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1. Definition

Metal welding (according to DIN EN 14610 and DIN 1910-100, Supplements)

Process of joining metal(s) by use of heat and/or pressure resulting in a continuous inner composition of the joined metal or metals.

Note 1 – Welding filler that has a melting temperature of the same order as the base material(s) can be applied. The welding result is the welded seam.

Note 2 – This definition includes build-up welding.

2. Metal welding procedures and metal welding processes

2.1 Metal welding procedures and energy carriers (according to DIN EN 14610)

Metal welding procedures:

- Pressure welding
- Fusion welding
- build-up welding
- Joint welding

Energy carriers:

Physical phenomenon that provides the required energy for welding either by transferring it onto the work piece(s) or converting it inside the work piece(s).

Energy carriers:

1 Solid body
2 Fluid
3 Gas
4 Electrical gas discharge
5 Radiation
6 Mass movement
7 Electrical current
8 Undefined

2.2 Metal welding processes

For the purpose of referencing in drawings (according to DIN EN 14610 and DIN EN ISO 4063), welding procedures commonly used at BLOA are listed. Only fusion welding is described in the following.

		Reference DIN EN ISO 4063
Oxyacetylene gas welding		3
Arc fusion welding		1
Manual arc welding		111
Tungsten inert-gas welding	(WIG welding)	141
Inert-gas metal arc welding	(MIG welding)	131
Active-gas metal-arc welding	(MAG welding)	135

2.3 General tolerances for welded constructions

Tolerances are specified in BLOA standard LHH-N 091.109.

2.4 Imperfections and their assessment in fusion welding

2.4.1 Imperfections (according to DIN EN ISO 6520-1)

These are divided into 6 groups.

1. Cracks : Microcrack, longitudinal crackg, cross-crack, star-shaped crack, crater-crack, crack accumulation, feather crack
2. Holes : Pores, porosity, pore groups, pore lines, gas channel, hose pore, surface pore, macro-bubble, micro-bubble, crater bubble
3. Solid inclusions : Slag inclusion, flux inclusion, oxide inclusion, oxide skin, foreign metal inclusion
4. Lack of fusion and insufficient penetration
5. Shape and size deviations : Indentation, root indentation, seam too large and root over-dimensions, steep seam transition, welding seam overrun, edge offset, angle offset, welding deposit runs off centre, burn out, top layer camber, excessive imperfection, imperfect seam line, root concavity, root porosity, offset error
6. Other imperfections : Arc burn, spatter, tungsten spatter, break, grinding indentation, chip indentation, undergrinding

The imperfections stated are specified by identification numbers and partially shown.

2.4.2 Assessment groups (according to DIN EN ISO 5817))

The assessment of the imperfections stated above can be carried out within three assessment groups:

D = low C = medium B = high

The threshold limit values are specified in the standard DIN EN ISO 5817. They apply for butt **and** fillet seams.

Group **C** or **B** may be specified at **BLOA**, whereby the selection is made according to economic and functional reasons. The selection is documented in the header of the drawing by crossing out the inapplicable group.

3. Representation on drawings (according to DIN EN 22553)

3.1 General

The seams must be specified according to the general rules for technical drawings (**pictorial** representation). In some cases, it is advisable to use a **symbolic** representation according to section 3.4. The drawing specifications according to DIN EN 22553 apply here. These may be used also in addition to the pictorial representation when additional specifications are necessary.

3.2 Pictorial representation

The edge form and the dimensioning are defined in 3.4 of this standard.

The welding seam profiles must be marked black in the drawing.

3.3 Symbolic representation

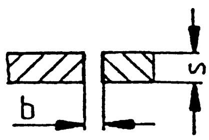
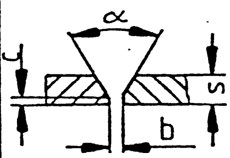
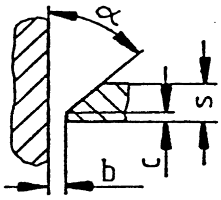
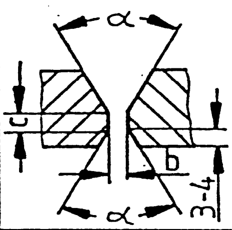
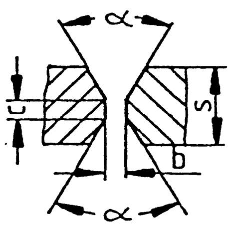
3.3.1 The symbolic representation includes

- A basic symbol (see section 3.4, first column)
- Additional symbols (see DIN EN 22553 section 4.3), surface shape and procedure type of seam, progression of seam, assembly seam
- Dimensions specification (see DIN EN 22553 section 6)
- Additional specifications (see DIN EN 22553 section 7.3 and 7.4)
  Type of welding process (DIN EN ISO 4063), assessment group
  (see section 2.4.2)
- Welding position (see DIN EN 22553), additional materials (DIN EN ISO 18273, DIN EN ISO 2560, DIN EN ISO 3581)

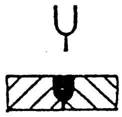
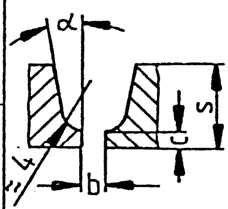
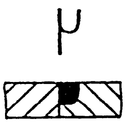
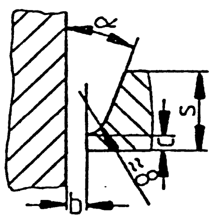
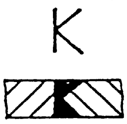
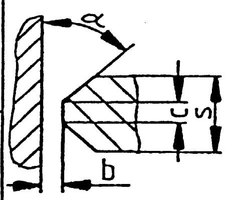
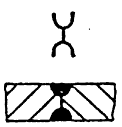
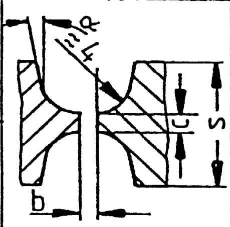
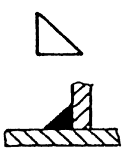
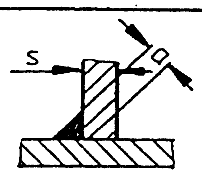
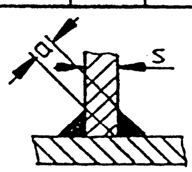
3.3.2 Position of the symbols in drawings

Observe the specifications according to DIN EN 22553 section 5.

3.4 Seam types, symbols, edge forms according to DIN EN ISO 9692-1

Nahtart Symbol Schnitt (bildl.)	Werkstück- dicke s mm	* Ausfg.- art	Schweiß- verfahren	Fugenform	α Grad	b mm	c mm	Bemerkung
I-Naht ǁ 	bis 3	eins. beids.	Lichtbogen			s s/2		Nur in w-Position
	bis 3	eins. beids.	Schutzgas (WIG) (MIG) (MAG)			0 b. s/2		
V-Naht V 	3 bis 8 4 bis 8	eins. beids.	Lichtbogen		60	3	1,5	Wurzel aus- arbeiten, Kapplage schweißen
	3 bis 8 4 bis 8	eins. beids.	Schutzgas			2		
HV-Naht V 	3 bis 8 5 bis 8	eins. beids.	Lichtbogen		50	3	1,5	
	6 bis 20	eins.	Schutzgas		55	3	1,5	
Unsymetr. Doppel- V-Naht X 	8 bis 16	beids.	Lichtbogen		60	3	2	Wurzel aus- arbeiten, Kapplage schweißen
	8 bis 16	beids.	Schutzgas					
Doppel- V-Naht (X-Naht) X 	12 bis 35	beids.	Lichtbogen		60	3	2	Wurzel aus- arbeiten
	12 bis 35	beids.	Schutzgas					

*Choose double-sided design, if accessible.

Nahtart Symbol Schnitt (bildl.)	Werkstück-dicke s mm	Ausfg.-art	Schweiß-verfahren	Fugenform	α Grad	b mm	c mm	Bemerkung
U-Naht 	16 bis 35	eins.	Lichtbogen		10	3	2	
	16 bis 35	eins.	Schutzgas		10	3	2	
HU-Naht (Jot-Naht) 	16 bis 35	eins.	Lichtbogen		20	3	2	
	16 bis 35	eins.	Schutzgas		20	3	2	
Doppel-HV-Naht (K-Naht) 	8 bis 35	beids.	Lichtbogen		50	3	2	Wurzel aus-arbeiten
	8 bis 35	beids.	Schutzgas		55	3	2	
Doppel-U-Naht 	≧ 35	beids.	Lichtbogen		10	3	2	Wurzel aus-arbeiten
	≧ 35	beids.	Schutzgas		10	3	2	
Kehlnaht 				 a = 0,7 × s	 a = 0,5 × s, s min ≧ 6			a min. = 3, a max. = 8

3.4.1 Glossary

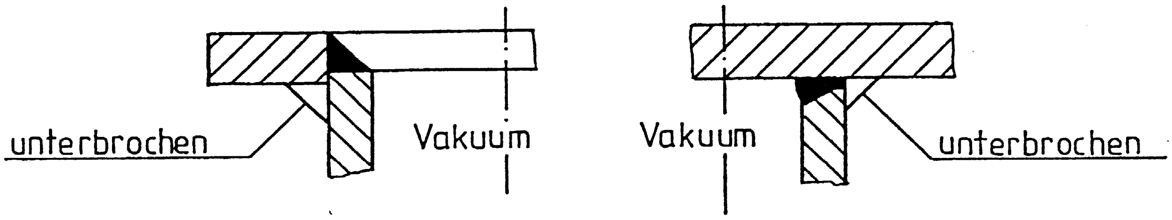
Make use of this glossary when reading table 3.4.

Nahtart	Seam type
Symbol	symbolic representation
Schnitt (bildl.)	section (pictorial)
Werkstückdicke	Workpiece thickness
Ausfg.-art	Design type
Schweißverfahren	Welding procedure
Fugenform	Edge form
Grad	Degrees
Bemerkung	Note
I-Naht	I-seam
bis 3	Up to 3
eins.	Single- sided
beids.	Double-sided
Nur in w-Position	Only w-position
V-Naht	V-seam
HV-Naht	HV-seam
Unsymetr. Doppel-V-Naht	Asymetric double-sided V-seam
Doppel-V-Naht (X-Naht)	Double-sided V-seam (X seam)
3 bis 8	3 to 8
Kapplage schweißen	Welding cap position
U-Naht	U-seam
HU-Naht (Jot Naht)	HU-seam (Y-seam)
Doppel-U-Naht	Double-sided U-seam
Kehlnaht	Fillet seam
Lichtbogen	Arc welding
Schutzgas	Inert gas
Doppel HV Naht (K-Naht)	Double HV seam (K-seam)
Wurzel ausarbeiten	Complete root

4. Guidelines for vacuum chambers and components

4.1 General

When welding vacuum chambers and components, the most important point is to avoid gas and dirt inclusions at the connection points. For this reason, the seams on the vacuum side must be continuous and double seams should be avoided (because of the gas inclusion). If double seams are required for structural and physical reasons, the outer seam must be interrupted several times.



interrupted vacuum vacuum interrupted

When determining the design of the welding seams keep in mind that the welding seams must be tested for vacuum tightness using a leak detector. Also for this reason, double seams should be avoided. If not possible the outer welding seam must be interrupted and should not be too long. In this way, possible leaks in the seam on the vacuum side can be located.

4.2 Technical welding guidelines

4.2.1 Cross and multiple joints are not permitted.

4.2.2 The distance between two stress-bearing seams should be greater than 4 x the sheet metal thickness.

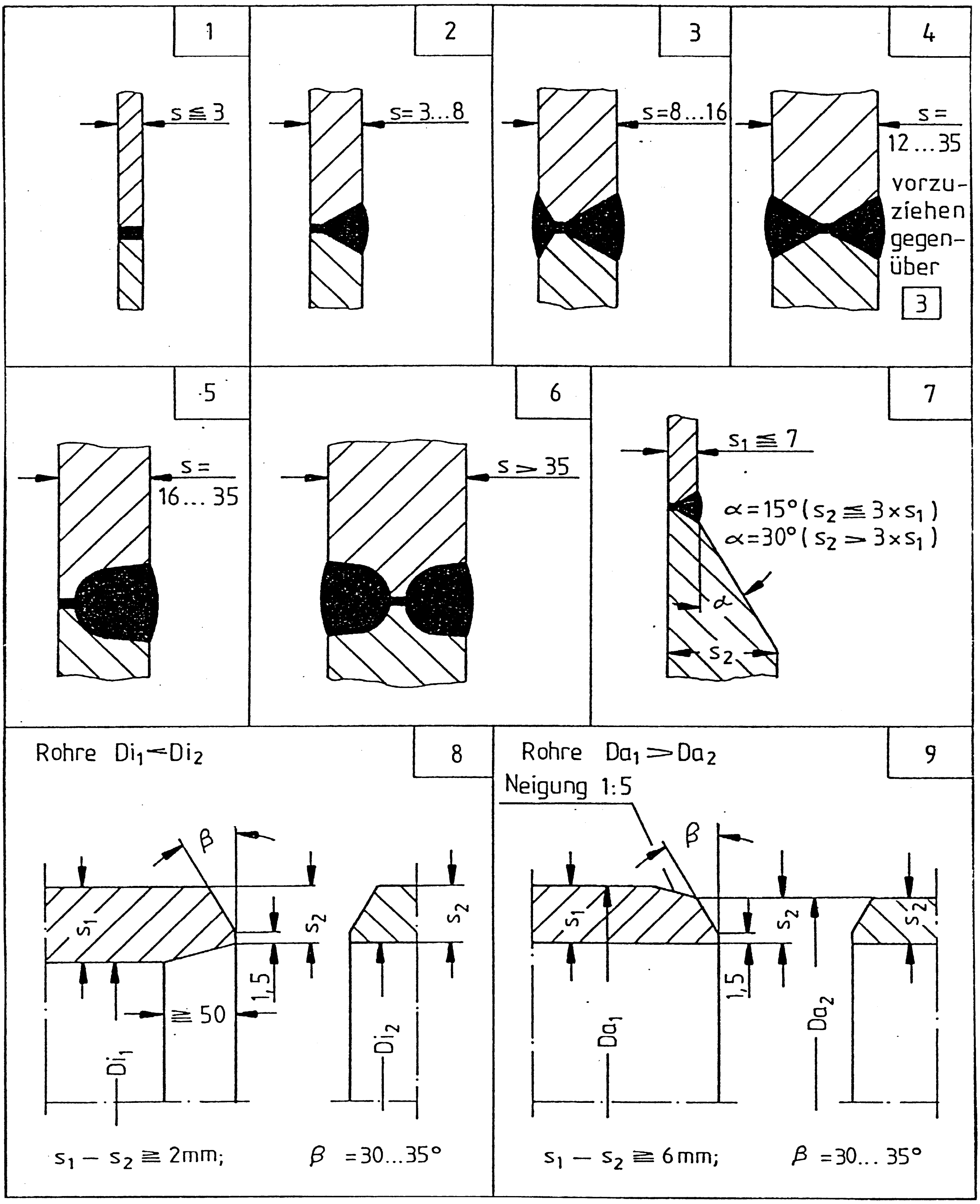
4.2.3 Stress-bearing main seams (e.g. circumferential and longitudinal seams on containers) may only be hidden by welded subparts in exceptional cases. In addition, the stress-bearing seam must be tested for correctness and tightness before welding of these subparts to the main part or the subpart must be designed so that a test is possible (e.g. sparing).

4.2.4 Avoid welding of stubs into circumferential or longitudinal seams.

4.2.5 Arrange the longitudinal seams with a 180° offset when welding pipe lengths together.

4.3 Welding joint examples

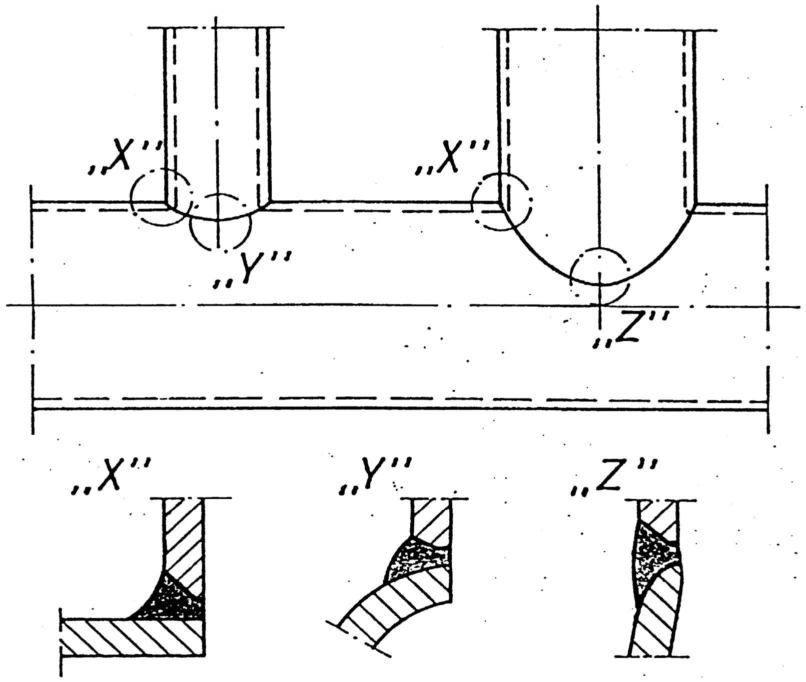
4.3.1 Sheet metal or pipe joints (in dependence of the metal thickness)



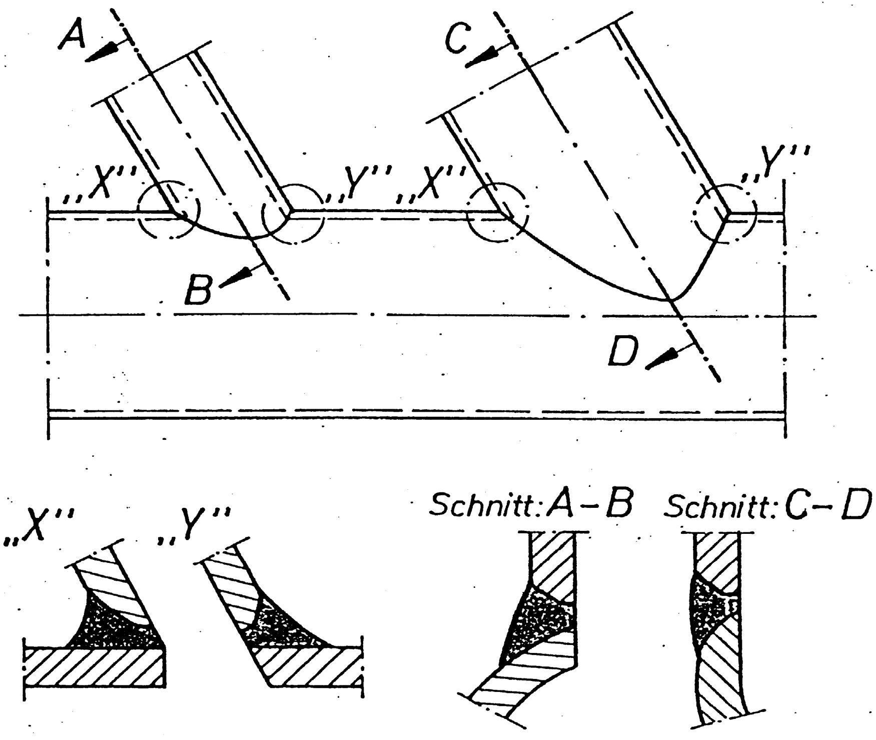
Glossary:

vorzuziehen gegenüber	to be preferred over
Rohre	pipe, pipes
Neigung	inclination

10



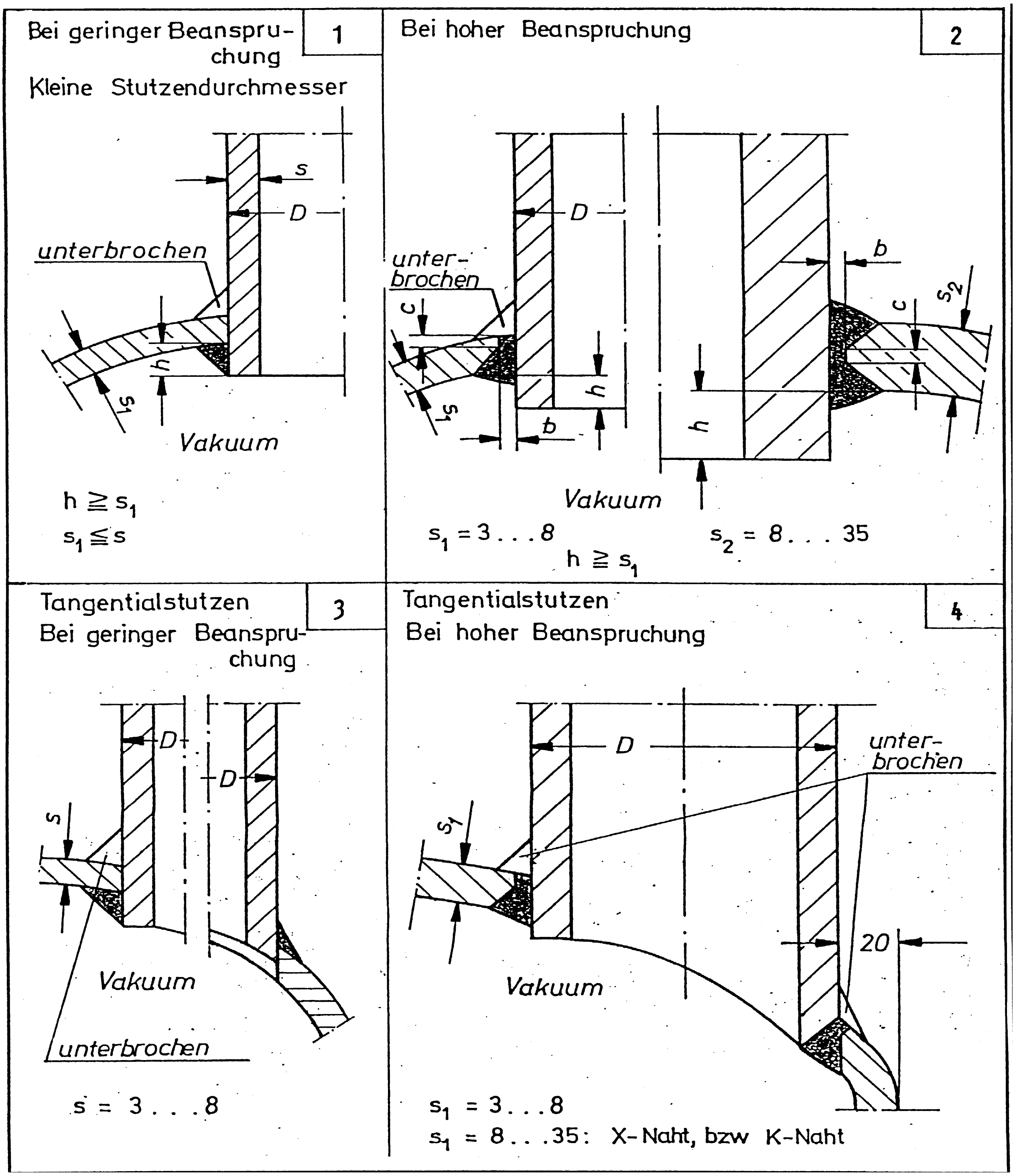
11



Glossary:

Schnitt: A – B	section: A - B
Schnitt: C – D	section: C - D

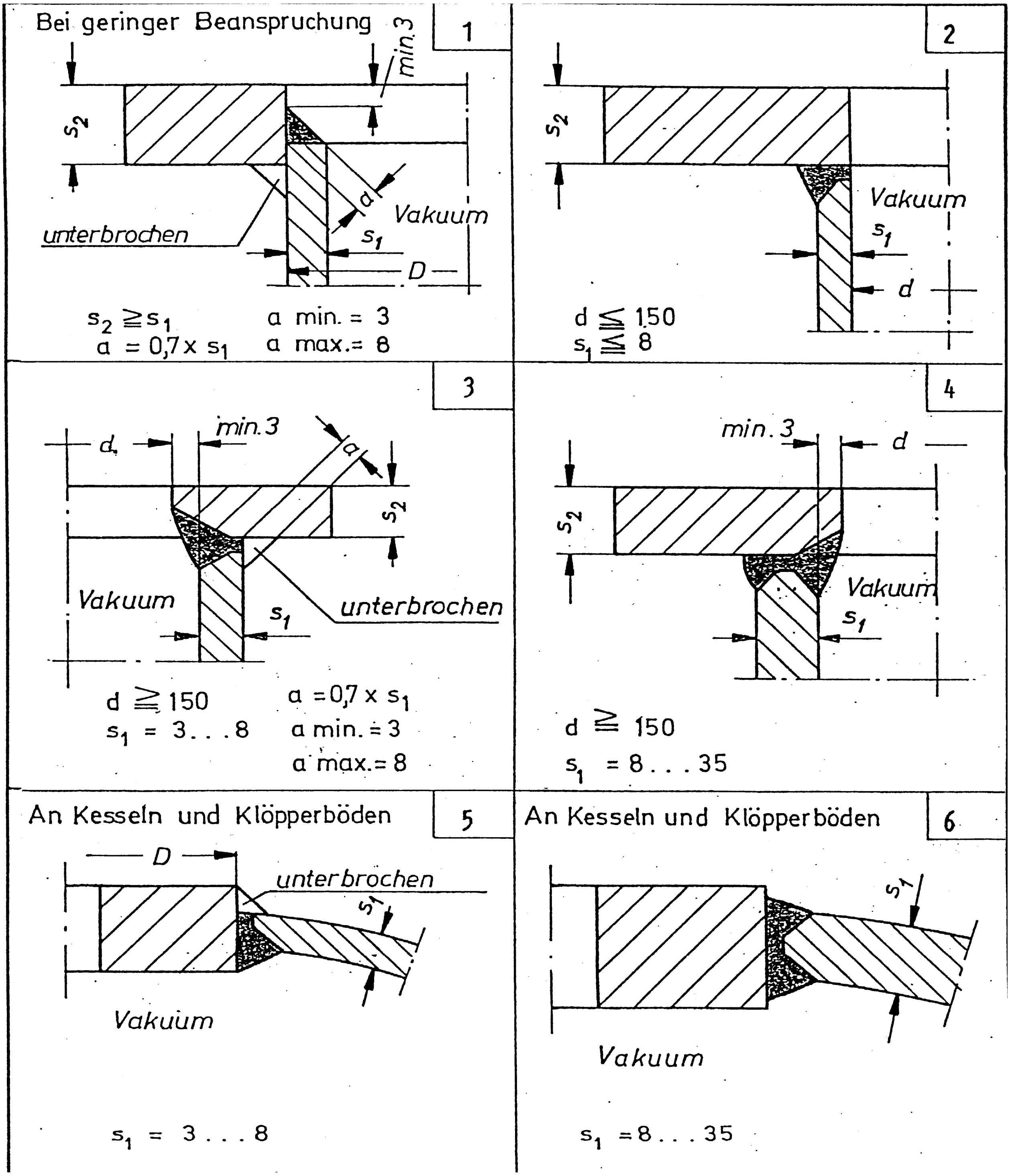
4.3.2 Pipe joints



Glossary:

bei geringer Beanspruchung	for low stress
bei hoher Beanspruchung	for high stress
kleine Stutzendurchmesser	narrow port diameter
Tangentialstutzen bei geringer Beanspruchung	Tangential port for low stress
Tangentialstutzen bei hoher Beanspruchung	Tangential port for high stress
X-Naht, bzw. K-Naht	X-seam, or K-seam

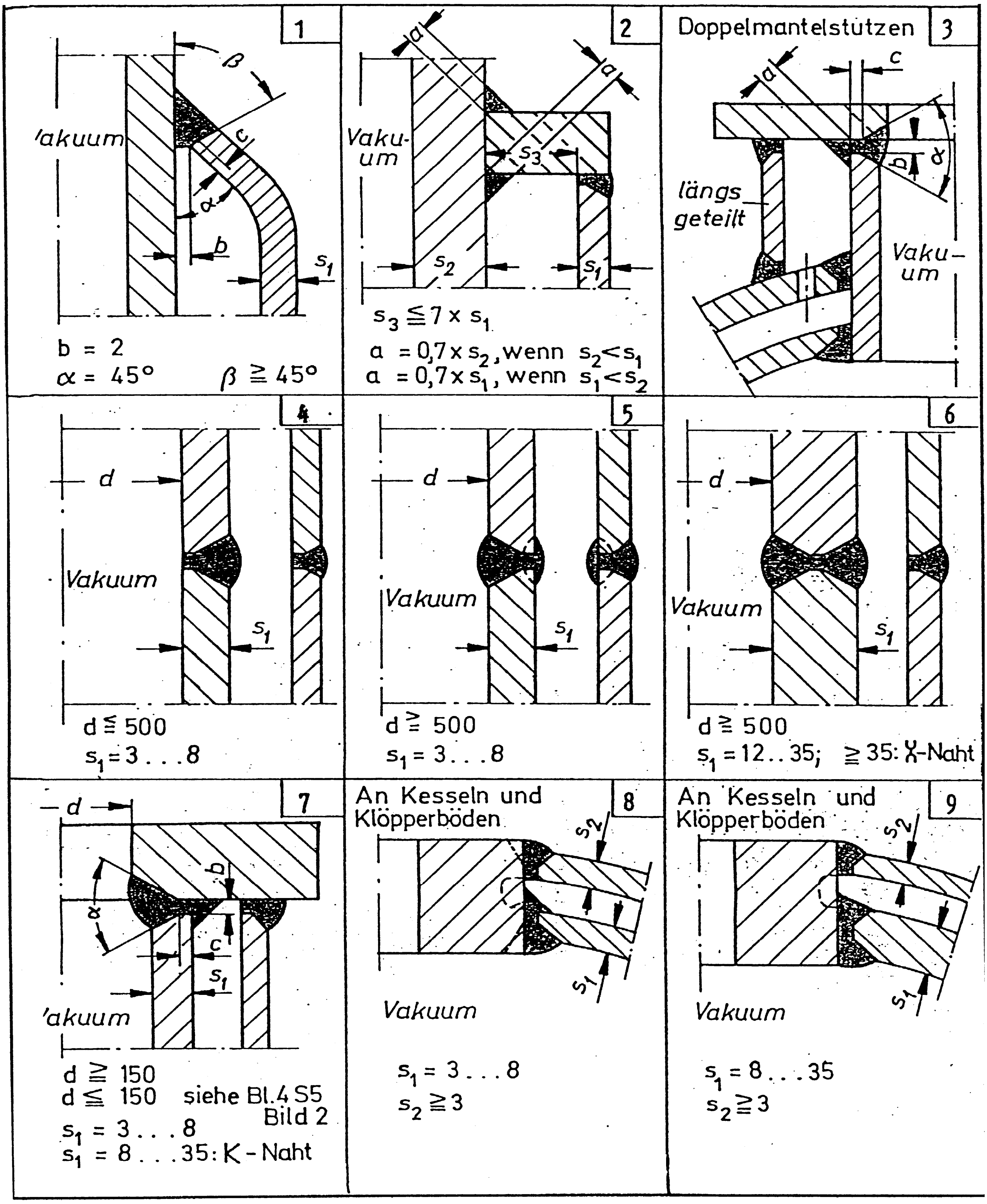
4.3.3 Flange joints

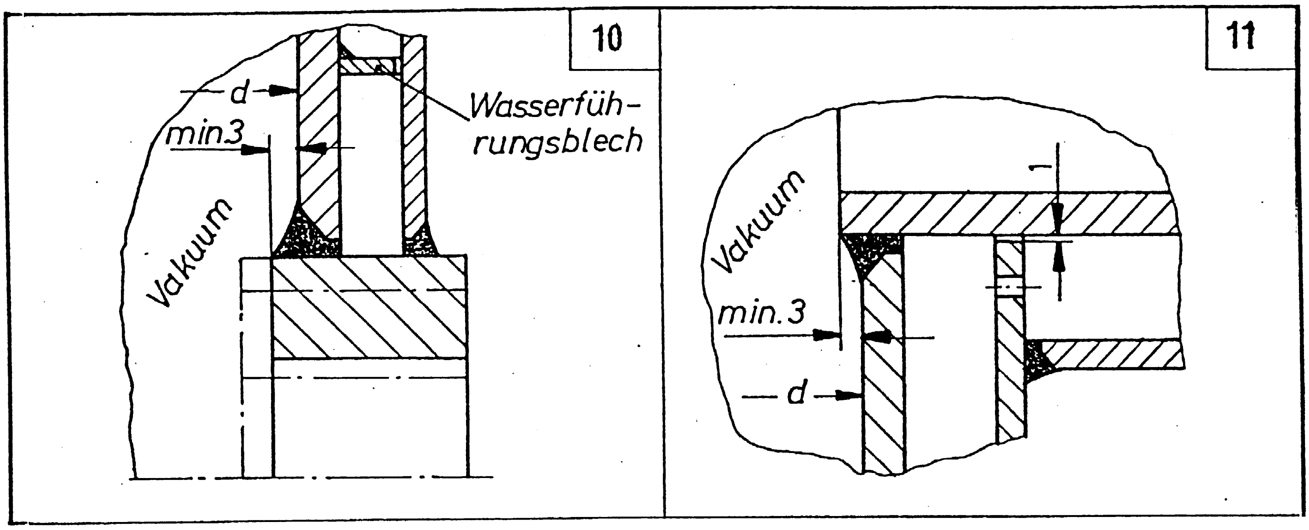


Glossary:

Bei geringer Beanspruchung	for low stress
unterbrochen	interrupted
Vakuum	vacuum
An Kesseln und Klöpperböden	on chambers and bases

4.3.4 Shell and double-shell joints

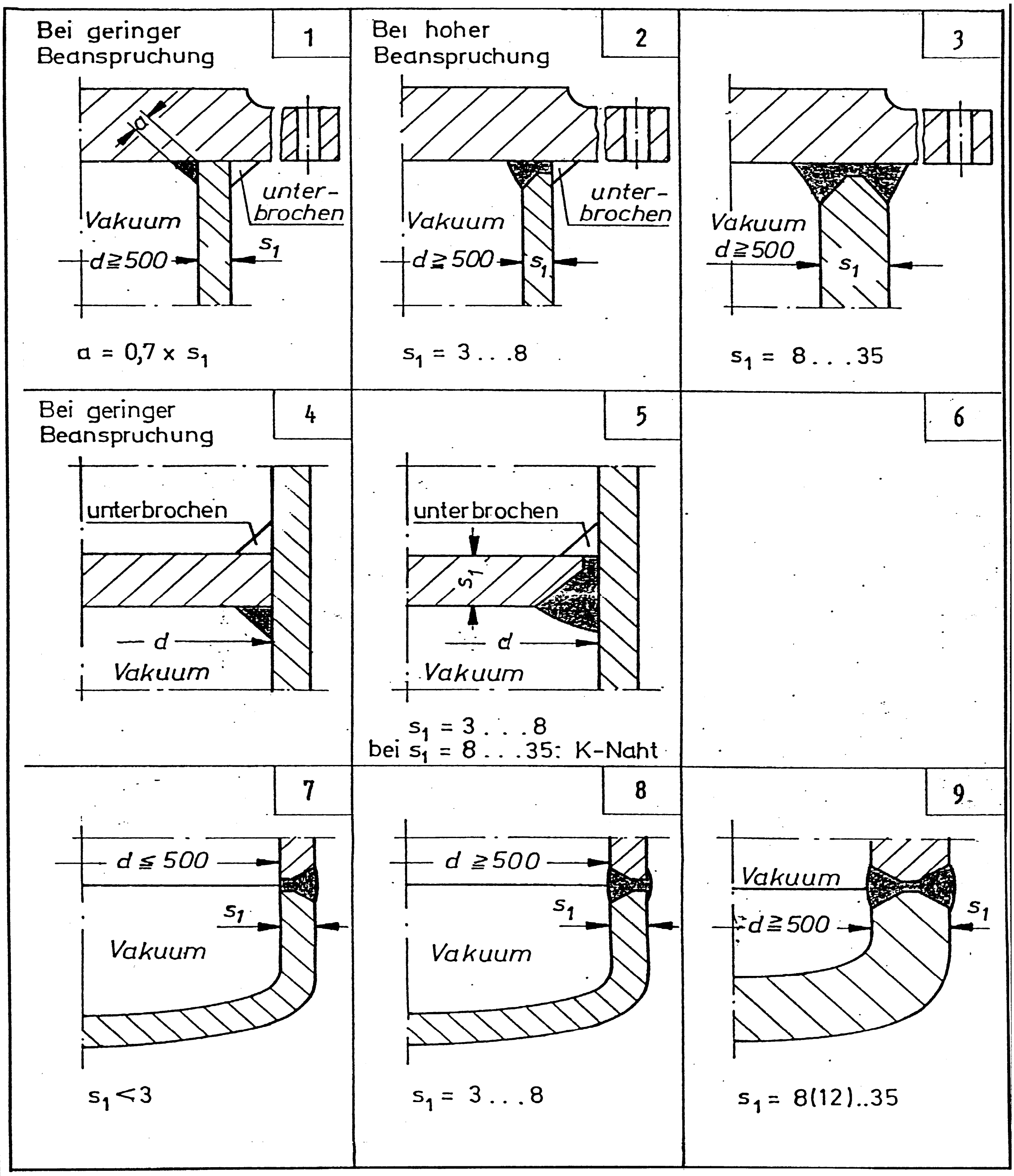




Glossary:

Vakuum	vacuum
Doppelmantelstutzen	double shroud port
längsgeteilt	separated lengthways
a = 0,7 x s2, wenn s2 < s1	a = 0.7 x s_2, if $s_2 < s_1$
Vakuum	vacuum
An Kesseln und Klöpperböden	on boilers and bases
siehe Bl. 4 S. 5 Bild 2	see 4.3.3 fig. 2
Wasserführungsblech	water guide plate

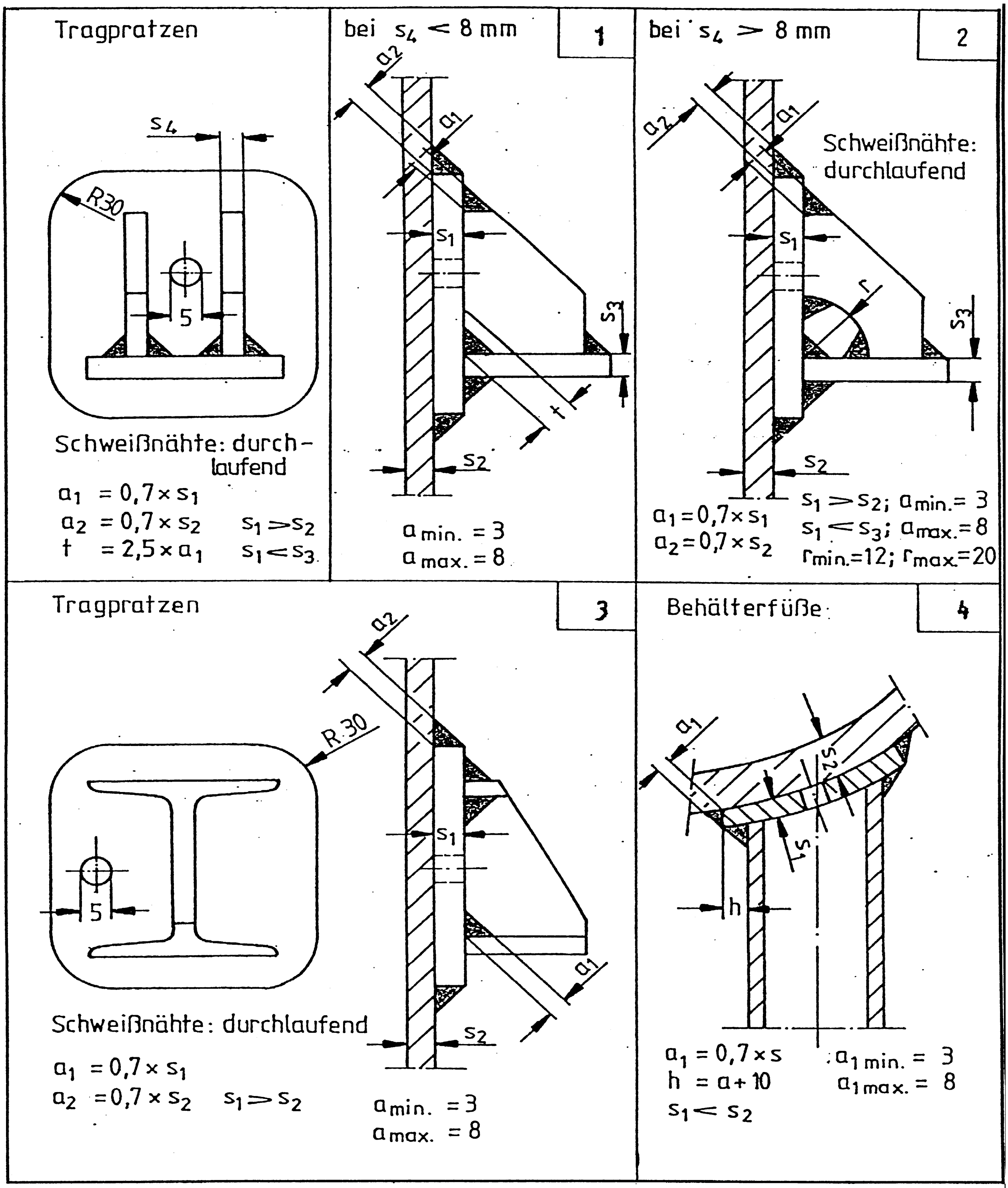
4.3.5 Joints between base plate and outer wall



Glossary:

Bei geringer Beanspruchung	for low stress
Bei hoher Beanspruchung	for high stress
unterbrochen	interrupted
Vakuum	vacuum

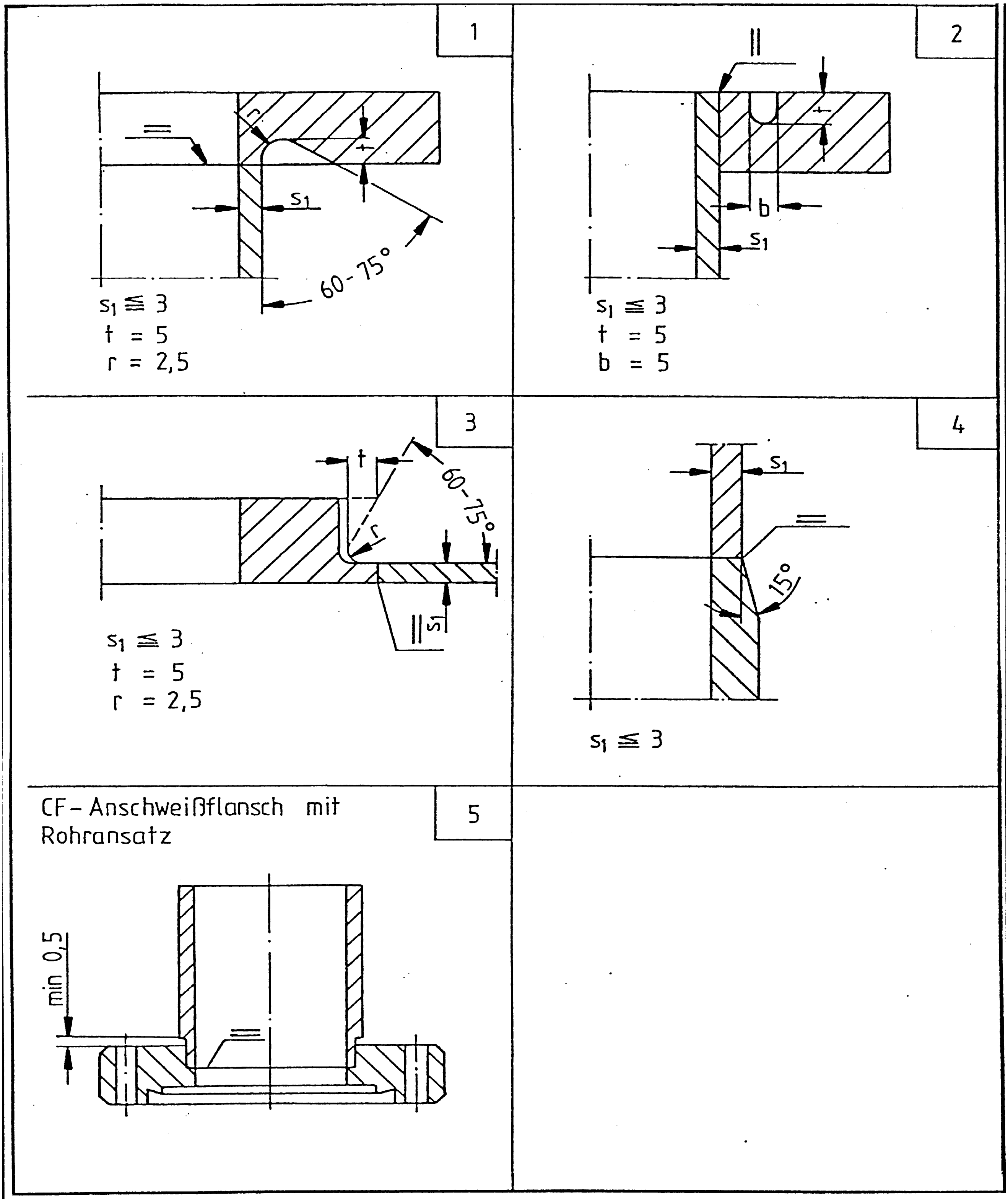
4.3.6 Claw and base joint (outside of the vacuum)



Glossary:

Tragpratzen	support claws
bei s4 < 8 mm	at s_4 < 8 mm
Schweißnähte: durchlaufend	welding seams: continuous
Behälterfüße	chamber feet

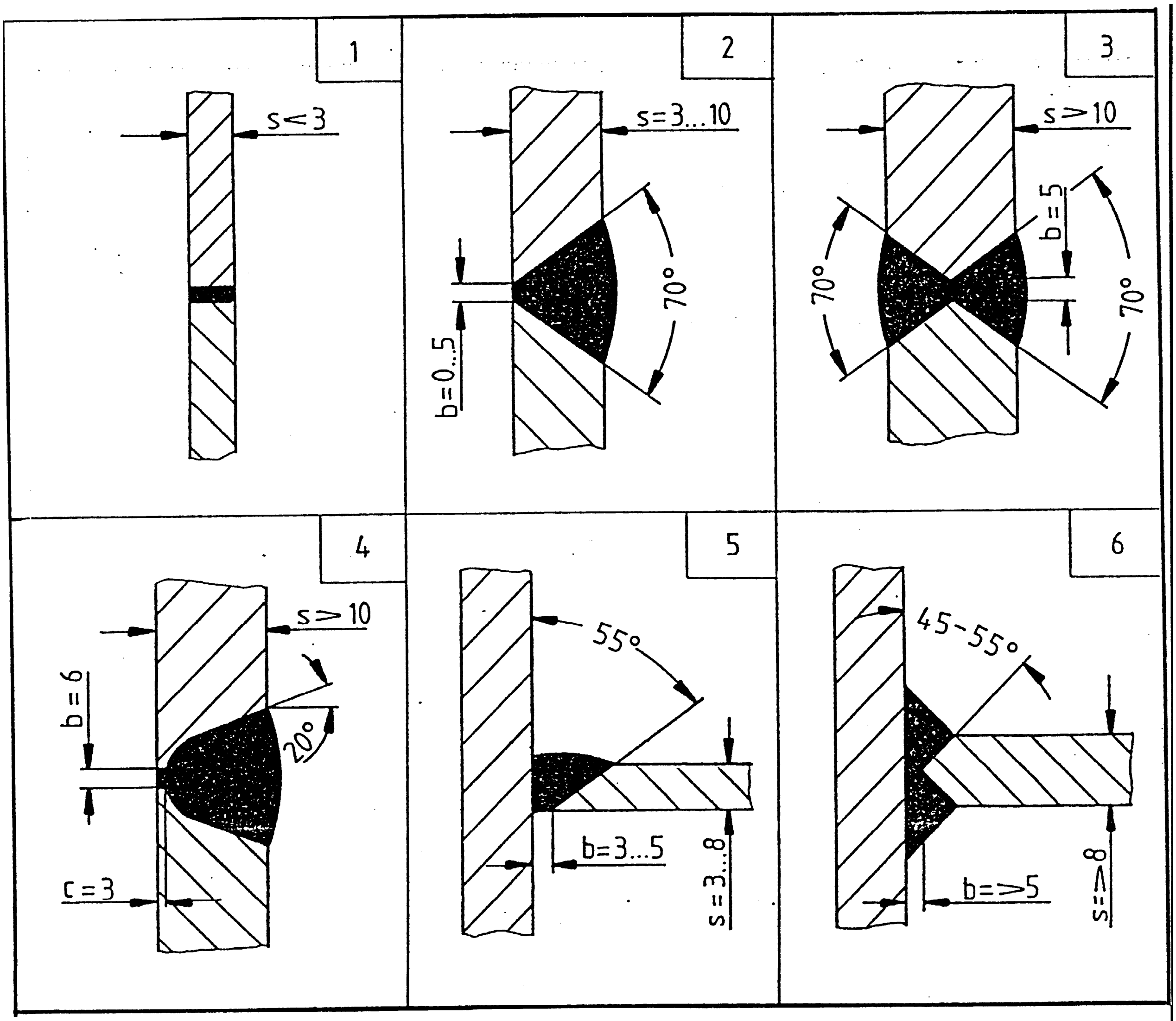
4.3.7 Welding of parts made of CrNi steel by WIG welding *without* additional material



Glossary:

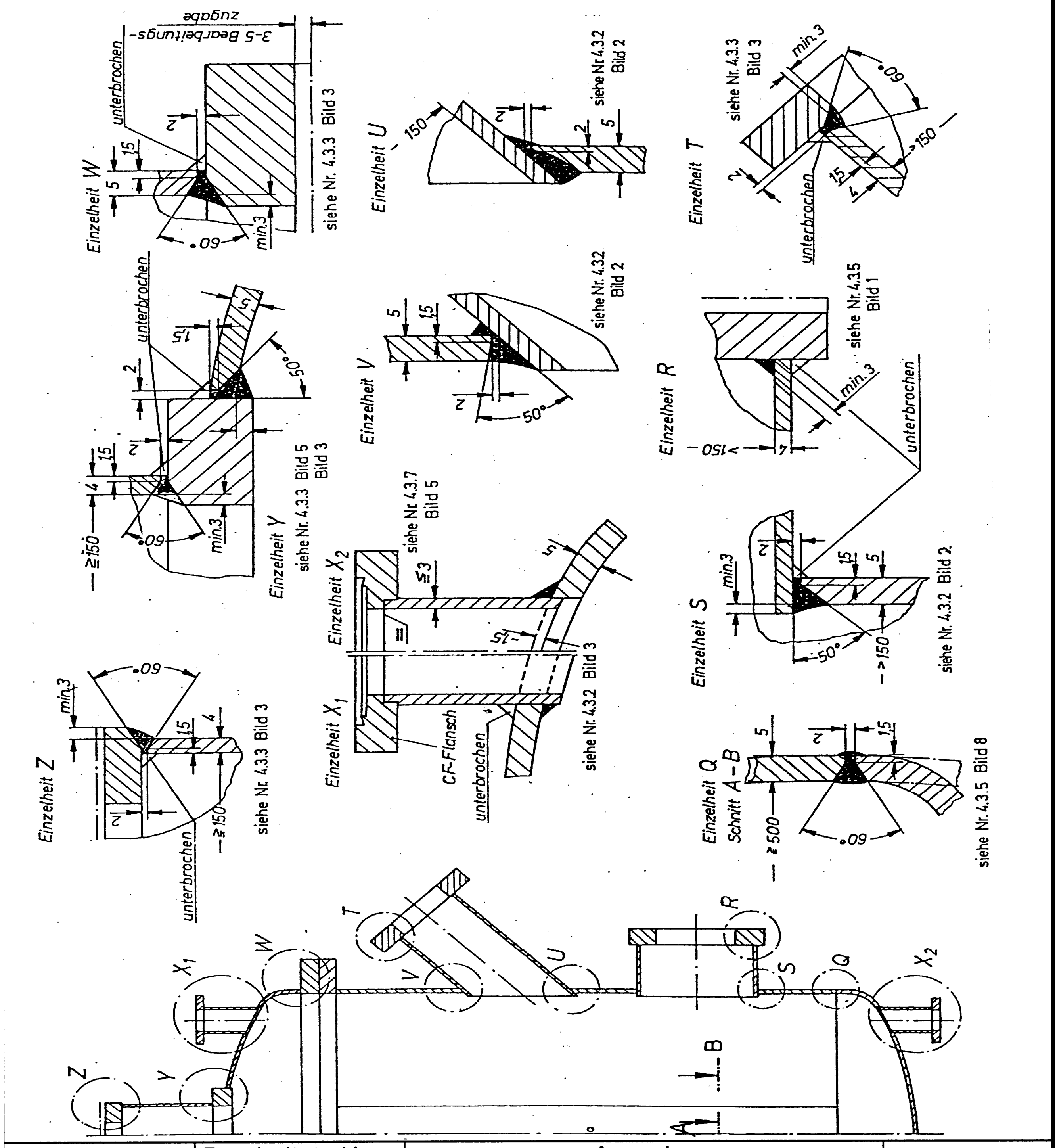
CF-Anschweißflansch mit Rohransatz	CF welding flange with pipe connection

4.3.8 Welding aluminium sheets and pipes



4.4 Use of the welding joint examples for tank construction

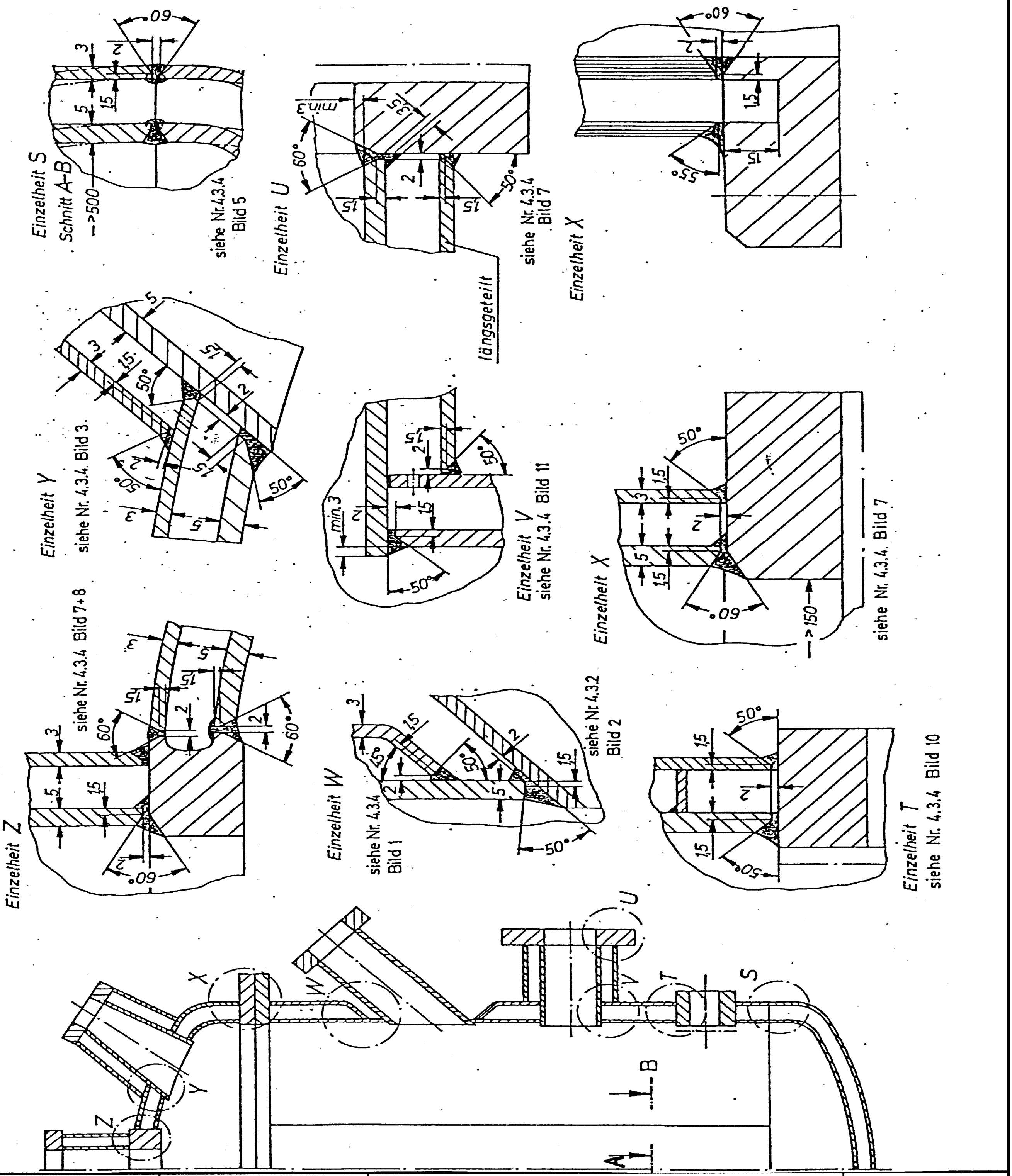
4.4.1 Welding joint examples for single-walled containers



Glossary:

Einzelheit Z	detail Z
siehe Nr. 4.3.3 Bild 3	see no. 4.3.3 fig. 3
CF-Flansch	CF flange
3-5 Bearbeitungszugabe	3-5 processing addition

4.4.2 Welding joint examples for double-walled containers



Glossary:

Einzelheit Z	detail Z
siehe Nr. 4.3.3 Bild 3	see no. 4.3.3 fig. 3
längsgeteilt	separated lengthways

5. Materials for vacuum technology

The following requirements must be met for materials that are to be used for vacuum technology:

- Largely impermeable to gas
- Low outgassing at operating temperatures
- Sufficient mechanical strength
- High degree of workability

Drawn, rolled or pressed material is preferable. Due to possible porosity, cast iron pieces can only be used in a few cases or if special casting techniques are applied. Metal alloys may only be used when they do contain only components with low vapor pressure even at the highest operating temperature.

Steel with **low carbon content** (≤ 0.22 %) should be used due to its **better welding characteristics.** Boiler plate is also suitable. The **main disadvantage** of normal steel is the **oxidation sensitivity.** Even slightly rusty material shows a considerably greater outgassing than polished material.

Stainless steel in general is particularly suited for welding. It is also especially suited for use in vacuum systems. Stainless steel surfaces are characterized by low outgassing in the vacuum due to high resistance to oxidation.

Copper is generally used in vacuum systems because of its high conductance for electrical current and heat. Generally oxygen-free copper is used for vacuum purposes, particularly with regard to welding. Copper alloys with components that have a high vapor pressure cannot be used at high temperatures. Copper is more resistant to oxidation than carbon steel. Especially at high temperatures, oxide layers form however easily in the presence of air, increasing normally the outgassing in the vacuum.

Aluminum is generally used as an alloy. The material has a high resistance to further oxidation, as it is always covered with a permanent oxide layer. However, the outgassing in the vacuum (for surfaces not baked-out) is more than 10 times higher than that for stainless steel.

The above specifications are for general use. The material selection must be made for the specific application concerned.

6. Calculation of welded joints

The calculation of the welded joints is depending on the special application. For each application specific regulations resp. calculation rules such as the AD guidelines for pressure containers, must be followed. Generally the usable welding seam cross section and the usable welding seam length have to be considered.

The permitted seam tension results from the permitted tension of the base material of the work piece to be welded, and from various correction values and safety factors. Correction values and safety factors to be used are depending on the application range of the component, the type of strain (static or dynamic), the welding procedure, the seam type (butt or fillet seam) and the material. These factors must be taken from the a.m. documents.

7. AD Guidelines

Design, calculation, ordering of material, manufacturing, finishing, testing and operation of components subject to acceptance*) must be executed according to the AD guidelines. Following guidelines will apply:
Series A - Equipment
Series B - Calculation
Series BP - Operation and testing
Series H - Manufacturing
Series HP - Manufacturing and testing
Series N - Non-metallic materials
Series W - Materials

The currently valid AD guidelines must be used.

Remark:

AD guidelines are prepared and issued by **A**rbeitsgemeinschaft **D**ruckbehälter (working group pressure vessels).

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*) Subject to acceptance:

The requirement for acceptance is defined in the applicable law, regulations and guidelines, e.g.

- German safety regulations (ProdSG)
- EC Machinery Directive (2006/42/EC)
- EC Pressure Equipment Directive (97/23/EC)