STUK

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ASSESSMENT OF RADIATION DOSES TO THE POPULATION IN THE ENVIRONMENT OF A NUCLEAR POWER PLANT

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Authorisation

By virtue of section 55, second paragraph, point 3 of the Nuclear Energy Act (990/1987) and section 29 of the Government Resolution (395/1991) on General Regulations for the Safety of Nuclear Power Plants, the 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 stated otherwise by STUK.

Translation. Original text in Finnish.

1 General

The use of nuclear energy is prescribed in the Nuclear Energy Act (990/1987) and the Nuclear Energy Decree (162/1988) as well as in the Government Resolutions (395/1991, 396/1991 and 397/1991). The use of nuclear energy falls also under section 2 (General principles) and chapter 9 (Radiation work) of the Radiation Act (592/1991).

According to section 3 of the Government Resolution (395/1991) *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 7 of the Resolution prescribes that *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 resolution are not exceeded.*

In accordance with section 9 of the Nuclear Energy Act *it shall be the licence-holder's obligation to assure the safe use of nuclear energy.* The licensee and when applying for a construction and operating licence the applicant for a licence have the obligation to demonstrate fulfilment of safety requirements. For this purpose the licensee/applicant for a licence shall assess the radiation exposure of the surrounding population.

This guide sets forth the principles to be followed in the assessment of the radiation exposure of the surrounding population.

The requirements of this guide apply to transient and safety analyses conducted in accordance with Guide YVL 2.2; to analyses assessing exposure from releases during normal operation; and to analyses in connection with emergency preparedness. In addition, they may be applied to other analyses for the operation of a nuclear power plant. This guide may be applied to other nuclear facilities as well. Guide YVL 7.3 deals with evaluation of the dispersion of radioactive substances in relation to radiation dose assessment.

According to Recommendation 91/4/Euratom issued by the Commission of the European Communities on the application of Article 37 of the EURATOM Treaty, the member states shall provide the Commission with information about the environmental impacts of the use of nuclear energy. If need be, the Radiation and Nuclear Safety Authority will instruct separately on the application of the Recommendation.

The licensee may use a simplified model that deviates from the detailed requirements of this guide. It shall then be justifiably demonstrated that the model is conservative.

2 General requirements

2.1 Analysis methods

The methods for assessing radiation doses to the population around a nuclear power plant shall be reliable and conservative. The models, calculation methods and computer programmes used shall be sufficiently qualified. The calculation parameters shall be suitable for conditions around the plant site.

The analyses shall include studies on the sensitivity of the results regarding the analysis methods and parameters used.

2.2 Defining the most exposed population group

The models for assessing dose to the surrounding population cannot fully consider all differences between individuals and their habits. Therefore, the so-called critical group [1, 2] shall be defined which, on the basis of its place of residence and habits, is estimated to receive the highest doses. Dose limits shall be compared with the dose average of this group.

The most exposed group shall be chosen for normal operation of the nuclear power plant and, separately, for accident analyses in accordance with Guide YVL 2.2. The concept of the most exposed group is practicable also in dose calculations made for emergencies in accordance with Guide YVL 7.4; however, the requirements

of this guide concerning the critical group do not generally apply to these calculations.

Assumptions concerning the most exposed group selected during the plant design and licensing phase for calculation of doses due to normal operation shall be reviewed during the operation of the nuclear power plant, taking into consideration local conditions.

The most exposed group, its composition and habits shall be chosen in accordance with the requirements of this guide, considering, as applicable, the principles set forth in [2]. The values of other calculation parameters shall be similarly chosen. When calculating the dose to the most exposed group, applicable mean values shall be employed for parameters that are dependent on the habits of the group's members. The doses calculated shall be representative of the average radiation exposure of a moderate-sized, homogenous population group.

2.3 Exposure pathways examined in dose calculation

In dose calculation, doses caused by external radiation from the facility and from transportation shall be considered as well as doses from atmospheric and aquatic discharges of radioactive materials. They shall be given as effective dose [1]. Internal exposure through inhalation or ingestion is represented by committed dose; in its calculation the dose equivalent rate is integrated over an examination period of 50 years for adults and 70 years for children.

In addition to doses received through various exposure pathways, a summary of doses to the most exposed group and a summary of collective doses shall be calculated. It shall also be specified by advance analyses what nuclides significantly contribute to dose through each exposure pathway and to total dose.

When calculating the migration of tritium and ^{14}C in the biosphere and the doses they cause to man through the ingestion of foodstuffs, methods shall be used that take into account the special character of these substances.

Radiation doses from atmospheric discharges of radioactive materials

Table 1 gives the exposure pathways that are to be considered in analyses or whose exclusion shall be justified when radioactive releases into the atmosphere are examined.

Doses from external radiation caused by radioactive materials in the atmosphere shall be calculated at a location one metre above ground level. A semi-infinite cloud model may be used to calculate beta radiation doses. For calculating doses from gamma radiation, either a model having as the radiation source an ambient air volume that contains radioactive substances or the semi-finite cloud model may be used, adjusted by correction factors that depend on dispersion parameters.

Similarly, when calculating doses from external gamma and beta radiation caused by radioactive substances deposited on the ground, radiation one metre above ground level shall be examined. The deposition of radioactive material in one unit area of ground, i.e. surface activity, shall be calculated from the concentration of airborne radioactive substances, taking into account dry and wet deposition.

When calculating concentrations of radioactive substances in flora, radioactive substances deposited on them either directly or by resuspension from soil, and those taken up from the soil by them, shall be considered.

When calculating concentrations of radioactive substances in milk, radioactive substances deposited on grazing grass directly, or by resuspension, shall be considered as well as those taken up by grass from the soil. It shall be taken into account that, along with the grass, the grazing animal can ingest contaminated soil as well.

Radiation exposure caused by the ingestion of natural products like wild berries and mushrooms shall be examined from the viewpoint of individual dose in particular.

Table I. *Exposure pathways to be considered in analyses of atmospheric discharges.*

External exposure	
direct and scattered radiation from onsite radiation sources and transportation	N, O, VL, VP
radioactive substances in a release plume	N, O, VL
radioactive substances deposited on the ground	N, O, VL, VP
radioactive substances deposited on bare skin, hair or clothing	O[1], VL[1]
radioactive substances resuspended into the air	O[1] , VP[1]
Internal exposure	
inhalation of radioactive substances in a release plume	N, O, VL
ingestion of plants containing radioactive substances originating in deposition	N, O, VP
ingestion of contaminated milk and other animal products	N, O, VP
radioactive substances directly desposited on surface waters or subsequently filtering from drainage areas in case the water is used for drinking or in case aquatic plants or animals are ingested	O[2], VP[2]
inhalation of radioactive substances transported into the air through resuspension	VP[1]
N Normal operation O Transients and accidents VL Emergencies, short term VP Emergencies, long term	

[1] usually of no significance
[2] may be of significance for individual dose

Table II. *Exposure pathways to be considered in analyses of aquatic discharges.*

External exposure	
radioactive substances accumulated on shorelines	N, O
radioactive substances in water during boating or swimming activities	N[1]
Internal exposure	
radioactive substances in fish	N, O
inhalation; via resuspension from substances accumulated on shorelines or via oversplash from a receiving body of water	N[1]
radioactive substances in drinking water in case water from a receiving body of water is used for drinking	N[1]
contamination of foodstuffs in consequence of the potential use of water from a receiving body of water for drinking water for cattle and for irrigation	N[1]
contamination of pastures or arable land as well as their produce through oversplash from a receiving body of water, or through other ways of accumulation	N[1]
N Normal operation O Transients and accidents	

[1] usually of no significance

When estimating doses incurred via plant and animal products, differences in growth and grazing periods in relation to other periods shall be taken into account in accordance with average conditions prevalent in the plant's municipality. The estimates shall also consider the possible use of contaminated fodder.

Radiation doses from discharges of radioactive materials to water systems

When evaluating radiation doses to the population caused by radioactive releases into water systems, both external and internal exposure shall be considered. Table II shows the exposure pathways that shall be considered at least.

The surface activity of shorelines may be calculated from concentrations of radioactive substances in water, using transfer factors equivalent to local conditions and considering the various transfer mechanisms of radioactive substances from water to shore.

Concentrations of radioactive substances in fish may be calculated from concentrations of radioactive substances in water, using concentration factors.

2.4 Individual dose assessment

Analyses in connection with licensing shall consider anticipated changes in prevailing conditions. As residential distance, a location in the immediate vicinity of the plant site shall be assumed where settlement is possible. The inclusion of population groups other than adults is necessary in case the most exposed group includes children.

The time spent outdoors by the most exposed group as well as the indoor and outdoor protection factors shall be chosen more unfavourable than under average conditions. The habits of the population and the characteristics of houses shall be considered when evaluating the conditions. The group's exposure to external radiation coming from the shores of a receiving body of water shall be assumed for a certain average yearly period.

When calculating internal exposure from inhaled radioactive substances, the same concentration levels shall be assumed both indoors and out.

The most exposed group shall be assumed to consume plants grown and fish caught in the plant's vicinity as well as milk produced in the neighbourhood. The milk and other animal products may be assumed to originate in the most adjacent processing plant.

2.5 Collective dose assessment

In collective dose assessment, the same exposure pathways shall be considered that are used to calculate doses to the most exposed group. When calculating collective dose, the effects of radiation shall be examined in an area extending at least 100 km from the plant, in the whole of Finland and globally. The area can be divided into subareas in whose examination data descriptive of the habits of the local population is used. The population in the area shall be divided into age groups, if necessary. Calculation parameters depicting the adult population only may be used when doses received during normal operation are examined.

When calculating collective doses from external radiation, shielding provided by buildings may be taken into account. When calculating collective doses received on the shores of a receiving body of water, the surrounding population up to 10–20 km from the water system shall be considered as well as the average time spent onshore.

When calculating collective doses from foodstuffs, the actual quantity of foodstuffs produced in an area shall be considered.

When calculating global collective dose commitments arising from some long-lived radioactive substances, conversion coefficients may be used that depict the collective dose received per unit of release.

3 Dose assessment in connection with licensing

3.1 Normal operation

External radiation from the nuclear power plant and during transport

When assessing radiation doses to the most exposed group caused by external radiation from the facility, the following factors shall be considered: location of onsite sources of external radiation, radiation intensities and radiation shields.

When assessing doses caused by external radiation during transport, the transport routes for

spent fuel and radioactive wastes as well as the population along the routes shall be considered.

Radiation doses from radioactive releases

The doses to the most exposed group and collective doses from radioactive releases into the atmosphere and water systems shall be analysed.

When estimating doses due to external radiation from deposition caused by releases during plant operation, it is usually sufficient to examine doses accumulating during 50 years.

In addition, the collective doses from long-lived nuclides such as ^{3}H, ^{14}C and ^{85}Kr, which spread over a large area, shall be estimated for a period of 500 years in the vicinity of the plant, in Finland and world-wide.

3.2 Transients and accidents

Guide YVL 2.2 presents requirements that apply to the analysis of anticipated operational transients, postulated accidents and severe accidents. Guide YVL 7.1 presents, for corresponding situations, limitations on public exposure to radiation for use in planning. Requirements that apply to analyses to be conducted as a basis for action during accident situations and for emergency planning are described in Guide YVL 7.4.

Accident analyses in accordance with Guide YVL 2.2 and emergency response related analyses in accordance with Guide YVL 7.4 shall, in a versatile manner, examine the radiation doses to the most exposed population group and to various age groups via different exposure pathways; long-term environmental contamination shall also be analysed. The analyses shall examine the contribution to total dose of various exposure pathways and dominant nuclides at different distances. When evaluating acute effects, the effect of inhaled or ingested nuclides shall also be examined. In addition, collective doses to the population in various target areas shall be assessed. The formation of collective dose shall be assessed classified in individual dose ranges.

Radiation dose assessment relating to accident analyses shall not include the effect of countermeasures to limit public exposure. Their effect shall be separately assessed during emergency planning.

When doses from internal radiation caused by inhaled radioactive substances are calculated it shall be assumed that individuals of the most exposed group stay within examination distance for the entire duration of the release period following the accident.

In severe accident analysis, short- and long-term doses in diverse weather and dispersion situations shall be separately examined. The contribution of various exposure pathways and significant nuclides shall be specified. In the assessment of long-term dose, examination periods exceeding three months are to be used.

In accordance with the requirements of section 12 of the Government Resolution (395/1991), severe accident analyses shall examine the long-term contamination of the plant's environment; exposure caused by caesium isotopes in particular shall be considered. The analyses shall show that any exposure arising from other radioactive substances does not significantly increase long-term public exposure in any period exceeding three months. When assessing long-term environmental contamination, the extent and duration of soil and water contamination shall be examined.

When assessing public exposure from accidents, calculations may statistically consider the variability of weather-dependent dispersion conditions as well as any seasonal differences in radiation doses accumulating through food chains. The results shall be given in the form of appropriate distributions as well as averages and fractiles. When determining compliance with dose constraints in accordance with the Government Resolution (395/1991) and Guide YVL 7.1 in various accident situations, instead of maximum values, dose estimates in compliance with the 99.5th percentile may be used.

4 Dose assessment during operation

When assessing radiation doses from releases measured during operation, the same methods and assumptions shall generally be used as are used for assessments made during the design of the nuclear power plant.

In addition, the quantities of radioactive substances and resultant doses in the environment of a nuclear power plant shall be assessed based on measurement results yielded by an environmental radiation monitoring programme implemented in accordance with Guide YVL 7.7. The dose calculation model used shall be updated, when necessary, on the basis of the measurement results.

5 Dose assessment during emergencies

The facility shall prepare for emergencies by supplementing the dispersion and dose assessments made during the plant's design and licensing. The supplementary assessments shall consider the following factors: development of calculation methods, improved knowledge of the plant, plant safety systems modifications and improved reliability of the data on environmental and dispersion conditions.

There shall be a computer-based system for dose predictions in the time period immediately following an accident as well as a readiness for corresponding simplified calculations on the basis of manuals and dispersion diagrams drawn beforehand.

Release estimates based on measurements shall be used in the calculations, when possible. In actual accident situations, the exposure duration, protection factors, etc shall primarily be assumed on the basis of prevailing conditions. The calculation system shall include plant-specific pre-estimates of typical accident releases and shall allow for the flexible alteration of release quantities to depict actual accident circumstances and event progression. When assessing the effects of imminent release situations, postulated releases applicable to the progression of the event in question shall be examined and corresponding dose forecasts shall be drawn up. When the accident has occurred dose assessment shall consider the deposition and concentrations measured in the environment.

Extensive documentation shall be available on the results of advance dispersion and dose calculations in which realistic assumptions have been used as well as several typical accident scenarios with dispersion and depletion parameters corresponding to diverse weather conditions. When selecting accident scenarios for the calculations, safety analyses conducted during the plant's design and licensing phase shall be considered. Release situations caused by highly unlikely severe accidents shall be included as well.

The practicability of the results of the advance calculations and of systems for calculating real-time dispersion and dose shall be tested in emergency exercises. Established procedures shall be reviewed based on experience.

6 Regulatory control

STUK reviews documents submitted to it during the licensing of the nuclear power plant and controls the plant's construction and operation in accordance with Guide YVL 1.1. Analyses on the dispersion of radioactive substances and subsequent doses are assessed by STUK during the review of the Preliminary Safety Analysis Report and the Final Safety Analysis Report as well as during the review of the emergency plan.

A description of the calculation models and parameter values used in the assessment of public exposure in the environment of the nuclear power plant during design, operation and emergencies shall be submitted to STUK for approval. The descriptions shall also state how validity of the models and applicability of the calculation parameters for the conditions in the plant site's environment have been assured. In addition, the composition of the most exposed group selected for dose calculations shall be justified.

7 References

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