



HEAT TREATMENT AND POST WELD HEAT TREATMENTS

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INTRODUCTION

- Heat treatment is a process where metals (or other materials) are heated and then cooled in a controlled way to change their properties, like making them stronger, harder, or more flexible. This is done without changing the shape of the material, only its internal structure.

STANDARD

- ASME SEC II PART A1
- ASME SEC II PART A2
- ASME SEC VIII DIV 1
- ASME SEC IX
- IS 2062

HEAT TREATMENT REQUIRED FOR RAW MATERIALS

FOR CARBON STEEL MATERIALS OF SA 516 GR (50 to 70)

- Plates 1.50 in. [40 mm] and under in thickness are normally supplied in the *as-rolled condition*. The plates may be ordered normalized or stress relieved, or both.
- Plates over 1.50 in. [40 mm] in thickness *shall be normalized*.
- *When notch-toughness* tests are required on plates 1 1/2 in. [40 mm] and under in thickness, the *plates shall be normalized* unless otherwise specified by the purchaser.

- If approved by the purchaser, cooling rates faster than those obtained by cooling in air are permissible for improvement of the toughness, provided the plates are subsequently *tempered in the temperature range 1100 to 1300° F [595 to 705° C]*.

FOR STAINLESS STEEL OF SA 240 TYP 304

- Hot-Rolled or Cold-Rolled, and Annealed or Heat Treated—Scale not removed, an intermediate finish. Use of plates in this condition is generally confined to heat-resisting applications. Scale impairs corrosion resistance.

- Hot-Rolled or Cold-Rolled, and Annealed or Heat Treated, and Blast Cleaned or Pickled—Condition and finish commonly preferred for corrosion-resisting and most heat resisting applications, *essentially a No.*

1 Finish.

- Hot-Rolled or Cold-Rolled, and Annealed or Heat Treated, and Surface Cleaned and Polished—Polish finish is generally No. 4 Finish.
- Hot-Rolled or Cold-Rolled, and Annealed or Heat Treated, and Descaled, and Temper Passed—Smoother finish for specialized applications.

FOR ALLOY STEEL MATERIALS OF SA 387 GR P11, P12 OR P22

- Except for Grade 91, all plates shall be thermally treated either by annealing, normalizing and tempering, or, when permitted by the purchaser, accelerated cooling from the austenitizing temperature by air blasting or liquid quenching,followed by tempering. Minimum tempering temperatures shall be as follows:

Grade	Temperature, ° F [° C]
➤ 2, 12, and 11	1150 [620]
➤ 22, 21, and 9	1250 [675]
➤ 5	1300 [705]

- Grade 91 plates shall be thermally treated, either by normalizing and tempering or by accelerated cooling from the austenitizing temperature by air blasting or liquid quenching, followed by tempering. Grade 91 plates shall be austenitized at 1900 to 1975° F [1040 to 1080° C] and shall be tempered at 1350 to 1470° F [730 to 800° C].
- Grade 5, 9, 21, 22, and 91 plates ordered without the heat treatment required by 5.1 shall be furnished in either the stress relieved or the annealed condition.

- For plates ordered without the heat treatment required by 5.1, heat treatment of the plates to conform to 5.1 and to Table 2 or Table 3, as applicable, shall be the responsibility of the purchaser.

FOR CARBON STEEL IS 2062

- A : *Impact test not required*, semi-killed/killed
- BR : *Impact test optional*; if required at *room temperature*; semi-killed/killed
- B0 : *Impact test mandatory at 0° C*, semi-killed/killed
- C : *Impact test mandatory at -20° C*, killed

P - NUMBER FOR MATERIALS

- *P-number 1:* Carbon-manganese or low-carbon steel.
- *P-number 4:* Low alloy steel (Cr-Mo Steels).
- Refer P number in ASME SEC IX *UW - 420*.

POST WELD HEAT TREATMENTS REQUIREMENT

FOR CARBON STEEL MATERIALS

- Table UCS-56-1
- Postweld Heat Treatment Requirements for Carbon and Low Alloy Steels — P-No. 1

FOR ALLOY STEEL MATERIALS

- Table UCS-56-3
- Postweld Heat Treatment Requirements for Carbon and Low Alloy Steels — P-No. 4

Table UCS-56-1
Postweld Heat Treatment Requirements for Carbon and Low Alloy Steels — P-No. 1

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UW-40(f)]	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 1 Gr. Nos. 1, 2, 3	1,100 (595)	1 hr/in. (25 mm), 15 min minimum	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (50 mm)
Gr. No. 4	NA	None	None

GENERAL NOTES:

(a) When it is impractical to postweld heat treat at the temperature specified in this Table, it is permissible to carry out the postweld heat treatment at lower temperatures for longer periods of time in accordance with [Table UCS-56.1](#).

(b) Postweld heat treatment is mandatory under the following conditions:

(1) for welded joints over 1½ in. (38 mm) nominal thickness;

(2) for welded joints over 1¼ in. (32 mm) nominal thickness through 1½ in. (38 mm) nominal thickness unless preheat is applied at a minimum temperature of 200°F (95°C) during welding. This preheat need not be applied to SA-841 Grades A and B, provided that the carbon content and carbon equivalent (CE) for the plate material, by heat analysis, do not exceed 0.14% and 0.40%, respectively, where

$$CE = C + \frac{Mn}{6} + \frac{Cr+Mo+V}{5} + \frac{Cu+Ni}{15}$$

(3) for welded joints of all thicknesses if required by [UW-2](#), except postweld heat treatment is not mandatory under the conditions specified below:

(a) for groove welds not over ½ in. (13 mm) size and fillet welds with a throat not over ½ in. (13 mm) that attach nozzle connections that have a finished inside diameter not greater than 2 in. (50 mm), provided the connections do not form ligaments that require an increase in shell or head thickness, and preheat to a minimum temperature of 200°F (95°C) is applied;

(b) for groove welds not over ½ in. (13 mm) in size or fillet welds with a throat thickness of ½ in. (13 mm) or less that attach tubes to a tubesheet when the tube diameter does not exceed 2 in. (50 mm). A preheat of 200°F (95°C) minimum must be applied when the carbon content of the tubesheet exceeds 0.22%.

(c) for groove welds not over ½ in. (13 mm) in size or fillet welds with a throat thickness of ½ in. (13 mm) or less used for attaching nonpressure parts to pressure parts. When the thickness of the pressure part exceeds 1¼ in. (32 mm), preheat to a minimum temperature of 200°F (95°C) shall be applied prior to welding each pass;

(d) for studs welded to pressure parts, provided preheat to a minimum temperature of 200°F (95°C) is applied when the thickness of the pressure part exceeds 1¼ in. (32 mm);

(e) for hard-facing weld metal overlay, corrosion resistant weld metal overlay, or for welds attaching corrosion resistant applied linings (see [UCL-34](#)), provided that when the thickness of the pressure part exceeds 1¼ in. (32 mm), a preheat to a minimum temperature of 200°F (95°C) shall be applied and maintained during application of the first weld layer.

(c) NA = not applicable

Table UCS-56-3
Postweld Heat Treatment Requirements for Carbon and Low Alloy Steels — P-No. 4

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UW-40(f)]	
		Up to 5 in. (125 mm)	Over 5 in. (125 mm)
P-No. 4 Gr. Nos. 1, 2	1,200 (650)	1 hr/in. (25mm), 15 min minimum	5 hr plus 15 min for each additional inch (25mm) over 5 in. (125 mm)

GENERAL NOTES:

- (a) Except for exemptions in General Note (b), postweld heat treatment is mandatory under the following conditions:
 - (1) on material of all thicknesses if required by [UW-2](#);
 - (2) on all other P-No. 4 Gr. Nos. 1 and 2 materials.
- (b) Postweld heat treatment is not mandatory under the conditions specified below:
 - (1) for circumferential butt welds between pipe, tube, and wrought or forged butt weld fittings that comply with the following conditions:
 - (a) a maximum nominal thickness of $\frac{5}{8}$ in. (16 mm);
 - (b) a maximum specified carbon content of not more than 0.15% (SA material specification carbon content, except when further limited by the purchaser to a value within the specification limits);
 - (c) a minimum preheat of 250°F (120°C).
 - (2) for pipe, tube, and wrought or forged fittings meeting the requirements of (1)(a) and (1)(b) above, having nonpressure attachments fillet welded to them, provided:
 - (a) the fillet welds have a maximum throat thickness of $\frac{1}{2}$ in. (13 mm);
 - (b) a minimum preheat temperature of 250°F (120°C) is applied.
 - (3) for pipe, tube, and wrought or forged fittings meeting the requirements of (1)(a) and (1)(b) above, having studs welded to them, a minimum preheat temperature of 250°F (120°C) is applied.
 - (4) for pipe, tube, and wrought or forged fittings meeting the requirements of (1)(a) and (1)(b) above, having extended heat absorbing fins electrically resistance welded to them, provided:
 - (a) the fins have a maximum thickness of $\frac{1}{8}$ in. (3 mm);
 - (b) prior to using the welding procedure, the Manufacturer shall demonstrate that the heat-affected zone does not encroach upon the minimum pipe or tube wall thickness.
 - (5) for tubes or pressure-retaining handhole and inspection plugs or fittings that are secured by mechanical means (tube expansion, shoulder construction, machine threads, etc.) and seal welded, provided the seal weld has a throat thickness of $\frac{3}{8}$ in. (10 mm) or less, and preheat to a minimum temperature of 250°F (120°C) is applied when the thickness of either part exceeds $\frac{5}{8}$ in. (16 mm).

HEAT TREATMENT REQUIRED FOR DISH END

UCS-79 FORMING PRESSURE PARTS

- The vessel will contain *lethal liquid or gaseous substances* (see UW-2).
- The nominal thickness of the part before cold forming *exceeds 5/8 in.*
(16 mm).
- The reduction by cold forming from the nominal thickness is more than 10% at any location where the extreme *fiber elongation exceeds 5%*.

CALCULATION FOR DISH END

FIBER ELONGATION CALCULATION

$$\text{Fiber elongation} = (75 * \text{DNT}) / (0.17 * \text{ID})$$

DNT - Dish nominal thickness

ID - Inner diameter

For carbon steel fiber elongation - **5%**

For SS materials fiber elongation - **20%**

CYCLE FOR HEAT TREATMENT

1. Loading Temperature
2. Rate of heating
3. Soaking temperature
4. Soaking time
5. Rate of cooling
6. Unloading temperature

1. *LOADING TEMPERATURE*

- The temperature of the *furnace shall not exceed 800° F (425° C)* at the time the vessel or part is placed in it.

2. *RATE OF HEATING*

- The rates of *heating and cooling need not be less than 100° F/hr (56° C/h)*. However, in all cases consideration of closed chambers and complex structures may indicate reduced rates of heating and cooling to avoid structural damage due to excessive thermal gradients.

- Above 800° F (425° C), *the rate of heating shall be not more than 400° F/hr (222° C/h) divided by the maximum metal thickness of the shell or head material in inches*, but in no case more than 400° F/hr (222° C/h). During the heating period there shall not be a greater variation in temperature throughout the portion of the vessel being heated than 250° F (140° C) within any 15 ft (4.6 m) interval.
- h = material thickness (dish end thick) or (shell and dish end welded). Higher thickness for shell or dish end thick shall be selected).
- Refer : UW 40 (F) for PROCEDURES FOR POSTWELD HEAT TREATMENT.

SOAKING TEMPERATURE

- soaking temperature or normal holding temperature is same
- Minimum soaking temperature is 595 ° C (Min)

**Table UCS-56-1
Postweld Heat Treatment Requirements for Carbon and Low Alloy Steels — P-No. 1**

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UW-40(f)]	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 1 Gr. Nos. 1, 2, 3	1,100 (595)	1 hr/in. (25 mm), 15 min minimum	2 hr plus 15 min for each additional inch (25 mm) over 2 in. (50 mm)
Gr. No. 4	NA	None	None

GENERAL NOTES:

- (a) When it is impractical to postweld heat treat at the temperature specified in this Table, it is permissible to carry out the postweld heat treatment at lower temperatures for longer periods of time in accordance with [Table UCS-56.1](#).
- (b) Postweld heat treatment is mandatory under the following conditions:
 - (1) for welded joints over 1½ in. (38 mm) nominal thickness;
 - (2) for welded joints over 1¼ in. (32 mm) nominal thickness through 1½ in. (38 mm) nominal thickness unless preheat is applied at a minimum temperature of 200°F (95°C) during welding. This preheat need not be applied to SA-841 Grades A and B, provided that the carbon content and carbon equivalent (CE) for the plate material, by heat analysis, do not exceed 0.14% and 0.40%, respectively, where

$$CE = C + \frac{Mn}{6} + \frac{Cr+Mo+V}{5} + \frac{Cu+Ni}{15}$$

(3) for welded joints of all thicknesses if required by [UW-2](#), except postweld heat treatment is not mandatory under the conditions specified below:

(a) for groove welds not over ½ in. (13 mm) size and fillet welds with a throat not over ½ in. (13 mm) that attach nozzle connections that have a finished inside diameter not greater than 2 in. (50 mm), provided the connections do not form ligaments that require an increase in shell or head thickness, and preheat to a minimum temperature of 200°F (95°C) is applied;

(b) for groove welds not over ½ in. (13 mm) in size or fillet welds with a throat thickness of ½ in. (13 mm) or less that attach tubes to a tubesheet when the tube diameter does not exceed 2 in. (50 mm). A preheat of 200°F (95°C) minimum must be applied when the carbon content of the tubesheet exceeds 0.22%.

(c) for groove welds not over ½ in. (13 mm) in size or fillet welds with a throat thickness of ½ in. (13 mm) or less used for attaching nonpressure parts to pressure parts. When the thickness of the pressure part exceeds 1¼ in. (32 mm), preheat to a minimum temperature of 200°F (95°C) shall be applied prior to welding each pass;

(d) for studs welded to pressure parts, provided preheat to a minimum temperature of 200°F (95°C) is applied when the thickness of the pressure part exceeds 1¼ in. (32 mm);

(e) for hard-facing weld metal overlay, corrosion resistant weld metal overlay, or for welds attaching corrosion resistant applied linings (see [UCL-34](#)), provided that when the thickness of the pressure part exceeds 1¼ in. (32 mm), a preheat to a minimum temperature of 200°F (95°C) shall be applied and maintained during application of the first weld layer.

(c) NA = not applicable

SOAKING TIME

Material	Normal Holding Temperature, °F (°C), Minimum	Minimum Holding Time at Normal Temperature for Nominal Thickness [See UW-40(f)]		
		Up to 2 in. (50 mm)	Over 2 in. to 5 in. (50 mm to 125 mm)	Over 5 in. to 10 in. (125 mm to 250 mm)
P-No. 1 Gr. Nos. 1, 2, 3	1,100 (595)	1 hr/in. (25 mm), 15 min minimum	2 hr plus 15 additional over 2 in.	Table 1
Gr. No. 4	NA	None	None	Minimum Holding Time at Normal Temperature for Nominal Thickness
GENERAL NOTES:		2 in.	2 hr.	
(a) When it is impractical to heat treatment at lower		1 3/4 in.	1 hr. 45 min.	
(b) Postweld heat treatment		1 1/2 in. if no preheat applied	1 hr. 30 min.	
(1) for welded joints		> 1 1/4 in. if no preheat applied	1 hr. 15 min.	
(2) for welded joints applied at a minimum to		1 in.	1 hr.	
B, provided that the car		3/4 in.	45 minutes	
and 0.40%, respectively.		1/2 in.	30 minutes	
(3) for welded joints conditions specified below:		From 1/16 to 1/4 in.	15 minutes	
(a) for groove welds connections that have a t that require an increase				
(b) for groove welds tubes to a tubesheet whe				
ckness two inches				
two				
(d) for stud welded thickness of the pressure				
(e) for corrosion res				
When the thickness of the				
maintained during application of the first weld layer.				
(f) NA = not applicable				

RATE OF COOLING

- The rates of *heating and cooling need not be less than 100° F/hr (56° C/h)*. However, in all cases consideration of closed chambers and complex structures may indicate reduced rates of heating and cooling to avoid structural damage due to excessive thermal gradients
- Above 800° F (425° C), *cooling shall be done in a closed furnace or cooling chamber at a rate not greater than 500° F/hr (280° C/h) divided by the maximum metal thickness of the shell or head material in inches*, but in no case more than 500° F/hr (280° C/h).

RATE OF COOLING

- UNLOADING TEMPERATURE

- At temperatures above 800° F (425° C), temperature variations within the heated portion during the cooling phase shall not be greater than 250° F (140° C) within any 15 ft (4.6 m) interval. *From 800° F(425° C), the vessel may be cooled in still air.*

TYPE OF HEAT TREATMENTS

1. ANNEALING
2. NORMALIZING
3. QUENCHING (OIL QUENCH)
4. QUENCHING (WATER QUENCHING)

