STUK

GUIDE **YVL 5.6** / 25 NOVEMBER 2004

AIR-CONDITIONING AND VENTILATION SYSTEMS AND COMPONENTS OF NUCLEAR FACILITIES

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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

In Finland, the authority that controls the safety of the use of nuclear energy is the Radiation and Nuclear Safety Authority (STUK). Guide YVL 1.1 defines the general control procedures of STUK's regulatory control pertaining to nuclear power plants. STUK's safety control includes controlling the air-conditioning and ventilation systems of nuclear facilities as far as they have an effect on the nuclear and radiation safety of the facilities.

This Guide defines the requirements for the design, implementation and operation of the air-conditioning and ventilation systems of nuclear facilities belonging to safety classes 3 and 4, and for the related documents to be submitted to STUK. Furthermore, the Guide describes the inspections of air-conditioning and ventilation systems to be conducted by STUK during construction and operation of the facilities. As far as systems and components belonging to safety class 2 are concerned, STUK sets additional requirements case by case.

In general, air-conditioning systems refer to systems designed to manage the indoor air cleanness, temperature, humidity and movement. In some rooms of a nuclear power plant, ventilation systems are also used to prevent radioactive materials from spreading outside the rooms.

Guide YVL 1.0 defines the safety principles concerning the air-conditioning and ventilation of nuclear power plants. Guide YVL 2.0 gives the requirements for the design of nuclear power plant systems. In addition, YVL Guide groups 3, 4, 5 and 7 deal with the requirements for air-conditioning and ventilation systems with regard to the mechanical equipment, fire prevention, electrical systems, instrumentation and control technology, and the restriction of releases.

The rules and regulations issued by the Ministry of the Environment and the Ministry of the Interior (RakMK, the Finnish building code) concerning the design and operation of air-conditioning and ventilation systems and the related fire protection design bases also apply to nuclear facilities.

Exhaust gas treatment systems, condenser vacuum systems of boiling water reactor plants and leak collection systems are excluded from the scope of this Guide.

2 Design and implementation of air-conditioning and ventilation systems

2.1 General requirements

In terms of nuclear safety, the most important function of air-conditioning systems is to maintain and secure such ambient conditions in the rooms of a nuclear facility that the components and structures important for plant safety are kept in good condition and operate flawlessly. Furthermore, the purpose of the air-conditioning systems is to maintain appropriate working conditions for the plant's operating and maintenance staff in such a way that the cleanness, temperature and humidity of indoor air comply with the regulations issued by the authorities.

The room of each parallel subsystem important for safety shall be fitted with an air-conditioning system, independent of the air conditioning of other parallel subsystems, in order to maintain the heating, cooling, fire safety and other required ambient conditions of the rooms.

In accordance with Section 7 of the Government Decision (395/1991), *radiation exposure arising from the operation of a nuclear power plant shall be kept as low as reasonably achievable.*

The function of the ventilation systems is

- to keep particularly the concentrations of radioactive materials at an acceptable level in terms of the personnel's radiation exposure
- to prevent radioactive materials from spreading inside the plant
- to keep the amount of radioactive materials released into the environment in the exhaust air at an acceptable level in terms of environmental radiation exposure.

The air-conditioning and ventilation systems shall perform these functions during normal operation, transients and accidents. Conditions during an accident shall be used as the design basis for the air-conditioning and ventilation systems planned to operate during accidents or thereafter. The air-conditioning and ventilation

components shall be protected from the effects of the accidents and transients that the components have been designed to manage.

2.2 Safety classification

The systems, structures and components of a nuclear power plant shall be classified on the basis of their safety significance. Guide YVL 2.1 defines the principles concerning the safety classification of air-conditioning and ventilation systems.

2.3 Area and zone classification

The buildings of a nuclear power plant and their rooms shall be classified into ventilation zones. Predetermined pressure differences that can be checked shall prevail between these zones in such a way that air flows, in terms of radiation safety, from the clean areas towards the less clean areas.

When classifying rooms into ventilation zones, the following facts shall be considered:

- the amounts and forms of occurrence of radioactive materials potentially released from the plant systems and components in the event of leaks
- the accessibility of the rooms during normal operation and accidents.

The air flow shall be designed in such a way that the concentrations of radioactive materials in the indoor air of manned plant rooms can be kept sufficiently low. The required periods of stay in these rooms shall be taken into account in the design.

The air-conditioning and ventilation systems of the rooms in the controlled area and in the clean area shall be completely separate. The rooms located on the boundary of the controlled area and the clean area, used for personnel traffic, are exceptions. Guide YVL 7.9 deals with the area and zone classification during the operation of nuclear facilities based on the plant's radiation conditions. The designs of the air-conditioning and ventilation systems of the rooms included in the controlled area shall also describe in which way radioactive materials are prevented from spreading to the environment in the event of a fire.

2.4 Supply air

The intake air centres and supply air systems of the buildings that house subsystems important for plant safety shall be designed and located such that, in the event of a fire, it is improbable that smoke can spread to them. If smoke should spread to the intake air centres in the event of a fire, it shall be possible to prevent the smoke from spreading further to the plant rooms by, for instance, switching off the supply air system.

Furthermore, the intake air centres and supply air systems of the buildings that house subsystems important for plant safety shall be designed and located such that it is improbable any combustible, poisonous or otherwise hazardous substances can spread to them. The spread of hazardous substances to the plant rooms shall be prevented by, for instance, switching off the supply air system.

The supply air systems shall be fitted with filtering equipment to prevent the impurities of outdoor air from accumulating in the plant rooms.

2.5 Exhaust air

Exhaust air from the controlled area shall be led in a controlled manner into the environment along the ducts and through the plant ventilation stack. However, the exhaust air system of the rooms in the controlled area containing subsystems important for safety may comprise common ducts outside these rooms and before the ventilation stack, if these ducts have been fitted with sufficient smoke and fire separation. The amount of radioactive materials in the exhaust air, the rooms through which ducts have been led, and the pressure differences between the ducts and their surroundings shall be considered when setting requirements for the tightness of the ducts.

In the material design for the ventilation ducts and equipment, and their coatings and geometry, the decontaminability of their surfaces from potential radioactivity shall be taken into account.

Combustible, poisonous or otherwise hazardous gases and vapours released into the plant rooms shall be removed with the aid of air conditioning. If the plant exhaust air contains or

may contain radioactive materials (in gaseous, aerosol or particulate forms) in amounts significant for environmental radiation exposure, the exhaust air shall be sufficiently filtered. If it is necessary to restrict the flow of exhaust air to reduce releases in the event of an accident, provision shall be made accordingly to filter and cool the air of the rooms concerned by room-specific equipment.

Guide YVL 7.1 defines the requirements for the limitation of radioactive releases.

2.6 Control room and emergency centre

The nuclear power plant's control room, emergency centre, radiation shelter and emergency operations rooms shall be protected in such way that the personnel is able to work in them even in the event of an accident. These rooms shall be fitted with closing and filtering devices of the supply air system and with measuring instruments that detect concentrations of radioactive and poisonous materials. The rooms shall also be provided with the necessary protective equipment for the personnel. The need for protection shall be determined by means of a risk analysis, which considers, for instance, the storage and transportation of hazardous substances at the plant site and in its vicinity.

Furthermore, the control room shall be fitted with over-pressure ventilation, which shall be designed to prevent smoke from getting into the control room in the event of a fire outside the control room [Guide YVL 4.3, Section 2.3.6].

2.7 Ensuring safety

In accordance with Guide YVL 2.7, the operation of auxiliary systems required in the initiation or operation of safety functions is considered to be part of the safety functions and, therefore, their reliability shall be equivalent to that of the safety functions.

Ventilation and filtering systems which reduce the concentrations of radioactive substances in the plant atmosphere, prevent the spreading of radioactive substances to other plant quarters or restrict the environmental releases of radioactive substances shall be capable of operating at their design power even in the event of a single failure during operational conditions and postulated accidents.

The inlet air filtering system of the nuclear power plant's control room, air raid shelter and the rooms required for the conduct of operations during accidents shall be capable of accomplishing its safety function even in the event of a single failure during operational conditions and accidents.

2.8 Fire safety

The rules and regulations issued in the Finnish building code [RakMK] shall be considered in the design of air-conditioning systems.

The fire resistance of the penetrations for ventilation ducts and the fire dampers in the structural elements of the fire compartments shall be at least half the fire resistance required for these structural elements (wall, floor, ceiling), however, at least EI 60. [Guide YVL 4.3, Section 2.3.3; RakMK].

Fire compartmentation EI-M 120 shall be used to protect redundant safety-related subsystems and to separate them from each other [Guide YVL 4.3, Section 2.3.3; RakMK]. Penetrations for ventilation ducts, which impair fire safety, should be avoided as far as possible in the separating structural elements between these subsystems. If it is necessary to make penetrations for ventilation in these elements, the penetrations, fire dampers and ventilation ducts shall have the same fire resistance as the separating structural elements.

The nuclear power plant shall be provided with air-conditioning systems that enable the hot, possibly corrosive and poisonous gases and smoke resulting from a fire to be extracted. The spread of gases and smoke inside the plant shall also be prevented.

The possibility of a fire in the air-conditioning system filters shall be taken into account in the design. Non-flammable materials shall be used for the filtering equipment, as far as possible. Filters that may contain significant amounts of radioactive materials shall be fitted with instruments that help detect a fire rapidly. Furthermore, a fire-fighting plan shall be drawn up for a filter fire. It shall be possible to separate burning filters from the rest of the air-conditioning system.

The ventilation and smoke extraction of the access and escape routes of nuclear power plants

shall be designed in such a way that people are able to exit from the buildings safely, the fire-fighters are able to operate efficiently and the personnel are able to move inside the plant to ensure execution of the necessary safety functions [Guide YVL 4.3, Section 2.3.4].

2.9 Coatings

Section 3.4 of Guide YVL 4.2 defines the requirements for the coatings of structures inside the containment. These requirements shall be taken into account in the design of air-conditioning and ventilation systems as well, except for such separate components whose coated surface area can be considered so small that any coating possibly coming off the surface does not cause a blockage in the flow paths.

2.10 Inspections and commissioning

Inspections of the pressure equipment are conducted in accordance with Guide YVL 3.0. STUK or an inspection organization approved by STUK carries out the construction inspection of equipment belonging to safety classes 3 and 4.

The licence-holder shall carry out the commissioning inspection of the air-conditioning and ventilation systems and components belonging to safety classes 3 and 4 that have been installed and modified. The purpose of the inspection is to verify that the installed component and system are in accordance with the accepted plans. In addition, it shall be verified that any defects and faults possibly discovered during previous inspections have been corrected. The commissioning inspection to be conducted by STUK at its discretion (see 3.2.4 below) does not replace this commissioning inspection conducted by the licence-holder.

3 Regulatory control by STUK

3.1 Construction licence phase

3.1.1 General

Section 35 of the Nuclear Energy Decree defines the documents that shall be submitted to STUK when applying for a construction licence. The requirements laid down in Guide YVL 2.0 concerning the design of systems and the documents to be submitted to STUK also apply to the air-conditioning and ventilation systems. The documents to be submitted shall include descriptions of the technical solutions and other necessary justifications by means of which the requirements for the air-conditioning and ventilation systems stated in the previous section are aimed to be fulfilled.

With regard to the important systems, the documents shall contain preliminary data on the process and instrumentation plans, the back-up provided for power supply units, the necessary auxiliary systems, the provision made for on-site and off-site factors that may damage plant systems, the operating conditions of the systems and the physical separation of the redundant subsystems. If a system's safety function is to restrict releases or to reduce occupational radiation exposure, the principal design data in terms of operation of the filtering equipment used, such as the filter type and retention efficiency, shall be given. Regarding the air-conditioning and ventilation systems necessary in the event of an accident, the accessibility of the equipment, and filters in particular, during the accident and thereafter shall be considered.

Guide YVL 1.1 defines the requirements for the documents to be submitted to STUK. The following sections describe the matters on which reports shall be submitted to STUK, in addition to those mentioned above.

3.1.2 Preliminary definition of room conditions

The conditions of those rooms that contain equipment belonging to safety classes 1–4 shall be defined. The definition of room conditions shall cover the factors most important for the design of air conditioning, such as temperature, humidity, radiation level, heat loads, pressure differences, and tightness and insulation requirements. Preliminary air change rate of the rooms shall be given on the basis of the definition of room conditions.

3.1.3 Fire protection design bases

The report shall describe how the design bases for air-conditioning systems and fire extraction and other factors affecting fire safety, defined in Section 3.3 of Guide YVL 4.3, have been taken into account.

A separate plan shall be submitted for overpressure ventilation and smoke extraction [Guide YVL 4.3, Section 4.4]. The plan shall describe with which measures the hot, possibly corrosive and poisonous gases and smoke that result from a fire are prevented from spreading inside the plant and how they are extracted.

3.2 Control during construction

3.2.1 General

During construction, the plans and descriptions related to the air conditioning and ventilation referred to in Section 3.1 above shall be finalized. The data can be presented as part of the final safety analysis report or as separate system- or component-specific documents. Furthermore, it shall be described how the requirements for fire ventilation and smoke extraction laid down in Guide YVL 4.3 have been fulfilled.

The system-level preliminary inspection documents that concern safety class 3 shall be submitted to STUK for approval and those concerning safety class 4 to STUK for information.

On the licence-holder's application, STUK may shift the approval of the construction plan for a component belonging to safety class 3 or 4 to an inspection organization that has been qualified in accordance with Guide YVL 1.3 for the inspection concerned. The licence-holder shall have administrative instructions on how to inspect the equipment belonging to class EYT. STUK supervises the appropriateness of the licence-holder's and inspection organizations' operations.

3.2.2 Construction plans for components

The construction plan for a component belonging to safety class 3 or 4 shall include the following documents or descriptions:

Design data

The data shall describe the design bases for the component, its functions, importance of its operation for the operation of the entire system and location at the plant. Any deviations from the data given in the preliminary safety analysis report shall also be presented and justified. The design data shall include all of the plant's operational states and accidents in which the component has been designed to function. Component-specific requirements have been given in the Appendix to this Guide.

Quality control plan

The quality control plan shall describe the systematic quality control measures to which a component is subjected, the inspection and testing plans to be implemented and the instructions that specify the measures.

The manner and scope of the inspections and tests, the requirements for their approval and the reporting shall be indicated in the instructions. If necessary, the requirements can be specified by referring to applicable standards.

Type-approved components

Type-approved and ETA-approved [22, 23] components can be employed in accordance with the decision of approval and the related instructions issued by the manufacturer. The suitability of the products for the intended use shall be demonstrated separately. If the decision on type approval does not cover installation of the product, installation instructions shall be drawn up for this purpose, which additionally include the quality control of installation work.

The decisions on type approval of the type-approved products shall be submitted to STUK for information.

The suitability of a product bearing a CE mark for its intended use shall be demonstrated in the construction plan. If a product bearing a CE mark is used in the manner required by the CE approval, no separate approval is needed.

Description of the manufacturer and testing organizations

The manufacturer shall have adequate expertise, competent personnel and an effective quality management system. The report on the manufacturer shall describe how these requirements are fulfilled.

The report shall include descriptions of the competence of the testing organizations. Guide YVL 1.3 deals with the requirements, acceptance procedures and supervision of the operations of the testing organizations and testers that carry out non-destructive testing.

The testing organizations that carry out destructive testing shall be accredited.

3.2.3 Control of the manufacture and construction inspection

Guide YVL 1.14 lays down the general requirements and procedures for controlling the manufacture of components and structures.

STUK or an inspection organization approved by STUK conducts the construction inspection of components belonging to safety classes 3 and 4.

The construction inspection includes

- a review of the implementation of the construction plan
- a review of the documentation of the manufacture
- a visual examination of the component
- potential functional and tightness tests.

The general requirements for construction inspections are given in Guide YVL 1.15.

3.2.4 Commissioning inspection and supervision of testing

STUK carries out a commissioning inspection of the air-conditioning and ventilation systems belonging to safety classes 3 and 4 within the scope it considers necessary. As part of the preliminary inspection of an air-conditioning and ventilation system, STUK defines the systems that will be subjected to a commissioning inspection. In general, STUK conducts the commissioning inspection of the entire, installed air-conditioning and ventilation system. During the inspection, the licence-holder shall demonstrate, for instance, that

- the construction plans have been approved
- the construction inspections have been approved
- the component has been installed in the accepted manner
- the testing programme has been approved.

STUK shall be requested in writing to conduct the commissioning inspection in good time before the date of inspection.

The testing programme shall be submitted to STUK in accordance with Guide YVL 2.5. STUK's representative monitors the testing within the scope he/she considers necessary. A report on the results of the testing concerning the tests whose test programmes STUK has approved shall be submitted to STUK for approval within two months of the completion of the testing.

3.3 Operating licence phase

Section 36 of the Nuclear Energy Decree defines the documents that shall be submitted to STUK for approval when applying for an operating licence. Guides YVL 1.1 and YVL 2.0 also give the requirements for the documents to be submitted.

3.4 Regulatory control during plant operation

STUK controls implementation of the preventive maintenance and periodic test programmes of the air-conditioning and ventilation systems by monitoring the implementation of actual measures at the plant site within the scope it considers necessary and by reviewing the related documents. Inspections are carried out as part of the periodic inspection programme of a nuclear power plant in accordance with Guide YVL 1.1.

3.5 Modifications, repairs and preventive maintenance

The requirements laid down in Guides YVL 1.8 and YVL 2.0 shall be met in modifications, repairs and preventive maintenance during plant operation.

4 References

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14. Particulate filtration in nuclear facilities, IAEA, Technical reports series No. 325, 1991.
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19. High efficiency particulate air filters (HEPA and ULPA). Part 4: Determining leakage of filter element (Scan method), EN 1822-4, 2001.
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21. IAEA Safety Requirements, No NS-R-1, Safety of Nuclear Power Plants: Design, 2000.
22. Ministry of the Environment Decision on Type Approval in the Building Sector 273/1989 *(in Finnish)*.
23. Act on the Approval of Building Products 230/2003 *(in Finnish)*.

APPENDIX Component-specific data to be given in the construction plan

Below, the components of air-conditioning systems are divided into the following groups:

- fans
- ducts
- closing and control devices
- filters
- heating/cooling units
- moisture separators.

If it is regarded as obviously unnecessary to give some of the design data mentioned below, considering, e.g., the location, mode of operation or function of a component, the data can be omitted.

Of the **fans** of the air-conditioning systems, the following data are given:

- component code
- safety class
- mode of operation (continuous operation, other)
- quality of the medium (temperature, pressure, humidity, etc.)
- required operating point and performance curve
- tightness requirements
- ambient conditions
- mode of installation (groundwork; duct and motor)
- power supply demand within the operating range, during start-up and at the highest possible load
- potential auxiliary systems required (cooling, sealing of shafts, etc.)
- types, allowable temperatures and vibrations of bearings
- structural data on the shaft seals, if specific tightness requirements have been set for the component
- maintenance points and intervals recommended by the manufacturer; the preliminary maintenance programme.

Drawings shall be presented of the fans, motors, their coupling and installation and of the couplings required by the auxiliary systems possibly connected to the fans. The data required to assess the acceptability of the design, manufacture, installation and operation of the fans shall be given in the drawings, i.e.

- composition, including component and structural material lists
- component dimensions and geometry and surface treatment
- types, locations and dimensions of joints and fixtures
- welds and surface treatments
- clearances, fits and play essential for the operation
- groundwork and installation.

Regarding the coupling of a fan to the motor, the connection of a fan to the duct and the data required about the motor, Guide YVL 5.7 should be complied with, where applicable.

Of the **filters** of the air-conditioning systems, the following data are given:

- component code
- safety class
- mode of operation (continuous operation, other)
- quality of the fluid medium (temperature, pressure, humidity, etc.)
- volume flow
- pressure losses (for a clean filter and maximum allowable)
- retention efficiency (reference to be made to the testing standard)
- tightness requirements for the filter casing and mounting frames
- filter section material.

Furthermore, detailed data shall be given on the quality of the filter material. These include:

- general quality and strength properties of the filter paper or material of particle filters
- data about the material of potential separators of filter folds
- coupling agents or other mounting accessories employed for the assembly

- quality of coal in gas filters (base material, particle size distribution, BET area, hardness, impregnation agent and its amount, volume weight, auto-ignition temperature)
- amount of coal and number of filter sections in the system and the mean retention times
- general structure of the filter casings and the tightness requirements set for the structure
- potential type approvals and data on operating experience
- ambient conditions.

Drawings shall be presented of the filters, filter casings and filter chambers and of how these connected to ducts. The following data, for instance, shall be given in the drawings:

- composition of the filtering unit, including component and structural material lists
- dimensions, geometry and surface treatment of the filter section and casing
- sealing arrangements to prevent leaks between filter sections and filter casings
- testing assemblies and potential flow controllers and mixers
- location of the fixed air flow measuring elements
- mode of installation (groundwork, mounting in the duct, flow direction).

Of the **closing and control devices** of the air-conditioning systems, the following data are given:

- component code
- safety class
- type (shutoff, flow control, back draft prevention, other) and size
- mode of operation
- quality of the fluid medium (temperature, pressure, purity, etc.)
- tightness requirements (tightness outwards and downstream)
- actuator and its operating principle (type, operation if auxiliary force is lost, etc.)
- ambient conditions
- drawings that show the main dimensions and geometry of the devices, including component and structural material lists, and their mode of installation in the ducts.

Regarding isolation valves of the containment air-conditioning systems, Guide YVL 5.3 shall be complied with, where applicable.

Of the **ducts** of the air-conditioning systems, the following data are given:

- system code and location (supply ducts, exhaust ducts, other) in the system
- safety class
- duct type (welded, spiral weld, other)
- types of duct joints (welded, flanged, other)
- tightness requirements
- how the ducts are mounted on the structures
- surface treatment requirements and implementation (inside and outside, decontaminability)
- main dimensions and structural materials
- fire insulation (class)
- ambient conditions (outside and inside the plant, other)
- drawings that show in detail how the ducts go from room to room at the plant and where the fire dampers and duct insulations based on the requirements for fire compartmentation are located and what type they are.

Of the **heating and cooling units** of the air-conditioning systems, the following data are given:

- component code
- safety class
- type and operating principle (water, electricity; downstream, upstream, etc.)
- cooling/heating capacity and other essential design values (water and air flow, temperature differences, conductance)
- design pressures (applies to pressure equipment, see YVL Guide group 3)
- the necessary auxiliary systems (cooling water, disposal of condensation water, other)
- mode of installation in the system, location in the system
- measuring assemblies required for condition monitoring and instrumentation (temperatures, pressure difference, flow)
- drawings that give the main dimensions and structural materials of the units.

Of the **moisture separators** of the air-conditioning systems, the following data are given:

- component code
- safety class
- type and operating principle
- efficiency (as dependent on the droplet size)
- the necessary auxiliary systems
- mode of coupling to the ducts
- tightness requirements
- drawings that give the main dimensions and structural materials of the moisture separators.