Safety Standards

of the
Nuclear Safety Standards Commission (KTA)

KTA 3405 (2015-11)

Leakage Test of the Reactor Containment Vessel

(Dichtheitsprüfung des Reaktorsicherheitsbehälters)

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KTA SAFETY STANDARD

2015-11	Leakage Test of the Reactor Containment Vessel	KTA 3405

CONTENTS

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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, 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 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 of 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 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". They specify among others that the leak tightness of the containment shall be demonstrated by way of an integral leak test before starting power operation for the first time. Furthermore, regular recurrent leak tests shall be performed, allowing an adequate conclusion with regard to the leak rate under design conditions. Safety standard KTA 3405 serves the purpose of concretizing the measures that, within its scope, must be taken to meet the above requirements. In this context, a number of individually cited, conventional engineering standards, in particular DIN standards, are referenced.

The requirements of the Safety Requirements cited above are comprehensively covered

- with respect to steel containment vessels by the following safety standards:

KTA 3401.1	Steel containment vessels; Part 1: Materials,
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: Inservice inspections,

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

KTA 3402	Airlocks on the reactor containment vessel of nuclear power plants – personnel locks,
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 vessel of nuclear power plants – equipment airlocks,

and

- with respect to the design life of components by safety standard:

KTA 3706	Ensuring the loss-of-coolant-accident resistance of electrotechnical components and of components in the instrumentation and controls of operating nuclear power plants.

Furthermore, the isolation of operation-system pipes penetrating the reactor containment vessel in the case of a release of radioactive substances into the reactor containment vessel is dealt within safety standard KTA 3404.

(3) Requirements for the testing manual are specified in safety standard KTA 1202.

(4) By fulfilling the requirements contained in the present safety standard regarding

a) requirements for the measurement system and qualification of the testing personnel,
b) testing schedule,
c) test preparation,
d) test procedure,
e) evaluation of the measurement values,
f) assessment of the results, and
g) documentation,

it is ensured that a leakage test can be properly performed.

1 Scope

This safety standard applies to the leakage test (test of the barrier function) of the reactor containment vessel of stationary nuclear power plants (in the following: the *containment vessel*) using a change-of-pressure procedure.

2 Definitions

(1) Resolution

Resolution refers to the required change of the measurement value that just begins to effect a change of the display of the measurement device.

(2) Evaluation period

The evaluation period is that time section of a measurement procedure dedicated to the evaluation of the leakage test.

(3) Stabilization period

The stabilization period is the time section of a leakage test between reaching the test pressure until the start of the evaluation period.

(4) Change-of-pressure procedure

The change-of-pressure procedure is a method for determining the leak-tightness of a test object. In this measurement procedure, the leakage flow rate is deduced from the pressure change with time in the test object (here: containment vessel) containment vessel. In this context, all influencing factors, like temperature, humidity and filling level, are taken into account.

(5) Free volume

The free volume of the containment vessel is the inner volume of the containment vessel minus the volumes of all those containment vessel internals which cannot be filled with the testing gas during pressure build-up.

(6) Leakage rate

The leakage rate is defined as the mass of the gas escaping from the containment vessel in a day, relative to the original mass of gas in the containment vessel at the beginning of the evaluation period.

Note:
In the specification for the containment vessel of a German nuclear power reactor, the limit values relative to the design pressure are specified as the permissible leakage rate in the dimensional unit of volume-% per day.

(7) Leakage flow rate

The leakage flow rate is defined as the pressure-times-volume flow (pV-flow) of a certain fluid medium flowing through a leak under specified conditions. Its dimensional unit is given as [Pa × m³ × sec⁻¹] (cf. DIN EN 1779).

(8) Frequency of measurements

The frequency of measurements, ν, is defined as the number of measurement cycles minus one, n-1, per time interval, Δt:

$$\nu = \frac{n-1}{\Delta t}$$

(9) Test period

The test period is the overall time needed for the build-up of pressure, stabilization before start of the evaluation period, evaluation period, and depressurization.

(10) Test pressure

The test pressure is the pressure specified for the leakage test of the containment vessel.

(11) Reduced pressure

The reduced pressure is the absolute pressure converted to the starting point of the evaluation period taking the free volume and the changes of temperature and humidity into account.

(12) Authorized Expert

The authorized expert for the tests and investigations under the present safety standard is the expert appointed in accordance with Sec. 20 Atomic Energy Act by the licensing or supervisory authority.

(13) Partial leakage rate

The partial leakage rate is the leakage rate of a single leak location.

3 Requirements

3.1 Measurement Systems

3.1.1 Basic requirements

When choosing type, number and distribution of the measurement systems it shall be considered that the leakage rate will be more accurately determinable

a) the smaller the standard deviation, s, of the reduced pressures,

b) the longer the evaluation period, Δt,

c) the larger the number of measurement cycles, n,

d) the larger the size of the leak, and

e) the larger the test pressure, p_a.

3.1.2 Gas pressure measurement

(1) The value and the change with time of the absolute pressure in the containment vessel shall be determined by measuring the gas pressure, p_a. The respective measurement devices and systems used shall be temperature compensated and shall meet the following requirements:

resolution	≤	0.01 %
measurement uncertainty	≤	0.03 %
error limits	≤	1 %

(2) In order to ensure the security of measurement data, a second pressure measuring device shall be kept in readiness.

(3) It shall be ensured that neither the type nor the design of the pressure sensing line including measurement system can have any impermissible effects on the measurement.

3.1.3 Gas temperature measurement

3.1.3.1 Basic requirements

(1) The temperature measurement devices and systems used shall meet the following requirements:

resolution	≤	0.05 K
measurement uncertainty	≤	0.1 K
error limits	±	3 K

(2) The temperature sensors shall be shielded against heat radiation.

3.1.3.2 Number and distribution of the temperature sensors

(1) The number and distribution of the temperature sensors shall be specified taking into account that the accuracy of determining the average gas temperature strongly depends on the invested complexity of measurement devices and on the size of change with time of the temperature field. In this context, each temperature sensor shall be assigned to a representative partial volume. At least one temperature sensor per 3000 m³, however, at least 10 temperature sensors shall be provided.

(2) The individual temperature sensors shall be arranged inside the containment vessel in horizontal layers of approximately equal heights such that the number of temperature sensors per layer is approximately proportional to the respective layer volume. The layer thickness shall basically be smaller than or equal to 5 m – the layer thickness smaller or equal 5 m applies to the case of a maximum vertical temperature gradient of 1.5 K/m. In the case of a well-insulated containment vessel prior to commissioning or after a longer plant outage with continuing air-circulation, larger layer thicknesses up to and including 10 m are permissible. In layers provided with only one temperature sensor, this sensor shall be located at the center of gravity of the layer. Layers with several temperature sensors (in the same plane) shall be sub-divided such that an almost equal partial volume is allotted to each sensor. Each temperature sensor shall be installed at the center of gravity of its allotted partial volume. The positioning tolerance of the measurement location shall normally be less than or equal to ± 0.5 m.

If temperature equalization is hindered by ceilings or walls, the temperature sensors shall be arranged in the individual rooms such that the average room temperature will be determined. In this context, the number and spatial distribution of the temperature sensors shall be based on the same criteria as specified above.

In the case of smaller rooms with similar thermal behavior, several rooms may be assigned collectively to one sensor. Rooms with heat sources larger than 10 kW shall be provided with temperature sensors even if their inner volume is less than 1500 m³.

3.1.4 Gas humidity measurement

3.1.4.1 Basic requirements

The humidity measurement devices and systems used shall meet the following requirements as converted to water vapor pressure:

resolution	≤	0.3 hPa
measurement uncertainty	≤	0.5 hPa
error limits	±	1 % of the test pressure

The calibration range of the gas humidity sensors shall be chosen in advance of the test to be large enough such that the calibration range will cover the expected gas humidity during the test.

3.1.4.2 Number and distribution of the gas humidity sensors

(1) The number of gas humidity sensors shall normally be equal to one sensor for every 10 temperature sensors; however, no less than four gas humidity sensors shall normally be deployed. The gas humidity sensors shall normally be distributed analogously to the distribution of the temperature sensors taking possible humidity sources into account. One calibrated gas humidity sensor shall be provided as a possible replacement.

(2) It is permissible to replace the gas humidity sensor in the suppression pool of a boiling water reactor (BWR) by the five-minute long spraying procedure performed with operational means at the beginning of the stabilization period to produce a relative humidity of 100 % in the atmosphere of the suppression pool. Each gas humidity sensor shall be assigned to a representative partial volume.

3.1.5 Filling level of the suppression pool of a BWR

The respective measurement devices and systems used shall meet the following requirements relative to the filling level of the suppression pool:

non-linearity	≤	0.1 % F.S. (full scale) or 1.0 mm*)
reproducibility	≤	0.1 % F.S. or 0.5 mm*)
hysteresis	≤	0.1 % F.S. or 0.5 mm*)

*) The larger respective value shall apply.

3.2 Testing Personnel

The testing personnel shall be qualified and certified as Level 1 in accordance with DIN EN ISO 9712 for the test procedure used and shall have relevant professional experience. Professional experience shall normally be attained by participation in leakage tests of containment vessels in nuclear power plants. Participation shall comprise test preparation and installation, execution of the test, measurement evaluation, and drawing up the final report.

4 Test Schedule

4.1 Basic Requirements

Prior to testing, a test instruction in accordance with Sec. 3.4 of safety standard KTA 1202 shall be drawn up. This shall address, in particular:

a) establishing and documenting the required condition of the individually involved nuclear power plant systems with regard to the test procedure,

   Note:

   Regarding a BWR, this includes considering whether or not pumping water out of the suppression pool will become necessary during the evaluation period.

b) documenting the condition of the test object before, during and after the test,

c) frequency of measurements,

d) point in time of test,

e) procedural chart (application of test pressure, stabilization period, evaluation period, pressure change gradient during pressure build-up or during depressurization),

f) type and extent of documentation,

g) measures regarding personnel protection, in particular, when accessing the containment vessel under test pressure,

h) measures regarding fire protection.

4.2 Test Pressure

4.2.1 Initial leakage test

Starting from the depressurized state, the initial leakage test shall be performed in two consecutive pressure steps: first, at a pressure of at least 0.5×10^5 Pa over ambient pressure, then, second, at the design pressure. In the case of facilities with a design pressure smaller than or equal to 1.5×10^5 Pa, the test pressure shall be specified in agreement with the proper authority or the authorized expert.

4.2.2 Recurrent leakage test during inservice inspections

After a corresponding preparation, it shall basically be possible to perform the recurrent leakage test during inservice inspection at design pressure. Starting from the absolute pressure level inside the containment vessel before the start of the test, the leakage test shall be performed by applying an absolute pressure of at least 0.5×10^5 Pa over ambient pressure. During the evaluation period, the differential pressure shall normally not fall below this minimum value of 0.5×10^5 Pa. In the case of facilities with a design pressure smaller than or equal to 1.5×10^5 Pa, the test pressure shall be specified in agreement with the proper authority or the authorized expert.

4.3 Stabilization period

Subsequent to average pressure change gradients larger than 50 hPa/h, a stabilization period of at least 6 hours shall be observed; after this time detrimental influences (e.g., gas storage in concrete pores) and unstable gas conditions from the influx of compressed air will have subsided.

4.4 Evaluation Period

4.4.1 Initial leakage test

The duration of the evaluation period shall normally be 36 hours; it may be shortened to 18 hours, provided, the requirement of Equation 7-6 is fulfilled.

4.4.2 Recurrent leakage test during inservice inspections

The duration of the evaluation period shall be at least 10 hours, provided, the requirement of Equation 7-25 is fulfilled.

4.5 Point in Time of Measurement

4.5.1 Initial leakage test

The initial leakage test may only be performed after the containment vessel has been protected against outside temperature influences and after the pressure test was performed in accordance with Ordinance on Industrial Safety and Health (BetrSichV).

4.5.2 Recurrent leakage test during inservice inspections

(1) The recurrent leakage test during inservice inspections shall be carried out in the test intervals specified for the containment vessel in accordance with safety standard KTA 3401.4.

(2) The point in time of the test shall be specified such that the plant is in a cooled-off and, as far as possible, isothermal condition, e.g., before start-up after a major inspection or after an extended shutdown of the plant.

5 Test Preparation

5.1 Measurement Devices

(1) The measured values shall normally be recorded at a central location outside of the containment vessel. In this context, an air-conditioned and adequately dust free room shall be provided. The place of, and mode of access to, this measurement room shall meet the relevant requirements.

(2) The placement and functional capability of the measurement sensors shall be checked. The results shall be recorded on the corresponding Form Sheets of **Appendix B**.

(3) The most recent calibration of the pressure and humidity sensors shall normally not go back further than one year.

(4) The installed measurement systems shall be randomly checked regarding plausibility and accuracy of the measured values.

(5) Suitable measures shall be taken to prevent possible loss of automatically recorded measured data.

5.2 Pressurizing Facility

(1) When operating the pressurizing facility to produce the test pressure, it shall be ensured that the test pressure and change-of-pressure gradient do not exceed the values specified in the test schedule.

(2) The oil separators, air coolers and filters of compressors shall be chosen such that it is ensured that the charged air contains only a least possible amount of humidity and oil.

(3) Suitable measures shall be taken to ensure that a backflow from the containment vessel through the pressure charging lines into the environment is prevented (e.g., by check valves, alarm devices). When the test pressure has been reached, the pressurizing facility shall be separated from the test object.

5.3 Test Object

(1) Before performing the initial leakage test, all containment vessel penetrations out to the first inner or outer anchor point as well as to their first inner or outer isolating devices shall basically be installed.

(2) The penetrations of the containment vessel shall be closed off by the designated isolation devices operated by means of their regular operation mechanisms. Only exceptions are those systems which, in accordance with the operating manual, must remain in operation during this operating condition of the power plant. Furthermore, during the initial leakage test, temporary blanks may be used on those systems which will not be in direct contact with the containment vessel atmosphere during later operation, provided, it can be verified that these systems have only a negligible effect on the test result of the initial leakage test.

(3) The inner hatches of air locks shall be in their open position; the outer hatches of locks shall be closed and shall be locked using their regular operation mechanisms.

5.4 Components

(1) As far as technically possible and permissible from the point of view of safety, it shall be ensured that all rooms, systems and components within the containment vessel can be pressurized to the level of the test pressure.

(2) It shall be checked whether component parts (e.g., vessels, operational instrumentation, lighting) could be damaged by the test pressure or whether the operational instrumentation will deliver false values (e.g., fire alarm). If necessary, measures shall be taken to prevent such effects.

(3) The lighting inside the containment vessel shall normally be reduced to a necessary minimum.

(4) During the leakage test, the residual heat removal systems shall remain in their stationary state of operation. As far as possible, a train-to-train switchover shall be avoided.

(5) The leak-tightness of vessels with a high inner gas pressure and whose pressure cannot be reduced to ambient pressure shall be tested before performing the recurrent leakage test during inservice inspections.

(6) Plant components inside the containment vessel shall be shut down, provided, this is permissible in accordance with the operating manual and the test instruction.

(7) The condition of the plant components inside the containment vessel shall be recorded on the respective Form Sheets of **Appendix B**.

6 Test Procedure

(1) The test shall be performed in accordance with the test instruction. The condition of the containment vessel closure devices, especially that of the air locks, shall not be altered during the evaluation period unless otherwise specified in the test instruction.

(2) The frequency of measurements shall be chosen to be at least 6 per hour. In this context, it shall be taken into consideration that a longer evaluation period or a higher frequency of measurements will significantly improve the accuracy of the test results.

(3) In the case of a failure of the measurement system lasting longer than one hour, the measurement period shall be increased by the length of the failure outage.

(4) During the measurement, all electrical measurement values shall be converted into the respective physical quantities, and the variables of state shall be determined for the gas mixture inside the containment vessel.

(5) The variables of state and the calculated reduced pressure shall promptly be graphically displayed to enable a continuous monitoring of the test.

(6) In case of a failure of individual measurement sensors, the further procedure shall be specified in agreement with the authorized expert. It is permissible to continue with the leakage test, provided, the trend of the previously measured values reveals that the measured values of the failed sensors have an only negligible effect on the test result.

(7) If, during the evaluation period, a flow of gases from the outside into the containment vessel is unavoidable or if gas is removed by means of a leakage exhaust system, then the respective mass flow shall be determined by measuring the volumetric flow and the gas state (pressure, temperature). A feedback into the containment vessel is not permissible.

(8) The filling level of the fuel pool of a pressurized water reactor (PWR)and the suppression pool of a BWR shall be kept constant during the leakage test, or any change of the filling level shall be kept as small as absolutely unavoidable.

(9) During the leakage test, the temperature of the cooling medium in the fuel pool should be at the same, or only slightly lower temperature as that of the ambient vessel atmosphere. In this context, the feedback cooling system of the fuel pool shall be properly adjusted and in good time before start of the test. In case, during the evaluation period, the temperature of the fuel pool cooling medium is far above the temperature of the

ambient vessel atmosphere, the plant operator and authorized expert shall assess in how far this affects the measurement result.

(10) If the pumping off of water from the suppression pool of a BWR becomes necessary as specified in Section 4.1 item a), then the pumping-off procedure shall normally be timed for the middle of the evaluation period. After the end of the pumping-off procedure, the measurements shall be continued for at least two more hours. In case of an offset of the two curve sections (each of equal duration) before and after the pumping-off procedure, this fact shall be subject to a special assessment.

Note:

The goal of the pumping-off procedure is to achieve that the suppression pool has similar filling level at the end as at the start of the evaluation period.

(11) If, in the course of the leakage test, it becomes apparent that the goal of the test will not be reached, the tester shall inform the responsible person of the plant operator. Any necessary leak detection shall be recorded on Form Sheet 19 of **Appendix B**. It is permissible that multiple groups perform the leak detection in parallel. Each measure for reducing the leakage rate shall be realized individually, however, only after release of the respective work task. After realization of an individual measure, a waiting period shall be observed to check its possible effect on the leakage rate. Further measures shall normally not be taken before the end of this waiting period.

7 Evaluation of the Measurement Results

Note:

The nomenclature of the equations is collectively presented in **Appendix A**.

7.1 Basic Requirements

(1) The following measurement values shall be determined:

a) test pressure, p_a,

b) gas temperature, T_r,

c) partial pressure, p_d,

d) volume ratio, V/V_0.

(2) It is permissible to neglect individual measured values (implausible or freak values), provided, it is clear that the individual measured value is not plausible or that it can be identified as having been caused by a disturbance. On account of neglected individual measured values, the evaluation period need only be extended if the overall respective measurement outage exceeds one hour.

(3) The evaluation shall be carried out in the following steps:

a) calculation of the reduced pressures,

b) calculation of the leakage rate,

c) calculation of the confidence limits of the leakage rate,

d) calculation of the leakage flow rate,

e) calculation of the confidence limits of the leakage flow rate.

7.2 Calculation of the Reduced Pressures

(1) Since the variables of state like temperature, humidity and vessel volume can change with time in comparison to the reference state, the pressure values shall be converted to this reference state. This reduced pressure shall be calculated according to the following equation:

$$p_b = (p_a - p_d)\frac{V \times T_0}{V_0 \times T} \qquad (7\text{-}1)$$

(2) For determining the partial pressures, the relative humidity, φ_j, shall be converted to the water vapor pressure, p_{d_j}, according to the following equations:

$$p_{d_j} = \varphi_j \times p_{s_j} \qquad (7\text{-}2)$$

$$\ln p_{s_j} = 56.88 - \frac{6891.3}{T_{r_j}} - 5.32 \times \ln T_{r_j} \qquad (7\text{-}3)$$

(p_s in [hPa]).

(3) The average absolute gas temperature of the gas mixture within the containment vessel shall be determined by a mass-proportional averaging according to the following equation:

$$T_r = \frac{\sum V_j}{\sum \frac{V_j}{T_{r_j}}} \qquad (7\text{-}4)$$

(4) The average water vapor pressure shall be determined by volume-proportional averaging according to the following equation:

$$p_d = \frac{\sum V_j \times p_{d_j}}{\sum V_j} \qquad (7\text{-}5)$$

(5) In view of the actual design conditions (e.g., structural design and choice of materials), it is permissible to neglect the pressure-dependent change in volume of the containment vessel.

(6) If the reduced pressure of the initial leakage test shows deviations from a linear course, each individual case shall be investigated with regard to whether the compensating lines, B(1) and B(2), of two immediately adjacent analysis sections, (1) and (2), have the same gradient. Each of the analysis sections shall represent a minimum evaluation period of five hours with the same frequency of measurements and the same number of measurement cycles, n(1) = n(2) = n. The following equation shall be satisfied:

$$\frac{|B(1) - B(2)|}{\sqrt{(s(1))^2 + (s(2))^2}} \times \sqrt{\sum t_i^2 - \frac{1}{n}\left(\sum t_i\right)^2} < t_{\alpha_1} \qquad (7\text{-}6)$$

The statistical parameter, t_{α_1}, shall be chosen as specified under **Table 7-1**.

Number, n, of the measurement cycles in the respective analysis section	Statistical parameter, t_{α_1}
3	4.30
4	2.80
5	2.40
6	2.30
7	2.20
10	2.10
20	2.03
30	2.00
50	1.98
100	1.97
over 100	1.96

Table 7-1: Statistical parameter, t_{α_1}, for various numbers of measurement cycles

If the condition of Equation 7-6 cannot be satisfied, then two analysis sections shall be picked out from the overall course of reduced pressure values which satisfy this condition. These two sections shall cover at least 36 hours and shall encompass three complete half waves consecutively following each other. If these two sections still do not satisfy Equation 7-6, the evaluation period shall be extended by at least 12 hours.

7.3 Calculation of the Leakage Rate

(1) The reduced pressure values calculated as specified under Section 7.2 shall be approximated by a straight line, since, for leakage rates smaller than or equal to 5 % per day, the pressure decrease with time is small enough such that the exponential pressure characteristic can be approximated by a linear pressure characteristic.

(2) The gradient, B, and on the ordinate section, A, of the linear regression line shall be calculated by the least mean square algorithm using the following equations (cf. A. Linder, Statistische Methoden, Birkenhauer Verlag, Basel 1964):

$$B = \frac{n \times \sum \left(t_i \times p_{b_i}\right) - \sum t_i \times \sum p_{b_i}}{n \times \sum t_i{}^2 - \left(\sum t_i\right)^2} \qquad (7\text{-}7)$$

$$A = \frac{1}{n}\left(\sum p_{b_i} - B \cdot \sum t_i\right) \qquad (7\text{-}8)$$

(3) Based on the gradient, B, and the ordinate section, A, of the linear regression line, the leakage rate shall be calculated using the following equation:

$$L_{integral} = -\frac{B}{A} \qquad (7\text{-}9)$$

(4) In the leakage test the measured partial leakage rates shall be taken into consideration. The corresponding change in mass, Δm, shall be calculated from the following equation:

$$L_{partial} = \frac{1}{\Delta t}\frac{\Delta m}{m} \qquad (7\text{-}10)$$

(5) If volumetric flows are measured, the following equation may be used:

$$L_{partial} = \frac{\dot{v}_{Gm} \times \overline{p}_{1,Gm} \times \overline{T}_{CV}}{V_{CV} \times \overline{p}_{1_a} \times \overline{T}_{Gm}} \qquad (7\text{-}11)$$

(6) Here, the free volume, V, of the containment vessel must be known. The respective uncertainty shall be no larger than ± 5 %.

(7) Those partial leakage rates effecting an increase of mass inside the containment vessel shall be characterized by a plus sign. Partial leakage rates effecting a loss of mass inside the containment vessel may only be taken into account, if the respective leaks will be permanently removed after the leakage test. These leakages rates shall be characterized by a minus sign. The leakage rate shall be calculated using the following equation:

$$L = L_{integral} + \sum L_{partial} \qquad (7\text{-}12)$$

7.4 Calculation of the Confidence Limits of the Leakage Rate

7.4.1 Confidence limits of the leakage rate

(1)The standard deviation of the reduced pressures (cf. A. Linder, 1964) shall be calculated using the following equations:

$$s = \sqrt{\frac{\sum\left(A + B \times t_i - p_{b_i}\right)^2}{n-2}} \qquad (7\text{-}13)$$

Then, the gradient of the linear regression line is

$$s_B = s \times \sqrt{\frac{n}{n \times \sum t_i^2 - \left(\sum t_i\right)^2}} \qquad (7\text{-}14)$$

and the ordinate section of the linear regression line is

$$s_A = s \times \sqrt{\frac{\sum t_i^2}{n \times \sum t_i^2 - \left(\sum t_i\right)^2}} \qquad (7\text{-}15)$$

(2) The confidence range for the leakage rate calculated as specified under Section 7.3 shall be equal to 2 × sL with s_L being calculated using the following equation:

$$s_L = \left(1 + \frac{s_A}{A} \times \frac{|B|}{s_B}\right) \times \frac{s_B}{A} \times t_{\alpha 2} \qquad (7\text{-}16)$$

$$\text{If} \quad \frac{s_A}{A} \times \frac{|B|}{s_B} << 1 \quad \text{then} \quad s_L = \frac{s_B}{A} \times t_{\alpha 2} \qquad (7\text{-}17)$$

may be used as approximation. The statistical parameter, $t_{\alpha 2}$, shall be chosen as specified in Table 7-2.

Number, n, of measurement cycles	Statistical parameter, $t\alpha_2$
4	13.10
6	5.60
8	4.30
10	3.83
15	3.37
20	3.20
30	3.05
50	2.94
100	2.87
200	2.84
500	2.82
over 500	2.81

Table 7-2: Statistical parameter, $t_{\alpha 2}$, for various numbers, n, of measurement cycles

The confidence limits of the leakage rate shall be calculated as:

$$L + sL \text{ and } L - sL \qquad (7\text{-}18)$$

7.4.2 Confidence limits of the leakage rate

The confidence limits of the leakage rate shall be calculated from the confidence range of the leakage rate and the error of the partial leakage rate measurements as follows:

$$\frac{s_{L_{partial}}}{L_{partial}} = \left[\left(\frac{G(V_{Gm})}{V_{Gm}}\right)^2 + \left(\frac{G(V_{CV})}{V_{CV}}\right)^2 + \left(\frac{G(p_{1,Gm})}{p_{1,Gm}}\right)^2 + \right.$$

$$+\left(\frac{G(p_{1a})}{p_{1a}}\right)^2+\left(\frac{G(T_r)}{T_r}\right)^2+\left(\frac{G(T_{Gm})}{T_{Gm}}\right)^2\Bigg]^{1/2} \quad (7\text{-}19)$$

$$s_L=\sqrt{\left(s_{L_{integral}}\right)^2+\left(s_{partial}\right)^2} \quad (7\text{-}20)$$

7.5 Conversion to Design Pressure

(1) In addition to the permissible leakage rate, $L_{1,perm}$, at the design pressure, $p_{ü1}$, the leakage rate, $L_{2,perm}$, at the pressure $p_{ü2}$ shall be calculated from the following equations:

In case $\frac{L_2}{L_1}\le\left(\frac{p_{ü2}}{p_{ü1}}\right)^{1/2}$ then

$$L_{2,perm}=L_{1,perm}\times\frac{L_2}{L_1} \quad (7\text{-}21)$$

and, in case $\frac{L_2}{L_1}>\left(\frac{p_{ü2}}{p_{ü1}}\right)^{1/2}$ then

$$L_{2,perm}=L_{1,perm}\times\left(\frac{p_{ü2}}{p_{ü1}}\right)^{1/2} \quad (7\text{-}22)$$

With

L_2 leakage rate measured in the initial leakage test at the pressure of the recurrent leakage test during inservice inspections,

L_1 leakage rate measured in the initial leakage test at design pressure

$p_{ü2}$ pressure of the recurrent leakage test during inservice inspections, and

$p_{ü1}$ design pressure.

(2) In the initial leakage test, the confidence range shall not exceed 4 % of the permissible leakage rate, L1,perm, that is

at design pressure:

$$\frac{s_{L_1}}{L_{1,perm}}\le 0.02 \quad (7\text{-}23)$$

and at the pressure of the recurrent leakage test during inservice inspections:

$$\frac{s_{L_2}}{L_{1,perm}}\le 0.02 \quad (7\text{-}24)$$

(3) The confidence range of the recurrent leakage test during inservice inspections shall not exceed 60 % of the permissible leakage rate, $L_{2,perm}$, that is

$$\frac{s_L}{L_{2,perm}}\le 0.3 \quad (7\text{-}25)$$

Note:

If one of the measured leakage rates, L_1, L_2, or both of the measured leakage rates are very small (≤ 0.01% per day), special measures shall be agreed upon between the parties involved.

7.6 Conversion of a Permissible Leakage Rate into a Leakage Flow Rate

7.6.1 Specification of the limit value for the recurrent leakage test during inservice inspections

The leak tightness criterion shall be converted from the design requirements to the test requirements as specified under Section 7.5. The leakage flow rate, q_L, shall be calculated using the following equation:

$$q_{L\,perm,\,test\,pressure}=\frac{L_{2,perm}\times V\times p_a}{8.64\times10^6} \quad (7\text{-}26)$$

$[Pa\times m^3\times s^{-1}]$

with

$L_{2,perm}$ [% per day],

V [m^3],

p_a average test pressure during evaluation period [Pa].

7.6.2 Conversion of the measurement result from a leakage rate into a leakage flow rate

7.6.2.1 Conversion of the measurement values

The measured leakage rate, L, shall be converted into a leakage flow rate, q_L, using the following equation:

$$q_{L,\,test\,pressure}=\frac{L\times V\times p_a}{8.64\times10^6}\quad[Pa\times m^3\times s^{-1}] \quad (7\text{-}27)$$

with

L [% per day],

V [m^3],

p_a average test pressure during evaluation period [Pa].

7.6.2.2 Conversion of the confidence range

The confidence range shall be converted using the following equation:

$$q_{L,\,confidence\,limit}=\frac{\pm s_L\times V\times p_a}{8.64\times10^6}\quad[Pa\times m^3\times s^{-1}] \quad (7\text{-}28)$$

8 Assessment of the Results

The leakage test shall be considered as successfully completed if the following relationship is fulfilled:

$$q_{L,\,test\,pressure}+q_{L,\,confidence\,limit}\le q_{perm,\,test\,pressure}$$

9 Documentation

9.1 On-site Report

Immediately after the end of measurements, the tester shall draw up an on-site report. This report shall comprise at least the following:

a) location, time and duration of the measurements,

b) calculated leakage flow rate including confidence range,

c) permissible leakage flow rate,

d) graphic representation of the course of the reduced pressure and of the leakage flow rate,

e) print-out of the essential input parameters of the software program for the evaluation,

f) singular events in the course of testing (e.g., outage times, walk-trough inspection of containment vessel, reasons for extending the measurement time).

9.2 Final Report

(1) The tester shall draw up a final report. This report shall comprise at least the following:

a) (filled in) Form Sheets of **Appendix B**.

b) calibration documents of the employed measurement devices,

c) quality assurance measures taken during the setup of the leakage test,

d) singular events relevant to the test results and the corresponding measures taken,

e) measures taken in connection with a possibly necessary leak detection.

(2) Form Sheets 1 through 19 shall be filled in by the plant operator. Form Sheets 20 through 28 shall be filled in by the tester.

(3) The final report shall be presented to the party that commissioned the leakage test within three months after completion of the recurrent leakage test during inservice inspections.

(4) The extent of the documentation shall be specified in accordance with safety standard KTA 1404.

Appendix A

Nomenclature

Symbols and Units

Symbols	Description	Units
A	ordinate section of the linear regression line	Pa
B	gradient of the linear regression line	Pa × h^{-1}
G	margin of error	-
L, $L_{partial}$, $L_{integral}$	leakage rate, partial leakage rate, integral leakage rate	% × d^{-1}
L_1	leakage rate at design pressure	% × d^{-1}
L_2	leakage rate at test pressure	% × d^{-1}
q_L	leakage flow rate	Pa × m^3 × s^{-1}
m, Δm	gas mass, gas mass difference	kg
n	number of measurement cycles	-
p_a	absolute pressure relative to vacuum (test pressure)	Pa
p_b	reduced pressure	Pa
p_d	water vapor partial pressure	Pa
p_s	saturation pressure	Pa
$p_{ü}$	pressure relative to atmospheric pressure	hPa
s	standard deviation of the reduced pressures	hPa
s_A	standard deviation of A	hPa
s_B	standard deviation of B	hPa × h^{-1}
s_L	confidence range of the leakage rate	% × d^{-1}
t, Δt	time, time difference	h, d
t_α	statistical parameter	-
T, ΔT	temperature, temperature difference	K
T_r	gas temperature inside containment vessel	K
V	free volume	m^3
ν	frequency of measurements	h^{-1}
φ_j	relative humidity	%

Indices und Special Characters

The symbols I and j are used as running indices. Time dependent values are indexed by I = 1, …, n and location dependent values by j = 1, …, k.

Index 0 indicates the reference condition used for the evaluation (e.g., V_0).

Time dependent average values are indicated by a top horizontal line (e.g., $\overline{T}$); flow values are indicated by a dot e.g., $\dot{v}$ is the volumetric flow. The index CV (e.g., T_{CV}) indicates containment vessel and Gm (e.g., V_{Gm}) gas meter. The index perm (e.g., $L_{1,perm}$) stands for “permissible”.

Appendix B

Form Sheets

This appendix contains form sheets – in a reduced format – that shall be used for describing the test condition and for documenting the test procedure. These form sheets are:

Form Sheet 1:	Cover sheet for the protocol
Form Sheet 2:	Basic information
Form Sheet 3:	Description of test conditions; Containment vessel
Form Sheet 4:	Description of test conditions; Assembly openings
Form Sheet 5:	Description of test conditions; Material air locks
Form Sheet 6:	Description of test conditions; Personnel air locks
Form Sheet 7:	Description of test conditions; Personnel emergency locks
Form Sheet 8:	Description of test conditions; Quick-closing butterfly valves of the air supply and ventilation system
Form Sheet 9:	Description of test conditions; Pipe penetrations
Form Sheet 10:	Description of test conditions; Cable penetrations
Form Sheet 11:	Description of test conditions; Leakage exhaust system
Form Sheet 12:	Description of test conditions; Steam generating system; Other pressure retaining systems
Form Sheet 13:	Description of test conditions; Fuel pool; Other containment vessel internals; Containment vessel ventilation; Reactor protection or control systems
Form Sheet 14:	Description of test conditions; Insulation and concrete internals of the containment vessel
Form Sheet 15:	Description of test conditions; Locations and nominal widths of the openings
Form Sheet 16:	Description of test conditions; Closures of the openings
Form Sheet 17:	Description of test conditions; Heat sources
Form Sheet 18:	Description of the pressurizing facility and installation schematic
Form Sheet 19	Leak detection
Form Sheet 20:	Description of measurement systems; Gas pressure measurement
Form Sheet 21:	Description of measurement systems; Gas temperature measurement
Form Sheet 22:	Description of measurement systems; Gas temperature measurement – volumetric correlation
Form Sheet 23:	Description of measurement systems; Gas temperature measurement – basic schematic
Form Sheet 24:	Description of measurement systems; Gas humidity measurement
Form Sheet 25:	Description of measurement systems; Gas humidity measurement – volumetric correlation
Form Sheet 26:	Description of measurement systems; Gas humidity measurement – basic schematic
Form Sheet 27:	Description of measurement systems; Other measurement systems
Form Sheet 28:	Execution of the leakage test

Form Sheet 1: Cover sheet for the protocol

Nuclear power plant
....

Unit
....

Site location
....

P R O T O C O L

for the

Leakage Test

of the Containment Vessel

This protocol consists of ______ pages, _____ sheets

....

Place, Date

Responsible person of the plant operator ....

Tester ....

Authorized expert under Sec. 20 AtG ....

Form Sheet 2: Basic Information

1 **General**

1.1 Manufacturer: ……………………………………………………………………

1.2 Power Plant Operator: ……………………………………………………………

1.3 Specification of the Plant: …………………………………………………………

……………………………………………………………………………………

1.4 Year of construction [ ] 1.5 Site Location [ ]

1.6 Start of testing Date [ ] Time [ ]

1.7 End of testing Date [ ] Time [ ]

1.8 Type of reactor:
- Boiling water reactor [ ]
- Pressurized water reactor [ ]
- Other [ ] (if yes, describe)

1.9 Design pressure [ ] bar

1.10 Permissible leakage rate [ ] %/d at design pressure

1.11 Free volume [ ] m^3 analytical / experimental value *)

1.12 Type of test:

- Initial test [ ]
- Pre-operation test [ ] (1st inservice inspection)
- Inservice inspection [ ] (running number)

1.13 Licensing authority:……………………………………………………………

1.14 Expert:……………………………………………………………………
(Name)

1.15 Authorized expert (Sec. 20 AtG):………………………………………………
(Name, Institution)

1.16 Executing Department:……………………………………………………
(Institution)

1.17 Tester:……………………………………………………………………
(Name, Institution)

*) strike out whichever is not applicable

Form Sheet 3: Description of test conditions; Containment vessel

2 Test Object

2.1 Containment Vessel

(Excluding all air locks, assembly openings and penetrations)

2.1.1 Type of containment vessel

(Shape, dimensions, structural materials, type of assembly or reference to technical drawings of the manufacturer or to the specifications)

………

………

………

2.1.2 State of construction, work tasks completed: ☐ YES ☐ NO (If NO, explain)

………

………

………

………

………

………

………

………

2.1.3 Previous work tasks performed having an effect on leak-tightness since the last inservice inspection (Assembly, disassembly, repair tasks):

………

………

………

………

………

………

2.1.4 Local leakage tests ☐ YES ☐ NO

(If YES, cf. Test Report No. ____________).

2.1.5 Miscellaneous

………

………

………

Notes:

Locations and nominal widths of the openings – cf. Form Sheet 15

Closures of the openings – cf. Form Sheet 16

Form Sheet 4: Description of test conditions; Assembly openings

2.2 Assembly Openings ☐ number

2.2.1 Type of assembly openings

(Shape, dimensions, structural materials, type of assembly or reference to technical drawings of the manufacturer or to the specifications)

………

………

………

2.2.2 State of construction, work tasks completed: ☐ YES ☐ NO (If NO, explain)

………

………

………

………

………

………

………

2.2.3 Previous work tasks performed having an effect on leak-tightness since the last inservice inspection (Assembly, disassembly, repair tasks):

………

………

………

………

………

2.2.4 Local leakage tests: ☐ YES ☐ NO

(If YES, cf. Test Report No. ____________).

2.2.5 Miscellaneous

………

………

………

Notes:

Locations and nominal widths of the openings – cf. Form Sheet 15

Closures of the openings – cf. Form Sheet 16

Form Sheet 5: Description of test conditions; Material air locks

2.3 Material Air Locks ☐ number

2.3.1 Type of material air locks

(Shape, dimensions, structural materials, type of assembly or reference to technical drawings of the manufacturer or to the specifications)

……
……
……

2.3.2 State of construction, work tasks completed: ☐ YES ☐ NO (If NO, explain)

……
……
……
……
……
……

2.3.3 Previous work tasks performed having an effect on leak-tightness since the last inservice inspection (Assembly, disassembly, repair tasks):

……
……
……
……
……
……

2.3.4 Local leakage tests ☐ YES ☐ NO

(If YES, cf. Test Report No. ____________)

2.3.5 Miscellaneous

……
……
……

Notes:

Locations and nominal widths of the openings – cf. Form Sheet 15

Closures of the openings – cf. Form Sheet 16

Form Sheet 6: Description of test conditions; Personnel air locks

2.4 Personnel Air Locks ☐ number

2.4.1 Type of personnel air locks

(Shape, dimensions, structural materials, type of assembly or reference to technical drawings of the manufacturer or to the specifications)

……

……

……

2.4.2 State of construction, work tasks completed: ☐ YES ☐ NO (If NO, explain)

……

……

……

……

……

……

2.4.3 Previous work tasks performed having an effect on leak-tightness since the last inservice inspection (Assembly, disassembly, repair tasks):

……

……

……

……

……

……

2.4.4 Local leakage tests ☐ YES ☐ NO

(If YES, cf. Test Report No. ____________).

2.4.5 Miscellaneous

……

……

……

Notes:

Locations and nominal widths of the openings – cf. Form Sheet 15

Closures of the openings – cf. Form Sheet 16

Form Sheet 7: Description of test conditions; Personnel emergency locks

2.5 Personnel Emergency Locks ☐ number

2.5.1 Type of personnel emergency locks

(Shape, dimensions, structural materials, type of assembly or reference to technical drawings of the manufacturer or to the specifications):

....

....

....

2.5.2 State of construction, work tasks completed: ☐ YES ☐ NO (If NO, explain)

....

....

....

....

....

....

2.5.5 Previous work tasks performed having an effect on leak-tightness since the last inservice inspection (Assembly, disassembly, repair tasks):

....

....

....

....

....

....

2.5.4 Local leakage tests ☐ YES ☐ NO

(If YES, cf. Test Report No. ____________).

2.5.5 Miscellaneous

....

....

....

Notes:

Locations and nominal widths of the openings – cf. Form Sheet 15

Closures of the openings – cf. Form Sheet 16

Form Sheet 8: Quick-closing butterfly valves of the air supply and ventilation system

2.6 Quick-closing Butterfly Valves of the Air Supply and Ventilation System ☐ number

2.6.1 Type of quick-closing butterfly valves

(Shape, dimensions, structural materials, type of assembly or reference to technical drawings of the manufacturer or to the specifications):

……

……

……

2.6.2 State of construction, work tasks completed: ☐ YES ☐ NO (If NO, explain))

……

……

……

……

……

……

2.6.3 Previous work tasks performed having an effect on leak-tightness since the last inservice inspection (Assembly, disassembly, repair tasks):

……

……

……

……

……

……

2.6.4 Local leakage tests ☐ YES ☐ NO

(If YES, cf. Test Report No. ____________).

2.6.5 Miscellaneous

……

……

……

Notes:

Locations and nominal widths of the openings – cf. Form Sheet 15

Closures of the openings – cf. Form Sheet 16

Form Sheet 9: Description of test conditions; Pipe penetrations

2.7 Pipe Penetrations ☐ number

2.7.1 Type of pipe penetrations

(Shape, dimensions, structural materials, type of assembly or reference to technical drawings of the manufacturer or to the specifications):

………

………

………

2.7.2 State of construction, work tasks completed: ☐ YES ☐ NO (If NO, explain)

………

………

………

………

………

………

2.7.3 Previous work tasks performed having an effect on leak-tightness since the last inservice inspection (Assembly, disassembly, repair tasks):

………

………

………

………

………

2.7.4 Local leakage tests ☐ YES ☐ NO

(If YES, cf. Test Report No. ____________).

2.7.5 Miscellaneous

………

………

………

Notes:

Locations and nominal widths of the openings – cf. Form Sheet 15

Closures of the openings – cf. Form Sheet 16

Form Sheet 10: Description of test conditions; Cable penetrations

2.8 Cable Penetrations ☐ number

2.8.1 Type of cable penetration

(Shape, dimensions, structural materials, type of assembly or reference to technical drawings of the manufacturer or to the specifications):

……

……

……

2.8.2 State of construction, work tasks completed: ☐ YES ☐ NO (If NO, explain)

……

……

……

……

……

……

2.8.3 Previous work tasks performed having an effect on leak-tightness since the last inservice inspection (Assembly, disassembly, repair tasks):

……

……

……

……

……

2.8.4 Local leakage tests ☐ YES ☐ NO

(If YES, cf. Test Report No. ____________).

2.8.5 Miscellaneous

……

……

……

Notes:

Locations and nominal widths of the openings – cf. Form Sheet 15

Closures of the openings – cf. Form Sheet 16

Form Sheet 11: Description of test conditions; Leakage exhaust system

2.9 Leakage Exhaust System

2.9.1 Type of leakage exhaust system

(Shape, dimensions, structural materials, type of assembly or reference to technical drawings of the manufacturer or to the specifications):

....
....
....
....
....
....

2.9.2 State of construction, work tasks completed: ☐ YES ☐ NO (If NO, explain)

....
....
....

2.9.3 Previous work tasks performed having an effect on leak-tightness since the last inservice inspection (Assembly, disassembly, repair tasks):

....
....
....
....

2.9.4 Local leakage tests ☐ YES ☐ NO

(If YES, cf. Test Report No. ____________).

2.9.5 Miscellaneous

....
....
....

Notes:

Locations and nominal widths of the openings – cf. Form Sheet 15

Closures of the openings – cf. Form Sheet 16

Form Sheet 12: Description of test conditions; Steam generating system; Other pressure retaining systems

2.10 Steam Generating System

2.10.1 Reactor shut down on: Time:

2.10.2 System is leak tight: ☐ YES ☐ NO
(If NO, describe; specify leakage amount)

……………………………………………………………………………………………………

……………………………………………………………………………………………………

2.10.3 Hydraulic seal exists: ☐ YES ☐ NO

2.10.4 Miscellaneous

……………………………………………………………………………………………………

……………………………………………………………………………………………………

2.11 Other Pressure Retaining Systems

2.11.1 Systems are under pressure: ☐ YES ☐ NO
(If YES, list those which are)

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

2.11.2 Systems are leak tight: ☐ YES ☐ NO
(If NO, describe; specify leakage amount)

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

2.11.3 Hydraulic seal exists: ☐ YES ☐ NO

2.11.4 Miscellaneous

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

Notes:

Locations and nominal widths of the openings – cf. Form Sheet 15

Closures of the openings – cf. Form Sheet 16

Form Sheet 13: Description of test conditions; Fuel pool; Other containment vessel internals; Containment vessel ventilation; Reactor protection or control systems

2.12 Fuel pool; filled with water: ☐ YES ☐ NO
(If YES, specify height of filling level)

……………………………………………………………………………………………………
……………………………………………………………………………………………………

2.13 Condition of other containment vessel internals
(Describe)

……………………………………………………………………………………………………
……………………………………………………………………………………………………

2.14 Containment vessel ventilation

Air circulation in operation: ☐ YES ☐ NO

2.15 Intervention in reactor protection or control system executed? ☐ YES ☐ NO
(If YES, describe)

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

Form Sheet 14: Description of test conditions; Insulation and concrete internals of the containment vessel

2.16 Insulation / Secondary Shielding

2.16.1 Type of Insulation / Secondary shielding

(Shape, dimensions, structural materials, type of assembly or reference to technical drawings of the manufacturer or to the specifications):

……………………………………………………………………………………………………
……………………………………………………………………………………………………

2.16.2 State of construction, work tasks completed: ☐ YES ☐ NO (If NO, explain)

……………………………………………………………………………………………………
……………………………………………………………………………………………………

2.17 Concrete Internals of the Containment Vessel

2.17.1 State of construction, work tasks completed; ☐ YES ☐ NO

(if NO, explain, e.g., details regarding decontaminable coating of concrete surfaces)

……………………………………………………………………………………………………
……………………………………………………………………………………………………

Form Sheet 15: Description of test conditions; Locations and nominal widths of the openings

2.18 Sheet	Locations and Nominal Widths of all Openings and Penetrations of the Containment Vessel			
			Location on the containment vessel	
Running. No. *)	Description	Nominal width	Height (m)	Circumferential angle (degrees)

*) if available, use numbering of the manufacturer

Form Sheet 16: Description of test conditions; Closures of the openings

2.19 Sheet	Closures of all Openings and Penetrations of the Containment Vessel	
Running No. *)	Description	Type of closure

*) if available, use numbering of the manufacturer

Form Sheet 17: Description of test conditions; Heat sources

2.20 Heat Sources Inside the Containment Vessel

2.20.1 Lighting inside the containment vessel: ☐ ON ☐ OFF

(If turned ON, specify power in kW)

....

....

2.20.2 Other heat sources inside the containment vessel

Running No. *)	Description	Power (kW)	Description of location or Room No.

*) if available, use numbering of the manufacturer

Form Sheet 18: Description of the pressurizing facility and installation schematic

3 Pressurizing Facility (Compressor Facility)

3.1 Number and power rating:

………

………

3.2 Type, model and manufacturer:

………

………

3.3 Oil separator available: ☐ YES ☐ NO
(If YES, specify type model and manufacturer)

………

………

3.4 Air cooler available: ☐ YES ☐ NO
(If YES, specify type model and manufacturer)

………

………

3.5 Filter available: ☐ YES ☐ NO
(If YES, specify type model and manufacturer)

………

………

3.6 Connection to the containment vessel
(Specify the respective penetration of the containment vessel)

………

………

3.7 Miscellaneous

………

………

3.8 Installation schematic of the pressurizing facilities (graphic figure)
(Connection to the containment vessel, closure valves, air receiver of compressor, pressure relief, etc.)

Form Sheet 19: Leak detection

Procedure of Detecting Leaks It is permissible that multiple groups perform the leak detection in parallel. Each measure for reducing the leakage rate shall be realized individually, however, only after release of the respective work task. After realization of an individual measure, a waiting period shall be observed to check its possible effect on the leakage rate. Further measures shall normally not be taken before the end of this waiting period.					
Running No.:	Observation	Measure taken	Date	Time	Effect on the recorded leakage rate

Form Sheet 20: Description of measurement systems; Gas pressure measurement

4 Measurement Systems

4.1 Gas pressure measurement

4.1.1 Measurement device – absolute pressure:

Type:..

Model:……..

Manufacturer: ....

Measurement range:...

4.1.2 Measurement device – atmospheric pressure:

Type:..

Model:……..

Manufacturer: ....

Measurement range:...

4.1.3 Measurement device – over pressure

Type:..

Model:……..

Manufacturer: ....

Measurement range:...

4.1.4 Magnitude of error of the measurement system *)

Resolution: ....(≤ 0.01 %)

Measurement uncertainty:...(≤ 0.03 %)

Error limits:…...(≤ 1 %)

4.1.5 Connection to the containment vessel:
(If applicable, running number of the penetration, length and nominal diameter of pressure hose, location of the measurement devices)

…..

…..

4.1.6 Conversion factors of the measurement parameters:
(Calibration factor, calibration table as an appendix, calibration function, etc.)

…..

…..

…..

*) The values specified refer to the entire measurement system involved in determining the measurement value, even if this system consists of a long chain of measurement sensors, instrumentation cables, measurement value recording equipment and output units.

Form Sheet 21: Description of measurement systems; Gas temperature measurement

4.2 Gas temperature measurement

4.2.1 Measurement sensors

Type:...

Model:……...

Manufacturer: ....

Measurement range:...

4.2.2 Number, distribution and volume allocation of the temperature sensors
cf. Section 4.2.9, Sheet 1 through Sheet _____ and Table 4.2.10 (cf. **Form Sheet 22**)

4.2.3 Instrumentation cables:
(designated names)

…...

…...

4.2.4 Heat radiation protection exists? ☐ YES ☐ NO

(If YES, cf. construction drawing as Appendix No. ___________)

4.2.5 Instrumentation cable penetration through containment vessel
(Type, model, location on containment vessel wall)

…...

…...

4.2.6 Measurement device

Type:...

Model:……...

Manufacturer: ....

Measurement range:...

4.2.7 Magnitude of error of the measurement system *)

Resolution: …….…...(≤ 0.05 K)

Measurement uncertainty:...(≤ 0.1 K)

Error limits:……………………...(± 3 K)

4.2.8 Conversion factors of the measurement parameters:
(Calibration factor, calibration table as an appendix, calibration function, etc.)

…...

*) The values specified refer to the entire measurement system involved in determining the measurement value, even if this system consists of a long chain of measurement sensors, instrumentation cables, measurement value recording equipment and output units.

4.2.9	Distribution of the temperature sensors (figure)
Sheet	

Form Sheet 22: Description of measurement systems; Gas temperature measurement – volumetric correlation

4.2.10 Temperature sensors – volumetric correlation

Running No.	Vj [m^3]	Running No.	Vj [m^3]
		X	ΣVj =______ [m^3]

Form Sheet 23: Description of measurement systems; Gas temperature measurement – basic schematic

4.2.11 Basic Schematic of the temperature measurement system

Form Sheet 24: Description of measurement systems; Gas humidity measurement

4.3 Gas humidity measurement

4.3.1 Measurement sensor

Type:..

Model:……..

Manufacturer: ....

Measurement range:...

4.3.2 Number, distribution and volume allocation of the humidity sensors
cf. Figure 4.3.8, Sheet 1 through Sheet _____ and Table 4.3.9

4.3.3 Instrumentation cables:
(designated names)

…..

…..

4.3.4 Instrumentation cable penetration through containment vessel
(Type, model, location on containment vessel wall)

…..

…..

…..

4.3.5 Measurement device

Type:..

Model:……..

Manufacturer: ....

Measurement range:...

4.3.6 Magnitude of error of the measurement system *)

Resolution:…….…..(≤ 0.3 hPa)

Measurement uncertainty:...(≤ 0.5 hPa)

Error limits:……………………….. (± 1 % of the test pressure)

4.3.7 Conversion factors of the measurement parameters:
(Calibration factor, calibration table as an appendix, calibration function, etc.)

…..

*) The values specified refer to the entire measurement system involved in determining the measurement value, even if this system consists of a long chain of measurement sensors, instrumentation cables, measurement value recording equipment and output units.

4.3.8	Distribution of the humidity sensors (figure)
Sheet	

Form Sheet 25: Description of measurement systems; Gas humidity measurement – volumetric correlation

4.3.9 Humidity sensors – volumetric correlation

Running No.	Vj [m³]	Running No.	Vj [m³]
		X	ΣVj =______ [m³]

Form Sheet 26: Description of measurement systems; Gas humidity measurement – basic schematic

4.3.10 Basic schematic of the humidity measurement system

Form Sheet 27: Description of measurement systems; Other measurement systems

4.4	Other measurement systems (e.g., volumetric flow, wall temperature)				
Sheet					
Running No.	Measurement parameter	Measurement sensor (Type, model, manufacturer, measurement range)	Number and distribution (Figure No.; Table No.) containment vessel connection or penetration	Measurement device (Type, model, manufacturer, measurement range)	Resolution, measurement uncertainty, margins of error, conversion factor

Form Sheet 28: Execution of the leakage test

5.	Execution of leakage test *)		
Sheet			
Running No.	Date	Time	Description of the events

*) Attach procedural diagram

Appendix C

Regulations Referred to in this Safety Standard

Regulations referred to in this safety standard are valid only in the versions cited below. Regulations which are referred to within these regulations are valid only in the version that was valid when the latter regulations were established or issued.

AtG		Act on the Peaceful Use of Atomic Energy and the Protection against its Hazards (Atomic Energy Act) dated 23 December 1959 (BGBl. I, p. 814) revised version of July 15, 1985 (BGBl. I, p. 1565), last amended by Article 307 of the Ordinance of August 31, 2015 (BGBl. I 2015, No. 35, p. 1474)
StrlSchV		Ordinance on the protection from damage by ionizing radiation (Radiological Protection Ordinance – StrlSchV) of July 20, 2001 (BGBl. I, p. 1714; 2002 I, p. 1459), most recently changed by Article 5, Sec. 7 of the Act of February 24, 2012 (BGBl. I 2012, No. 41, p. 212)
BetrSichV		Ordinance concerning the protection of safety and health in the provision of work equipment and its use at work, concerning safety when operating installations subject to monitoring and concerning the organization of industrial safety and health at work (Betriebssicherheitsverordnung – Ordinance on Industrial Safety and Health – BetrSichV) of September 27, 2002 (BGBl. I, p. 3777), most recently changed by Article 8 of the Ordinance of December 18, 2008 (BGBl. I, p. 2768)
SiAnf	(2015-03)	Safety Requirements for Nuclear Power Plants (SiAnf) of 22 November 2012 (BAnz AT 24.01.2013 B3), revised version of March 3, 2015 (BAnz AT 30.03.2015 B2)
Interpretations on the SiAnf	(2015-03)	Interpretations of the "Safety Requirements for Nuclear Power Plants of 22 November 2012" (BAnz AT 24.01.2013 B3), revised version of March 3, 2015 (BAnz AT 30.03.2015 B2)
KTA 1202	(2009-11)	Requirements for the Testing Manual
KTA 1404	(2013-11)	Documentation during the Construction and Operation of Nuclear Power Plants
KTA 3401.1	(1988-09)	Steel Containment Vessels; Part 1: Materials
KTA 3401.2	(Draft 2015-11)	Steel Containment Vessels; Part 2: Analysis and Design
KTA 3401.3	(1986-11)	Steel Containment Vessels; Part 3: Manufacture
KTA 3401.4	(1991-06)	Steel Containment Vessels; Part 4: Inservice Inspections
KTA 3402	(2014-11)	Airlocks on the Reactor Containment of Nuclear Power Plants - Personnel Airlocks
KTA 3403	(2015-11)	Cable Penetrations through the Reactor Containment Vessel
KTA 3404	(2013-11)	Isolation of Operating System Pipes Penetrating the Containment Vessel in the Case of a Release of Radioactive Substances into the Containment Vessel of Nuclear Power Plants
KTA 3407	(2014-11)	Pipe Penetrations through the Reactor Containment Vessel
KTA 3409	(2009-11)	Airlocks on the Reactor Containment of Nuclear Power Plants - Equipment airlocks
KTA 3706	(2000-06)	Ensuring the Loss-of-Coolant-Accident Resistance of Electrotechnical Components and of Components in the Instrumentation and Controls of Operating Nuclear Power Plants
DIN EN 1779	(1999-10)	Non-destructive testing – Leak testing – Criteria for the method and technique selection; German version EN 1779:1999
DIN EN ISO 9712	(2012-12)	Non-destructive testing - Qualification and certification of NDT personnel (ISO 9712:2012); German version EN ISO 9712:2012