AGREEMENT

Number:	V-DK-010
Titel:	**Heat Treatment of Welded Joints**
Signatories:	FDBR Vd-TÜV VGB
Publication Date:	January 2018

Agreement on Steam Boilers 010

2018-01

between

FDBR FDBR e. V. Fachverband Anlagenbau, Düsseldorf,

VGB PowerTech e. V., Essen,

VdTÜV Verband der TÜV e. V., Berlin

on the

Heat Treatment of Welded Joints

Preamble

This agreement is intended to supplement the pertinent rules and regulations. It is a collection of experience made, recommendations and, where required, a concretization of the rules and regulations, which, to the best of our knowledge, reflects the state-of-the-art at its date of publication.

This agreement aims at ensuring the operational safety of steam boiler plants and their components. No liability will be taken for the correctness of the contents of this agreement. Patents and other protective rights shall be clarified under the responsibility of the user.

The associations having participated in the establishment of this guideline will appreciate the support and further development of its contents through other national and international associations/institutions.

Contents

1 Scope

1.1 This agreement applies to the steel grades listed in the tables when used in boiler construction.

It can be applied if post-weld heat treatment is required for steam boiler plants including related pipework to comply with valid rules and regulations.

Depending on the steel grade and/or weld metal this heat treatment may be stress relieving and/or tempering. Depending on the material, the stress-relief heat treatment may cover the range of tempering temperature for the base material.

1.2 Welding procedure qualification tests performed prior to the effective date of this agreement and the range of application of which was extended by production control tests at temperatures laid down in this agreement, need not be repeated if agreed upon by the independent body.

2 Annealing temperatures and information on their application

2.1 During post-weld heat treatment of the steel grades and their combinations as well as of weld filler metals listed under Table 1, the pertinent annealing temperatures mentioned in this table shall be used. Other annealing temperatures may be used if this permitted by the applicable standard. For annealing temperatures deviating from this agreement a welding procedure qualification shall be performed. The user shall render evidence of appropriate procedure qualifications to show the allowable range of temperatures. The annealing temperatures of this agreement consider the experience gained with the operating behaviour of the steels and welded joints as well as the usual accuracy of the temperature measuring and control devices.

2.2 In case of furnace annealing, the medium range of the indicated temperature range should be strived for in due consideration of the procedure qualification on the component.

2.3 In case of local annealing, the upper limit of the temperature range shall be obtained at the component surface in due consideration of the procedure qualification if it cannot be ensured by other means that at least the lower limit of the temperature range or of the qualified region (the higher value shall govern) is obtained at the inner surface.

2.4 Deviations are permitted upon agreement between the parties concerned. In the case of quenched and tempered heat-resisting steels higher annealing temperatures are possible upon agreement with the product manufacturer.

3 Duration of heat treatment

The duration required for the given annealing temperatures requires sufficient soaking of the component. Holding within the temperature range depends on the component thickness. When measuring the annealing temperature at the component surface, the holding times given in Table 4 are recommended (also see sections 5.4 and 5.5).

Where the duration of annealing is exceeded essentially (e.g. in case of repeated annealing in the range of the upper temperature limit) the mechanical propertied may deteriorate.

Where the holding time is interrupted, e.g. in case of power failure, time counting will be continued upon reaching again the annealing temperature.

Note: For temperature gradients during heating/cooling the stipulations e.g. of DIN EN 13445-4 chapter 10 shall be considered (50 K/h).

4 Allowable combinations of steel grades and weld filler metals

The allowable combinations of steel grades and weld filler metals are shown in Table 3. The use of other combinations is permitted if appropriate evidence is rendered by a welding procedure qualification.

5 Additional information

5.1 In case of welded joints of the steel grades X10CrMoVNb9-1 (1.4903), X11CrMoWVNb9-1-1 (1.4905), X10CrMoWVNb9-2 (1.4091), X20CrMoV11-1 (1.4922), GX 23 CrMoV 12-1 (1.4931) as well as 7CrMoVTiB10-10 (1.7378) (only if similar weld metals are used) or in combination with other steel grades, cooling as indicted hereafter is required upon welding and prior to heat treatment:

- X20CrMoV11-1 and GX 23 CrMoV 12-1, cooling temperature 80 °C to 130 °C, minimum holding time the same time holding time as during heat treatment,
- X10CrMoVNb9-1, X11CrMoWVNb9-1-1 and X10CrMoWVNb9-2 as well as 7CrMoVTiB10-10 cooling temperature to less than 100 °C. In the case of shop welds cooling to room temperature is possible. In this case, 50 % of the weld metal volume should already have been deposited. Cooling of site welds should be stopped at least at 60 °C. The minimum holding time shall be the same as that during heat treatment. Where the cooling temperature does not fall below 80 °C, the temperature shall be hold at least for one hour.

Simple butt welded joints with wall thicknesses up to 50 mm may cool to room temperature upon welding.

Where filler metal similar to the steel grades X10CrMoVNb9-1 (1.4903), X11CrMoWVNb9-1-1 (1.4905), X10CrMoWVNb9-2 (1.4091) is used, the information given by the filler metal manufacturer shall be observed when selecting the heat treatment temperature. Deviations from this requirement are possible if the deviating temperature has been proved by means of a welding procedure qualification.

5.2 The examination with portable hardness test equipment (e.g. EQUOTIP, MICRODUR) only allows an assessment whether heat treatment has been performed. The procedures are not standardised and require the operating experience of the user and secured correlations to work samples to prevent wrong interpretation.

5.3 In the case of forgings made of the steel grade X20CrMoV11-1 with a thickness > 120 mm and a minimum 0.2% proof stress > 490 N/mm^2, the tempering temperature shall be obtained from the manufacturer to determine the heat treatment parameters.

5.4 In the case of welded joints with similar filler metals of the steel grades 15CrMoV5-10 (1.7745), X20CrMoV 11-1 (1.4922), X10CrMoVNb 9-1 (1.4903), or X11CrMoWVNb 9-1-1 (1.4905) or X10CrWMoVNb9-2 (1.4901), the holding time mainly depends on the intended weld metal properties (see clause 5.2). In the case of slag-forming welding processes the instructions of the filler metal manufacturer shall be observed.

Depending on the component thickness, the minimum holding time given in Table 4 is recommended to obtain optimum material properties.

5.5 If the steel grade 14MoV6-3 is provided in the air-hardened condition, repeated annealing should not exceed a total duration of 10 hours according to experience gained up to now. In this case, the heat treatments following the first annealing should not exceed the annealing temperature of 710 °C applied during first annealing.

5.6 In the case of components made of the steel grade 14MoV6-3 with thicknesses > 60 mm, deviations from the given annealing temperatures shall be agreed separately.

5.7 As no concrete specifications for temperature measurement are given in the harmonised product standards/applicable rules and in the German AD 2000 rules, the following recommendations are made.

5.7.1 Number, location and attachment of measuring points

The number and location of the measuring points can be found in Table 1.

Table 1: Location of thermocouples and number related to the circumference

Outer diameter D [mm]	**Number of thermocouples**	**Distribution over the circumference [°]**
D < 170	1	0
170 < D < 370	2	0, 180
D > 370	4	0, 90, 180, 270

The thermocouple conductors shall be attached by means of precision spot welders on the weld itself or, where required, on the base metal. In case of attachment on the weld metal, the distance to the welded joint should not exceed one times the weld thickness. The precision spot welder shall be suited for the conductor diameter to be welded on. The welding current shall be selected to correspond to the diameter of the thermocouple wires.

For each measuring point to be used for control it is recommended (starting with material group 6) to attach a further replacement thermocouple so that in case of failure of one measuring point (e.g. cable break) a substitute measuring point is available. Depending on the component and requirements it may be purposeful to use this measuring point for recording.

5.7.2 When selecting the temperature recorders, sufficient class accuracy shall be considered. The selection of class accuracy depends on the annealing temperature to be observed.

Temperature recorders with a class accuracy of ± 0.5% of the full scale value are usual. Higher class accuracies shall be agreed between customer and contractor.

For temperature measurements during heat treatments on welded joints X10CrMoVNb9-1, X11CrMoWVNb9-1-1, X10CrWMoVNb9-2 und 7CrMoVTiB10-10 temperature recorders with a class accuracy of 0.25 or digital paperless chart recorder with class accuracy 0.1 are required. Both temperature recorders with temperature chart recorder and print screens with electronic memory (compact flash card, FTP-transfer) and data output of the recorded parameters are permitted as recoding instruments.

5.7.3 As regards the quality requirements, the stipulations of DIN EN ISO 17663 „Welding - Quality requirements for heat treatment in connection with welding and allied processes“ apply.

Table 2a: Annealing temperature for similar welded joints and dissimilar welds independently of the product form (Material groups 1, 4 and 5)

Material sub-group to CEN ISO TR 15608	Material	Matl. No..	Material groups						
			1		4	5			
				1.5415	1.6368	1.7335	1.7380 1.7383	1.7362	1.7386
			1.1, 1.2 1.3, 1.4	1.1	4.2	5.1	5.2	5.3	5.4
1.1	C22.3	1.0427	550-600 [1]						
1.1	P250GH	1.0460							
1.1	P195GH, P235GH, P265GH	1.0345 1.0348 1.0425 1.0425							
1.1	WStE255	1.0462							
1.1	P275GH	1.0487							
1.2	P295GH	1.0481							
1.2	P355GH	1.0473							
1.2	P355NH	1.0565							
1.3	P420NH	1.8932							
1.3	P460NH	1.8935							
1.4	P315NH (WStE315)	1.0506							
1.4	P380NH (WStE380)	1.8930							
1.4	P500NH (WStE500)	1.8937							
1.1	16Mo3	1.5415	550-600 (unleg. / ~Mo)	550-620 (~Mo)					
4.2	15NiCuMoNb5-6-4	1.6368	550-600 (~Mo)	550-620 (~Mo)	570-620 [2] (~Mo, 1NiMo)				
5.1	13CrMo4-5	1.7335	–	600-620 (~Mo)	600-620 (~Mo, 1NiMo)	600-700 (~CrMo1)			
5.2	10CrMo9-10	1.7380	–	600-620 (~Mo)		650-700 (~CrMo1)	650-750 (~CrMo2)		
5.2	11CrMo9-10	1.7383	–	600-620 (~Mo)		650-700 (~CrMo1)	650-750 (~CrMo2)		
5.3	X11CrMo5	1.7362	–				680-730 (~CrMo2)	680-730 (~CrMo5)	
5.4	X11CrMo9-1	1.7386	–				720-750 (~CrMo2; ~CrMo9)	–	720-780 (~CrMo9)

Material sub-group to CEN ISO TR 15608	Material	Matl. No..	Material groups						
			1		4	5			
				1.5415	1.6368	1.7335	1.7380 1.7383	1.7362	1.7386
			1.1, 1.2 1.3, 1.4	1.1	4.2	5.1	5.2	5.3	5.4
6.1	14MoV6-3 3)	1.7715	–		680-720 (~CrMo1)		690-730 (~CrMo2)		
6.2	15CrMoV5-10	1.7745	–				710-740 (~CrMo2)		
6.2	7CrMoVTiB10-10	1.7378	–				730-750 (~CrMo2)		
6.4	X20CrMoV11-1	1.4922	–				730-750 (~CrMoWV12); 710-750 (~CrMo2)		
6.4	X10CrMoVNb9-1	1.4903	–				730-750 (~CrMo9-1); 710-750 (~CrMo2)		
6.4	X11CrMoWVNb9-1-1	1.4905	–				730-750 (~CrMoWVNb9-1-1); 710-750 (~CrMo2)		
6.4	X10CrWMoVNb9-2	1.4901	–				~750 (~CrMoWVNb9-2); 730-750 (~CrMo2)		
6.4	X12CrCoWMoVNb12-2-2	1.4915	–				730-750 (~CrMo9-1, ~CrCoW11-2)		
6.4	X11CrWMoMnV12-1-1 (HCM12)		–						
6.2	7CrWVMoNb9-6	1.8201	–				720-750		
9.1	12MnNiMo5-5	1.6343	550-590			–			
9.1	13MnNiMo5-4	1.8807				–			
9.1	11NiMoV5-3	1.6341				–			

Legend:
1) In case of full-body annealing of valves with seat buttering made of Fe8 and Fe10 to DIN EN 14700: 520 °C at maximum.
2) In case of heat treatment of the welded joint, the annealing temperature shall be below the tempering temperature of the semi-finished product; in case of repair of air-hardened 1.6368, the lower temperature range up to 530 °C shall be strived for.
3) In case of repeated annealing, the total duration of heat treatment should not exceed 10 hours in which case repeated annealing following the first annealing should not exceed 710 °C..

Table 2b: Annealing temperature for similar welded joints and dissimilar welds independently of the product form (Material groups 6 and 9)

Material sub-group to CEN ISO TR 15609	Material	Matl. no.	Material group									
			6									9
			1.7715	1.7745	1.7378	1.4922	1.4903 1.4905	1.4901	1.4915	HCM12	1.8201	
			6.1	6.2		6.4						9.1
6.1	14MoV6-3 [3]	1.7715	690-730 (~MoV)									
6.2	15CrMoV5-10	1.7745	690-730 (~CrMoV1, ~MoV)	710-740 (~CrMoV1)								
6.2	7CrMoVTiB10-10	1.7378			730-750 (~CrMo2VNb)							
6.4	X20CrMoV11-1	1.4922			730-750 (~CrMo2VNb)	720-770 (~CrMoWV12)						
6.4	X10CrMoVNb9-1	1.4903			730-750 (~CrMo2VNb, ~CrMo9-1)	750-770 (~CrMo9-1)	750-770 (~CrMo9-1)					
6.4	X11CrMoWVNb9-1-1	1.4905					750-770 (~CrMoWVNb9-1-1)					
6.4	X10CrWMoVNb9-2	1.4901			730-750 (~CrMo2VNb, CrMoWVNb9-2)		750-770 (~CrMo9-1, ~CrMoWVNb9-2)	750-780 (~CrMoWVNb9-2)				
6.4	X12CrCoWMoVNb12-2-2	1.4915			730-750 (~CrMo2VNb, ~CrCoW11-2)		750-770 (~CrMo9-1; ~CrMoWVNb9-1-1)	750-780 (~CrMoWVNb9-2)	760-790 (~CrCoW11-2)			
6.4	X11CrWMoMnV12-1-1 (HCM12)									700-780 (~HCM12)		
6.2	7CrWVMoNb9-6	1.8201		720-740	730-750	720-770	750-770	750-780	760-780	720-780	720-780 (~CrWV2)	
9.1	12MnNiMo5-5	1.6343	–									530-590
9.1	13MnNiMo5-4	1.8807	–									
9.1	11NiMoV5-3	1.6341	–									

Legend:
1) In case of full-body annealing of valves with seat buttering made of Fe8 and Fe10 to DIN EN 14700: 520 °C at maximum.
2) In case of heat treatment of the welded joint, the annealing temperature shall be below the tempering temperature of the semi-finished product; in case of repair of air-hardened 1.6368, the lower temperature range up to 530 °C shall be strived for.
3) In case of repeated annealing, the total duration of heat treatment should not exceed 10 hours in which case repeated annealing following the first annealing should not exceed 710 °C.

Table 3: Annealing temperature for welded joints between differing heat-resisting cast steel and rolled and forged steels, using the recommended weld filler metals.

Ser. no.	Combinations		Recommended filler metals	Annealing temperature [°C]
	Component	Weld attachment		
1	GP240GH (1.0619)	P235GH P265GH	unalloyed	540 to 600
		16Mo3	similar to 16Mo3	
2	G20Mo5 (1.5419)	16Mo3	similar to 16Mo3	
		13CrMo4-5 / 10CrMo9-10 / 11CrMo9-10	similar to 16Mo3 oder	
			similar to 13CrMo4-5	630 to 680
3	G17CrMo5-5 (1.7357)	13CrMo4-5 / 10CrMo9-10 / 11CrMo9-10	similar to 13CrMo4-5 or similar to 10CrMo9-10	640 to 700
		14MoV 6-3	similar to 13CrMo4-5	670 to 720
4	G17CrMoV5-10 (1.7706)	13CrMo4-5	similar to 13CrMo4-5	
		10CrMo9-10 / 11CrMo9-10 14MoV6-3 21CrMoV5-7 (1.7709)	similar to 10CrMo9-10 or similar to 17CrMoV5-11 similar to 21CrMoV5-7	
	G17CrMo9-10 (1.7379)	10CrMo9-10 / 11CrMo9-10 21CrMoV5-7 (1.7709)	similar to 10CrMo9-10 similar to 17CrMoV5-11	
		X20CrMoV11-1	similar to X20CrMoV11-1 or S Ni 6082 / E Ni 6082 (NiCr20Mn3Nb)	
5	GX23CrMoV12-1 (1.4931)	14MoV6-3	similar to 17CrMoV5-11 or similar to X20CrMoV11-1 or S Ni 6082 / E Ni 6082 (NiCr20Mn3Nb)	
		10CrMo9-10 / 11CrMo9-10	similar to 10CrMo9-10 or similar to X20CrMoV11-1 or S Ni 6082 / E Ni 6082 (NiCr20Mn3Nb)	
		21CrMoV5-7 (1.7709)	similar to 17CrMoV5-11 or similar to X20CrMoV11-1 or S Ni 6082 / E Ni 6082 (NiCr20Mn3Nb)	
		X20CrMoV11-1	similar to X20CrMoV11-1 or S Ni 6082 /E Ni 6082 (NiCr20Mn3Nb)	680 to 730

Table 4: Holding time during post-weld heat treatment of welded joints in dependence of the component thickness

Steel grade **Short designation / material no.**	**Weld metal thickness [mm]**	**Holding time [min]**
15CrMoV5-10 (1.7745)	≤ 8	30 min
	> 8 to ≤ 20	60 min
	> 20	≥ 3 min/mm
7CrMoVTiB10-10 (1.7378)	> 10	60 min
X10CrMoVNb9-1 (1.4903) X11CrMoWVNb9-1-1 (1.4905) X10CrWMoVNb9-2 (1.4901) X12CrCoWMovNb12-2-2 (1.4915)	≤ 8	at least 30 min
	> 8	≥ 2,5 min/mm, at least 30 min
X20CrMoV11-1 (1.4922)	≤ 8	30 min
	> 8 to ≤ 30	60 min
	> 30 to ≤ 60	120 min
	> 60	ca. 180 min
Other steel grades	≤ 15	at least 15 min
	> 15 to ≤ 30	at least 30 min
	> 30	approx. 60 min

In addition to these instruction the weld filler metal manufacturers‘specifications shall be observed.

6 Former agreements

This agreement overrides the agreement 2003/3.

7 Effective date

This agreement shall apply to all steam boilers and becomes effective upon signature.

Düsseldorf, 9th January 2018
FDBR e. V. Fachverband Anlagenbau e. V.
signed

Dr. Maaß

Essen, 3rd January 2018
VGB PowerTech e. V.
signed

Christensen

Berlin,16th January 2018
VdTÜV Verband der TÜV e. V.
signed

Dr. Bühler