STUK

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PRIMARY AND SECONDARY CIRCUIT PRESSURE CONTROL AT A NUCLEAR POWER PLANT

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Authorisation

By virtue of the below acts and regulations, the Radiation and Nuclear Safety Authority (STUK) issues detailed regulations that apply to the safe use of nuclear energy and to physical protection, emergency preparedness and safeguards:

- Section 55 of the Nuclear Energy Act (990/1987)
- Section 29 of the Government Decision (395/1991) on the Safety of Nuclear Power Plants
- Section 13 of the Government Decision (396/1991) on the Physical Protection of Nuclear Power Plants
- Section 11 of the Government Decision (397/1991) on the Emergency Preparedness of Nuclear Power Plants
- Section 8 of the Government Decision (398/1991) on the Safety of a Disposal Facility for Reactor Waste
- Section 30 of the Government Decision (478/1999) on the Safety of Disposal of Spent Nuclear Fuel.

Rules for application

The publication of a YVL Guide does not, as such, alter any previous decisions made by STUK. After having heard those concerned, STUK makes a separate decision on how a new or revised YVL Guide applies to operating nuclear power plants, or to those under construction, and to licensees' operational activities. The guides apply as such to new nuclear facilities.

When considering how new safety requirements presented in YVL Guides apply to operating nuclear power plants, or to those under construction, STUK takes into account Section 27 of the Government Decision (395/1991), which prescribes that *for further safety enhancement, action 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.*

If deviations are made from the requirements of the YVL Guides, STUK shall be presented with some other acceptable procedure or solution by which the safety level set forth in the YVL Guides is achieved.

Translation. Original text in Finnish.

1 General

Primary and secondary circuit pressure control is of essential importance to ensure the safety of a nuclear power plant. This Guide contains design and analysis requirements for the primary and secondary circuit pressure control systems of nuclear power plants equipped with pressurised and boiling water reactors. For the purposes of this Guide, pressure control means pressure regulation, overpressure protection and pressure reduction.

To ensure the safety of the nuclear power plant it is essential that there are no interruptions in heat transfer from the reactor to the ultimate heat sink. An uninterrupted heat transfer is ensured when the coolant volume and the pressure and temperature conditions in the circuits are appropriate. To maintain appropriate conditions, pressure control must function reliably during normal operational conditions and anticipated transients.

Overpressure protection of the primary and secondary circuit is essential for maintaining the integrity of the heat transfer chain. The pressure-temperature limits during normal operation of the primary circuit are determined on the basis of sufficient safety margins in order to prevent rapid fracturing of pressure equipment. For a pressurised water reactor, on the other hand, these limits are determined on the basis of a sufficient margin with respect to boiling.

Pressure reduction may be required during an accident to interrupt a coolant leak, or to ensure reactor emergency cooling or residual heat removal.

During a severe accident, a rupture of the reactor pressure vessel at high pressure endangers containment integrity. Primary circuit pressure reduction is thus an integral part of a severe accident management strategy.

Requirements on systems design are given in Guide YVL 2.0, on the commissioning of systems in Guide YVL 2.5, on control systems in Guide YVL 5.5, on safety valves in Guide YVL 5.4 and on strength and brittle fracture analyses in Guide YVL 3.5. Requirements on systems maintenance and operation during service life are contained in Guides YVL 1.8 and YVL 1.9. The dose limits for radioactive releases are given in Guide YVL 7.1.

2 General design requirements

The defence in depth principle shall be applied in the design of pressure control at the nuclear power plant. According to the principle, systems and equipment with different capabilities shall be used for pressure control in such a way that preventive actions to ward off the consequences of a transient or accident are proportional to the severity of the event.

The design bases shall specifically ensure that during operational conditions it is not necessary to

- remove primary coolant out from closed systems, with the exception of a possible brief discharge to manage a transient
- operate a safety valve.

According to Guide YVL 1.0, pressure control during primary to secondary leaks at a PWR plant shall be so arranged that it will not be necessary to discharge coolant into the environment. However, a brief discharge to the environment through the discharge valve of the steam line can be accepted during an accident if acceptability of event management can be demonstrated by means of an analysis in compliance with sub-section 7.4.

The overpressure protection and the reactor scram system of a BWR plant shall be designed to operate so that the successful operation of these systems is independent of each other. A scram must not fail during an accident described in sub-section 7.2.2 that proves to be the most limiting for overpressure protection even if none of the safety valves designed for overpressure protection open. Correspondingly, even if the scram function fails, the overpressure protection function must be accomplished as described in sub-section 7.2.3.

The diversity principle shall be applied in the design of the pressure control systems of the reactor cooling system to reduce the likelihood of common cause failures. This means that the system shall contain components of different types or components having different operating principles (see Guide YVL 2.7).

3 Pressure regulation

Systems used for pressure regulation in a reactor plant include the pressuriser injection systems and electric heaters of the PWR, the discharge valves of the secondary circuit, the bypass valves of the turbine; the regulating valves of the BWR turbine and the bypass valves of the turbine, as well as the systems that control these systems.

According to Guide YVL, 1.0, rector pressure control shall be designed such that, during normal operational conditions, pressure can be maintained within the limits required by normal cooling even in the event of a single failure of some pressure regulating component or control system. As a rule, anticipated operational transients shall be taken care of by using the pressure control systems intended for normal plant operation so that it will not be necessary to use high capacity relief valves to limit overpressurisation of the primary circuit.

The control and maintenance of primary and secondary circuit pressure shall be ensured even in an event where the offsite power supply has been lost.

4 Overpressure protection

Components used for overpressure protection of the primary and the secondary circuit of a reactor plant include discharge valves, safety valves and protection systems that are designed to prevent erroneous operation of systems that can increase pressure.

Components that can increase pressure in the primary circuit (e.g. pressuriser heaters and pumps) shall be equipped with a protection system that will stop the operation of the component to prevent erroneous pressure increase. The protection system shall be capable of implementing the protection function also in case of a single failure.

Special attention shall be paid to the reliable closing of pressure relief and safety valves. The closing of the discharge line shall be ensured, if necessary, by adding a stop valve to the line. In other respects, the requirements for the design of safety valves (sub-section 6) also apply to discharge valves.

At low operating temperatures the ductility and pressure resistance of the structural materials of the nuclear power plant's main components may be essentially lower than at normal operating temperatures. The permitted loadings of the nuclear power plant's main components at low operating temperatures shall be established and on their basis the pressure and temperature ranges for the safe operation of the components shall be determined. Deviations from the determined ranges shall be reliably prevented during operation even in the event of a single failure. Operational transients and accidents shall be analysed as operational loads B, C or D, in compliance with Guide YVL 3.5.

5 Pressure reduction

The primary circuits of a PWR and a BWR plant and also the steam generators of a PWR plant shall be provided with devices, which can be used for reduction of pressure controllably during accidents. These devices shall have a remote control function and a power supply unit which is independent of the electrical power supply units designed for operational conditions and postulated accidents. Valves designed for this purpose shall be so designed that, once they have opened, they stay open reliably.

6 Safety valves

The primary circuit and the steam generators of a PWR plant shall be equipped with several redundant safety valves. Redundant safety valves protecting the same item shall be set to open at several stages so that the number of opened valves corresponds to the discharge requirement. In this way the opening of too many valves is prevented, the risk posed by a stuck-open valve is reduced and a transient associated with the valve's opening is mitigated.

If possible, a stop valve should not be placed between the protected item and the safety valve, in the discharge line of the safety valve or in the control line required in the opening of the safety valve. If exceptions to this rule are made to facilitate testing or maintenance or to provide against

a stuck-open safety valve, the stop valve's inadvertent closing shall be reliably prevented.

The safety valve shall be equipped with a position indicator which is independent of the control equipment.

In the design of the safety valves, their pilot valves and connecting pipelines, the possible accumulation of uncondensed gases and condensate plus their harmful effects shall be considered.

The system of safety valves for overpressure protection and the associated piping shall be designed to discharge steam and also steam-water mixture and water.

Detailed instructions for the design of safety valves and equivalent relief valves are given in Guide YVL 5.4.

7 Demonstration of the acceptability of pressure control systems

7.1 General

Analyses shall be conducted demonstrating that the pressure control systems meet the design requirements.

The cases to be analysed are those during which the reactor pressure tends to increase or decrease in consequence of an initiating event and situations where the reactor circuit pressure must be reduced by means of automatic systems or operator action.

As presented in Guide YVL 2.2, initiating events are divided into anticipated operational transients and postulated accidents according to their frequency.

A reduction of the primary circuit pressure during a severe reactor accident shall also be analysed as well as a reduction of the primary circuit and/or secondary circuit pressure during accidents in which pressure needs to be reduced in order to ensure removal of decay heat and/or cooling of the reactor.

7.2 Events resulting in pressure increase

7.2.1 Anticipated operational transients

When analysing situations mentioned in this sub-section, it is assumed that before and during a transient all systems of the power plant operate as designed and in conformity with the nominal parameters, with the exception of the failure initiating the transient and the direct consequences of the failure.

The acceptance criterion for anticipated operational transients is that the primary circuit design pressure is not exceeded and that not a single safety valve needs to open.

7.2.2 Postulated accidents

When conducting analyses of accidents which lead to pressure increase, the input values and assumptions for the analyses are chosen according to Guide YVL 2.2, with the following additions:

- reactivity coefficients are the least favourable for the situation in question considering the entire operating cycle of the reactor
- reactor scram occurs after the second reactor protection system signal
- pressure reduction systems other than safety valves and the equivalent relief valves fail
- the number of safety valves and equivalent relief valves that fail in the closed position as follows:

total no of safety valves	failed
2–3	1
4–8	2
9–	one fourth of the number rounded off to the next integer

- the discharge flow capacity of safety valves and equivalent discharge valves equals to the nominal capacity determined on the basis of an applicable standard and the opening pressure equals to the nominal setting
- safety valves with different discharge flow capacities fail in the order of size (starting from the largest) as follows: first, fourth, ninth, thirteenth, etc, always at intervals of four
- safety valves which have the same discharge flow capacity but have been set to open at different pressures fail in the order of the opening pressures (starting from the lowest pressure) as follows: first, fourth, ninth, thirteenth, etc, always at intervals of four
- if an applicable standard requires more than one control device to control the operation of a discharge or safety valve and the devices have been set at different pressures, the opening pressure is the higher setting pressure.

An analysis shall be conducted to demonstrate that the pressure of the item to be protected keeps lower than 1.1 times the design pressure of the protected item.

7.2.3 Anticipated transients without scram (ATWS)

When analysing ATWS events, the assumptions presented in Guide YVL 2.2 are used. The acceptance criterion for these analyses is that the pressure of the protected item does not exceed a pressure that is 1.3 times the design pressure of the item. In addition, any deformation of the reactor primary circuit and damage to the reactor pressure vessel internals must not prevent safe reactor shutdown. A conservative value based on test results is the acceptable pressure limit for the heat transfer tubes of the steam generators.

7.2.4 Pressure increase at low operating pressure

The analyses to be performed at low operating temperatures, as specified in Guide YVL 2.2, shall separately consider each event resulting in pressure increase. The analyses shall demonstrate that the systems designed to prevent pressure increases maintain pressure and temperature at such values that sufficient margins against rapid fracturing of the equipment due to a postulated failure are guaranteed at each operating load in compliance with Guide YVL 3.5.

7.3 Pressure reduction during accidents

The acceptable operation of controlled pressure reduction systems during accidents shall be demonstrated by analyses examining the accomplishment of safety functions for whose implementation controlled pressure reduction is required.

7.4 Overpressure protection of PWR secondary circuit

The assumptions and analysis approval criteria presented in sub-section 7.2.2. are applied to the analysis of the over-pressure protection of the secondary circuit of a PWR with the following exception: when the isolation valves of all steam lines close, the sections of the secondary circuit that are within the isolation valves of the steam lines are analysed as a single protected item. Valves designed for over-pressure protection that fail in closed position are defined in accordance with sub-section 7.2.2. Failed valves shall be divided between the different steam generators in a manner that is most unfavourable to the end result of the analysis.

A brief discharge into the environment through the discharge valve of the steam line is acceptable during a primary-to-secondary circuit leak classified as a postulated accident, provided that the radiation dose resulting from the discharge remains below the dose limit defined for the postulated accident in an analysis performed in compliance with sub-section 4.1.1 of Guide YVL 2.2

8 Oversight by STUK

The design bases and the analyses for pressure control shall be included in the preliminary and final safety analysis reports of the plant unit.

STUK controls compliance with the requirements that pertain to pressure control in connection with the reviews of the preliminary and the final safety analysis reports of a new plant unit. Any changes in pressure control at existing plant units are reviewed in connection with the conceptual design phase of the systems and components associated with pressure control, the system preinspection documentation and the construction plans of the components.

STUK assesses the systems and components utilised in pressure control as part of the inspections included in the operational inspection programme. STUK controls in particular how the licensee arranges appropriate maintenance of these systems and components, and how the results of their tests as well as their operating experience are taken into consideration.