Boiler repair practices

Heat treatment requirement for butt welding of tubes / pipes

Metal working results in distortion of grain structure. A weldment also results in different grain structure at different distance from weldment.

A WELDING MAY GO WITH ANY OF THE FOLLOWING HEAT TREATMENT PROCESSES

- Preheating
- Inter-pass temperature control
- Post heating or delayed cooling
- Post weld heat treatment

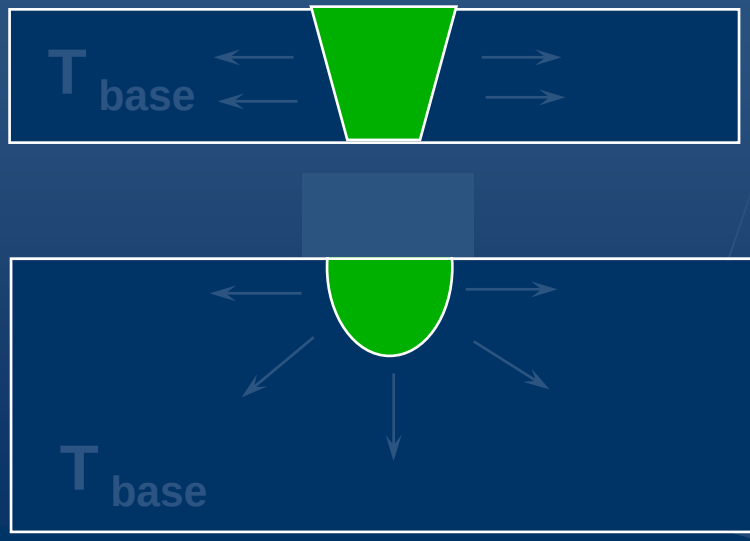
Chemistry of material, thickness of material & type of joints decide the type of heat treatment

Why Preheat?

- Preheat reduces the temperature differential between the weld region and the base metal
  - Reduces the cooling rate, which reduces the chance of forming martensite in steels
  - Reduces distortion and shrinkage stress
  - Reduces the danger of weld cracking
  - Allows hydrogen to escape

Using Preheat to Avoid Hydrogen Cracking

- If the base material is preheated, heat flows more slowly out of the weld region
  - Slower cooling rates avoid martensite formation
- Preheat allows hydrogen to diffuse from the metal



Cooling rate $\propto (T - T_{base})^3$

Cooling rate $\propto (T - T_{base})^2$

Interaction of Preheat and Composition

$$CE = \%C + \%Mn/6 + \%(Cr+Mo+V)/5 + \%(Si+Ni+Cu)/15$$

- Carbon equivalent (CE) measures ability to form martensite, which is necessary for hydrogen cracking
  - CE < 0.35-no preheat or post-weld heat treatment
  - 0.35 < CE < 0.55-preheat
  - 0.55 < CE -preheat and post-weld heat treatment
- Preheat temp. ↑ as CE ↑ and plate thickness ↑

Why Post-Weld Heat Treat?

- The fast cooling rates associated with welding often produce martensite
- During post-weld heat treatment, martensite is tempered (transforms to ferrite and carbides)
  - Reduces hardness
  - Reduces strength
  - Increases ductility
  - Increases toughness
- Residual stress is also reduced by the post-weld heat treatment

Preheating methods

- Gas rings / muffle furnace (at factory)
- Electrical resistance heaters (at site)
- Induction heating (at factory)
- Oxy acetylene or other gas torches (at site)

Postweld Heat Treatment and Hydrogen Cracking

- Postweld heat treatment (~ 1200°F) tempers any martensite that may have formed
  - Increase in ductility and toughness
  - Reduction in strength and hardness
- Residual stress is decreased by postweld heat treatment
- Rule of thumb: hold at temperature for 1 hour per inch of plate thickness; minimum hold of 30 minutes

Post weld heating methods

- Gas rings / muffle furnace (at factory)
- Electrical resistance heaters (at site)
- Induction heating (at factory)

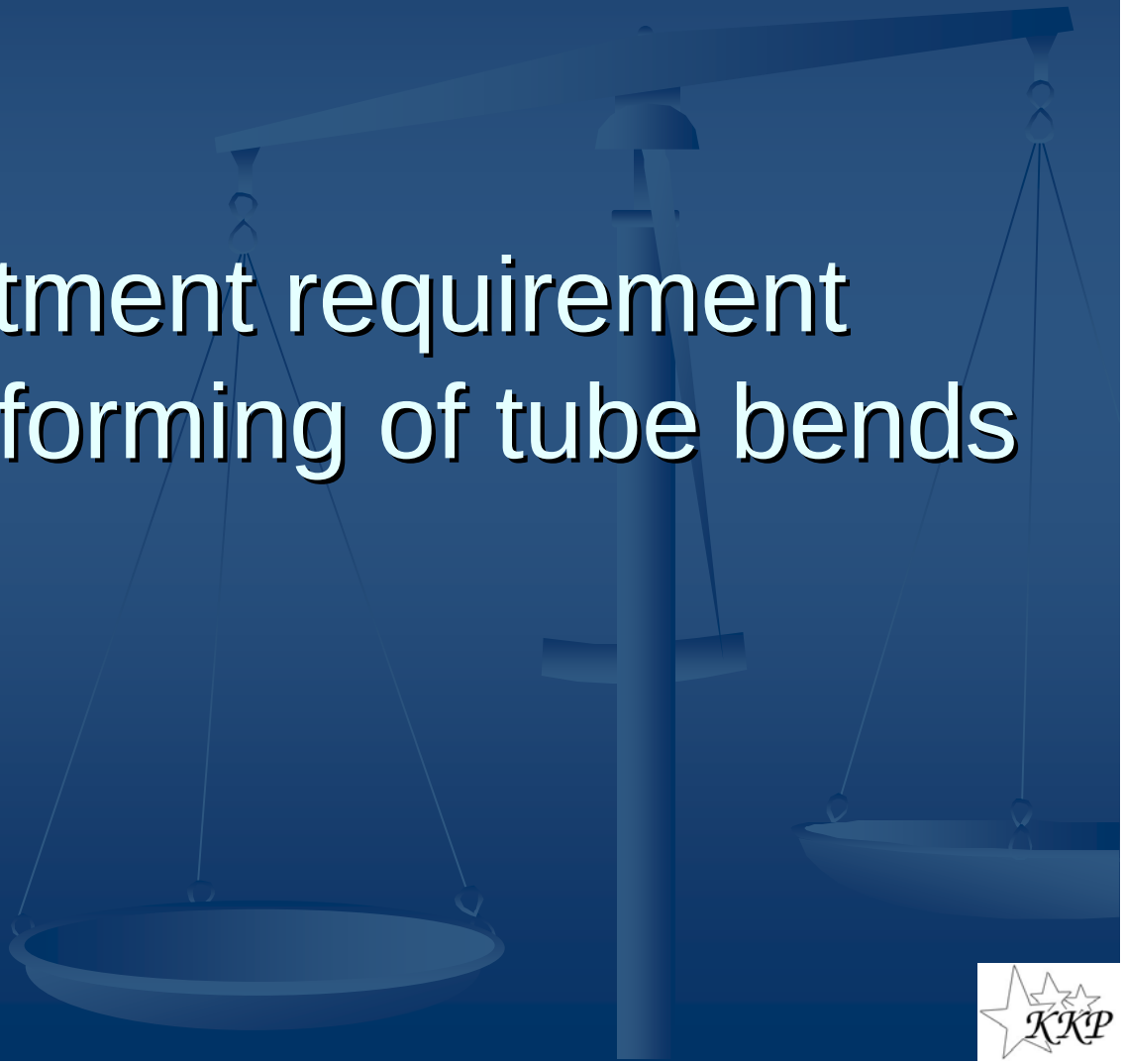
Post weld heating methods

- Weld should be free of grease, oil , chloride and sulfur bearing compounds.
- Heat band should cover 3 times weld thk / material thk.
- Post weld heat treatment must be monitored with temperature recorders.

Materials and P Number grouping						Table 1
P no Group	**Common name**	**Plates**	**Tubes**	**Pipes**	**forgings**	**Castings**
P1 AB	Carbon Steel	BMC 10	SA 178 A	SA 106 Gr B	IS 1875 Cl II	SA 216 WCB
		BMC 16	SA 192	DIN St 35.8	DIN C 22	
		BMC 20	SA 210 GR A1	DIN St 45.8	BS 1503 161 Gr 28 B	
			SA 226	BS 3604 HFS 27		
			DIN St 35.8			
			DIN St 45.8			
			BS 3059 S2 33			
			JIS St B 42 S			
P1C	High strength carbon steel	SA 515 Gr 70	SA 210 Gr C	SA 106 Gr C	SA 105	SA 216 WCC
		SA 299	BS 3059 S2 45			
		DIN 17 Mn 4				
P3 A	Carbon Moly Steel	AISI 6120	SA 209 T1			SA 217 WCI
			DIN Mo 3			
			SIS St BA 125			
P4 AB	1 Cr 1/2 Mo	SA 387 Gr 11	SA 213 T11	SA 335 P11	SA 182 F 11	SA 217 WC 6
	1 1/2 Cr 1/2 Mo	SA 387 Gr 12	SA 213 T 12	SA 335 P12	SA 182 F 12	
			DIN 13 Cr Mo 44	DIN 13 Cr Mo 44		
			BS 3059 S2 620			
			JIS St BA 225			
P 5A		SA 387 Gr 22	SA 213 T 22	SA 335 P22	SA 182 F22	SA 217 WC 9
			DIN 10 Cr Mo 910	DIN 10 Cr Mo 910		
	2 1/4 Cr 1 Mo		BS 3059 S2 622	BS 3604 - 622		
P5 D	5 Cr 1 Mo	SA 357	SA 213 T5	SA 335 P5	SA 182 F5	SA 217 C5
P5 F	9 Cr 1 Mo		SA 213 T 9	SA 235 P 9	SA 182 F 9	SA 217 C 9
	Cr Mo V	DIN 14 Mo V 63	DIN 14 Mo V 63	DIN 14 Mo V 63	DIN 14 Mo V 63	
		CSN 15123	CSN 15123	BS 3604 HFS 660	CS 15123	
					BS 1503 660 B	
P8 B 1	18 / 10 / Ti	SA 240.321	SA 213-TP 321 H	SA 376- F 321 H	SA 182- F 321 H	SA 351 -CF 8
P8 B 2	18/8	SA 240.304	SA 213-TP 304 H	SA 376- F 304 H	SA 182- F 304 H	SA 351 -CF 8M
P8 B 3	16/13/3/ Mo	SA 240.316	SA 213 -TP 316 H	SA 376- F 316 H	SA 182- F 316 H	SA 351 -CF 8C
P8 B 4	18/10/ Cb	SA 240. 347	SA 213 -TP 347 H	SA 376- F 347 H	SA 182- F 347 H	
	12-15 Cr	SA 240 429				SA 351 CH 20
	25 Cr 12 Ni					CHRONITE
	50 Cr 50 Ni					

GIRTH BUTT WELDS TUBES & PIPES DIA < = 108 MM(Dissimilar)								Table 8
Applicable for thickness upto 19 mm for P1 ABC and thickness upto 13 mm for other materials.								
A - GTAW , SMAW , GMAW (STBW)								
B - Induction pressure welding								
Material	**Process**		**P1 ABC**	**P3 A**	**P4 AB**	**P 5A**	**P5 F**	**P 8**
P1 ABC	A	Preheat	Nil					
		PWHT	Nil					
	B	PWHT	Nil (note 1)					
P3 A	A	Preheat	Nil	Nil				
		PWHT	Nil	Nil				
	B	PWHT	Nil (note 1)	Nil (note 1)				
P4 AB	A	Preheat	120	120	120			
		PWHT	Nil (note 2)	Nil (note 2)	Nil (note 2)			
	B	PWHT	650 - 700	650 - 700	650 - 700			
P5 A	A	Preheat	150	150	150	150		
		PWHT	Nil (note 2)	Nil (note 2)	Nil (note 2)	Nil (note 2)		
	B	PWHT	680 - 700	680 - 700	680 - 720	680 - 750		
P5 F	A	Preheat	200	200	200	200	200	
		PWHT	680 - 700	680 - 700	680 - 720	680 - 750	680 - 775	
	B	PWHT	680 - 700	680 - 700	680 - 720	680 - 750	680 - 775	
P8	A	Preheat	Nil	Nil	120	150	200	Nil
		PWHT	Nil	Nil	Nil	Nil	680 - 775	Nil
		PWHT	Nil (note 1)	Nil (note 1)	650 - 720	680 - 750	680 - 775	Nil
Note 1: All IPW welds where one of the material is SA 210 Gr C or SA 209 T1 shall be post weld heat treated at 620 - 700 deg C. If SA 210 Gr C is ordered with C restricted to 0.3 %max, it may be heat treated as P1 AB material.								
Note 2: When the weld is scheduled to undergo post weld heat treatment, preheat may not be required.								

Heat treatment requirement for cold / hot forming of tube bends



COLD BENDING AND HOT BENDING OF BOILER TUBES AND PIPES						Table 2
COLD BENDING				Hot bending (see notes 3, 4, 5)		
P no Group	Heat treatment reqd	dia > 108 mm	dia <= 108 mm	Heat treatment reqd	dia <= 108 mm	dia > 108 mm
P1 AB	For	R/D < 2.5	R/D < 2.5	Hot bend at deg C	870 -980	900- 990
		Or t > 19 mm	Or t > 22 mm	For	R/D < 1.25	All bends
Note 5	SR at deg C	600 - 700	600 - 675	SR / temper at Deg C	600 - 700	Nil
P1C	For	R/D < 3		Hot form at deg C	870 -980	900- 991
		Or t > 19 mm		For	R/D < 3	All bends
Note 1	SR at deg C	600 - 690		SR / temper at Deg C	600- 690	Nil
P3 A	For	All bends		Hot form at deg C	870 -980	
				For	All bends	
	SR at deg C	620 - 700		SR / temper at Deg C	620 - 700	
P4 AB	For	R/D < 3	R/D < 4	Hot form at deg C	870 -980	
		Or t > 13 mm	Or t > 22 mm	For	R/D < 2	
	SR at deg C	650 - 720	650 - 720	SR / temper at Deg C	650- 720	
P5 A	For	R/D < 3	All bends	Hot form at deg C	870 -980	920 -1010
		Or t > 13 mm		For	All bends	All bends
	SR at deg C	680-750	680-750	SR / temper at Deg C	680 - 775	680 - 720
P5 F	For	R/D < 3		Hot form at deg C	870 -980	950 - 1010
		Or t > 13 mm		For	All bends	All bends
	SR at deg C	680- 775		SR / temper at Deg C	680 - 775	680 - 720
P8	For	All bends		Hot form at deg C	870 -980	
				For	All bends	
	Soln HT at deg C	1060 - 1100		SR / temper at Deg C	1060 -1100	
BS 622	For	R/D <3.5		Hot form at deg C	950 - 1010	
Note 2	Normalise deg C	910 - 940		For	910 - 940	
	Temper Deg C	680 - 710		SR / temper at Deg C	680 - 710	
BS 660	For	R/D <3.5		Hot form at deg C	950 -1010	
Note 2	Normalise deg C	960 - 980		For	960 - 980	
	Temper Deg C	680 - 710		SR / temper at Deg C	680 - 710	

Note 1 : P1C material shall be in the normalised condition prior ro cold bending. If not it shall be hot bent.

Note 2 : For BS 622 and 660 materials, soaking time for tempering shall be 180 minutes irrespective of thickness , except for pipes upto and including 12.5 mm , the soaking may be 30 minutes.

Note 3 : Hot forming Shall be completed above lower critical temperature. P1 ABC= 730 deg C; P4 AB = 775 deg C ; P5 A = 800 deg C

Note 4 : No water quenching shall be carried out during hot bending . In exceptional cases, if permitted for carbon steels, the bends shall be tempered.

Note 5 : Tempering may be clubbed with final DWHT, if any.