Primary and secondary circuit pressure control at a nuclear power plant

This Guide is in force as of 1 March 1996, until further notice. It replaces Guide YVL 2.4 issued on 19 September 1984.

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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 Radiation and Nuclear Safety Authority (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.

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.

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 can be prevented by reducing the primary circuit pressure controllably and without delay.

2 General design requirements

The concept of defence in depth shall be applied in the design of the nuclear power plant's pressure control system. According to the concept, 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.

According to Guide YVL 1.0, the reactor's pressure control shall be so designed that during operational conditions pressure can be kept within the range needed for normal cooling in the event of a single failure in a component or system used for pressure control. 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.

The overpressure protection and scram system of a BWR plant shall 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 5.1.2 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 5.1.3.

The diversity principle shall be observed in the design of the pressure control 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 control during operation

3.1 Pressure control at normal operating temperature

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.

Equipment which may contribute to the increase of primary circuit pressure (such as pressuriser heaters or pumps) shall be fitted with a protection system, which stops their operation, prevents an erroneous pressure increase and which is capable of accomplishing the protection function even in the event of a single failure.

The control systems of primary and secondary circuit pressure control devices shall be so designed that a single failure of a control system component does not increase or decrease the pressure or prevent the designed operation of the pressure control function.

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 shut-off valve to the line. In other respects, the requirements for the design of safety valves (sub-section 4.1) also apply to discharge valves.

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.

3.2 Pressure control at low operating temperatures

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 allowable 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.

4 Pressure control during accidents

During accidents, the pressure control systems are needed for overpressurisation protection and for the pressure reduction of the primary and secondary circuits in order to manage an event or mitigate its consequences.

In addition to normal pressure control systems, the systems which are used for the functions mentioned above are safety valves, protection systems and specific pressure reduction devices.

4.1 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, shut-off valves 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 shut-off 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.

4.2 Pressure reduction

The primary circuits of a PWR and a BWR plant and also the steam generators of a BWR plant shall be provided with devices, which can be used to reduce 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.

5 Demonstration of the acceptability of pressure control systems

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. Also severe accidents are defined.

5.1 Events leading to pressure increase

5.1.1 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.

Analyses shall be conducted at low operating temperatures, separately examining every event leading to an increase in pressure and demonstrating that systems designed to prevent pressure increase keep pressure within the allowable operating range even in the event of a single failure.

5.1.2 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 valves	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 pressure
- 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.

Accident analyses at low operating temperatures shall also be conducted using assumptions presented in Guide YVL 2.2. The acceptance criterion for the analyses is that the integrity of the primary or secondary circuit is not jeopardised.

5.1.3 Anticipated transient 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 calculated maximum tension in any part of the primary circuit does not exceed the value equivalent to level C operational conditions referred to in standard ASME Code, Section III, point NB-3234 /1/. Deformations to the reactor primary circuit configuration shall 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.

5.2 Pressure reduction

The acceptable operation of controlled pressure reduction systems during accidents shall be demonstrated by analyses examining the accomplishment of the safety function for which the implementation of controlled pressure reduction is designed.

6 References

1 ASME Boiler and Pressure Vessel Code, Section III, NB-3234, 1995.

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YVL 4.2 Steel structures for nuclear facilities, 19 Jan. 1987

YVL 4.3 Fire protection at nuclear facilities, 2 Feb. 1987

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YVL 5.2 Nuclear power plant electrical systems and equipment, 23 Jan. 1997 (in Finnish)