



<b>ONR GUIDE</b>			
<b>VENTILATION</b>			
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## 1. INTRODUCTION

- 1.1 ONR has established its Safety Assessment Principles (SAPs) which apply to the assessment by ONR specialist inspectors of safety cases for nuclear facilities that may be operated by potential licensees, existing licensees, or other duty-holders. The principles presented in the SAPs are supported by a suite of guides to further assist ONR's inspectors in their technical assessment work in support of making regulatory judgements and decisions. This technical assessment guide (TAG) is one of these guides.

## 2. PURPOSE AND SCOPE

- 2.1 This assessment guide covers the Principles for Ventilation of the designated radioactive areas within the buildings on nuclear licensed sites, from the point where air is drawn into the building, to where it is discharged to atmosphere after appropriate conditioning, filtration and monitoring.
- 2.2 This guidance is to assist and inform ONR inspectors in the exercise of their professional regulatory judgement. The TAG addresses United Kingdom (UK) legislation and European Union (EU) directive requirements and identifies sources of relevant good practice from recognised sources such as Western European Nuclear Regulators' Association (WENRA), International Atomic Energy Agency (IAEA) as well as ONR's technical assessment guides. Comments on this guide, and suggestions for future revisions, should be recorded in accordance with ONR's standard procedures.

## 3. RELATIONSHIP TO LICENCE AND OTHER RELEVANT LEGISLATION

- 3.1 There are no licence conditions [Ref.1] dealing explicitly with ventilation. However, certain licence conditions are more likely to be used by inspectors when dealing with ventilation equipment and processes. Licence Condition 34 is of significant importance as it addresses control and containment of radioactive materials and wastes on site.
- *Licence Condition 6: Documents, records, authorities and certificates* - The licensee shall make adequate records to demonstrate compliance with any of the conditions attached to this licence
  - *Licence Condition 10: Training* - The licensee shall make and implement adequate arrangements for suitable training for all those on site that have responsibility for any operations which may affect safety
  - *Licence Condition 11: Emergency Arrangements* – Without prejudice to any other requirements of the conditions attached to this licence the licensee shall make and implement adequate arrangement for dealing with any accident or emergency arising on the site and their effects
  - *Licence Condition 12: Duly authorised and other suitably qualified and experienced persons* - The licensee shall make and implement adequate arrangements to ensure that only suitably qualified and experienced persons perform any duties which may affect the safety of operations on the site or any other duties assigned by or under these conditions or any arrangements required under these conditions
  - *Licence Condition 14: Safety documentation* - The safety case for the plant, is produced and assessed by the licensee under this condition, which also requires documentation to be submitted to ONR on request. It should cover SSCs critical to safety through the entire lifecycle

- *Licence Condition 15: Periodic review - The licensee shall make and implement adequate arrangements for the periodic and systematic review and reassessment of safety cases*
- *Licence Condition 22: Modification or experiment on existing plant – The licensee shall make and implement adequate arrangements to control any modification or experiment carried out on any part of the existing plant or processes which may affect safety*
- *Licence Condition 23: Operating Rules – The licensee shall, in respect of any operation that may affect safety, produce an adequate safety case to demonstrate the safety of that operation and to identify the conditions and limits necessary in the interests of safety. Such conditions and limits shall hereinafter be referred to as operating rules*
- *Licence Condition 24: Operating instructions - The licensee shall ensure that all operations which may affect safety are carried out in accordance with written instructions hereinafter referred to as operating instructions*
- *Licence Condition 25: Operational Records - The licensee shall ensure that adequate records are made of the operation, inspection and maintenance of any plant which may affect safety*
- *Licence Condition 26: Control and supervision of operations – The licensee shall ensure that no operations are carried out which may affect safety except under the control and supervision of suitably qualified and experienced persons appointed for that purpose by the licensee*
- *Licence Condition 27: Safety mechanisms, devices and circuits – The licensee shall ensure that a plant is not operated, inspected, maintained or tested unless suitable and sufficient safety mechanisms, devices and circuits are properly connected and in good working order*
- *Licence Condition 28: Examination, inspection, maintenance and testing – The licensee shall make and implement adequate arrangements for the regular and systematic examination, inspection, maintenance and testing of all plant which may affect safety*
- *Licence Condition 34: The licensee shall ensure, so far as is reasonably practicable, that radioactive material and radioactive waste on the site is at all times adequately controlled or contained so that it cannot leak or otherwise escape from such control or containment*

3.2 The following key legislation and advisory documentation are pertinent to the design, installation and operation of ventilation systems for nuclear facilities. This list is not exhaustive and inspectors should satisfy themselves that the licensee has taken account of all legislative requirements relevant to any particular ventilation system. Of particular interest for ventilation systems are The Workplace (Health, Safety & Welfare) Regulations 1992 (Regs 5 and 6 for ventilation) and The Ionising Radiation Regulations 1999 with Reg 8 is directly applicable, which states “All necessary steps must be taken to restrict the exposure to ionising radiation to as low as reasonably practicable (ALARP).”

#### **Key Legislation:**

- The Health and Safety at Work etc. Act 1974
- The Energy Act 2013
- The Ionising Radiations Regulations 1999
- The Nuclear Installations Act 1965

- The Environmental Permitting (England and Wales) Regulations 2010
- The Management of Health and Safety at Work Regulations 1999
- The Workplace (Health, Safety and Welfare) Regulations 1992
- The Radioactive Substances Act 1993 (Scotland)
- The Control of Substances Hazardous to Health Regulations 2002
- The Construction (Design and Management) Regulations 2015
- The Dangerous Substances and Explosive Atmospheres Regulations 2002
- The Confined Spaces Regulations 1997

3.3 A number of the above Regulations have one or more accompanying Approved documents or guidance which provides recommended procedures for compliance with the regulations.

#### 4. RELATIONSHIP TO SAPS, WENRA REFERENCE LEVELS AND IAEA SAFETY STANDARDS ADDRESSED

4.1 Any ventilation system provided in the interests of safety should meet the Key Engineering Principles within the SAPs [Ref.2]. In addition there are a number of specific containment and ventilation Principles which the system should meet. These are listed below. These specific Principles do not specify any standards or criteria which should be followed; however, the licensee should clearly state the standards used and the associated performance targets.

##### **Safety Assessment Principles (SAPs)**

4.2 The following SAPs are relevant to the assessment of nuclear ventilation:

- *ECV.1 - Radioactive material should be contained and the generation of radioactive waste through the spread of contamination by leakage should be prevented*
- *ECV.2 - Containment and associated systems should be designed to minimise radioactive releases to the environment in normal operation, fault and accident conditions*
- *ECV.3 - The primary means of confining radioactive materials should be through the provision of passive sealed containment systems and intrinsic safety features, in preference to the use of active dynamic systems and components*
- *ECV.4 - Where the radiological challenge dictates, waste storage vessels, process vessels, piping, ducting and drains (including those that may serve as routes for escape or leakage from containment) and other plant items that act as containment for radioactive material, should be provided with further containment barrier(s) that have sufficient capacity to deal safely with the leakage resulting from any design basis fault*
- *ECV.5 - The need for access by personnel to the containment should be minimised*
- *ECV.6 - Suitable and sufficient monitoring devices with alarms should be provided to detect and assess changes in the materials and substances held within the containment*
- *ECV.7 - Appropriate sampling and monitoring systems should be provided outside the containment to detect, locate, quantify and monitor for leakages or escapes of radioactive material from the containment boundaries*
- *ECV.8 - Where provisions are required for the import or export of materials or equipment into or from containment, the number of such provisions should be minimised*
- *ECV.9 - The design should ensure that controls on fissile content, radiation levels, and overall containment and ventilation standards are suitable and sufficient*
- *ECV.10 - The safety functions of the ventilation system should be clearly identified and the safety philosophy for the system in normal, fault and accident conditions should be defined*
- *EQU.1 - Qualification procedures should be applied to confirm that structures, systems and components will perform their allocated safety function(s) in all normal operational, fault and accident conditions identified in the safety case and for the duration of their operational lives*

- *EDR.1 - Due account should be taken of the need for structures, systems and components to be designed to be inherently safe, or to fail in a safe manner, and potential failure modes should be identified, using a formal analysis where appropriate*
- *EDR.2 - Redundancy, diversity and segregation should be incorporated as appropriate within the designs of structures, systems and components*
- *EDR.3 - Common Cause Failure (CCF) should be addressed explicitly where a structure, system or component employs redundant or diverse components, measurements or actions to provide high reliability*
- *EDR.4 - During any normally permissible state of plant availability, no single random failure, assumed to occur anywhere within the systems provided to secure a safety function, should prevent the performance of that safety function*
- *EKP.3 – Defence in depth - Nuclear facilities should be designed and operated so that defence in depth against potentially significant faults or failures is achieved by the provision of multiple independent barriers to fault progression*
- *EMT.1 - Safety requirements for in-service testing, inspection and other maintenance procedures and frequencies should be identified in the safety case*
- *EMT.2 - SSCs should receive regular and systematic examination, inspection, maintenance and testing as defined in the safety case*
- *EMT.3 - SSCs should be type tested before they are installed to conditions equal to, at least, the most onerous for which they are designed*
- *EMT.4 - The continuing validity of equipment qualification of structures, systems and components should not be unacceptably degraded by any modification or by the carrying out of any maintenance, inspection or testing activity*
- *EMT.5 - Commissioning and in-service inspection and test procedures should be adopted that ensure initial and continuing quality and reliability.*
- *EMT.6 - Provision should be made for testing, maintaining, monitoring and inspecting SSCs (including portable equipment) in service or at intervals throughout their life, commensurate with the reliability required of each item*
- *EMT.7 - In-service functional testing of structures, systems and components should prove the complete system and the safety function of each functional group*
- *EMT.8 - Structures, systems and components should be inspected and/or re-validated after any event that might have challenged their continuing reliability*
- *EMC.1 - Before operating any facility or process that may affect safety it should be subject to commissioning tests defined in the safety case*
- *ERL.1 - The reliability claimed for any structure, system or component should take into account its novelty, experience relevant to its proposed environment, and uncertainties in operating and fault conditions, physical data and design methods*
- *ERL.2 - The measures whereby the claimed reliability of systems and components will be achieved in practice should be stated*
- *ERL.3 - Where reliable and rapid protective action is required, automatically initiated, engineered safety measures should be provided*

- *ERL.4 - Where safety-related systems and/or other means are claimed to reduce the frequency of a fault sequence, the safety case should include a margin of conservatism to allow for uncertainties*
- 4.3 Table 1 of EKP.3 identifies the fourth level as control of severe plant conditions in which the design basis may be exceeded, including the prevention of fault progression and mitigation of the consequences of severe accidents. An important aspect of defence in depth is the provision of ventilation as a means of minimising the release of radioactive substances to the workforce and the environment and to aid the confinement of radiological substances at specified locations.
- 4.4 These Principles should be considered as goal setting and although they do not place quantitative requirements on a licensee, the safety case for a particular facility should clearly identify how the facility addresses them as appropriate. In general the Principles represent good practice but it may still be possible to implement further improvements that reduce the risks to as low as reasonably practicable (ALARP).

### Technical Assessment Guides (TAGs)

- 4.5 ONR inspectors assessing a ventilation system should be aware of the ONR's general expectations for the licensees' development of safety cases (NS-TAST-GD-051). In addition, the following generic TAGs may also be relevant: [Ref.4]
- *NS-TAST-GD-005 Demonstration of ALARP*
  - *NS-TAST-GD-009 Examination, Inspection, Maintenance and Testing of items important to safety*
  - *NS-TAST-GD-021 Containment: Chemical Plants*
  - *NS-TAST-GD-026 Decommissioning*
  - *NS-TAST-GD-038 Radiological Protection*
  - *NS-TAST-GD-050 Periodic Safety Reviews*
- 4.6 The update of this TAG has also considered the Western European Nuclear Regulators Association (WENRA) [Ref.5] and International Atomic Energy Agency (IAEA) [Ref.6-8] and the Nuclear Energy Agency [Ref.9] publications for specific applicability. To note that the SAPs are intended for both existing and new facilities whereas the WENRA Reactor Safety Reference Levels are intended for existing reactors. However there is little difference between the general requirements of each. The WENRA and IAEA documents considered in this TAG are focused on nuclear reactor power plants and so do not have the same broad scope intent of the SAPs and this TAG.

### WENRA

- 4.7 There are no specific WENRA Reference tables devoted to ventilation, however the following from Reference Level S, (Protection Against Internal fires) is worthy of note:
- *Ventilation systems shall be arranged such that each fire compartment fully fulfils its segregation purpose in case of fire*
  - *Parts of ventilation systems (such as connecting ducts, fan rooms and filters) that are located outside fire compartments shall have the same fire resistance as the compartment or be capable of isolation from it by appropriately rated fire dampers*

## IAEA

- 4.8 There are various IAEA guidance documents providing details on ventilation systems and the control of airborne radioactive material, the main publications are listed below:
- IAEA SSR-2/1, Safety of Nuclear Power Plants; Design [Ref.6]
  - IAEA TECDOC-1744- Treatment of Radioactive Gaseous Wastes [Ref.7]
  - IAEA STI/DOC/010/325 - Particulate Filtration in Nuclear Facilities. [Ref.8]

## International Guidance

- 4.9 International design guidance for ventilation systems on Nuclear Licensed sites include:
- *BS ISO 26802:2010 Nuclear Facilities. Criteria for the design and operation of containment and ventilation systems for nuclear reactors.* [Ref.10]
  - *ISO 17873:2004 Nuclear Facilities. Criteria for the design and operation of containment and ventilation systems for nuclear installations other than nuclear reactors.* [Ref.11]

## National Guidance

- 4.10 Under the auspices of the Safety Directors' Forum, the National Nuclear Ventilation Forum (NNVF) and the UK nuclear industry have developed the following guidance on the design of nuclear ventilation systems:
- ES\_0\_1738\_1\_issue 1, Ventilation Systems for Radiological Facilities Design Guide [Ref.3]
- 4.11 ES\_0\_1738\_1\_Issue 1 [Ref.3] identifies other relevant national standards that apply at a component design level, or for the sub-components that are part of the whole ventilation system; fans, ducts and housings etc.
- 4.12 It is recommended that the ES\_0\_1738\_1\_Issue 1 [Ref.3] should be used by ONR inspectors alongside this TAG.



## 5. ADVICE TO INSPECTORS

- 5.1 A sealed volume providing physical containment is the most effective way to prevent the escape of particulate and gaseous contamination. This of course is not always possible due to process, operational and maintenance requirements. The main function of any ventilation system therefore is to support the physical containment in controlling and minimising the escape and spread of contamination.
- 5.2 In the event of faults ie breaches in the containment boundary, the ventilation system should be capable of maintaining sufficient air flow, through such breaches to limit back diffusion from the higher contaminated areas into the lower contaminated areas. Consideration should also be given to the effect of extreme weather conditions, eg wind, temperature, and external hazards such as flooding etc. The total air flow through a system should also be minimised to limit the potential for the spread of contamination.
- 5.3 The actual environmental discharge requirements are a matter for the Authorising Departments (currently the Environment Agency, the Scottish Environment Protection Agency and Natural Resources Wales) and any liaison should be conducted under the relevant Memoranda of Understanding (MoU).
- 5.4 The principles in this section apply generally unless the wording makes it clear that limited application was intended or unless it can be shown that the total amount of nuclear matter concerned is sufficiently small or is in such a chemical or physical form as to make it unnecessary to apply any one or more of the principles.

### General Principles

- 5.5 The following general safety principles are applicable to radioactive ventilation systems:
- *The amount of loose radioactive material or contamination in areas being ventilated should be minimised, so far as is reasonably practicable*
  - *The air flow and air patterns in the working environment should be adequate to ensure any airborne contamination is within acceptable levels*
  - *Sufficient fresh air should be provided to occupied areas to ensure acceptable hygiene conditions and comfort*
  - *Ventilation only provides a supporting role to physical containment by means of maintaining a negative pressure (depression) within the containment. The system should provide a sufficient inward air velocity through unavoidable openings (e.g. doors) or accidental openings (e.g. containment fault breaches), to limit the egress of particles or gases*
  - *Where a ventilation system is called upon to prevent release of radioactive material during a fault condition, the system should be shown to perform this function under the conditions (temperature and pressure) that may prevail as a result of the fault. Also consider the potential for containment to be lost if ventilation systems fail – for example, if furnaces rely on ventilation flows to remove excess heat*
- 5.6 The functions of nuclear ventilation systems can include various combinations of the following:
- *Maintaining acceptable working conditions (temperature, humidity, etc.)*

- *Allowing entry to otherwise inaccessible areas*
  - *Controlling the spread of contamination during normal, fault and post-accident conditions*
  - *Providing an inert atmosphere to maintain quality during manufacture or to allow safe processing of reactive materials*
- 5.7 Each licensee should classify an area of plant in compliance with the Ionising Radiations Regulations (IRRs) and the associated hazards, consequences and risks. In practice licensees across different sites classify areas according to their particular needs which can vary from site to site. To aid the inspector's understanding, a comparison of the area classifications against a colour code system recognised by the industry (eg NNVF) is as follows:
- **WHITE**, means a clean area free from radioactive contamination, whether surface or airborne (may be referred to as C1 and/or supervised area)
  - **GREEN**, means an area which is substantially clean. Only in exceptional circumstances is airborne contamination such that provisions must be made for its control (may be referred to as C2, LOW or C2 controlled area)
  - **AMBER**, means an area in which some surface contamination is expected. In some cases there will be a potential for airborne contamination such that provision must be made for its control (may be referred to as C3 MEDIUM or C3 controlled area)
  - **RED**, means an area in which contamination levels are so high that there is normally no access without appropriate respiratory protection (may be referred to as C4 HIGH or C4 and C5 controlled area)
- 5.8 Ventilation systems play a key role in limiting contamination in nuclear facilities. To this end, the plant may be divided into zones separated by barriers. Where there are multiple barriers required, the first will often be that provided by a total enclosure eg a glove box or packaging. An additional containment (barrier) may be required to protect against the release of radioactive material to the workforce and surrounding plant eg cave or cell, and the structure of the building surrounding the inner containments may be the final barrier required to protect the public and environment.
- 5.9 Each zone should be ventilated so that there is a pressure gradient between adjacent zones, the aim being to ensure that any movement of airborne radioactive contamination is from the zone with the lowest to that with the highest potential for contamination (eg from WHITE towards RED).
- 5.10 Air should enter the building and be cleaned through appropriate inlet filtration. This will reduce the resulting build-up of dust on the extract filters and hence prolong their life and minimise higher-level waste arising and protect against backflow in the event of loss of the extract system. Inlet filtration will also protect the building from potential releases from adjacent buildings during fault conditions. Environmental conditions should also be considered, as relative humidity conditions will vary between winter and summer necessitating the need for pre-heaters and / or anti-frost coils. Whilst recognising the need to minimise openings, suitable access openings should be provided to enable periodic cleaning and maintenance of the air inlet and associated systems.
- 5.11 In most cases air will be extracted from the various areas via ductwork to a discharge duct or stack. The number, type and positioning of filters will vary dependant of the requirements of the safety case hazard assessment. Depending on the activities being performed ie solvent extraction, evaporation, effluent treatment, fuel dismantling and

storage, and the length and routing of ductwork, it is possible that radioactive particulate may lodge in the ductwork prior to being captured by the filter (particularly on legacy plants). In such circumstances the potential for condensation washing radioactive deposits out of crevices in degraded ducting may be present, which in extreme cases may present criticality or fire hazards. The inspector should therefore be satisfied that adequate detection and maintenance arrangements are in place to ensure contamination levels are kept as low as reasonably practicable.

- 5.12 The total air flow through the system from inlet to discharge into the atmosphere should be minimised and appropriate for the processes being undertaken. This will result in the number of filters to be disposed of as radioactive waste and the risk to filter maintenance personnel also being minimised.
- 5.13 The ventilation system may also include equipment such as gas cleaning facilities which may be provided to mitigate the consequences of radioactive release. These systems will also include a variety of mechanical / electrical / control and instrumentation items, the reliability of which may have a direct bearing on the risk to workers, the public and environment. Where equipment forming part of the ventilation system serves as part of a safety system, the general principles applicable to engineering and safety systems should also be applied. Moisture removal may also be required to avoid wetting of the filtration system which can significantly affect both performance and life.
- 5.14 Guidance has been prepared by a number of different organisations on the design of ventilation systems. An approved guide detailing the requirements 'Ventilation Systems for Radiologically Facilities' (Design guide) [Ref.3] has been developed through the National Nuclear Ventilation Forum (NNVF) and the Ventilation Working group (VWG).
- 5.15 ONR recommends use of the above guidance for judging the level of compliance and is intended to give the inspector some confidence that the licensee is making use of relevant good practice and standards. The inspector should be satisfied that the licensee is applying such guidance appropriately and that adequate consideration has been given to reducing risks as low as reasonably practicable (ALARP).
- 5.16 Ventilation systems are generally provided in conjunction with other containments to ensure the adequate segregation of nuclear materials from the general environment, workers and ultimately the public and wider environment. The contribution that a ventilation system makes to the overall containment strategy may however vary between existing and new plants.
- 5.17 Improvements in engineering techniques and the characteristics of the process may result in the demand, configuration and safety function requirements for the ventilation system being changed. The inspector should be satisfied that any modifications have been subject to the appropriate rigour, in line with the licensee arrangements, and compliant with LC22: Modification or experiment on existing plant.
- 5.18 Ventilation systems, by necessity, have various mechanical and electrical components such as motors, fans, filters, bursting discs, isolation valves, pressure relief valves and control systems. These should meet the necessary standards of redundancy and diversity to ensure continued safe operation. Along with the segregation of essential services (eg electrical supplies), these should be considered during the multi-discipline assessment of the safety case.
- 5.19 The potential for a fire can have a major impact on the ventilation and containment system, influencing for example the operational philosophy, and position, number and type of fire dampers required in the system. It is therefore important that any ventilation

dampers should be suitably located to enable operation and maintenance in accordance with their safety significance. In addition to the principles in this section, other effects of fire may need to be considered, and reference should be made to the SAPs concerning external and internal hazards (EHA series).

- 5.20 The safety case should contain a clear statement on the duty of the ventilation system including for example its role in reducing air contamination levels, any general duty in providing a satisfactory working environment as regards temperature and humidity, and as part of the overall containment system. Such differing duties may result in conflicts in the requirements for the ventilation system which will have to be justified.
- 5.21 The safety case should clearly identify what happens in fault situations and should indicate how the design incorporates mitigation systems or processes to manage the situation so that risks are ALARP. For example, when a glove fails in a glove box, an additional flow of air is required to prevent backflow of radioactive material into the working environment, or in the case of a Rapid Ventilation Safety System<sup>1</sup> (RVSS) within larger enclosures where specific ventilation routing and over pressure protection may be required.
- 5.22 The licensee may use one of a number of approaches to the design of a ventilation system dependent on the duty. A clear statement should be made on the standards and any design codes being used. This relates not only to the design philosophy of the system but also to the sizing, the materials of construction, the radiological protection standards, fire protection standards, the explosion standards, the mechanical/electrical equipment and the control and protection systems.
- 5.23 The design and use of radioactive ventilation systems will be many and varied, however, some of the philosophies and principles adopted for the more frequently used systems will be typically the same. The following lists those structures, systems and components that inspectors will be most likely to encounter, which may require an active ventilation system. It should be noted that the list is by no means exhaustive and detailed requirements for each system in terms of depression, emergency extract and process will be determined in the safety case.

### **Ductwork**

- 5.24 The ductwork should be of a design that address the requirements of containment, pressure duty, structural stability and environmental conditions (internal and external). Ducts commonly also deliver ventilation air as part of the supply air, ensuring acceptable indoor air quality as well as thermal comfort. An extensive range of fabricated ductwork and tube is employed for active ventilation requirements including:
- High integrity low leakage mild steel ductwork or stainless steel ductwork
  - Fabricated ductwork, high or low velocity requirements
  - Fabricated ductwork in stainless steel or other materials
  - Copper tube
  - Plastic ductwork or plastic tube
  - Glass fibre ductwork
  - Flexible ductwork

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<sup>1</sup> Rapid Ventilation Safety System: Ventilation by means of an adjustable ventilation opening or openings which will allow the movement of substantial volume of air in a short time period.

Further details for Ductwork standards and applicability in specialist areas can be found in ES\_0\_1738\_1\_issue 1 [ref.3] chapter 20.

### **Glove boxes**

- 5.25 Gove boxes are typically used for the handling of:
- certain alpha radioactive materials
  - certain beta radioactive materials
  - toxic non-radioactive materials
  - pyrophoric materials in oxygen free atmospheres, these materials may also be of low moisture
  - bio-hazardous material
- 5.26 Usually these types of operations are undertaken by operators at the glove box face through gloved access.
- 5.27 Glove boxes handling these materials should be maintained at a suitable depression to create sufficient inflow and hence limit the escape of particulate matter or radioactive gases, from any leaks within the containment that may exist or be caused by a fault. It should be noted that flow rates will vary dependant on whether a dry or wet process is being undertaken ie for dry it would be desirable to have low flow rates to minimise disturbance of the product whereas for wet process a higher flow rate may be appropriate to prevent condensation.
- 5.28 The depression should be appropriate for the process therein but in general should be as small as practicable taking account of glove operability (ie the greater the depression the more difficult it will be for an operator to undertake gloved movements). Depressions for normal operations may vary but will typically be of the order of 375 Pascals. Suitable over/under-pressure detection systems should be in place to ensure the integrity of the containment structure.
- 5.29 In Fault conditions e.g. glove failure or other loss of containment, the ventilation system should be designed to provide the maximum emergency flow whilst maintaining the glove box in a safe condition, this may require the addition of an automatic emergency system such as a Vortex Amplifier<sup>2</sup> (VXA). Licensees may, particularly on older facilities, claim alternative arrangements such as operator training and procedures, and the use of personal protective equipment (PPE) in place of such emergency extract devices. In such cases the inspector should be satisfied that the safety case is adequate for such claims and the risk is ALARP.
- 5.30 It should be noted that cases can exist where glove boxes operate above atmospheric pressure with inert atmospheres eg to prevent fires during machining metal. Such instances would require special consideration of the safety case and the effect on the ventilation system.

### **Caves and Cells**

- 5.31 Operations and processes carried out in caves and cells are varied but in general they will often entail operations where direct manual intervention at the work face is not possible. They can be single containments or built-in suites and may have interconnecting shield doors which, by nature, will not provide a fully hermetic seal. The ventilation requirements can therefore regularly change and be very challenging.

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<sup>2</sup> Vortex Amplifier: a fluidic device with no moving parts that can change its resistance in response to an upstream pressure variation (often used to induce a breach flow within glove boxes and cells).

- 5.32 As with glove boxes, most caves and cells are operated under depression with respect to adjacent areas. Depressions will generally not be as low as glove boxes ie will be of the order of 125 Pascals. Nevertheless, the average flow velocity should be high enough to limit the potential for the spread of contamination. The actual velocity of flow should be determined by the safety case but the ventilation system should be capable of a minimum of 1 m/s during fault conditions. If this is not the case then the inspector should be satisfied that consideration has been given to providing enhanced ventilation during accident and fault conditions (eg via a Vortex Amplifier or other).
- 5.33 Due to the type of operations carried out in caves and cells, work may be undertaken by Master Slave Manipulators with viewing generally through shielded windows. To achieve satisfactory visibility a high illumination level is often required, which can give rise to high internal heat gains which must also be addressed by the ventilation system. It is important that these considerations have been assessed and the appropriate ventilation and filtration materials have been used to reduce premature aging and degradation factors impacting on the containment materials, and to protect the equipment therein from the effects of excessive temperatures.

### **Fume Cupboards**

- 5.34 Where the safety case allows, and complete containment is not feasible due to the requirement for operator access, fume cupboards are generally used. They are particularly prevalent within laboratories and where the licensee may be undertaking analytical and research work. Fume cupboards should be designed to envelope, as far as possible, the equipment and processes being worked on whilst maintaining access to the front face.
- 5.35 Unlike a glove box, a fume cupboard will not provide full containment and consists of an enclosed chamber with a sash or sliding door which is opened for working access. Through this opening a flow of air is induced which provides a velocity to limit the spread of substances from the enclosure to the work place, typically flow rates of between 0.7 m/s and 1.0 m/s are used by the industry.
- 5.36 A common misunderstanding when operating fume cupboards is, the higher the velocity flow the greater the operator protection. Excessive velocities may create turbulent and uncontrolled air flow that has the potential to flow backwards towards the operator. The inspector should therefore expect to see some form of flow indication, visual and audible alarm or that some other method of operator warning and protection (eg PPE) has been appropriately considered.

### **Temporary Ventilation**

- 5.37 Technical guidance on the requirements of temporary ventilation is outside the scope of this TAG. However, the inspector should be aware of the existence of temporary ventilation systems, used on occasions, when the primary containment boundary is breached, either as part of a planned activity or as a result of an event. The general principles of temporary containment are the same as that of the primary containment but with higher demands due to increased risk. However, the existing containment may require additional temporary containment (eg tent, blister bag). Similarly, the existing ventilation system may have to be supported by the use of dedicated stand-alone temporary plant and equipment (eg Mobile Filtration Units (MFUs)). In such circumstances there are many factors to be considered, a few key ones of interest are listed here:
- The requirements of the local area Radiation Protection Adviser (RPA)
  - The life span of the temporary system

- Modification to the existing ventilation system and possible effects on the building/plant and equipment
- The use of temporary connections and ductwork
- The inlet and extract arrangements
- Sub change facilities
- Examination, Inspection, Maintenance & Testing (EIMT) in terms of substantiation for temporary use
- Testing and commissioning of the temporary arrangement
- Decommissioning, dismantling and disposal

#### 5.38 Filtration Systems

5.39 ; Filters should be compatible with materials and fluids that may enter the ventilation system from process fluids. Due consideration should be given to the installation, testing, monitoring and changing of all filters with particular emphasis on a safe change procedure to protect the operator and on filter management and storage prior to disposal. The by-passing of filters is a common problem and a suitable testing programme should be in place to ensure the performance criteria are met.

5.40 Filters should be supplied with clear labelling providing storage instructions, handling and stacking requirements, date and batch identification of manufacture, shelf life and design life. Filters should be stored in a dry environment unless manufacturers prescribe otherwise, which should include temperature control to meet the storage condition.

5.41 Traceability of filters and filter housings should be maintained throughout their lives. Licensees should be able to demonstrate that their records provide an adequate ability to identify, locate and remove defective filters. Systems should be in place to ensure that filters do not exceed their shelf / design lives; since filter collapse can cause unacceptable discharges to the atmosphere.

5.42 During transportation and handling filters can be susceptible to damage and defects, post testing and certification by the manufacturer. Licensees should have arrangements to perform appropriate systematic pre-installation inspection of filters to confirm no damage or defect is present and the filter type is appropriate for the installation to minimise risks of unnecessary contaminated radioactive waste arising.

#### **HEPA Filters**

5.43 Cylindrical rather than rectangular high efficiency particulate air (HEPA) filters are generally preferred for new plants to reduce by-passing and waste volumes. These should also be more appropriate for safe change philosophies.

5.44 The problems of liquor droplets and the deposition of hygroscopic solids can result in rapid blockage of filters and damage to the mechanical and electrical equipment. This may determine the need for some form of clean up equipment. Similarly, debris being transported within the ventilation system may require the provision of electrostatic precipitators or spark arrestors.

5.45 The potential for overpressure of a system should be considered, and the consequences associated with the breach of containment and filter damage mitigated.

5.46 HEPA Filters require careful through-life management with consideration of the following:

- The filters should be Type approved for the application and in-situ tested
- There should be relevant documentation and traceability of installed units
- The filters should be packaged and stored correctly taking account of the OEM guidance
- The life and ageing effects should be evaluated and carefully managed, based on exposure and conditions
- All HEPA filters should be included within the EIMT schedule
- For filters that directly affect safety or environmental protection good practice would be an assessment of filter condition every 5 years
- Filters should be changed every 10 years, unless there is an ALARP justification for not doing so, eg Decommissioning

5.47 Further detailed guidance is contained within ES\_0\_1738\_1\_Issue 1 [Ref.6]

### **Building Ventilation**

- 5.48 The system should be sized to ensure the required airflow and depressions are achieved and maintained in normal, fault and accident situations. Each parameter should be justified to ensure that back-contamination does not occur through openings such as doors, engineered flow paths or glove box openings. Entrainment of any material being processed should be considered to ensure adequate precautions are taken to prevent deposition of solids in the ventilation ducts.
- 5.49 The in-leakage through uncontrolled openings (eg doors) should be minimised as this may reduce the efficiency of the ventilation systems. Some facilities may have a very high requirement for the minimisation of leakages and such facilities should have arrangements to warn if undue leakage occurs.
- 5.50 The pressure gradient should be from clean areas through to those with potentially contaminated conditions and the flow through openings between areas should be sized to prevent back contamination.
- 5.51 The ventilation system should be designed to ensure the appropriate radiological protection criteria are met and the different areas maintain their radiological classification. There should be clear statements as to how this is achieved and confirmed by suitable monitoring arrangements. The air flow should be such that the radiological protection conditions for each section of the plant are maintained. Such conditions should be specified in that part of the safety case dealing with radiological protection.
- 5.52 The ventilation systems serving incident control rooms should be capable of independently maintaining acceptable environmental conditions within the safety case set parameters if the main ventilation or electrical systems fail. Intakes for these systems should be located or protected from contamination such that they will not be affected by the accident / incident.
- 5.53 The level of redundancy and diversity required in the component parts of the ventilation system should be identified. Of particular importance is the ability of the system to resist internal and external hazards, fire being recognised as a major challenge to a ventilation system, and seismic effects should also be considered.
- 5.54 Expectation of system performance testing and validation, needs periodically to confirm the ventilation systems is meeting the design intent and assumptions are being maintained. Lock-off of adjustment dampers are necessary to prevent system performance alterations only detectable by a secondary air quality monitoring system.



## Fire Safety

- 5.55 The design and operation of the ventilation system plays an important part in the control of the consequences of a fire, both the regulatory requirement and the containment philosophies need to be determined. The problems created by the accident situation involving a fire, has no ideal solution, but the involvement of all stakeholders and subject matter experts will lead to a satisfactory compromise, and this should be considered from the concept phase in the design for the ventilation system.
- 5.56 Fire barriers and dampers will be part of the ventilation system design and be integrated into the building design for conventional fire safety with consideration of the following:
- Additional fire zones as a result of a Radiological Fire Safety assessment
  - System design to keep size and number of all penetrations in the fire barriers to a minimum
  - Where ductwork passes through a fire boundary (fire barrier) then a fire damper is required
  - Fire dampers should be type tested and certified by an approved authority in accordance with a recognised standard
  - The materials of construction of a fire damper should be suitable for the likely environment, eg corrosive
  - Fire dampers should be tested for correct operation; this may be conducted locally or from a control point giving indication of damper position
  - Fire dampers should be located allowing easy access for examination, inspection, maintenance and testing to be conducted

## Ventilation Stacks

- 5.57 Back-flow (flow-reversal) of gases exhausted from one part of a plant may affect safety of another if exhaust fans discharge into common ducts or stacks in normal, fault, and accident situations. In such circumstances consideration should be given to the provision of dedicated exhaust paths. Design of ventilation stacks should be undertaken with decommissioning in mind and should not present undue hazard to neighbouring facilities or people whilst being constructed, operated or dismantled.

## Ventilation Assessment

- 5.58 During the assessment of ventilation systems many factors have to be considered, the majority of which have their own specific standards and codes. The level of protection for each area will be determined by each factor's effect on safety and the risk such a factor poses to workers and others. The hazard and risk assessment prepared to justify the safety of the facility should clearly identify the particular operating conditions being maintained by the ventilation system in normal operation, fault, and accident situations. Suitable monitoring arrangements should be in place to ensure that safe conditions are being maintained.
- 5.59 Some of the factors which may arise in the assessment are:
- Inspectors should ensure that appropriate standards and codes of practice have been used for all parts of the ventilation system. Where computer codes are part of the safety arguments these should be verified and validated; a review of the particular code of practice or standard may be all that is

necessary to give the confidence that suitable provisions have been made, but a check on the accurate interpretation and implementation may also be necessary

- The materials of construction should be compatible with the materials being processed, any requirements for decontamination, decommissioning and any materials generated following fault conditions
- As with other equipment appropriate construction and installation codes and practices should be followed
- Adequate consideration should be given to the maintenance, testing, monitoring and inspection requirements of the total system in normal, accident and fault conditions
- The specification and supply chain management of ventilation structures, systems and components (SSCs) important to nuclear safety should be the subject of periodic review and quality assurance oversight
- Ventilation SSCs important to nuclear safety should be subject to arrangements preventing the supply chain from making changes to specification or materials of construction without authority

5.60 Existing nuclear ventilation systems should be assessed by the dutyholder periodically to confirm fitness for purpose. It is unlikely that anyone other than an engineer experienced in nuclear ventilation system design or commissioning could undertake such an assessment. The assessment should consider current running parameters, system deterioration and any plant modifications having the potential to change ventilation flows (typically, structural modifications could do this). The requirement for, extent of, and periodicity of such assessments should be commensurate with the safety significance of the ventilation system and should be identified by those experienced engineers as part of the safety case.

### **Electrical Supplies**

5.61 The electrical supply and control philosophy does not form part of this technical guidance; however the inspector should be aware of some of the control philosophies which may be adopted. Where redundant ventilation systems are provided each system should have been sized to carry the total load, have diverse routes and different supplies so far as is reasonably practicable. Threat to the normal mains supply should have been considered and if necessary an independent source of power provided (ie diesel standby generators). Furthermore, the safety case should consider the actions necessary after complete or partial power failure, to avoid spread of contamination due to adverse pressure gradients.

5.62 Ventilation systems should be instrumented and monitored to detect advantageous in-leakage and to ensure the appropriate volume flow rates and depressions are obtained and maintained. This matters equally to those areas where there is direct operator contact (eg glove boxes) and the important gas cleaning facilities such as filters, cyclones and scrubbers. The efficient operation of such devices will contribute to reducing doses and risks to workers and others to as low as reasonably practicable (ALARP) levels.

### **Operating Experience**

5.63 Effective utilisation of operational experience (OpEx) and the creation of a learning culture to drive continual improvement are widely recognised as a core part of a strong operational safety culture within the nuclear industry. The analysis of experience gained from operation of ventilation systems (including the investigation of incidents)

provides important opportunities to identify actions that dutyholders can take to improve containment safety through the use of the ventilation system.

5.64 In the process of assessing ventilation systems, OpEx historical detail provides areas for attention and consideration, some of which are listed below:

- The site's arrangements for through lifetime asset management and ageing management of ventilations systems
- The 'design intent' for the ventilation system is maintained over the lifetime of the facility
- Maintaining containment with multiple building and boundary penetrations
- The robustness of plant modification in delivering the changes safely and not introducing further fault sequences
- Reliability of the existing infrastructure to maintain an operating ventilation system, electrical power supplies, distribution and alternatives
- The integration of new 'modern' deigned equipment with existing legacy infrastructure, with particular attention to electrical and electronic plant
- Defects identified, being resolved in a timely manner and not remaining outstanding for long periods
- The ease of access and egress in the facilities and ventilation system design for examination, inspection, maintenance and testing to be conducted
- The arrangements for the management of HEPA filters including, periodic inspection and replacement on age, condition and performance
- Maintenance instructions to include and identify features critical to safety
- Identification and procurement of critical spares (eg duty/standby fans)
- Awareness/attendance of the national nuclear ventilation forum (ie nationally recognised guidance and OpEx)
- Consideration should be given to moisture ingress and corrosion from coastal atmospheric air and extreme weather conditions
- Consideration of incident control rooms (must still operate/be protected from contamination)

## 6. REFERENCES

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## 7. GLOSSARY AND ABBREVIATIONS

AECP	Atomic Energy Code of Practice
ALARP	As Low As Reasonably Practicable
DG	Design Guide
EA	Environment Agency
ECV	Engineering Containment and Ventilation
IAEA	International Atomic Energy Agency
IRR	Ionising Radiation Regulations
HEPA filter	High Efficiency Particulate Air filter
HSWA74	The Health and Safety at Work etc Act 1974
LC	Licence Condition
NNVF	National Nuclear Ventilation Forum
NRW	Natural Resources Wales
ONR	Office for Nuclear Regulation
SAP	Safety Assessment Principle(s)
SME	Subject Matter Experts
SEPA	Scottish Environment Protection Agency
SSC	Structure, System and Component
TAG	Technical Assessment Guide
VWG	Ventilation Working Group
WENRA	Western European Nuclear Regulators' Association