INTERNATIONAL STANDARD

ISO 16647

First edition
2018-09

Nuclear facilities — Criteria for design and operation of confinement systems for nuclear worksite and for nuclear installations under decommissioning

Installations nucléaires — Critères pour la conception et l'exploitation des systèmes de confinement des chantiers nucléaires et des installations nucléaires en démantèlement

Reference number
ISO 16647:2018(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by ISO/TC 85, *Nuclear energy, nuclear technologies, and radiological protection*, SC 2, *Radiological protection.*

Nuclear facilities — Criteria for design and operation of confinement systems for nuclear worksite and for nuclear installations under decommissioning

1 Scope

This document specifies the requirements applicable to the design and use of airborne confinement systems that ensure safety and radioprotection functions in nuclear worksites and in nuclear installations under decommissioning to protect from radioactive contamination produced: aerosol or gas.

The purpose of confinement systems is to protect the workers, members of the public and environment against the spread of radioactive contamination resulting from operations in nuclear worksites and from nuclear installations under decommissioning.

The confinement of nuclear worksites and of nuclear installations under decommissioning is characterized by the temporary and evolving (dynamic) nature of the operations to be performed. These operations often take place in area not specifically designed for this purpose.

This document applies to maintenance or upgrades at worksites which fit the above definition.

NOTE The requirements for the design and use of ventilation and confinement systems and for liquid confinement in nuclear reactors or in nuclear installations other than nuclear worksites and nuclear installations under decommissioning are developed in other ISO standards.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 16170, *In situ test methods for high efficiency filter systems in industrial facilities*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
climatic shelter
shelter whose function is to provide suitable protection against the weather (sun, rain, wind, snow and extreme temperatures), usually structurally separated from radiological containment

3.2
aerosol
solid particles and liquid droplets of all dimensions in suspension in a gaseous fluid

3.3
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.

3.4
discharge stack
duct (usually vertical) at the termination of a system, from which the air is discharged to the atmosphere

3.5
air conditioning
arrangement allowing the sustainment of a controlled atmosphere (temperature, humidity, pressure, dust levels, gas content, etc.) in a closed volume

3.6
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

Note 1 to entry: 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.

3.7
worksite containment
specific containment implemented to cover the temporary and evolving nature of worksite activities

3.8
dynamic confinement
action allowing, by maintaining a preferential air flow circulation, to limit 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

3.9
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

3.10
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

3.11
gas cleaning
action of decreasing the content of undesirable constituents in a fluid

Note 1 to entry: Gas cleaning is sometimes called "scrubbing".

Note 2 to entry: Aerosol filtration and iodine trapping are examples of gas cleaning.

3.12
filter
device intended to trap particles suspended in gases and fluids or to trap gases themselves

3.13
high efficiency particle air filter
HEPA filter
aeorosol filter that corresponds to the classes H35, H40 or H45 according to ISO 29463-1

3.14
last filtration stage
LFS
last filtering stage implemented on the dynamic confinement release network protecting the environment

EXAMPLE HEPA filters for aerosols, iodine filters, etc.

3.15
Derived air concentration
DAC
amount of contamination in air, which, if 2 200 m^3 is inhaled, would result in the annual limit of intake (ALI)

Note 1 to entry: DAC is defined in ICRP 103 and expressed in Bq/m^3.

Note 2 to entry: The ALI is calculated using reference conversion factors given by ICRP (International Commission for Radiological Protection) for each radionuclide (ICRP 119).

3.16
airtight bag
ventilated airtight bag
flexible containment used to establish an enclosure around a contaminated item, allowing personnel to accomplish works or manipulations potentially via gloved sleeves without contacting the contaminated environment

Note 1 to entry: The airtight bag may include inlet and extract ventilation in order to achieve an air velocity in leakage points or negative pressure within the containment.

3.17
spark arrestor
device fitted upstream of the main filters to minimize transport of particles and the deterioration of main filters, by capture of incandescent large particles

3.18
prefilter
filter fitted upstream of the main air filters to minimize the dust burden on the latter, by removal of large particles

3.19
negative pressure
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

3.20
confinement system
system constituted by a coherent set of physical barriers and/or dynamic systems intended to confine radioactive substances

3.21
ventilation system
totality of network components such as ducts, fans, filter units and other equipment, that ensures ventilation and gas cleaning functions

3.22
air-change rate
ratio between the ventilation air flow rate of a containment enclosure or a compartment and the volume of this containment enclosure or compartment, during normal operating conditions

3.23
ventilation
organization of air flow patterns within an installation

4 Functions ensured by the confinement

The confinement of nuclear worksite and nuclear installations under decommissioning (sometimes in complement with the existing confinement of the installation) enables the improved safety of the workers, members of the public and provides protection of the environment. It plays the role of:

— **Safety and radioprotection**, by contributing to limit the contamination impact on the workers, members of the public and the environment.

— **Protection of equipment and rooms**, maintaining the level of cleanliness to avoid any radiological releases of contamination.

Confinement system ensures the following main functions:

— **Confinement**, by acting in a static and/or dynamic manner. The role of this function is to control the release and spread of radioactive products, in aerosol or gas form, in environment, and to protect workers, in particular those that do not have respiratory protection from existing volume radioactivity or volume radioactivity generated by activities.

— **Cleaning** 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 that can lead to an explosion hazard, fume gas evacuation, etc.).

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

— **Radiological cleanliness** maintaining the level of the atmospheric and surface contamination of equipment and rooms, as low as possible

The dynamic confinement system may also contribute to the following functions:

— **Surveillance** of the releases, in particular when the static containment faces the environment by orientating the airflows to the contamination sensors to the exhaust points.

— **Conditioning** of the atmosphere of considered volumes to ensure ambient conditions continually compatible with the proper functioning of the equipment.

5 Principles for radioactive substances confinement

5.1 General principles

Confinement systems shall ensure the safety and radioprotection functions defined in Clause 4, in all normal operating conditions of nuclear worksites and nuclear installations under decommissioning. They shall also ensure that these functions continue during abnormal operating conditions, or accident situations that are to be defined case by case depending on the safety analysis.

Before beginning any confinement design, a risk assessment shall be made so that actual targets are adequately defined. 5.2 provides an outline of the risk assessment process.

5.2 Risk assessment procedure

The design of an appropriate confinement system requires preliminary analysis, taking into account:

- radiological hazards generated by materials and operations leading to the need to confine the rooms or work areas where hazardous substances are handled, including:
  - permissible levels of surface or airborne contamination inside the room or rooms where are contained confined enclosures;
  - requirements for airborne contamination monitoring;
- verification of discharge authorization limits in respect of actual discharges through existing ventilation systems or ventilation systems to be set up;
- risks associated with the facility to which the confined enclosures and ventilation systems can be exposed and that can be considered plausible on the installation (e.g. load drop, fire, flood, external explosion, earthquakes, wind and extreme temperatures, etc.);
- human activities deployed nearby facilities (collocated operations);
- possible temporary unavailability of fluids or energy necessary for the proper functioning of the confinement system (electricity, compressed air, neutral gases, cooling water, etc.);
- non-radiological hazards associated with equipment and operations implemented in confined enclosures (e.g. sudden break of containment due to mechanical failure, sudden change in pressure, over pressure risks, explosion, fire, corrosion, condensation, load drop), which consequences may be resuspension of radioactivity. As an example, when the worksite confinement is used in the fire safety demonstration, special analyses are needed for cases where fire extinguishers are likely to create a breach in the confinement, e.g. by pressurizing the static confinement because of their potential impact on dynamic confinement or for glove boxes for which water cannot be used when they are criticality risks.

For each consideration, a risk assessment is to 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. This may consist of a deterministic approach, based on incidental or accidental conservative situations.

Other factors to consider in the design of confinement systems are:

- to reduce the amount of waste produced and radioactive release (liquid and gaseous) to a level as low as reasonably achievable, for the protection of the environment;
- to minimize the level of contamination in the rooms or work areas as far as reasonably achievable, in particular by implementing dynamic confinement as close as possible to the source;
- the impact on the existing installation of modifications of ventilation network, enclosure, containment enclosure layout, etc.;
- physical and radiological state of the existing installation (e.g. for static confinement, cable, drains);
- incidental or accidental situations;
- appropriate work conditions that should be provided to workers;
- robustness of confinement system (e.g. fan redundancy), if considering worksite containment with high permanent volumic activity.

The risk assessment procedure is needed to define the requirements for the worksite confinement provisions and to give appropriate health physics coverage to the workers prior to the start of the activities: e.g. process provisions/rinsing/cleaning of systems to be removed or decommissioned, additional local shielding, access control.

Performing such adequate analysis optimizes confinement provisions.

There are several safety topics to be considered in the analysis, and in particular ALARA (as low as reasonably achievable) principle for worker radiations exposure, waste, etc.

5.3 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 to levels that are as low as reasonably achievable, through dedicated monitored pathways, but also to reduce the level of contamination inside the nuclear worksite or the nuclear installation under decommissioning;

— in accidental situations, to limit the radiological consequences for the environment and the workers to acceptable levels.

The application of this principle leads to the provision of different confinement systems between the environment and the radioactive substances. Each confinement system and the associated devices are designed to suit the risks they are intended to control. The goal is to maintain, in any case, the functionality of at least one stage of effective containment and filtration between the contaminated areas and the environment under all circumstances, including some accidental situations, (such as a fall from a contaminated sample component) and in all cases to limit to the radiological consequences for workers and the environment to acceptable levels.

The application of this principle requires knowing precisely the following:

— nature, spectra and quantities of radioactive material (contamination and activation) at the equipment to be modified/dismantled and particularly in areas of cutting or volume reduction;

— the state of the installation (e.g. building's architecture and ventilation system of buildings and processes);

— tools and processes used for maintenance/dismantling/cleaning and resuspension factors related to activities to be realized;

— the sequence and procedures of operations to be performed to derive scenarios of accidental situations and their associated probability level.

For these input, a conservative approach in the confinement design may also be accepted.

5.4 Confinement system

5.4.1 General

The objective of "confinement system(s)" is to limit the spread of radioactive substances in accessible work areas to levels that are as low as reasonably achievable and to prevent the spread of radioactive substances into the environment. Usually a double containment is in place, however according to radiological issues and to existing configurations, the implementation of three levels of containment or a single containment may be an optimal configuration.

Two main configurations can be met, other configurations shall be considered on a case by case study:

— case of a worksite containment located in an existing "confinement system" (usually an "historic" nuclear ventilation system, but can also be set up for the needs of a particular worksite);

— case of a worksite containment located beyond any "confinement system".

5.4.2 Case of a worksite containment located in an existing "confinement system"

The goal of "**worksite containment**" is to avoid, as much as possible, the release of radioactive materials from containment in areas accessible to unauthorized or unprotected persons (radiologically).

It includes walls of containment, if necessary associated ventilation systems: ventilation ducts, filters installed in ducts or on-through, etc.

The design of the worksite containment shall reflect the maximum amount of dispersible radioactive substances within the containment and the possible consequences of risks caused by industrial process(es).

In this case, the goal of **second confinement system** (existing “historic” confinement or new one to set up if necessary), is to prevent the release of radioactive contamination outside the building in the event of failure of worksite containment. It provides protection of the environment and members of the public to an acceptable level. It comprises the walls of the confinement system and the ventilation and air conditioning system associated.

A "**complementary containment**" located as close as possible to the activities generating the spread of radioactive materials may be necessary depending on the radiological issue (airtight bag, ventilated airtight bag, dynamic exhaust close to the source).

5.4.3 Case of a worksite containment located beyond any "confinement system"

The goal of "**worksite containment**" is to control the release of radioactive contamination outside this worksite containment. It provides protection of the environment and members of the public.

It includes walls of containment, if necessary associated ventilation systems: ventilation ducts, filters installed in ducts or on -through, etc.

The containment design shall take into account the maximum amount of dispersible radioactive substances within the containment and the possible consequences of risks caused by industrial process(es).

A "**complementary containment**" located as close as possible to the activities generating the spread of radioactive material may be necessary. It shall be implemented according to the safety requirements. It is generally recommended in installations with high risk of spreading radioactive material or in which high radiotoxicity materials are manipulated (e.g., alpha particle emitters).

Depending on the level of airborne contamination and weather conditions, it may be necessary to implement a containment and/or a climatic shelter encompassing the worksite containment.

5.4.4 Summary of different natures and levels of confinement

Table 1 below describes the different types of confinement that may be used. Figure 1 provides an explanatory block diagram of their implementation.

Table 1 — Typical examples of different natures of confinement

Type	Nature of confinement
Additional containment	Additional containment, as close as possible to the source of contamination, implemented according to the radiological issue of the activity. It may consist of worksite containment or a confinement provision as close as possible to the source (airtight bag, ventilated airtight bag, dynamic exhaust at the source).
Worksite containment	Worksite containment usually consists of temporary walls: soft walls (vinyl), semi-rigid walls (polycarbonate) or rigid walls (metal or masonry). It can also be based on the existing rooms.
Existing confinement (historical or, if necessary, to be created)	Nuclear-type ventilation of buildings or rooms, or climatic shelters (protecting against weather: sun, rain, wind, snow, extreme temperatures).
NOTE Climatic shelter has no role of confinement but protects the containment, see 6.6.	

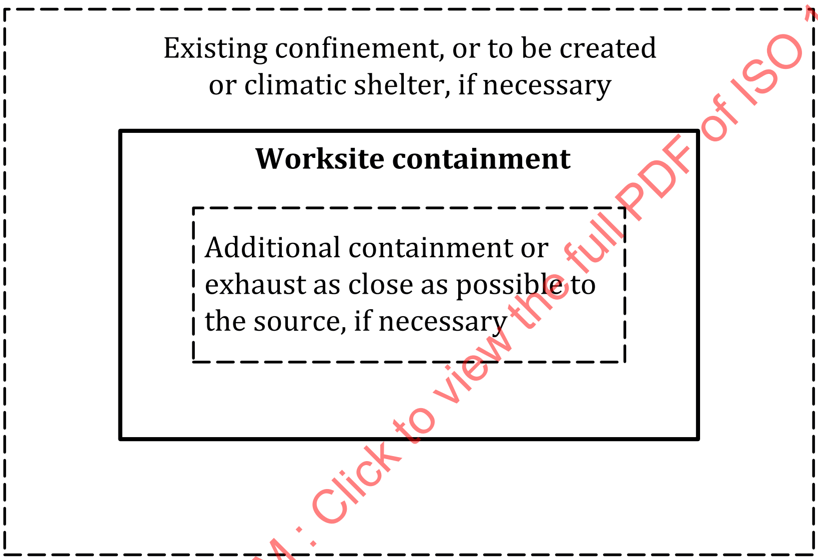

Figure 1 — Schematic diagram of the composition of the different levels of confinement

The number of confinement systems required shall be determined by a risk assessment. To this end, the following factors shall be considered: consequences and estimated frequency of potential accidents, amount of radioactivity, radiotoxicity and potential dispersibility (gas, liquid, solid) of the concerned materials.

In the definition of confinement, the principle of confinement of radioactive substances as close as possible to the source of release is to be preferred. For this, additional measures may be implemented. These measures can reduce the requirements for static-dynamic containment or make it useless if their efficiency has been demonstrated, mainly including:

— exhaust at source (local air extraction, possibly with cover of the tool);

— depressurization of the circuit on which the intervention is performed;

— establishment of airtight bag or ventilated airtight bag (see 6.5).

5.5 Static containment

An airtight enclosure containment is an efficient way to prevent the release of radioactive substances in the form of particles or gas medium. However, depending on the type of use required, a perfect seal is not possible (if some openings in containment are necessary for the transfer of materials and equipment, unsealed room in which is placed the containment etc.). In these cases, the dynamic confinement provisions mentioned in 5.6 help to support the confinement function.

NOTE In order to achieve the confinement function, both static and dynamic requirements are in some cases needed. The links between static containment and dynamic confinement provisions are detailed in 6.4.

5.6 Dynamic confinement

The dynamic confinement is complementary to the static containment. It is based on the implementation of a dynamic barrier between the source and the area accessible to unprotected workers: air flow direction, calibrated air velocity or level of depression. The idea is to keep the largest depression in areas where radioactive materials are present (process equipment, glove boxes or airlock), so that the air flows are directed from less contaminated to the most contaminated area.

Static containment mentioned in 5.5 helps to support the dynamic confinement function.

This type of dynamic confinement is provided primarily by the ventilation system described in Clause 6.

5.7 Air clean-up modalities before release

Confinement systems shall not create unnecessary additional hazards and should be designed to limit the spread of radioactive substances within the installation. The modalities of air clean-up and release should help to limit the impact on the environment. To this end:

— the points of release and intake are selected to avoid any possibility of local recycling of releases, or releases from another facility, and to limit their impact on the environment;

— the air cleaning devices shall be designed and constructed in order to provide, if necessary, a suitable resistance to the various hazards, to fugitive or periodic mechanical constraints or to chemical origin aggressions.

6 Methodology and recommendation for confinement design

6.1 Classification of the installation into working areas

6.1.1 General

The installations in which work on radioactive materials takes place are classified according to the degree of radioactive hazard they contain. The classification is usually set according to the direct radiation (external exposure), and the potential level of surface contamination and/or airborne contamination (internal exposure).

6.1.2 Confinement area classification

In order to homogenize and to make consistent containment of nuclear worksites and nuclear installations under decommissioning, a classification into containment areas, according to the normal or foreseeable accidental risk of spreading of airborne contamination, can be defined.

Different systems of classification are used around the world. Most of them use a grade subdivision (as in ISO 17873), called in the text below D1, D2, D3, D4 and D4* area. The definitions of these areas are given in Table 2. Annex A provides an example of such a classification system.

Table 2 — Usual classification of confinement areas

Class	Expected normal and/or occasional contamination
D1	Area with a very low level of contamination in normal operation. Only a low level of contamination is accepted in accidental circumstances.
D2	Area with a low level of contamination in normal operation. Only a moderate level of contamination is accepted in accidental circumstances.
D3	Area with a moderate level of contamination in normal operation. A high level of contamination is accepted in accidental circumstances.
D4	Area with a high or very high level of contamination during normal operation. A very high level of contamination is accepted in accidental circumstances.
D4*	Area with a very high level of contamination during normal operation, A huge level of contamination under accidental circumstances.

It is important to note that the notion of confinement class area is always associated with operations and/or activities considered during design phase and that are realized in this containment. A significant change in the operation of these activities (i.e. that significantly modifies resuspension of activity in normal or accidental operation) shall be followed by a check and possibly a modification of the design, operating conditions and monitoring of the containment area.

It may be necessary occasionally or for short periods, to change the classification of some areas or parts of areas, for example due to operational or maintenance requirements (e.g. maintenance, component transportation, opening of a glove box). In this case, the confinement design and/or operating needs to be adapted to the requirements of the new classification.

6.1.3 Other classifications for areas

Furthermore, in the event of a radiation exposure hazard (external exposure), a complementary classification of the installation into radiological zones shall be made, according to the ICRP recommendations. The following radiological area designations are used if needed: unrestricted areas, supervised, controlled and forbidden areas.

Also depending on the level of surface contamination and activation of walls and components, a radioactive waste classification could be implemented.

It is important to note that the confinement area classification shall remain consistent with other existing classifications systems.

This shall be made through the specific risks procedure assessment, mentioned in Clause 5 to be performed prior to the worksite activities.

6.2 Static containment design

Static containment is ensured by different means: soft walls (e.g. vinyl, materials with shrinkable properties under thermal conditions…), semi-rigid walls (e.g. polycarbonate…), rigid walls (concrete or steel structures, the walls of the building, the walls of the rooms containing radioactive substances), and/or the envelope of the process, etc. It may consist of a more or less complex combination of the aforementioned means (for example creating an opening for access to the process to dismantle).

The quality of its design, and especially its degree of tightness, which is chosen according to the potential risk presented by the operations, has a consequential influence on all the functions attributed to the ventilation systems that are associated with it, in particular the dynamic confinement function.

Following the same principles, it is generally true that good leak-tightness of a building or room can only be favourable for the overall safety of the installation, especially if failure of the dynamic confinement is considered possible.

The static containment shall be of optimum size to carry out the work safely and comfortably, without risk of breaching the barrier and comfortably, whilst avoiding being too large, in order to restrict the spread of contamination and reduce waste.

The static containment separates work areas and change rooms, if confirmed by the analyses performed according to Clause 5.

It is designed with consideration of decontamination, dismantling and disposal or reuse.

Static containment should have means of access for equipment and the removal of waste for cases where equipment is introduced inside the static containment or when waste are removed (e.g. pass-throughs, materials airlock).

Specific factors to be considered in determining the static containment include: maximum number of occupants, nature of activities, need for interim storage, and handling of materials equipment and/or waste, tools and equipment to be used. Furthermore, the time necessary for the planned activities to be realized can have an impact on the static containment conception.

The proposed location for the static containment shall be considered to ensure that the design is not affected by local processes or activities and conversely the static containment does not inhibit any operations, or emergency access arrangement.

It is recommended that suitable clear windows be included in the walls of the static containment to enable other personnel to view what is going on inside without having to enter. The number and location of windows depend on the location, size and complexity of the static containment. The aim is, as far as reasonably practicable, to provide a view of all parts of the temporary containment.

The static containment can also be located in the external environment. Therefore, the design shall ensure, if required by the risk assessment, that it is protected from prevailing weather conditions (sun, rain, wind, snow, high/low ambient temperatures), see 6.6.

The consideration of external events (such seismic design, external explosion) of static containment provisions depends on the results of the analyses performed in 5.2.

6.3 Dynamic confinement design

Dynamic confinement is usually realized by a ventilation system which provides in the confined area as appropriate and gradually:

— air flow direction from outside to inside the containment;

— calibrated air velocity from a permanent or temporary opening (air velocity on calibrated hole for example);

— a level of depression in the containment.

Ventilation used can be a network of existing building or rooms ventilation, or a mobile ventilation set up to perform a specific activity.

Depressions between zones create a required air flow in permanent or accidental openings that is not less than specified criteria for normal or abnormal/accidental conditions. Depressions can be maintained through control dampers, control valves, fan with fixed or variable speed, etc. The extraction air flows and eventually air intake may be adjusted to maintain the necessary depressions in the containment area.

To ensure the adequacy of the dynamic confinement function in all operating conditions, criteria shall be defined during the design, taking into account the influence of various factors, including:

— different predictable short-term disturbances such as opening airlocks or changes in operating conditions of ventilation systems;

— conditions/intervention tools (pneumatic tools, ventilated suits, etc.);

— uncertainties related to the operation of ventilation systems and their regulation (among others: the accuracy of the measurement systems, the response time of control equipment, the drift of the functional characteristics of components of the ventilation system (aging, clogging, degradation);

— wind speed on the facades of the building (with accidental or temporary openings);

— temperature differences between local rooms and between rooms and the outside;

Air clean-up systems supporting the dynamic confinement functions are detailed in 6.9.

NOTE The convention at many facilities is to bring the air into the containment from a high elevation and exhaust it from a low elevation.

6.4 Integrated confinement design (static-dynamic confinement)

The overall approach to design static-dynamic confinement of worksite containment site should follow the methodology of risks assessment, type safety analysis presented in Clause 5. This selected confinement system shall be adapted to the potential consequences of an event and its probability of occurrence, that may consist of a deterministic approach based on incidental or accidental conservative situations.

The approach presented below focuses on obtaining a dynamic confinement criterion, which shall be adapted to radiological issues. Indeed, it is this criterion that guarantees that an air flow direction is continuously maintained from lower to higher contaminated areas with a margin suitable to radiological issues.

However, its achievement depends heavily on the design of static containment (air tightness level) and the air change rate. Optimizing the static-dynamic confinement should also focus on these parameters.

It is important to note that by obtaining a dynamic confinement, criteria are also checked:

a) a sufficient static air tightness containment, and

b) a significant level of extraction air flow (high air change rate) without which the achievement of the dynamic criterion would not be possible.

On this basis, the static-dynamic criterion of confinement may follow the approach outlined in Figure 2.

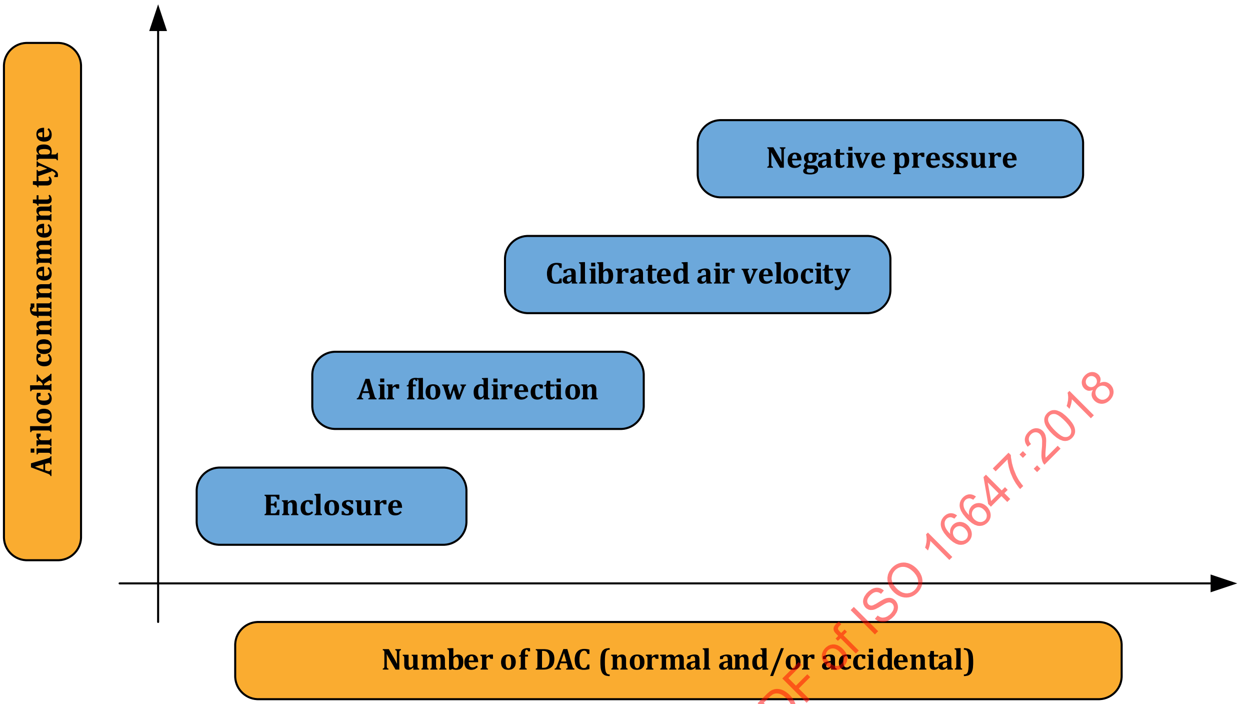

Figure 2 — Static-dynamic confinement criteria based on the radiological issue

The static-dynamic criteria thus defined are necessary when activities with risk of dissemination are realized in the containment. Generally, for other situations the static worksite containment is sufficient, if adapted to residual risks, and may allow, for example:

— break depression for removal of waste from containment;

— stop worksite ventilation outside working hours depending on the level of contamination and residual airborne contamination in the containment.

In cases where the source of release is not related to current activities (in the event of resuspension by evaporation, for example) the above principle does not apply. The input/output, and operation outside working hours shall be considered on a case by case basis as function of radiological issues.

Dynamic criteria (air flow direction, calibrated air velocity, depression levels) are needed in normal operation of worksite containment; they are the limits of loss of the confinement. To meet these limits, the hydraulic ventilation system design should take into account a margin including normal fluctuations of ventilation.

Table 4 provides, for indication, the usual values of dynamic confinement criteria (air flow direction, calibrated air velocities, depression level) in different containments based on their classification and on the number of level of containment implemented. Furthermore, indicative guide value for usual number of confinement systems is given in Table 3.

For the implementation of a single containment level, the dynamic confinement criteria given are to be checked against the atmospheric conditions outside the containment.

If it is a containment level implemented in an existing confinement, dynamic confinement criteria are to be checked against the atmospheric conditions in the existing confinement. In this case, the existence of two levels of containment is credited; this implies that there are few common mode failure hazards in the two levels of containment. In addition, an indication of the dynamic confinement criteria of the existing confinement is also given for the implementation of confinement of class D3 and D4.

The use of at least two levels of containment is recommended for activities with high radiologic issue of type D4, depending on the duration, the frequency, the use of specific enclosure, the robustness of the containment barrier, the total activity likely to be spread and the nature of the risks compared to the initial risk inside the volume.

The use of confinement provisions as close as possible to the source, or the use of vacuum cleaning devices, reduces the risks for the operators. It can allow the reduction of requirements for the design of the other confinement system, in consistency with the risk assessment procedure (see 5.2), and limit the confinement class. To be efficient, the couple distance versus flow rate is an important parameter.

It should be noted however, that larger depressions might be required for glove boxes or containment enclosures.

In certain circumstances, for example, where the effects of wind loading and thermal convection have to be considered, it may be necessary to enhance depressions (see 6.6).

Table 3 — Indicative guide values for usual number of confinement systems

	Number of needed confinement system to protect workers	Number of additional needed confinement system to protect the environment	Minimal number of total confinement system
D1	0 or 1	0 or 1 (if first column was 0)	1
D2	1	0	1
D3	1	0 or 1[a]	1 or 2[a]
D4	1	0[b] or 1[a]	1[b] or 2[a]
D4*	1 or 2[a]	1	2 or 3[a]

[a] The number depends on the duration, the frequency, the use of specific enclosure, the robustness of the containment barrier, the total activity likely to be spread and the nature of the risks compared to the initial risk inside the volume.

[b] Exceptional case that requires a risk analysis based on the duration, the frequency, the use of specific enclosure, the robustness of the containment barrier, the total activity likely to be spread and the nature of the risks compared to the initial risk inside the volume

NOTE The system protecting the workers is also used to protect additionally the environment.

The dynamic criterion maintained between two adjacent areas with different classification should be selected to meet the particular conditions of activities that are performed but in any case, it should be measurable during operation.

Table 4 — Indicative guide values for usual dynamic confinement criteria

Nature of room or area	Confinement class	Minimal criterion	
		For only one level of containment implemented	For two levels of containment (one level already in place)
Rooms free from contamination	Unclassified	Atmospheric pressure or slight overpressure	Atmospheric pressure or slight overpressure
Areas with very low levels of airborne or surface contamination	D1	Enclosure or air flow direction	Enclosure or air flow direction or no containment
Areas with low airborne contamination	D2	Calibrated air velocity[b]	Enclosure or air flow direction or no containment
Areas with moderate airborne contamination	D3	≥20 Pa[a]	Calibrated air velocity[b] and ≥20 Pa [a]
Areas with high airborne contamination	D4	To study case by case[c]	Calibrated air velocity[b] and ≥20 Pa[a]
Areas with very high airborne contamination	D4*	Shall not exist	To study case by case

[a] Relative negative pressure compared to the adjacent room or to the reference external atmospheric pressure.

[b] e.g. air velocity >1 m/s in a ⌀100 mm orifice.

[c] The number of confinement systems depends on the duration, the frequency, the use of specific enclosure, the robustness of the containment barrier, the total activity likely to be spread and the nature of the risks compared to the initial risk inside the volume.

NOTE Some countries use face velocity across personnel entry ways (e.g. 0,25 m/s).

6.5 Airtight bag and ventilated airtight bag

Airtight bag or ventilated airtight bags can be used for nuclear worksites and dismantling. They are generally used for sampling (radiological inventory), or single activities, or in locations where the installation of a worksite containment remains difficult.

For the use of an airtight bag or ventilated airtight bag, it is necessary be consistent with the approach and requirements on static dynamic containment previously defined.

However, calculating a number of equivalent DAC in small volumes of various sizes cannot correctly quantify the "radiological toxicity", therefore no confinement class are usually associated directly to an airtight bag or ventilated airtight bag.

As for worksite containment (see 5.4), two main configurations are possible:

— Case 1: Use in an existing confinement system:

The use of an airtight bag or ventilated airtight bag within an existing confinement system can limit the airborne contamination in the containment.

Limit of their use results from the consideration of a new accident situation which involves the deterioration of the bag. In this case, the resulting airborne contamination in the existing system of confinement shall remain compatible with the accidental limit allowed in this confinement.

— Case 2: Use beyond any confinement system:

In this case, the airtight bag or ventilated airtight bag ensures the function of protection of the workers, member of the public and environment.

To define the limit of use, the following methodology can be used:

— the worksite containment that should be implemented to achieve these activities, is considered, thus allowing the calculation of the number of equivalent DAC of the activities (for example a ventilated worksite containment for airtight bag, and a ventilated worksite containment with exhaust as close as possible to the source for a ventilated airtight bag);

— the use is limited for low radiological issues, i.e. worksite containments D1 or D2 class;

— exceptionally, airtight bags or ventilated airtight bags may also be used for higher radiological issues when a gain is obtained compared to the use of an airlock containment in terms of radiation received (e.g., work in a high personnel dose location for personnel involved), or safety (e.g., work at height). Formal analyses then justify the use of such provisions.

The operating and monitoring requirements associated with airtight bags or ventilated airtight bags arise from those defined for worksite containment of type D1 or D2 as appropriate (see Clause 7 for the monitoring of a static or dynamic criterion).

6.6 Protection against weather: sun, rain, wind, snow and extreme temperatures

An outdoor containment is subject to weather conditions. Suitable protection against the weather (sun, rain, wind, snow and extreme temperatures) may be required depending on the duration of use of containment.

It is recommended that the functions of protection against weather and radiobiological containment are structurally separated.

Wind effects on containment can cause temporary dynamic leakages by producing a comparable level of depression or even higher level than the depression level kept in worksite containment on the walls on the opposite side of the wind.

In the case of extreme weather conditions (e.g. strong wind), a "climatic shelter" can be set up, which should only function to "stop the wind effects" on the walls of the worksite containment in order to maintain the confinement function by respecting dynamic worksite containment criteria previously defined.

6.7 Air-change rate

The number of air changes are determined by the conventional ventilation requirements necessary to provide fresh air, and to remove odours, potential asphyxiants, vapours and heat, etc. In addition, the air change rates may be determined by the radiological requirement to maintain correct depression and air flows between areas, and to allow efficient air monitoring where this is required.

As an indication, the air change rates usually used in worksite containments are from 1 to 30 based on the radiological issue, on the sizes of containment and the type of equipment used.

Air change rate lower than 1 are possible case by case, in particular for large volume containment (e.g. >3 000 m^3), or according to the radiological issue (particularly for low airborne contamination during normal operation).

Significant air change rate may be selected, depending on the airborne contamination or activities performed (especially when generating high level of fume gas), or rooms function (airlock, change rooms, workshop).

As a guide, the conventionally adopted air change rates are given in Table 5.

Table 5 — Guide for air change rates

Compartment	Typical air changes (per hour)	Typical confinement class
Change room	4 to 5	/
Containments with low level of contamination	1 to 2	D1-D2
Containments with moderate level of contamination	2 to 5	D2-D3
Containments with high level of contamination	5 to 10	D3-D4
Containment as close as possible to the source	1 to 30 (depending entirely on the process, the volume of the containment enclosure and hazard)	Case by case

Increasing air change rates may also come from the assessment of other risks inside the rooms of the facility (e.g. explosion risks, thermal risks, anoxia, etc.).

However, in areas which have a potential for airborne activity, increasing the air change rate may not result in a significant reduction of airborne activity levels next to the worker. Excessive flow rates should be avoided, since they can cause resuspension of contamination and hence increase airborne activity levels (when the contamination is not fixed). However, increased flow can reduce the average concentration in the area as a whole. Distribution of the clean air at the operator level (positioning of extraction air) is important and shall be optimized as function of radiological issue and of activities to be performed.

Finally, the air change rate is adapted to the processes in the work area: for example, using hot spots cutting techniques such as plasma torch may require high air change rate, not for radiological reasons, but for maintaining the thermal conditions in the room or for reducing accumulation of fume gas potentially generated.

6.8 Air inlet filtration and air-transfer between confinement system

Installing an inlet air network for worksite containments is generally not necessary (air inlets being made by leakages from the containment). Similarly, air transfer from worksite containment to another is rarely used.

However, for the following two cases, the recommendation below may be applied:

— air inlet in a worksite containment by air inlet ventilation network (typically for relatively tight cells (leak rate lower than 10^{-1} air change per hour) and for significant airborne contamination levels);

— air transfer from rooms to containment (this requires a high quality containment).

The air lock alone may supply sufficient fresh air for small or simple worksite containment. However, for larger or poorly located worksite containment, additional air inlets may be required. These air inlets should be provided with filtration, or with any provision preventing back flow of potential contaminated air (e.g. flaps, relief valves).

For worksite containment equipped with air inlet equipment (air inlet ventilation network), air should enter the building through industrial grade filters to reduce the quantity of dust and impurities in the inlet air, which would otherwise find its way to the HEPA filters in the extraction network. The air may be treated to maintain the designed environmental conditions.

Similarly, consideration should be given to supply air next to the operator work station, in order to direct the flow from the source of dissemination to the extraction points where radioactive contamination is potentially released.

Excessive air inlet rates should be avoided because they may cause a resuspension of the contamination and thus an increase in airborne activity levels.

Finally, for the calculation of confinement classes, the following recommendations should be taken into account:

The transfer of air without filtration from a containment to another can affect activity airborne contamination in normal operation which shall be taken into account for determining the confinement class of the containment.

Similarly, the transfer of air from a containment area to another, with or without filtration, in the case of gaseous radioisotopes can have a significant impact on the airborne activity in normal operation, which shall be taken into account for determining the confinement class of the containment.

6.9 Air clean-up system design

6.9.1 Areas not classified under radiological dispersal

Areas that have not been classified for radiological dispersal should normally not be filtered (they can be filtered for industrial cleanliness of the installation). Appropriate air treatment should be foreseen only when the corresponding rooms are occupied by workers or contain electric or electronic material. The extract air can be exhausted locally without filtration.

6.9.2 Areas classified under the radiological release

In general, the air exhaust discharge network from D1 or D2 areas includes at least one HEPA filtration stage before release.

Compared to D2 areas, the level of contamination of the air extracted from D3 areas can be such that a stage of additional HEPA filtration can be required before final discharge to the stack.

Containments for D4 areas, which contain usually loose radioactive materials, a proportion of which is airborne, require special consideration. The activity extracted from these facilities is directly proportional to both the airborne contamination concentration and the extract air flow rate. As a general rule, several HEPA filtration stages are recommended to provide the necessary clean-up for these extracts.

For the design of air clean-up systems, the following recommendations should be considered:

— HEPA filtration before discharge is the Last Filtration Stage (LFS);

— the filters shall be installed on the suction side of the fan;

— the implementation of a prefilter, possibly with automatic cleaning system, upstream HEPA filters is recommended for all activities generating a significant amount of dust;

— the implementation of spark arrestor upstream of the first stage of filtration is recommended for all worksites, with the risks of sparks (e.g. hot cuts);

— specific air cleaning systems should be implemented in case of a significant inventory of nuclides for which HEPA filters are not efficient (iodine, tritium, carbon, cesium gaseous form): e.g. iodine charcoal filters, gas sorption systems, washing columns, etc.

It should be noted, in this context, that reducing the level of airborne activity is not directly associated with worker access conditions, but more with the need for discharge filtration, which is rather a process of discharges optimization to the environment; this latter requirement arises more from the need to keep discharges as low as reasonably practicable.

Mobile Filtration Unit can be used. It generally consist of fan and fan motor, one or several filtration units, damper, control, instrumentation and alarms all mounted on a base frame.

6.10 Connection to any existing ventilation networks

6.10.1 General

Worksite containments usually have a temporary and evolving nature. For these reasons, the connection of their ventilation systems to existing ventilation systems ("historical" ventilation or ventilation implemented for a particular worksite) should be considered on a case by case basis.

Two main configurations can be met and are detailed in the following clauses, other configurations shall be considered on a case by case:

— worksite containment located in a building, room or enclosure equipped with nuclear ventilation;

— worksite containment located beyond any nuclear ventilation (in a building, room or an enclosure without any nuclear ventilation system or outdoor).

6.10.2 Worksite containment located in a building, room or enclosure equipped with a nuclear ventilation

In this case (see Figure 3), it is recommended not to connect the worksite containment to the existing ventilation network. The air is discharged after specific filtration in the room, close to the existing ventilation network extraction, and then is exhausted to the discharge stack after HEPA filtration by the last filtration stage (LFS). This configuration offers the features below:

— the ventilation network is not disturbed by the implementation of the worksite;

— this configuration provides flexibility and simplicity of implementation;

— the room discharge should not be located neither in workstation areas, nor in pathway areas, or a measurement device of activity airborne concentration should be installed as recommended in 7.3.4.

The connexion to the existing ventilation network is the best solution for security when mobile fan is not necessary.

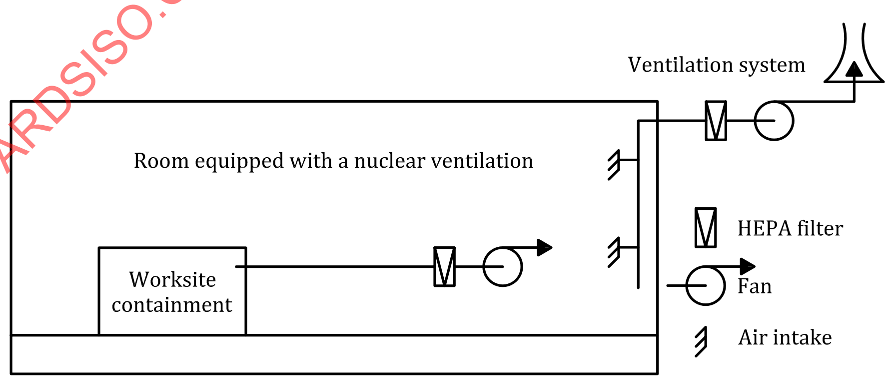

Figure 3 — Worksite containment not connected and located in a room equipped with a nuclear ventilation

Even though the connection to the existing ventilation network is not recommended when mobile fan is necessary, there are cases where there is no other way to re-create a confinement system. The connection to the existing ventilation system is then possible but should be preferred based only on radiological issues of activities performed, presence in significant amounts of radioelement in gaseous form (unfiltered), and acceptable radiological conditions in the area where is located the worksite containment. In this case (see Figure 4), specific provisions are described in 6.10.4.

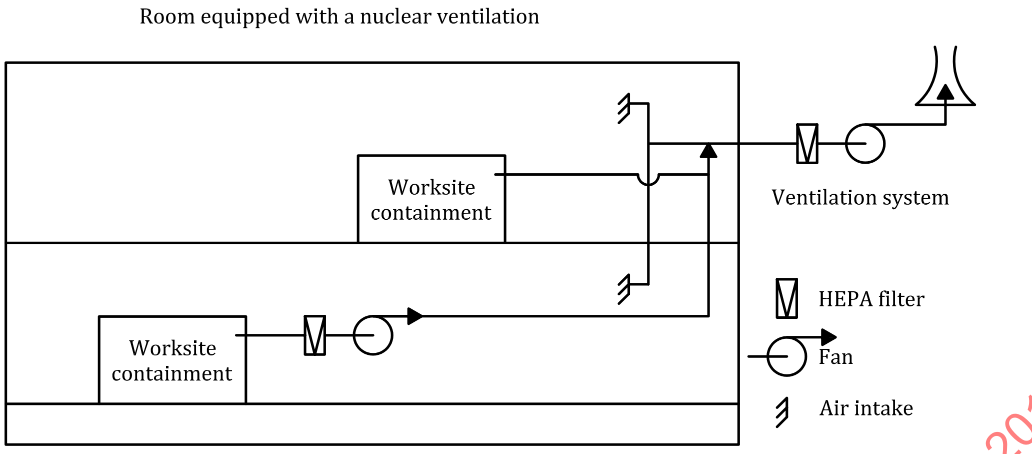

Figure 4 — Worksite containment connected and located in a room equipped with nuclear ventilation

6.10.3 Worksite containment beyond any nuclear ventilation

In this case, it is recommended to connect the worksite containment to a ventilation network system in the vicinity, if any. The air is discharged by the worksite containment, after optional filtration, in the existing extraction of existing ventilation system, and then is exhausted to the discharge stack after HEPA filtration by the last filtration stage (LFS).

In this case described in Figure 5, specific provisions are described in 6.10.4.

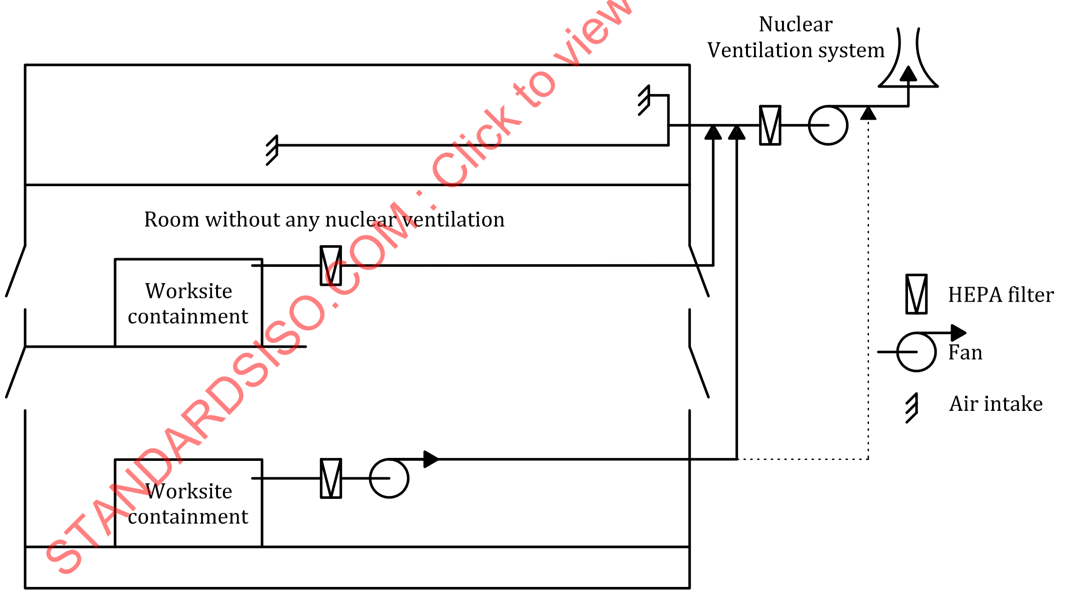

Figure 5 — Worksite containment connected and located in a room without nuclear ventilation

Non connection to existing ventilation system is possible (see Figure 6 cases) if there is a major technical problem for connection, or the lack of nuclear ventilation system. Depending on radiological issues, on activity to be performed, on potential releases generated and on national regulations, it may be necessary to set up a new release outlet especially for emissions records.

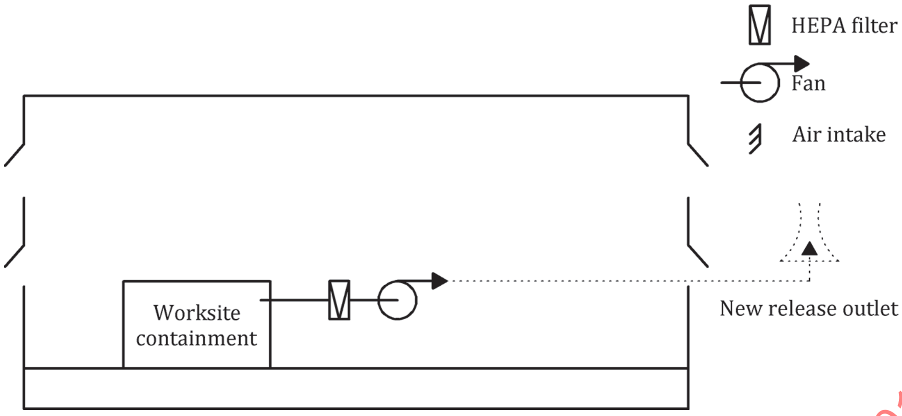

Figure 6 — Worksite containment not connected and located in a room without any nuclear ventilation

6.10.4 Additional recommendations

For the possible connection to existing ventilation networks ("historical" ventilation or ventilation implemented for a specific activity to be performed), the following recommendations should be considered:

— **If the worksite containment is not connected to the existing ventilation networks**:

— attention should be paid to radioelements for which HEPA filters are ineffective (iodine, tritium, carbon, cesium gaseous form). Indeed, discharges at worksite containment output shall be compatible with the radioprotection constraints and the allowed radiological conditions of the area where the discharge of the worksite containment is located;

— air monitoring could be needed in the area where the discharge of the worksite containment is located

— **If the worksite containment is connected to existing ventilation networks** (even though the connection to the existing ventilation network is not recommended):

— special attention should be paid to the non- disturbance of the ventilation system because of this connection, including the possible degradation of other rooms containment ventilated by the existing ventilation network (for a worksite ventilation with mobile fan in operation and, if needed, mobile fan stopped);

— similarly, for worksite connected to the general ventilation and using a mobile fan, the risk of backflow in case of an unscheduled stop of general ventilation should be studied. If necessary, procedures or palliative measures shall be implemented;

— in case of the use of relay fans, in order to avoid further contamination in rooms crossed by the new worksite ventilation network, special attention has to be paid on:

— the leak tightness of ducts that are downstream the relay fan. This would be of importance for the commissioning of the worksite ventilation network depending on the confinement class of the rooms crossed by the ducts;

— the need to stop quickly the relay fan in case of the loss of the existing ventilation system (see 7.4).

6.11 Recommended ventilation configuration as function of confinement class

In addition to the classification into confinement area classes, and in accordance with the previous requirements, it is possible to establish basic rules for the overall design of specific equipment for worksite containments.

Annex A provides examples of configuration for worksite containment based on the normal contamination levels as well as the potential accident contamination levels. This annex does not specify requirements but only guidelines (adaptation can be done according to the risks analysis).

6.12 Worksite containment usually used

Several major types of temporary worksite containment (sometimes called airlock) are usually implemented:

— The soft walls (flexible) airlock, e.g. made with layers of polyethylene or PVC (vinyl) attached by adhesives or rivet on a tubular steel structure. The soft walls airlock is the lightest and is quick and easy to install.

  Airlock with thermo shrinkable material mounted on a structure of carbon or steel which generally allows complex shapes are also part of this category.

— The semi-rigid walls airlock made of translucent and interchangeable modular panels, generally made with polycarbonate. Links between panels are usually made by an inner and an outer rail.

— The rigid airlocks, using metal panels (black painted steel, galvanized steel, stainless steel) freestanding or attached in civil engineering. Even masonry airlocks are possible.

Airtight bag, ventilated airtight bag and glove bags are also used.

It is difficult to know, *a priori*, the allowed dynamic criteria for a type of airlock. Indeed, the design of an airlock depends substantially of:

— dimensions of the airlock, frames and stiffening that is implemented;

— local conditions including chance of fire and installation constraints;

— duration of use.

The choice of materials used for the construction of worksite containments are determined by a number of factors. This includes the duration of use and environmental conditions (exposure to wind, rain, sun, snow, high/low temperatures).

Therefore, the necessary aeraulic conditions in worksite containment (air flow direction, calibrated air velocity, level of depression) apply regardless of the type of airlock used and its ability to withstand harder conditions.

Finally, the mechanical design of the airlock shall take into account a margin on dynamic criteria used in normal operation to ensure its solidity in all circumstances, including the phases of commissioning, adjustment and potential evolution of the ventilation configuration (especially when connecting the worksite containment to an area with high depression).

Annex B gives guidelines for the selection of materials constituting the worksite containment.

Annex C gives practical guidance on worksite containment arrangements.

7 Recommendations concerning commissioning, monitoring and operation of containment

7.1 General

Worksite containment and purification system, as well as associated monitoring and control equipment, shall be subject to commissioning and testing during operation. In addition, a clear set of commissioning, monitoring and operating procedures shall be developed.

Confinement can be considered "in operation" when activities involving resuspension of activity are regularly implemented or are to be soon implemented or when a source of spread of activity is present in the containment.

The achievement of commissioning tests (see 7.2), is a prerequisite to consider a containment "in operation".

Containment may be considered "out of operation" when no more activity involving resuspension of activity is regularly implemented or is to be soon implemented and when there is no more risk of spread of activity present in the containment.

Radiological decommissioning is a prerequisite to consider containment "out of operation".

Operation (see 7.4) and monitoring (see 7.3) requirements are necessary when the containment is considered "in operation”. Confinement can be considered "out of operation" for a long time.

7.2 Pre-commissioning inspection

Before operation of worksite containment, compliance with the expected requirements shall be validated by a commissioning test and be recorded.

These verifications shall be performed in all the functional regimes: manual, automatic, etc. and operated from the different control consoles, if any. During these tests, a number of system adjustments and measurements are made, including the adjustment of the extraction air, and air supply, if any, and eventually air flow from containment, the pre-setting of control and monitoring loops.

These tests focus on the following:

— a visual inspection of enclosure as well as taps and ventilation ducts, to ensure they were built correctly and that the air tightness is effective;

— visually check the correct installation of filters, prefilters, spark arrestor if implemented;

This good control shall be performed and formalized for each replacement or removal of materials.

— efficiency testing of HEPA filters using on-loop, or *in situ* (if required), and other possible treatment means;

— verification of dynamic criterion to be maintained in the worksite containment (air flow direction, calibrated air velocity, level of depression);

— verification of proper operation of audible and/or visual alarm and automated monitoring of dynamic criteria to be maintained, if any;

— in case the worksite containment is connected to the existing ventilation network:

  — verification for affected rooms, that the required air flow conditions are always fulfilled in different operational situations;

  — verification, in case of significant rate increase of general ventilation flow rate, that pressure drop of HEPA filters LFS on existing ventilation network remains below the replacement level.

Acceptance tests shall be undertaken in conditions that are as representative as possible of the operational conditions specified for the design of the ventilation systems.

Commissioning test may also include the simulation of some failures of equipment (to simulate abnormal operating rates of the confinement systems, extractor fans out of order, unintended closing of a valve, etc.) leading to a degraded situation.

In the event of significant change or if the worksite containment has been put "out of operation" for a long duration, the above elements that may have been modified shall be retested.

7.3 Monitoring of the confinement

7.3.1 General

The aim of monitoring and monitoring system is to verify the continued proper performance of the worksite confinement system, and when necessary to identify possible corrective actions.

7.3.2 Monitoring of static containment

Regular visual inspection of the physical condition of the walls of enclosure and taps and ventilation ducts is recommended and should be formalized.

7.3.3 Monitoring of dynamic confinement

Dynamic confinement should be monitored during operation.

Monitoring devices:

Depending on the radiological issue of the containment, it is recommended to equip the confinement system with the following specific devices:

— differential pressure indicator or air velocity, and/or flow rate measurement or similar device to provide indication that the ventilation system is providing an adequate dynamic confinement;

— in addition, radioactivity detectors shall be installed. Techniques required for the sampling, monitoring and achievement of these measurements are described in ISO 16639;

— an audible and/or visual warning in case of loss of required dynamic criteria to provide local warning to personnel working within worksite containment;

— flow measurements in the main ventilation ducts.

Monitoring during operation:

Monitoring during operation and its frequency should be adjusted to the radiological issue of the worksite and to the dynamic criterion monitored. It is recommended to adjust the frequency of this monitoring in relation with the importance of dynamic criterion to be checked:

— a periodic record of the actual extraction flow rate in the containment;

— a periodic record of the air velocity from a permanent opening of the containment or in a calibrated orifice (or equivalent measure);

— a periodic record of the negative pressure in the containment;

— a periodic control of audible and/or visual alarm systems of the containment.

According to radiological issues, some of the previous parameters may be required to be performed under permanent recording.

This monitoring during operation should be formalized, in the form of a test record, including the date and time of the test.

The monitoring systems of dynamic criterion required for the worksite containment (or the associated operating procedures) are designed to avoid untimely tripping, especially during the opening and closing of airlock doors, and during phases of waste packages handling.

In case of non-respect of the monitored criteria, operating procedures shall specify the actions to be taken before resuming the worksite activities (for example: ongoing work should be stopped, the reason of the defect shall be researched, and corrective actions shall be realized). If the defect cannot be corrected quickly, the worksite shall be secured and evacuated. Return to normal operating conditions allows resumption of work.

In the design of confinement systems for highly contaminated areas, direct evidence shall be available to the operator, by means of pressure gauges or flow indicators, that the required pressure differences are being maintained between such areas and the operating areas.

7.3.4 Monitoring of purification systems

It is recommended to equip the purification system of the following specific devices, which may be subject to periodic monitoring.

<u>Monitoring of filters pressure drop:</u>

In order to guard against a rupture of the filter media by excessive clogging, it is necessary to have an indication of the pressure drops of all filters at each filtration stage. The acceptance criteria are based on the manufacturer's specifications.

Depending on the risk of clogging, these filters shall be either, periodically monitored with recording the pressure drop with indication of the date and time of recording, or, continuously monitored with an alarm (visual and/or audible), at the worksite level, in case of exceeding the pressure drop replacement value.

In addition, if flow variations are or could be performed on this ventilation, the pressure drop record shall be associated with a flow rate record.

When reaching the pressure drop replacement value, filters shall be replaced as soon as possible.

Several limit values may be defined, with different consequences, for example: stop of the activities generating dust, stop of the ventilation.

In order to reduce the effects of flow rate changes resulting from filters clogging, specific provisions could be needed such as compensation dampers, variable rotating fan speeds, etc.

<u>Monitoring of HEPA filters efficiency:</u>

It is recommended to equip the ventilation system with specific devices that allow accurate measurement of HEPA filters constituting the Last Filtration Stage (LFS) or filter that are not LFS depending on radiological issue of activities. This is of considerable importance, since the safety justification for the operation of the facility is based on the verification of the criteria, particularly with respect to the radiological protection of personnel and environment.

NOTE The stage of filtration LFS is usually on the existing ventilation system and not at the worksite containment.

HEPA filters on worksite ventilations networks that discharge in a room without nuclear ventilation (filters LFS) shall be tested for efficiency when filters are implemented, or at each filter replacement, and periodically.

Periodic efficiency testing for HEPA filters that do not constitute the Last Filtration Stage but that discharge in a room with nuclear ventilation, may be necessary depending on the radiological issue during normal operation and during accidental situations of the worksite.

For HEPA filters that need in-situ efficiency tests, test their efficiency according to ISO 16170.

In addition, for HEPA filters, it is recommended to install a measurement devise of activity airborne concentration near the outlet of the worksite ventilation in order to prevent operators in case of filtration failure.

Filters dose rate monitoring:

The monitoring of filters dose rates has the objective of limiting the dosimetry of the operators changing the filters. The frequency of tests and acceptance criteria are set according to the radiological issue.

For the monitoring of the filters dose rate, depending on the radiological issue, it is recommended:

— to follow up the activity of filter that may be heavily contaminated;

— to provide, where appropriate, means of protection to limit the dose rate (implementation of shield for example);

— to change the filters when excessive dose rates are reached versus the room radiological classification.

7.3.5 Other monitoring

During the commissioning and routine dose rates monitoring of room radiological classification, dose rates monitoring of the worksite confinement network may be necessary, as function of radiological issue of the worksite, in order to check the compliance with this radiological classification (e.g. dose rates along the ductwork parts accessible to workers, or dose rate through openings).

7.4 Containment operation

Fans stop of worksite containments:

The risks assessment study performed in 5.2 shall specify the possibility to stop the fans associated with the worksite confinement system during some operation period, including the accidental situations that may occur when workers are not present.

For worksite whose ventilation is not connected to the existing ventilation, all worksite fans can be stopped outside working hours (in order to limit fire risk) after checking that this stop does not introduce other risks (e.g. explosion risks, risks of spread of contamination, thermal risks, anoxia).

For worksite whose ventilation is connected to the existing ventilation, several options are possible:

— stop fans of worksite containments outside working hours. It is necessary in this case to ensure that the disruption of the existing ventilation related to the stop of worksite fans is acceptable (this can be achieved through ventilation design and checked during commissioning);

— keep fans of worksite containment in continuous operation (it should be compatible or made compatible with all potential risks including fire studies in the perimeter of the worksite).

In addition, it is necessary, for these configurations, to ensure that the worksite fan stops in case of loss of existing ventilation (during and outside working hours) by means of design (automatism) or operation (operator action). The choice between an automatism and an operator action depends on the outcomes of the risk analysis associated with a long operator action time.

Where worksite containment is stopped (end of daily work), the stop of the containment ventilation is possible, if it meets the criteria of radiological cleanliness that have to be defined.

7.5 Containment disassembly

After the end of the worksite activities, decontamination, dismantling and disposal (or storage for reuse) of the structure and equipment shall be undertaken in a controlled manner.

The cleaning should include the inside surfaces of the worksite containment as well as all equipment either contained or used within it.

During airlock disassembly, arrangement to avoid any spread of contamination (e.g. keep extraction flow during disassembly or stick contamination before removing the airlock) shall be implemented.

When the facility ventilation system has provided the ventilation extraction for the worksite containment, either via an installed worksite containment connection or a modification to the installed system, the system may need to be returned to its reference design arrangement. This may require the blanking of open ports, re-instatement of modified ductwork and/or the rebalancing of the ventilation system.

8 Considerations about other risks than radiological risks related to confinement

Some other risks are possible during worksite and dismantling activities:

— release of toxic gases or vapours;

— burns, heat stress and heat stroke;

— anoxia risks;

— cryogenic risk and other cold stresses;

— asbestos;

— work at height;

— smokes from processes and internal combustion engines equipment;

— etc.

Users shall ensure that they comply with national or international regulations and standards for the risks other than radiological risks (e.g. toxic gases, excessive heat, anoxia risks, etc.).

Only the impact on the design and operation presented in Clauses 6 and 7 imposed by these other risks shall be assessed.

If these others risks or if the design and operation provisions associated with other national or international regulations are the drivers of the provisions, then they have to be considered, provided that they are not contradictory with the provisions defined in the standard.

When there are contradictory risks, only a case by case analysis can be performed in order to assess the actual provisions to consider.