# Nuclear Ventilation Regulations and Standards in the UK

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## ABSTRACT

These notes give an introduction to the UK nuclear industry, a brief summary of the Sellafield site, the regulation of UK Nuclear Licensed Sites, the UK approach to the design of nuclear ventilation systems to comply with Regulator requirements; and the ongoing work of the National Nuclear Ventilation Forum in the continuous development of the UK nuclear industry ventilation Engineering Standards and Design Guides.

## INTRODUCTION

The design, fabrication, inspection, testing and operation of ventilation systems for nuclear facilities in the UK are controlled by a wide range of regulations, legislation, directives, guides and standards. These range from legal requirements placed upon Nuclear Licensed Sites by the UK Office for Nuclear Regulation (ONR) and the Environmental Agency (EA), UK legislation (or statutory law), European regulations, directives and harmonised standards, British Standards and International ISO Standards.

To comply with this broad range of requirements, the UK nuclear industry has written specific ventilation Design Guides and Engineering Standards. These consist of the top level UK good practice design guide for the ventilation of radiological facilities ES_0_1738_1, generic procurement specifications (Engineering Standards) for ventilation plant items in nuclear facilities, and plant item specific design guides (Engineering Guides) to complement those generic procurement specifications.

## THE UK NUCLEAR INDUSTRY [1]

The UK has 36 nuclear licensed sites. These 36 sites have installations which include: nuclear power stations (operational, decommissioning and under construction); research reactors being decommissioned; nuclear fuel manufacturing; uranium enrichment and isotope production facilities; nuclear fuel stores; nuclear fuel reprocessing facilities; sites for building, maintaining and refueling nuclear submarines; sites for building, maintaining and dismantling nuclear weapons; radioactive waste stores; and sites for both the storage and disposal of radioactive waste [1]. 8 of these sites still have operating nuclear reactors. There are 15 operational nuclear reactors across these 8 sites, which between them generate approximately 20% of the UK's electricity [2]. 14 of these operational reactors are gas cooled and 1 - the last nuclear power station to be built in the UK in 1995 – is a Pressurised Water Reactor located at Sizewell B.

EDF Energy is in the process of constructing 2 European Pressurised Water Reactors at Hinkley Point C, which will generate 3260MW of electricity. NuGen have plans to build a new generation nuclear power station at the Moorside site in Cumbria [3]. The Korea Electric Power Corporation (Kepco) has been identified as the preferred bidder for the acquisition of NuGen with the aim of building APR-1400 reactors on the site. Horizon Nuclear Power (wholly owned subsidiary of Hitachi Ltd) is planning to build 2 Advanced Boiling Water Reactor plants at Wylfa and Oldbury to provide 5400MW capacity [4].

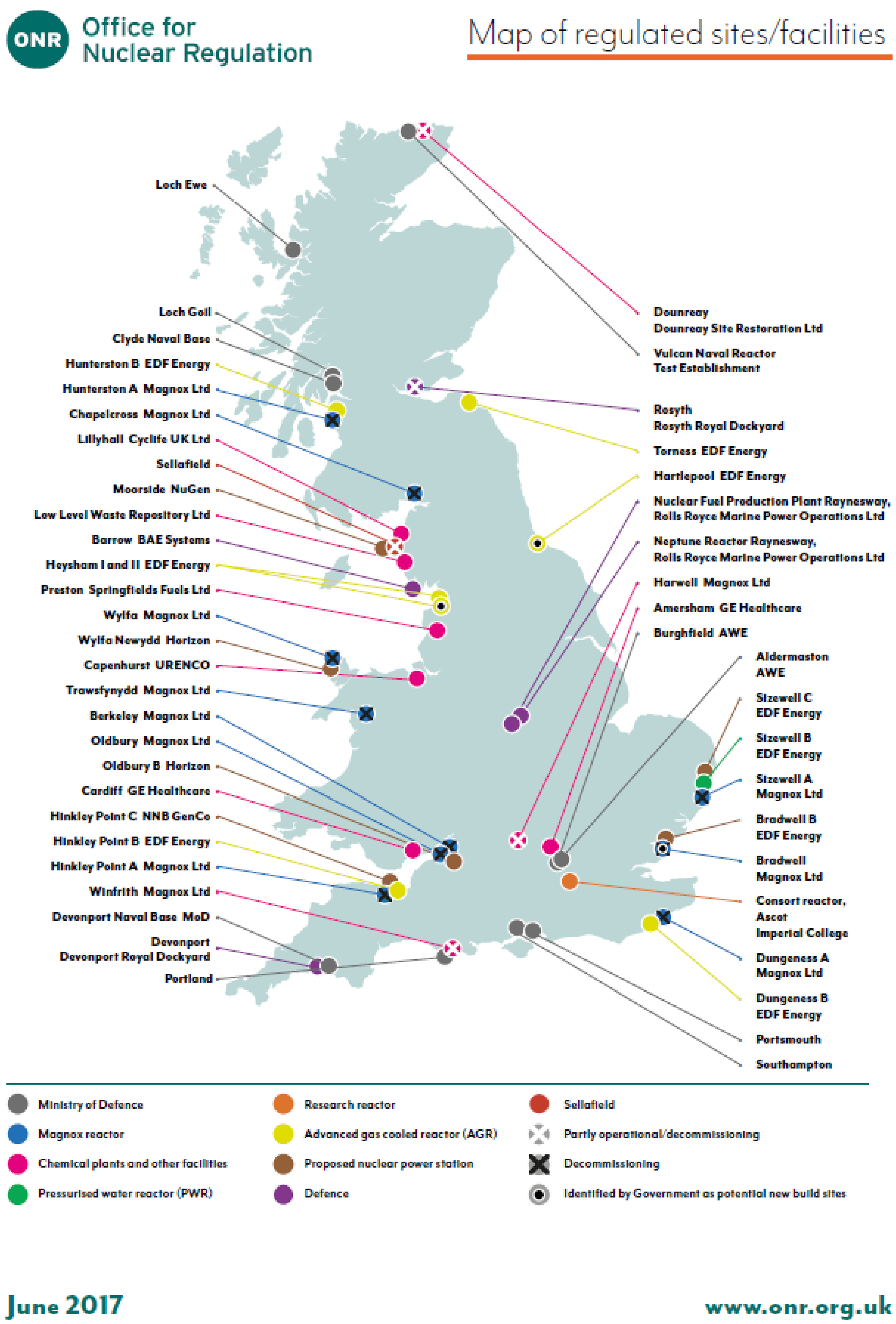


Figure 1 – Map of UK Nuclear Regulated Sites [5]

Many UK nuclear licensed sites are going through various stages of decommissioning and are under the ownership of the Nuclear Decommissioning Authority.

### Nuclear Decommissioning Authority [6]

The Nuclear Decommissioning Authority (NDA) own 17 of the UK nuclear licensed sites and are responsible for decommissioning and cleaning up these nuclear facilities. The NDA employs 16,000 people in 12 businesses across these 17 sites. The sites include the first generation of Magnox power stations, various research and fuel facilities; and the largest, most complex site, Sellafield. The NDA's programme of work in cleaning up the UK's nuclear legacy is the largest, most important environmental restoration programme in Europe.

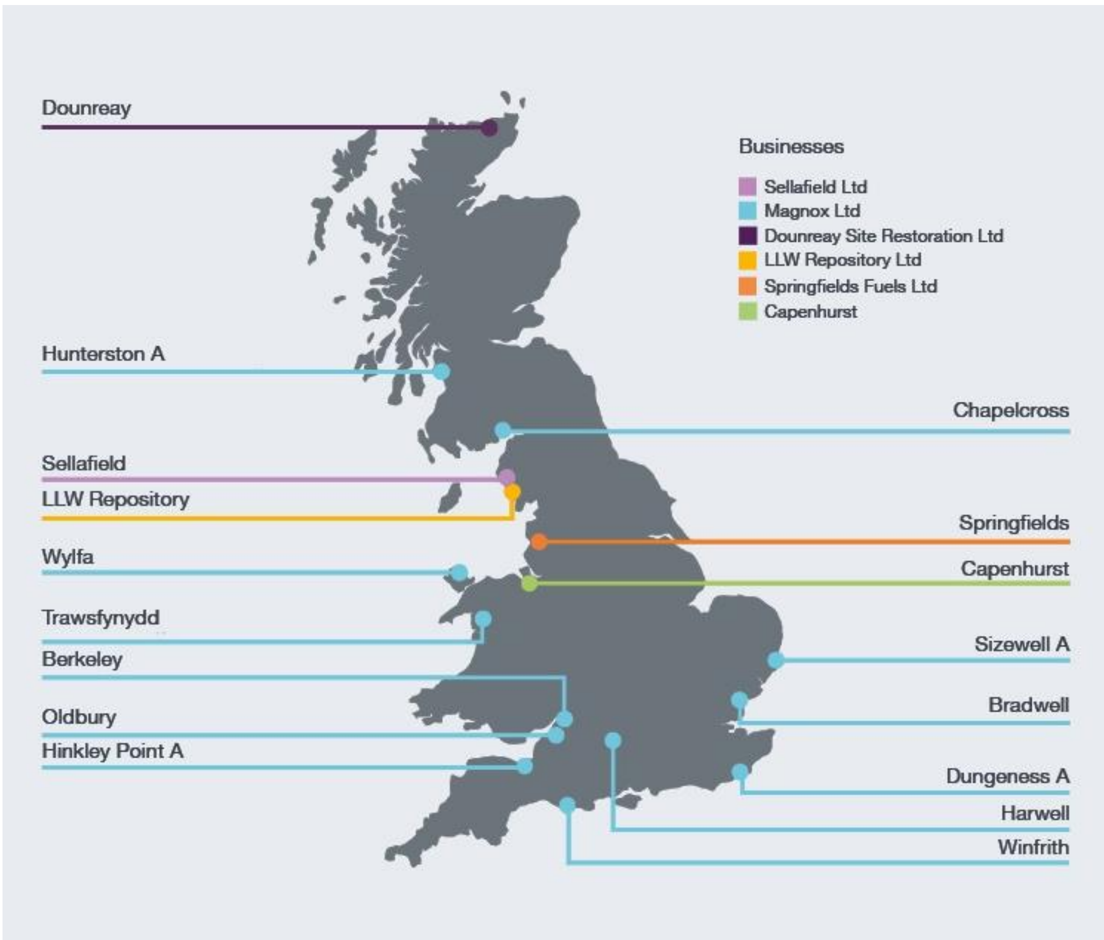


Figure 2 – UK Nuclear Decommissioning Authority Sites [6]

### Sellafield Site [6]

Sellafield is a 665 acre site with £2billion planned expenditure in 2018/19. The site is complex and at one time or another, has been home to just about every process within the nuclear fuel cycle. For over 50 years the site has been the home for nuclear reprocessing in the UK. The next few years however will see a huge transformation in the site's operations with the end of reprocessing on the site and the focus moving onto accelerated progress in decommissioning and hazard reduction. This transformation of the site will focus on 4 main key work themes or value streams: Site Retrievals; Special Nuclear Materials; Remediation; and Spent Fuel Management.

Figure 3 – Sellafield Site [6]

**Sellafield Site Retrievals [6]**

The areas of principal focus for site retrievals are the redundant Legacy Ponds and Silos facilities, which supported the development of the nuclear programme in the UK from the early 1950s. Latterly, they have supported the generation from the UK's fleet of Magnox power stations. The retrievals programme includes the removal of nuclear fuel, sludge and solid material which require the provision of equipment to retrieve the various wastes; and then treat and store them in passive conditions.

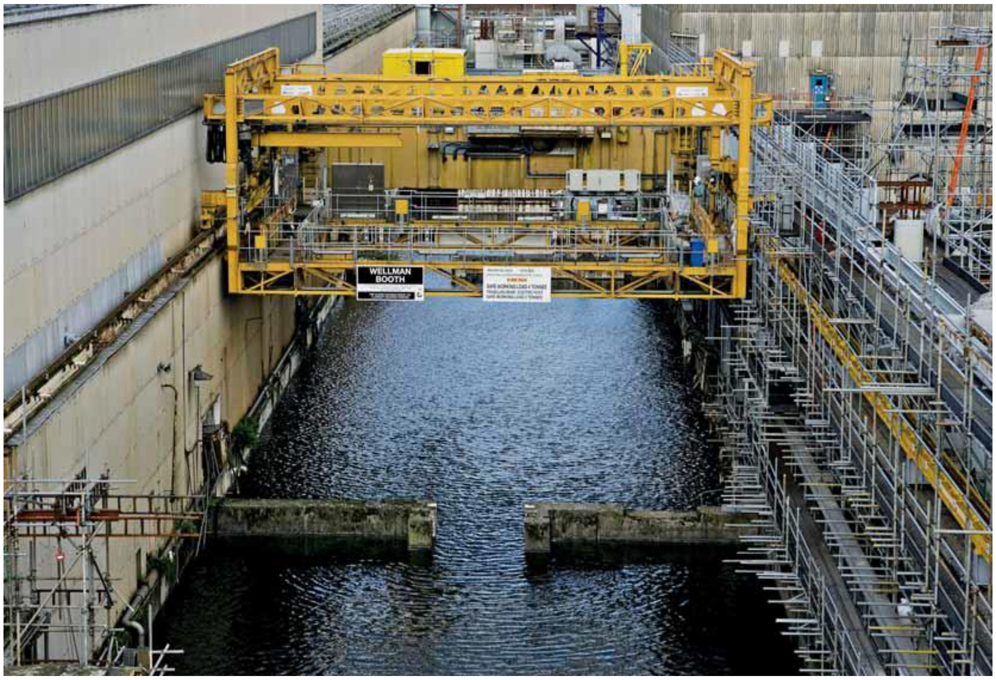


Figure 4 – Retrievals from legacy ponds on the Sellafield site [7]

**Sellafield Special Nuclear Materials [6]**

Sellafield is the custodian of the majority of the UK's stockpile of special nuclear materials which are held in safe and secure storage. Consolidation of materials is an ongoing activity and will continue to be part of the site's mission. The site has plants dedicated to the processing and packaging of these special nuclear materials into containers; and plants to store these containers in a safe and secure environment.

Figure 5 – Containers for Special Nuclear Materials

**Remediation on the Sellafield Site [6]**

Sellafield is the only nuclear site in the UK that can safely manage all three forms of radioactive waste; low, intermediate and high.

- Low level waste is compacted, sized reduced and loaded into purpose designed ISO freight containers. The containers are sent to the national Low Level Waste Repository for grouting and placing into concrete vaults designed for long term storage.

Figure 6 – Low level waste storage container [8]

- Intermediate level waste is mixed with a grout material in engineered stainless steel drums to form a solid, stable form. This makes it suitable for long-term storage and disposal.  The containers are placed in on-site purpose built Intermediate level waste stores and could eventually be stored in a long-term Geological Disposal Facility.

Figure 7 – Intermediate level waste storage containers [7]

- As a by-product of reprocessing on the site, 3% of the reprocessed fuel ends up as highly active waste. This waste is discharged from the reprocessing plants as liquor and sent to the Highly Active Liquor Evaporation and Storage The liquor is evaporated and stored in tanks within the facility. The concentrated Highly Active Liquor is then transferred to the Waste Vitrification Plant where it undergoes a vitrification process. High level waste is dried to a powder, mixed with glass and heated to form a molten mixture. This is then poured into stainless steel containers to solidify. The waste is then placed into a store before final disposal in the UK or return to its country of origin.

Figure 8 – High level vitrified waste storage container [7]

**Sellafield Spent Fuel Management [6]**

All of the spent fuels discharged from the operating UK's Advanced Gas-Cooled Reactor power stations and defueling Magnox power stations reactors are sent to Sellafield for management. In simple terms, reusable uranium (96%) and plutonium (1%) is separated from the high level waste (3%), allowing 97% of the used fuel to be recycled. The uranium is then made available to customers for the manufacture of new fuel. After more than 50 years of reprocessing at the site, the next few years will bring a number of landmark achievements at Sellafield as nuclear reprocessing on the site comes to an end as part of the site's decommissioning mission.

**Complete THORP Reprocessing in 2018 [6]**

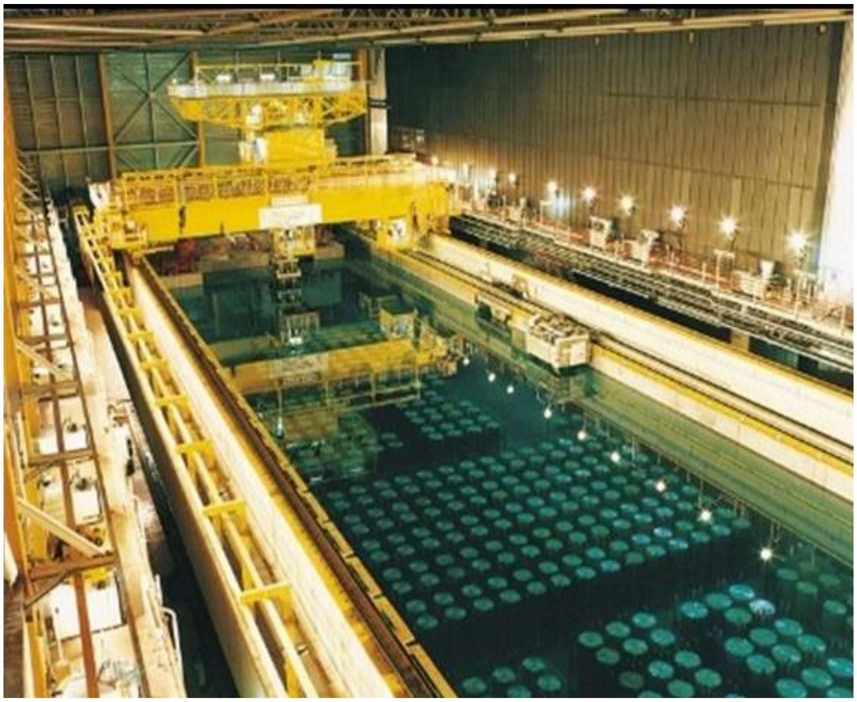

Figure 9 – Thermal Oxide Reprocessing Plant [7]

Sellafield's Thermal Oxide Reprocessing Plant (THORP) began reprocessing operations more than 20 years ago. THORP reprocesses the oxide fuels from EDF's power stations and overseas customers. The decision was taken in 2012 to close THORP in 2018, once reprocessing of the current contracts is complete.

To upgrade THORP and its support plants to allow it to continue running beyond 2018 was not considered to be cost effective. Future funding will therefore be directed towards work to decommission and remediate the site. When THORP stops operating, it will enter into a Post Operations Clean Out phase when the remaining radioactive and non-radioactive materials are removed prior to the commencement of facility dismantling and decommissioning. Not all of THORP will close in 2018. The receipt and storage pond will continue to receive and store the fuel from the UK's operational reactors for many years to come.

The end of reprocessing operations in THORP provides a clear transition point for Sellafield when the site will move from commercial operations to decommissioning and continued management of spent fuel and waste.

**Magnox Reprocessing Complete by End of 2020 [6]**

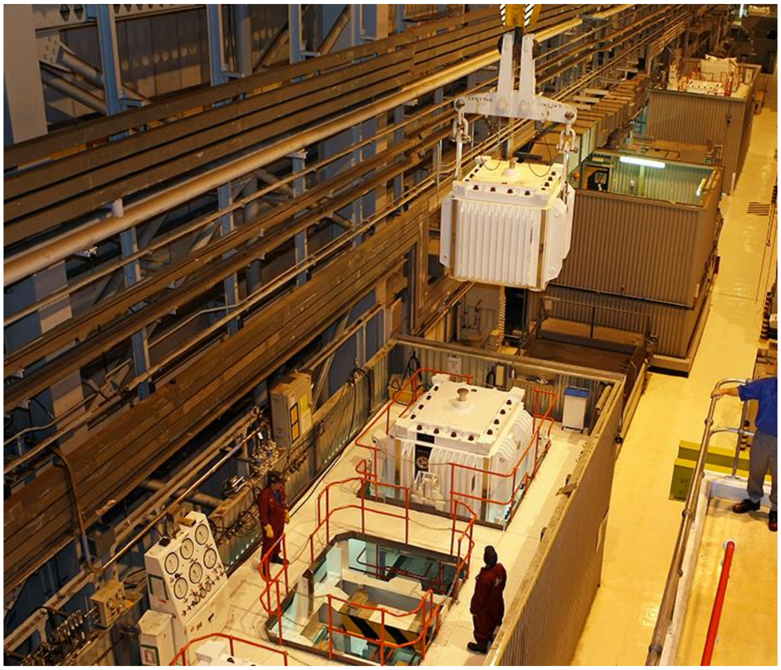

Figure 10 – Magnox Reprocessing [7]

The Magnox Reprocessing Plant began reprocessing fuel from Britain's early nuclear reactors in 1964. It is scheduled to complete its operations in 2020 once all of the Magnox fuel has been reprocessed. The closure is scheduled to follow the defueling of the final Magnox station, Calder Hall, in 2019. Like THORP, Magnox reprocessing relies on the availability of a number of ageing plants and support services across Sellafield.

## REGULATION OF UK NUCLEAR LICENSED SITES [1]

The Office for Nuclear Regulation (ONR) is the independent regulator of nuclear safety and security across the UK. ONR has responsibility for regulating safety and security at the 36 nuclear licensed sites in the UK.

### Nuclear Site Licence Conditions

The ONR publishes 36 standard licence conditions attached to nuclear site licences with which each nuclear site has to comply [9].

### ONR Safety Assessment Principles

ONR's inspectors use Safety Assessment Principles (SAPs) [1] to guide their regulatory judgements and recommendations when undertaking technical assessments of UK nuclear site licensees' safety submissions. Underpinning these is the legal duty on licensees to reduce risks so far as is reasonably practicable, and this informs the use of these SAPs.

### ONR Technical Assessment Guides

The SAPs are supported by Technical Assessment Guides [10] (TAGs) to further assist decision making within the nuclear safety regulatory process and, although they are not sufficient on their own to be used as design or operational standards, they may also provide guidance to designers and duty-holders on the appropriate content of safety cases.

### ONR Engineering Principles for Containment and Ventilation

The SAPs include a series of Engineering Principles, with Air Cleaning broadly covered by 10 specific Engineering Principles for Containment and Ventilation (ECVs). These ECVs are included in Appendix A of these notes and are supported by the Technical Assessment Guide (TAG) written specifically for Ventilation - NS-TAST-GD-022 [11]. Designers of ventilation systems in UK radiological facilities need to consider the ECVs, and for those appropriate to the specific plant design, ensure that the ventilation systems are configured to address these principles.

### The Environment Agency Regulations

The Environment Agency Radioactive Substances Regulation (RSR) Regulatory Environmental Principles (REPs) and permit conditions provide a basis for investigating management of assets at nuclear licensed sites. Technical Guidance documents are also written for nuclear regulators to support them in their role of assessing compliance of operators with permit conditions; and are equally useful to designers in sharing good practice, establishing the main design aspects of, for example, radioactive discharge monitoring systems, and meeting regulatory requirements [12].

### UK Law

Aside from Regulator requirements, which are specific to nuclear sites, there is also a significant amount of non-nuclear specific legislation which is also applicable to designers and operators of nuclear facilities in the UK.

The primary piece of legislation covering occupational health and safety in the UK is the Health and Safety at Work Act 1974; and under that are a number of other Acts and pieces of secondary legislation relevant to the working environment, which are made under specific Acts of Parliament. There are many examples of UK legislation which engineers need to be aware of such as Workplace Regulations, Supply of Machinery Regulations, Construction Design & Management Regulations, Construction Product Regulations, Fire Safety Regulations, Electrical Safety Regulations, Control of Noise Regulations, Building Regulations, etc, etc. In addition there are also a host of relevant European Regulations and directives which are mandatory in the UK.

### British, European and ISO standards

In addition to mandatory regulations, UK and European law, engineers responsible for the design of ventilation systems in nuclear facilities are also obliged to demonstrate that they are taking account of best practice. This involves the consideration of all relevant British Standards, European Standards and International ISO standards.

## COMPLYING WITH REGULATIONS

Engineers therefore need to comply with Regulator requirements, UK & EU law and take into account a whole host of other standards to demonstrate best practice. To comply with this broad range of requirements, the UK nuclear industry has written specific ventilation Design Guides and Engineering Standards. These consist of the top level UK good practice design guide for the ventilation of radiological facilities ES_0_1738_1 [13], generic procurement specifications (Engineering Standards) for ventilation plant items in nuclear facilities, and plant item specific design guides (Engineering Guides) to complement those generic procurement specifications.

### ES_0_1738_1 Ventilation Systems for Radiological Facilities Design Guide

The top level document ES_0_1738_1 is the UK standard for good practice for ventilation system design for radiologically controlled buildings. The document is continuing to be developed and evolved from previous UK nuclear ventilation design guides, the first of which was AECP 1054, first published in 1979. When ES_0_1738_1 was written in 2015 it was reviewed by the UK regulators. As part of that review, both the ONR and the Environment Agency have had input into the design guide; and so this top level document has the support of the UK regulators. The document is under periodic review and will be rebadged as EG_0_1738_1 later in 2018.

Since AECP 1054 was first published in 1979, the approach to sizing ventilation air flows in UK nuclear facilities has changed. AECP 1054 guidance was based on using the dilution principle as a basis for promoting increasing air change rates for areas which had increasing potential for airborne activity. Consequently ventilation air flows through nuclear facilities were very high. In addition, the areas with the greatest airborne contamination had the highest air change rates which led to increased potential for transferring contamination onto filters and an increase in aerial discharges.

In the late 1980's and 1990's, the air change rate method for determining air flow rates through a containment was reviewed and it was concluded that dilution of the airborne activity concentration within a containment was not a method which should be used for determining air flows. The concentration of airborne activity within an enclosure, that would make it an acceptable breathing zone, is so low to make it impractical to use ventilation to reduce the concentration of any airborne activity by an amount which would be significant in determining the radiological classification of that area; i.e. the ventilation flow rate through a primary containment will have an insignificant effect on the airborne activity level at the threshold where it can cause harm to people. Air change rates within a containment containing nuclear material, therefore, are not a method which should be used as a driver to determine air flow rates through that containment.

Current UK design guidance therefore based on ES_0_1738_1 does not specify minimum air change rates for different radiological area classifications. In areas of high potential airborne contamination, air flow rates should be the minimum required to meet the process requirements of the area and to maintain containment. Increasing the air flow rate above these minimum requirements could lead to greater entrainment of airborne activity into the exhaust air stream. Where filtration is not installed at the point of extract from the containment, this would then lead to a greater potential for accumulation of contamination on internal ductwork surfaces upstream of filters and increased activity on the filters. This could possibly lead to increased shielding requirements for ductwork and filter housings.

This approach has led to a vast reduction in the size of ventilation plant for modern UK nuclear facilities compared with those pre 1980's designed facilities.

**Nuclear Ventilation System Design Principles, Design Intent and Plant Hazards**

To comply with the ONR ECVs, ES_0_1738_1 emphasises that the nature of the Plant specific hazards must be understood to establish the design intent of ventilation systems for a nuclear facility. The hazards will relate to the physical and chemical properties of the nuclear material, the integrity of the primary containment in which the material is enclosed and any requirements to breach that containment. The mitigation of these hazards will be a key element in identifying the functional requirements and design objectives of the ventilation systems in support of preventing the loss of any of that material to the environment; and minimising the potential for contamination to spread outside of the containment.

Although preserving the containment of the nuclear materials will always be the ultimate aim, there may sometimes be hazards presenting a more immediate concern which can lead to different primary functional requirements. For example, high level waste or nuclear material, which generates heat, will have a cooling requirement; and it may be the case that, only on loss of that cooling, will the containment be challenged. Consequently, the cooling system, which will help preserve the engineered physical containment boundaries - rather than ventilation air flows to maintain containment depression - could well be the more immediate safety function. Similarly, waste streams from which hazardous gases are evolved may have a primary functional requirement to prevent the build-up of those gases from reaching a lower explosive limit, such that dilution, rather than containment, is the more immediate concern.

The differing functions and design objectives, of ventilation systems in nuclear facilities, are covered in ES_0_1738_1. These design objectives will, in all likelihood, include provisions to protect contamination spread, or migration of activity, from the source of nuclear material to the occupied areas utilising a series of containment barriers along with supporting ventilation systems. Multiple containment barriers and cascade ventilation air flows to support these containment barriers at weak points or breaches in these barriers is a key theme of ES_0_1738_1.

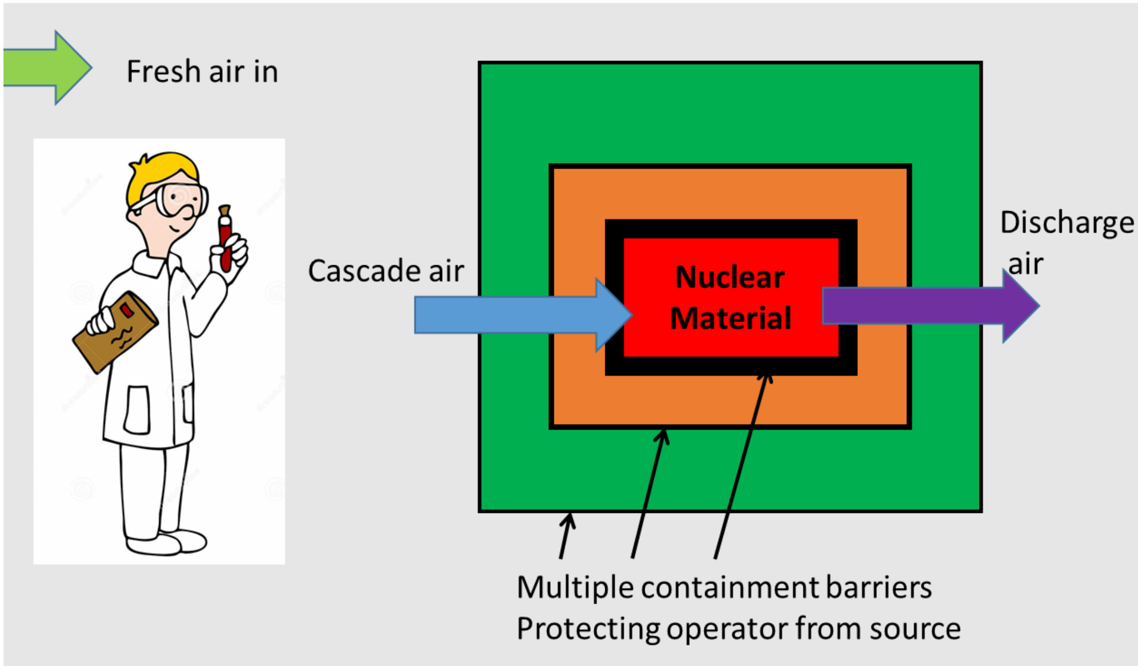


Figure 11 – Barriers protecting operator

**Consider the integrity of the containment around the nuclear material**

The location of the nuclear material within the facility and the robustness of the containment(s) which enclose the material in terms of preventing leakage of airborne particulate are key to the ventilation system designer. If the containment is sealed, the only threat of contamination spread may be due to degradation of the containment. Therefore, the preservation of the containment either through cooling or heating, to prevent condensation leading to surface corrosion, may be sufficient.

For containments with leakage paths or engineered breaches, ES_0_1738_1 gives a methodology for estimating design air flows for the building at concept design stage, starting with the most hazardous areas and working outwards against the ‘cascade’ flow of air; which is engineered to flow from areas of least contamination potential to areas of highest contamination potential. The method looks sequentially at flows required across each successive barrier away from the primary containment. Hence, for example an accessible room or enclosure classified as say C3 or AMBER area (based on potential for leakage of air borne contamination from the primary containment) will require an air flow into this enclosure (from an adjacent C2 ‘free breathing zone’ or GREEN classified area) sufficient to avoid any migration of activity, from the C3

AMBER enclosure into the C2 GREEN area, if such activity should leak out from the primary C5 RED containment.

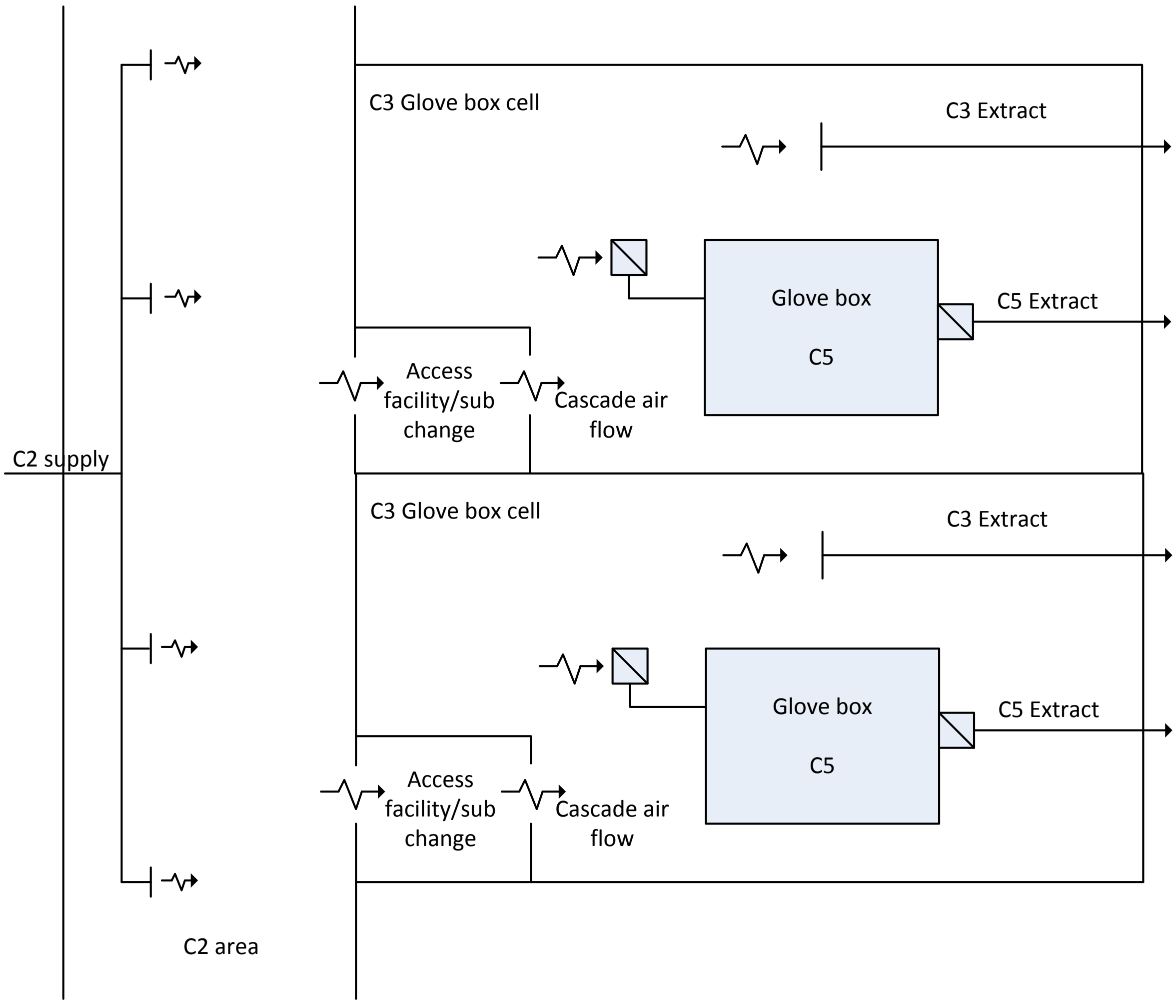


Figure 12 – Typical air flow cascade across multiple barriers

Normal practice for man entry points into this type of C3 AMBER classified enclosure (say a glovebox cell) would be an access facility, or sub-change room, with an engineered cascade of air through the sub-change room, from the C2 free breathing GREEN classified 'clean' entry side of the sub-change room to the C3 AMBER classified 'dirty' exit side; typically as depicted in Figure 12. Accepted 'containment' air flows for this arrangement is a minimum of 0.5m/s (100ft/min) across an open doorway on entry and exit.

**Notional flow diagram for a radiological facility**

Using this method of cascade flows a flow diagram for a hypothetical radiological building could be built up. Figure 13 is taken from ES_0_1738_1 [13] and gives a diagram covering many but not all ventilation sub-system configurations. It shows some major items of plant required, the direction in which air cascades from one radiological classified area to another, and typical supply and extract arrangements.

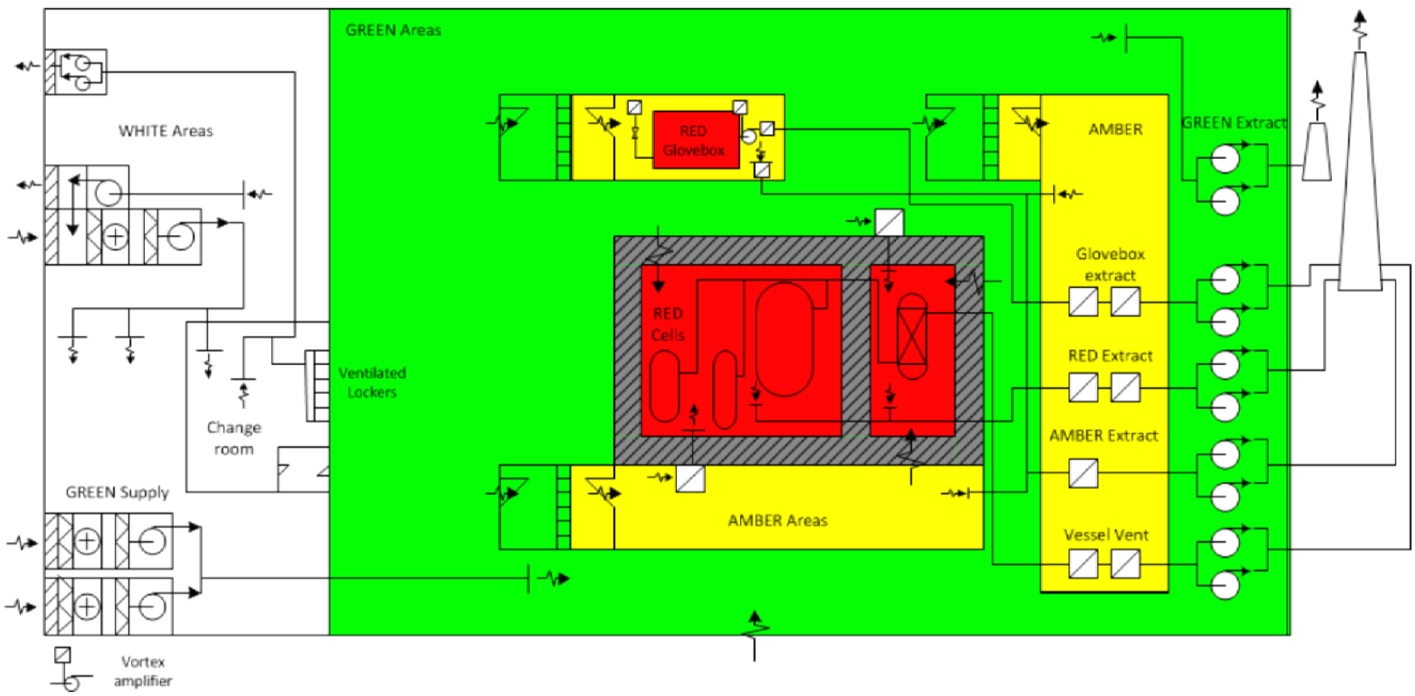


Figure 13 – Notional flow diagram for a radiological facility

The red areas would be the C5 classified areas containing the nuclear material. Although it would be unusual to have gloveboxes (i.e. alpha containments) as well as heavily shielded cells (i.e. beta gamma containments) in the same building, these are both shown to illustrate that alpha plants are normally fitted with an extra stage of HEPA filtration compared with beta gamma plants. Similarly beta gamma plants may have air streams giving off very high radiation doses and so may require shielded in-cell clean up plant.

In an alpha facility the discharge air from a C5 RED area glovebox suite would typically have terminal HEPA filtration and 2 further stages of HEPA filtration prior to the extract fans and stack discharge, with flow rates kept as low as possible.

Air discharges from process vessels within C5 RED area shielded cells could require in-cell clean-up (if the discharge air is high in activity) and 2 stages of HEPA filtration prior to the extract fans and stack discharge. Flow rates on a vessel vent system are kept as low as possible, usually to account for gaseous arisings in the vessels or purge air to the vessels. Air discharges from C5 RED area shielded cells may require in-cell clean up, if the air borne activity in the cell gives off high radiation doses and 2 stages of HEPA filtration prior to the extract fans and stack discharge. Flow rates on C5 RED area cell systems are kept as low as possible, normally governed by cell heat gains or cell leakage.

Flow rates through the C3 AMBER areas are normally dictated by the magnitude of the flow required to be cascaded into the C5 RED area containment and with the engineered cascade of air through the sub-change room or entry facility from the adjacent C2 GREEN classified area.

As this entry flow based on a minimum of 0.5m/s (100ft/min) across an open doorway on entry and exit is relatively high - around 800l/s (1700cfm) - and the cascade flow into the C5 RED area containment is kept as low as possible, there is often a need for a dedicated extract system from the C3 AMBER areas to remove the balance of air between that flowing in across the entry sub-change room and that being cascaded into the C5 RED area containments. This is more prevalent on an alpha or glovebox facility where C5 RED area glovebox flow rates are very low, but not so much on buildings which have large shielded cells where C5 RED area flow rates can be higher to take into account cell fabric leakage.

Air extracted from the C3 AMBER areas would generally have a single stage of HEPA filtration for a beta gamma plant and 2 stages of HEPA filtration in an alpha plant. The reason for this extra stage of filtration in an alpha plant relates to the nature of alpha sources which can often be powdery and can become readily airborne; and the increased harm potential from the ingestion of very tiny doses of that airborne alpha activity.

If mechanical extract ventilation is required from the C2 GREEN area, for beta gamma plants, which have low potential for airborne contamination, they would normally be considered as clean and would not require any discharge HEPA filtration. For an alpha Plant, due to the increased harm potential of airborne alpha activity, C2 GREEN extracts would typically have a single stage of HEPA filtration.

## THE HISTORY OF UK GUIDES AND STANDARDS FOR NUCLEAR VENTILATION SYSTEMS

### United Kingdom Atomic Energy Authority

The UK Atomic Energy Authority (UKAEA) was responsible for producing Nuclear Industry standards from the 1960s to the 1990s. These Atomic Energy Standard Specifications (AESS's) included standards for the specification of ventilation ductwork AESS 6008 Parts 1 to 3; and AESS 6019 for the specification of fans.

Along with a number of UK Nuclear Site Licensees, the UKAEA formed the Filter Development and Standards Working Party (FDSWP) who were responsible for the production of AESS purchasing specifications for HEPA filters. To meet the requirements of the HEPA filter purchasing specifications, filters had to be Type Approved. Type Approval of HEPA filters was carried out at the Atomic Energy Research Establishment Harwell laboratory. Filter developments were coordinated by the Nuclear Industry wide FDSWP and the Containment and Ventilation Treatment Working Party (CVTWP). Both of these committees and the filter testing service at Harwell were closed down in the early to mid-1990s. As the type testing facility, as written into the AESS filter specifications no longer existed, type approval of HEPA filters supplied to UK sites had time expired by approximately 2000.

An Atomic Energy Code of Practice AECP 1054 was published in June 1979 to be used throughout the UK Nuclear Industry as an aid to designing ventilation systems for radiological facilities. The Code of Practice was prepared by the Working Party – AECP 1054 'Ventilation of Radioactive Areas' – comprising members from the UKAEA and other UK Nuclear Site Licensees.

Following the break-up of the UKAEA and the demise of the cross industry FDSWP and CVTWP committees in the 1990s, collaboration between the various UK Nuclear Site Licensees was much reduced and some of the licensed sites produced their own versions of the standards.

## Institution of Mechanical Engineers Nuclear Ventilation Seminars

The loss of the UKAEA and the cross industry FDSWP and CVTWP committees inevitably led to a period of reduced dialogue and knowledge sharing in the nuclear ventilation discipline between the UK site licensees. In the late 1990's the lack of cross industry education and training specifically in the area of nuclear ventilation was recognised, and The Nuclear Power Committee of the Institute of Mechanical Engineers (IMechE) arranged for a ventilation seminar to be held in 2000 organised by a group made up from BNFL and Nuclear Installations Inspectorate (now the ONR). The one day event focused on raising the level of awareness of ventilation issues across the nuclear industry.

Subsequent seminars held in 2002 and 2005 became 2 day events with more wide ranging ventilation topics and case studies presented. The audience was looking for more up to date UK industry wide guidance on the design of ventilation systems for nuclear facilities as the last issue of AECP 1054 had been published in 1989. From the 2005 seminar, a cross industry group started to update AECP 1054 and this group evolved into the National Nuclear Ventilation Forum (NNVF). The IMechE Seminars continue to be held every 2 years, with the last event held in November 2017, to provide education, learning and knowledge share across the UK nuclear ventilation community.

## National Nuclear Ventilation Forum

The UK National Nuclear Ventilation Forum (NNVF) meets 3 times per year to discuss and document good practices relating to nuclear ventilation. The forum is open to representatives from all UK nuclear ventilation industry companies. The Ventilation Working Group (VWG) is for Site licensees and Regulators to discuss the implementation of ventilation practice on licensed sites. The VWG guide the NNVF work programme and endorse documentation.

The NNVF is a sub-group of the Nuclear Engineering Directors Forum. The Strategic priorities of the Nuclear Engineering Directors Forum are Standards, Asset & Ageing Management and Skills. To this end, the NNVF has taken an active role in the production and update of UK Nuclear Industry Guides and Standards. Although Sellafield Ltd is responsible for producing and maintaining the UK Engineering Standards and Guides on behalf of the UK Nuclear Decommissioning Authority, it does so through collaboration with and input from the NNVF. Hence, from 2014 all ventilation Engineering Standards and Guides have been reviewed and updated through the National Nuclear Ventilation Forum (NNVF).

Input into the Engineering Standards and Guides from site licensees and the supply chain has aimed to improve the standards, feed Learning From Experience (LFE) into updates of the standards, and establish them as UK common Nuclear Industry standards, which provides clarity for plant manufacturers if they can manufacture plant items to the same standard irrespective for which UK Nuclear Licensed site the plant item is specified.

## WHY ARE UK NUCLEAR INDUSTRY SPECIFIC GUIDES AND STANDARDS REQUIRED?

Many nuclear facilities cost hundreds of millions of pounds, or sometimes billions of pounds, to construct. To get a return on the investment and because of the high cost to replace these facilities, operating lives can be relatively long; 50 years plus in some cases. It is not uncommon for nuclear facilities to be operated well in excess of their original design lives. To replace worn out plant items it will be impractical to shut down the facility, purely to allow that plant item to be replaced, and sometimes the installation of temporary systems may be required whilst the plant item is being taken off line and replaced; so the replacement costs can often be many times the actual purchase cost of the plant item itself.

Typically when taking into account the associated design costs, project planning work, modifications to interfacing systems, the lengthy process and the many procedures that are required to be followed on a Nuclear Licensed Site to modify or replace a plant item that may have a role in providing a Safety Function, then the overall costs can run into the millions of pounds to replace a piece of plant with a purchase cost of say in the tens of thousands. Hence, overall replacement costs of worn out plant items in nuclear facilities can be vastly disproportionate to the basic purchase cost of that plant item.

A building with an operating life of say 50 years may require ventilation plant to remain operational through Post Operational Clean Out (POCO) and through part of the potentially lengthy decommissioning period. Consequently the facility ventilation systems may need to function for 60 to 70 years.

A standard Commercial off-the Shelf (COTS) ventilation plant item may need to be replaced every 15 to 20 years, or less if it was operating with air streams in a corrosive coastal environment. Consequently COTS plant items may need to be replaced up to 3 times during the overall life of a nuclear facility. Compared with that, there are examples of fans on the Sellafield site that have been operating in excess of 50 years; evidence that plant items specified with a more robust construction can last well beyond the design life of COTS plant. As a result those disproportionate replacement costs can be reduced significantly; and in the long term, this could reduce overall life cycle costs for a facility by a considerable margin.

There are also plant integrity issues to be considered for ventilation systems which move potentially contaminated air. In such cases, those systems have to be virtually leak tight to ensure that airborne contamination cannot leak out. Plant Procurement standards are therefore required to specify plant, which is more robust and of higher integrity than standard COTS plant. Sellafield Ltd policy is to use British Standards, International Standards or other relevant

National Standards wherever possible. Generally there are often no appropriate BS/EN or ISO stds which fully satisfy those needs, which is why a specific Engineering Standard is required. Those recognised standards are not ignored, however, as the Engineering Standards refer out to many BS, EN or ISO standards, and other industry standards, for the specification of materials, components, fabrication methods and testing. Consequently, BS, EN, ISO and other industry standards are specified where appropriate.

The Office for Nuclear Regulation (ONR) Technical Assessment Guide NS-TAST-GD-077 'Supply Chain Management Arrangements for the Procurement of Nuclear Safety Related Items or Services' [10] includes a section on mitigating measures to be deployed to reduce the risk of Counterfeit, Fraudulent and Suspect Items (CFSI) being deployed on a Nuclear Licensed Site. Those measures include robust Supply Chain Management (SCM) and procurement process arrangements including effective Supply Chain oversight and assurance, including inspection and testing. The 2018 revisions of the Engineering Standards will include Master Inspection and Test Plans and documentation requirements such that the appropriate oversight and assurance arrangements can be specified by the designer in the defence against CFSI.

## CURRENT STATUS OF UK GUIDES AND STANDARDS FOR NUCLEAR VENTILATION SYSTEMS

Below the top level document ES_0_1738_1 are NDA Ventilation Engineering Standards and NDA Ventilation Engineering Guides.

### NDA Ventilation Engineering Standards

NDA Ventilation Engineering Standards are Generic Procurement Specifications for the main ventilation Plant Items, which are procured for nuclear ventilation systems. There are 10 Engineering Standards [14] which cover ventilation plant item procurement. The standards generally follow the same form, with the bulk of the document a generic technical specification for that plant item. At the back of each standard are Technical Information Sheets, Part A of which is completed by the designer, to specify the plant specific requirements for each Plant Item.

Part B of the Technical Information Sheets is for the Plant Item manufacturer to complete and return with the Tender. The purpose of this is to demonstrate to the designer that, prior to placing an order, the manufacturer has fully understood what is required and so can submit a compliant tender. All Engineering Standards start with the ES pre-fix, where ES denotes Engineering Standard and contain a 4 digit 1700 series number with all of the ventilation engineering standards within the series ranging from 1701 to 1738.

### NDA Ventilation Engineering Guides

NDA Ventilation Engineering Guides [15] provide background information to the designer on the related Engineering Standards to explain some of the reasoning behind why the standards specify certain criteria. The guides are also intended to help the designer to complete the Technical Information Sheets in the back of the Engineering Standards for Plant Procurement.

Virtually all of the Engineering Standards, with the exception of the HEPA filters, have a related Engineering guide generally with the same 4 digit 1700 series number, but with an EG pre-fix rather than an ES pre-fix. There are 8 Engineering Guides, which cover the main ventilation plant items.

**NNVF Guidance documents**

The UK industry also has several useful guidance documents, relating to ventilation systems, which are available on the National Nuclear Ventilation Forum (NNVF) & Ventilation Working Group (VWG) web page http://www.nuclearinst.com/NNVF-VWG.

## UK HEPA FILTER STANDARDS

With the disbanding of the cross industry Filter Development and Standards Working Party and the closure of the filter testing service at Harwell in the early to mid-1990s, the UK AESS HEPA filter standards were no longer maintained and type approval of HEPA filters supplied to UK sites no longer carried out.

This lead in 2013 to a review, carried out by the Health and Safety Laboratory, of the adequacy of HEPA filters manufactured for use in the UK's Nuclear Industry. The review established that whilst the overall quality of HEPA filter manufacture for the nuclear sector was high, there were concerns around the reliance upon standards which have not been revised for over 20 years. As a result the AESS HEPA filter standards were updated and replaced by Engineering Standards.

An NNVF filter sub-group was formed with representatives from site licensees and filter manufacturers to improve the standards, feed LFE back into updates of the standards and establish them as new UK Nuclear Industry filter standards. In addition HEPA filter Type Testing has now been re-established in the UK with filter manufacturers responsible for commissioning type testing of their own filters.

There are now 9 Engineering Standards covering HEPA filters [16], filter media and type testing. These cover the conventional 850l/s (1800cfm) rectangular filters, used on legacy plants, the 950l/s (2000cfm) radial flow filters used on modern plants, push through glovebox filters, canister filters, screw on filters and spark arrestors (see Figures 14 to 16).

All of the UK HEPA filter Engineering Standards are based on the use of filter media which complies with ASME AG-1; and with some additional production tests on the media covering bursting strength and media stiffness. The media qualification testing requirements are the same as ASME AG-1. The standards require that all HEPA filters are production tested for air flow resistance and efficiency. In addition the Type Testing Standard ES_0_1705_2 requires every type of HEPA filter to be tested at 5 yearly intervals. These type tests cover efficiency, pressure drop, dust loading, performance testing after oven heating and pleated media tensile strength testing.

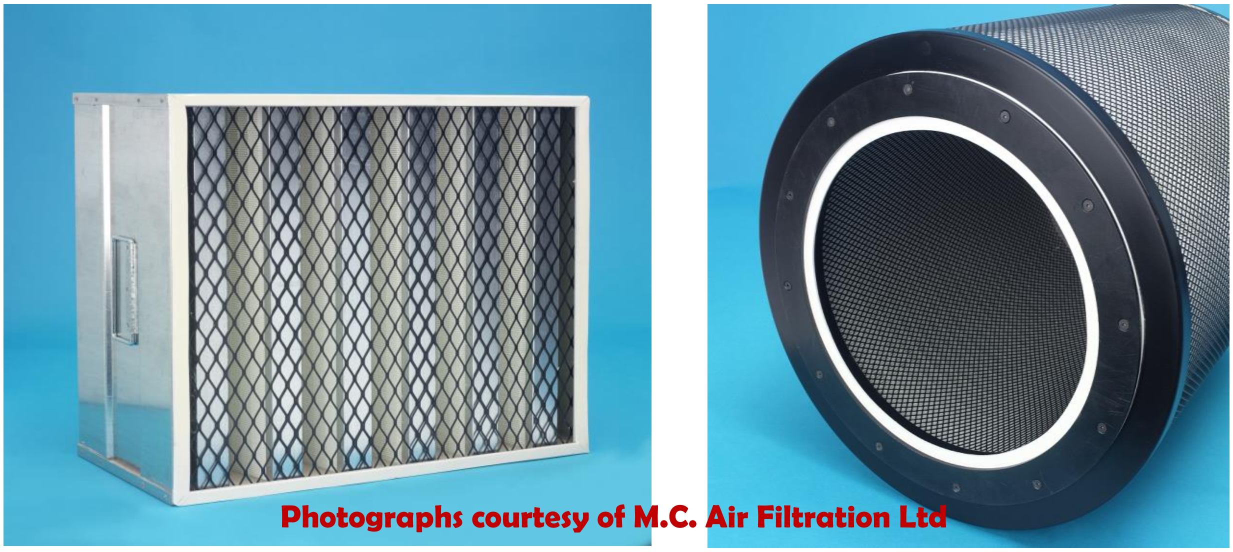


Figure 14 – Rectangular and cylindrical HEPA filters to ES_0_1731_2 & ES_0_1737_2

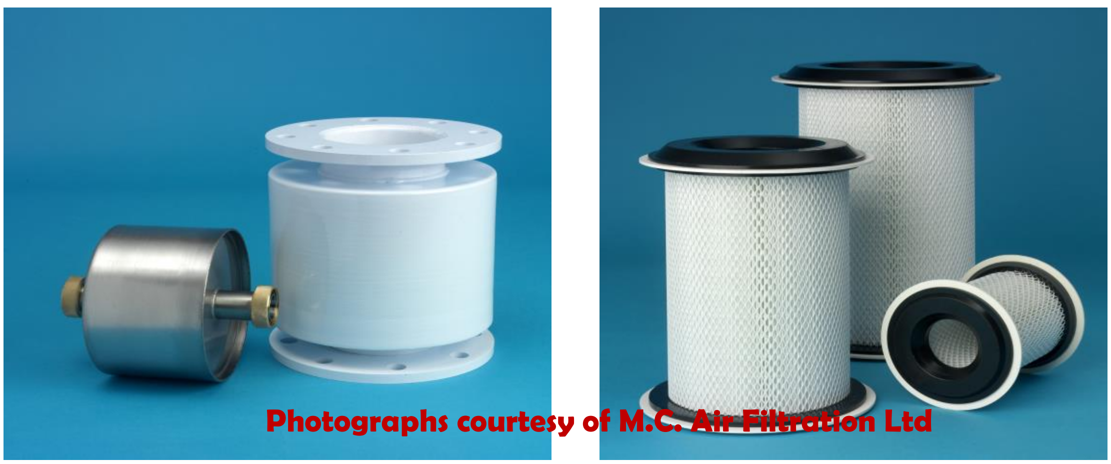


Figure 15 – Canister and push-through HEPA filters to ES_0_1733_2 & ES_0_1735_2


Figure 16 – Screw on HEPA filters to ES_0_1734_2

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    - ES_0_1704_2 Procurement Specification for attenuators in ventilation systems
    - ES_0_1708_2 Procurement Specification for Air Handling Units
    - ES_0_1709_2 Procurement Specification for Type “A” centrifugal and axial fans for air handling units and low integrity ventilation systems
    - ES_0_17010_2 Procurement Specification for Type “B” and “D” centrifugal fans for process and high integrity ventilation systems
    - ES_0_1711_2 Procurement Specification for filter housings for 950l/s & 470l/s circular plug-in HEPA filters
    - ES_0_1715_2 Manufacture of ventilation dampers
    - ES_0_1721_2 Procurement Specification for low integrity sheet metal ventilation ductwork
    - ES_0_1722_2 Procurement Specification for high integrity mild steel ventilation ductwork
    - ES_0_1723_2 Procurement Specification for high integrity stainless steel ventilation ductwork
15. Ventilation Plant Item Engineering Guides: -
    - EG_0_1701_1 Design Guide for the Specification of Coils in Ventilation Systems
    - EG_0_1704_1 Design Guide for the Specification of attenuators and acoustic insulation in ventilation systems
    - EG_0_1708_1 Design Guide for the Specification of Air Handling Units

- EG_0_1709_1 Design Guide for Type “A” centrifugal and axial Fans for air handling units and low integrity Ventilation systems
- EG_0_1710_1 Design Guide for Type “B” and “D” centrifugal fans for process and high integrity ventilation systems
- EG_0_1711_1 Design Guide for filter housings for 950l/s & 470l/s circular plug-in HEPA filters
- EG_0_1715_1 Design guide for ventilation dampers
- EG_0_1720_1 Design Guide for Ventilation Ductwork

16. HEPA Filter Engineering Standards: -
    - ES_0_1705_2 Type Testing and Approval of High Efficiency Particulate Air (HEPA) Filters
    - ES_0_1730_2 Procurement Specification for HEPA Filter media
    - ES_0_1731_2 Procurement Specification for rectangular mini pleat 550/850l/s capacity HEPA filter inserts
    - ES_0_1732_2 Procurement Specification for rectangular deep pleat 100 - 500l/s capacity HEPA filter inserts
    - ES_0_1733_2 Procurement Specification for HEPA Canister Filters 5, 25 and 50 l/s capacities
    - ES_0_1734_2 Procurement Specification for screw mounting 3 and 6l/s capacity HEPA filters
    - ES_0_1735_2 Procurement Specification for circular push-through 12.5 to 160l/s capacity HEPA filters
    - ES_0_1736_2 Procurement Specification for Spark arrestors
    - ES_0_1737_2 Procurement Specification for circular plug-in 470 and 950l/s capacity HEPA filter inserts

## APPENDIX A - ONR Safety Assessment Principles relating to Containment and Ventilation

The following Engineering Principles for Containment and Ventilation are as listed in the ONR Safety Assessment Principles for Nuclear Facilities 2014 Edition: -

<table>
<tr><td>Engineering principles: containment and ventilation: containment design</td><td>Prevention of leakage</td><td>ECV.1</td></tr>
<tr><td colspan="3">Radioactive material should be contained and the generation of radioactive waste through the spread of contamination by leakage should be prevented.</td></tr>
<tr><td>Engineering principles: containment and ventilation: containment design</td><td>Minimisation of releases</td><td>ECV.2</td></tr>
<tr><td colspan="3">Containment and associated systems should be designed to minimise radioactive releases to the environment in normal operation, fault and accident conditions.</td></tr>
<tr><td>Engineering principles: containment and ventilation: containment design</td><td>Means of confinement</td><td>ECV.3</td></tr>
<tr><td colspan="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.</td></tr>
<tr><td>Engineering principles: containment and ventilation: containment design</td><td>Provision of further containment barriers</td><td>ECV.4</td></tr>
<tr><td colspan="3">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.</td></tr>
<tr><td>Engineering principles: containment and ventilation: containment design</td><td>Minimisation of personnel access</td><td>ECV.5</td></tr>
<tr><td colspan="3">The need for access by personnel to the containment should be minimised.</td></tr>
<tr><td>Engineering principles: containment and ventilation: containment monitoring</td><td>Monitoring devices</td><td>ECV.6</td></tr>
<tr><td colspan="3">Suitable and sufficient monitoring devices with alarms should be provided to detect and assess changes in the materials and substances held within the containment.</td></tr>
<tr><td>Engineering principles: containment and ventilation: containment monitoring</td><td>Leakage monitoring</td><td>ECV.7</td></tr>
<tr><td colspan="3">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.</td></tr>
<tr><td>Engineering principles: containment and ventilation: import and export of nuclear material</td><td>Minimisation of provisions for import or export of materials or equipment</td><td>ECV.8</td></tr>
<tr><td colspan="3">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.</td></tr>
<tr><td>Engineering principles: containment and ventilation: import and export of nuclear material</td><td>Containment and ventilation system design</td><td>ECV.9</td></tr>
</table>

| | | |
|---|---|---|
| The design should ensure that controls on fissile content, radiation levels, and overall containment and ventilation standards are suitable and sufficient. | | |
| **Engineering principles: containment and ventilation: ventilation design** | Ventilation system safety functions | 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. | | |