STUK

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RADIATION MONITORING SYSTEMS AND EQUIPMENT OF 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

The permanently installed (stationary) and portable radiation monitoring systems and equipment are used to ensure the radiation safety of a nuclear power plant and its environment. Their purpose is to measure the radiation dose rates and radiation exposures within the plant as well as to monitor the concentrations of radioactive materials in the systems and the radioactive releases.

The measurements conducted at a nuclear power plant include dose rate measurements of external radiation, surface contamination measurements, air activity concentration measurements and workers' dosimetry and determination of internal radioactivity (whole body counting). The purpose of radiation measurements of the systems is to monitor the transport of radioactive materials in the liquid and gas process systems inside the plant. The measurements of radioactive effluents are aimed to monitor liquid and gaseous release of radioactive materials from the plant.

The use of nuclear energy is prescribed in the Nuclear Energy Act (990/1987) and the Nuclear Energy Decree (161/1988) as well as in the Government Decision (395/1991) issued in accordance with the Act. In addition, the regulations issued in Section 2 (General principles) and Chapter 9 (Radiation work) of the Radiation Act (592/1991) apply to the use of nuclear energy.

This Guide defines the requirements for the design, qualification and manufacture of the stationary radiation monitoring systems of a nuclear power plant as well as for their commissioning at the plant and their operation. The Guide also describes regulatory control pertaining to these issues. This Guide does not deal with neutron flux measurements of the reactor or radiation measurements carried out at the NPP laboratory. This Guide may also be applied to other nuclear facilities.

Guide YVL 7.6 gives the basic requirements for the control of radioactive releases from a nuclear power plant. Guide YVL 7.7 deals with radiation monitoring in the environment of a nuclear power plant. The radiation safety of nuclear power plant workers and the monitoring of occupational exposure are discussed in Guides YVL 7.9 and YVL 7.10. Guide YVL 7.4 deals with the emergency preparedness arrangements for a nuclear power plant.

The requirements defined in the following guides also apply to the radiation monitoring systems dealt with in this Guide: Guide YVL 2.0 "Systems design for nuclear power plants" and Guide YVL 2.1 "Nuclear power plant systems, structures and components and their safety classification" as well as Guide YVL 5.2 "Electrical power systems and components of NPPs" and Guide YVL 5.5 "Instrumentation systems and components at nuclear facilities".

Radiation monitoring systems are instrumentation and control systems, for which special requirements are laid down in this Guide. The Guide describes the independent requirements and, furthermore, the requirements are defined referring to Guide YVL 5.5. Portable radiation measuring instruments are either individual instruments or they form sets of equipment, for which the requirements are laid down in this Guide.

The alarm and control functions of radiation measurements depend on the safety systems of the nuclear power plant. The control functions may include the reactor protection function or the process control (for example, purification control or closing of the release line). However, the measurements also have an immediate control function linked with radiation safety of the area concerned, and therefore all the radiation monitoring systems and equipment of a nuclear power plant are required to be of high quality and to operate reliably.

Compared with other instrumentation and control systems, special requirements set by radiation measurements are due, e.g., to the different sensor types and their physical principles of measurement, sampling arrangements and protection from background radiation. The functional performance characteristics of radiation measuring instruments are connected with the statistical phenomena linked with the physical implementation of the radiation measurement. Not all properties of the measuring instruments can be tested at the site of manufacture and operation but at an appropriate radiation measurement standard laboratory.

2 General requirements

Section 3 of the Government Decision (395/1991) concerning general safety requirements for nuclear power plants states that *the general objective is to ensure nuclear power plant safety so that nuclear power plant operation does not cause radiation hazards which could endanger safety of workers or population in the vicinity or could otherwise harm the environment or property.*

Section 3 of the Government Decision defines the general requirements pertaining to radiation exposure and radioactive releases from a nuclear power plant. In accordance with Section 7 of the Decision, *radiation exposure arising from the operation of a nuclear power plant shall be kept as low as reasonably achievable. A nuclear power plant and its operation shall also be designed so that the limits presented in this decision are not exceeded.*

In accordance with Section 11 of the Radiation Decree (1512/1991), *working conditions affecting radiation exposure shall be determined and monitored at the workplace in such a way that undue radiation exposure can be detected and prevented.*

In accordance with Section 12 of the Radiation Decree, *methods and equipment used for monitoring radiation exposure and the relevant working conditions are subject to approval by STUK.*

In accordance with Section 2.1 of Guide YVL 1.0, *to ensure radiation monitoring, there shall be a sufficient number of fixed and portable radiation measurement devices at the plant for determining the external dose rate and what radioactive substances there are in the air, systems or on surfaces. There shall also be appropriate laboratory facilities and equipment for sample analysis and equipment for individual dose monitoring.*

Furthermore, alarming measuring instruments shall be used for radiation monitoring in such a way that, in the nuclear power plant's operational conditions, nobody is exposed to radiation without knowing it and to a degree harmful to health.

In accordance with Section 2.1 of Guide YVL 1.0, *when designing radiation monitoring, provision shall also be made for accidents. It shall be possible to take at least the following measures during accidents:*

- *measurement of dose rate inside the containment*
- *determination of the concentration of radioactive substances in gas phase inside the containment*
- *determination of the concentration of radioactive substances in the coolant.*

In accordance with Section 3.6 of Guide YVL 1.0, *for the purpose of accident monitoring and management, appropriate measuring and monitoring instrumentation shall be designed for the plant by which the operating personnel obtains sufficient data for event assessment and for the planning and implementation of countermeasures.*

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The measurement systems designed for accident monitoring and management shall maintain operability even in the event of a single failure.

In accordance with Section 2.2 of Guide YVL 1.0, *it must be possible to monitor the releases of radioactive substances along planned pathways also in the event of a single failure during operational conditions and accidents.*

In accordance with Section 3.6 of Guide YVL 1.0, *the control equipment shall be designed to record process parameters indicating plant state and also system control signals so that the plant's operational events can be analysed afterwards.*

The requirements defined in Sections 2 to 5 of Guide YVL 5.5 shall be fulfilled in the design and implementation of radiation monitoring systems.

3 Radiation monitoring systems and equipment

The radiation monitoring systems shall be permanently installed and fitted with centralized remote displays and alarms in the control room. To supplement the permanently installed measuring systems, the nuclear power plant shall be provided with portable or locally installed measuring instruments.

3.1 Stationary measuring systems for external radiation

The controlled area shall be provided with stationary measuring instruments for monitoring external radiation, particularly those accessible areas where changes in the plant's operational state or other events may cause a significant increase in the local dose rate.

At LWR plants, measuring instruments shall be placed at least in the following areas:

- the reactor containment building
- the reactor hall
- the spent fuel stores and the fuel handling machine
- the radioactive waste treatment and storage facilities
- the decontamination facilities.

3.2 Stationary and portable measuring systems for air activity concentration

The activity concentration in the air shall be determined for such accessible rooms of the controlled area whose air may contain radioactive materials in amounts significant for the workers' radiation doses. The determination may be based on continuously monitoring stationary or portable measuring instruments or on the analysis of separately collected samples at the laboratory.

In the containment of a PWR, it shall be possible to measure the activity concentration of the air (gas) continuously.

It shall be possible to assess the radionuclide concentrations in the containment gas on the basis of sampling or some other method even during serious accidents.

3.3 Other stationary radiation measuring systems

Nuclear power plant systems shall be fitted with stationary radiation measuring instruments to monitor the activity of liquids and gases, if necessary. These measurement data are necessary to detect any fuel failures and radioactive leaks and to control them. Corresponding measurements can also be used to control the operational state of filters and tanks.

Stationary radiation measuring instruments shall be used to monitor at least the activity concentration of the primary coolant of PWRs and the activity concentration of the live steam of PWRs and BWRs. The treatment system of radioactive gases and the primary coolant purification system of PWRs shall be fitted with measuring instruments. Radiation measuring instruments shall also be placed in steam and water circuits that may become significantly contaminated in the event of leaks occurring in circuits that contain radioactive materials.

In an accident, it shall be possible to determine the activity concentration of the water inside the containment. Sampling equipment shall be available for this purpose even during a severe reactor accident.

3.4 Portable radiation measuring equipment

A sufficient number of portable instruments shall be available at the nuclear power plant to measure the dose rate of gamma radiation in the working areas and plant facilities. Some of the instruments shall be fitted with a telescopic arm to enable remote radiation measurements of the object.

Measuring instruments for neutron radiation shall be provided for situations in which neutron radiation may occur (spent fuel transfers, for instance).

A sufficient number of portable instruments shall be provided to measure the activity concentration of air in the working areas where stationary measuring instruments do not give representative results.

A sufficient number of portable measuring and sampling instruments of surface contamination (primarily for beta but also alpha radiation) shall be provided for use in the different operational conditions of the nuclear power plant.

The exit routes of the controlled area shall be provided with measuring equipment to ensure that the tools, protective clothing and skin of a person exiting from the controlled area are not radioactive.

The plant shall have a measuring instrument for internal contamination to ensure that any radioactive materials within the body while working in the controlled area are detected and the dose caused by them can be assessed.

4 Qualification of the equipment

4.1 Applicable standards

The licence-holder shall present and specify the standards to be complied with in designing the systems and equipment. The references listed below contain standards concerning radiation monitoring in force at the moment of issuing this YVL Guide. This section describes the principal requirements for the properties of radiation measuring instruments. Guide YVL 5.5 lays down general requirements for the standards applied as the design basis for the systems and equipment and for demonstration of their compliance with the requirements.

4.2 Measuring range and response

In accordance with Guide YVL 1.0, *the measurement systems shall be capable of measuring accurately enough over the entire range within which the measured parameters vary during operational conditions or accidents.*

If it is necessary to use two or more measuring channels to cover the measuring range of the object, the measuring ranges of the channels must sufficiently overlap. The measuring instrument shall be capable of indicating the measurement result even in the event that the maximum value of the measuring range is exceeded.

The response of the measuring instruments for external gamma radiation shall fulfil the requirements set in the applicable standards both with calibration radiation and as a function of the energy of radiation, at least when the energy emitted by the radiation is between 80 keV and 1.5 MeV.

The indication of the measuring equipment shall follow the actual values of the measured object without significant delay.

If ^{16}N is the main source of radiation, the instrument response to the gamma radiation emitted by ^{16}N must be known. If radiation other than gamma radiation (beta radiation, neutrons) can occur at the point of measurement, the response and effect on the measurement shall be investigated and considered. Furthermore, the need for a separate measurement shall be determined.

The response of instruments intended to measure the activity concentration and surface contamination using anticipated nuclide compositions shall be known.

4.3 Measuring equipment used in a severe accident

The measuring equipment for the external dose rate in the containment, which is designed to function during a severe accident, shall be capable of displaying the dose rate that is caused by the release of a significant fraction of the radioactive materials from the reactor core into the containment. The measuring range shall extend to a dose rate of 10^6 Gy/h (Sv/h).

The measuring range of the sampling and instrumentation intended to measure the concentrations of iodine isotopes and radioactive aerosols in the containment shall extend at least to a value of 10^{15} Bq/m^3. The locations of the sampling points shall be justified.

Continuous measurement of the air activity concentration in the areas close to the containment shall be conducted considering the necessary inspection and control measures in these areas during accidents.

A sufficient number of portable measuring instruments for external radiation whose upper limit of the measuring range is no less than 10 Gy/h (Sv/h) shall be available for measurements to be carried out during an accident.

The range of the measuring system for releases into the air shall be such that the system is capable of functioning even during a severe accident. The release measurement shall be protected in such a way that external background radiation does not prevent or disturb the measurement.

4.4 Environmental conditions

The measuring systems shall maintain their operability under the conditions and stresses in which they have been designed to function. In assessing their operation, at least the following factors shall be taken into account:

- the temperature
- the pressure
- the humidity
- the mechanical vibrations

- the effects of radiation
- the chemical effects
- the changes in the operating voltage
- the electrical and magnetic disturbances.

The environmental qualification of the radiation monitoring equipment shall be demonstrated by tests. Supplementary requirements have been laid down in Guides YVL 5.2 and YVL 5.5.

4.5 Other requirements

Radiation measurement data provided by the stationary measuring instruments shall be displayed in the plant control room, collected in accordance with the purpose of use. The measurement results shall also be recorded in an appropriate manner.

Stationary radiation measuring instruments shall usually be fitted with local alarms, which indicate malfunction of the instruments and if the set value of the measured variable is exceeded. The alarms shall also be transmitted to the main control room or a separate operational control centre to detect the exceeding of set limits or the malfunction of a measuring instrument rapidly enough. The implementation of the alarm limits and other equipment adjustments shall be designed in such a way that no changes in them can be effected accidentally and an activated alarm cannot go off without operational action.

The measuring instruments for radioactive materials shall be designed in such a way that the need for decontamination is small and their decontamination is easy.

The instruments and their location shall be designed in a way that enables the necessary calibration, testing and maintenance.

If the signal of a measuring instrument is employed to actuate protective functions, the requirements set in Section 2 of Guide YVL 5.5 apply to the measuring system.

The power supply to the nuclear power plant's stationary, safety-classified radiation monitoring systems shall be secured. The basis for the redundancy and its implementation shall be described in respect of each measuring instrument and related function.

The air activity concentration shall be measured in a way that makes the sampling as representative as possible, irrespective of any local differences in concentration. Furthermore, the measuring instruments shall be placed or the samples taken in such a way that no significant air contamination goes unnoticed. The location of potential sources of contamination and the air conditioning of the area concerned shall be taken into account.

In calibrating portable meters for surface contamination used for general radiation protection measurements, a radiation source shall be used that well represents the contamination occurring in the plant facilities. The measuring instrument shall be capable of detecting changes in the normal background radiation. In addition, the measuring ranges shall exceed the contamination limit values set in Guide YVL 7.9 for the highest class of the controlled area at least by a factor of ten.

The energy response and measuring accuracy of the dosimeters of the real-time work dosimetry system shall fulfil the requirements set for the measuring instruments of external gamma radiation.

5 Commissioning of the systems and equipment

5.1 General requirements

The properties of the radiation monitoring systems and equipment used at a nuclear power plant shall be demonstrated by type tests and tests carried out during manufacture as well as by the facility and site acceptance tests, pre-operational testing and commissioning. Detailed requirements for these are defined in Guides YVL 2.5 and YVL 5.5.

5.2 Stationary measuring systems for external radiation

During pre-operational testing, the measuring channels shall be calibrated for each decade of the measuring scale, normally at least up to a dose rate value of 10^{-2} Gy/h (Sv/h). The measuring instruments for external radiation of the containment shall be calibrated throughout their measuring range.

The pre-operational testing shall include verifying that the visible and audible alarms and the alarm limits function as designed. Furthermore,

an installation inspection shall be carried out, including the inspection and testing of the installations, couplings and actuators.

5.3 Other stationary radiation measuring systems

Each measuring channel shall be calibrated during pre-operational testing using a suitable radiation source. The purpose of calibration is to establish the response of measuring equipment to a known radionuclide concentration under normal operating conditions. The activity response of a detector shall be demonstrated using actual measuring geometry, if possible. If a radioactive calibration source or the measuring geometry deviates from the operating condition of the measuring equipment, the analogy between the calibration measurement results and the operating measurement results shall be assessed and the data recorded.

The alarm limits shall be tested in at least two points of the measuring range (within the highest and lowest decades of measurement). The functioning of visible and audible alarms shall be verified. In addition, the effect of background radiation shall be measured using a suitable radiation source. Installations, couplings and the tightness of flow channels and joints shall be checked.

5.4 Portable measuring instruments for external radiation

Instruments intended to measure gamma radiation shall be calibrated before commissioning for each decade of the scale, at least up to a dose rate value of 10^{-2} Gy/h (Sv/h). Alarm limit settings and alarm functions, if available, shall be checked.

Gamma radiation measuring instruments for high dose rates shall be calibrated throughout their operating range at a laboratory approved by the Radiation and Nuclear Safety Authority before they are brought into use.

The linearity of the functioning of measuring instruments for neutron radiation shall be verified electrically before commissioning. Furthermore, potential alarm limits and alarms shall be checked. An instrument representing each type shall be sent to a laboratory approved by the Radiation and Nuclear Safety Authority for calibration.

5.5 Measuring instruments for surface contamination

The functioning of the instruments for measuring surface contamination shall be verified within their measuring ranges using at least two surface sources of beta radiation, whose distribution of radionuclide radiation energy corresponds to that of the plant. The activity emitted by one of these shall be equivalent to the beta radiation limit values set for the lowest class of surface contamination in the controlled area in accordance with Guide YVL 7.9. The functioning of alarm limits shall be verified.

In addition, the measurement and alarm functions of personal surface contamination monitors shall be correspondingly checked within their measuring ranges.

The installation and couplings of stationary measuring instruments shall be checked and the functioning of the instruments shall be tested.

6 Operation, periodic tests and maintenance

Operating instructions shall be drawn up for the radiation monitoring systems and equipment. The operating instructions shall cover the normal operational states and accidents in which these systems and equipment are needed.

The condition of the radiation monitoring systems and equipment shall be regularly controlled during the nuclear power plant operation. To this end, preventive maintenance, condition monitoring and periodic testing programmes shall be drawn up for the radiation monitoring systems and equipment. The Technical Specifications of the nuclear power plant shall include requirements for the operability and periodic testing of the radiation monitoring systems and equipment important for safety.

The preventive maintenance programme shall describe the maintenance measures pertaining to the radiation monitoring systems and equipment, whose aim is to ensure that the systems and equipment function reliably and in accord-

ance with the designs. The purpose of condition monitoring is to ensure that the overall operability of the equipment is maintained and that, for instance, the conditions at the measuring points are maintained in accordance with the designs.

The periodic testing programme shall describe the system and instrument-specific functional tests carried out at regular intervals to verify that the systems and equipment function in accordance with the designs. The programme shall specify the testing frequencies or the plant operational states under which tests are required. The test procedures and the acceptance criteria for the tests shall be specified in the instructions.

Experience of operation shall be assessed regularly to identify any type defects and weaknesses of the equipment. Section 5 of Guide YVL 5.5 defines the requirements for monitoring the ageing of equipment. Advances in radiation monitoring technology shall be monitored, and justified modifications enabled by technological progress shall be implemented, if necessary.

7 Regulatory control

7.1 Review of the design

Guide YVL 2.0 lays down general requirements for inspection of the systems designs. In accordance with the Guide, the Radiation and Nuclear Safety Authority assesses the systems of a new nuclear power plant on the basis of the preliminary and final safety analysis reports. The pre-inspection of a system modified or added during the nuclear power plant operation is correspondingly conducted on the basis of a separate conceptual design for the modification concerned and the pre-inspection documentation. Guide YVL 5.5 gives requirements for contents of the documents.

The feasibility assessment of the radiation measuring instruments belonging to safety classes 2 and 3 in accordance with Guide YVL 2.1 shall be submitted, together with their appendices, to the Radiation and Nuclear Safety Authority for approval. Requirements for the feasibility assessment have been given in Guide YVL 5.5. The feasibility assessment of the radiation measuring instruments belonging to safety class 4 shall be submitted to the Radiation and Nuclear Safety Authority for information.

If a portable or transferable measuring instrument used for radiation protection purposes is not included in the plant's safety-classified instruments, a control procedure in accordance with safety class 4 is followed in this case. The instruments can be considered as sets of equipment, and the information concerning them that fulfils the requirements set in this guide section can be given in suitable entities.

7.2 Control during the manufacturing, installation and pre-operational testing

The Radiation and Nuclear Safety Authority shall be reserved the opportunity of making inspections during the manufacturing of systems and equipment and the quality management during manufacturing. The test programmes during manufacture and the test results shall be sent to the Radiation and Nuclear Safety Authority for information.

The Radiation and Nuclear Safety Authority monitors the installation of radiation monitoring systems at the plant within the scope it considers necessary.

The pre-operational test programmes and the result reports on pre-operational testing concerning the radiation monitoring systems and equipment shall be sent to the Radiation and Nuclear Safety Authority. The documentation about the systems and equipment belonging to safety classes 2 and 3 shall be submitted for approval, and about those belonging to safety class 4 for information. The Radiation and Nuclear Safety Authority monitors the testing and commissioning at the plant within the scope it considers necessary.

The Radiation and Nuclear Safety Authority carries out a commissioning inspection of the radiation monitoring systems that belong to safety classes 2 and 3.

7.3 Control during system operation

The Radiation and Nuclear Safety Authority controls radiation monitoring systems and instruments by inspecting their repairs and modifications and by supervising the licence-holder's

operations that are aimed to ensure the reliable functioning of these instruments and systems. The licence-holder's operations are evaluated by audits in accordance with the operation control programme and, if necessary, by other audits.

Operating instructions for the radiation monitoring systems and the periodic inspection instructions shall be submitted to the Radiation and Nuclear Safety Authority for information.

The Radiation and Nuclear Safety Authority controls any supplements, additions and modifications to the radiation monitoring systems and equipment in accordance with the same procedures as it controls their original implementation at the nuclear power plant.

8 References

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