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Nuclear facilities — Criteria for the design and operation of ventilation systems for nuclear installations other than nuclear reactors

Installations nucléaires — Critères pour la conception et l'exploitation des systèmes de ventilation des installations nucléaires autres que les réacteurs nucléaires

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO 17873 was prepared by Technical Committee ISO/TC 85, *Nuclear energy*, Subcommittee SC 2, *Radiation protection*.

Introduction

This International Standard applies to all types of nuclear installations other than primary containment envelopes of nuclear power plants or certain categories of research reactors.

The installations concerned are particle accelerators, radiation generators, fusion machines, research and examination laboratories and, more generally, all types of nuclear fuel cycle installations (e.g. enrichment plants, nuclear fuel fabrication and examination laboratories, plutonium-handling facilities, reprocessing plants, radioactive waste treatment stations, radioactive waste storage facilities, etc).

It can also be applied to the primary containment envelope of research reactors, where only low pressure can occur during accident scenarios, as well as to auxiliary rooms of nuclear power plants.

Specific features associated with the containment envelope of nuclear power plants or certain categories of research reactors will be developed in another International Standard.

Nuclear facilities — Criteria for the design and operation of ventilation systems for nuclear installations other than nuclear reactors

1 Scope

This International Standard specifies the applicable requirements concerning the design and use of ventilation systems in nuclear installations such as hot cells, nuclear fuel fabrication and examination laboratories, plutonium-handling facilities, reprocessing plants, enrichment facilities, nuclear-waste treatment stations, storage facilities, etc.

The purpose of ventilation and containment systems is to and ensure safety functions and protect workers, public and environment against the spread of radioactive contamination resulting from the operational processes of these installations.

This International Standard does not apply to the containment envelope of nuclear power plants and some research reactors where high pressure can occur during accident scenarios. It does apply to auxiliary rooms of these facilities.

The requirements for the design and use of ventilation systems that ensure safety functions in nuclear reactors will be developed in another International Standard.

2 Normative references

The following Standards contain provisions that, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 2889, *General principles for sampling airborne radioactive materials*

ISO 10648-2, *Containment enclosures — Part 2: Classification according to leak tightness and associated checking methods*

ISO 11933-4, *Components for containment enclosures — Part 4: Ventilation and gas-cleaning systems such as filters, traps, safety and regulation valves, control and protection devices*

ICRP 60, 1990, Recommendations of the International Commission on Radiological Protection, ICRP Publication 60, Annals of the ICRP, 21, (1-3), Pergamon Press, Oxford (1991)

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
aerosol
solid particles and liquid droplets of all dimensions in suspension in a gaseous fluid

3.2
air-change rate
ratio between the ventilation air-flow rate of a containment enclosure or a compartment, during normal operating conditions, and the volume of this containment enclosure or compartment

3.3
air conditioning
arrangements allowing the sustainment of a controlled atmosphere (temperature, humidity, pressure, dust levels, gas content, etc.) in a closed volume

3.4
barrier
structural element, which defines the physical limits of a volume with a particular radiological environment and which prevents or limits releases of radioactive substances from this volume

EXAMPLE Containment enclosure, shielded cell, filters.

3.5
balancing damper
control valve
adjustable device inserted in an aerodynamic duct allowing balancing of the fluid flow and/or the pressure of the fluid during plant operation

3.6
cell
or shielded enclosure
term generally used to designate an enclosure equipped with a shielding structure, of fairly large dimensions, possibly leaktight

See **containment enclosure** (3.9).

3.7
containment
confinement
arrangement allowing users to maintain separate environments inside and outside an enclosure, blocking the movement between them of process materials and substances resulting from physical and chemical reactions which are potentially harmful to workers, the external environment, or to the handled products

See **containment enclosure** (3.9) or **barrier** (3.4).

NOTE The word “confinement” is used in several IAEA documents to mean the function of confining radioactive or toxic products whereas “containment” is used to mean the physical barrier that achieves the objective of confinement, i.e. a confined area.

3.8
containment compartment
CC
compartment of which the walls (or the nearest walls of a volume that includes one or several fire compartments) are able to contain radioactive substances that would be generated by any plausible fire that could break out in one of the fire compartments included

NOTE It is often more practicable to limit the spread of a fire by fire-resistant walls, and to prevent the spread of contamination in the adjacent volumes.

3.9
containment enclosure
enclosure designed to prevent either the leakage of products contained in the pertinent internal environment into the external environment, or the penetration of substances from the external environment into the internal environment, or both simultaneously

NOTE This is a generic term used to designate all kinds of enclosures, including glove boxes, leaktight enclosures and shielded cells equipped with remotely operated devices.

3.10
containment system
system constituted by a coherent set of physical barriers and/or auxiliary dynamic systems intended to confine radioactive substances in order to ensure the safety of the workers and the public and the protection of the environment

3.11
contamination
presence of radioactive substances on or in a material or a human body or any place where they are undesirable or could be harmful

3.12
decontamination factor
measure of the efficiency achieved by a filtration system and corresponding to the ratio of the radiological contents of the inlet and outlet of the filtration system

3.13
discharge stack
duct (usually vertical) at the termination of the ventilation system, from which the air is discharged to atmosphere

3.14
dynamic confinement
action allowing, by maintaining a preferential air-flow circulation, the limitation of back-flow between two areas or between the inside and outside of an enclosure, in order to prevent radioactive substances being released from a given physical volume

3.15
filter
conventional term used to designate a device intended to trap solid or liquid particles suspended in gases or fluids or to trap gases themselves

NOTE A particle filter consists of a filtering medium, generally made of a porous or fibrous material (i.e. glass fiber or paper) fixed within a frame or casing. During the manufacturing process, the filter is mounted in a leaktight manner in this frame, using a lute. Gas filters are generally found in physical or chemical process units where the primary aim is to trap certain gases.

3.16
fire compartment
FC
reference volume delimited by construction elements for which fire resistance has been chosen according to the plausible fire that could break out within this volume or penetrate into it

3.17
fire damper
fire blocking valve
device which is designed to prevent, generally by automatic action under specified conditions, the ingress of fire through a duct or through the walls of a room

3.18
fire load
heat energy that could be released by the complete combustion of the whole combustible contents of a volume, including the surfaces of the walls, partitions, floors and ceilings

3.19
gas cleaning
action (sometimes called “scrubbing”) that consists of decreasing the content of undesirable constituents in a fluid

NOTE Aerosol **filtration** and iodine **trapping** are examples of gas cleaning.

3.20
iodine trap
scrubbing device, usually based on activated carbon, intended to remove volatile radioactive components such as radioactive iodine from the air or the ventilation gases

3.21
negative pressure or depression
pressure difference between the pressure of a given volume, which is maintained lower than the pressure in a reference volume or the external ambient pressure

3.22
negative pressure system
regulated ventilation system, which ensures a negative pressure between the ventilated area and an adjoining zone or the external ambient pressure

3.23
prefilter
filter fitted upstream of the main air filters to minimize, by removal of large particles, the dust burden on the latter

3.24
pressure drop
pressure loss in an air stream due to its passing through a section of ductwork, or a filter or fittings

3.25
process ventilation system
ventilation system that deals specifically with the active gases and aerosols arising within process equipment (such as reaction vessels, piping networks, evaporators and furnaces) but excludes the ventilation of the containment enclosures in which such equipment is generally located (e.g. hot cells, glove boxes, fume cupboards or high-radioactivity plant rooms)

3.26
safety flow rate
flow rate that guarantees air flow through any occasional or accidental opening, sufficient to either limit the back-flow of contamination (radioactive or other) from the working volume, or to avoid the pollution of products handled within the working volume

3.27
ventilation
organization of air-flow patterns within an installation

NOTE Two systems are commonly used:

— ventilation in series: ventilation of successive premises by transfer of air from one to the next;

— ventilation in parallel: ventilation by distinct networks or premises or group of premises presenting the same radiological hazard. Utilised also to indicate that the totality of blowing and extraction circuits of each particular volume is directly connected to the general network (in contrast to ventilation in series).

3.28
ventilation duct
envelope, generally of rectangular or circular section, allowing air or gas flow to pass through

3.29
ventilation system
totality of network components, such as ducts, fans, filter units and other equipment, that ensures ventilation and gas-cleaning functions as defined in the present document

4 Functions ensured by the ventilation system

The ventilation of nuclear facilities enables the improvement of the safety of the workers, general public and environment and/or if necessary, the protection of the products to be handled. It plays a role of

— safety, by contributing to keep the workers, the general public and the environment free of contamination, and

— protection of the equipment and the handled products (and thus indirectly safety), by maintaining the internal atmosphere in a state (temperature, humidity, physical and chemical properties) compatible with the proposed operational materials and process conditions.

Ventilation ensures the following functions.

a) **Confinement**, by acting in a dynamic manner in order to counteract any defects in the leaktightness of the static containment constituted by the walls of the relevant enclosures. In this case, the “dynamic” confinement ensured by the ventilation systems has two aspects.

   — Between items of equipment, enclosures (or cells) and rooms of the same building (i.e. internal dynamic confinement), the ventilation ensures a hierarchy of pressure in order to impose a circulation of air from volumes with a low potential hazard of radioactive contamination to volumes with a high potential of radioactive contamination hazard. Dynamic confinement is also able to circumscribe, to process and to control the contamination as close as possible to its source, complementing the other systems provided to protect the operators from the hazards of ionizing radiation.

   — At the interface with the environment (i.e. external dynamic confinement), the ventilation system maintains a significant depression within controlled areas with a high potential radioactive contamination, in order to avoid uncontrolled releases as well as to direct the gaseous effluents towards identified release points, and to enable, if required, cleaning (purification) and monitoring the gases discharged.

b) **Purification** (or gas cleaning) by conveying the collected gases, including any dust, aerosols and volatile components, towards defined and controlled points for collection, processing and elimination where possible (by using filters, traps, etc.).

c) **Monitoring** of the installation, by organizing air flows in such a manner as to allow meaningful measurements in order to detect and to limit any spread of radioactive components during normal as well as abnormal conditions, including fire events. Ventilation systems, with or without surveillance monitoring, can also contribute to the improvement of some radiological measures inside rooms by helping to control the background level of natural radioactivity (radon).

d) **Cleaning** of the atmosphere of the enclosure or room, by renewing the volumes of air within it, in order to minimise the risks associated with the corresponding atmosphere (for example, the elimination of any gas necessary to make credible an explosion hazard).

e) **Conditioning** of the atmosphere of the enclosures or the rooms, to obtain the optimum functioning of machines or to improve the safety of some otherwise hazardous operations (for example, the maintaining of ambient conditions compatible with the proper functioning of equipment).

f) **Comfort**, by ensuring processing (heating or refreshing) of the air, regulation of the temperature and the relative humidity of the atmosphere of the rooms, in order to maintain the climatic conditions to suit the work that the personnel have to undertake.

The first five functions are safety functions.

The achievement of optimal climatic conditions is indirectly a safety function, because “human risks”, which could be caused by inadequately regulated climatic conditions, are then substantially reduced.

5 Safety aspects of ventilation systems

5.1 General principles

Ventilation systems shall be able to ensure the safety and protection functions defined in the previous clause, in all normal operation and maintenance conditions of the enclosures. Ventilation systems shall ensure some of these functions, based upon a safety assessment, during abnormal operating conditions, maintenance operations, exceptional interventions or accidental situations that are to be defined case by case.

Before beginning any ventilation design, a hazard assessment shall be made so that design safety principles and actual targets will be adequately defined. Subclause 5.2 provides an outline of the hazard assessment process as it relates to ventilation design.

In addition, designers of ventilation systems for nuclear installations also have to comply with all national legislation and with any more stringent safety requirements specified by the national regulatory authority.

5.2 Risk assessment procedure

The design of an appropriate ventilation system requires preliminary analyses, taking into account:

a) radiological hazards arising from the materials and operations which lead to the need for ventilation of the enclosures and rooms containing dangerous substances, including:

   — the permitted levels of air and surface contamination within the building, and the air monitoring requirements, leading to a classification of the area regarding the contamination hazard, as defined in 8.1.1;

   — the risk of radiological exposure, leading to the classification of radioactive areas in accordance with the definitions proposed by ICRP 60[1];

b) an adequate margin between the authorized discharge limits and the anticipated actual discharges resulting from the ventilation system as a whole, as well as the air-cleaning requirements prior to these discharges;

c) non-radiological hazards related to the processes and equipment implemented in the volumes which have to be ventilated (e.g. catastrophic rupture of containment caused by some mechanical failure, abrupt variation of pressure, explosion, fire, corrosion, condensation);

d) hazards of external origin to which the enclosures and the ventilation system itself can be exposed (e.g. fire, floods, external explosion, earthquakes, wind and extreme temperatures);

e) possible temporary unavailability of the fluids or energy supply needed for the correct functioning of the ventilation system.

For each consideration, a risk assessment shall be carried out using the safety analysis methodology where the risk is defined as the combination of the consequences of the event and its estimated frequency. An alternative deterministic approach may also be carried out, based on incidental or accidental envelope situations. It is important not to exclude some scenarios combining internal and external hazards (e.g. strong wind and some other event leading to the dispersion of radioactive contamination inside the building). In any case, the associated loads on the system shall be described in the safety report, according to the safety assessment policy of the organisation(s) concerned.

1) ICRP: International Commission on Radiological Protection.

Other factors which should be taken into account, when designing ventilation systems, include the following.

— There is a need to minimize, as far as reasonably practicable, the level of contamination in the workroom air.

— For protection of the environment, it is now conventional practice to design nuclear- process plant systems so as to minimize radioactive waste arising and radioactive releases (liquid and gaseous) as far as practicable. Thus attention must be paid to the whole-life considerations of waste streams produced by operational, maintenance and decommissioning activities (consumable seals, filters, swabs; contaminated fluids from lubrication, cleaning, off-gas scrubbing, etc.). It is also usual practice to minimize the quantity of high-activity waste instead of conventional waste, or low-activity waste. In particular, contaminated filters, being of low density, are very expensive to store or dispose of as radioactive waste. Consideration shall be given to the use of self-cleaning or cleanable filters, cyclone filtration etc., or filter compaction techniques.

— The design of an enclosure, through which air is exhausted via ductwork, filters, fans and a stack to the outside atmosphere, must take into account the pressure, temperature, humidity and other variations to be tolerated by each component, in an appropriate range of operational and fault conditions.

— Comfortable working conditions must be provided for operational and maintenance staff.

It arises from the foregoing that certain general safety principles shall be followed when designing ventilation systems for radioactive premises, as listed below:

1) The total air flow through the system, from inlet to discharge into the atmosphere, shall be minimized, while still achieving the necessary function.

2) The air-flow magnitude and air-flow patterns in the working environment must be adequate to give the occupants protection against airborne contamination, with a view to obtaining doses “As Low As Reasonably Practicable”.

3) Sufficient fresh air must be provided to ensure acceptable industrial hygiene conditions in the spaces that are normally occupied.

4) Filtration systems are recommended for the air inlets to reduce firstly, the quantity of dust and impurities burdening extract filters and hence prolong their lifetime and secondly, the back-flow of contaminant products through the inlet circuits in case of failure of the ventilation systems.

5) Physical containments (e.g. total enclosures) are the most effective means for minimizing radioactive releases and for protecting the product to be handled. Ventilation provides a supportive role to this physical containment by ensuring an adequate air circulation between different containment areas.

6) The system shall provide a sufficient inward air velocity through unavoidable or accidental openings in containment barriers to limit the egress of particulate, aerosol and vapour contamination as far as is reasonably practicable.

7) The air flows shall, as far as reasonably practicable, be adequate for both the normal conditions and the potential accident conditions.

8) The systems shall incorporate optimum energy efficiency (e.g. heat reclamation from exhaust air), but this must not compromise the containment and safety requirements.

6 Principles of containment of radioactive material

6.1 General requirements

The basic principle with regard to the prevention of the spread of the radioactive material is:

— in normal situations, to limit the release of radioactive material outside the facility (with regard to the regulatory authorization), but also to maintain a level of contamination as low as is reasonably achievable inside the facility;

— in accidental situations, to limit to acceptable levels the radiological consequences for the environment, for personnel directly involved in the operations leading to the spread of radioactive contamination, for other operators in the same facility and for the general public.

The application of this principle leads to the provision of different containment systems between the environment and the radioactive substances. Each containment system and the associated devices are designed to suit the risks they are intended to control. The goal will be to maintain, in any case, the functionality of at least one stage of effective filtration between the contaminated areas and the environment under all circumstances, including accident situations, such as fire or explosion.

Attention must be paid to designing protection for personnel in charge of operations that may lead to the spread of radioactive contamination, as well as additional protection for personnel in adjacent areas.

In nuclear facilities, generally several containment systems are distinguished. Each containment system can be made of (see Figure 1):

— one or several static containment barriers;

— complemented if necessary, by means of dynamic systems, consisting of a specific ventilation system and appropriate air-cleaning devices.

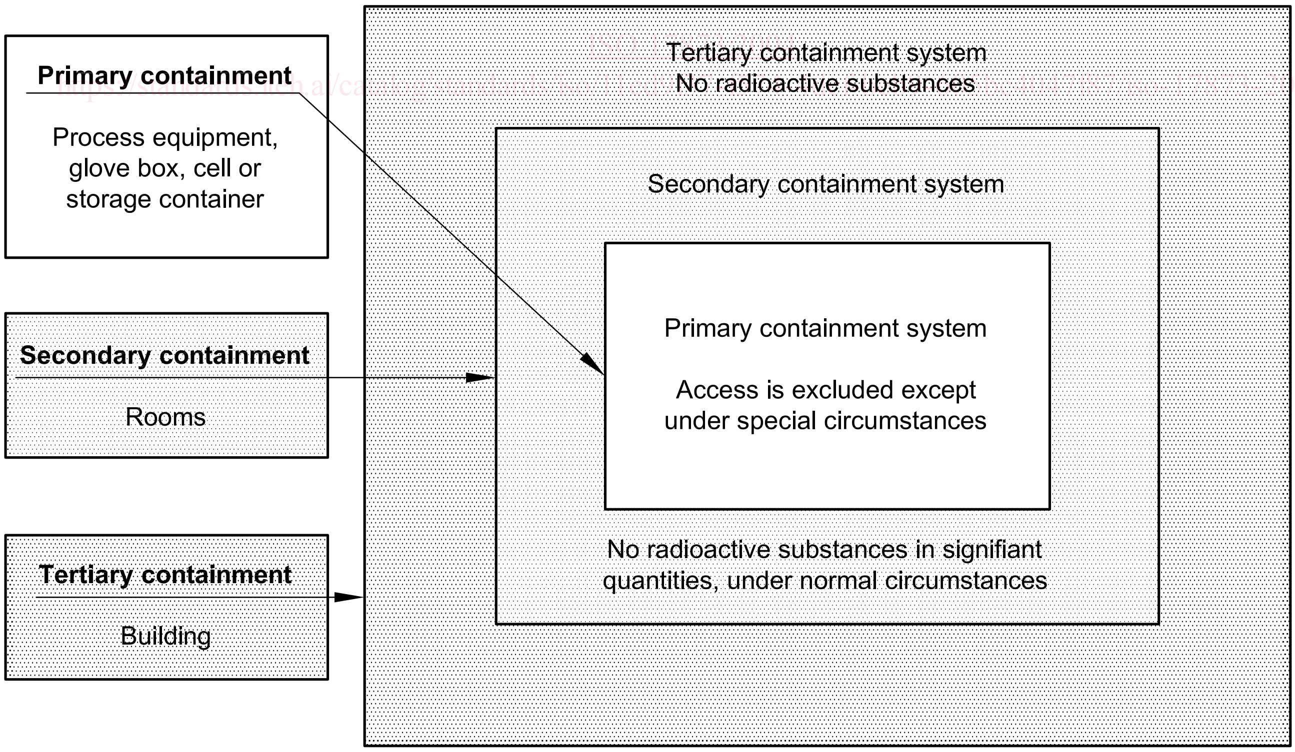

Figure 1 — Schematic drawing of a three-containment system