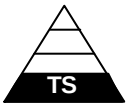

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DOE HANDBOOK

NUCLEAR AIR CLEANING HANDBOOK

U.S. Department of Energy
Washington, DC 20585

INTRODUCTION

The 4th edition of the Nuclear Air Cleaning Handbook succeeds three previous editions: ERDA 76-21, *Nuclear Air Cleaning Handbook* (1976); ORNL/NSIC-65, *Design, Construction and Testing of High-Efficiency Air Filtration Systems for Nuclear Applications* (1970); and NSIC-13, *Filters, Sorbents, and Air Cleaning Systems as Engineered Safeguards in Nuclear Installations* (1966). It benefits from over 25 years of industry experience since the previous edition was published.

Along with U.S. Nuclear Regulatory Commission documents and consensus standards such as the American Society of Mechanical Engineers (ASME) *Code On Nuclear Air and Gas Treatment* (ASME AG-1), this handbook addresses systems and equipment used in nuclear facilities to capture and control radioactive aerosols and gases. It differs from other documents in that it is intended to be specific for U.S. Department of Energy (DOE) and National Nuclear Security Administration (NNSA) nuclear applications. This handbook is not intended for application to commercial systems other than for general historical information and discussions of basic air cleaning theory. DOE handbooks are nonmandatory documents unless invoked by DOE policy or Order, DOE-approved contractor document, or by contract.

This revision updates the information provided in ERDA 76-21 and incorporates current thinking as provided by manufacturers, subject matter experts from the DOE complex and members of the ASME Committee on Nuclear Air and Gas Treatment (ASME AG-1 Committee). Chapters have been added on History, Fire Protection, and Occupational Safety and Health.

This handbook draws from many special technical areas, each of which requires years of education and practice to master. The authors do not intend to make the reader an "instant expert" in the overall subject or in any of the disciplines of the contributors. For example, reading the chapter on fire protection will not make the reader a fire protection engineer, nor will reading the chapter on gloveboxes make one a glovebox expert. This handbook is intended to provide a very brief overview of the subjects discussed and identify potential issues. Qualified subject matter experts should be contacted for the areas discussed in this handbook.

While this handbook is written for nuclear applications, it is recognized that these systems have shared engineering characteristics that may, with professional discretion exercised by trained engineering and public health professionals, be applicable to nonradiological toxic materials. Such materials include, but are not limited to, asbestos and other particulate carcinogens, beryllium, and biological agents.

We would like to acknowledge the contributions of Humphrey Gilbert, who from the days of the Manhattan Project, was responsible for the initial development of the technology discussed in this handbook. He played a significant role in the development, writing, and technical review of this and previous editions. We wish to express our appreciation to Melvin First, Harvard School of Public Health, who provided a draft that was used in the development of this document; and to Richard C. Crowe, Department Manager for Environment, Safety, and Health (NNSA Service Center), without whose continued support this handbook would not have been possible.

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FOREWORD

TO
THIRD EDITION
(ERDA 76-21)

This handbook is a revision of ORNL/NSIC-65, *Design, Construction, and Testing of High-Efficiency Air Filtration Systems for Nuclear Application*, which was issued in January 1970. For simplification, the title has been shortened to *Nuclear Air Cleaning Handbook*, and the report has been issued under an ERDA number.

The new edition updates the information of the original volume, corrects some errors that appeared in it, and adds some new material, particularly in the areas of sand filters, deep-bed glass fiber filters, and requirements for plutonium and reprocessing plants. Although A. B. Fuller was unable to contribute directly to this edition, his earlier material on single-filter installation and glove boxes has been largely retained, though rewritten and updated. With this issue, J. E. Kahn of the Union Carbide Corporation Nuclear Division's (UCCND) Engineering staff joins the writing team, contributing particularly in updating the material on glove boxes and writing the sections on sand filters and deep-bed glass fiber filters in Chapter 9. Others who have contributed to this edition include J. C. Little, UCCND Engineering, and a host of reviewers who provided technical evaluation of the draft. Particular thanks are due Dr. M. W. First of the Harvard University School of Public Health, and Mr. Humphrey Gilbert, consultant to the Energy Research and Development Administration (ERDA) and the Nuclear Regulatory Commission (NRC) and former safety engineer with the U.S. Atomic Energy Commission, for their detailed and thorough review of the complete draft. Others who reviewed the complete draft were J. F. Fish, chairman of ANSI Committee N45-8; J. C. Little, UCCND Engineering; J. C. Dempsey, ERDA Division of Nuclear Fuel Cycle and Production; A. B. Fuller, president of Fuller Engineering; and J. T. Collins of NRC. Thanks are also due to the members of ANSI Committee N45-8 who, perhaps unknowingly, supplied certain data and served as a sounding board for some of the concepts presented in the handbook. We wish to thank the many vendors and ERDA contractors who supplied drawings and photographs used in the book. We also acknowledge the work of Oak Ridge National Laboratory's Technical Publications Department, particularly that of the Composition and Makeup groups, that of R. H. Powell who provided editorial assistance, and especially that of P. J. Patton who edited and coordinated publication of this handbook.

Reviewers who contributed in the technical review of particular sections of the handbook include:

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Sheet Metal and Air Conditioning Contractors' National Association

C. A. Burchsted

Oak Ridge, Tennessee
March 31, 1976

FOREWORD TO SECOND EDITION (ORNL-NSIC-65)

This handbook fills a large gap in the literature concerning air cleaning and filtration, the gap that encompasses design, construction, and testing of very high-efficiency air cleaning systems. The project was originally conceived by Mr. Humphrey Gilbert of the USAEC and was sponsored by the Division of Reactor Development and Technology of the USAEC. In preparing for the project we surveyed air-cleaning systems at atomic energy facilities and industrial installations throughout the United States and Canada. We visited AEC production reactors, commercial power reactors, laboratories, radiochemical plants, reactor fuel manufacturers, clean rooms, equipment manufacturers, and one chemical-biological warfare installation. The purposes of these visits were to review current practices in high efficiency air cleaning and to define the problems in operating, maintaining, and controlling contamination release from very high-efficiency air-cleaning systems from experienced people who were dealing with such problems daily. The handbook reflects a consensus of our findings in these travels, in addition to information gleaned from the available literature.

The handbook is addressed primarily to designers and architect-engineers. We frequently observed a lack of communication and feedback from people with problems in the field to designers. Our intention is to bring to the attention of designers of future systems the kind of problems that an operator faces and what he, the designer, must do to preclude or alleviate them. We have purposely pointed out some poor practices in current design in addition to our recommendations in the hope that such practices will go no further. To give "do's" without "don'ts" may encourage some designers to offer a poor design because he mistakenly believes that "it worked before."

Those who have contributed to the handbook number literally in the hundreds and include those we consulted with and those who have given of their time in reviewing drafts or have supplied specific bits and pieces of information. We take this opportunity to thank the many friends we have made in the course of this project, particularly for their candidness in discussing problems and ways of solving those problems, and for their help in supplying photographs and information. In particular we want to thank Mr. Humphrey Gilbert and I. Craig Roberts of the USAEC for their guidance, W. B. Cottrell of ORNL for his help in getting the book published, T. F. Davis of the USAEC's Division of Technical Information for his assistance in indexing the material, J. H. Waggoner of ORNL for doing the illustrations, and Dr. M. W. First of Harvard University for his meticulous page-by-page review of the draft and suggestions for this final issue.

C. A. Burchsted
A. B. Fuller

Oak Ridge, Tennessee
July 10, 1969

FOREWORD TO FIRST EDITION (ORNL-NSIC-13)

This review presents the latest developments in the trapping of airborne radioactive materials encountered in reactor operations, fuel fabrication and processing plants, and radiochemical plants of all types. The containment of these radioactive aerosols and gases is essential to the safe operation of such installations. Research and development is directed toward increases in containment reliability under adverse conditions, as well as lowered costs and increased efficiencies.

Air cleaning problems and their solutions are related to the physical and chemical properties of the materials to be retained. For example, until recently radioactive iodine was caught on unimpregnated activated charcoal, but recent investigations indicate that the iodine exists in several chemical forms, one of them being methyl iodide, which must be caught on impregnated charcoal.

High-efficiency particulate air (HEPA) filters of fire-resistant fiber glass are now required in the trapping of fine particles in USAEC installations. New HEPA filters for nuclear installations in the United States must show a minimum efficiency of 99.97% for the retention of monodisperse 0.3-μ dioctyl phthalate particles in the standard USAEC Quality Assurance test. A difference of 0.02% is allowed between the rating of new filters by the Quality Assurance test and the rating of filter systems (including single installed filters) by the in-place test. To qualify as high-efficiency, the system or installed filter must have an efficiency of 99.95% in the in-place test.

Radioactive noble gases from high-velocity gas streams must be diluted to permissible concentrations before release to the atmosphere. Noble gases can be removed near the source, but only if treated in small volumes or if low-velocity gas streams are used.

Siting of nuclear power reactors is influenced by the potential hazard of released fission products. Fortunately, a number of transport phenomena, such as agglomeration, absorption, adsorption, deposition, and steam condensation within the containment vessel, serve to reduce the amounts of fission products available for release to the environment. Nevertheless, reactor designers depend on gas cleaning systems as an engineered safeguard to reduce the fission product concentration in the containment system in the event of a reactor accident resulting in fission product release. Clearly, it is important that the effectiveness of various air cleaning systems for removing radioactivity of the types and forms expected in the event of accidents to reactors, nuclear fuel processing plants, or radiochemical plants be demonstrated.

Efforts toward greater reactor safety by the use of engineered safeguards are encouraged by the AEC. However, only limited credit for engineered safeguards is presently allowed in establishing reactor site criteria. Furthermore, the dependability of such systems under accident conditions must be demonstrated beforehand.

Engineered safeguards, in addition to the containment enclosure, are classified into four general types: (1) emergency coolant to prevent melting of the fuel materials, (2) air cleaning systems for removing fission products from the containment enclosure, (3) methods, such as pressure suppression, for reducing the internal pressure, which in turn reduces leakage to the atmosphere, and (4) provision for two or more barriers around the primary system, which will prevent a major leak of fission product activity.

Air cleaning systems are provided to clean the containment atmosphere either during recirculation or by treatment before the air is released to the environment. Several nuclear power companies have installed filter systems in the newer plants, and some credit will be taken in calculating the effects of the maximum accident. A number of the systems have been tested and show >99.99% iodine retention. However, generally only

95% efficiency has been assumed for an installed filter system until detailed behavior of iodine is better established for accident conditions.

The air cleaning system is usually within the containment envelope, where blowers induce air movement through the filter system. Two important considerations are the general reliability of the blowers, filters, filter housings, seals, etc., and the relative vulnerability of the system to damage from particles, missiles, chemical reagents, vapors, etc. This report does not cover engineering design or specifications for filter units or high-efficiency air cleaning systems. An engineering manual, addressed primarily to architects and engineers who are not familiar with the special requirements of such systems, is being prepared for the USAEC by the Oak Ridge National Laboratory and is expected to be available in 1967. The manual will contain design criteria, drawings, and specifications for HEPA filter units and systems in which they are used and will discuss problem areas concerned with the selection and installation of HEPA and activated charcoal filter units.

The methods for trapping radioactive aerosols (including solids and mists) and gases generated in nuclear installations are presented in three parts.

Part I, Fibrous Filters, is concerned with the high-efficiency removal of particles. Here, we review the properties of aerosols, filtration theory, aerosol sampling, analysis of particles, filter media, testing filter efficiency, and the generation of test aerosols for use in testing filters.

Part II, Sorbents, reviews the mechanisms for the sorption of gases and vapors, with particular emphasis on the trapping of fission product iodine and the noble gases.

Part III, Air Cleaning Systems, includes the design of air cleaning systems, in-place testing, filter failures and their prevention, with emphasis on the reduction of fire hazards, and typical engineered safeguard systems applicable to the containment of fission products, including pressure-suppression containment.

At present standard equipment in gas cleaning systems for reactors includes the following: a prefilter unit to remove most of the radioactivity and reduce the fission product decay heat load on later units; next, an HEPA filter to remove very small particles (submicron range); then, a solid adsorber to remove specific gases and vapors. These may be followed by another HEPA filter to protect against any dusting from the solid adsorber. Finally, a high off-gas stack to the atmosphere is required, since nonadsorbable and noncondensable radioactive gases that cannot be removed by the gas cleaning system must be diluted to permissible levels of radioactivity before their release to the environment.

Acronyms, Abbreviations, and Conversion Charts

ACGIH	American Conference of Governmental Industrial Hygienists
ACI	American Concrete Institute
ADC	Air Diffusion Council
ADL	Additional Dynamic Loads
AEC	U.S. Atomic Energy Commission (predecessor of ERDA, DOE, and NRC)
AFI	Air Filter Institute
AGS	American Glovebox Society
AgX	silver-exchanged zeolite
AHJ	Authority Having Jurisdiction
AISI	American Iron and Steel Institute
AISC	American Institute of Steel Construction
ALAP	as low as practicable (obsolete term for ALARA)
ALARA	as low as reasonably achievable
AMCA	Air Moving and Conditioning Association
AMD	aerodynamic mean diameter (of particles)
ANS	American Nuclear Society
ANSI	American National Standards Institute
APA	American Plywood Association
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWS	American Welding Society
BET	Brunauer, Emmett, and Teller (test for surface area of adsorbents)
BWR	boiling water reactor
CAM	continuous air monitors
CBR	chemical, biological, and radiological (filter)
CFD	continuous fire detector
CFR	Code of Federal Regulations
CG	concentration guide
CH_3I	Methyl iodide
CONAGT	Committee on Nuclear Air and Gas Treatment (a subcommittee of ASME)
CRSI	Concrete Reinforced Steel Institute
CVS	Confinement Ventilation System
CWS	U.S. Army Chemical Warfare Service Laboratories
DAC	derived air concentration
DBA	design basis accident

DBE	design basis earthquake
DBS	deep-bed sand (filter)
DBGF	deep-bed glass fiber (filter)
DF	decontamination factor
DoD	Department of Defense
DOE	U.S. Department of Energy
DOP	dioctyl phthalate
DP	differential pressure
DNFSB	Defense Nuclear Facilities Safety Board
DPD	design pressure differential
DSA	Documented Safety Analysis (replaces the term SAR)
ECCS	Emergency Core Cooling System
EL	external loads
ERDA	Energy Research and Development Administration
ES	equipment specification
ESF	engineered safety feature
ESP	electrostatic Precipitator (prefilter)
FHA	Fire Hazard Analysis
FML	Fluid Momentum Loads
FRP	fiber-reinforced plastic
FTF	Filter Test Facility
GFRP	Glass-Fiber-Reinforced Plastic
HEMF	high-efficiency metal filter
HEPA	high-efficiency particulate air (filter)
HEPA-Vac	HEPA Vacuum Cleaning Systems/Units
HF	hydrogen fluoride
HFATS	High Flow Alternative Test System
HVAC	heating, ventilating, and air conditioning
HWESF	Hanford Waste Encapsulation and Storage Facility
IAEA	International Atomic Energy Agency
IBC	International Building Code
IEEE	Institute of Electrical and Electronic Engineers
IEST	Institute of Environmental Sciences and Technology
IPF	Iodine Protection Factor
KI	potassium iodide
Kr	Krypton
LANL	Los Alamos National Laboratory
LCO	limiting conditions for operation
LEL	lower explosive limit
LER	Licensee Event Report
LMD	light scattering mean diameter

LMFBR	liquid-metal fast breeder reactor
LOCA	loss-of-coolant accident
LWR	light water reactor
MCE	maximum considered earthquake
MCFL	Maximum Credible Fire Loss
MERV	Minimum Efficiency Reporting Value
MMD	mass median diameter (of particles)
MPC	maximum permissible concentration
MPFL	maximum possible fire loss
MPPS	Most Penetrating Particle Size
NACE	National Association of Corrosion Engineers
NBS	National Bureau of Standards
NCIG	Nuclear Construction Issues Group
NDRC	National Defense Research Council
NEC	Nuclear Air Cleaning Conference
NEMA	National Electrical Manufactures Association
NFPA	National Fire Protection Association
NIST	National Institutes of Science and Technology
NMD	number mean diameter (of particles)
NOPD	normal operating pressure differential
NPH	natural phenomena hazards
NQA	Nuclear Quality Assurance
NRC	U.S. Nuclear Regulatory Commission
NRL	U.S. Naval Research Laboratory
NRR	noise reduction rating
NSIC	Nuclear Safety Information Center
NSSS	Nuclear Steam Supply System
OBE	operating basis earthquake
ORFTF	Oak Ridge Filter Test Facility
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Safety and Health Administration
PAO	Polyalphaolefin
PC	performance category
PEL	permissible exposure limit
PHFS	portable HEPA filtration system
PPE	personal protective equipment
PPH	Precipitation Hardening (grade of stainless steel)
PSHA	Probabilistic Seismic Hazard Analysis
PSL	Polystyrene Latex
PSS	Passive Safe Shutdown
PVC	polyvinyl chloride
PWR	pressurized water reactor

QA	quality assurance
QAS	quality assurance station
QC	quality control
QPL	qualified product list
RFETS	Rocky Flats Environmental Technology Site
RFFTF	Rocky Flats Filter Test Facility
RG	Regulatory Guide
RH	relative humidity
RPP	radiation protection program
RSCV	removable surface contamination value
RSIC	Reactor Shielding Information Center
RTP	Rapid-Transfer Port
RTV	room temperature vulcanizing
RWP	radiological work permit
SBMS	Standards Based Management Systems
SMACNA	Sheet Metal and Air Conditioning Contractors' National Association
SMP	Size of Maximum Penetration
SOP	standard operating procedure
SOPD	System Operating Pressure Differential
SRL	Savannah River Laboratory
SRP	Standard Review Plan
SRS	Savannah River Site
SSC	Structures, Systems, and Components
SSE	safe shutdown earthquake
SSPC	Steel Structures Painting Council (now the Society of Protective Coating)
TAPPI	Technical Association of the Pulp and Paper Industry
TEDA	triethylene diamine
TEFC	totally enclosed fan cooled
TLV	threshold limit value
TMI	Three Mile Island
TURF	Thorium-Uranium Recycle Facility
UL	Underwriters Laboratories, Inc.
ULPA	ultra low penetration air (filter)
VLSI	Very Large-Scale Integrated
VOC	volatile organic chemical
WESF	Waste Encapsulation and Storage Facility (Hanford B-Plant)
WWII	World War II
Xe	Xenon

UNITS OF MEASURE AND METRIC EQUIVALENTS USED IN THIS HANDBOOK

acfm	actual cubic feet per minute		
BTU	British thermal unit		
cfm	cubic feet per minute	x 0.000472 = m^3/sec	cubic meters per second
Ci	curies		
dBA	decibel A-weighted		
fpm	feet per minute	x 0.00508 = m/sec	meters per second
ft	feet	x 0.3048 = m	meters
ft^2	square feet	x 0.09290 = m^2	square meters
ft^3	cubic feet	x 28.32 = L	Liter
		x 0.02832 = m^3	cubic meters
gpm	gallons per minute		
Hz	Hertz		
in.	inch	x 2.54 = cm	centimeters
in.wc	inches water column		
in.wg	inches water gauge	x 0.24836 = kPa	kilopascals
kPa	kilopascals		
mCi	millicuries		
mm	millimeter, 0.001 inch		
m^3/hr	cubic meters per hour		
mmwg	millimeter water gauge		
m/s^2	meters per seconds squared		
pH	percent hydrogen (measure of acidity/alkalinity), power of the hydrogen ion		
ppm	parts per million		
psi	pounds per square inch		
psia	pounds per square inch absolute		
psig	pounds per square inch in gauge		
rem/hr	rems (roentgen equivalent man) per hour		
scfm	standard cubic feet per minute		
µCi	microcuries		
µg	micrograms		
µin	microinch		
µm	micrometer		
vpm	volume parts per million		

GLOSSARY

Absolute, AEC, or CWS Filter—Obsolete terms for HEPA filters.

Acceptance Test—A test made upon completion of fabrication, installation, repair, or modification of a system unit, component or part to verify to the user or owner that the item meets specified requirements.

Adsorber—A device for removing gases or vapors from air by means of preferential physical condensation and retention of molecules on a solid surface. Adsorbers used in nuclear applications are often impregnated with chemicals to increase their activity for organic radioactive iodine compounds.

Adsorber Cell—A modular replaceable adsorber element.

Aerosol—A dispersion of very small particles and/or droplets in air.

Air Cleaning Stage—An Air cleaning stage is a single component or a bank of identical components in an air cleaning unit or an air cleaning system. A system that has one bank of components (e.g., HEPA filters) in each of three air cleaning units, arranged in parallel, is a single stage system. A multistage unit or system has two or more stages in tandem.

Air Cleaning System—An air cleaning system is an assembly of one or more air cleaning units plus all external components needed to convey air or gases from one or more intake points, through the air cleaning units, to one or more points of discharge. The system may be either recirculating or once through.

Air Cleanup System—A system provided to decontaminate the air in, or exhausted from, a contained space following s system upset or prior to personnel access to the contained space.

Air Cleaning Unit—An air cleaning unit is an assembly of components, which comprises a single subdivision of a complete air cleaning system, including all components necessary to perform the air cleaning function of that subdivision.

ALARA—As Low As Reasonably Achievable. The design philosophy used to determine the need for, or extent of, air cleaning and off-gas facilities, based on their cost effectiveness in reducing adverse impact with respect to offsite and onsite dose criteria. Formerly known as ALAP.

Array—An array is the arrangement of internal components in a bank, expressed as the number of components across the width of a bank times the number high (e.g., a 4 by 3 array of HEPA filters).

Bag-in/Bag-out—A method of introducing and removing items from a contaminated enclosure that prevents the spread of contamination or opening of the contaminated space to the atmosphere through the use of plastic bagging material.

Blinding—Water vapor or droplets that interfere with particulate capture.

Case, Casing—The frame or cell sides of a modular filter element.

Clean-Air Device—A clean bench, clean workstation, downflow module, or other equipment designed to control air cleanness (particle count) in a localized working area and incorporating, as a minimum, a HEPA filter and a fan.

Clean Room—An occupied room designed to maintain a defined level of air cleanness under operating conditions; inlet and recirculated air is cleaned by HEPA filters.

Coating—Paint or other protective surface treatment applied by brushing, spraying, or dipping (does not include electro plating).

Combustible—A material that will ignite and burn in the form that it is used.

Combustible Liquid—A liquid with a high flash point, greater than 100 degrees F. The flash point is the temperature of the liquid above which vapors will be released that can be ignited by a flame source.

Component—A component is a filter, adsorber cell, fan, damper, or other basic element of an air cleaning system which cannot be disassembled without nullifying the capability of performing its designed task.

Confinement (contained volume)—A building, building space, room, cell, glovebox, or other enclosed volume in which air supply and exhaust are controlled, and typically filtered.

Confined Space—A space that: (1) is large enough and so configured that an employee can bodily enter and perform assigned work; (2) has limited or restricted means for entry or exit (e.g., tanks, vessels, silos, storage bins, hoppers, vaults, and pits); and (3) is not designed for continuous employee occupancy. Also, an enclosure that contains an oxygen deficiency, where oxygen concentration is less than 19.5 percent.

Containment (containment vessel or building)—A gastight enclosure around a nuclear reactor or other nuclear facility designed to prevent fission products from escaping to the atmosphere. Typically, when a containment vessel or building is exhausted, it occurs through an engineered filtration system.

Contamination—Any unwanted material in the air, in process fluids, or on surfaces. For the purposes of this handbook, contamination is usually assumed to be radioactive.

Contamination Zone—An isolable area which is, or which could become, contaminated and which is designed to facilitate decontamination.

Controlled Area—An area to which access is restricted.

Cover Gas—An inert gas, under pressure, provided in a contained space or process equipment item to prevent inleakage of air.

Criticality—The state of sustaining a chain reaction, as in a nuclear reactor. When fissionable materials are handled or processed, they must be kept in a subcritical geometry, configuration, or mass to avoid accidental criticality.

Critical System, Unit, or Item—One that is essential for adequate or safe operation, failure of which would cause loss of function.

Decay Heat—The heat produced by radioactive materials as nuclides spontaneously transform into other nuclides or into different energy states. Each decay process has a definite half-life.

Decontamination—The removal of unwanted substances from personnel, rooms, building surfaces, equipment, etc.

Decontamination Factor—A measure of air cleaning effectiveness; the ratio of the concentration of a contaminant in the untreated air or gas to the concentration in the treated air or gas.

Demister—A device designed to collect and divert moisture away from downstream filters (i.e., prefilters, HEPAs, and adsorbers). Demisters are installed in final filter plenums upstream of the first stage HEPA filters to prevent water damage to the filters.

Design Basis Accident (DBA)—The most serious accident that can be hypothesized from an adverse combination of equipment malfunction, operating errors, and other unforeseen causes.

Design Pressure—The pressure that is used for the structural design of a unit, component, or system, and which includes allowance for forces encountered under system upset conditions.

Monodisperse Aerosol—An aerosol generated by controlled vaporization and condensation of liquid test agent to give a cloud of droplets with diameters of approximately 0.3 micrometers.

Polydisperse Aerosol—An aerosol generated by blowing compressed air through liquid test agent and exhausting through special nozzles under controlled conditions to produce a cloud of droplets with a light-scattering mean diameter of approximately 0.7 micrometers.

Dose—The amount of ionizing radiation energy absorbed per unit mass of irradiated material at a specific location. In the human body, it is measured in Roentgen equivalent man (rems); in inanimate bodies, it is measured in radiation absorbed dose (rad).

Efficiency—Is defined as treated air concentration ÷ untreated air concentration x 100.

Enclosed Filter—A filter that is completely enclosed on all sides and both faces except for reduced end connections or nipples for direct connection into a duct system. Enclosed filters are installed individually because there is a separate run of duct to each filter unit.

Engineered Safety Feature (ESF)—A unit or system that is provided to directly mitigate the consequences of a DBA.

Extended-Medium Filter—A filter having a pleated medium or a medium in the form of bags, socks, or other shape to increase the surface area relative to the frontal area of the filter.

Face Guard—A screen, usually made from 4-mesh galvanized hardware cloth, permanently affixed to the face of a filter unit to protect it against damage caused by mishandling.

Face Shield—A screen or protective grille placed over a filter unit after it is installed to protect it from damage that might be caused from operations carried on in the vicinity of the filter.

Fail Safe—A design to give equipment the capability to fail without producing an unsafe condition.

Filter—A device having a porous or fibrous medium for removing suspended particles from air or gas that is passed through the medium.

Filter/Adsorber Bank—A parallel arrangement of filters/adsorbers on a common mounting frame installed within a single housing.

Final Filter—The last filter unit in a set of filters arranged in series.

Fire Resistance Rating—A term associated with the qualification of fire barriers. Fire barriers are tested to a standard fire exposure detailed in ASTM E-119, *Standard Method of Fire Tests of Building Construction and Materials*.

Flammable Liquid—A liquid with a low flashpoint, less than 100° F. These liquids are a greater fire hazard than combustible liquids, because they will readily burn at room temperature or below.

Flame Spread Rating—A term associated with the qualification of exposed interior finish materials. Materials are tested to determine their flame spread rating by a standard test in ASTM E-84, *Standard Test Method for Surface Burning Characteristics of Building Materials*.

Functional Design—The establishment of airflow rates, airflow capacities, types of components to be employed, general system layout, operational objectives and criteria, decontamination factors and rates, space allocations, and other overall features of a system.

Gallons per Minute (gpm)—This is a measurement of the quantity of water flowing through a pipe. The design specifications of water spray and sprinkler systems are based on the quantity of water flowing through the pipes and out of the nozzles.

Gas Chromatograph—An analytical instrument used for quantitative analysis of extremely small quantities of organic compounds whose operation is based upon the absorption and partitioning of a gaseous phase within a column of granular material.

Gas Residence Time—The calculated time that a contaminant or test agent theoretically remains in contact with an adsorbent, based on active volume of adsorbent and air or gas velocity through the adsorber bed.

High-Efficiency Particulate Air Filter or HEPA Filter—A throw-away extended-pleated-medium dry-type filter with: (1) a rigid casing enclosing the full depth of the pleats, (2) a minimum particle removal efficiency of 99.97 percent for particles with a diameter of 0.3 micrometers, and (3) a maximum pressure drop of 1.0 in.wg. or 1.3 in.wg. when clean and operated at its rated airflow capacity.

Hot cell—A heavily shielded and environmentally controlled enclosure in which radioactive materials can be handled remotely with manipulators and viewed through shielding windows to limit danger to operating personnel.

In-place Leakage Test—A system or bank test for leakage of filter units or charcoal adsorbers made after they are installed.

Ionizing Radiation—Any radiation (alpha, beta, or gamma) that directly or indirectly displaces electrons from the outer domains of atoms.

Isotope—One of several forms or nuclides of the same chemical element that have the same number of protons in the nucleus and therefore have the same chemical properties, but have differing numbers of neutrons and differing nuclear properties.

Leaktightness—The condition of a system unit or component where leakage through its pressure boundary is less than a specified maximum value at a specified pressure differential across the pressure boundary.

Lower Flammable Limit (LFL)—The least amount of a flammable vapor or gas that will support combustion when mixed with air. The LFL is usually expressed in volume per cent. Mixtures that contain less than the LFL of a material are too lean to burn.

Medium (plural, media)**—**The filtering material in a filter.

Mounting Frame—The structure to which a filter unit is clamped and sealed.

Noncombustible Materials—Materials that under ordinary conditions will not burn. Composite materials are determined to be noncombustible if they successfully pass the test criteria contained in ASTM E-136, *Test for Behavior of Materials in a Vertical Tube Furnace at 750 Degrees C.*

Nuclear Reactor—An apparatus in which a chain reaction of fissionable material is initiated and controlled.

Off-gas—The gaseous effluent from a process or operation.

Open-Face Filter—A filter with no restrictions over the ends or faces of the unit, as opposed to the enclosed filter with reduced-size end connections.

Operating Pressure—The desired pressure corresponding to any single condition of operation.

Overpressure—Pressure in excess of the design or operating pressure.

Particle, Particulate—A minute piece of solid matter having measurable dimensions.

Penetration—The measure of the quantity of a test agent that leaks through or around an air cleaning device when the device is tested with an agent of known characteristics under specified conditions.

Poison—Any material that tends to decrease the effectiveness of an adsorbent by occupying adsorption sites on the surface of the adsorbent or by reacting with the impregnants in the adsorbent.

Prefilter—Prefilters are throwaway type filters that are located upstream of HEPA filters. Prefilters are intended to collect and hold the larger airborne particles that are in the passing airstream. Prefilters are sometimes called roughing filters.

Production Test—Test made on each item or a sample of items or product from a production run to verify that the item meets specification requirements.

Permanent Single-Unit (PSU) Adsorber—An adsorber that is permanently installed in a system and that can be emptied of and refilled with adsorbent without removing it from the system.

Pyrophoric Material—Materials or compounds in a form that will ignite in air at a temperature of 150° C or below in the absence of external heat, shock, or friction.

Qualification/Proof of Design Test—A periodic test made on a product or equipment item when it is proposed as a candidate to meet certain service requirements, which will verify to the user or owner that the item can meet his requirements (see production test).

Rad—Radiation Absorbed Dose, the basic unit of ionizing radiation. One rad is equal to the absorption of 100 ergs of radiation energy per gram of matter.

Radiation—The propagation of energy through matter or space in the form of electromagnetic waves or fast-moving particles (alpha and beta particles, neutrons, etc).

Radioactivity—The spontaneous decay or disintegration of an unstable atomic nucleus accompanied by the emission of radiation.

Rated Airflow—The manufacturer's assigned design airflow capacity of a HEPA filter at a "not to exceed" designated clean filter resistance. With a media velocity limit of 5 feet per minute, the rated airflow is obtained by multiplying the filtration velocity of 5 feet per minute by the effective area of filter media.

Recirculation Air Cleanup System—An air cleaning system that recirculates the air of a contained space.

Redundant Unit or System—An additional and independent unit or system, which is capable of achieving the objectives of the basic system and is brought online in the event of failure of the basic system.

Rem—Roentgen Equivalent Man. The unit of absorbed radiation dose in rads multiplied by the relative biological effectiveness of the radiation.

Roughing Filter—A prefilter with high efficiency for large particles and fibers but low efficiency for small particles; usually of the panel type.

Safety-class Structures, Systems, and Components (SC SSCs)—Structures, systems, or components including portions of process systems, whose preventive and mitigative function is necessary to limit radioactive hazardous material exposure to the public, as determined from the safety analyses.

Safety-significant Structures, Systems, and Components (SC SSCs)—Structures, systems, and components which are not designed as safety-class SSCs but whose preventive or mitigative function is a major contributor to defense in depth and/or worker safety as determined from safety analyses.

Scrubber—A device in which the gas stream is brought into contact with a liquid so that undesirable components in the gas stream are removed by reacting with or dissolving in the liquid.

Separators—Corrugated foil (usually aluminum) used to separate the folds of a pleated filter medium and to provide air channels between them.

Service Environment—The aggregate of conditions (temperature, pressure, humidity, radioactivity, chemical contaminants, etc) to which the components of a system are exposed.

Shielding—A mass of absorbing material placed around a radioactive source to reduce ionizing radiation to levels.

Shock Overpressure—The pressure over and above atmospheric or operating pressure produced by a shock wave from an explosion, a suddenly closed damper, or other event.

Single-Component Air Cleaning Unit—A single-component air cleaning unit is one in which there is only one component (HEPA filter, prefilter, etc.) per stage, as opposed to a bank installation in which there are two or more components per stage.

Smoke Developed Rating—The numerical value assigned a material tested to the ASTM E-84 flame spread test method.

Specific Radioactivity—Radioactivity per unit weight of a material with an isotope.

Surveillance Test—A test made periodically to establish the current condition of a system, unit, component, or part.

Test Program—A formalized schedule of tests, which specify the test sequence, the procedures to be employed, and the acceptance criteria.

Train—A set of components arranged in series.

Treatment—The process of removing all or a part of one or more chemical components, particulate components, or radionuclides from an off-gas stream.

Ventilation System—The ventilation system includes the total facilities required to supply air to, circulate air within, and remove air from a building or building space by natural or by mechanical means.