minutes per mm thickness).***
4. ***Where a hardness limit is specified in Table 331.1.1, at least 10% of welds, hot bends, and hot formed components in each furnace heat treated batch# and 1200% of those locally heat treated shall be tested. When dissimilar metals are joined by welding, the hardness limits specified for the base and welding materials in Table 331.1.1 shall be met for each material.***
5. ***Cool as rapidly as possible after the hold period.***
6. ***Cooling rate to 1200ºF (649ºC) shall be less than 100ºF (56ºC)/hr; thereafter the cooling rate shall be fast enough to prevent embrittlement.***
7. ***Postweld heat treatment is neither required nor prohibited, but any heat treatment applied shall be as required in the material specification.***
8. ***Cooling rate shall be >300ºF (167ºC)/hr to 600ºF (316ºC).***
9. ***Heat treat within 14 days after welding. Hold time shall be increased by 1/2 for each 1 in. (25mm) over 25 mm thickness. Cool to 800ºF (427ºC) at a rate ≥500ºF (278ºC)/hr, per 1 in. (25mm) nominal thickness, 500ºF (278ºC)/hr max. Cool in still air from 800ºF (427ºC).***
10. ***Heat treatment temperatures listed for some P-No. 4 and P-No.5 materials may be higher than the minimum tempering temperatures specified in the ASTM specifications for the base material. For higher-strength normalized and tempered materials, there is consequently a possibility of reducing tensile properties of the base material, particularly if long holding times at the higher temperatures are used.***

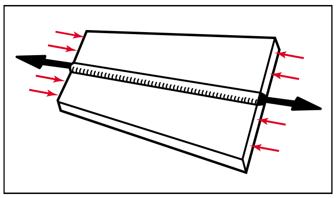
Examples of Tensile Stress



The case weld metal is the same length as the plates when hot, but tries to contract as it cools.



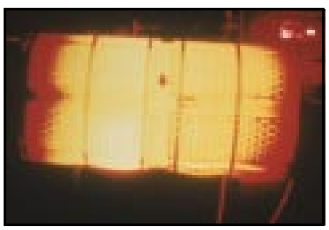
If this weld metal could be separated from the plates, the cold weld would be shorter than the plate.



The weld metal is rigidly attached to the plates and, after cooling must remain the same length. It is, therefore, stretched by the plates and subject to tensile stress. The plates develop a corresponding compressive stress.

Benefits of Tempering

Tempering (softening) helps improve resistance to brittle fracture by producing a more ductile and tougher weld metal and heat-affected zone (HAZ). Softening also helps minimize the risk of hydrogen sulfide stress cracking and other failures created by exposure to potentially damaging service environments.



FCP heating pads are typically used for postweld heating. Our crews have the experience to help achieve optimum results.

Documentation for Quality Assurance

Regulatory agencies, as well as many in-house quality assurance departments, often require permanent records of PWHT.

All thermocouples and recorders used or supplied by Cooperheat-MQS have certificates of conformance or calibration, respectively, traceable to the National Institute of Standards and Technology (NIST).

Common Postweld Heat Treatment Cycles

PWHT for carbon and low-alloy steels will fall into one of three categories:

1. *Subcritical* PWHT, the most common, is typically completed between 1,100ºF and 1,400ºF and at lower temperatures for hydrogen removal.
2. *Supercritical* PWHT, although less common, is used to anneal, normalize, harden, and remove hydrogen. It is typically performed between 1,500ºF and 1,700ºF.
3. *Intercritical* PWHT is generally not desirable because of partial material transformation.

When small areas are treated, *subcritical* PWHT is used in order to avoid creating partially transformed material.

Practical Options

Cooperheat-MQS offers experience and expertise in PWHT technologies, electrical resistance and combustion. Our experienced, and highly trained technicians will carefully assess your needs, and then implement a cost-effective program to achieve the desired results.

You have various options for meeting your PWHT requirements including complete, on-site service. Or if you prefer, you can purchase postweld heat treatment equipment from Cooperheat-MQS with assurance that the equipment you select will be the finest available

Serving industries throughout North America with on-site and lab services

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