CHAPTER 9

SPECIAL APPLICATION REQUIREMENTS

9.1 Introduction

Preceding chapters of this handbook have discussed the general requirements of high-efficiency air cleaning systems as they pertain to relatively common applications. This chapter discusses some special requirements that may have to be considered for certain applications, including:

1. Designing to survive natural phenomena such as a tornado or earthquake,
2. High-capacity sand filters.

9.2 Natural Phenomena

The ability of a system to survive and function during and/or following a natural disaster such as an earthquake or tornado must be taken into consideration in the design of air cleaning systems. By definition, such systems serve to control and limit the consequences of releases of energy and radioactivity in the event of occurrences.

9.2.1 Natural Phenomena Hazards

The natural phenomena hazards (NPH) of interest at a site include earthquakes, winds/tornadoes, floods, and lightning. Earthquakes and winds/tornadoes can lead directly to a release of hazardous materials. Floods and lightning, on the other hand, usually are not directly responsible for the release of hazardous materials, but can initiate other events such as fires or spills that lead to releases. These last two events should be discussed without specific details (unless deemed necessary for a specific site). U.S. Department of Energy (DOE) Order 420.1A, *Facility Safety*,[1] and DOE Guidance 420.1-2, *Guide for the Mitigation of Natural Phenomena Hazards for DOE Nuclear Facilities and Nonnuclear Facilities*,[2] establishes the policy and requirements for NPH mitigation for DOE sites and facilities. DOE Order 420.1A[1] utilizes a graded approach to provide for the health and safety of facility occupants; the public; and the environment, to protect against property losses, and to preserve production and research objectives. This graded approach in design, evaluation, and construction of structures, systems, and components (SSCs) varies in conservatism and rigor, ranging from normal-use buildings to nuclear power plant structures. DOE Order 420.1A[1] specifies that consistent NPH requirements in a graded approach are implemented by the use of target probabilistic performance goals. Performance goals are expressed as the annual probability of exceeding acceptable behavior limits beyond which an SSC may not perform its function or maintain structural integrity. Performance goals are targeted by specifying probabilistic NPH estimates and deterministic design and evaluation methods (including intentional and controlled conservatism). Performance Categories (PC) 1 through 4 are defined with target performance goals.

DOE Order 420.1A[1] requires use of DOE-STD-1020, *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities*,[3] to provide design and evaluation criteria for earthquakes, wind/tornadoes, and floods, and requires this standard to be used as guidance in implementing NPH mitigation requirements. DOE-STD-1020 specifies performance goals and relevant hazard probabilities for PC 1 through PC 4 to establish the design basis loads.[3] The goals of DOE-STD-1020 are to ensure that NPH evaluations are performed on a consistent basis, and that DOE facilities can withstand the effects of natural phenomena. Considerable new information and analysis/design methods have been developed since DOE-STD-1020 was issued. DOE-STD-1020 has been recently revised and republished to incorporate the current seismic analysis/design requirements of the *International Building Code* (IBC).[4] [Note: The IBC is a commercial code written without regard to nuclear requirements.]

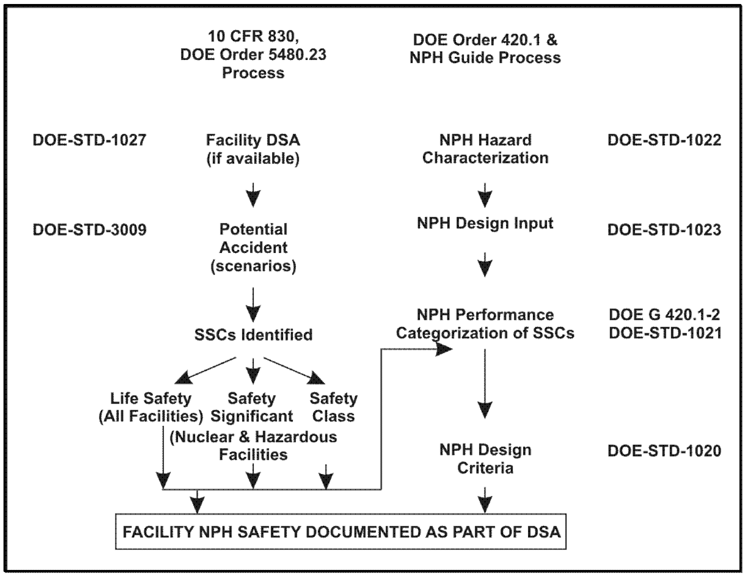

Figure 9.1 – Natural Phenomena Hazards Design Input

The overall DOE NPH design input, as well as applicable DOE Orders and standards, are shown in **Figure 9.1**.

Additional guidance addressing NPH events is provided in several other DOE NPH standards:

- DOE-STD-1021, *Natural Phenomena Hazards Performance Categorization Criteria for Structures, Systems, and Components.*[5]
- DOE-STD-1022, *Natural Phenomena Hazards Site Characterization Criteria*.[6]
- DOE-STD-1023, *Natural Phenomena Hazards Assessment Criteria*.[7]
- NFPA 780, *Standard for the Installation of Lightning Protection Systems*, 2000 edition.[8]

9.2.2 Earthquake

Earthquakes differ from other natural phenomena in that there are no advance warnings. **Table 9.1** shows the mean annual exceedance probabilities for the design basis earthquake (DBE) for various PCs.

Table 9.1 – Seismic Performance Categories and Seismic Hazard Exceedance Levels

Performance Category	***Mean Seismic Hazard Exceedance Levels P_H***	***Remarks***
0	No requirements	–
1	4×10^{-4}	Use IBC 2000, Seismic Use Group I Criteria 2/3 MCE Ground Motion
2	4×10^{-4}	Use IBC 2000, Seismic Use Group III Criteria MCE Ground Motion
3	4×10^{-4} (1×10^{-3}) (see note 2)	Analysis per DOE-STD-1020[3]
4	$1 \text{ x } 10^{-4}$ (2×10^{-4}) (see note 2)	Analysis per DOE-STD-1020[3]

Notes:
1. For PC 1 through PC 3, the P_H levels are based on Maximum Considered Earthquake (MCE) Ground Motion, which is generally a 2 percent exceedance probability in 50 years.
2. For sites such as Lawrence Livermore National Laboratory, Sandia National Laboratories-Livermore, Standard Linear Accelerator, Lawrence Berkeley Laboratory, and the Energy Technology Engineering Center, which are near tectonic plate boundaries.

Specific criteria regarding nuclear power plant designing for earthquakes are defined by the U.S. Nuclear Regulatory Commission, (NRC).

The two main steps in evaluating the potential impact of an earthquake for a particular facility are: (1) estimate the probability of exceeding the earthquake magnitude of interest (as discussed below), and (2) estimate the damage the facility will sustain for this magnitude of earthquake. From this assessment, the consequences can be calculated. Most DOE sites are in areas of relatively low seismic activity; thus, damaging earthquakes are considered unlikely (California sites excepted). If a recent site-specific Probabilistic Seismic Hazard Analysis (PSHA) for a site is available, it should be verified because it would document the probabilistic analysis used to determine the ground motion levels and the recurrence intervals corresponding to the various sizes of earthquakes possible at the site. An example from the Pantex site (1998) (see **Figure 9.2**) shows the results of an analysis at the Pantex soil site plotted as peak horizontal ground acceleration (expressed in units of the acceleration of gravity, g = 32.2 ft/s^2) versus the annual probability of exceedance.

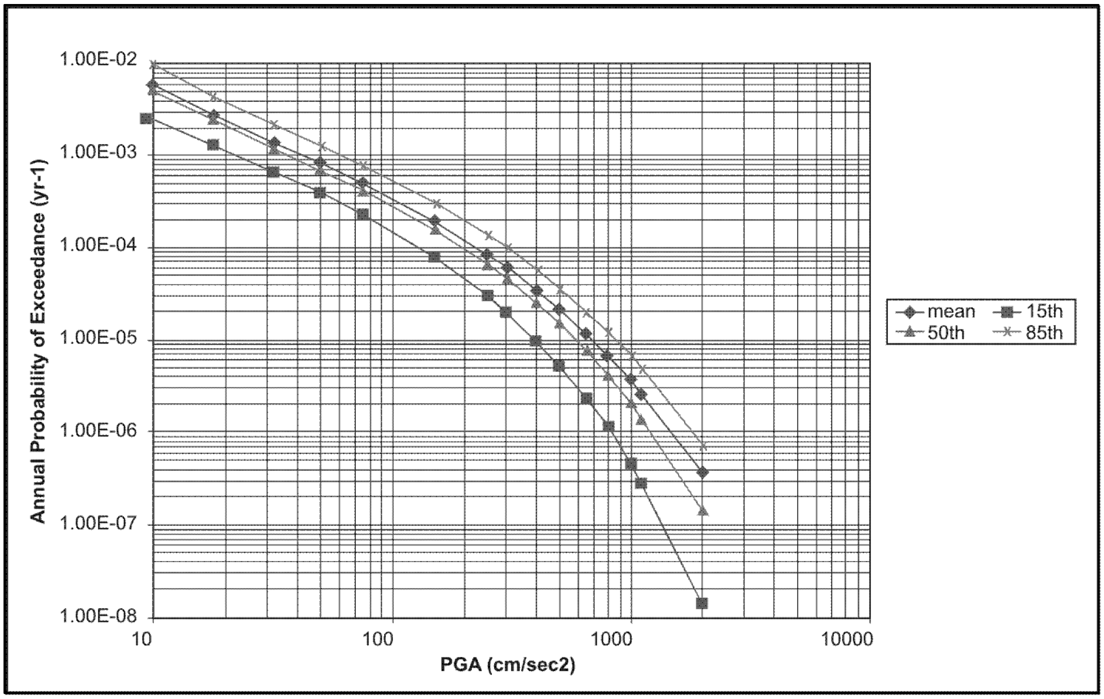

Figure 9.2 – Seismic hazard Curves for Pantex Soil Site

The earthquake problem arises from the possibility of associated malfunction of fans, dampers, filters, or other functional components of the system, or the rupture or structural damage of pressure-boundary components (ducts, housings, fan, or damper casings) when the system is subjected to rapid, violent, repetitive shaking or dislocations, either as a lumped mass or as parts of the assembly are independently dislocated from each other. Fortunately, the physical masses of air cleaning system components are generally small in relation to the massive concrete building elements to which they are anchored. If natural frequencies are greater than about 30 Hertz (Hz) and the parts of any single air cleaning unit are anchored to the same building element, a satisfactory earthquake-resistant air cleaning system can be achieved fairly easily. Problems arise when portions of the same air cleaning unit (e.g., different segments of the ductwork) are anchored to different building elements that can vibrate independently. The design and design qualification of earthquake-resistant air cleaning systems is discussed below.

Seismic Qualification of Air Cleaning Systems

External components of the system (e.g., housings, fans, etc.) should be rigidly anchored to major building elements (walls, floors, partitions). General seismic criteria for DOE facilities are provided in

DOE-STD-1020.[3] Similar information for facilities licensed by the U.S. Nuclear Regulatory Commission (NRC) is available in NRC Regulatory Guide 1.100, *Seismic Qualification of Electric and Mechanical Equipment for Nuclear Power Plants*,[9] and the NRC *Standard Review Plan*.[10]

The components should perform their intended functions and, if required by procurement specifications, should not sustain damage during or after they are subjected to excitations resulting from ground motions due to the DBE. This is demonstrated through a process called A-seismic qualification. This seismic qualification may be achieved following any one or a combination of the following methods described below: analysis, testing, and experience-based data. [Institute of Electrical and Electronic Engineers (IEEE) Standard 344, *Recommended Practice for Seismic Qualification of Class1E Equipment for Nuclear Power Generating Stations*,[11] provides excellent discussion of equipment seismic qualification procedures.]

Analysis

In general, analysis is a cost-effective tool to demonstrate seismic qualification. This method is applicable if: (1) the target component can perform its function as long as its structural integrity is maintained, and (2) the structural response of the target component can be reliably determined from analysis. In an analysis, structural responses such as stresses, strains, and displacements are calculated and compared with their respective allowable values, which are predetermined from material properties and component characteristics (e.g., clearance).

Analysis can be static, equivalent static, or dynamic. If the fundamental frequency of the component is high (e.g., greater than 33 Hz), amplification of motion through the component structure is usually negligible (i.e., the structure is considered rigid), and structural response can be determined by applying a static load (i.e., mass x 0 period acceleration) to the component. If the fundamental frequency of the component is unknown, the equivalent static (or static efficient) method can be applied in return for additional conservatism. In this method, an equivalent static force is calculated by multiplying the mass plus a static coefficient by the peak acceleration of the required response spectrum at the appropriate damping value (mass + static coefficient x peak acceleration). A damping coefficient of 3 percent is acceptable for all components except piping. Larger damping values may be justified.

A static coefficient of 1.5 has been established from experience to account for the effects of multifrequency and multimode response for linear frame-type structures. When the use of static or equivalent static analysis cannot be justified, structural responses are determined via dynamic analysis, although at additional cost. If the structural responses of the component are less than the respective allowable limits, the component will be considered qualified provided structural integrity alone demonstrates its functional operability.

Components, or the complete system, may also be qualified by structural analysis. The objective of the analysis is to predict the stresses, displacements, and deflections that will develop in critical parts of the component or system as a result of the specified input or time-history motion applied at the base (anchor points) of the component or system. The structural model is defined by the physical properties of the system to be analyzed; its mass, stiffness, and damping characteristics; and the time-varying accelerations, displacements, and relative velocity changes introduced at its foundation (anchor points).

If the mass of the component or system to be analyzed is small compared to the mass of the building element to which it is anchored, the supported component or system may be treated as a lumped-mass, multi-degree-of-freedom system with an input at its foundation (anchor points) equal to the motion of the building element to which it is attached (i.e., no interaction is assumed).

If the natural frequency of the item (component or system) is less than 0.2 Hz or more than 33 Hz, the item may be analyzed statically. The seismic forces on each element of interest are obtained by concentrating its mass at its center of gravity and multiplying by the appropriate maximum floor acceleration. Operating live and dead loads are added to the seismic loads in their appropriate directions. Displacements may be the limiting factor and must be accounted for in the design analysis. If the mass of the component or system is large compared to the mass of the building element to which it is attached, or if the item is not anchored rigidly to a building element, the interaction of the system on the building element must be considered and the system must be dynamically analyzed as a multi-degree-of-freedom mathematical model. The item (component or system) may be modeled as a series of discrete mass points connected by mass-free members, with sufficient mass points to ensure adequate representation of the item as it is supported in the building structure. The resulting system may be analyzed using the response spectrum or time-history analysis technique. A stress analysis should be made next, using the inertial forces or equivalent static loads obtained from the dynamic analysis for each vibration mode. If the response spectrum analysis technique is used, the seismic design stress usually may be obtained by taking the square root of the sum of the squares of the individual modal stresses. The absolute sum of the individual stresses should be taken, however, for closely spaced, in-phase vibration modes. In the analysis, each of the two major horizontal directions is considered separately and simultaneously with the vertical direction in the most conservative manner.

The analysis must include an evaluation of the effects of the calculated stresses on mechanical strength, alignment (if critical to proper operation of the air cleaning system), and operational (functional) performance of the components and the system as a whole. Maximum displacements at critical points must be calculated, and interference or plastic deformation must be determined and evaluated.

Testing

Either components or a complete system may be qualified by testing under simulated earthquake conditions. For a very few select cases where the component structure is simple and its potential failure mechanism is known (e.g., binding of shaft), a static test under the application of a conservative static force may be acceptable. Otherwise, dynamic testing is required. In such cases, the specimen to be tested is mounted on a biaxial or triaxial vibration generator in a manner that simulates the intended service mounting, and vibratory motion is applied independently to each of the perpendicular axes. Displacement induced in the vertical axis should be considered equal to at least 0.67 times the displacement in the major horizontal axis. The magnitudes of horizontal acceleration and displacement are those magnitudes for which the specimen is to be qualified. Where practicable, accelerations, displacements, and relative velocity change should be the maximum that the equipment can tolerate without loss of function. For fans, motors, dampers, and other operating equipment, sufficient monitoring devices must be located on the test specimen or assembly so that the maximum response is always obtained. Tests are made at several sinusoidal frequency steps that represent the range of frequencies for which the item is to be qualified at the natural frequency or at a number of predetermined frequencies, as discussed in the following sections.

Exploratory Vibration Test

An exploratory test should be made first, using a sinusoidal steady-state input of low magnitude to determine the presence and location of any natural frequencies within the range of 1 to 33 Hz, or the frequency range stated in the project specification. The test should be performed at a maximum sweep rate of 1 octave per minute and a minimum acceleration of 0.2 g, with dwell at resonance for at least 30 seconds. If no resonating frequencies are found, the item may be analyzed statically or may be tested via: (1) continuous sine test, (2) sine-beat test, or (3) multiple-frequency test. If one or more resonant frequencies are found in the exploratory test, the design of the component should, f possible, be modified to move the resonating frequencies above 33 Hz or to the maximum frequency at which the item is to be qualified. If the item cannot be readily modified, a performance test should be made at the resonant frequency and at an amplitude of at least the corresponding value for that frequency from the response spectrum for the building element of interest.

Continuous Sine Test. A continuous sinusoidal motion at the qualification frequency and the corresponding maximum acceleration is imposed for a length of time that is conservatively consistent with the service for which the item will be used. The item is operated during and after shaking to demonstrate its ability to perform its function. The test duration is specified in a detailed test procedure. The item is mounted on the vibration generator in a manner that represents its installation under service conditions. The vibratory forces are applied to each of the three major perpendicular axes independently unless symmetry justifies otherwise. Sufficient monitoring equipment must be used to evaluate performance accurately before, during, or after the test, depending on the nature of the item to be tested.

Sine-beat Test. This test is conducted by inducing sine beats of peak acceleration corresponding to those for which the item is to be qualified, at the frequency and amplitude of interest. The duration and amplitude of the beat for each test frequency must be chosen to produce a magnitude equivalent to that produced by the particular building-element response, with appropriate damping factors. For a test at any given frequency, 5 beats of 10 cycles per beat are normally used, with a pause between the beats so that no significant superposition of motion will result. Mounting of equipment and instrumentation shall be per approved methods.

Multiple-Frequency Test. Multiple-frequency testing provides a broadband test motion that is particularly appropriate for producing a simultaneous response from all modes of multi-degree-of-freedom systems. The test may be performed by applying a random excitation to the component (simultaneously in each of the three orthogonal directions), and adjusting the amplitude of the excitation in a frequency band not exceeding 1/3 octave. The resulting test response spectrum should envelop the required response for qualification.

Experience-based Data

In a similarity analysis, the dynamic and physical characteristics of the component and the required response spectrum are compared with those for a component that has already been qualified. This requires the availability of a database of qualified components. Engineers who are familiar with the component design and functional requirements should establish the dynamic similarity. Databases derived from past qualification and earthquake experience are captured in DOE/EH-0545.[12]

Combination Method

By combining different elements of the various qualification methods, a hybrid method may be developed that will make the qualification practical and potentially highly cost effective. For example, a system may be too large for a shake table, but may contain sensitive components that require qualification by testing. In such cases, the system may be structurally analyzed to determine the motions at the component locations, and these motions (e.g., expressed as response spectra) can be used as the required input motion for qualification of the components via dynamic testing. Similarly, by supplementing experience data with a simplified structural analysis, a powerful, cost-effective qualification method may be devised. Similar application has been proposed and reviewed for advanced light water reactors.[13, 14] This proposal includes duct qualification using a design-by-rule method—simple static analysis of linear duct models.

Documentation

The selected method(s) of seismic analysis, mathematical models and their natural frequencies, and input time-histories, as well as corresponding response spectra, damping values, and allowable stress criteria, must be shown in a qualification report together with the results of all tests and analyses. If the similarity analysis method is used, the comparison, including the experience data, should be documented. The documentation must provide detailed information that demonstrates the item meets specified requirements when subjected to the seismic motion for which it is to be qualified. A licensed professional engineer qualified in the analysis of such systems should certify the analytical and test results, including the operational data.

All instruments, including the heater, damper, and fan controls, should meet the requirements of IEEE 323,[15] *Standard for Qualifying Class 1E Electrical Equipment for Nuclear Power Generating Stations*, and IEEE 344,[11] *Recommended Practice for Seismic Qualification of Class 1E Equipment in Nuclear Generating Stations*. NRC Regulatory Guide 1.100,[9] *Seismic Qualification of Electrical Equipment for Nuclear Power Plants*, and NRC Regulatory Guide 1.105,[16] *Instrument Set-points*, are also applicable. Instrument controls and control panels should meet the design, construction, installation, and testability criteria in Section IA of ASME Code AG-1.[17]

The design, construction, and test requirements of Section BA of ASME Code AG-1[17] apply to Safety Class and Safety Significant systems' fans and motors. All Safety Class and Safety Significant systems must be built to ASME AG-1. Motors must meet the qualification requirements in IEEE 334,[18] IEEE 323,[15] and IEEE 344.[11] The structural design of Engineered Safeguard Feature (ESF) air cleaning systems must consider the service conditions that the components and housing may experience during normal, abnormal, and under accident conditions. The air cleaning system must remain functional following dynamic loading events such as an earthquake. The structural design of all safety class air cleaning systems, including all components, must be verified by analysis, testing, or a combination of both. Qualification criteria are contained in Section AA of ASME AG-1.[17] The design requirements for determining housing plate thickness, stiffener spacing, and size are contained in ASME-AG-1,[17] Sections AA, HA, and SA.

Equipment Qualification

The fundamental reason for qualifying equipment is to provide adequate levels of safety for the life of the facility. Equipment qualification is often a requirement for an operating license, and is designed to provide reasonable documented evidence that the system will satisfy the following three characteristics:

- <u>Qualification goals may be generic or application specific</u>. Generic qualification is probably best for the original equipment manufacturer because it enables use of the qualified item for a variety of applications. This type of qualification program requires test parameters that may exceed the needs of the current program, but are not extreme enough to reduce the chances of a successful qualification. An application-specific qualification limits the use of the component or system to those having the same or reduced environmental stresses.

- A mild environment qualification can usually be accomplished without determining a qualified life (per Section 4 of IEEE 323),[15] whereas a harsh environment program usually requires testing to verify performance under extreme accident conditions. <u>Simulated aging is necessary to arrive at "end-of-life conditions</u>" prior to accident condition testing. The walkdown requirements will be per DOE/EH-0545.[12]

- <u>It is necessary to determine whether the components are designated as safety-related or non-safety-related</u>. A non-safety-related item can often be excluded from the qualification process when it can be shown that a failure of that component would not adversely affect the safety function of the overall equipment.

The qualification plan must be developed in accordance with IEEE 323,[15] and must include a determination of the qualification method, listing of the environmental service conditions, description of any required aging programs, protocol of the test sequence, and a definition of the accident test profiles.

An aging program might consist of stressors such as thermal aging, mechanical/cyclic aging, radiation exposure, and mechanical vibration. All of these are designed to simulate conditions that would be encountered during the expected life of the test specimen prior to its undergoing an accident condition or test such as seismic pressure.

The requirements of IEEE 323[15] must be followed when preparing a qualification plan. The entire facility should be considered when designing an air cleaning system. Two questions must be addressed: (1) how can the system under design affect other systems and areas, and (2) how can the remainder of the facility affect this system?

There are system characteristics that apply to all air cleaning systems regardless of specific function or nature of the facility. One is that they must be capable of continuing to meet quantifiable test criteria to provide verifiable evidence of maintaining acceptance limits over the life of the installation. Therefore, an ability to maintain and test systems is as important as the ability of those systems to meet the initial performance criteria. The factors described in the following sections apply to all systems and must be addressed.

9.2.3 Volcanic Eruption

Sites, such as Hanford and Idaho National Engineering and Environmental Laboratory (INEEL), with a potential for volcanic eruption and the resulting ashfall must consider the consequences of such an event (e.g., the Hanford Reservation and the 1980 Mount Saint Helens eruption). The authorization basis documents should discuss the potential for such events, including the magnitude and duration of the ashfall event. In the event of a volcanic eruption, information and advanced notification should be available on the predicted time the ashfall will arrive. At Hanford, an eruption in the Cascade Mountains is predicted to yield an ashfall duration of approximately 20 hours. For one Hanford facility, this would require changing 95 percent intake filters every 4 hours.

9.2.4 Tornado

Structural damage from a tornado can arise from missiles, wind, or atmospheric pressure changes that occur when the funnel cloud passes over the building. Assuming the building is constructed to be tornado-resistant, damage to the air cleaning system will result mainly from pressure changes that occur in the stack, ducts, and building spaces surrounding the ducts. The design basis tornado hypothesizes that pressure on the building will decrease over time, remain at the depressed level, then return to normal. Because the operation of a ventilation system substantially relies on stable atmospheric conditions to maintain pressure differentials between the confinement zones of a building and to prevent the release of contaminants, it is likely that system upset, overrunning or reversal of fans, or even reverse flow could occur due to atmospheric depressurization, and failure of the dampers could exacerbate the condition. On the other hand, stack(s), ducts, and fans would attenuate the depressurization. The effects of high airflow rates, large pressure differentials, and sustained pressurization or depressurization on air cleaning systems and components are relatively unknown. The dynamic effects of tornadoes and pressure transients on air cleaning and ventilation systems need to be considered, and methods for describing, analyzing, and calculating the forces to which these systems would be subjected, along with their response to these forces, need to be mathematically modeled and developed. For further information on tornadoes, refer to Lawrence Livermore National Laboratory's 1985 study on the subject.[19]

Wind and tornadoes can potentially damage buildings and other structures in a variety of ways. Loose objects picked up by the wind can be turned into missiles that can penetrate a structure. The roof covering and siding material can be blown off the building. Winds passing sharp corners of the building tend to separate from the building, causing an outward pressure. In general, the windward surfaces of the building experience an inward pressure, and all other exterior surfaces experience an outward pressure. Likewise, the internal air pressure can rapidly change if air can pass into or out of a structure through openings such as those caused by a wind-driven missile. If the opening is on the windward side of the building, the internal pressure increases, reinforcing the outward pressure of the outside air on the other surfaces. If the opening is on any other side of the building, the internal pressure decreases, counteracting the outward pressure of the outside air. In any case, if the atmospheric pressure change (APC) exceeds the structural strength of the building, the building can suffer significant damage. The APC is especially important in tornadoes. See **Table 9.2** for design APC.

Table 9.2 – Summary of Minimum Wind Design Criteria per DOE-STD-1020 [3]

	Performance Category			
	1	*2*	*3*	*4*
Straight Wind and Hurricane				
Annual Probability of Exceedance	2×10^{-2}	1×10^{-2}	1×10^{-3}	1×10^{-4}
Importance Factor	1.0	1.0	1.0	1.0
Missile Criteria	NA	NA	2 × 4 timber plank 15 lb at 50 mph (horizontal); maximum height 30 ft.	2 × 4 timber plank 15 lb at 50 mph (horizontal); maximum height 50 ft.
Tornado				
Annual Probability of Exceedance	NA	NA	2×10^{-5} (see note)	2×10^{-6} (see note)
Importance Factor	NA	NA	1.0	1.0
APC	NA	NA	40 psf at 20 psf/sec	125 psf at 50 psf/sec
Missile Criteria	NA	NA	2 × 4 timber plank 15 lb at 100 mph (horizontal); maximum height 150 ft at 70 mph (vertical). 3-in.-diameter standard steel pipe, 75 lb at 50 mph (horizontal); maximum height 75 ft at 35 mph (vertical).	2 × 4 timber plank 15 lb at 150 mph (horizontal); maximum height 200 ft at 100 mph (vertical). 3-in. diameter standard steel pipe, 75 lb at 75 mph (horizontal); maximum height 100 ft at 50 mph (vertical). 3,000 lb automobile rolls and tumbles at 25 mph.

Note: These are the minimum values for APC and tornado missile criteria. Tornado hazard curves developed by Lawrence Livermore National Laboratory and applicable site-specific tornado design values should be used for DOE sites.

High-speed winds can be classified as "straight," "tornado," or "hurricane." Straight winds are nonrotating winds that cover a wide area, typically many tens of miles across, and can reach speeds exceeding 100 miles per hour (mph). They are generally associated with thunderstorms, mesocyclones, and orographic effects. Tornadoes are violently rotating winds that are highly localized, a few miles or less across, and can reach speeds in excess of 200 mph. They can accompany severe weather events such as thunderstorms and even hurricanes. Hurricanes are very large-scale rotating winds, typically hundreds of miles across. Hurricanes are important for coastal DOE sites, but not for ones interior to the continent, as hurricanes typically do not reach inland more than a few hundred miles. For any type of wind, whether straight or rotating, a building is small compared to the size of the area affected by the wind, and the response of the building is the same. A distinction is made between different types of wind because of the differences in the hazard curves, which show the wind speed as a function of the annual probability of exceeding that wind speed. For straight winds and tornadoes design speeds, see Table 9.2, which is taken from DOE-STD-1020.[3]

The performance goals established for PC 1 and PC 2 are met by model codes or national standards. Since model codes specify straight winds at probabilities greater than approximately 1×10^{-2}, tornado design criteria are specified only for SSCs that are designated as PC 3 and higher, where hazard exceedance probabilities are less than 1×10^{-2}.

All wind speeds are 3-second gusts, which is consistent with the American Society of Civil Engineers (ASCE 7-98[20]) approach. Design tornado wind pressures on SSCs should be used with Exposure Category C, regardless of the actual terrain roughness. For SSCs in PC 3 and PC 4, it is important to determine whether tornadoes should be included in the evaluation based on geographical location and historical tornado occurrence records. Site-specific tornado hazard assessments are available for most DOE sites, and a quantitative approach should be taken. Details of the approach are presented in Appendix D of DOE-STD-1020.[3]

The weakest link in the load path of an SSC will determine the adequacy or inadequacy of the performance of the SSC under wind load. As a result, evaluation of the existing SSCs normally should focus on the strengths of connections and anchorages, as well as the ability of the wind loads to find a continuous path to the foundation or support system.

Failure caused by wind and tornado is a progressive process, initiating with an element failure. Once the initial element failure occurs at the lowest calculated wind speed, the next event in the failure sequence can be anticipated. All obvious damage sequences should be examined for progressive failures. Once the postulated failure sequences are identified, the SSC performance is compared with the stated performance goals for the specified PC. Damage to facilities can arise from both wind impacts (pressure changes) and airborne missiles driven by the wind. The PCs for facilities are related to the exceedance probabilities for the NPH events, as discussed above. In the case of wind, the PCs are also related to missile penetrations. These are given in DOE -STD- 1020[3] and are summarized in Table 9.2.

Table 3-3 in DOE-STD-1020[3] lists recommended “straight wind” missile barriers for SSCs categorized as PC 3 and PC 4. Similarly, Tables 3-4 and 3-5 of this standard show recommended barriers for “tornado” missiles for PC 3 and PC 4, respectively. Although wind pressures, APC, and missile impact loads can occur simultaneously, the missile impact loads can be treated independently for design and evaluation purposes.

9.2.5 Flood

In accordance with DOE Order 420.1A,[1] flood design and evaluation criteria seek to ensure that safety SSCs at DOE sites satisfy the performance goals described in DOE-STD-1020.[3] The determination of the design basis flood (DBFL) that must be considered in flood design for design of civil engineering systems such as structures, site drainage, roof systems, and roof drainage is addressed in DOE-STD-1023.[7] The criteria specified in terms of the flood hazard input, hazard annual probability, design requirements, and emergency operation plan requirements are described in Chapter 4, Table 4-1, of the DOE-STD-1020.[3] The mean hazard probability is 2×10^{-3} for PC 1 SSCs, 5×10^{-4} for PC 2 SSCs, 1×10^{-4} for PC 3 SSCs, and 1×10^{-5} for PC 4 SSCs.

Flooding occurs when the rate of water entry into an area or facility exceeds the removal rate. According to DOE-STD-1020,[3] both storm sewers and open channels must be sized to accommodate runoff from the 25-year, 6-hour storm. The potential effects of larger storms (up to the 100-year, 6-hour storm) should also be considered. Flooding is important because it can damage facilities, spread contamination, and potentially lead to a criticality. Flooding may be caused by locally heavy rains as well as by distant rains that cause nearby rivers to overflow. An accident analysis should examine the statistics of both heavy rain and river flooding. The water load on roofs is also a concern during periods of heavy precipitation. If drainage is blocked, ponds could form on flat roofs and possibly cause structural failure. For example, a pond 1,000 square feet in area (e.g., 25 by 40 feet) and 2 inches deep weighs over 5 tons. This could be enough to breach a roof.

Because floods have a common-cause impact on SSCs located in proximity to one another, the design basis for the most critical SSC may govern the design for other SSCs or for the entire site. Therefore, it may be more realistic economically and functionally to develop a design strategy that satisfies the performance goals of the most critical SSC and, simultaneously, that of other SSCs. Hardening a site by constructing a levee system might be more feasible for a specific site, thereby protecting all SSCs.

Flood hazard assessment consists of identifying sources of flooding (e.g., rivers, lakes, local precipitation) and the individual associated flood hazards (e.g., hydrostatic forces, ice pressures, hydrodynamic loads). On the rare occasion, an individual SSC or the entire site may be impacted by multiple sources of flooding and flood hazard. DOE-STD-1023[7] presents guidelines for conducting a probabilistic flood hazard assessment. As a part of such a probabilistic assessment, an evaluation of uncertainty is also performed. The DFB events that must be considered are shown in **Table 9.3**.

Table 9.3 – Design Basis Flood Events*

Primary Hazard	***Event Combination to be Considered with Primary Hazard***
River Flooding	1 peak flood evaluation 2 wind waves
Dam Failure	3 ice forces 4 erosion, debris, etc. 1 all models
Local Precipitation	2 wind waves 3 erosion, debris, etc.
Storm Surge, Seiche (due to hurricane, seiche, squall lines, etc.)	1 site runoff 2 ponding on the roof 3 rain and snow
Levee or Dike Failure	1 tide effects
Snow	1 snow and drift – roof
Tsunami	1 overtopping 2 wave action 1 tide effects

* For event combinations, see DOE-STD-1020[3].

Limited flood hazard assessments for some DOE sites have been conducted. Flood loads are assessed for the DBFL on an SSC-by-SSC basis. If the hazard annual probability for a primary flood hazard is less than the design basis hazard annual probability for a given PC, as mentioned above, it need not be considered a design basis event. For example, if the hazard annual probability for PC 1 is 2×10^{-3} per year, failure of an upstream dam need not be considered if it can be shown that the mean probability of flooding due to dam failure is less than 2×10^{-3}.

The strategy of hardening an SSC or site and providing emergency operation plans is secondary to siting facilities above the DBFL level because some probability of damage does exist and, as a result, SSC operations may be interrupted. Flood mitigation systems (e.g., exterior walls, flood-proof doors, etc.) must be considered in accordance with the requirements specified in the applicable regulations.

Unlike design strategies for seismic and wind hazards, it is not always possible to provide a margin in the flood design of an SSC. When a site is inundated, it will cause significant disruption. Under these circumstances, there is no margin, as the term is used in the structural sense. Therefore, the SSC must be kept dry, and operations must not be interrupted to satisfy the performance goals. Refer to DOE-STD-1020[3] for further details.

9.2.6 Lightning

DOE facilities have been struck by lightning numerous times, causing equipment damage and adversely affecting facility safety and operations. At any given time, some 2,000 thunderstorms are occurring around the world, creating approximately 100 lightning strikes every second.

Lightning is a high-current electrical discharge in the atmosphere with a path length typically measured in km. Electrical currents from lightning range from one to hundreds of kA. The upper one-percentile current (99 percent of all lightning flashes have a lower current) has been determined to be about 200 kA; this is identified (by lightning scientists) as the severe threat level. The median (50th percentile) value lies in the 20- to 30-kA range. Lightning can travel at 35,000 to 100,000 km/sec.

It is important to assess the severity and frequency of lightning strikes for several reasons. Lightning can cause a fire, a breach in a building, sensor failures or false alarms, communications and electronic component failures, and power failures that give rise to other system failures.

Lightning data for the United States is given in the *Lightning Protection Code*, National Fire Prevention Association (NFPA) 780[8] and a yet to be published DOE Standard entitled *Lightning Hazard Management Guide for DOE Facilities*. The probability of lightning striking a particular object located on the earth (ground) is found by multiplying the object's lightning-attractive area by the local ground-flash density (lightning strikes to ground per square kilometers per year).

For flat terrain without buildings or other structures, the probability of a lightning strike is the same throughout the area. Structures, however, especially tall ones such as stacks, water towers, and power poles, attract lightning and increase the probability of a strike at those locations, thus decreasing the probability at other nearby locations. These taller structures thus provide some protection for the shorter structures nearby. The "circle of protection" offered by a tall structure depends on its height and on the peak current in the lightning strike. The higher the structure, the larger the circle of protection. As a rule of thumb, for a medium-current strike, the radius of the circle of protection is equal to the height of the grounded lightning attractor. This is not valid for all lightning, however, as the radius of the circle of protection also depends on the current in the lightning strike—the larger the current, the larger the circle of protection. A building that may be protected by a larger nearby structure for a high-current lightning strike may not be protected from a lower-current strike. Elevated conducting wires that are horizontal and grounded can also protect facilities below them. Power lines, therefore, could be considered to provide some protection for certain buildings. In general, the stacks, water towers, and power lines of a site offer protection for only a small portion of a site.

Lightning strikes are of greatest concern to facility managers during the late spring, summer, and early fall. A review of the DOE Occurrence Reporting and Processing System database revealed that 89 percent of lightning-related events occurred during the second and third quarters of the year.

Lightning protection equipment can degrade over time or after suppressing numerous strikes, and can suddenly fail without warning. Deficiencies such as failed surge arresters or degraded insulation can cause ground faults and electrical distribution system failures. If NFPA-specified lightning protection is provided, the likelihood of lightning damage is, of course, greatly reduced.

Risk analysis should consider the consequences of a lightning strike and its likelihood of occurrence. DOE sites such as Sandia National Laboratories, the West Valley Site, Fernald, Hanford, the Savannah River Site, and Pantex are a few of the sites where damaging lightning has been reported. The risk for facilities that contain high-energy systems or components such as explosives (e.g., Pantex) would be elevated because of the potential damage from a detonation. Instruments and control systems at many facilities are also vulnerable to damage and lightning-induced malfunction. Brief over-voltages caused by lightning strikes and manmade transient voltages can immediately destroy low-power solid state components such as computer chips, or can weaken them to the point that they fail months after a lightning event.

Not every lightning strike is damaging. The amount of damage depends on the amount of current in the return strike, the magnitude of any continuing current, and the susceptibility of the target to lightning damage. Electronic equipment, for example, is more susceptible to failure from a lightning strike than a concrete pad is to fire damage. The main danger to a site from lightning is from fire, as fire can potentially lead to a release of radioactive or chemically hazardous material. Lightning-induced fire can be caused in several ways. Examples are listed below.

- Fire can be started in dry combustible material such as a wooden structure or dry grass by the weak "continuing current" between lightning strikes. About 20 percent of lightning strikes have a continuing current large enough to start such a fire. The magnitude of the peak current is not relevant here, as the return strike is too brief to start a fire.

- A lightning strike on a building can induce large currents in the electrical wiring in the building. It is possible that the high current will cause a breakdown in both the insulation on the wiring and the insulation provided by the air, causing an electrical arc to form between the wire and a nearby grounded object. A followon current from the electrical circuit would then sustain the arc and could continue for many seconds or even minutes, long after the lightning strike is gone. Combustible material in the immediate vicinity could then be ignited. Although arcing is more likely with larger-current strikes, any magnitude of strike could produce it. To be conservative, all lightning strikes on a building should be considered.

- A lightning-induced spark or voltage surge can initiate a fire. Such fires have been observed in reinforced concrete facilities when lightning struck power lines several miles away.

- Damage to electronic components from lightning strikes can create spurious control system signals. The potential for such signals to initiate the release of radioactive or chemically hazardous materials should be evaluated.

9.3 Deep-Bed Sand Filters

Some of the following material is taken directly from ERDA 76-21.[21] Although dated, it is still relevant today, and has been updated where appropriate.

Deep-bed sand (DBS) filters have been used in the ventilation and process exhaust systems of radiochemical processing facilities since 1948. The major attractions of DBS filters include large dust-holding capacity, low maintenance requirements, inertness to chemical attack, high heat capacity, fire resistance, and the ability to withstand shock loadings and large changes in airstream pressure without becoming inoperative. The disadvantages of DBS filters include high capital cost; large area; high pressure drop; high power costs; and uncertainties in selection, availability, grading, and handling of suitable sands; and issues with disposal of the spent unit.

DBS filters are deep (several feet thick) beds of rock, gravel, and sand, constructed in layers graded with about two-to-one variation in granule size from layer to layer. Airflow direction is upward, and granules decrease in size in the direction of airflow. A top layer of moderately coarse sand is generally added to prevent fluidization of finer sand. The rock, gravel, and sand layers are positioned and sized for structural strength, cleaning ability, dirt-holding capacity, and long life. **Figure 9.3** shows the cross-section of a typical DBS filter. Ideally, the layers of larger granules, through which the gas stream passes first, remove most of the larger particles and particulate mass, and the layers of finer sands provide high-efficiency removal. Below the fixed bed of sand and gravel is a course of hollow tile that forms the air distribution passages. The filter is enclosed in

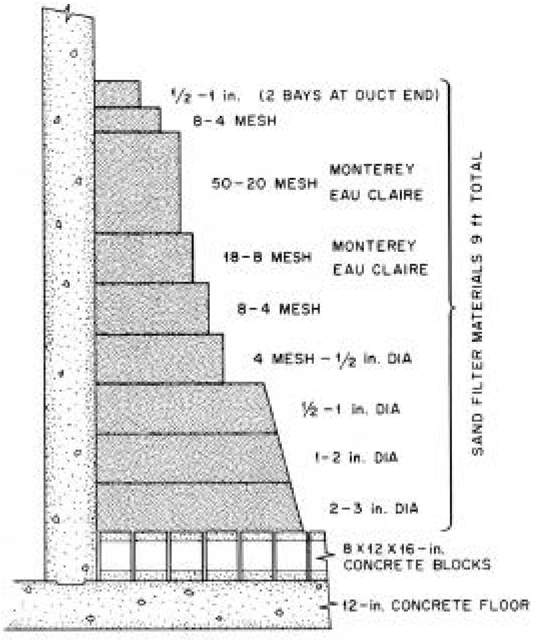

Figure 9.3 – Section through Typical Sand Filter

a concrete-lined pit. The superficial velocity is around 5 fpm, and the pressure drop across 7 layers, sized from 3 1/2 inches to 50 mesh, is from 7 to 11 in.wg. Collection efficiencies up to 99.98 percent [determined by in place test with polydispersed 0.7-number mean diameter (NMD) test aerosol have been reported.[22] The approximate capital cost of a sand filter is $300 per cfm in 2001 dollars.

A removal efficiency approaching that of a single HEPA filter has been claimed for DBS filters if the proper sands are used and the contact path is long enough. Efficiency tests of DBS filters can only be made using polydispersed test aerosols with an NMD of about 0.7 µm and the in-place test procedures described in Chapter 8. True efficiency tests of HEPA filters, on the other hand, are made with a monodispersed test aerosol with an NMD of 0.3 µm. In addition, tests of very large units, such as DBS filters, are often made under conditions that sometimes yield results that are difficult to interpret. For these reasons, although the efficiency of DBS filters approaches that of HEPA filters, it should not be assumed that the efficiency of DBS filters for submicron particles is actually equivalent to that of HEPA filters.

DBS filters have received renewed interest in the past few years because of increased concern about the effects of natural phenomena (earthquake, tornado), fire, and explosion, and because procurement and maintenance costs of alternative air cleaning methods have increased substantially. DBS filters are characteristically one-of-a-kind designs. They are literally constructed in the field as the gravel is positioned and the sand is poured in place. No standards exist, so most of the information for new designs must come from reports of previous applications. A bibliography and review of DBS filters built prior to 1970 was prepared by Argonne National Laboratory.[23]

Following initial installation of a DBS filter at DOE's Hanford Site, nine others were installed at Hanford, Savannah River, and the Midwest Fuel Recovery Plant at Morris, Illinois. All but one[22] of these were designed for cleaning ventilation air from fuel reprocessing facilities, and only five (all at Savannah River) are currently used for this purpose. There is a DBS filter in the roof of the Zero Power Research Reactor[24] at Idaho Falls, but it is for emergency exhaust cleanup only and is not operated under normal conditions. Details of existing U.S. DBS filters are given in **Table 9.4**. Properties of sands and aggregates used as the filtration media of these filters are given in **Table 9.5**.

9.3.1 DEEP-BED SAND FILTER DESIGN

A rough approximation of the collection efficiency of sand, on an activity basis, is given by the following equation:[21]

$$? = - \exp\left(-KL^{1/2}V^{-1/3}D^{-4/3}\right) \qquad (9.1)$$

where:

? = fractional collection efficiency on a radioactivity or mass basis

L = depth of fine sand, feet

V = superficial gas velocity, fpm

D = average sand grain diameter, inches

K = proportionality factor

[Note: The values of L, V, and D vary with sands from different sources of the same mesh size and must be determined experimentally for any given sand.]

Table 9.4 – Dimensions and Operating Data of Existing U.S. Deep-Bed Sand Filters

DBS Filter No.[a]	Plan Dimensions[b] (ft)	Design Flow (cfm)	Design Superficial Velocity (fpm)	Design Pressure Drop (in.wg)	Year of Initial Operation	Present Status of DBS
1	108×46	25,000	5.0	5.0	1948	Standby
2	108×46	25,000	5.0	7.0	1948	Standby
3	96×96	40,000	4.3	10.0	1950	[c]
4	85×85	40,000	5.5	12.0	1951	Active
5	240×100	20,000-30,000	4.8	~10.0	1954	Active
6	240×100	20,000-30,000	4.8	9.2	1955	Active
7	360×100	210,000	5.8	~10.0	1975	Active
8	360×100	210,000	5.8	~10.0	1976	Active
9	140×103	74,000	5.1	Not available	1974	Active
10	72×78	32,000	5.7	Not available	1974	[c]
11	50 to 62.5 (diameter)	*E*	*D*	Not available	1968	Active
12	120 x 192	115,000	5.0	8.0	1995	Active
13	Not available					
14	Not available					

[a] Filter identification:

1. T Plant, Building 291-T, Hanford West Area, Richland, WA.
2. B Plant, Building 291-B, Hanford East Area, Richland, WA.
3. U Plant, Building 291-U, Hanford, Richland, WA.
4. Redox Facility, Building 291-S, Hanford, Richland, WA.
5. F Area, Building 294-F, Savannah River Site, Aiken, SC.
6. H Area, Building 294-H, Savannah River Site, Aiken, SC.
7. F Area, Building 294-1F (new), Savannah River Site, Aiken, SC.
8. H Area, Building 294-1H (new), Savannah River Site, Aiken, SC.
9. SRL, Building 794-A, Savannah River Laboratory, Aiken, SC.
10. Midwest Fuel Recovery Plant (MFRP),[c] Morris, IL.
11. Zero Power Plutonium Reactor Facility, Argonne National Laboratory, Idaho Falls, ID.
12. S Area, Defense Waste Processing Facility, Savannah River Site, Aiken, SC
13. F Area, Building 235-F, Savannah River Site, Aiken, SC.
14. Pit Conversion and Disassembly Facility (PCDF), Savannah River Site, Aiken, SC (under construction).

[b] Inlet side shown first, outlet side italicized.

[c] MFRP is not engaged in reprocessing, only storage; sand filter is active.

[d] This is an emergency relief system.

Values for the proportionality constant, *K*, for several sands tested at Hanford are:

Type of Sand	*K*
Hanford	0.053
AGS flint	0.045
Rounded grain sand (Ottawa, Eau Claire, Monterey)	0.035

Collection efficiency on a radioactivity basis gives a higher number than the collection efficiency on a count basis, as reflected by the test aerosol test, because larger, more easily collected particles may carry more radioactivity and bias the analysis to give greater value to larger particles. The relationship between count and activity collection efficiency cannot be determined without accurate information on aerosol size distribution and the relationship of aerosol size to radioactivity.

Table 9.5 – Properties of Sands and Aggregates Used in Existing U.S. Deep-bed Sand Filters

Property	**Filter No.[a]**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9, 12**	**10**
Depth of bed, feet	9	8.5	8	8	8	8	7.5	7.5	7.5	8
Number of layers	9	8	7	7	7	7	6	6	6	
Depth of layers (inches)										
Granule size range, mesh (unless inches noted)										
Layer A 2-3 inches	12									
2 1/2-1 1/4 inches		12								
3-1 1/4 inches					12	12	12	12	12	
3-1 inches			12	12						18
Layer B 1-2 inches	12									
1 3/4-5/8 inches		12	12	12						12
1 1/2-5/8 inches					12	12	12	12	12	
Layer C 1-1/2 inch	12									
3/4 inch ~ 6		12	12	12						
5/8-1/4 inch					12	12	12	12	12	
Layer D 1/2 inch -4	12									
3/8 inch -3										12
Layer E 4-8	12	6	6	6	6	6	6	6		6
1/4 inch -8									6	
Layer F 8-20	12	12	12		12	12	12	12	12	6
8-18				12						
Layer G 20-40										
30-50					36[b]	36	36	36	36	
20-50			36	36[b]						36

[a] See Table 9.4 for locations corresponding to number.

[b] Removed 12 inches from G layer, July 1972, to reduce pressure drop.

The approximate void fraction of a sand bed is generally about 0.4. Sand permeability tests have shown that intense vibration can cause extreme compaction, resulting in near doubling of the pressure drop.[25, 26, 27] Factors that must be considered include the effects of compaction, steam injection, relative humidity, and velocity change on efficiency and pressure drop. Besides permeability and filtration requirements, the sand must be abrasion- and fracture-resistant and must resist corrosion from the fumes likely to be present in the exhaust airstream.

Filter life is determined by the increase in pressure drop and the decrease in gas flow caused by the collection of solids within the sand bed. Filter life can be significantly reduced if solids collection is concentrated in small fractions of the bed or on the finer sand. Uniform concentration of coarse aggregate layers upstream of the fine sand layer tends to maximize filter life.

Clogging of DBS filters is aggravated by local decreases in porosity at the interfaces between graded layers. The mixing of aggregates (sand, gravel) at the interfaces usually results in a lower void fraction at the interface than if no mixing is permitted. The extent of reduction in void fraction depends on the characteristics of the aggregates and on the technique used to charge them into the filter bed. The lowest layer may require hand placement for the first few inches so that no rocks fall through the openings in the distribution blocks. Significant improvement in filter life can be obtained by careful attention to loading.

The DBS filter housing is a poured concrete structure, located partially underground, with walls capable of withstanding the DBE without cracking and the design basis flood without leaking. The floor has channels for distributing the incoming air and is covered by the special hollow block shown in the view of the empty sand filter. The floor and the distribution system must bear the weight of the sand column above it. With corrosion and aging, withstanding this weight has been a problem in some DBS filters. The floor should be sloped to a drain and have a built-in capability for drainage if it becomes necessary. It is often prudent not to connect the drain line so that a determination of what to do with the drainage can be made after the event if flooding occurs. The filter should be on the suction side of the fan so that it is negative to the atmosphere and all leakage is inward. See **Figure 9.4**.

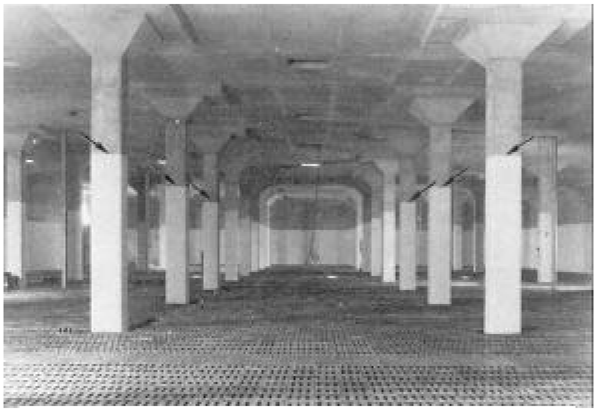

Figure 9.4 – Interior of New Sand Filter at Savannah River Laboratory Before Loading of Sand and Aggregate

When a DBS filter has been used in series with HEPA filters at plutonium facilities, it should be located upstream of the HEPA filters. An isometric of this filter is show in **Figure 9.5**.

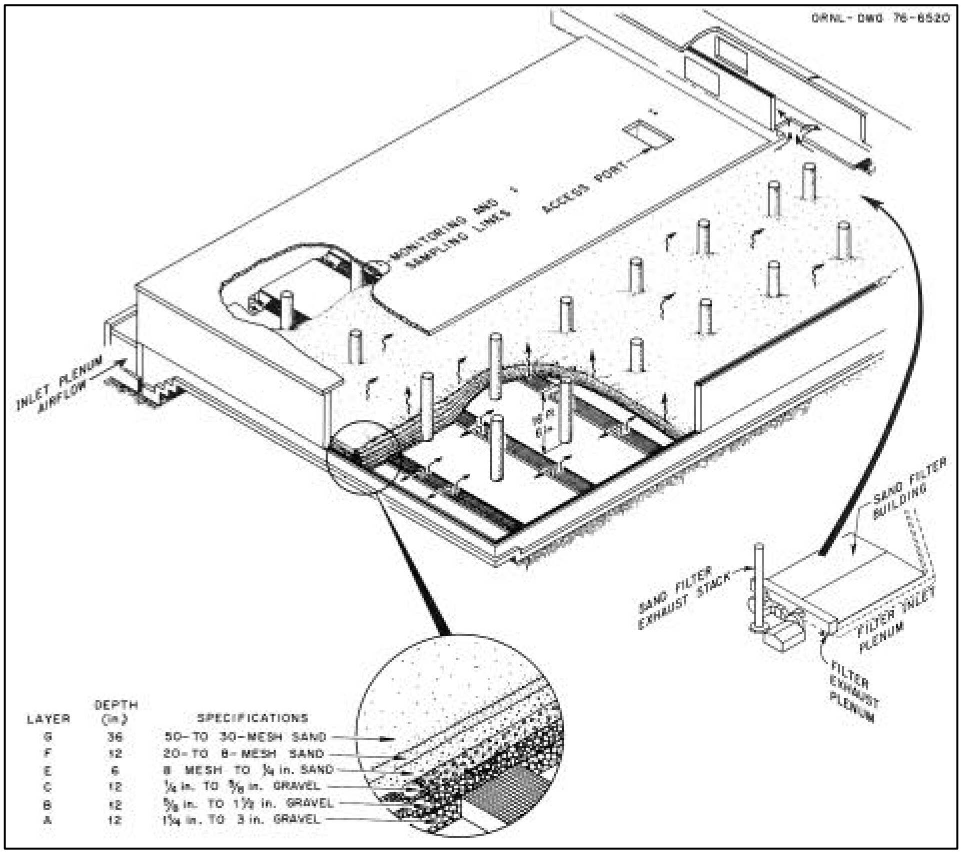

Figure 9.5 – Overall Isometric View and Details of New Sand Filter at Savannah River Laboratory

9.3.2 Deep-Bed Sand Filter Plugging

Some filters have experienced plugging at low dust loadings. In one case, the plugging was caused by moisture entering through cracks in the concrete sidewalls of the unit. In another instance, plugging was caused by crystal growth in the filter media fines, probably due to a reaction of nitric acid vapors from the process building with calcite, with dolomite present in the original sand, and with cement dust generated by severe erosion and acid attack on the concrete entry ducts and support structures.

9.3.3 Spent Media Disposal

Deactivation of existing filters is generally accomplished by sealing and abandoning the filter. Spent media are stored in place within the unit. The total unit is replaced by a new filter located close by. Present Government regulations for radioactive solid waste, though unclear, may rule out such in-place disposal in the future. If the material were handled as high-level radioactive waste, each 1,000-cfm capacity of filter would require about two hundred 55-gallon drums for disposal. A detailed analysis of filter decommissioning was performed for the PDCF Project at the Savannah River Site. This is currently the best available information on the cost of decommissioning.

9.3.3.1 Burial in Place

Burial in place (or entombment) for DBS filters is feasible and could be economical if provisions are applied during initial design of the filters to ensure that the walls, floors, and roof integrity are sufficient to satisfy the requirements of 10 CFR 61,[28] and the requirements of other regulatory agencies such as the U.S. Environmental Protection Agency and South Carolina Department of Health and Environmental Control. To ensure that the selected location of the DBS filter can be licensed, the location must be suitable for near surface disposal in accordance with 10 CFR 61,[28] Subpart D. The primary emphasis in disposal site suitability is given to isolation of the waste. This involves evaluation of long-term impacts and disposal site features that ensure that the long-term performance objectives of 10 CFR 61,[28] Subpart C, are achieved. (Note: 10 CFR 61 applies specifically to NRC facilities, but is used for guidance here).

To ensure that the facility can be licensed as a near-surface land disposal facility, initial site characterization and the installation of long-term ground water monitoring wells during construction is essential. Estimated costs associated with this method of disposition are provided in **Table 9.6**.

Table 9.6 – DBS Filter Entombment Decontamination and Decommissioning Cost Estimate**

Cost Parameter	*Unit Cost/ft^3*	*Volume (ft^3)*	*Total Cost***
Licensing			500,000
Initial Site Characterization			200,000
Monitoring Well			100,000
Grout Void Space	$5.00	144,000	720,000
Cover Fill (5 meters)	$0.50	590,400	295,200
Tunnel Decon			2,073,474
		Total	$3,888,674

Assume the void space above the fill to be 4 feet high, 300 feet wide, and 120 feet long, with a volume of 144,000 cubic feet.

** All costs are for FY 2002.

9.3.3.2 Decontamination

Because of the irregular surface areas and porous nature of the clay tile, stones, gravel, and sand filter media utilized in DBS filters, decontamination methods currently available would be mostly ineffective. Ancillary materials such as concrete confinement walls and supports and steel grating, if utilized, are potential candidates for decontamination, but make up a relatively small percentage of the total mass of the DBS filter.

9.3.3.3 Onsite Disposal

Low-level waste onsite disposal techniques include:

- Onsite transport in steel containers from point of origin to storage vaults,
- Manual sorting of waste to separate out compactable waste,
- 55-gallon drum compaction, when practical,
- Return to steel containers, and
- Final interment in the waste storage vaults.

Onsite disposal techniques are well developed and currently licensed. However, existing permits limit current space availability. **Table 9.7** provides a cost estimate for onsite disposal of filter materials and stabilization by grout of the remaining structural members.

Table 9.7 – Sand Filter Onsite Disposal Cost Estimates*

Without Characterization					
Activity		***Volume (ft^3)***		***Cost/ft^3***	***Cost $***
Filter Media Disposal		288,000		$106	$30,528,000
Activity	***Volume (ft^3)***	***Hr/ft^3***	***Cost/ft^3***	***Labor $/hr***	
Media Removal	288,000	0.10		$57.76	$1,663,488
Grout Fill	432,000		$5.00		$2,160,000
Tunnel Decon					$2,073,474
Total					$34,351,488
With Characterization					
Activity		***Volume***		***Cost/ft^3***	***Cost $***
Filter Media Disposal		144,000		$106	$15,264,000
Activity	***Volume (ft^3)***	***Hr/ft^3***	***Cost/ft^3***	***Labor $/hr***	
Media Removal	288,000	0.10		$57.76	$1,663,488
Characterization	288,000	0.05		$83.09	$1,196,496
Grout Fill	432,000		$5.00		$2,160,000
Tunnel Decon					$2,073,474
Total					$20,283,984
Sand Filter Specifications:					
Required Flow	***Velocity***	***Face***	***Length***	***Width***	***Depth***
160,000 cfm	5 fpm	32,000	300 ft	120 ft	8 ft
Waste Volume		***Face***			
288,000 ft^3		36,000			

* All cost estimates are for FY 2000.

9.3.3.4 Offsite Disposal

An alternative approach would be for removal of filter media from the sand filter structure and disposal at an offsite near-surface land disposal site. Offsite disposal methodologies would be similar to onsite disposal impacts, except that the increased costs of offsite burial would be incurred. Labor costs for offsite disposal would be similar to those incurred for onsite disposal. **Table 9.8** provides a cost estimate for offsite disposal of filter media and stabilization by grout of remaining structural members.

9.3.3.5 Long-Term Safe Storage

This approach requires continuing surveillance and security measures to prevent inadvertent intrusion. While costs may not be severe on an annual basis, in the long term they can be significant. This alternative constitutes a continuing threat to the public and the environment. Ultimate disposal would still be necessary, but at escalated costs.

Table 9.8 – Sand Filter Offsite Disposal Cost Estimates*

<table>
<tr><th colspan="6">Without Characterization</th></tr>
<tr><th colspan="2"><i>Activity</i></th><th><i>Volume ft^3)</i></th><th></th><th><i>Cost/ft^3</i></th><th><i>Cost $</i></th></tr>
<tr><td colspan="2">Filter Media Disposal</td><td>288,000</td><td></td><td>$570</td><td>$164,160,000</td></tr>
<tr><th><i>Activity</i></th><th><i>Volume (ft^3)</i></th><th><i>Hr/ft^3</i></th><th><i>Cost/ft^3</i></th><th><i>Labor $/hr</i></th><th></th></tr>
<tr><td>Media Removal</td><td>288,000</td><td>0.10</td><td></td><td>$57.76</td><td>$1,663,488</td></tr>
<tr><td>Grout Fill</td><td>432,000</td><td></td><td>$5.00</td><td></td><td>$2,160,000</td></tr>
<tr><td>Tunnel Decon</td><td></td><td></td><td></td><td></td><td>$2,073,474</td></tr>
<tr><td colspan="5">Total</td><td>$167,983,488</td></tr>
<tr><th colspan="6">With Characterization</th></tr>
<tr><th colspan="2"><i>Activity</i></th><th><i>Volume</i></th><th></th><th><i>Cost per ft^3</i></th><th><i>Cost $</i></th></tr>
<tr><td colspan="2">Filter Media Disposal</td><td>144,000</td><td></td><td>$570</td><td>$82,080,000</td></tr>
<tr><th><i>Activity</i></th><th><i>Volume (ft^3)</i></th><th><i>hr/ft^3</i></th><th><i>Cost/ft^3</i></th><th><i>Labor $/hr</i></th><th></th></tr>
<tr><td>Media Removal</td><td>288,000</td><td>0.10</td><td></td><td>$57.76</td><td>$1,663,488</td></tr>
<tr><td>Characterization</td><td>288,000</td><td>0.05</td><td></td><td>$83.09</td><td>$1,196,496</td></tr>
<tr><td>Grout Fill</td><td>432,000</td><td></td><td>$5.00</td><td></td><td>$2,160,000</td></tr>
<tr><td>Tunnel Decon</td><td></td><td></td><td></td><td></td><td>$2,073,474</td></tr>
<tr><td colspan="5">Total</td><td>$87,099,984</td></tr>
</table>

* All costs are for FY 2000.

9.4 References

1. DOE (U.S. Department of Energy), 2002, *Facility Safety*, DOE Order 420.1A, Washington, DC.

2. DOE (U.S. Department of Energy), 2000, *Guide for the Mitigation of Natural Phenomena Hazards for DOE Nuclear Facilities and Nonnuclear Facilities*, DOE Guide G420.1-2, Washington, DC, March 28.

3. DOE (U.S. Department of Energy), 2002, *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities*, DOE-STD-1020, Washington, DC, January.

4. International Code Council Inc., 2000, *International Building Code 2000*, IBC 2000, Falls Church, VA.

5. DOE (U.S. Department of Energy), 2002, *Natural Phenomena Hazards Performance Categorization Criteria for Structures, Systems, and Components*, DOE-STD-1021, Washington, DC, April.

6. DOE (U.S. Department of Energy), 2002, *Natural Phenomena Hazards Site Characterization Criteria*, DOE-STD-1022, Washington, DC, April.

7. DOE (U.S. Department of Energy), 2002, *Natural Phenomena Hazards Assessment Criteria*, DOE-STD-1023, Washington, DC, April.

8. NFPA (National Fire Protection Association), 2000 edition, *Standard for the Installation of the Lightning Protection Systems*, NFPA 780, Quincy, MA.

9. NRC (U.S. Nuclear Regulatory Commission), 1988, *Seismic Qualification of Electric and Mechanical Equipment for Nuclear Power Plants*, NRC Regulatory Guide 1.100, Revision 2., Washington, DC, June.

10. NRC (U.S. Nuclear Regulatory Commission), 1996, *Standard Review Plan for the Review of Safety Analysis Reports of Nuclear Power Plants*, NUREG-0800, Sections 3.9 and 3.10, Washington, DC.

11. IEEE (Institute of Electrical and Electronic Engineers), 1987, *Recommended Practice for Seismic Qualification of Class1E Equipment for Nuclear Power Generating Stations*, IEEE Standard 344-1987, New York, NY.

12. DOE (U.S. Department of Energy), 1997, *Seismic Evaluation Procedure for Equipment in U.S. Department of Energy Facilities*, DOE/EH-0545, Washington, DC, March.

13. MPR Associates and EQE International for Advanced Reactor Corporation, 1996 *Advanced Light Water Reactor (ALWR) First-Of-A-Kind Engineering Project on Equipment Seismic Qualification*, February.

14. EQE International for Advanced Reactor Corporation, 1995, *Advanced Light Water Reactor (ALWR) First-Of-A-Kind Engineering (FOAKE) Project on Design by Rule for HVAC Ducting and Supports*, April.

15. IEEE (Institute of Electrical and Electronic Engineers), 1983 (R1996), *Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations*, IEEE-323, New York, NY.

16. NRC (U.S. Nuclear Regulatory Commission), 1999, *Instrument Set-Points*, Regulatory Guide 1.105, Revision 3, Washington, DC.

17. ASME (American Society for Mechanical Engineers), 2003, *Code of Nuclear Air and Gas Treatment*, ASME AG-1, New York, NY.

18. IEEE (Institute of Electrical and Electronic Engineers), 1994, *Standard for Qualifying Continuous Duty Class 1E Motors for Nuclear Power Generating Stations*, IEEE-334, New York, NY.

19. Lawrence Livermore National Laboratory, 1985, *Development of a Probabilistic Tornado Wind Hazard Model for the Continental United States*, UCRL-ID-140922, (prepared for the U.S. Department of Energy).

20. ASCE (American Society of Civil Engineers), 1998, *Minimum Design Loads for Buildings and Other Structures*, ASCE 7-98, New York, NY.

21. ERDA (Energy Research and Development Administration), 1976, *Nuclear Air Cleaning Handbook: Design, Construction, and Testing of High-Efficiency Air Cleaning Systems for Nuclear Applications*, ERDA 76-21. Oak Ridge National Laboratory, Oak Ridge, Tennessee, 2nd Edition, Washington, DC.

22. Mover, R. A., J. H. Crawford, and R. E. Tatum, 1975, "Deep-Bed Sand Filter at Savannah River Laboratory," 13th Atomic Energy Commission Air Clean Cont., USAEC Report CONF-740807.

23. Juvinall, R. A., R. W. Kessic, and M. J. Steindler, 1968, *Sand-Bed Filtration of Aerosols: A Review of Published Information on Their Use in Industrial and Atomic Energy Facilities*, USAEC Report ANL-7683, Argonne National Laboratory, Chicago, IL, February.

24. Lawroski, H., "Zero Power Plutonium Reactor Facility," Nuclear News 11(47), American Nuclear Society, Washington, DC.

25. Lapple, C. E., 1948 and 1949, *Interim Reports-200 Area, Stack Contamination*, U.S. Atomic Energy Commission Report HDC-743, and HDC-987, General Electric Co., Richland, WA, October 11 and January.

26. Work, J. B., 1948, *Decontamination of Separation Plant Ventilation Air*, USAEC Report HW-11529, General Electric Co., Richland, WA, November 10.

27. Schurr, G. A., D. B. Zippier, and D. C. Guyton, 1972, "Deep-Bed Filter Tests," 12th Atomic Energy Commission Air Cleaning Conference, USAEC Report CONF-720828, August.

28. 10 CFR 61 (Code of Federal Regulations), 2003, *Licensing Requirements for Land Disposal of Radioactive Waste*, NRC, Washington, DC, January 1.

TABLE OF CONTENTS
