

Pressure vessels at nuclear facilities

General guidelines

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Authorisation

By virtue of section 55, second paragraph, point 3 of the Nuclear Energy Act (990/87) and section 29 of the Council of State Decision (395/91) on General Regulations for the Safety of Nuclear Power Plants, the Finnish Centre for Radiation and Nuclear Safety (STUK) issues detailed regulations concerning the safety of nuclear power plants.

YVL Guides are rules an individual licensee or any other organisation concerned shall comply with, unless STUK has been presented with some other acceptable procedure or solution by which the safety level set forth in the YVL Guides is achieved. This Guide does not alter STUK's decisions which were made before the entry into force of this Guide, unless otherwise stated by STUK.

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1 General

In this Guide, a pressure vessel means in accordance with the Pressure Vessel Decree (549/73), a steam boiler, pressure container, pipework or other such appliance in which the pressure is above or may come to exceed the atmospheric pressure. In this Guide, it is apparent from the context what group of components the word “pressure vessel” refers to.

Regulation of pressure vessels at nuclear facilities is based on section 60 of the Nuclear Energy Act (990/87) which prescribes that the Nuclear Energy Act and the rules and regulations issued by virtue of it, and to the extent applicable, the Pressure Vessel Act (98/73) and the rules and regulations issued by virtue of it shall be applied to pressure vessels at nuclear facilities, as prescribed in more detail by decree.

Section 15 of the Nuclear Energy Decree (161/88) describes in general terms the regulatory control by the Finnish Centre for Radiation and Nuclear Safety (STUK). The Centre controls also pressure vessels of nuclear facilities according to section 117 of the Decree. According to sections 3 and 5 of the Pressure Vessel Decree, the Centre controls and inspects nuclear power plant pressure vessels. How this control is related to the Centre’s other functions as the authority regulating nuclear facilities is explained in Guide YVL 1.1. This Guide (YVL 3.0) aims at giving an overall picture of the control of fixed pressure vessels at nuclear facilities.

In this Guide, licence-holder is licence-holder as meant in the Nuclear Energy Act (990/87). According to section 9 of the Nuclear Energy Act, it is the obligation of the licence-holder to look after the safety of the use of nuclear energy.

According to the Pressure Vessel Decree, certain components to which it is not necessary to apply requirements concerning the manufacture, inspection and operation of pressure vessels are also defined as pressure

vessels. At the licence-holder’s request and if necessary, the Finnish Centre for Radiation and Nuclear Safety confirms a list of these components at the nuclear facility.

The provisions of the Chemicals Act or the Act on Explosive Substances shall be taken into account as such in so far as they apply to pressure vessels at nuclear facilities.

The submission of documents to the Centre is addressed in Guide YVL 1.2.

2 General safety requirements for pressure vessel design

The Council of State Decision (395/91) contains several regulations which apply to pressure vessels at nuclear facilities. According to section 29 of the Decision, *detailed regulations relating to the safety of a nuclear power plant are issued by the Finnish Centre for Radiation and Nuclear Safety*. Safety principles complementing the Decision and which are followed in the design of a nuclear power plant are presented in Guide YVL 1.0.

According to section 5 of the Council of State Decision (395/91), *advanced quality assurance programmes shall be employed in all activities which affect safety and relate to the design, construction and operation of a nuclear power plant*. Quality assurance during construction and operation of nuclear facilities is addressed in more detail in Guides YVL 1.4 and 1.9.

According to section 13 of the Decision (395/91), *in design, construction and operation, proven or otherwise carefully examined high quality technology shall be employed to prevent operational transients and accidents*. Detailed requirements for pressure vessels and piping are set forth in YVL Guide series 3. Requirements relating to earthquakes, steel

structures, valves and their actuators, safety valves, electrical and automation systems and components and pumps are described in Guides YVL 2.6, 4.2, 5.3, 5.4, 5.5 and 5.7.

According to section 16 of the Decision, *the primary circuit of a nuclear reactor shall be designed so that the stresses imposed upon it remain, with sufficient confidence, below the values defined for structural materials for preventing a fast growth crack during normal operational conditions, anticipated operational transients and postulated accidents. The possibility of a primary circuit break due to other reasons shall be low, too.* Every component's performance, integrity and leaktightness requirements are set on the basis of their intended operation. The principles to ensure endurance of the components are described in Guide YVL 3.5.

According to section 21 of the Decision, *the functions important to the safety of the systems, structures and components of a nuclear power plant shall be defined and the systems, structures and components classified according to their safety significance.* In the same section it is further required that *structures, systems and components important to safety shall be designed, manufactured, installed and operated so that their quality level and the inspections and tests required to verify their quality are adequate considering any item's safety significance.* The safety classification criteria are given in Guide YVL 2.1. Attention shall also be paid to the quality of components in lower safety classes, since their failure may cause initial events which end up in reactor damage.

According to section 24 of the Decision, *the reliable operation of systems and components shall be ensured by adequate maintenance as well as by regular in-service inspections and periodic tests.* As prescribed in Guide YVL 1.0, provision shall be made for the inspection, testing and servicing of nuclear power plant systems and structures. This shall be ensured by making the location, design, geometry and finishing of items subject to inspection as per Guide YVL 3.8 such that appropriate testing methods can be used. In designing acces-

sibility, special attention shall be paid to the option of mechanised testing. Construction materials shall be reserved for reference pieces, and test pieces shall be tailored for the purpose of developing the testing methods. Construction materials shall be reserved for the qualification of testing procedures, equipment and personnel, and test pieces equivalent to the actual examination areas shall be tailored.

According to Guide YVL 1.0, *in nuclear power plant design, the service life and the effect of their ageing on the safety of all safety-significant structures, components and materials shall be assessed using sufficient safety margins. Furthermore, provision shall be made for the surveillance of their ageing and, if necessary, their replacement or repair.* This means that construction materials shall be reserved and test pieces equivalent to the structure shall be tailored to study i.a. the effects of irradiation, the ageing of construction and weld materials and the development of repair methods.

According to section 27 of the Decision, *for further safety enhancement, actions shall be taken which can be regarded as justified considering operating experience and the results of safety research as well as the advancement of science and technology.* Requirements relating to modifications, repairs and preventive maintenance are given in Guide YVL 1.8.

The Pressure Vessel Act and the rules and regulations issued by virtue of it also apply to pressure vessels at nuclear facilities.

3 Manufacturer of pressure vessels for nuclear facilities

The manufacturing of pressure vessels also includes their installation, repair and modification. Pressure vessels for nuclear facilities may be manufactured only by a company whose prerequisites for practice STUK has estimated as sufficient. The

prerequisites for practice are grouped according to how demanding the practices are.

According to section 6 of the Pressure Vessel Decree, *a manufacturer of pressure vessels shall have*

- 1) *a skilled staff*
- 2) *appropriate facilities, and machinery, instruments and equipment, as well as*
- 3) *sufficient administrative and technical procedures to ensure compliance with rules and regulations which apply to pressure vessels.*

The manufacturer shall request from STUK an assessment of the prerequisites for practice and shall manufacture an appropriate sample specimen under STUK's supervision. The manufacturer shall also request STUK to assess every three years whether the prerequisites for practice are still sufficient.

As prescribed in section 6 of the Pressure Vessel Decree, *the manufacturer is under obligation to ensure that this Decree and the regulations issued by virtue of it are applied in the manufacturing of pressure vessels.*

As prescribed in section 6 of the Pressure Vessel Decree, pressure vessels shall be manufactured under the supervision of a supervisor of manufacture. As required in section 9 of the Decree, *the supervisor of manufacture shall*

- 1) *hold an academic degree taken at a university of technology or other institution of higher education suited for the task considering the intended use of the pressure vessels to be manufactured and the operating characteristics fixed for them, or a diploma from a technical college*
- 2) *have sufficient practical experience of the manufacture of pressure vessels.*

The manufacturer shall request from STUK an assessment of the competence of the supervisor of manufacture. The supervisors of manufacture are classified according to their competence.

According to section 11 of the Pressure Vessel Decree, *the supervisor of manufacture is responsible for ensuring that the pressure vessel is manufactured in accordance with the approved construction plan by using appropriate techniques, and that the relevant regulations are complied with.*

Detailed requirements which apply to domestic and foreign manufacturers and supervisors of manufacture are presented in Guide YVL 3.4.

4 Examination organisations and personnel

To ensure their integrity, the structures and components of nuclear power plants are tested by non-destructive examination methods according to programmes devised in advance by the licence-holder. As prescribed in section 113 of the Nuclear Energy Decree, *the inspections and tests of nuclear facility systems, structures and components can only be performed by the licence-holder or, in his place, by an inspector or an inspection agency that has been specifically accepted by the Finnish Centre for Radiation and Nuclear Safety for this purpose.* The qualification of domestic and foreign examination organisations and personnel in the use of non-destructive examination methods, the approval procedures and other prerequisites for practice are described in Guide YVL 1.3.

Examination organisations and personnel using non-destructive examination methods must fulfil the requirements of chapter 4 of the Ministry of Trade and Industry Decision (391/84). STUK approves, without a specific application, examination organisations and personnel approved by the Safety Technology Authority (TUKES) or its predecessor, to carry out destructive examinations.

5 Pressure vessel inspections

The Finnish Centre for Radiation and Nuclear Safety conducts the following inspections of pressure vessels at nuclear facilities:

- review of the construction plan
- review of the location plan
- supervision of manufacture
- construction inspection of the pressure vessel and its installation
- commissioning inspection
- inservice inspections
- additional inspections
- control of inspections conducted as per Guide YVL 3.8
- other regular inspections.

If necessary, and on the licence-holder's application, the Finnish Centre for Radiation and Nuclear Safety can approve some other examination organisation or inspection agency to make the above inspections. What is said below of examinations conducted by STUK applies also to an approved examination organisation or inspection agency. An examination organisation and an inspection agency must also comply with what is stated in the decision granting approval.

As prescribed in section 9 of the Nuclear Energy Act, the licence-holder shall see to it that the use of nuclear energy is safe. The manufacturer of pressure vessels, and the supervisors of manufacture and operation ensure for their part that pressure vessels are manufactured, operated and inspected according to regulations. The various inspections carried out by STUK are explained below.

5.1 Review of construction plan

A construction plan shall be drawn up for the manufacturing of a pressure vessel. It shall be mentioned in the plan that the requirements of YVL Guides have been met. If the construction plan deviates from the requirements of the YVL Guides it shall be explained how the quality level required in the YVL Guides is

achieved. The licence-holder running a nuclear facility shall obtain STUK's approval for the construction plan. Requirements concerning the contents of construction plans are presented in Guides YVL 1.8, 2.6, 3.1, 3.3, 3.5, 3.9, 5.3, 5.4 and 5.7.

The pressure vessel shall be designed and manufactured in such a way, and using such procedures that it is safe when operated in the designed manner which also includes anticipated operational transients and postulated accidents.

The pressure vessel shall be dimensioned and designed to withstand with sufficient safety margins design basis operational and accident conditions. Dimensioning can be divided into basic dimensioning and stress analysis.

Basic dimensioning shall be based on design basis loads. In stress analysis, various strength-related failure mechanisms such as ductile fracturing and fatigue shall be analysed using all specified loads. In addition, a separate brittle fracture analysis shall be made for ferritic pressure vessels. The requirements concerning stress and brittle fracture analyses as well as operational loads and the surveillance of irradiation-induced embrittlement are given in Guide YVL 3.5.

For pressure vessels having less significance for the safety of nuclear power plants, basic dimensioning and the consideration of potential vibrations caused by operation, and the bringing of the vibrations to an acceptable level by means of construction is usually sufficient. Dimensioning is described in the component-specific YVL Guides.

In its review of the construction plan, STUK decides whether the pressure vessel plan complies with the regulations and the applicable YVL Guides.

In connection with the approval of the construction plan and if necessary, STUK determines the conditions and requirements concerning the pressure vessel's construction and inspection to ensure the vessel's safe use.

As regards a pressure vessel's installation, a separate installation construction plan shall be presented to STUK for approval with the necessary information about the manufacturer, dimensioning, welding and quality control plus drawings, unless information about the installation can be found in other documents (e.g. the piping construction plan). If not yet decided at the time of presenting the plan, the manufacturer shall be announced to STUK in writing later, however, before work relating to the installation is started.

5.2 Review of location plan

STUK reviews the location of pressure vessels at the facility as part of the review of the preliminary and final safety analysis reports. The safety analysis reports shall give general information about the location of the pressure vessels and their location drawings.

The pressure vessel shall be located and the rooms and structures around it shall be designed and made such that a possible pressure discharge in case of failure or operational transient causes as little damage as possible. If necessary, safety analyses related to the matter shall be made and structural supports or shields shall be built to restrict damage. The location of safety-significant electrical and instrumentation equipment and their potential damaging shall be considered in the location plan. The location and accessories of the pressure vessel shall not prevent the pressure vessel's appropriate use, inspection and maintenance. When the pressure vessel's location is considered, the potential risk to the safety of the facility and its personnel posed by the vessel's contents shall be considered. Every detail related to the pressure vessel's location shall be such that the simultaneous use of the pressure vessel, its piping and accessories is safe.

The location plans of the below pressure vessels shall have the approval of the Finnish Centre for Radiation and Nuclear Safety:

- 1) steam boilers
- 2) pressure tanks containing significant amounts of radioactive or otherwise hazardous liquids or gases and the product

of whose numerical values indicating the highest operating pressure (bar) and volume (m³) is greater than 5.

- 3) other pressure tanks the product of whose numerical values indicating the highest allowable operating pressure (bar) and gas volume (m³) is greater than 10.

The licence-holder can submit the location plan and the layout drawings for the piping for approval in connection with the construction plan.

5.3 Control of manufacture

The quality of a pressure vessel depends on manufacturing in the first place. The quality of a pressure vessel cannot be fully assessed by non-destructive examination methods but must be verified also by sufficient manufacturing supervision.

STUK witnesses manufacturing in the extent it considers necessary. Requirements for i.a. the manufacturing supervision of pressure vessels are presented in Guide YVL 1.14.

5.4 Construction inspection of pressure vessels and their installation

STUK inspects the construction and installation of pressure vessels. The construction inspection comprises inspection of the implementation of the construction plan, control of the work quality, review of the results of tests to demonstrate durability and a pressure test. After installation of the pressure vessel, installation-related manufacturing is inspected. The construction inspection is addressed in Guide YVL 1.15. Detailed further information pertinent to each type of component is given in the component-specific YVL Guides.

In the construction inspection, it is ascertained that the pressure vessel's construction is safe when the vessel is used according to design. When a pressure vessel has passed the construction inspection the manufacturer or importer must stamp an identification number and the year of manufacture on the pressure

frame and, in an identification plate permanently attached to the pressure vessel the data required in section 8 of the Decision of the Ministry of Trade and Industry (69/75).

Irrespective of safety class, pressure vessels mentioned in section four of the Pressure Vessel Act are not registered but the conducting of inservice inspections (see sub-section 5.6) is ensured in an agreed manner other than the monitoring of data stamped in the identification plates. Pressure vessels shall be stamped according to section 8 of the Decision of the Ministry of Trade and Industry (70/75).

The installation of a pressure tank or steam boiler in its place of operation may be started after the tank or the boiler has passed the construction inspection, and the installation construction plan (see sub-section 5.1) and the location plan have been approved. If the pressure vessel is found to have suffered damage during transportation STUK re-inspects it after repair and prior to installation. The installation of piping is addressed in more detail in Guide YVL 3.3.

5.5 Commissioning inspection

STUK conducts a commissioning inspection of the pressure vessel before it is placed in service. Requirements relating to the commissioning inspection are presented in Guide YVL 3.7. Matters relating to the trial operation of nuclear power plants are explained in more detail in Guide YVL 2.5.

In the first phase of the commissioning inspection it is ascertained that all components covered by the inspection plus their installation and location have been inspected. In the second phase of the inspection it is ascertained that the components and structures perform according to design.

A pressure vessel may not be placed in service before both phases of the commissioning inspection have been completed. Start-up testing of the pressure vessel to adjust the equipment and to test the vessel's readiness for use is allowed, however, provided that sufficient care is taken when this is done.

The pressure vessel can be placed in service after STUK has approved it in the commissioning inspection. The inspection document is a document which contains possible licences, protocols and other essential material relating to the pressure vessel. The pressure vessel manufacturer or importer shall see to it that documents, drawings, strength calculations and inspection documents approved by authorities and on which the inspections of the construction, installation and location plans are based are attached to the inspection document which shall be handed over to the licence-holder in the commissioning inspection at the latest. The licence-holder shall keep quality control related records, including radiographic films and other necessary samples, carefully and protect them from damage as long as the pressure vessel in question is in service. However, an inspection document is not required of class EYT (non-nuclear) pressure vessels which comply with section 4 of the Pressure Vessel Decree. The licence-holder must keep the protocols of the commissioning inspection as well as any other inspection documents received.

The pressure vessel manufacturer or importer shall give the licence-holder instructions for use and maintenance in his preferred domestic language unless the licence-holder has by separate agreement approved the use of some other language.

5.6 Inservice inspections

STUK carries out the following inservice inspections of nuclear facility pressure vessels:

- internal inspection
- operational inspection
- full inspection.

The licence-holder shall submit to STUK pressure vessel specific inspection plans before the inservice inspection dates.

In the inservice inspection STUK ascertains that the pressure vessel is safe and operational.

STUK makes the inservice inspections of registered Class EYT (non-nuclear) pressure vessels and of Safety Class 1, 2 and 3 pressure vessels included on the list of pressure vessels approved by STUK. The contents of the pressure vessel list are discussed in more detail in chapter 7.

STUK carries out an internal inspection of the pressure vessels every four years. The Centre ascertains in connection with the inspection that a pressure vessel's condition is sufficiently good for the next operating cycle.

If necessary, an internal visual inspection can be replaced with some other inspection defined in the approved inspection plan.

STUK conducts an operational inspection of pressure vessels every four and of steam boilers every two years.

In the operational inspection it is ascertained that the control and measuring devices of the pressure vessel function appropriately and that the pressure vessel is safe to use.

STUK carries out a full inspection every eight years which includes an internal inspection, an operational inspection and, if necessary, a pressure test.

A damaged pressure vessel which has been repaired is subjected to a full inspection before it is placed in service, unless STUK decides that the effect of the repairs on the operational safety of the pressure vessel can be adequately determined in some other way.

STUK inspects the pressure vessels of freezing plants as prescribed in section 23 of the Decision of the Ministry of Trade and Industry (69/75).

After the first full inspection and on the licence-applicant's request, STUK can extend the inspection interval: an internal inspection can take place every eighth year, the operational inspection interval can be extended by one year and a full inspection can take place every 16th year.

STUK can also shorten the inspection interval depending on the pressure vessel's condition. The internal inspection interval of a steam boiler in specifically heavy use is shortened after two full inspections have been conducted since commissioning.

The inspection interval is counted from the date of the commissioning inspection or full inspection. STUK postpones an inspection date by 13 months at the most. The postponement does not affect the determination of forthcoming inspection dates.

If the inspection reveals that the pressure vessel contains faults or deficiencies that impair the safety of its use, STUK can determine new operating parameters for the pressure vessel or forbid its use.

Inservice inspections of the piping are explained in Guide YVL 3.3.

5.7 Additional inspections

STUK conducts additional inspections when

- the pressure vessel has been moved
- the pressure vessel has been modified and repaired
- the pressure vessel's accessories, operating parameters and use have changed
- there is specific reason to ensure safety (e.g. experience gained abroad and research results).

5.8 Control of inspections as per Guide YVL 3.8

Non-destructive examination methods shall be used in regular inspections as per Guide YVL 3.8 which are carried out on Safety Class 1 and 2 pressure vessels, piping, pumps and valves and their supporting structures as well as on the internals of the reactor pressure vessel.

Preservice examinations shall be conducted before the commissioning of the nuclear power plant. Operational examinations are usually made during outages. The preservice examination shall be made even during plant

operation if a component or a section of piping included in the scope of the examination is repaired, modified or replaced.

The examination programme forms an entity of documents containing the nuclear power plant's inspection-related

- summary programme
- preservice examination programme
- operational inspection programmes.

All these documents shall have STUK's approval.

The examination organisation and its personnel shall have STUK's approval according to Guide YVL 1.3.

STUK witnesses inspections at the plant site and makes audits in the extent it deems necessary. Subject to control are general inspection arrangements, result reporting and information flow between the parties in the process.

The summary reports of the preservice examination or the operational inspection shall be submitted to STUK for approval in four months from the end of a nuclear power plant unit's inspections or repair outage.

5.9 Other regular inspections

In inspections repeated at regular intervals, STUK estimates the size and number of pressure vessel loads. At the same time, the correctness of reports submitted by the licence-holder are assessed. Monitoring of changes in the reactor pressure vessel's material properties is also estimated. STUK supervises the implementation of condition monitoring and pre-maintenance programmes of pressure vessels and also inspects valves, pumps, piping and, if necessary, other pressure vessels in connection with their dismantling.

Outage control at nuclear power plants is discussed in general terms in Guide YVL 1.13.

6 Supervision of use

The licence-holder shall have a staff who have a good understanding of the construction, use and maintenance of pressure vessels. The licence-holder shall see to it that a pressure vessel is used, serviced and controlled according to regulations and the operating and maintenance instructions of the manufacturer, importer or the supplier of pressure vessel accessories.

The licence-holder shall nominate from its organisation a supervisor of the use of the pressure vessel and, if necessary, one or more qualified deputies for him. The supervisor of use and his deputies shall have sufficient knowledge of the construction, use and maintenance of pressure vessels. The licence-holder shall see to it that the supervisor is given the possibility to maintain and use the pressure vessel in such a way that there will be no damage to individuals, property or the environment. Information about the supervisor of operation and his deputy and their competence shall be sent to STUK for information.

The supervisor of use of the pressure vessel shall personally supervise the use and condition of pressure vessels and shall also be in contact with STUK in matters relating to inspections. The supervisor shall also see to it that the pressure vessel's inservice inspections are carried out as prescribed. He shall also ensure that markings as required in the Pressure Vessel Decree and in the regulations issued by virtue of it and which must be done by the supervisor are entered in the inspection document and that notifications about the use and condition of the pressure vessel are made to STUK.

The supervisor of use shall attach to the inspection documents of respective pressure vessels all additional protocols of the commissioning and inservice inspections.

7 List of pressure vessels

A list shall be drawn up of a nuclear facility's pressure tanks and steam boilers in which all pressure tanks and steam boilers are presented system by system. On the list shall be indicated each pressure vessel's component identification, name, the safety classification of rooms, design pressure and temperature as well as capacity and contents. Pressure vessels which fall within the scope of the inservice inspection requirements shall be specified on the list. Registration in accordance with the Pressure Vessel Decree shall be indicated.

The scope of construction and inservice inspections carried out by STUK shall be indicated on the pressure vessel list.

The list shall be submitted to STUK for approval.

The licence-holder shall update the list when modifications are made.

8 Decommissioning of pressure vessels

Guide YVL 8.1 is applied when a pressure vessel classified as reactor waste according to Guide YVL 8.2 is decommissioned.

When a pressure vessel which has not been in service for over a year is placed in service again STUK conducts a commissioning inspection of it. Based on the protocols of previous inspections, however, the Centre can choose not to conduct the inspection or can extend it to include also an internal inspection and a pressure test.

9 References

- 1 Nuclear Energy Act (990/87)
- 2 Nuclear Energy Decree (161/88)
- 3 Decision of the Council of State on the General Regulations for the Safety of Nuclear Power Plants (395/91)
- 4 Pressure Vessel Act (98/73)
- 5 Pressure Vessel Decree (549/73)
- 6 Resolution of the Ministry of Trade and Industry Relating to the Design and Fabrication of Pressure Vessels (391/84)
- 7 Resolution of the Ministry of Trade and Industry Relating to the Implementation of the Pressure Vessel Decree (69/75)
- 8 Resolution of the Ministry of Trade and Industry Relating to the Pressure Vessels Mentioned in § 4 of the Pressure Vessel Decree (70/75)
- 9 Resolution of the Ministry of Trade and Industry Relating to Pipework Joined to a Steam Boiler and a Pressure Container (71/75)