

Safety Standards

of the
Nuclear Safety Standards Commission (KTA)

KTA 3407 (2022-11)

Pipe penetrations through the Reactor Containment Vessel

(Rohrdurchführungen durch den Reaktorsicherheitsbehälter)

Previous versions of this safety standard
were issued in 1979-06 and 2009-11.

If there is any doubt regarding the information contained in this translation, the German wording shall apply.

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KTA SAFETY STANDARD

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Pipe penetrations through the Reactor Containment Vessel

KTA 3407

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PLEASE NOTE: Only the original German version of this safety standard represents the joint resolution of the 35-member Nuclear Safety Standards Commission (Kerntechnischer Ausschuss, KTA). The German version was made public in the Federal Gazette (Bundesanzeiger) on July 25, 2023. Copies of the German versions of the KTA safety standards may be mail-ordered through the Wolters Kluwer Deutschland GmbH (info@wolterskluwer.de). Downloads of the English translations are available at the KTA website (<http://www.kta-gs.de>).

All questions regarding this English translation should please be directed to the KTA office:

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Comments by the editor:

Taking into account the meaning and usage of auxiliary verbs in the German language, in this translation the following agreements are effective:

shall	indicates a mandatory requirement,
shall basically	is used in the case of mandatory requirements to which specific exceptions (and only those!) are permitted. It is a requirement of the KTA that these exceptions - other than those in the case of shall normally - are specified in the text of the safety standard,
shall normally	indicates a requirement to which exceptions are allowed. However, the exceptions used, shall be substantiated during the licensing procedure,
should	indicates a recommendation or an example of good practice,
may	indicates an acceptable or permissible method within the scope of this safety standard.

Basic principles

(1) The safety standards of the Nuclear Safety Standards Commission (KTA) have the task of specifying those safety-related requirements which shall be met with regard to precautions to be taken in accordance with the state of science and technology against damage arising from the construction and operation of the plant (Sec. 7, para. (2), subpara. (3) Atomic Energy Act - AtG) in order to attain the protective goals specified in the AtG, the Radiation Protection Act (StrlSchG) and the Radiation Protection Ordinance (StrlSchV) as well as further detailed in the Safety Requirements for Nuclear Power Plants (SiAnf) and the Interpretations of the SiAnf.

(2) Requirements for pipe penetrations through the reactor containment vessel are contained in the Safety Requirements for Nuclear Power Plants in Requirement No. 3.6, "Requirements for the Safety Enclosure" as well as in Sec. 6 "Containment" of Interpretation I-2 "Requirements for the design of the reactor coolant pressure boundary, the external systems as well as the containment". Here, distinction is made between reactor containment penetrating pipes connected to the reactor coolant or the inner atmosphere of the reactor containment vessel and such pipes not connected to the reactor coolant or the inner atmosphere of the reactor containment vessel.

(3) Containment vessel penetrating pipes shall be so designed and constructed as to safely withstand the loadings resulting from pressure and temperature in the reactor containment vessel.

(4) The pipe penetrations covered by this safety standard are intended to have fluid pipes penetrated through the reactor containment vessel wall such that the pipes are pressure-resistant and gas leak-tight. This results in designs with or without bellows expansion joints depending on the loadings on the individual pipe, the reactor containment vessel and their mutual influences.

(5) Pipe penetrations are of special importance as they have to meet the safety-related and operational requirements for both the reactor containment vessel and the piping. In this connection, the following requirements to be harmonized for pipe penetrations shall be met:

- ascertainment of the enclosure of the reactor containment vessel atmosphere during operation
- ascertainment of the enclosure of the reactor containment vessel atmosphere during loss-of-coolant accidents
- requirements from the penetrating piping systems
- requirements from postulated failure of fluid piping

With respect to the safety requirements Clause 4.1 defines specific sections.

(6) This safety standard only lays down requirements for penetrations. In addition, reference is made to:

- KTA 3201.1, KTA 3201.2 and KTA 3201.3
- KTA 3211.1, KTA 3211.2 und KTA 3211.3
- KTA 3401.2, KTA 3401.3 und KTA 3401.4

Note:

For operational and safety reasons a reactor containment vessel is provided with air locks, pipe and cable penetrations. The respective requirements are contained in:

- | | |
|----------|---|
| KTA 3402 | <i>Air locks through the Containment Vessel of Nuclear Power Plants - Personnel Locks</i> |
| KTA 3403 | <i>Cable Penetrations through the Reactor Containment Vessel</i> |
| KTA 3409 | <i>Air Locks for the Reactor Containment Vessel for Nuclear Power Plants - Material Locks</i> |

KTA 3404 applies to the isolation of operating system pipes penetrating the containment vessel in the case of release of radioactive substances into the containment vessel.

1 Scope

(1) This safety standard shall apply to pipe penetrations through the reactor containment vessel made of steel for nuclear power plants with light-water reactors. For pipe penetrations through concrete reactor containment vessels with liner this safety standard may be applied accordingly taking the provisions under building law into account.

(2) The pipe penetration comprises

- all components between the sleeve in the containment vessel and the fluid pipe including the attachment weld to the containment vessel sleeve
- the fluid pipe between inner and outer isolation valve. Where no inner isolation valve is provided, the first accessible circumferential pipe weld outside the containment vessel is considered to be the boundary.

(3) The sleeves welded into the containment vessel and the isolation valves are not considered to be part of the pipe penetration.

(4) In the case of pipe penetrations where both isolation valves are located outside the containment vessel, the fluid pipe between these isolation valves is considered to be part of the pipe penetration.

(5) Requirements for the pressure-retaining wall of isolating devices are not covered by this safety standard.

Note:

Requirements are contained in:

- | | |
|----------|--|
| KTA 3201 | <i>Components of the Reactor Coolant Pressure Boundary of Light Water Reactors, Parts 1 to 3</i> |
| KTA 3211 | <i>Pressure and Activity Retaining Components of Systems outside the Reactor Coolant Pressure Boundary, Parts 1 to 3</i> |
| KTA 3601 | <i>Ventilation Systems in Nuclear Power Plants</i> |

2 Definitions

(1) Design loading levels

In the penetration section components of pipe penetrations with the same requirements are assigned to design loading levels R1 to R3.

- Design loading level R1 covers the requirements for components of pipes used for enclosing the reactor coolant and the reactor containment vessel boundary.
- Design loading level R2 covers the requirements for components of pipes of specific safety-related importance with regard to their failure (see general specification on the "Basis safety of pressurised components") and the enclosure of the reactor containment vessel atmosphere.
- Design loading level R3 covers the requirements for components not to be assignable to design loading levels R1 or R2, as the enclosure of the reactor containment vessel atmosphere is ensured by a second barrier.

(2) Welding end

The welding end is the connection between the respective bellows end and the connecting pipe penetration and containment vessel end (see **Figure 2-1**).

(3) Working pressure

The working pressure of a fluid is the inner or outer gauge pressure intended for the course of one or several basic operations in a plant component.

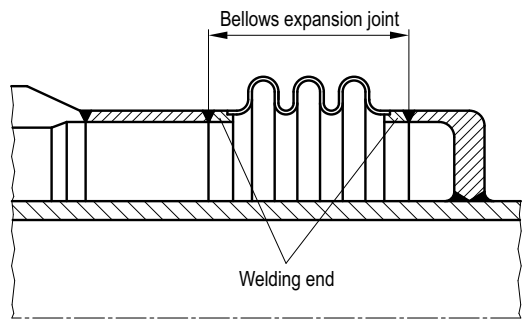


Figure 2-1: Welding end

(4) Operating temperature

The operating temperature of a fluid is the temperature intended for the course of one or several basic operations in a plant component.

(5) Bellows

A bellows is a convoluted pipe the convolutions of which are capable of performing axial, angular and lateral movements due to their flexibility. Reinforcing collars (see Figure 2-2) and parts for guiding the convolutions are not part of the bellows.

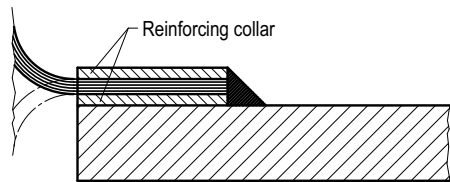


Figure 2-2: Reinforcing collar

(6) Bellows expansion joint

The bellows expansion joint is a component consisting of the two welding ends and the parts of guided expansion joints, if any (see Figure 2-3).

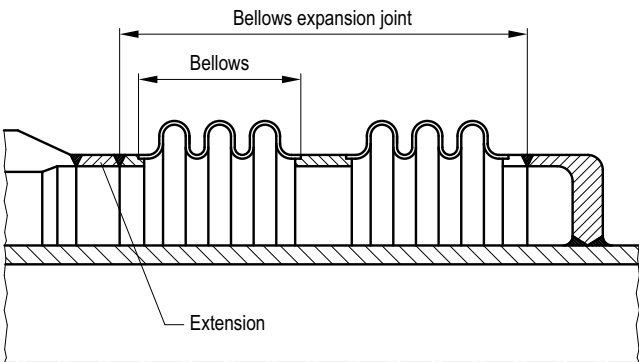


Figure 2-3: Bellows expansion joint

(7) Components of pipe penetrations

Components of pipe penetrations are (see Figure 2-4):

- a) fluid pipes inside or outside the penetrated section
- b) anchor plates, forged on or welded on
- c) discharge or extension pipes
- d) integral or non-integral support structures
- e) bellows expansion joints.

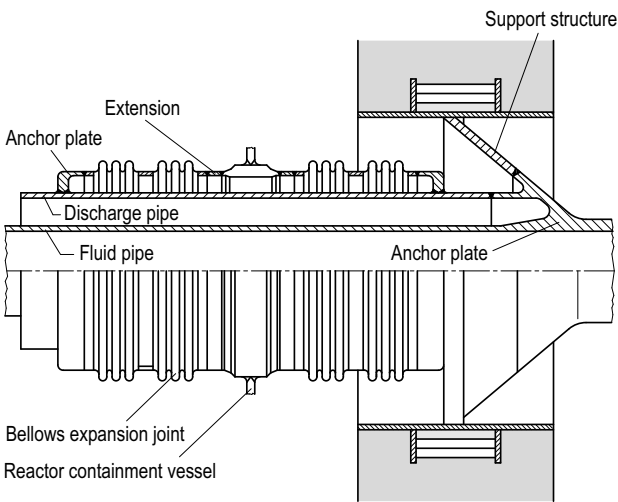


Figure 2-4: Components of pipe penetrations

(8) Penetrating section

The penetrating section is the section between the attachment welds of the fluid pipe as per Figure 4-1.

(9) Individual part groups

Components of pipe penetrations have been assigned to individual part groups 1 (EG 1) and 2 (EG 2) as follows:

- a) Part group EG 1 comprises components subject to a pressure differential between the atmosphere and the fluid pipe. Connecting elements which connect these components as well as attachment welds to these components and to integral support structures are assigned to part group EG 1.
- b) Part group EG 2 comprises components welded to part group EG 1 components including their attachment welds.

Examples for assigning components to part group EG 1 and EG 2 are given in Table 2-1.

Part group 1 (EG 1)	Part group 2 (EG 2)
a) Pipes (fluid pipes, discharge pipes and extension pipes) b) Pipe bends c) Anchor plates d) Bellows expansion joints e) Nozzles for test connections f) Attachment welds on part group EG 1 components g) Attachment welds of guide plates to containment vessel sleeve h) Flanges and flanged joints i) Welded attachments for integral support structures	a) Guide plates and lugs b) Attachment welds of guide plates to wall pipes not belonging to the containment c) Vent pipes within the enclosure

Table 2-1: Examples for assignment of components to part groups EG 1 and EG 2

(10) Clamp weld

A clamp weld is an edge-weld without groove by which the ends of the individual layers of multi-ply bellows expansion joints are welded.

(11) Fluid pipes

These are pipes used for the transport of liquid or gaseous fluids or steam.

(12) Pipe penetrations

Pipe penetrations are designed to permit the pressure-resistant and gas leak-tight penetration of fluid pipes through the reactor containment vessel.

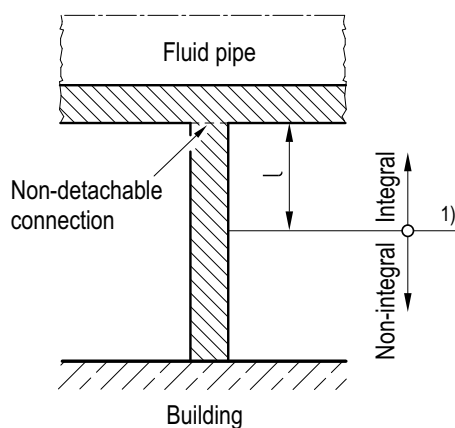
(13) Authorized inspector

The authorized inspector for the tests and inspections to be conducted in accordance with this safety standard is the authorized inspector called in by the licensing or supervisory authority in accordance with Section 20 of the Atomic Energy Act. The inspections/reviews required by this safety standard shall be performed on the basis of applications made by the competent authority.

(14) Support structures

a) Integral support structures

Integral support structures are components which are rigidly attached to the pipe or pipe penetration (e.g. welded, forged, machined from the solid) and have support functions (see **Figure 2-5**).



1) Limit of area of influence of fluid pipe

Figure 2-5: Schematic representation of integral support structures

Here, areas are concerned which are directly attached to the pressure-retaining wall of the pipe and are within the die-out length „l“ (see **Figure 2-6**). Where a detachable connection is provided within the die-out length „l“, the boundary between integral and non-integral support structure lies at the point of attachment (see **Figure 2-7**). The die-out length „l“ for shells (e.g. tubular nozzles or skirts) shall be determined as follows:

$$l = 0.5 \cdot \sqrt{\bar{r} - s_N}$$

where:

$\bar{r}$: mean radius of pipe

s_N : nominal wall thickness of the pipe, exclusive allowances

b) Non-integral support structures

Non-integral support structures are components which are detachably connected to the pipe or pipe penetration (e.g. bolted or studded) and components having support functions which are provided in areas outside the die-out length „l“ (see **Figures 2-5 to 2-7**).

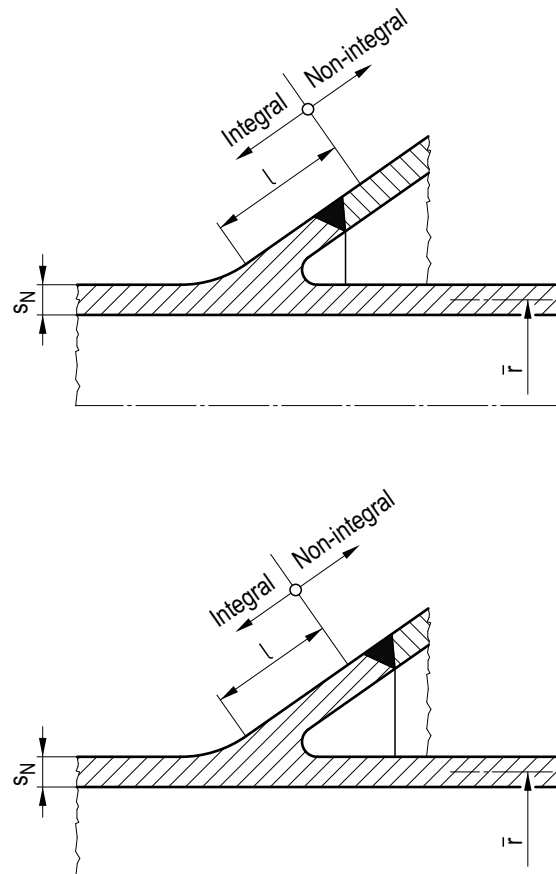
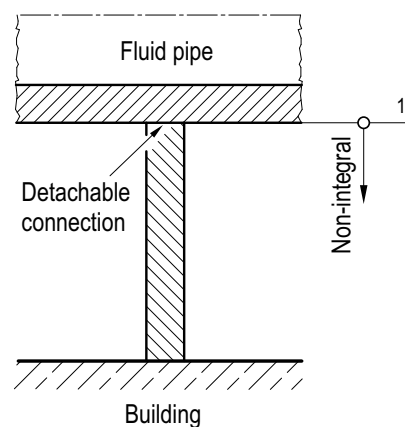


Figure 2-6: Examples of support structures



1) Limit of area of influence of fluid pipe

Figure 2-7: Schematic representation of non-integral support structure

(14) Reactor containment

The reactor containment is the system comprising the containment vessel and its surrounding building as well as the auxiliary systems for trapping and filtering leaking fluids, if any, from the reactor containment vessel.

(15) Allowable working pressure

The allowable component working pressure is the highest internal or external pressure at which this component is allowed to operate, on account of its material and the design principles, at the allowable operating temperature for trouble-free operating conditions.

3 Materials

(1) For components and welds of part group EG 1 the following materials are permitted

- a) for design loading level R1, the materials to KTA 3201.1 and the welding filler metals and consumables to KTA 3201.3,
- b) for design loading level R2, the materials to KTA 3211.1 and the welding filler metals and consumables to KTA 3211.3,
- c) for design loading level 3, the materials, filler metals and consumables to **Annex B**.

The lowest temperature to be withstood by ferrite, which is used in the acceptance testing of base metals and filler metals, shall be the temperature of pressure testing for the reactor containment vessel. The lowest temperature to be withstood by the pipe shall suffice if, during pressure testing of the reactor containment vessel, the primary membrane stresses in the component under consideration only amount to 20 % of the yield strength of the material. Otherwise, the lowest temperature of the reactor containment vessel shall apply.

(2) For components and welds of part group EG 2, the materials to **Annex B** are permitted for design loading levels R1 to R3.

(3) The requirements for bellows expansion joint materials are laid down in **Annex A**, section A 2.

4 Conceptual design

4.1 Safety requirements

(1) The safety and operational functions of pipe penetrations relate, on the one hand, to the reactor containment vessel function (enclosure of radioactivity, ventilation ducting) and, on the other hand, to the piping function (fluid enclosure). To fulfill this functions the integrity of the pipe penetrations shall be evidenced for specified operation and the following incidents and events:

- a) Pressure build-up in the reactor containment vessel by loss-of coolant
- b) Rupture of fluid pipes inside and outside the pipe penetration as per clause 4.2, subclauses 1 and 2.

(2) Combined loadings (e.g. earthquake or expansion of fluid due to heating of the enclosed fluid upon loss-of-coolant accident) are laid down in **Table 6-1**.

(3) For explosion blast wave and aircraft crash events, the fluid pipe integrity shall only be evidenced if the piping system integrity must be maintained on the occurrence of such events.

(4) With respect to the abovementioned requirements the pipe penetration shall be subdivided into the following sections (see **Figure 4-1**):

- Section I: covers components having enclosure safety functions (e.g. weld end of reactor containment vessel sleeve, anchor plates, bellows expansion joints). In the case of systems open at the inside like design type II (see **Figure 5-2**) also components such as extension pipes or fluid pipes up to the first isolation valve are covered.
- Section II: covers protective components for Section I and the reactor containment vessel (e.g. discharge pipe or similar designs)
- Section III: covers components of the fluid pipe which at specified operation are intended to enclose the fluid. The closure of a reactor containment vessel is only relevant to safety in the case of loss-of-coolant accidents and where the emergency cooling criteria have to be satisfied. This does, however, not lead

to requirements for the integrity of the piping between the isolation valves if criteria 1 (see clause 5.3, subclause 2a) is satisfied.

(5) It shall be ensured that a rupture or leakage of the fluid pipe outside Section I will not effect direct damage on Section I or on the fluid pipe on the other side of the containment vessel and that the functional capability of the building isolation valve on the other side of the containment vessel is maintained.

(6) The pipe rupture load case represents an incident (accident) for the entire pipe penetration. Components of design loading level R1 shall be designed for service loading level D of KTA 3201.2 and components of design loading levels R2 and R3 shall be designed for service loading level D of KTA 3211.2.

4.2 Postulated rupture

(1) Within Section III such ruptures (load case ST 4 and ST 5 to **Table 6-1**) shall be postulated as are assigned to the penetrating pipe.

(2) Where the accident analyses show that, at the above postulated ruptures, effects not covered by the plant design occur, additional measures shall be taken. These may be process measures, secondary protective measures or additional safety measures to exclude ruptures.

(3) Within the sections I, II and III no rupture or leakage shall be assumed to occur as individual defects in the case of enclosure service loading (load case ST 1 to **Table 6-1**).

4.3 Classification of pipe penetrations

(1) The fluid pipe shall basically be classified like the penetrating pipe. For penetrating pipes not covered by KTA safety standards, **Annex B** shall apply.

Note:

For pipe penetrations distinction shall be made between non-chambered (single barrier) and chambered (double barrier) designs.

(2) The requirements for the safety enclosure integrity are deemed to have been satisfied if the requirements assigned to the classification hereinafter are met for the components of the penetrated section. The following shall apply:

- a) Design loading level R2 if a protective barrier is provided.

A classification into design loading level R3 instead of R2 is permitted for penetrating pipes if a protective barrier is provided, the anchor plate and the fluid pipe are integrally forged, austenitic steel or a ferritic steel allowable for the reactor containment vessel has been used and oversizing of Section I (anchor plate/area of attachment to the fluid pipe) is proved. This proof shall be rendered to the authorized inspector.

Oversizing is achieved if the equivalent stress derived from the primary stresses in loading level A and loading level B is only utilized up to a maximum of 40 % of the design stress (this corresponds to a safety factor of 2.5).

- b) Design loading level R3 if two barriers are provided.

(3) The classification of pipe penetration components in dependence of the penetrating pipe can be seen in **Table 4-1**. This classification shall apply accordingly for welds and integral support structures.

4.4 Bellows expansion joints

Annex A, Section A 3 lays down the requirements for the design of bellows expansion joints.

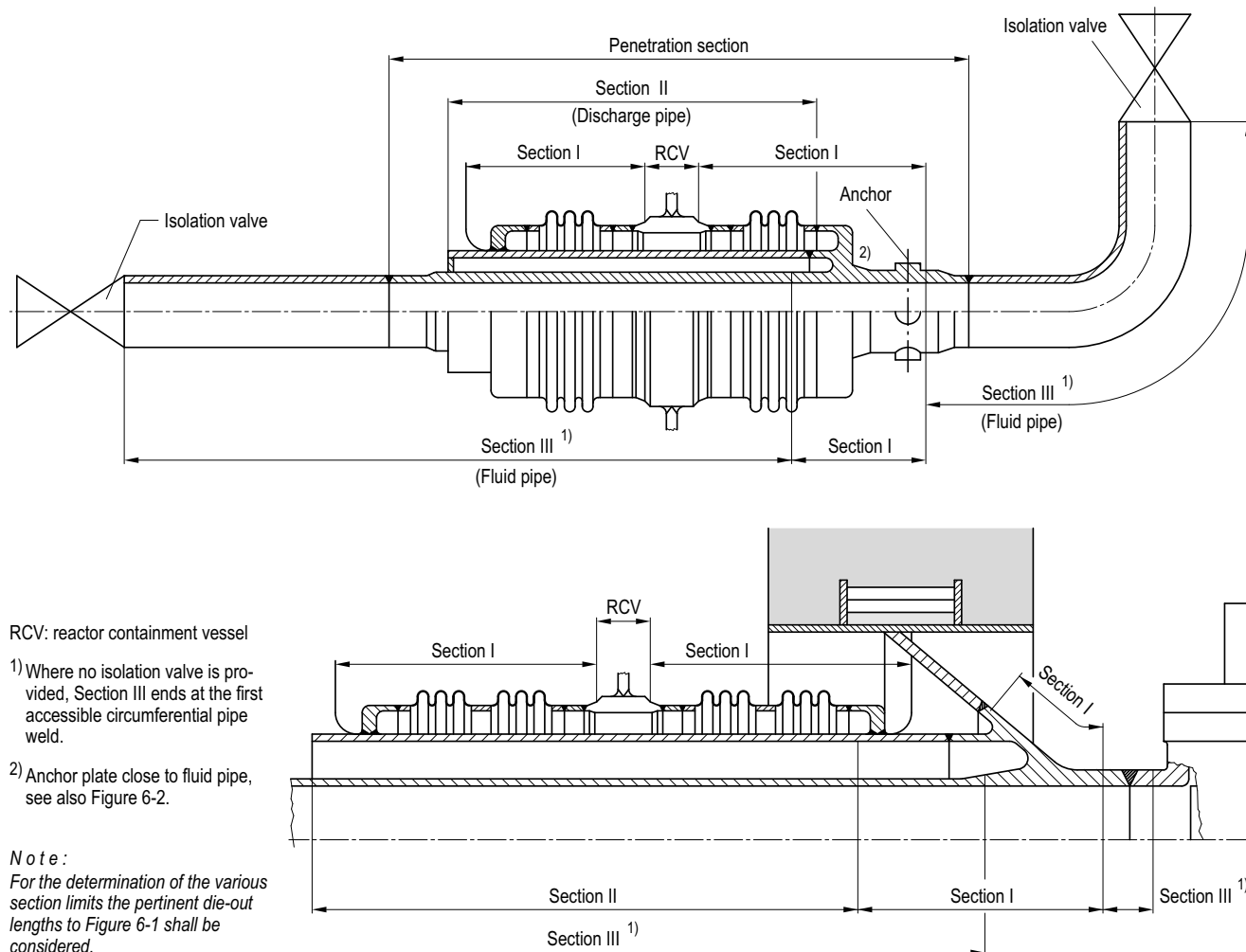


Figure 4-1: Representation of Sections I, II and III for assignment of safety requirements

Penetrating pipe covered by	Fluid pipe outside the penetrated section ¹⁾	Pipe penetration components					
		Non-integral support structures	Fluid pipe in penetrated section ¹⁾ and forged anchor plate, if any	Welded-on anchor plate, discharge pipe and extension pipe		Bellows expansion joint	
		Beam load-bearing structures	Plane load-bearing structures		Non-chambered		Chambered
KTA 3201	KTA 3201	KTA 3205.1	Annex B	R1	R2	R3 ²⁾	R3 ²⁾
KTA 3211 and leak-before-break criterion (KTA 3211.3 Section 14)	KTA 3211 with additional re-quirements to KTA 3211.3 Section 14	KTA 3205.2		R2 with additional requirements to KTA 3211.3 Section 14	R2	R3 ²⁾	R3 ²⁾
KTA 3211	KTA 3211	KTA 3205.2		R2	R2	R3 ²⁾	R3 ²⁾
Technical rules beyond the scope of KTA safety stand-ards	Annex B	KTA 3205.2		R2 ³⁾	R2 ³⁾	R3 ²⁾	R3 ²⁾

¹⁾ For ≤ DN 50 the requirements for small dimensions shall be laid down by agreement with the authorized inspector.

²⁾ Classification of bellows, discharge pipe and anchor plate in design loading level R2 if a single barrier is provided.

³⁾ Classification into design loading level R3 if the proof as per clause 4.3 (2) can be made.

Table 4-1: Requirements for pipe penetration components in dependence of the classification of the penetrating pipe in due consideration of Figure 4.1

5 Design and construction

5.1 General

(1) Pipe penetrations shall basically be welded to the reactor containment vessel sleeve. Pipe penetrations welded to the reactor containment vessel are permitted by agreement with the authorized inspector if the leak tightness requirements are met (see **Figure 5-1.1**).

Note:

For certain reasons, extension pipes are used to avoid austenitic/ferritic connecting welds at the reactor safety containment.

(2) When designing pipe penetrations it shall be taken into account that the temperature of penetrating pipes may be higher than the design temperature of the reactor pressure vessel sleeve. Where required, respective insulation or heat dissipation shall be made possible to prevent the allowable temperature of the reactor pressure vessel sleeve from being exceeded.

(3) Penetrations which due to the high loading (criterion 1, see clause 5.3, subclause 1a) cannot be connected to the reactor containment vessel sleeve, shall be connected by means of bellows expansion joints. It shall be ensured by respective devices (e.g. chambered connecting area) that leak tests can be performed on the bellows expansion joints. Chambers shall be provided with nozzles for leak testing. The nozzles shall be located at the lowest point.

(4) In the case of non-horizontal pipe penetrations of design types I and IV (see **Figures 5-1.1, 5-1.2, 5-4.1, and 5-4.2**) the components shall be arranged such as to avoid dead corners where corrosion products may accumulate.

(5) For pipe penetrations of design types III and IV the distance between the reactor containment vessel sleeve and the fluid pipe or discharge pipe shall be fixed such that no unacceptable loadings (e.g. by contact) occur in the case of operational load cases or incidents). The anchor points shall be arranged such that the bellows expansion joint is not subjected to torsional loading.

(6) A list of all pipe penetrations shall be established and updated to contain

- a) type of pipe penetration
- b) nominal width
- c) penetrating pipe
- d) classification of penetrating pipe
- e) fluid
- f) materials of fluid pipe
- g) design data
- h) identification of the reactor containment vessel sleeve. Containment vessel sleeves that are not used shall also be listed.

5.2 Arrangement

(1) Pipe penetrations shall be arranged such that

- a) the penetrations through the containment vessel are arranged and designed such that an incidence at one penetration does not lead to damage on adjacent penetrations. The arrangement of pipe penetrations shall also meet the requirement for separation of redundant systems, which results from the conceptual design of the entire facility.
- b) accessibility is ensured for maintenance work and in-service inspections.

(2) Short pipe lengths shall preferably be used between the isolation valves and the reactor containment vessel. In such areas, pipe branching is basically not permitted. Exceptions (such as drain nozzles, test assemblies) shall be subjected to a safety analysis.

(3) Several fluid pipes are permitted to penetrate one reactor containment vessel sleeve (see **Figure 5-1.2**). Pipes exceeding DN 25 shall basically be assigned to have the same redundancy and, if used for conveying reactor coolant, shall be isolatable. Several pipes exceeding DN 25 may even penetrate the sleeve if there are no requirements as to redundancy.

5.3 Determination of pipe penetration design types

(1) The following design types are permitted

- a) design type I, rigid attachment, without chamber (see **Figures 5-1.1 and 5-1.2**)
- b) design type II, rigid attachment, with chamber (see **Figure 5-2**)
- c) design type III, with bellows expansion joint on both sides of the containment vessel wall, with chamber, without discharge pipe (see **Figure 5-3**)
- d) design type IV, with bellows expansion joint on both sides of the containment vessel wall, with chamber and discharge pipe (see **Figure 5-4.1 and 5-4.2**)
- e) special designs (rigid attachment, without chamber, with discharge pipe)

(2) The pipe penetration design type shall be determined by combining the steps to **Figure 5-5**.

a) Step 1

It shall be checked whether, in the case of rigid attachment, the forces and moments allowable for the reactor containment vessel sleeves are exceeded due to mutual influence of piping and containment vessel during operation or incidents (criterion 1).

b) Step 2

It shall be checked whether, upon postulated failure of the fluid pipe within Section III, as per clause 4.2, subclauses 1 and 2, the integrity of the enclosure cannot be evidenced (criterion 2),

ba) because due to a possible consequential effect from the postulated rupture on the opposite side of Section III the integrity of the enclosure is affected, or

bb) the opposite side cannot be isolated.

c) Step 3

It shall be checked whether a failure (see clause 4.2) of the fluid pipe in Section III leads to consequential failure in Section I or on the containment vessel (criterion 3).

d) Step 4

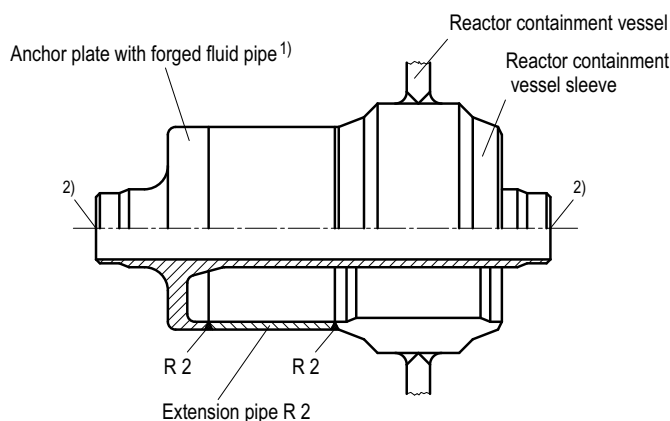
It shall be checked whether the pipe penetration within the area of the sump water level is open to the containment vessel atmosphere, no internal isolation valve is installed and a failure of the fluid pipe to KTA 3301, clause 5.2.2.2, can be postulated during the long-time period after an incident (criterion 4).

5.4 Design meeting testing and inspection requirements

(1) Within the conceptual design of pipe penetrations care shall be taken to ensure that pressure-retaining and dynamically loaded welds can be subjected to first and in-service non-destructive tests, except for longitudinal welds on bellows. Welds that are neither accessible for in-service internal inspections nor in-service non-destructive tests, shall be limited to nominal stresses smaller than or equal to 50 N/mm² during operation.

(2) Chambered pipe penetrations shall make in-service leak tests possible.

Forged design



Welded design

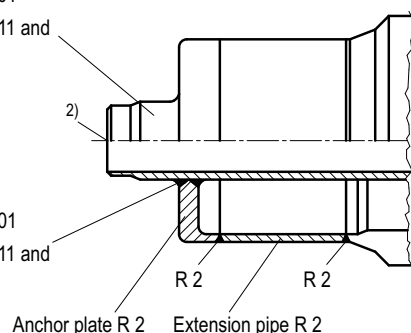
Fluid pipe:

R 1 for piping to KTA 3201

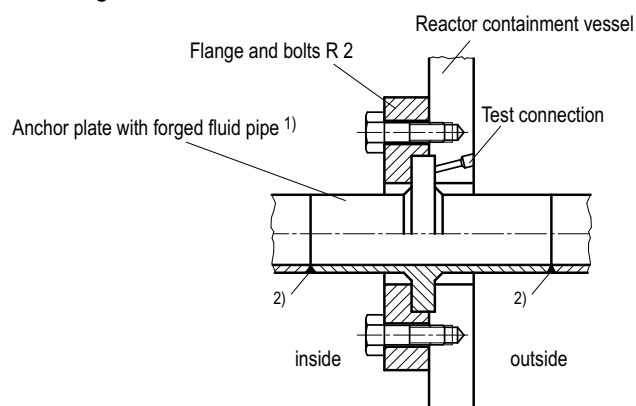
R 2 for piping to KTA 3211 and other piping

R 1 for piping to KTA 3201

R 2 for piping to KTA 3211 and other piping



Bolted design



¹⁾ R 1 for piping to KTA 3201

R 2 for piping to KTA 3211 and other piping

R 3 for other piping if the proof to clause 4.3, subclause 2 can be provided.

²⁾ Connecting welds to fluid pipe:

R 1 for piping to KTA 3201

R 2 for piping to KTA 3211

R 3 for other piping

Figure 5-1.1: Examples of pipe penetration of design type I with fluid pipe and identification of design loading levels R1, R2 and R3

Design with welded-in fluid pipe

Fluid pipe:

R 1 for piping to KTA 3201

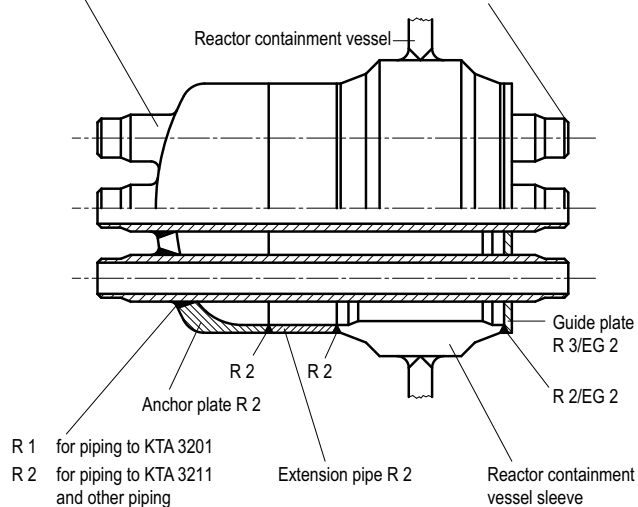
R 2 for piping to KTA 3211 and other piping

Connecting welds to fluid pipe:

R 1 for piping to KTA 3201

R 2 for piping to KTA 3211

R 3 for other piping



Design with rolled or hydraulically expanded pipe

Austenitic fluid pipe and seal welds:

R 1 for piping to KTA 3201

R 2 for piping to KTA 3211 and other piping

Connecting welds to fluid pipe:

R 1 for piping to KTA 3201

R 2 for piping to KTA 3211

R 3 for other piping

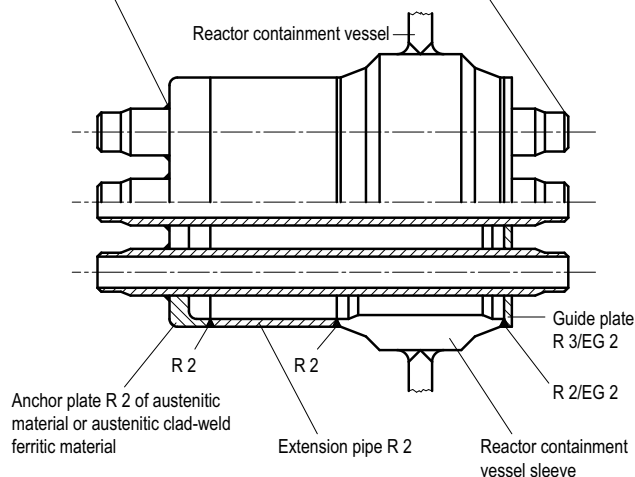


Figure 5-1.2: Example of pipe penetration of design type I with several fluid pipes and identification of design loading levels R1, R2 and R3