d) where it is proposed to use materials in thickness greater than permitted by the low temperature requirements.

NOTE Guidance on fracture mechanics analysis is given in publications [5] to [10] listed in the bibliography.

Such analyses shall be undertaken in accordance with the requirements of B.2.4.2 to B.2.4.5.

B.2.4.2 Fracture toughness properties shall be obtained in accordance with fracture toughness testing procedures using full thickness single edge notched bend specimens or equivalent compact tension tests with fatigue cracks located through thickness in the weld centre-line and in parent material. Further test sampling of heat affected zone regions shall also be specified, particularly when fatigue or some other in-service crack growth mechanism may be significant.

When HAZ tests are specified special considerations are necessary with regard to the placement of the notch and metallurgical sectioning subsequent to testing.

B.2.4.3 For material not covered by the low temperature requirements of methods 1 or 2, a similar level of tolerance to fracture can be obtained. This can be done by specifying fracture toughness requirements determined from the use of assessment procedures such as in [9] with a reference defect size as determined by the manufacturer (e.g. a through wall flaw of total length equal to 10 mm, or a quarter wall thickness surface flaw with length six times its depth). Also inputs of an equivalent stress (or strain) relating to the hydraulic test condition, for a defect in a region of stress concentration and subject to residual stresses equivalent to the room temperature yield strength of the base material for as welded components, or 30 % of yield for post weld heat treated components can be specified.

B.2.4.4 If non-destructive testing methods are employed which allow accurate sizing of defects, these values, together with information on the stress state of the critical regions in the vessel, shall be used with appropriate fracture assessment procedures to specify more accurate toughness requirements than those specified by Method 1 or 2.

B.2.4.5 For materials which are covered by the low temperature requirements for Method 1 or 2, but where the Charpy impact energy requirements cannot be met, a fitness for purpose assessment using representative fracture toughness data and inspection requirements may be employed to determine the integrity of the vessel for its intended use.

B.3 General test requirements

B.3.1 General

Where impact tests are required, Charpy-V-notch tests shall be performed in accordance with EN ISO 148-1:2010. The impact energy requirements shall be met in the base material, heat affected zone and weld metal.

The specimen position shall be in accordance with the specifications in the technical delivery conditions of the product form for materials for pressure equipment. For welded joints the specimen position for weld metal and HAZ shall be in accordance with EN 13480-4:2017.

From each sample three specimens shall be tested for each of the required positions and material impact test temperature T_{KV}. The mean value of the three specimens shall be at least equal to the impact energy requirement. Only one specimen may show a lower value, but this value shall not be less than 70 % of this requirement.

The required values for base material shall refer to the transverse direction. If geometry does not allow to extract specimen in the transverse direction the impact energy values shall be taken from tests in the longitudinal direction. The minimum impact energy requirements specified for transverse test pieces shall then be multiplied by the factor 1,5 for C, CMn, fine grained, low alloyed steels and high strength steels.

B.3.2 Sub-sized specimens

If sub-sized Charpy specimens shall be used, the measured value of the Charpy energy shall be proportionally converted to the reference specimen thickness of 10 mm. Table B.3-1 gives an example for 7,5 mm and 5 mm thick specimens. Where test pieces at least 5 mm wide cannot be obtained, the material shall not be subject to impact testing. For pipes with nominal thickness lower than 6,3 mm no impact testing is required.

Table B.3-1 — Impact requirements for sub-sized Charpy V-notched specimen if the base material is less than 10 mm thick

Reference value	Sub sized specimen	
Specimen geometry		
10 mm × 10 mm	10 mm × 7,5 mm	10 mm × 5 mm
Minimum impact energy J		
27	20	14
40	30	20

If full size Charpy specimen cannot be extracted from components and welds sub-sized specimens shall be tested. To represent the behaviour of a full thickness specimen a lower impact test temperature shall be applied. The temperature shifts shall be in accordance with Table B.3-2.

Impact tests should be performed on the maximum thickness, which can be extracted from the component under consideration.

Table B.3-2 — Equivalent impact energy requirements when sub sized specimens are extracted from thicker sections

Required impact energy	Specimen geometry	Sub-sized specimen requirement		
KV J	mm	*KV* J	Specimen geometry mm	Shift of impact test temperature °C
27	10 × 10	20 14	7,5 × 10 5,0 × 10	T_{KV} – 5 T_{KV} – 20
40	10 × 10	30 20	7,5 × 10 5,0 × 10	T_{KV} – 5 T_{KV} – 20
20	7,5 × 10	14	5,0 × 10	T_{KV} – 15
30	7,5 × 10	20	5,0 × 10	T_{KV} – 15
14	5,0 × 10	—	—	—
20	5,0 × 10	—	—	—

B.4 Welds

B.4.1 General

When materials are to be joined by welding, the choice of welding consumables and welding procedures shall ensure that in addition to the requirements of EN 13480-4:2017, the required impact energy properties are achieved in weld metal and heat affected zone regions, when tested in accordance with B.3.

The required impact energy shall be at least equal to the specified minimum impact energy for the base metal. The requirements of method 1 or 2 shall be met.

B.4.2 Welding procedure qualification

Welding procedure qualification shall be performed in accordance with EN 13480-4:2017.

B.4.3 Production test plates

For tubes and fittings with longitudinal or helical welds according to harmonised European Standards as normative references in this European standard, no further production testing is needed. For non standard components production testing shall be carried out in accordance with EN 13445-4:2014**.**

B.5 Materials for use at elevated temperatures

B.5.1 General

B.5 applies for pressure equipment with design temperature for normal operation higher than 50 °C and where:

— the material temperature at start up, shut down and at possible process upsets is not lower than –10 °C and

— start up and shut down procedure is under controlled conditions as given in B.5.4 and

— the conditions for pressure test as specified in B.5.5 are fulfilled.

If any of these requirements is not satisfied the methods for low temperature materials shall be applied.

NOTE The limitation regarding start-up and shut-down, process upsets and pressure test are not applicable to austenitic stainless steels.

B.5.2 Materials

Materials including weldments, in the finished pressure equipment shall have a specified minimum impact energy measured on a standard Charpy-V-notch impact test specimen (see EN ISO 148-1:2010) as follows:

— ≥ 27 J for ferritic and 1,5 % to 5 % Ni alloyed steels;

— ≥ 40 J for steels of material group 8, 9.3 and 10,

at a temperature not higher than 20 °C.

B.5.3 Welding procedure qualification and production test plates

Welding procedure qualification shall be performed in accordance with EN 13480-4:2017.

The weld production test plate shall be performed in accordance with EN 13480-4:2017.

B.5.4 Start up and shut down procedure

To avoid brittle fracture occurrence of pressure equipment made of ferritic or austenitic-ferritic steels during start-up and shut-down procedures, the pressure shall not exceed 50 % of the design pressure at temperatures lower than 20 °C.

This start-up and shut-down procedure need not to be considered, if the evaluation of the specified minimum impact values against Method 2 allows design pressures at lower temperatures.

B.5.5 Pressure test

Hydrostatic pressure test of piping made of ferritic or austenitic-ferritic steels shall not be carried out at material temperatures lower than 10 °C.

This temperature limitation needs not to be considered, if the evaluation of the specified minimum impact values against Method 2 allows design pressures at lower temperatures.

Table B.4-1 — Reference thickness e_B

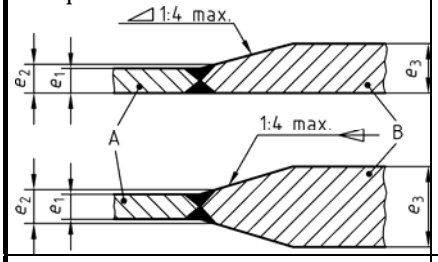
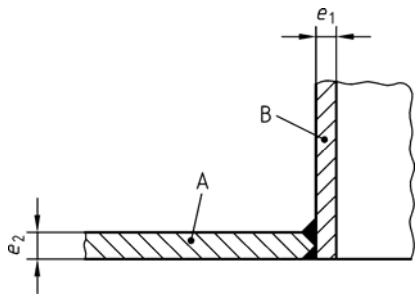
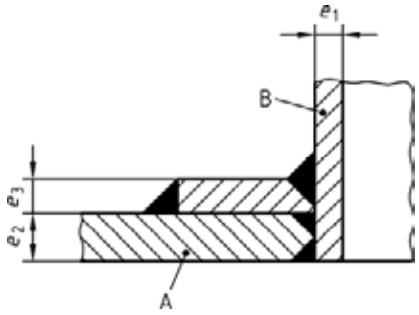
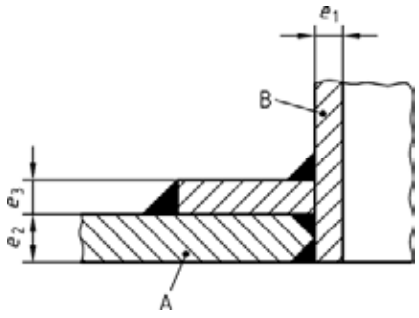
No.	Construction detail	as-welded (AW) or post weld heat treated (PWHT)	Reference thickness		
			Part A	Weld	Part B
1	Butt welded components of unequal thickness 	AW	e_1	e_2	e_2 [a] check e_3 [a] in Figures B.2-2, B.2-4, B.2-6, B.2-8
		PWHT	e_1	e_2	e_3
2	Branches and nozzles 	AW	e_2	e_2	e_1
		PWHT	e_2	e_2	e_1
3		AW	e_2	e_2 or e_3, if thicker	e_1
		PWHT	e_2	e_2 or e_3, if thicker	e_1
4		AW	e_2	e_2 or e_3, if thicker	e_1
		PWHT	e_2	e_2 or e_3 if thicker	e_1

Table B.4-1 (*continued*)

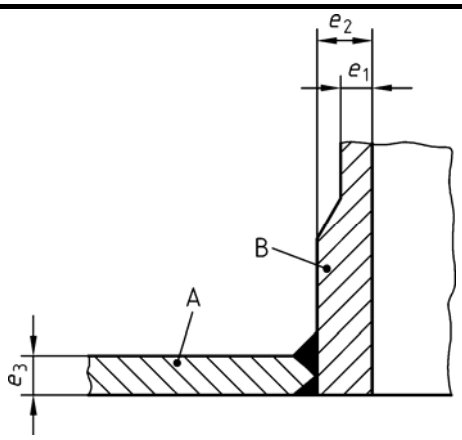
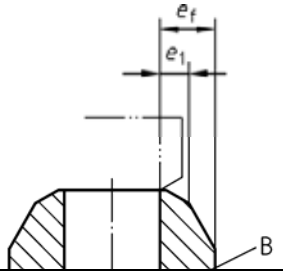
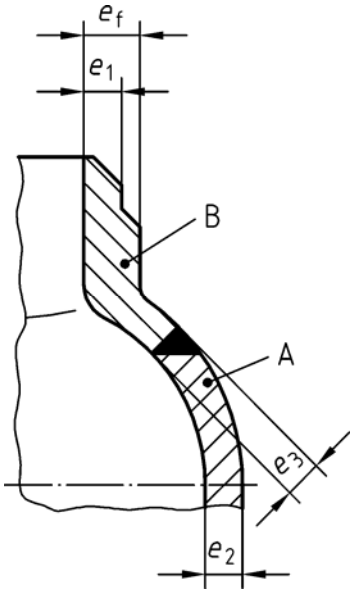
No.	Construction detail	as-welded (AW) or post weld heat treated (PWHT)	Reference thickness		
			Part A	Weld	Part B
5		AW	e_3	e_2 or e_3, if thicker	e_2
		PWHT	e_3	e_2 or e_3, if thicker	e_2
6	‼ INCLUDEPICTURE "../EN%2013480-2_2012_Issue%203_2014-08/EN_13480-2_2011_Issue%201/Figures_EN_13480-2_A2_2010/TB6_6.tif" * MERGEFORMAT 	AW	e_2	e_2	e_1 or $e_f/4$ if thicker
		PWHT	e_2	e_2	e_1[a] or $e_f/4$ [a], if thicker if necessary check e_1 in Figures B.2-1, B.2-3, B.2-5, B.2-7
7		AW	e_2	e_3	e_3 or $e_f/4$, if thicker ,
		PWHT	e_2	e_3	e_3 [a] or $e_f/4$ [a], if thicker if necessary check e_1 in Figures B.2-1, B.2-3, B.2-5, B.2-7

Table B.4-1 (*continued*)

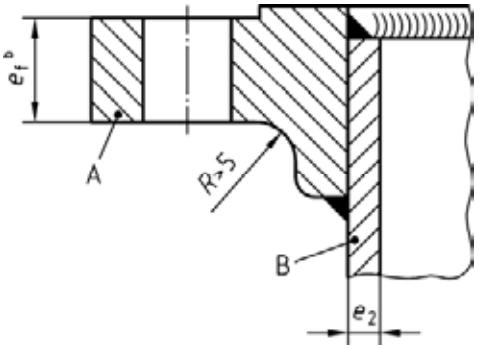
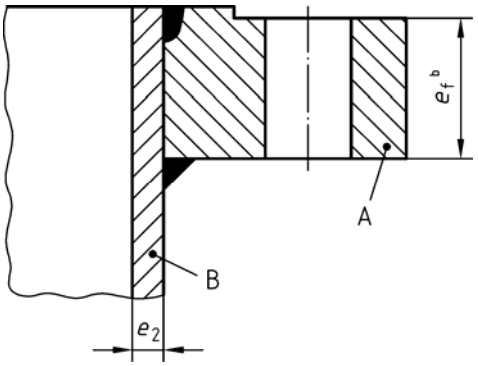
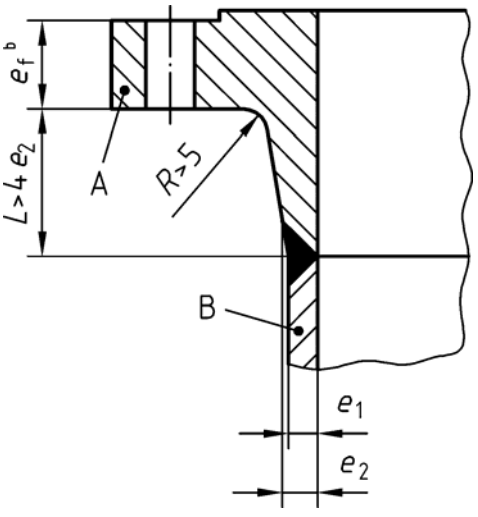
No.	Construction detail	as-welded (AW) or post weld heat treated (PWHT)	Reference thickness		
			Part A	Weld	Part B
8	Slip-on and plate flanges [c] 	AW	e_2 *or* $e_f/4$, if thicker	e_2 *or* $e_f/4$, if thicker	e_2
		PWHT	e_2 *or* $e_f/4$, if thicker	e_2 *or* $e_f/4$, if thicker	e_2
9		AW	e_2 *or* $e_f/4$, if thicker	e_2 *or* $e_f/4$, if thicker	e_2
		PWHT	e_2 *or* $e_f/4$, if thicker	e_2 *or* $e_f/4$, if thicker	e_2
10	Forged or cast welding neck flanges [c] 	AW	e_2 [a] check $e_f/4$ [a] in Figures B.2-1, B.2-3, B.2-5, B.2-7	e_2	e_1
		PWHT	e_2 or $e_f/4$, if thicker	e_2	e_1

Table B.4-1 (*continued*)

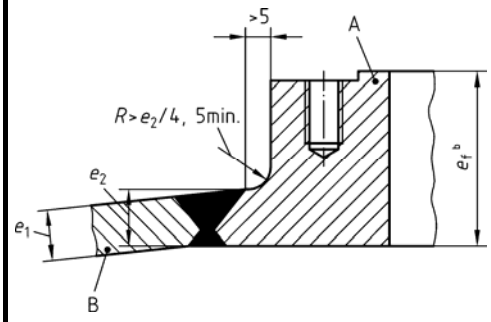
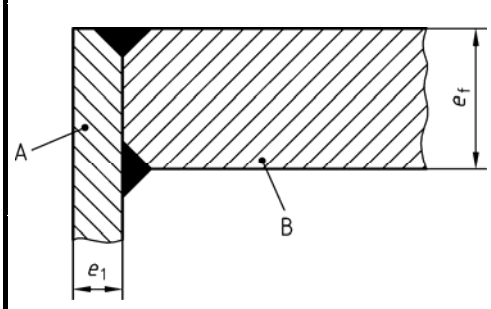
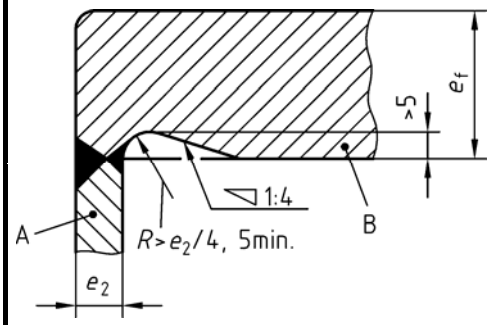
No.	Construction detail	as-welded (AW) or post weld heat treated (PWHT)	Reference thickness		
			Part A	Weld	Part B
11	Pad-type flanges 	AW	e_2 [a] check $e_f/4$ [a] in Figures B.2-2, B.2-4, B.2-6, B.2-8	e_2	e_1
		PWHT	e_2 or $e_f/4$, if thicker	e_2	e_1
12	Flat ends 	AW	e_1	e_1	$e_f/4$ or e_1, if thicker
		PWHT	e_1	e_1	$e_f/4$ or e_1, if thicker
13		AW	e_2	e_2	e_2 [a] or check $e_f/4$ [a], in Figures B.2-2, B.2-4, B.2-6, B.2-8
		PWHT	e_2	e_2	e_2 or $e_f/4$, if thicker

Table B.4-1 (*continued*)

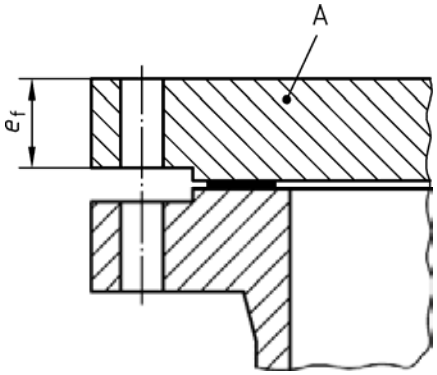
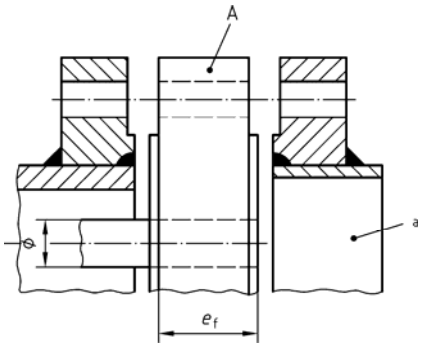
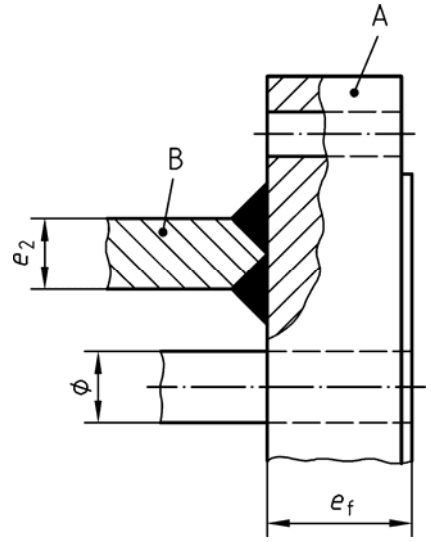
No.	Construction detail	as-welded (AW) or post weld heat treated (PWHT)	Reference thickness		
			Part A	Weld	Part B
14	Covers and blind flanges 	AW	$e_f/4$	—	—
		PWHT	$e_f/4$	—	—
15	Measuring Plate 	AW	(n. a.)	(n. a.)	(n. a.)
		PWHT	$e_f/4$	(n. a.)	(n. a.)
16		AW	$e_f/4$ or e_2, if thicker	e_2	e_2
		PWHT	$e_f/4$ or e_2, if thicker	e_2	e_2

Table B.4-1 (*continued*)

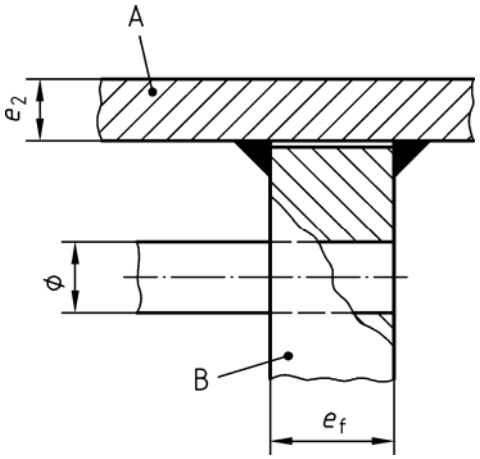
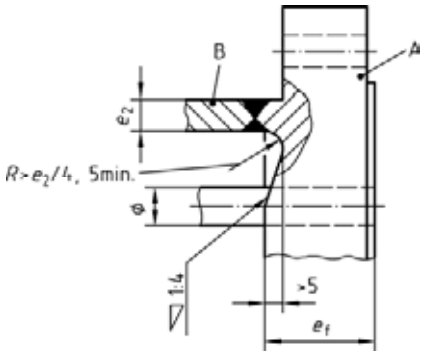
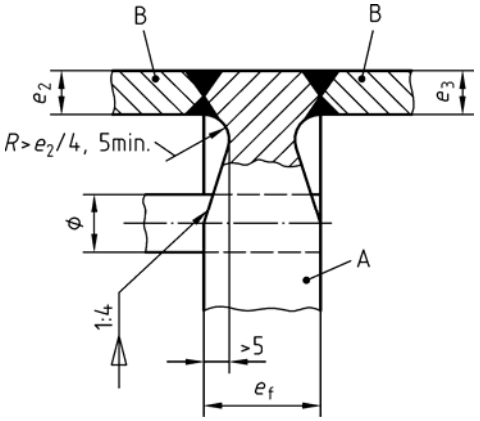
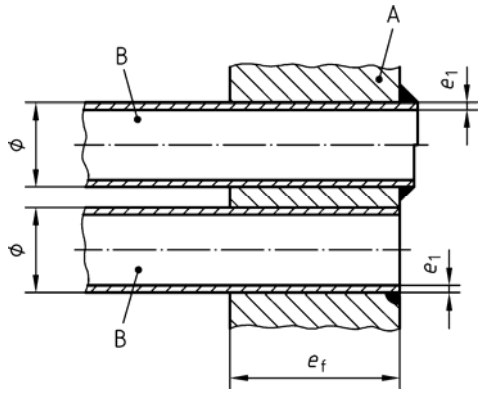
No.	Construction detail	as-welded (AW) or post weld heat treated (PWHT)	Reference thickness		
			Part A	Weld	Part B
17	Welded into shell/channel 	AW	e_2, check $e_f/4$ in Figures B.2-2, B.2-4, B.2-6, B.2-8	e_2	e_2 or $e_f/4$ if thicker
		PWHT	e_2 or $e_f/4$, if thicker	e_2	e_2 or $e_f/4$ if thicker
18	Forged tube plate with stubs 	AW	e_2 [a] check $e_f/4$ [a] in Figures B.2-2, B.2-4, B.2-6, B.2-8	e_2	e_2
		PWHT	$e_f/4$ or e_2, if thicker	e_2	e_2
19		AW	e_2 [a] or e_3 [a], if thicker check $e_f/4$ [a] in Figures B.2-2, B.2-4, B.2-6, B.2-8	e_2 (e_3)	e_2 (e_3)
		PWHT	$e_f/4$ or e_2 or e_3, if thicker	e_2 (e_3)	e_2 (e_3)

Table B.4-1 (*continued*)

No.	Construction detail	as-welded (AW) or post weld heat treated (PWHT)	Reference thickness		
			Part A	Weld	Part B
20	Tube-to-tube plate connection 	AW	(n. a.)	e_1	e_1
		PWHT	b	e_1	e_1

NOTE 1 (n. a.) means "not applicable".

NOTE 2 e_1, e_2 and e_3 refer to the nominal thickness of the various components shown in the figures.

1 e_f may be measured radically if that gives an advantage.

[a] The minimum test temperature of the two conditions: e_x (AW), e_y (PWHT) shall be taken.

[b] Reference thickness of part A is unaffected by this connection.

[c] For welding neck flanges and slip on flanges according to EN 1092-1:2007, R shall be as given in EN 1092-1:2007.