

Safety Standards

of the
Nuclear Safety Standards Commission (KTA)

KTA 3401.2 (2016-11)

**Steel Containment Vessels
Part 2: Design and Analysis**

(Reaktorsicherheitsbehälter aus Stahl;
Teil 2: Auslegung, Konstruktion und Berechnung)

Previous versions of this Safety Standard
were issued 1980-06 and 1985-06

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

Editor:

KTA-Geschaefsstelle

c/o Bundesamt fuer kerntechnische Entsorgungssicherheit (BfE)

Willy-Brandt-Strasse 5 • 38226 Salzgitter • Germany

Telephone +49-30-18-333-1621 • Telefax +49-30-18-333-1625

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Steel Containment Vessels;
Part 2: Design and Analysis

KTA 3401.2

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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) of March 3rd 2017. 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:

KTA-Geschaefsstelle c/o BfE, Willy-Brandt-Strasse 5, D-38226 Salzgitter, Germany or kta-gs@bfe.bund.de



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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.

Fundamentals

(1) The safety standards of the Nuclear Safety Standards Commission (KTA) have the objective to specify safety-related requirements, compliance of which provides the necessary precautions in accordance with the state of the art in science and technology against damage arising from the construction and operation of the facility (Sec. 7 para. 2 subpara. 3 Atomic Energy Act - AtG) in order to achieve the fundamental safety functions specified in the Atomic Energy Act and the Radiological Protection Ordinance (StrlSchV) and further detailed in the Safety Requirements for Nuclear Power Plants as well as in the Interpretations on the Safety Requirements for Nuclear Power Plants.

(2) Basic requirements for the reactor containment are contained in the Safety Requirements for Nuclear Power Plants in Requirement No. 3.6, "Requirements for the containment system" 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".

Safety standard KTA 3201.4 "In-Service Inspections and Operational Monitoring" is intended to specify detailed measures which shall be taken to meet these requirements

The safety requirements cited above are transferred to specific requirements with respect to steel containment vessels by the following safety standards:

KTA 3401.1	Steel containment vessels; Part 1: Materials and product forms
KTA 3401.2	Steel containment vessels; Part 2: Design and analysis
KTA 3401.3	Steel containment vessels; Part 3: Manufacture
KTA 3401.4	Steel containment vessels; Part 4: In-service inspections
KTA 3405	Leakage test of the containment vessel
KTA 3413	Determination of Loads for the Design of a Full Pressure Containment Vessel against Plant-Internal Incidents

and, with respect to penetrations and airlocks, by the following safety standards:

KTA 3402	Airlocks on the Reactor Containment of Nuclear Power Plants - Personnel Airlocks
KTA 3403	Cable Penetrations through the Reactor Containment Vessel
KTA 3407	Pipe Penetrations through the Reactor Containment Vessel
KTA 3409	Airlocks on the Reactor Containment of Nuclear Power Plants - Equipment airlocks.

Furthermore, Safety Standard KTA 3404 applies to the isolation of operation-system related pipes penetrating the reactor containment vessel in the case of a release of radioactive materials into the reactor containment vessel.

(3) The task of the steel containment vessel is to resist the pressure and temperature loads which can occur during plant accidents connected with the release of radioactive materials inside the containment, in particular in conjunction with the leakage cross-sections of the primary coolant system to be assumed; thus, no unallowed release of radioactive materials to the environment becomes possible. For this reason, the containment and all penetrations and cooling systems, as far as their function is required for controlling the consequences of the accident, shall be designed such that, under consideration of the allowed leakage rate, they resist the dynamic, static and thermal loads occurring in conjunction with the above mentioned accidents and the consequential failures. During normal operation, the containment, furthermore, has the task of conducting the air flow.

(4) In the case of stationary light-water reactors, the containment is designed as a technically airtight steel sphere into which the pipe and cable penetrations as well as personnel

and material locks are inserted. In order to comply with the above mentioned task, it is necessary to set up standards for technical and organizational measures, e.g.,

- choice and use of materials of high fracture toughness and good workability,
- design and construction in consideration of a well-suited stress flow,
- choice of fabrication and testing procedures and documentation of testing steps and results,
- unambiguous instructions regarding the activities during manufacture and processing of the materials.

(5) These measures are dealt with in the four Safety Standards KTA 3401.1, KTA 3401.2, KTA 3401.3 and KTA 3401.4. The compliance with the provisions laid down in the present Safety Standard regarding

- a) load cases and loading levels,
- b) design,
- c) assessment of load-bearing capacity,

will ensure that the safety-related requirements for design, construction and analysis of the reactor containment vessel are satisfied.

1 Scope

This safety standard applies to the design and analysis of steel containments of stationary nuclear power plants with light-water reactors, including the nozzles integrally connected to the containment and the pressure retaining parts of the locks.

2 Definitions

(1) Design pressure (excess pressure) of the reactor containment

The design pressure of the reactor containment is the pressure determined in accordance with the requirements of KTA 3413, section 6.1.

(2) Design temperature of the reactor containment

The design temperature of the reactor containment is the maximum balanced temperature of the reactor containment atmosphere determined for accidents in accordance with KTA 3413, section 6.1.

(3) Design sub-atmospheric pressure

The design sub-atmospheric pressure is the maximum negative pressure determined in accordance with KTA 3413, sub-clause 6.1 (6).

(4) Nominal stress

Nominal stresses are stresses determined by calculation (e.g. analytical calculations) in which case notch effects from discontinuities due to component geometry are not taken into account.

(5) Test pressure (excess pressure) during first pressure testing

The test pressure (excess pressure) during first pressure testing is 1.1 times the design pressure multiplied with the ratio of yield strengths at test and design temperature, respectively.

(6) Test pressure (negative pressure) during first pressure testing

The test pressure (negative pressure) during first pressure testing is the test pressure determined in accordance with KTA 3401.3, section 10.7.

(7) Maximum pressure at accident

The maximum pressure at accident is the maximum pressure occurring in case of a loss-of-coolant accident (LOCA), which is to be determined in accordance with KTA 3413, section 6.

3 General principles

Unless otherwise stipulated below, the design and analysis of a containment shall be carried out in accordance with the principles of mechanical engineering and under consideration of the generally accepted standards of civil engineering.

4 Load cases and loading levels

4.1 General

(1) Load cases shall be classified in accordance with Section 4.2.

(2) Load cases relevant to the containment shall be correlated to loading levels in accordance with Section 4.4.

4.2 Load cases (Plant conditions)

4.2.1 General

(1) With respect to achieving the fundamental safety functions distinction shall be made between various plant conditions leading to the loadings shown in **Table 4-1**. The load cases result of a combination of loadings and shall be classified as follows:

- a) design load cases (DF),
- b) erection load cases (MF),
- c) load cases from specified normal operation
 - ca) normal operation load cases (NB),
 - cb) anomalous operational load cases (AB),
 - cc) test load cases (PF),
- d) accident load cases (ST),
- e) redundancy-wide impact from an external event (EVA).

(2) From these load cases, those decisive for the containment vessel shall be correlated to the loading levels in accordance with Section 4.4.

4.2.2 Design load cases (DF)

(1) Design load cases are such on which the first dimensioning of wall thicknesses for components of the containment vessel is based. The calculation is based on the design pressure (excess pressure) and the design sub-atmospheric pressure.

Note:

As regards the final dimensioning of wall thicknesses, see sub-clause 5.1 (2).

(2) In the case of loads from internal pressure, the design temperature shall be considered to occur coincidentally with the design pressure.

4.2.3 Erection load cases (MF)

All loads resulting from the site, from construction and erection procedures shall be considered to be erection load cases of a specific condition of erection. Transportation and repair procedures shall, as necessary, be demonstrated as being allowable.

4.2.4 Load cases from specified normal operation

a) Normal operational load cases (NB)

Normal operational load cases are operating procedures for which the nuclear power plant is specified and which it is able to perform on the assumption of functional condition (undisturbed condition) of the plant components and systems. All related loads shall be considered.

b) Anomalous operational load cases (AB)

Anomalous operational load cases are operating procedures occurring upon malfunction of plant components and systems (undisturbed condition) unless continued operation is excluded on account of safety related reasons. All related loads shall be considered.

c) Test load cases (PF)

Test load cases are the pressure test, the leakage test and the in-service inspections.

Note:

The pressure level of the pressure test is specified in Sec. 10.2.2 and the test temperature in Sec. 10.2.3 of KTA 3401.3. The loadings shall be based on these specified values.

4.2.5 Accident load cases (ST)

Accidents are procedural events in the event of which the operation of the plant cannot be continued for safety reasons and for which the plant is designed. All loads related to accidents shall be considered.

4.2.6 Redundancy-wide impacts from an external event (EVA)

These external events are considered to be design-basis earthquake, aircraft crash and explosion pressure waves.

Note:

Due to the requirements for the plant as regards the protection against redundancy-wide internal impacts (plant-internal flooding, fire and explosions), which among others have been laid down in KTA safety standards 2101 - "Fire Protection in Nuclear Power Plants" and 2103 - "Explosion Protection in Nuclear Power Plants", redundancy-wide internal events will not lead to loads on the reactor containment to be considered.

4.3 Loads

(1) All actions that cause loadings in the containment vessel shall be considered as loads. Here, distinction shall be made between the following loads:

a) permanent loads

the dead weight of the containment vessel, the dead weight of the components integrally connected with it, and other permanently acting loads.

b) pressure differences and temperature differences during

- ba) normal operation
- bb) anomalous operation
- bc) test load cases (first pressure test, leakage test)
- bd) accidents
- be) redundancy-wide impact from an external event

In the case of pressure differences all pressures with their local and temporal distribution including locally acting pressures (e.g. jet forces due to pipe rupture close to the wall) shall be considered.

In the case of temperature differences the local and temporal distribution of temperatures including locally limited temperature fields (e.g., in the vicinity of pipe penetrations or due to pipe rupture close to the wall) as well as temperature gradients in the containment vessel cross-section under consideration of the influence of thermal insulation shall be taken into account.

c) static and dynamic loads resulting from attachments and internals as well as pipes and filling loads

Note:

The assignment of pipe loadings to the load cases shown in this safety standard is laid down in KTA 3407.

d) traffic loads

e) wind loads (assembly condition)