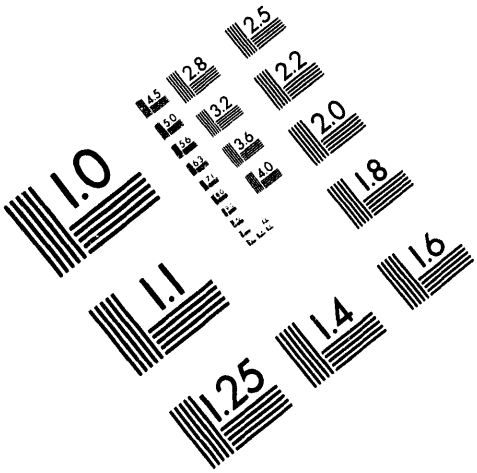

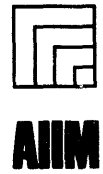

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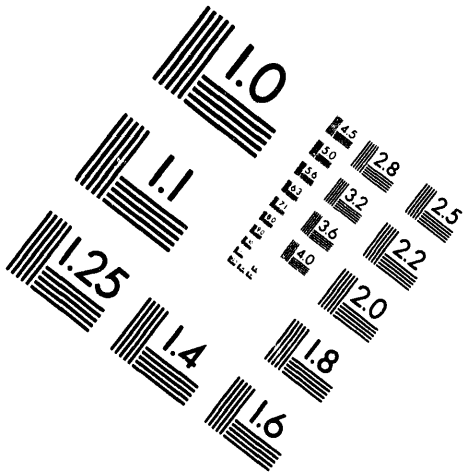

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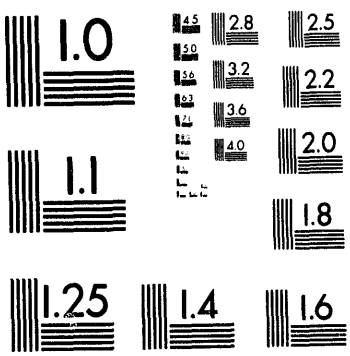

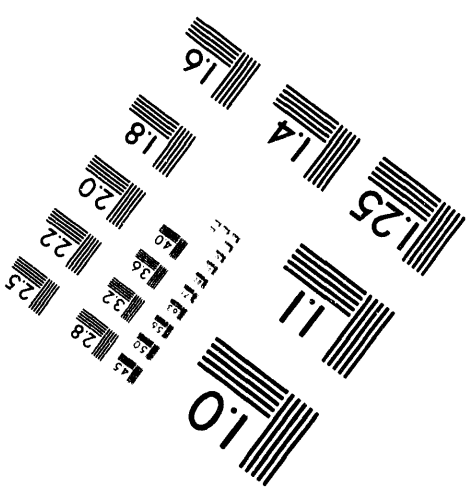

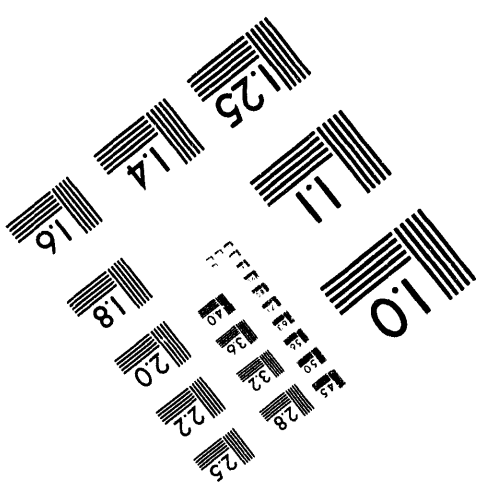

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DOE/DP-0125

OPERATING EXPERIENCE REVIEW -

VENTILATION SYSTEMS AT DEPARTMENT OF ENERGY FACILITIES

MAY 1994

U.S. Department of Energy
Office of the Assistant Secretary for Defense Programs
Deputy Assistant Secretary for
Facility Transition and Technical Support
Office of Special Projects

MASTER

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EXECUTIVE SUMMARY

The Office of Special Projects (DP-35), formerly Office of Self-Assessment (DP-9), analyzed occurrences caused by problems with equipment and material[1] and recommended the following systems for an in-depth study:

- Selective Alpha Air Monitor (SAAM)
- Emergency Diesel Generator
- Ventilation System
- Fire Alarm System

Further, DP-35 conducted an in-depth review of the problems associated with SAAM and with diesel generators, and made several recommendations.

This study focusses on ventilation systems. The intent was to determine the causes for the events related to these systems that were reported in the Occurrence Reporting and Processing System (ORPS), to identify components that failed, and to provide technical information from the commercial and nuclear industries on the design, operation, maintenance, and surveillance related to the system and its components. From these data, sites can develop a comprehensive program of maintenance management, including surveillance, to avoid similar occurrences, and to be in compliance with the following DOE orders:

- DOE 6430.1A, General Design Criteria
- DOE 5480.5, Safety of Nuclear Facilities
- DOE 5480.23, Nuclear Safety Analysis Reports
- DOE 5480.22, Technical Safety Requirements
- DOE 5480.19, Conduct of Operations Requirements for DOE Facilities
- DOE 4330.4B, Maintenance Management Program
- DOE 5700.6C, Quality Assurance

From January 1991 to January 1994, 704 ventilation-related events were reported in the ORPS, of which 201 were Unusual events, and 503 were off-normal events. Only the Unusual Occurrence Reports (UOR) were reviewed because each report needed an in-depth analysis to identify the affected component and the cause for the event. Table A.1 shows the outcome of the analyses and lists all the reviewed occurrences, the affected components, and the causes for the events. The analyses showed that Programmatic deficiencies caused 47 percent of the occurrences, while hardware failures caused 52 percent of the occurrences.

Several generic programmatic deficiencies which appear to be the prime causes are listed in Table A.1 and the acronyms used in the table are illustrated in Appendix A. The following are the major deficiencies:

- insufficient/improper maintenance and testing
- procedural deficiencies
- inadequate management of wearout/aging

The components that often failed or were affected by the problem in the ventilation system are fans, bearings, belts, controllers, dampers, filters, motors, diesel engines, breakers, and valves. These components also are listed in Table A.1 for each event. Section 3 discusses in detail the programmatic deficiencies and hardware failures.

Nearly all of the facilities reported occurrences where each one of these programmatic deficiencies and hardware failures were identified as a problem. All of the unusual occurrence reviews were done without the benefit of facility-specific, design-related documentation. Therefore, this report is based only upon information that could be obtained from the specific UORs. The individual facilities should take a more detailed look at these UORs, as well as those that fall under the off-normal category, for the site specific significance of the failures of ventilation systems and their associated components.

Similar programmatic deficiencies and component failures were discussed in several of the Operating Experience Weekly Summary (OEWS) reports published by the Office of the Deputy Assistant Secretary for Nuclear Safety. The OEWS numbers and these deficiencies are listed in Appendix B.

DOE Order 6430.1A, General Design Criteria, issued in 1989, provides general design criteria for use in the acquisition of the DOE's facilities and establishes responsibilities and authorities for the development and maintenance of those criteria. This order references numerous industrial standards for design bases, and provides some guidance on maintenance, surveillance, inspection, and test requirements.

DOE Order 4330.4B, Maintenance Management Program, recommends a graded approach for DOE nuclear facilities to determine the depth of detail required, and magnitude of resources to be expended, for each of the maintenance program element described in the order. For each nuclear facility, the maintenance program must be described in a Maintenance Implementation Plan (MIP), which must cover the 18 elements in the sequence and format of Chapter II of the DOE order. Many deficiencies identified in this analysis and in the OEWS fall within these 18 elements. System-specific guidance for maintenance management is not within the scope of this order. However, DOE published guidelines to good practices, as DOE Standards, which are related to maintenance activities.

To provide a more comprehensive technical basis to the sites in preparing their site-specific maintenance management program for ventilation systems, Section 2 of this report reviews the general design, the system components, and the areas of concern for contamination. Section 4 reviews industrial standards. Table 4-1 compares the requirements in industry's standards for various components of the ventilation system. Section 5 contains insights from NRC Standard Technical Specifications, inspection procedures, and other NRC sources.

Many DP facilities of concern were constructed in the 1950s and 1960s. Since several current standards pertain to the initial design, construction, and performance-testing of the facilities, emphasis in this report was placed on extracting from these standards the requirements and recommendations on the inspection, tests, and maintenance of ventilation systems and their components.

The following points became apparent from reviewing the various codes and standards covering ventilation systems:

- NFPA 90A, "Standard for the Installation of Air Conditioning and Ventilation Systems," has an entire appendix devoted to maintenance. (It has been incorporated into this report).

- NFPA 45, "Standard on Fire Protection for Laboratories Using Chemicals," and American National Standards Institute/American Industrial Hygiene Association (ANSI/AIHA) Z9.5-1992, "American National Standard for Laboratory Ventilation," also contain specific recommendations on maintenance and testing intervals for ventilation components. Most emphasis is placed on ventilation filters, such as activated carbon filters, measurements of laboratory-hood airflow, and on inspecting, testing, and maintaining blowers, motors, and drives.

- Often, there is a wide disparity in the intervals recommended for inspection, test, and maintenance, particularly for fans, blowers, motors, and controls. For example:

  - NFPA 45 recommends that In-Service Inspection (ISI) of these components occur at 1-year intervals and fan belts at 3 months

  - ANSI/AIHA Z9.5, a recently issued standard for laboratory ventilation, recommends ISI of fans and motors at 1-week intervals, with V-belt driven fans stopped for inspection once per month.

- HEPA filters are one of the most important components of Ventilation Systems. The major standards applicable to filters are the American Society of Mechanical Engineers (ASME) N509 and N510. In particular, ASME N510, "Testing of Nuclear Air Treatment Systems," provides a basis for developing test programs and detailed acceptance and surveillance test procedures, and specifies the minimum requirements for reporting the results. ASME N510, especially, is cited for testing High Efficiency Particulate (HEPA) air filters and adsorption units, such as carbon bed absorbers. This testing is characterized by an air-aerosol mixing uniformity test, known as the Dioctyl Phthalate (DOP) test.

- For DOE Order 6430.1A, Section 0109, "Reference Codes and Standards,"

  - the only standards specifically applicable to DOE nuclear facilities are those published by the National Fire Protection Association (NFPA), in particular, the NFPA Recommended Fire Protection Practices:
    NFPA 801 for facilities handling radioactive materials,
    NFPA 802 for nuclear research reactors, and
    NFPA 803 for light water nuclear power plants.
    However, those standards are not referred in the Order.

- NFPA 45 and NFPA 90A are referred to directly.

- Since the DOE order was issued in 1989, the ANSI/AIHA Z9.5-1992, "American National Standard for Laboratory Ventilation," was issued.

  Consideration should be given to revising the DOE order to reference this standard, if this is not underway already.

- Numerous codes and standards about ventilation systems are referenced by DOE Order 6430.1A. If there is no such document already, it may be beneficial to establish a Ventilation System Handbook consolidating all the applicable portions of DOE Order 6430.1A and the respective portions of the codes and standards for use by DOE contractors and assessment personnel.

Following are the recommendations for site-specific analysis and maintenance of ventilation systems:

- This study analyzed only unusual occurrences to identify the major components and programmatic deficiencies, and minimize the time and cost of the study. Any site-specific analysis should involve both unusual and off-normal occurrences.

- Section 4, Comparison to DOE Orders and Industry Standards, gives inspection and maintenance recommendations and intervals from DOE and industrial standards for ventilation system components. The site-specific inspection and maintenance management activities should be prioritized, based on the facility's function and site-specific problems as documented in inspection records and occurrence reports.

- A sample format for conducting an inspection is given in Appendix C, NRC Inspection Manual Procedure 93801, Safety System Functional Inspection . Several similar procedures are available in the nuclear industry which the sites could use to develop their specific plans.

- DOE Order 4330.4B gives general guidance for Maintenance Management Program. DOE has published several related guidance documents, as DOE Standards, to assist the sites in managing maintenance.

- Section 3 identified failures of ventilation system components at the DOE facilities due to equipment malfunction and human errors. Therefore, it may be useful to apply, on a trial basis, some combination of predictive maintenance techniques with either an expert system or a neural network, or both, at a selected facility to determine if the system's performance can be significantly improved.

ACRONYMS

Acronym	Meaning
371OPS	371 Operations
771OPS	771 Operations
774OPS	774 Operations
AABC	Associated Air Balance Council
ACGIH	American Council of Governmental Industrial Hygienists
AIHA	American Industrial Hygiene Association
ALARA	As low as reasonably achievable
ALO	Albuquerque Office
AMCA	Air Movement and Control Association
ANALYTOPS	Analytical Operations Facility
ANSI	American National Standards Institute
ASHRAE	American Society of Heating Refrigeration and Air Conditioning Engineers
BWR	Boiling Water Reactor
CAD	Containment Atmosphere Dilution System
CCRS	Central Control Room Supervisor
CH	Chicago Office
CMR - LANL	Chemistry & Metallurgy Research
CPU	Central processing unit
DBA	Design basis accident
DCF	Design change form
DCS	Drywell Cooling System
DOE	Department of Energy
DOP	Dioctyl Phtalate
DP	Defense Programs
ECCS	Emergency Core Cooling System
ELECON	Electrical conductor
ERDA	Energy Research and Development Administration

Acronym	Meaning
ESF	Engineered Safety Feature
ESHSUPT -LANL	Environment, Safety and Health Support
ETCS	Emergency Tritium Clean-up System
FBACS	Fuel Building Air Cleanup System
FBLINE	FB-Line
FCAN	F-Canyon
FMEF	Fuel Materials Engineering Facility
HBLINE	HB-Line
HCAN	H-Canyon
HEPA	High-Efficiency Particulate Air Filter
HQ	Headquarters
HVAC	Heating Ventillation and Air Conditioning
ICNTRL	Instrumentation, controller
ICPP	Idaho Chemical Processing Plant
ID	Idaho Office
INDREC	Instrumentation, indicator/recorder
INEL	Idaho National Engierring Laboratory
ISI	In-service inspection
KCP	Kansas City Plant
LANL	Los Alamos National Laboratory
LCO	Limiting conditions of operation
LLNL	Lawrence Livermore National Laboratory
LOCA	Loss of coolant accident
LTA	Laboratory Technical Area
MDAC	Master data aquisition and control
MP	Mound Plant
NA	Not applicable
NFPA	National Fire Protection Association
NMP&M	Nuclear Materials Production And Manufacturing

Acronym	Meaning
NNM	Non-Nuclear Manufacturing
NPRDS	Nuclear Plant Reliability Data System
NTS	Nevada Test Site
NVOO	Nevada Operations Office
OPDRV	Operations w/ potential for draining the reactor vessel
OR	Occurrence report
ORO	Oak Ridge Office
ORPS	Occurrence Reporting And Processing System
OSR	Operational Safety Requirement
PAP	Process Air Programmer
PFP	Plutonium Finishing Plant
PIP	Pinellas Plant
PM	Preventive maintenance
PP	Pantex Plant
PPE	Personal protective equipment
PREACS	Pump Room Exhaust Air Cleanup System
PUFAB	Plutonium Fabrication Pyrochemical Operations
PWR	Pressurized Water Reactor
RD&T	Research, Development, And Testing
REACK	K-Reactor
RFO	Rocky Flats Office
RFP	Rocky Flats Plant
RHRS	Residual Heat Removal System
RL	Richland Office
SAN	San Francisco Office
SAR	Safety Analysis Report
SCFM	Standard cubic feet per minute
SCIV	Secondary containment isolation valves
SEPGEN	Separations General Facilities

Acronym	Meaning
SGTS	Standby gas treatment system
SMC	Specific Manufacturing Capability
SNL	Sandia National Laboratory
SNM	Special Nuclear Matertial
SRS	Savannah River Site
SUPPORT	Support Services
TA55	Plutonium Processing & Handling Facility
TLV	Threshold limit value
TRIT	Tritium Facility
TRITFACILS	Tritium Facilities, WX5
TSTA	Tritium Systems Test Assembly
UCNI	Unclassified Controlled Nuclear Information
UOR	Unusual Occurrence Report
v/o	Volume per cent oxygen
VFTP	Ventilation filter test program
W.G.	Water gauge
X10CHEMTEC	Chemical Technology Facility
XCS	Experimental Clean-up Studies
Y12SITE	Y-12 Site

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1. INTRODUCTION

The U.S. Department of Energy nuclear weapons production complex is organized into three functional elements:

- Laboratories and test sites used for research, development, and testing (RD&T).
- Plants for nuclear materials production and manufacturing (NMP&M) involving tritium, weapons-grade plutonium, and highly enriched uranium and other components extracted from retired stockpile weapons or newly produced from nuclear reactor and uranium enrichment facilities.
- Plants for non-nuclear manufacturing (NNM) of components for nuclear weapons

The research, development, and testing sites include:

- Los Alamos National Laboratory (LANL)
- Lawrence Livermore National Laboratory (LLNL)
- Sandia National Laboratory (SNL)
- Nevada Test Site (NTS)

The current nuclear materials production and manufacturing sites include:

- Idaho National Engineering Laboratory (INEL)
- Oak Ridge Y-12 Plant (Y-12)
- Savannah River Site (SRS)
- Rocky Flats Plant (RFP)
- Pantex Plant (PP)

The Hanford Site has recently been turned over to DOE's Office of Environmental Management for deactivization.

The non-nuclear manufacturing sites include:

- Kansas City Plant (KCP)
- Mound Plant (MP)
- Pantex Plant (PP)
- Pinellas Plant (PIP)
- Rocky Flats Plant (RFP)
- Oak Ridge Y-12 Plant (Y-12)

There is functional overlap in that the Rocky Flats, Pantex, and Oak Ridge Y-12 plants manufacture nuclear and non-nuclear material.

The Office of Special Projects (DP-35), formerly Office of Self-Assessment (DP-9), conducted an analysis of occurrences caused by equipment and material problems[1] and recommended the following systems for in-depth study:

1. Selective Alpha Air Monitor (SAAM)
2. Emergency Diesel Generator
3. Ventilation System
4. Fire Alarm System

Further, DP-35 conducted an in-depth review of problems associated with SAAM and Diesel generators and made several recommendations.[2,3]

This study focusses on ventilation systems. The intent of this study was to identify causes for the ventilation-related events reported in the Occurrence Reporting and Processing System (ORPS), identify components that failed in the system, and to provide available technical information from commercial and nuclear industries on design, operation, maintenance, and surveillance related to the system and components so that the sites can develop a comprehensive maintenance management program, including surveillance, to avoid similar occurrences, and be in compliance with the following DOE orders:

- DOE 6430.1A, General Design Criteria
- DOE 5480.5, Safety of Nuclear Facilities
- DOE 5480.23, Nuclear Safety Analysis Reports
- DOE 5480.22, Technical Safety Requirements
- DOE 5480.19, Conduct of Operations Requirements for DOE Facilities
- DOE 4330.4A, Maintenance Management Program
- DOE 5700.6C, Quality Assurance

The Ventilation System and, where applicable, the associated Glove Box Operation System are integral to the series of barriers preventing the spread of radioactive or chemical contamination first from endangering the health and safety of the operating personnel and other staff on the facility site, and second, from similarly endangering the general public located off site. Even though the ventilation systems in the DOE facilities must comply with very strict standards to severely reduce radioactive emissions, their design is similar in many respects to those in industrial applications.

The purpose of this report is to focus primarily on the Unusual Occurrence Reports filed in the Operations Reporting and Processing System (ORPS) from January 1991 to January 1994, so that significant events and lessons learned can be highlighted, to provide a basis for DOE staff or contractor personnel to compare current DOE practices to industry standards. When combined with on-site assessments and interaction with the operations staff, this should suggest the most effective corrective actions to reduce the frequency and severity of such component failures on the Ventilation Systems.

To provide a more comprehensive technical basis to the sites to prepare site-specific maintenance management for ventilation systems, Section 2 of this report provides a review of the general design, the system components, and the areas of concern for contamination, and Section 4 provides a review of industry standards. Table 4-1 compares the requirements of DOE Order 6430.1A to the requirements in industry standards for various ventilation system components.

2. DESCRIPTION OF TYPICAL VENTILATION SYSTEMS

2.1 General Design

General ventilation, otherwise known as dilution ventilation, commonly used is in non-hazardous environments, such as office spaces, where there is limited concern over toxic substances in the atmosphere. Air then can be recirculated internally through the building by sending the exhaust air back to the supply point. Sufficient mixing with fresh air is required to prevent indoor air pollution. In the interest of reducing heating costs, oftentimes too little fresh makeup air is used.

Dilution ventilation is used only to control hazardous operations when local ventilation is impractical. Outside air must be added to reduce contamination to acceptable levels and the internal recirculation of air must be limited unless an effective cleaning system is incorporated.

In all cases, the inner contaminated areas must be maintained at negative pressure with respect to the outer, noncontaminated areas within the building to prevent their accidental contamination. The goal always is to force the flow of air from the cleaner areas to the more contaminated areas.

Supply systems control the comfort of the building's environment, i.e. the HVAC system, and also replace the air naturally exhausted. Supply systems typically consist of an air intake section with filters, HVAC equipment such as steam heating, chilled water cooling and air conditioning, one or more fans, ducts, and grilles or registers for distributing air within the building's work spaces. An air supply unit, airhouse or air handling unit are the terms used to designate a unit which combines the filters, HVAC equipment, and supply fan.

Two broad categories of exhaust systems are General exhaust systems and Local exhaust systems. The former operates on the principle of inducing large quantities of air through a given space to control the temperature or to remove contamination. To control contamination, sufficient outside air must be drawn in and mixed to reduce the contamination to a safe level. Following filtration, often by means of HEPA (High Efficiency Particulate) filters, the contaminated air is discharged, usually to the atmosphere.

The Local exhaust ventilation system operates on the principle of capturing contamination at or near the source. Such a system is more effective because it focuses on specific areas of contamination, as opposed to purifying large mixtures of clean and contaminated air. Therefore, both heating and air cleaning costs are lower because of the smaller exhaust flow rate.

There are five basic components in Local exhaust systems:

- the hood
- the duct system
- air cleaning device, if applicable
- the fan
- the ejector (stack)

By inducing an air stream within the hood, the contaminant produced by the particular process can be removed via a duct system typically to the air cleaning device, or else, to the fan from which the contaminated air is led to a central air cleaning device for a group of hoods. The fan must produce the required flow rate and pressure conditions while overcoming all frictional losses due to the hood's entry, duct work, fittings and the air cleaning device. The duct system on the fan outlet must discharge the air to an atmospheric exhaust stack which minimizes the probability of the exhaust air entering the supply air intake, (Ref. 1).?

2.2 Design of Ventilation Systems for Department of Energy Nuclear Facilities

2.2.1 General Design Requirements

A useful description of the basic design requirements for HVAC systems for nuclear facilities is given in the 1991 ASHRAE Handbook - HVAC Applications, (Ref. 2). The discussion in the Handbook pertains to nuclear power plants, fuel fabrication and processing plants, plutonium processing plants, and, to a lesser degree, hospitals, corporate and academic research facilities, and other facilities housing nuclear operations or materials.

Nuclear-related HVAC systems differ from other special HVAC systems in that nuclear criticality, radiation, and the consequent regulations designed to prevent exposure of both facility workers and the general public to radiation must be considered.

Materials subject to criticality concerns are designated as special nuclear material (SNM). Only a limited number and type of facilities - including fuel plants, weapons facilities, and some national laboratories - handle such materials.

For the DOE facilities, the DOE orders are the means for regulating the weapons-related facilities and national laboratories listed in the Introduction. The DOE orders which govern ventilation in such facilities are discussed in detail in Section 6.1 of this report. In general, the goal of the DOE orders is to minimize radiation exposure to as low as reasonably achievable (ALARA).

The following factors should be considered in designing HVAC systems for facilities handling radioactive materials:

- Potential airborne radioactivity that could be encountered in the form of either particulate or gaseous matter.

- Control of the HVAC system so that portions can be effectively shutdown, in any event, accident, or natural catastrophe.

The **normal design basis**, or power design basis for nuclear power plants, covers normal plant operation, including the normal operation mode and normal shutdown mode. This design requirement does not impose additional ones on various systems and components above and beyond those imposed by the standard criteria specified for indoor conditions.

The **safety design basis** requires all systems and components to be under active control during and after any event, accident, or natural catastrophe, if the facility cannot be shutdown readily and isolated to an inactive state at any time.

Indoor conditions consist of temperature, pressure, and radioactivity. The ambient indoor temperature results from the occupancy, equipment or process activities, and human activities. The design temperature of the HVAC system is based on the environmental qualification of the safety-related equipment located in the air-conditioned space, and by ambient conditions during its different operating modes.

A particular pressure related to the outside atmosphere or adjacent areas must be specified when control of air pattern is required. The Confinement System section of a facility's Safety Analysis Report specifies the pressure relationships for process facilities where pressure zones have been identified.

In facilities where zoning differs from those of process facilities, and when rooms are in the same zone but where potential airborne radioactivity must not spread, any airborne radioactivity must be controlled by airflow.

A facility usually is protected from the rapid, sharp drop in pressure caused by a **tornado** passing over by tornado dampers and missile barriers in all appropriate openings in the outside walls of the structure. Tornado dampers are heavy-duty, low leakage dampers designed for pressure differences greater than 3 PSI, and which normally are environmentally and seismically qualified.

Requirements for **fire protection** of nuclear facilities is discussed further in Section 4.2 concerning industry standards. Of particular concern is fire protection for the HVAC system itself, especially dampers to isolate the smoke from the rest of the building environment, and the filtration system. Heat detectors and Halon systems should be considered for special operations, such as gloveboxes.

The following areas of a facility are of particular concern, and ventilation must be controlled to keep them free from contamination:

- Control rooms
- Laboratories
- Mechanical and electrical equipment rooms
- Battery rooms
- Air locks
- Alarm stations
- Office areas
- Locker rooms and rest rooms

Filtration of the ventilated air is one of the key functions of ventilation systems. In all facilities, the filter system must contain the contaminant to be controlled. Filter systems must be capable of being tested reliably in situ, and the filtration components must be easily replaceable.

In nuclear power plants, or in nuclear production reactors, HVAC system filters remove radioactive particulates and gases. Potentially contaminated exhaust is filtered before discharge to the environment to protect personnel in plant areas and the public. The filter train typically consists of the following components in series:

- Demister
- Heater
- Prefilter
- Charcoal filter (adsorber)
- High efficiency particulate air (HEPA) filter

For nuclear processing facilities, the primary confinement zone, where contamination normally exists, usually is exhausted through multiple HEPA filters, a sand filter, or a combination of both. Secondary and tertiary confinement zones are exhausted through HEPA filters. The number of stages may differ, depending on specific conditions and regulations. In laboratories and other facilities handling radioactive materials, the air is exhausted also through HEPA filters.

The following types of filters are used typically in nuclear facilities:

- **Dust filter/ Prefilter** Dust filters vary in efficiency, and so their selection is based upon the particular requirements of the ventilation system. High-efficiency dust filters often serve as the first stage filters to protect downstream special filters, such as HEPA filters, sand filters, and charcoal filters.

- **HEPA Filters** In cases where there is a potential for airborne radioactive particulates, HEPA filters are used. Each filter provides a minimum removal efficiency of 99.97% for particles of 0.3 μm diameter. An example of a filter medium is glass felt sheeting, which is considered fire resistant and water repellent and has relatively high wet strength characteristics. HEPA filters are tested by a standard procedure, ANSI/UL 586, (Ref. 3), using a cold-generated smoke of mono-dispersal dioctylphthalate (DOP).

- **Sand Filters** A sand filter consists of multiple beds of sand and gravel through which air is drawn. The air is distributed across the base of the sand by smaller cross-sectional laterals running perpendicular to the inlet tunnel, which runs the entire length of the filter. The air then rises, at a flow rate typically of 5 feet per minute, through several layers of sand and gravel of various sizes, after which the air is discharged to atmosphere upon collection in an outlet tunnel.

- **Charcoal Filters** For removing radioactive iodine in particular, which is a vapor or gas, absorbers of activated charcoal-based impregnated charcoal are used typically with bed depths of 2 or 4 in. Filtration efficiencies are normally 99.9% for elemental iodine, and 95 to 99% for organic iodine. With increasing relative humidity, the efficiency of the filter decreases rapidly, so that a heating element normally is installed to maintain the relative humidity of the incoming air below 70%.

- **Demisters or Mist Eliminators** When the airstream contains entrained moisture droplets, HEPA and charcoal filters are protected by demisters, which are fire resistant and which also have heaters downstream to prevent saturated air from reaching the filters.

2.2.2 Design of Typical Process Confinement Systems

The ventilation systems at DOE facilities are designed to conform to a philosophy of confinement of radioactive and other hazardous materials as opposed to a philosophy of strict containment of such materials. The degree of confinement must be sufficient to limit releases to the ALARA level. Critical items and systems of plutonium processing facilities are designed to confine radioactive materials under normal operation and under Design Basis Accident (DBA) conditions as required by Reactor Site Criteria, 10 CFR 100, "Reactor Site Criteria". The regulation is based on limiting releases to the general public around the site boundary and to the operating staff within the site boundary. Figure 2.1 shows a typical confinement system at a process facility.

Primary Confinement The interior of a hot cell, canyon, glovebox, or other containment for handling radioactive material is the primary confinement. The spread of radioactivity within the primary confinement must be prevented, along with the release of radioactivity from the building under both normal and upset conditions as severe as a DBA for the facility. Complete isolation from neighboring facilities is required by multistage HEPA and/or sand filtration of the exhaust.

Secondary Confinement This zone is defined as being bounded by the walls, floors, roofs, and associated ventilation exhaust systems of the cell or enclosure surrounding the process material or equipment.

Tertiary Confinement The final barrier against release of hazardous material is the tertiary confinement zone which is provided by the walls, floors, roofs, and associated ventilation exhaust systems of the facility.

Uncontaminated Zone Support buildings, such as offices and the cold shop, are part of the uncontaminated zone.

The essential element of Confinement is **zone pressure control.** Negative static pressure increases (becomes more negative) from the uncontaminated zone to the primary confinement zone. Therefore, all air leakage flows from uncontaminated zones to higher levels of potential contamination, i.e. from uncontaminated to tertiary, from tertiary to secondary, etc. All zones, including the uncontaminated zone, are kept at negative pressure with respect to the ambient atmospheric pressure. In some cases, the uncontaminated zones are kept at positive pressure with respect to the ambient atmospheric pressure.

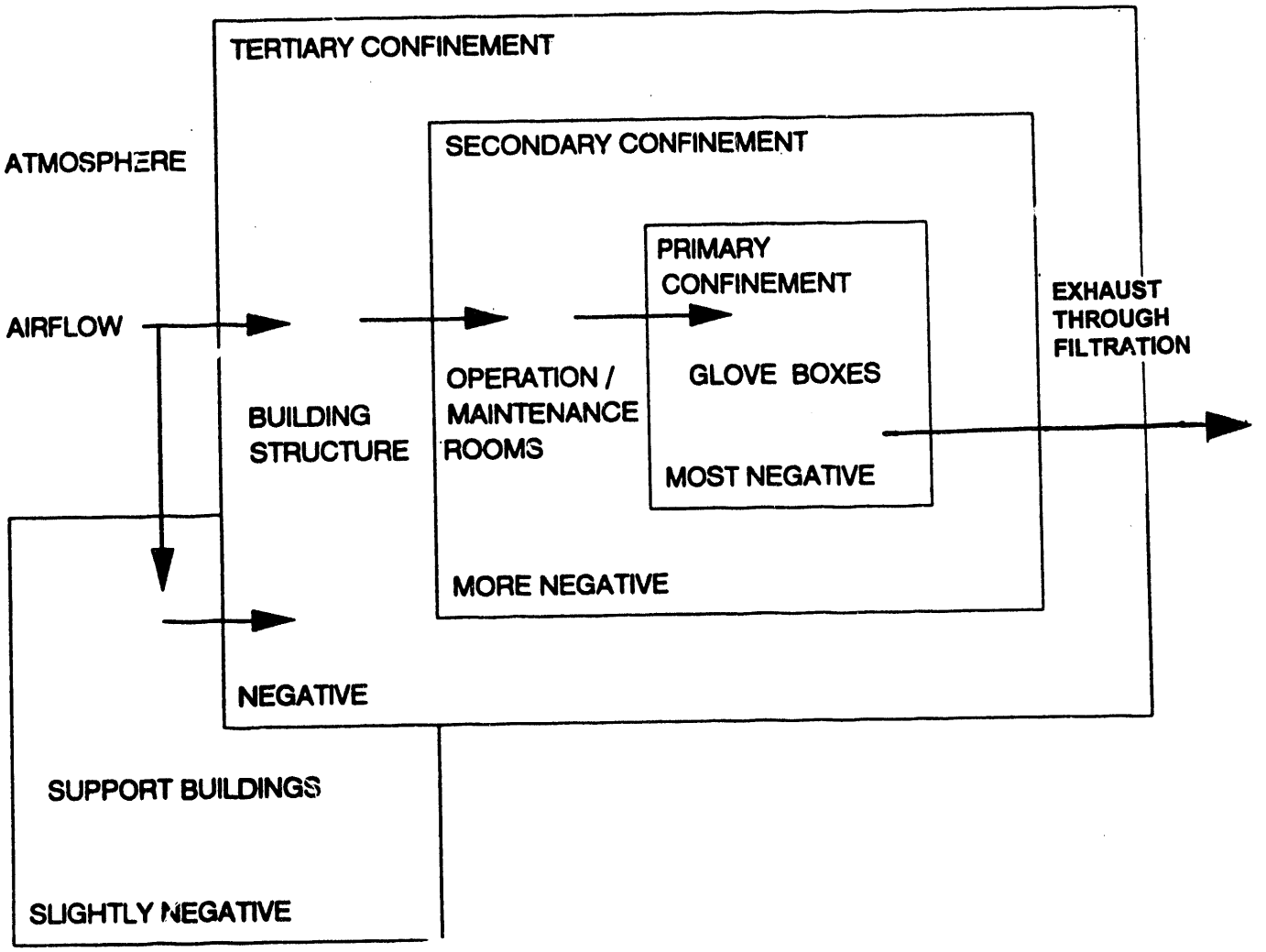


Figure 2.1 Typical Process Facility Confinement Systems (Ref. 12)

For secondary and tertiary zones, **recirculation** of zone air, which is the reuse of air in a particular zone by returning it to the primary air-handling unit for reconditioning, often is permissible as long as the recirculated air passes through HEPA filters before it is reintroduced to the same space or to a zone of greater potential contamination. If contamination is detected downstream of the HEPA filters, the recirculation systems must convert immediately to 100% outside air. Reciruclated air is never permitted for primary confinement zones. When required, inert atmospheres are used in encloures; then, recirculation systems often are incorporated.

Although there are exceptions, recirculation systems are only used for nontoxic and nonradioactive applications. Means for bypassing the recirculating system may be required because the discharge flow must be vented directly to the exhaust system. For all normal conditions, air flows must be toward zones of potentially higher contamination. The air-handling units must be able to prevent reversal of air flow under upset conditions, such as the improper use of an air lock, occurrence of a breach in the confinement barrier, or excessive loading of the credible HEPA filters.

Each facility's Safety Analysis Report (SAR) establishes the minimum requirements for the acceptable response for the ventilation system and its instrumentation and controls under Normal, Abnormal, and Accident conditions up through the DBA. In conformance with DOE Order 6430.1A, the number of required exhaust filtration stages from any area of the facility is determined by analysis to limit quantities of airborne radioactive material or toxic material released to the environment during normal and accident conditions.

The following **safety-related** portions of the ventilation system are usually supplied with emergency power:

- Exhaust system
- Fire detection and suppression system

Control power for these systems is generally supplied by an uninterruptible emergency power supply.

Failure of any single component or control function should not compromise adequate ventilation. Sufficient redundancy and/or spare capacity should ensure adequate ventilation during normal operations and DBA conditions.

Ventilation systems often are designed for independent shutdown or isolation of portions of the systems where it could be advantageous for:

- Operations
- Filter change
- Maintenance
- Emergency procedures, such as fire fighting

The possible effects of the shutdown on airflow in other interfacing systems may require that there are positive means to control backflow of air that might transport contaminants. A HEPA filter at the interface, including a prefilter to reduce loading on the HEPA filter, between the enclosure and the ventilation system minimizes contamination in the ductwork. These filters are **not** to be considered as the first stage of an airborne-contamination cleaning system.

Specific Ventilation Components

The overall air filtration and air conditioning system may be comprised of:

- Air-sampling devices
- Filters:
  - -Carbon bed absorbers
  - -Absorption
  - -HEPA
  - -Sand
  - -Glass fiber
  - -Prefilters
- Scrubbers
- Demisters
- Process-vessel vent systems
- Condensers
- Distribution baffles
- Fire-suppression systems
- Fire and smoke dampers
- Exhaust stacks
- Fans
- Coils
- Heat-removal systems (e.g. chilled water)
- Pressure and flow meters
- Radiation-monitoring devices
- Critically safe drain systems
- Tornado dampers

The following are some specific elements of the design of the ventilation system and fire-suppression system:

- Systems are designed for fail-safe operation.
- The ventilation system is appropriately instrumented and alarmed.
- Control areas and utility service areas receive reports and record the system's behavior.
- Both manual and automatic controls may be required to alter the operation of the system during unusual conditions.
- Components in the supply, exhaust, and filtration systems must be able to be:
  - conveniently maintained
  - decontaminated
  - replaced
- One bank of filters should be able to be completely isolated from the ventilation system by appropriate location of dampers and/or valves during replacement of the filter's elements.
- Redundancy in filters may be required to maintain the system operation.

Radioactive Air and Gas Effluents

Exhaust ducts or stacks downstream of the final filtration that may contain radioactive contaminants must have two monitoring systems. One system should be a continuous type, and the other a fixed sampling type. These systems may be a combined unit. The monitoring probes typically are designed for isokinetic sampling and located according to ANSI N13.1, "Guide for Sampling Airborne Radioactive Materials," (Ref. 4). Each monitoring system typically is connected to an emergency power supply.

2.2.3 Specific Design of Some DOE Facilities

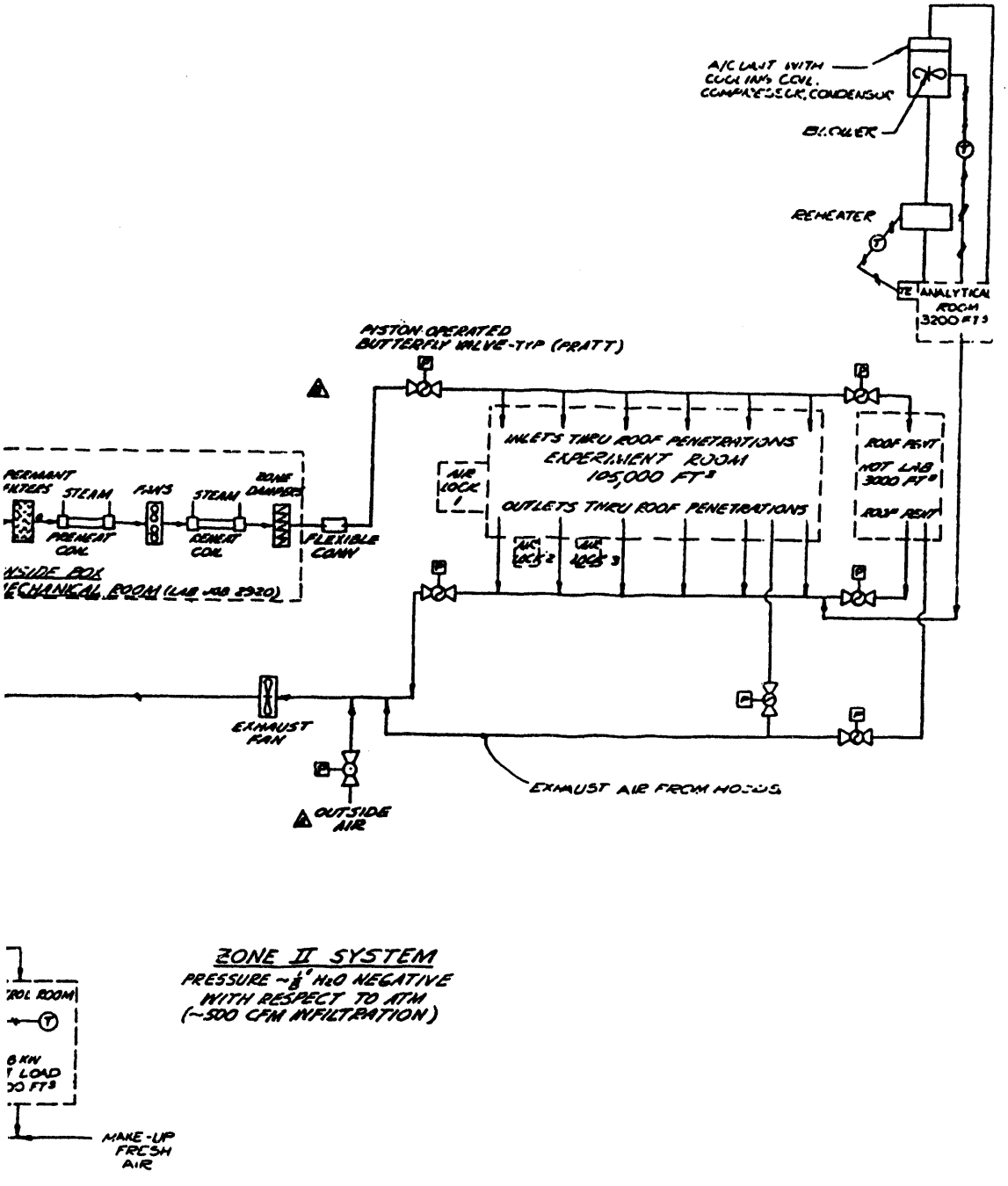
2.2.3.1 Tritium Systems Test Assembly at Los Alamos

The design of the Ventilation system for the Tritium Systems Test Assembly (TSTA) at Los Alamos is discussed here as an illustrative example (Ref. 5). The TSTA is not part of the Defense Programs complex, but rather, is dedicated to developing, demonstrating, and interfacing technologies related to the deuterium-tritium fuel cycle for large-scale commercial fusion reactor systems. The primary goal of TSTA is to demonstrate that large quantities of tritium, approximately 360 moles per day of deuterium-tritium, can be handled routinely and safely.

The TSTA Building Ventilation System has two zones. The Zone I system provides heating and ventilation for areas from which tritium is excluded, and is maintained at a slight positive pressure of +0.23 torr with respect to atmospheric pressure to minimize the infiltration of dust. The Zone II system is maintained at a slight negative pressure of -0.23 torr with respect to atmospheric pressure to minimize possible diffusion of tritium to the environment. The Master Data Acquisition and Control System (MDAC) has a separate ventilation system. There is a separate air conditioning system for the room housing the Gas Analysis System.

The TA-21-155 building is the final barrier for containing the TSTA tritium inventory. The secondary containment systems around the primary tritium handling equipment maintain the concentration of tritium within the building atmosphere at levels low enough to allow the ventilation air to be exhausted directly to a 30 m high stack. Figure 2.2 is the conceptual flow schematic for the Building Ventilation System. Both Zone I and Zone II have sufficient air changes to maintain room pressures and discharge air temperatures in accordance with recommendations of the ASHRAE Guide and Data Book. Inlet and exhaust ventilation is routed through the walls and ceiling with the ducts located on the roof. The air conditioning system for the Control Room removes the heat generated by the MDAC and maintains a minimum relative humidity.

The Zone II ventilation system assure the isolation of Zone II in the event of a tritium release in the cell. Automatic isolation valves on the inlet and exhaust ducts close when a tritium release is detected. The Experimental Cleanup Studies (XCS) equipment test room has Isolation valves to isolate it from the main experimental room. The system is designed such that detection of a tritium release causes the Zone II supply blower to shut down and outside air to be supplied to the Zone II exhaust blower. Inlet ventilation air to Zone II is by diffuser-type deflectors to maximize mixing of the room's air.



bly (TSTA) Building Ventilation System.[15]

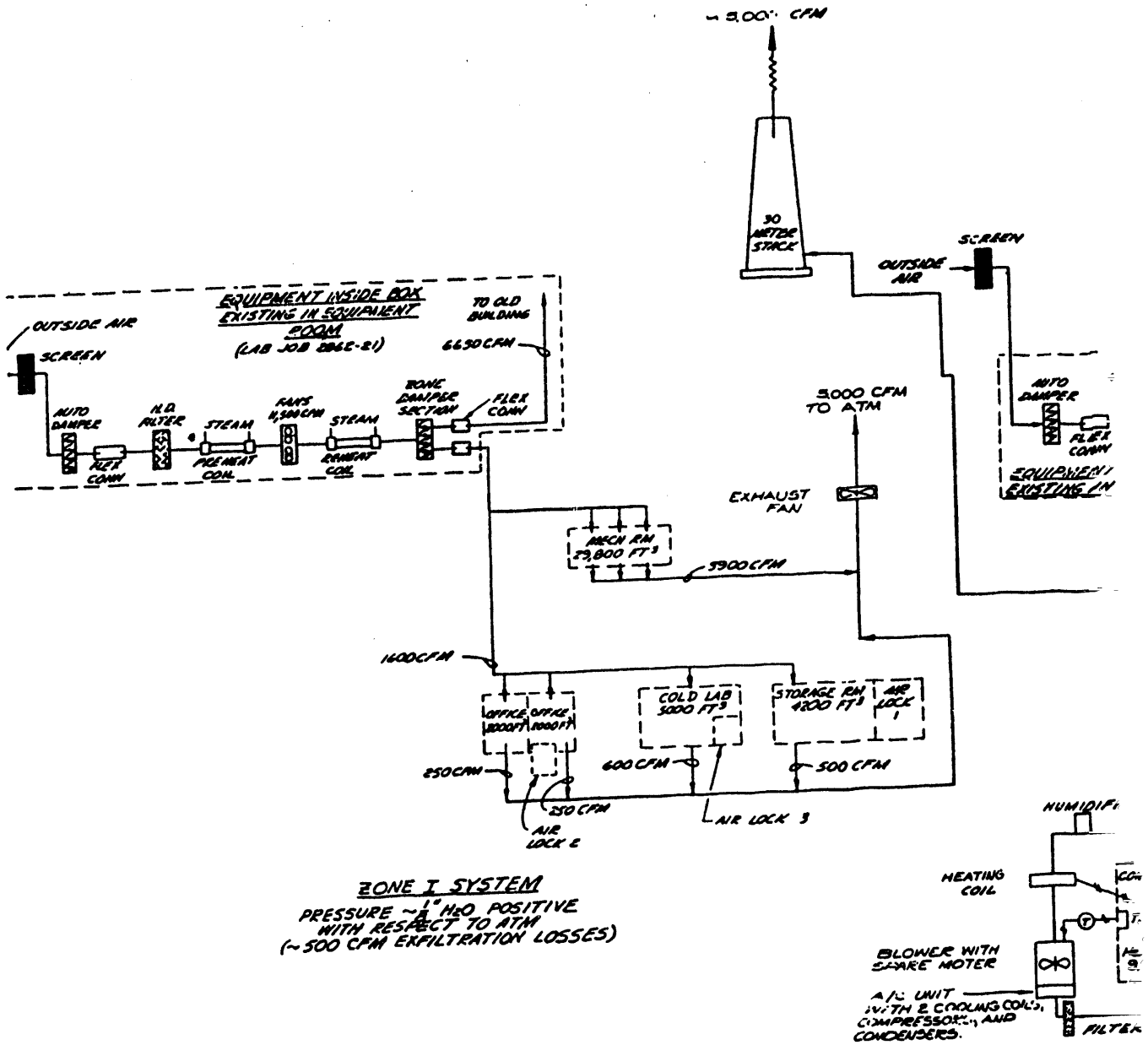


Figure 2.2 Los Alamos Tritium Systems Test Asse

Since both the Zone I and Zone II ventilation systems existed before the TSTA was built, there is no redundancy in either the Zone I or Zone II systems.

Operation of the ventilation system is monitored by pressure and differential pressure transducers, temperature sensors, flow switches, and valve position-indicators. Conventional control systems regulate temperatures and maintain pressure differentials. Zone II areas are continuously monitored for tritium releases by ionization chamber-type integrating air monitors. Its exhaust air also is monitored continuously by concentration/integrating monitors to assure that the average concentration in the stack is maintained below the maximum permissible concentration, and that the tritium released to the environment is kept below the design limit of 200 Ci/year.

The building's ventilation system contains abnormal releases of tritium within the main experimental room. The Emergency Tritium Cleanup System (ETCS) processes the contaminated atmosphere to reduce hazards to personnel working in adjacent rooms and to off-site personnel. Duct isolation valves are designed to fail safe, i.e. in the closed position. If these valves fail to close during a tritium release into the experimental room, the entire release could be vented up the stack. Periodic maintenance of the duct-isolation valves mitigates this possibility.

The exhaust duct of the main experimental room was pressure tested following its installation, and any subsequent leaks are discovered by routine inspections and/or by the inability of the building ventilation system to maintain proper working pressure in the room.

2.2.3.2 Hanford Fuel Materials Engineering Facility (FMEF)

Figure 2.3 illustrates the design of the Fuel Materials Engineering Facility (FMEF) at the Hanford Reservation in Richland, Washington (Ref. 6). The classifications of the confinement zones are presented in Table 2.1. Air enters the facility through a tornado isolation damper which prevents reverse flow in the event of a tornado. The supply air is filtered to remove dust. A supply blower compensates for the pressure drop through the filters. There are four zones, with I being the most contaminated and IV being uncontaminated. Before reaching the cellulose HEPA filters, the air from Zone IV normally flows to Zones III and II for discharge through an ember screen, fire spray, and de-mister, which are there for fire protection. (If the HEPA filters caught fire, all their accumulated activity would be released.) Part of Zone II is a recirculation area; in an accident, the recirculation flow would be stopped and replaced by once-through flow. The air pressure is slightly below atmospheric so air leaks into the facility, and there is a decreasing pressure gradient from the lowest activity level to the highest. The lowest pressure occurs at the inlet to the stack or exhaust blowers.

Two of the three stack blowers are normally operating and the third is a standby. Each stack blower is supplied with emergency electric power to prevent diffusion of radioactivity if the blower fails to operate due to loss of normal power. Air flows, pressure differentials, and radioactivity levels are monitored and alarmed throughout the facility.

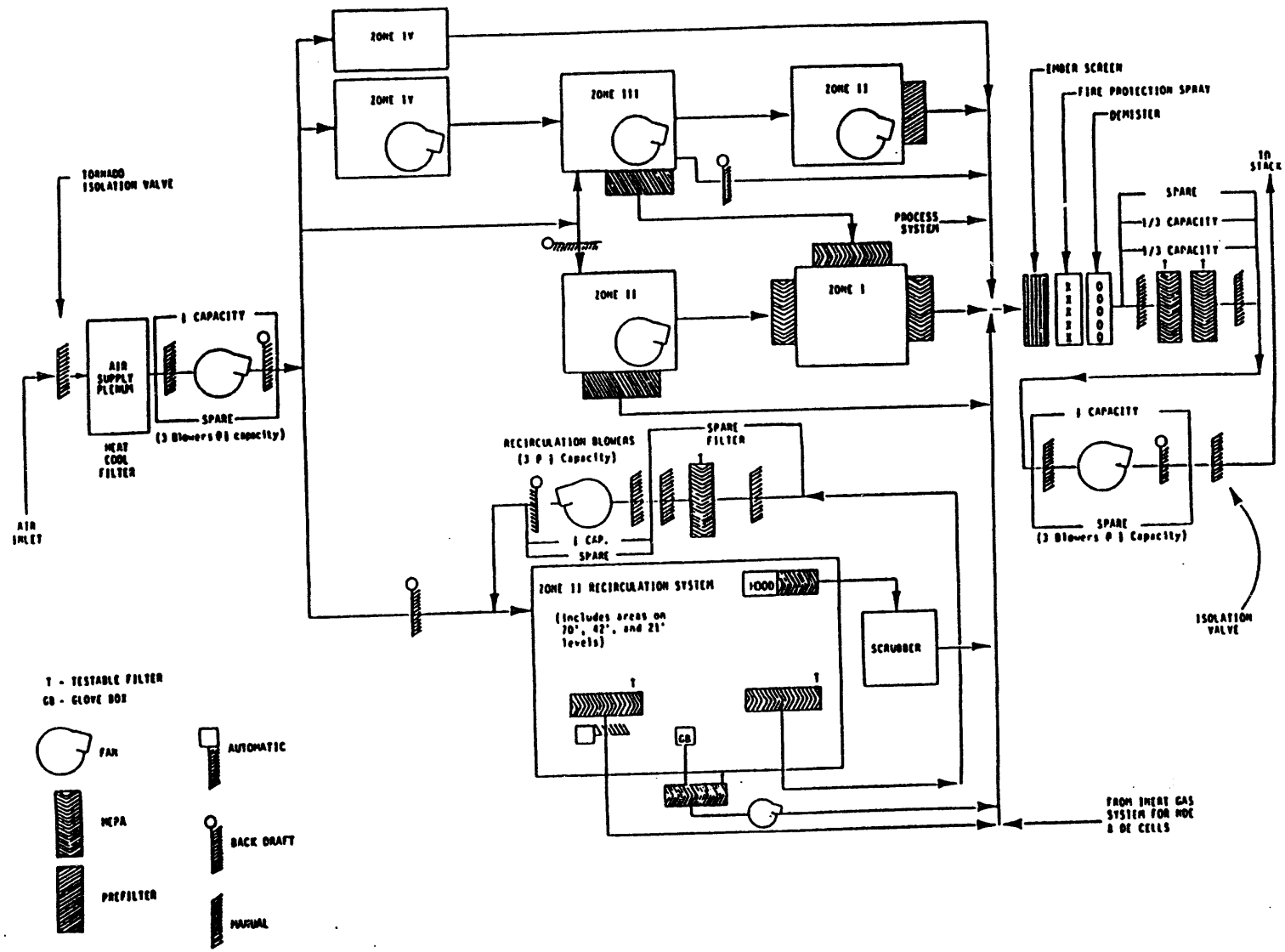


Figure 2.3 Fuel Materials Engineering Facility (FMEF) Building Ventilation System

Table 2.1 Confinement zone design parameters: fuel materials engineering facility.

Zone and Description	Contamination Potential	Pressure (in. H_2O)
Zone I: Enclosures or cells having uncontaminated radioactive materials in process.	Contaminated	-1.0 ± 0.25: low gamma areas: glove boxes, process and transfer enclosures. -0.9 ± 0.25: Decon cell, transfer tunnel, and high gamma shipping and receiving.
Zone II: Operating areas, normally occupied by personnel.	Low Contamination	-0.25 ± 0.05: low gamma areas: process operating galleries. -0.25 ± 0.05: other areas: suspect repair and horizontal transfer corridor.
Zone III: Operating corridors and equipment rooms.	Very low: may become contaminated in an accident.	-0.1 ± 0.05
Zone IV: Emergency generator equipment room; truck lock.	No contamination; unrestricted outside access.	0.0

3. RECENT PERFORMANCE OF VENTILATION SYSTEMS

3.1 Methodology for Study

To support the goals of this effort, this study focused on significant events and lessons learned with the intention of comparing current practices to industry standards, and of suggesting the most effective corrective actions to reduce the frequency and severity of such component failures on the ventilation systems.

The Occurrence Reporting and Processing System (ORPS) (Ref. 17) was used to search for failures involving ventilation systems at Defense Programs facilities from January 1991 to January 1994. There were 704 occurrences, of which 201 were Unusual and 503 were Off Normal. While much valuable information was available from the Off Normal Reports, it was decided to concentrate on the Unusual Occurrence Reports which identify the more serious incidents. Any events which identified failures of other systems during which the ventilation system performed successfully or was not directly involved were eliminated. This resulted in 151 Unusual Occurrences which were considered "Ventilation-Related (VR)."

In Section 4, the applicable DOE orders pertaining to ventilation systems are discussed, and there is a heavy emphasis on gathering together the requirements of existing industry standards pertaining particularly to inspecting, testing, and maintaining of ventilation systems. This approach will facilitate comparison with current practices at particular facilities to ensure that such practices are as reasonably close to industry standards as practical.

3.2 Data Analysis and Results

3.2.1 Data Retrieval

The source of the data used in this analysis of the DOE Defense Programs ventilation systems was the Occurrence Reporting and Processing System (ORPS). The database was queried to identify those occurrence reports (ORs) which met the following search criteria:

1. ***Program Office***: Defense Programs
2. ***Narrative Search***: ventilation@
3. ***Discovery Dates***: 01/01/91 through 01/07/94

Item 2 of the search criteria is used to identify those ORs which contain the string "ventilation", with the @ symbol acting as a wild card to capture any combination of word possibilities within the ORPS database. The discovery dates were chosen at the time of the download (01/07/94) in an effort to capture a large enough sample of ORs related to the ventilation system that would be categorized as "final reports". With these search criteria, 704 ORs were retrieved from the ORPS database, of which 201 were categorized as ***Unusual Events.***

This analysis was limited to reviewing the Unusual Event category ORs since it was assumed that this category would contain events of higher significance on the failure of ventilation systems or those related systems which would adversely affect their functionality.

The 201 ORs were reviewed thoroughly to identify, among other things, which ones were associated with the failure, degradation, or reduced capacity or operability of any portion of a ventilation system or function; 151 were identified. The majority (42) of the 50 ORs that were deemed to be "not ventilation-related" were ORs which contained the word ventilation, but did not involve ventilation systems per se. The following are some examples of these ORs:

- ...the doors were opened to provide **ventilation**...

- ...filters in the **ventilation** system were changed...

- ...the fire department verified that the fire had not travelled into the hood's heating, **ventilation** and air conditioning system...

- ...the vendor representative checked inside the **ventilation** louvers with a flashlight and discovered the TDG surge protector severely scorched.

In addition, there were 8 ORs that did not contain the word **ventilation** or an equivalent word string; these ORs are believed to have been included due to noise within the telecommunication line during downloading.

The following sections in this chapter will concentrate on the review of the 151 ORs.

3.2.2 Data Review

The review of the ventilation-related OR set involved several necessary steps which were useful in the subsequent final analysis. To determine trends, resource allocation, and other conclusions associated with those ventilation systems under the jurisdiction of the Defense Programs complex of facilities, a spreadsheet database was also created which was used to catalog key attributes associated with each OR.

In developing the spreadsheet database, important parameters associated with each event needed to be gleaned during the review for future analyses. The database fields, and applicable coding, were defined to parallel those currently being used in the Nuclear Plant Reliability Data System's (NPRDS) (Ref. 18), NPRDS-Plus database. The following is list of the fields constructed:

- OR number
- Field Office
- Failure Discovery Date
- Component Failure
- UCNI
- Affected Component
- Detection Method
- Failure Cause Category
- Failure Cause Description (Three Columns)

The title of each field identifies the information to be extracted from each OR. However, some explanation is necessary about the exact meaning of each field and its contents. As mentioned, the NPRDS database provided a very useful starting point by way of its failure-event classification fields, as well as the coding schemes that describe key attributes associated with the event. The following table (3.1) identifies each field name, describes its contents, and lists the applicable code or entry.

The following Section 3.2.3 gives the results of the spreadsheet/database analysis from identifying trends and patterns within the ventilation-related ORs using these fields and associated coding. In addition to the graphical results, several examples taken from the ORs are discussed.

3.2.3 Findings from the Data Analysis

The underlying basis for reviewing the DP occurrence reports related to ventilation systems or functions was to identify the trends or patterns in the following areas:

- component failures,
- operational/procedural problems,
- organizational deficiencies,

In addition, this review would identify those specific facilities where these problems were occurring most frequently as a basis for follow-on site reviews.

Based on the review of the ORs, and their subsequent categorization in the spreadsheet database, the following case studies are discussed, along with the appropriate conclusions and recommendations.

Table 3-1 Descriptions of spreadsheet database fields.

Field Name	Description of Contents	Applicable Code or Entry
OR Number	Full Occurrence Report number from ORPS system.	OR number.
Field Office	Two-to-four character field office code.	ALO; CH; HQ; ID; NVOO; ORO; RFO; RL; SAN; SR.
Discovery Date	ORPS database supplied date of discovery of occurrence.	Numerical date serial number in the form of xx/yy/zz.
UCNI	Identification from ORPS database for UCNI-related events.	Y or N.
Failed Component	Determination from OR review on whether a hardware failure occurred.	Y or N.
Component Affected	Identification of the component, if any, associated with the OR. Applicable for both hardware and non-hardware related ORs.	Abbreviation of component's name based on *NPRDS** derived codes. Ventilation-specific codes added as applicable.
Detection Method	Determination of detection method from OR review. Basically, how the failure was identified (e.g. surveillance test, abnormal operation).	Single letter detection code based on *NPRDS** derived codes.
Cause Category	Categorization of cause of failure based on OR review (e.g. wear out/aging, eng./design, operating error).	Single letter code, based on *NPRDS** failure categorization.
Failure Cause Description 1, 2, 3	Identification of cause or contributing factor(s) to the failure, as determined by OR review.	Two-letter code based on *NPRDS** failure cause descriptions of cause of failure.

*NPRDS code definitions appear in Appendix A.

Part of the categorization process for each OR was identifying whether a hardware failure occurred as part of the overall event. From the results of all of the ventilation-related ORs the breakdown of ORs which included hardware failures to those which did not was nearly identical (51.7% versus 47%, respectively, and 1.3% NA). This finding suggests that facilities were submitting occurrence reports for situations that involved non-hardware deficiencies as often as those that did not. Some examples of the non-hardware events included: procedural errors, violations of Operational Safety Requirements (OSR), configuration management errors, and non-conformance situations. The exact meaning of this result, in the generic sense of the DP complex, is open to several possible interpretations; these may include focussing resources towards the review of 1) existing and planned maintenance activities and their associated procedures, 2) operations, and 3) administrative procedures, in the context of the existing facilities design bases.

Trending of Cause Categories

As part of the OR review process an attempt was made to identify a failure cause for each OR event to develop a focus for follow-on studies. As indicated in Table 3-1 this information was input as a single character code based on the NPRDS failure categorization list provided in Appendix A. Figure 3.1 provides the results of the cause category breakdown. As shown by this figure, over one-quarter of the events did not have sufficient information to make a determination of cause. The majority of these OR report types were Notification, 10-day, and 10-day update reports, which almost always required further review of the event to determine the various causes (e.g. direct, contributing, and root). For the purposes of this report the focus is not on these ORs since determining their cause would only be speculative. The remainder of this discussion will look at the major cause categories that were identified and provide examples from the OR database for illustration purposes.

Aside from the "unknown" category, the leading OR failure cause categories were identified as follows:

- Insufficient/Improper Maintenance and Testing
- Incorrect/Inadequate Procedures
- Management of Wear Out/Aging

To further narrow the failure cause of the OR event up to three additional fields entitled "Failure Cause Description 1, 2, and 3" were utilized. Figure 3.2 provides the distribution of failure events categorized by cause description. The codes used for these fields can also be found in Appendix A. Some examples of the usage for the cause category and cause description fields in the database can be described in the following manner:

Example 1
Cause Category: A - engineering/design
Cause Description 1: AG - abnormal stress
Cause Description 2: AA - foreign/wrong part
Example 2
Cause Category: F - maintenance/testing
Cause Description 1: BJ - incorrect action
Cause Description 2: AN - incorrect procedure

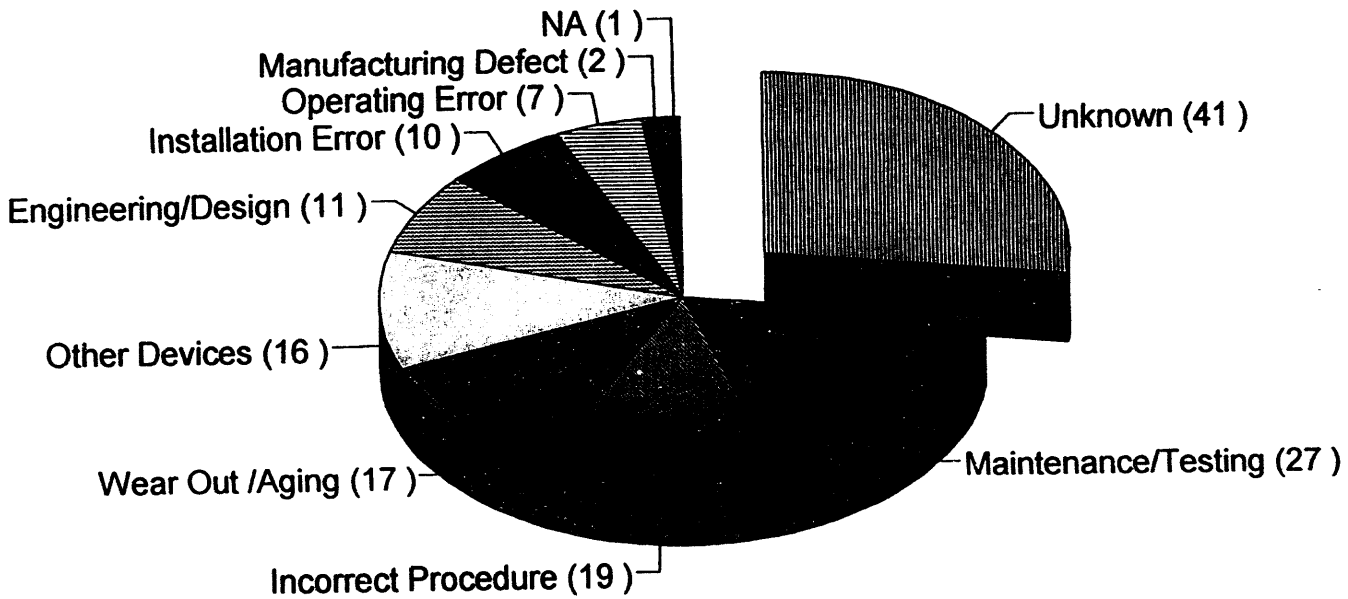


Figure 3.1 Distribution of Cause Category for Ventilation Related ORs

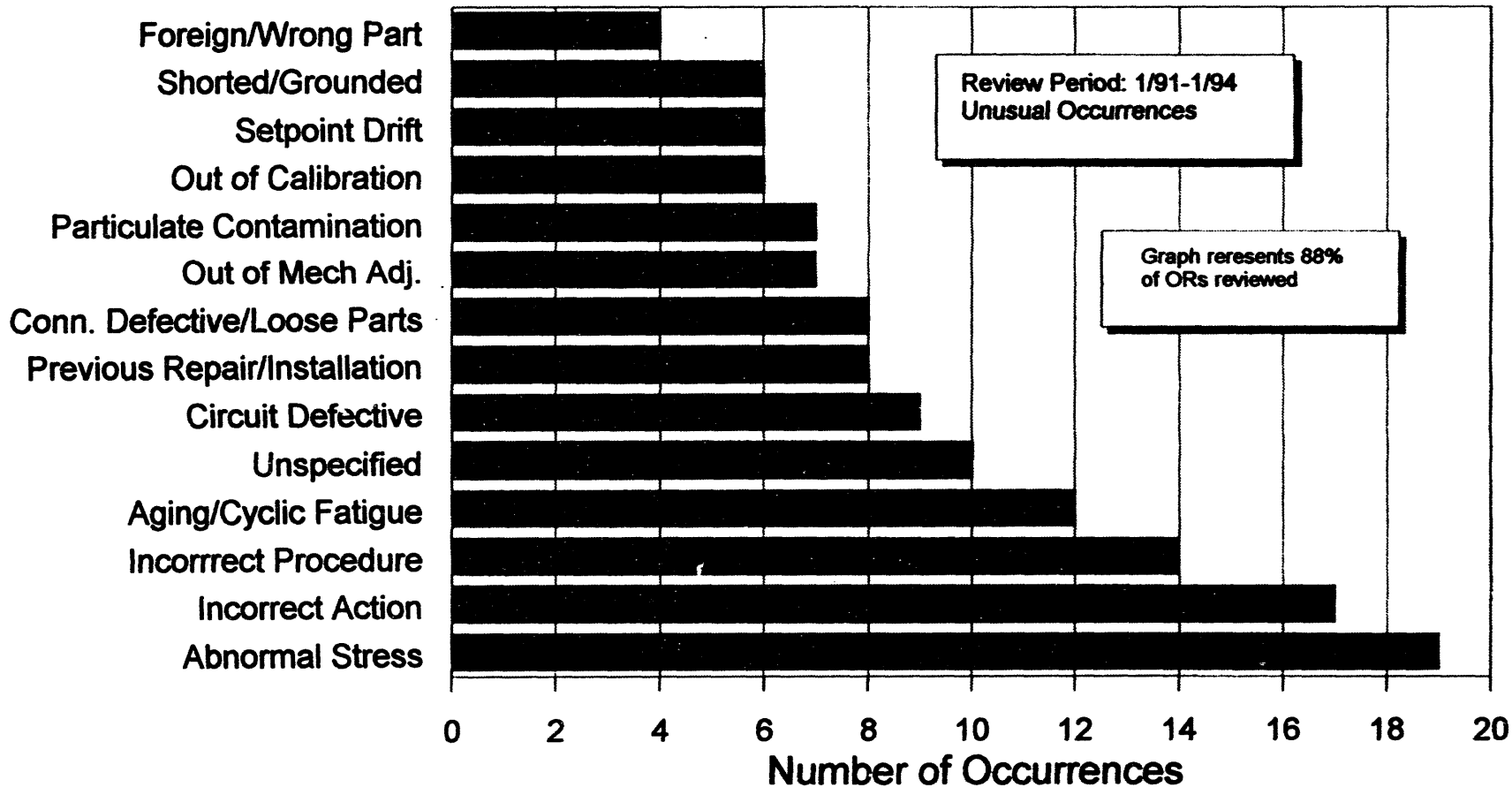


Figure 3.2 Distribution of Ventilation-Related OR Causes

Example 1 involved an event where a deficiency was identified in the engineering or design of the system or component (code A). An external event (extreme cold temperatures) led to abnormal stress (code AG) on the component, which in turn caused the system to shutdown when it should have continued operation. Further review of the event identified that the component in use was not adequately designed for the service temperatures that were experienced by the system, therefore a code of AA (foreign/wrong part) was also assigned to the event in the database.

Example 2 involved an event in which a subcontractor inadvertently cut a pneumatic control line in the process of removing obsolete equipment. During this maintenance activity (code F), the worker cut the pneumatic lines (code BJ) which were still in use by the system. This was partially due to inadequate markings on the equipment, as well as a poorly worded work package (code AN). In this example the work package is equated to a procedure which the maintenance activity is governed by. It is shown in this example that for the purpose of cataloging the OR events a procedure can be related to operation, test, or in this case maintenance activities.

The following sections provide a summary of the OR findings relative to the selected aforementioned cause categories. In each section the cause category is described and examples from the OR database are discussed.

Maintenance and Testing

ORs in this cause category (code F) involve failures resulting from improper maintenance or testing, lack of maintenance, or personnel errors that occur during maintenance or test activities. This category also includes events where a failure to follow maintenance procedure was identified, as well as errors reinstalling components or piece parts. The following examples from the ORPS database were typical for this cause category.

The following ORs (**RFO--EGGR-ANALYTOPS-1991-1086, RFO--EGGR-ANALYTOPS-1991-1104, RFO--EGGR-ANALYTOPS-1992-0057, RFO--EGGR-ANALYTOPS-1992-0093**) had causes attributed to lack of an adequate preventive maintenance program to periodically replace hood and "B"-box filters. In each incidence the ventilation system failed a surveillance test which measures the face velocity in the hoods and boxes. The filters were found to be dirty, thus restricting the air flow. It was determined that the filters were not being changed periodically, in some cases for as long as 18 months. These ORs were assigned **cause category** F, and **"Cause Description-1"** equal to AC, particulate contamination. In two of the events a second cause description of "incorrect procedure - AN" was also identified due to the improper method that the procedure specified for taking the flow measurements of the hoods and "B"-boxes.

Another recurring cause of maintenance/testing-related ORs involved incorrect actions. In these events an incorrect action during the maintenance or testing activity caused a failure of the system to meet its intended function, or caused the failure of a component. An example of this can be found in OR **RFO--EGGR-371OPS-1993-0067**. In this event a surveillance test revealed that a SAAM had no air flow going to it. Further investigation revealed that a Radiation Instrumentation Technician (RIT) had not adequately tightened two internal connections to the SAAM. A critique of the event identified that the RIT claimed that

he was given an additional workload that he perceived had to be completed by the end of his shift. Although he claims to have followed the proper installation procedures, it appears that there may have been some inattention to detail which led to the failure of this SAAM surveillance.

Another example of "incorrect action - BJ", involved an event where a supervisor, overseeing housekeeping activities on a particular diesel generator (DG) (details omitted due to UCNI-related material), inadvertently "bumped" the NORMAL-IDLE switch for the diesel, leading to the loss of DG output voltage and subsequent loss of required tunnel static pressure (**SR--WSRC-FCAN-1993-0054**). The OR indicated that there was inattention to detail on the part of the supervisor which led to the switch being bumped. There is no corrective action associated with the redesign of the switch and/or its housing provided in the OR. However, a review of the Office of Nuclear Safety (ONS) Operating Experience Weekly Summary 93-45, indicates that a hinged Plexiglass® cover was installed over the switch to prevent a recurrence of this event. To clear the entire matter up a call was placed to the responsible system engineer. He indicated that the corrective action was to place a Plexiglass® cover over the entire control panel for the diesel, and the reason that this did not appear in the "final" OR was that the facility decided on this corrective action after the OR was written to further assure that this event would not be repeated.

The "bumping" of switches and other devices, along with their unanticipated, and unsafe consequences, are not limited to this OR, Appendix B identifies five additional instances where this was a problem. In these other events the bumping of switches and other components, led to conditions that could have jeopardized the safe operation of their facilities, such as:

- junction box bumped causing inadvertent release of Halon, (**SR--WSRC-FBLINE-1991-1020**)
- bumped switch causes a loss of radiation monitoring and ventilation equipment (**RFO--EGGR-ANALYTOPS-0009**),
- inadvertent shutdown of a facility's only operating fan due to a bumped motor starter (**RL--WHC-TANKFARM-1993-0011**)
- surge suppressor toggle switch bumped causing the loss of power to stack monitors (**SR--WSRC-FCAN-1993-0031**)

In some of these instances the cause of bumping into components could be attributed to a lack of space where the components were located. In these instances more attention to detail must be paid when preparing maintenance/test procedures for confined work spaces. In other instances, simply more attention to the existing surroundings are required so that inadvertent bumping does not take place.

Other maintenance-related events involved such cause descriptions as incorrect procedures, previous repair or installation status, and abnormal stress. A complete listing of OR events with the cause category identified as "maintenance/testing" - code F, can be found in Tables A.1 and A.2

Incorrect/Inadequate Procedures

There were 19 OR events whose **cause category** was identified as incorrect procedure (code B). The incorrect procedure cause category involves those events where a failure was attributed to an incorrect or inadequate procedure that was followed as it was written. Conversely, the failure to follow a procedure was categorized as an operating error (code E), or a maintenance/testing error (F), dependant on the circumstances surrounding the event. Included among this category are events that are characterized as configuration management deficiencies. While the review of the ORPS database for this report was limited to the **unusual** event report category, and includes some discussion on configuration management problems, more events related to this problem can be found in the **off-normal** category. The majority of procedure-related events (12) also had **cause descriptions** identified as incorrect procedure (code AN).

The ORs in this category involved procedures that were being used by a particular group for a particular purpose (e.g. maintenance, operations, and surveillance) that did not meet the intent of the current design nor the mission of the facility. In some instances this involved incorrect information in the procedure (i.e misidentification of a fan, or valve) as well as cases where the procedure was not updated to reflect the current design of the system. This cause category also encompasses those events which fall into the area of inadequate configuration management and document control, as they relate to incorrect or deficient procedures. Some examples where incorrect or deficient procedures (code-B) were identified as the cause category, specifically configuration control and/or document control problems, can be found in the following ORs:

- SR--WSRC-REACK-1991-1170
- RL--WHC-PFP-1991-1018

A case in point involved a situation at Savannah River (SR--WSRC-REACK-1991-1170) where modifications were performed on two dampers regularly without being adequately documented. The event involved approved work on two fans which required that both be shutdown and restarted at some point during the maintenance. After shutting down one fan and restarting the other, the Central Control Room Supervisor (CCRS) noticed that process air flow was reduced. It was discovered that a discharge damper would not open fully as required by design. Examination of the damper revealed that it was pinned in place so that it could not be actuated remotely. Further investigation identified that there was a history of operating difficulties with the damper's pneumatic actuators. An evaluation suggested that the repair or replacement of the actuators is of little immediate importance, and, therefore, was a low priority. As a result of the recurring operating difficulties and the low priority, temporary modifications were routinely implemented and removed on the dampers alternately, but because these modifications had to be made so often, a permanent change in design was necessary. Manually opening and closing the dampers was deemed to be an acceptable permanent change. A design change form (DCF) was imposed on both dampers' operating mechanisms that provided for manual pinning of the dampers in the desired position (open/closed) in place of the original remote actuation. The direct cause of the degradation of the ventilation system identified with this event was that the Central Control Room was

not cognizant of this permanent design change in the dampers which would make their remote actuation inoperable. The root

cause was attributed to less than adequate administrative controls/enforcement also referred to as configuration management.

The review of this event identifies the procedure (DPSOL-105-1183A, "Ventilation System Operation") which required revision, before the reactor engineering department's release for operation (RFO). Also, it is noted that a request for engineering assistance (REA-91-0311) was specified to document the permanent change to the dampers' actuation mechanism. The chronology of the events was that the REA which requests the DPSOL revision was dated 9/21/91, the event occurred on 10/26/91, and the DPSOL finally was revised to reflect the design change form (DCF) on 11/21/91. The combination of the time delays to enforce the REA, and modify the operating list (DPSOL), created the potential for this event to occur. The discussion of the root cause for this event indicates that the procedure (RDP 5.01, "Reactor Plant Modification and Design Control Program") for making the modifications and for the release for operation (RFO) process, along with subsequently ensuring that the appropriate procedures are modified, was in place but not enforced. Also contributing to this situation was the large number of design change forms (DCF) and the newness of the procedure (RDP 5.01). This event is representative of those ORs which occur because a facility group, such as operations or maintenance, refers to a procedure which is not revised to reflect the current design or configuration of a component or system.

A similar occurrence of a procedure not reflecting an existing system configuration can be found in OR: **RL--WHC-PFP-1991-1018**. In this event, preventive maintenance was being performed on a central processing unit (CPU) which automatically controls the dampers for the ventilation system. While attempting to secure power to the CPU, an interlock was activated which shuts down the ventilation system; there was a complete loss of ventilation for nearly two hours. A contributing cause was identified as an inaccurately developed procedure which did not contain the complete and proper information on powering down the CPU system, nor did it reflect the current configuration of the system. The OR noted that changes and updates to the system were not being communicated to people working with the system, such as maintenance personnel. It was apparent that an interlock was added to the system and the wiring to the interlock was tied into the circuit which powers the module racks. When the racks were de-energized, the interlock was inadvertently activated, thereby losing ventilation. In retrospect, had the drawings, procedures, and other associated documentation been updated, provisions could have been made which would have prevented the subsequent loss of the ventilation system. The "Final Evaluations and Lessons Learned" section of this OR indicates that "...in the future, maintenance personnel shall not use unapproved preventive maintenance procedures..."; at the time this PM procedure was used, the maintenance department unknowingly was using a procedure which did not reflect the existing configuration of the system. However, this problem does not lie with the maintenance department per se, but with that group which was responsible with modifying the system, and for coordinating the effects of these changes with the responsible departments that were holding the procedures. This point is borne out by "Corrective Action" #5 which says to "...evaluate the work control system to determine possible improvements in areas of coordination between modification packages and ongoing maintenance involving preventive maintenance and PISCES (i.e. documents to be impacted by modifications)..." This

sentence, taken verbatim out of context, uses the acronym "PISCES", which stands for Plant Instrumentation, Surveillance, Calibration and Evaluation System. PISCES appears to be a centralized system for tracking the surveillance, calibration, and subsequent evaluation of instrumentation systems using "job cards" to maintain a historical

record of PMs, modifications, and calibrations performed on a given instrumentation system. With the proper implementation and execution of the PISCES system, with regard to the specific CPU identified in this event, maintenance personnel more likely would have had the opportunity of knowing about the modifications, which would have prevented the loss of ventilation.

Other ORs associated with the incorrect/inadequate procedure cause category involved events where procedures for maintaining or testing systems or components were not consistent with those identified in the Operational Safety Requirements (OSR). Two examples of this type of event can be found in the following ORs:

- SR--WSRC-HCAN-1991-0034
- ORO-MMES-X10CHEMTC-1991-1004

In the **HCAN** event, it was determined that testing of the Old HB-Line HEPA filters was not being performed at the frequency identified in the OSR. The Health Protection procedures specified that the filters should be DOP (dioctyl phthalate) tested annually. The OSR surveillance requirement specifies that the DOP test for HEPA filters not exceed a 9 month time interval. The Old HB-Line HEPA filters (all 32) were being tested at a frequency which exceeded the OSR requirement by 3 months. The performance of the surveillance requirement to DOP test the HEPA filters in Old HB-Line has not been in compliance since the OSRs were revised in 1985. The direct cause for this event was identified as inadequate administrative control where management's interpretation of responsibilities and custodianship resulted in an oversight of linking the OSR document with the writing of the HP procedures.

The procedural problems identified in the **X10CHEMTC** event involved the inability to adequately document the monthly operation of the spare ventilation fans required by the OSR. The documented check of the system exceeded grace period by 2 days. The cause for this OSR violation was attributed to surveillance "checksheets" that were not "user-friendly". A corrective action identified in the OR write-up indicated that the checksheet needed to have specific references to highlight the OSR Limiting Condition of Operation (LCO), and provide those limits on each parameter making it clear when a test was either successful or not.

Another example of an "incorrect/inadequate procedure" involved the event described in **RFO--EGGR-ANALYTOPS-1993-0007**. This OR describes a post-maintenance test where a procedure, which was not updated to reflect a preexisting hardware deficiency, caused the inadvertent actuation of the Process Air Programmer to initiate a ventilation fan interlock sequence. Previous problems in performing this activity identified problems in the fan selector switch circuitry. The problem surfaced when technicians performed a changeover from the lead or operating fan, to the standby fan, causing the control circuit to "sense" a loss of glovebox exhaust fans. The problem was subsequently avoided in previous switchovers by placing the local control switches in what is identified as the "HAND" mode, thereby

bypassing the lead/lag circuitry that has the deficiency. This "lessons learned" information was not incorporated into the procedure, thus leading to the event that is described here. Unaware of this temporary "fix", the Stationary Operating Engineer (SOE) proceeded according to "Ventilation System Operating Procedure - UOP-559-7, for the post-maintenance testing resulting in the temporary loss of both fans. This event is an example of not incorporating "lessons learned" into procedures with known problems, resulting in the unwanted/unanticipated shutdown of safety related equipment.

Tables A.1 and A.2 provide a complete listing of ORs with incorrect/inadequate procedure identified as the cause category (Code B).

Wear Out/Aging

The final category discussed involves events identified as "wear out/aging" - code H. These events involve situations where the failure of a component was determined to be caused by expected wear or aging. The majority of these events (10 of 17) also had **cause descriptions** identified as aging/cyclic fatigue - code BD. Examples of ORs in this category can be found in the following reports:

- RFO--EGGR-ANALYTOPS-1991-1006
- SAN--LLNL-LLNL-1992-1013
- SR--WSRC-FCAN-1992-0061

In **RFO--EGGR-ANALYTOPS-1991-1006**, an Agastat relay involved with controlling the Process Air Programmer (PAP), failed to change state during a monthly surveillance test which included a simulated loss of off-site power. The time-delay relay prevented the PAP from restarting the associated HVAC components. The direct cause of the relay failure was attributed to excessive service life; additional investigations found several other Agastat relays in the PAP control circuitry to be out-of-tolerance. It was determined that these relays were operating for "several" years beyond the expectancy of the manufacturer, and were not covered by any documented preventive maintenance program. The "Final Evaluations and Lessons Learned" section of the OR identified that a new Integrated Work Control Package (IWCP) would include a preventive maintenance activity along with elements that govern replacement of components based on manufacturer's recommended normal service life data. A specific mention was made for electrical/electronic equipment whose wear or degradation may not cause periodic problems or appear to experience wear. This corrective action would appear to address any future issues regarding this and similar electrical/electronic components. A comprehensive PM program will further the goal toward more reliable components and their associated systems. It was mentioned in the "root cause" section of the OR that "...recent efforts to establish a PM program are now fully supported by management, but time will be required for this new program to become effective.." Management involvement is required and necessary in the effort to assure that problems of this nature receive the required attention based on the importance of these ventilation components and systems so that they may be avoided in the future.

There were ORs which exemplified the successful implementation of PM and surveillance programs, while at the same time identifying components that reached their end-of-life; OR number **SAN--LLNL-LLNL-1992-0013** is a case in point. In this event a surveillance

test identified the degradation of one of two glovebox exhaust HEPA filters in both "legs" of the exhaust system. Based on the facility's OSR required surveillance test, each filter must have an efficiency of 99.97%. The measured efficiencies of the failed filters were 99.90% and 99.95% respectively. The filters were immediately changed and verified to meet the OSR specifications. Additional data supplied by the stack ventilation radioactivity monitors continued to read normal during the event indicating that radiation was not being released to the atmosphere due to the failed HEPA filters.

An example of excess wear out/aging can be found in events such as **SR--WSRC-FCAN-1992-0061**. In this event a failed seal on a diesel engine turbocharger led to the excessive consumption of lubricating oil (15 gallons in a 24 hour period), while worn-out intake valves and guides led to a condition of high crankcase pressure due to blowback. The occurrence report did not specify the exact cause of the turbocharger seal failure, nor the cause of premature valve and valve guide wearout. In the case of the turbocharger seal it is speculated that excessive wear or aging was caused by the thermal stresses on turbocharger subcomponents caused by the high temperature of the associated engine exhaust gases (>700°F). The high temperatures probably led to faster than normal wearout of these seals. In most applications critical operating parameters (e.g. turbocharger seal coolant temperature, turbocharger lube-oil temperature/pressure, exhaust manifold discharge temperature, exhaust flow rates) are monitored. Under "normal" commercial power plant conditions these parameters are trended, and limits are set such that conditions approaching critical values are alarmed locally and/or in a central control room. Based on the OR review it is not clear if this is being done for any or all of this diesel generator engine's critical operating parameters..

With regard to the valve and valve guide wear-out problem, periodic inspections performed at manufacturer recommended intervals are designed to avoid such failures. Again, it is unclear whether periodic engine inspections to avoid such catastrophic failures is taking place among this population of diesel generators.

In a number of ORs associated with diesel generators there is a sense that ownership of these vital components is less than adequate, specifically in regard to PM and overall system responsibility. Several diesel generator-related ORs identify PM as a direct or contributing failure. The lack of preventive maintenance is further exacerbated by the fact that in many cases the diesel generators, while providing a vital safety function, are not the sole property of the facility using them but are leased from various sources. In several ORs it is pointed out that certain information necessary to determine the cause of a particular failure is missing and usually attributed to the lack of ownership responsibilities.

Judging by the review of these OR types it appears that adequate records are not being maintained for the diesels to provide the proper background information with respect to the individual diesel's maintenance history. Based on the importance of the diesel generators to the continued operation of ventilation systems, and in some cases the facilities themselves, more accurate records need to be maintained by the owners of these vital pieces of equipment. In situations where the DGs are leased by a facility on a temporary basis this documentation needs to be provided by the lessor to the appropriate facility cognizant system engineer. The review of the OR database indicates that there is missing information that would only be found in historical component records.

This raises the question of ownership and responsibility with regard to equipment which provides a vital function such as back-up, or primary power for fans which are used to maintain a critical balance of supply and exhaust ventilation. In cases where these units are leased on a temporary basis it is important to know that proper preventive maintenance has been performed during the life of the engine to assure a high availability of the engine. Equally important, but probably more difficult to obtain, are records related to the surveillance tests that have been performed on these engines prior to releasing them for standby or normal service.
These are issues of ownership, as well as document control and quality assurance, that must be reviewed when assessing the overall performance of a facility's ventilation system.

OR number **RFO--EGGR-ANALYTOPS-1991-1081**, describes a situation where ...."unusual noises were heard emanating from Recirculation Fan, F304B". The description of the direct cause is listed as failure of the rotor bearings in the fan rotor hub, which was assumed in this review to have taken place due to age or cyclic fatigue. This event was previously classified as an off-normal event, but later upgraded to an unusual event because smoke-testing indicated that there was inadequate SAAM coverage in room 103 due to the shutdown of fan 304B. This is an out-of-tolerance condition based on the facility's limiting conditions of operation (LCO). No root cause is provided for this event. A review of the preventive maintenance practices for this facility would assist in determining if the proper frequencies were adhered to, versus the existing standards for similar equipment, operating under the given conditions.

Another example of aging/cyclic fatigue failure was found in **RFO--EGGR-ANALYTOPS-1992-0013** which identifies the failure of the inboard shaft bearing for Plenum Fan - F301A, detected during a general "walk through" as a "strong burning odor". Based on corrective action item 1, the bearing failure could be attributed to a lack of preventive maintenance. The specific wording of the corrective action item is "...evaluate the need for PM on vital safety systems".

Taking this statement at face value indicates that preventive maintenance is not an integral part of scheduled activities for maintaining the availability of this, and other vital safety systems, at the Rocky Flats Analytical Operations Facility. From the perspective of good engineering practice, the lack of a well defined PM program could be looked upon as a deficiency on the part of facility management, due to the increased likelihood of accelerated wear, and subsequently, of longer forced downtimes.

Based on such events, we recommend that a more thorough review of PM practices take place for vital safety systems at the DP facilities to identify those areas where there it is lacking. It should be understood that, based on this review, there may be justification at some facilities for a scaled down, or a complete absence of a PM program. These conclusions could only be made after a comprehensive review of a facility's mission(s), schedules and budget. More focus should also be put on developing a comprehensive PM program when aging/cyclic fatigue-related failures of vital safety system components increase to the point of causing numerous OSR shutdowns, or violations.

Component Failures

The "Affected Component" distribution chart (Fig. 3.3), shows the number of ORs where the component identified was in some way affected during the OR event and includes both failure and programmatic deficiency related events, and will be referred to as the "total group". The "confirmed" component failure distribution (Fig. 3.4) represents the population, ordered by component, for those ORs where hardware failure was identified by the reviewer, or by the facility reporting the OR. The basis for establishing the two figures was to identify those components that were actually failed (confirmed), versus those components that were cited in the OR and fell into one of the following categories indicative of programmatic problems:

1) out of calibration,
2) misalignment,
3) improper configuration,
4) procedural error,
5) operator/human error.

A review of the total group (Fig. 3.3) shows that the top five affected components are 1) instrumentation/control, 2) fans, 3) dampers, 4) engines, and 5) filters. A matrix showing the breakdown of the associated causes of failure, is given as Table 3.2. A graphical representation, Figure 3.5, shows this same breakdown in pie-chart form for each of the four components. There is a brief discussion provided below on each of the components.

Fans

Fans were expected to be associated with a significant portion of the OR events because they are a primary component of any type of ventilation system. As shown in Figures 3.3 and 3.4, fans were the second most frequently affected component (27), as well as the leading failed component (15). For those ORs with fans identified as the "affected" component, the following were the three main cause descriptions:

- incorrect action
- aging/cyclic fatigue
- unidentified
- abnormal stress
- circuit defective

Aging/Cyclic Fatigue-Fans

The following are three examples of fan-related ORs in which aging/cyclic fatigue was specifically identified, or could be inferred from the narrative of the cause description:

- RFO--EGGR-ANALYTOPS-1991-1081
- RFO--EGGR-ANALYTOPS-1992-0013
- RFO--EGGR-ANALYTOPS-1992-0062

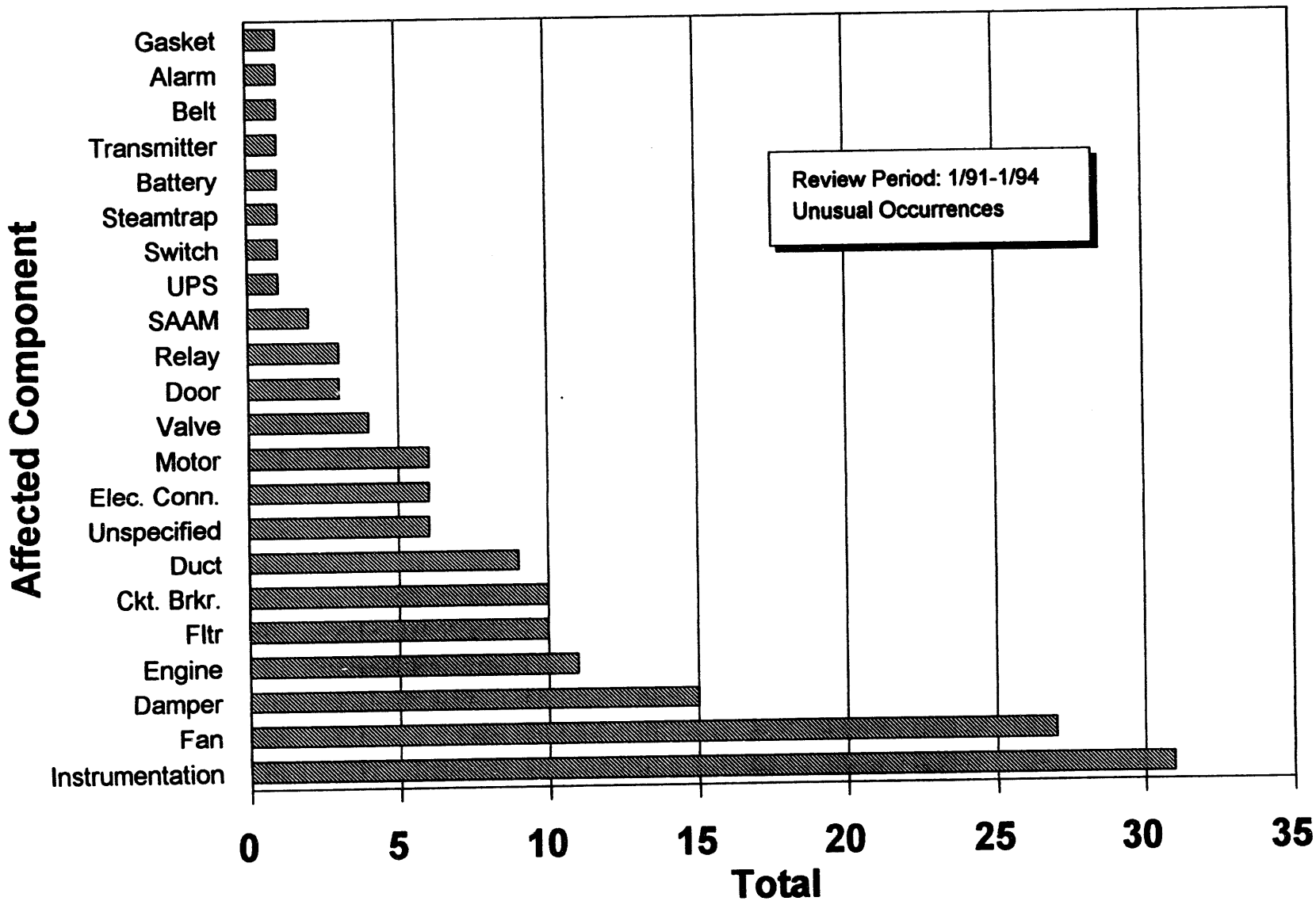


Figure 3.3 Distribution of Affected Component for Ventilation ORs

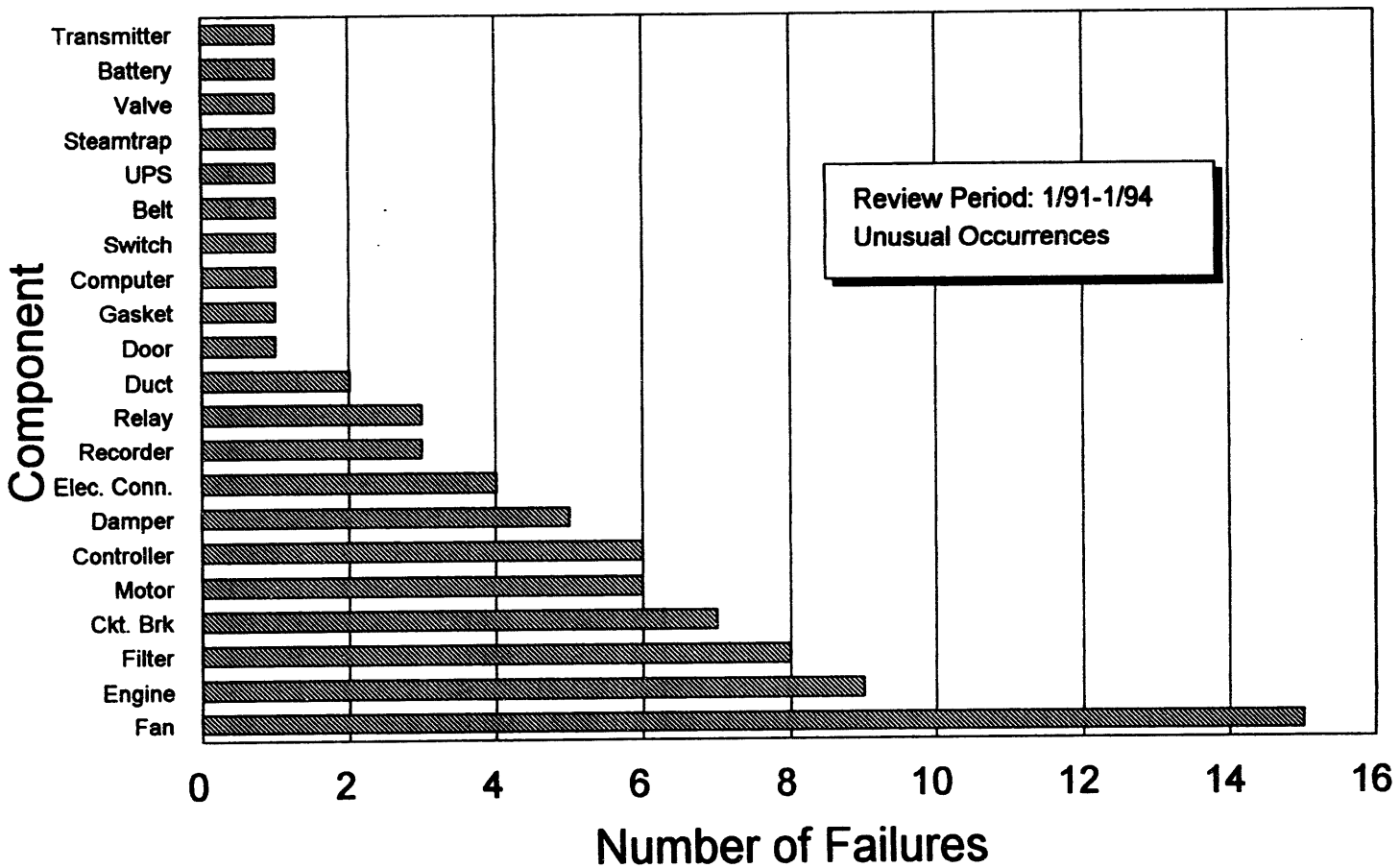


Figure 3.4 Confirmed Component Failure Distribution

Cause Description	Component					
	Damper	Engine	Fan	Filter	Instrumentation	Sum
Abnormal Stress		2	3		5	10
Aging/Cyclic Fatigue	1	1	3	1	3	9
Circuit Defective		1	3		3	7
Connection Defective	2	2	2			6
Corrosion	2					2
Electrical Overload		1			1	2
Foreign/Wrong Part					2	2
Incorrect Action	2	1	4		2	9
Incorrect Proced.	5		2	1	3	11
Material Defect				1		1
Open Circuit		1	1			2
Out of Adjustment	2		2			4
Out of Calibration		1			3	4
Particulate Contamination				5		5
Previous Repair/Maintenance	1		2	2		5
Setpoint Drift					5	5
Unidentified		1	3		2	6
Shorted/Grounded			2		1	3
Mechanical Damage/Binding					1	1
Sum	15	11	27	10	31	94

Table 3.2 Major Component Failure Cause Description Breakdown

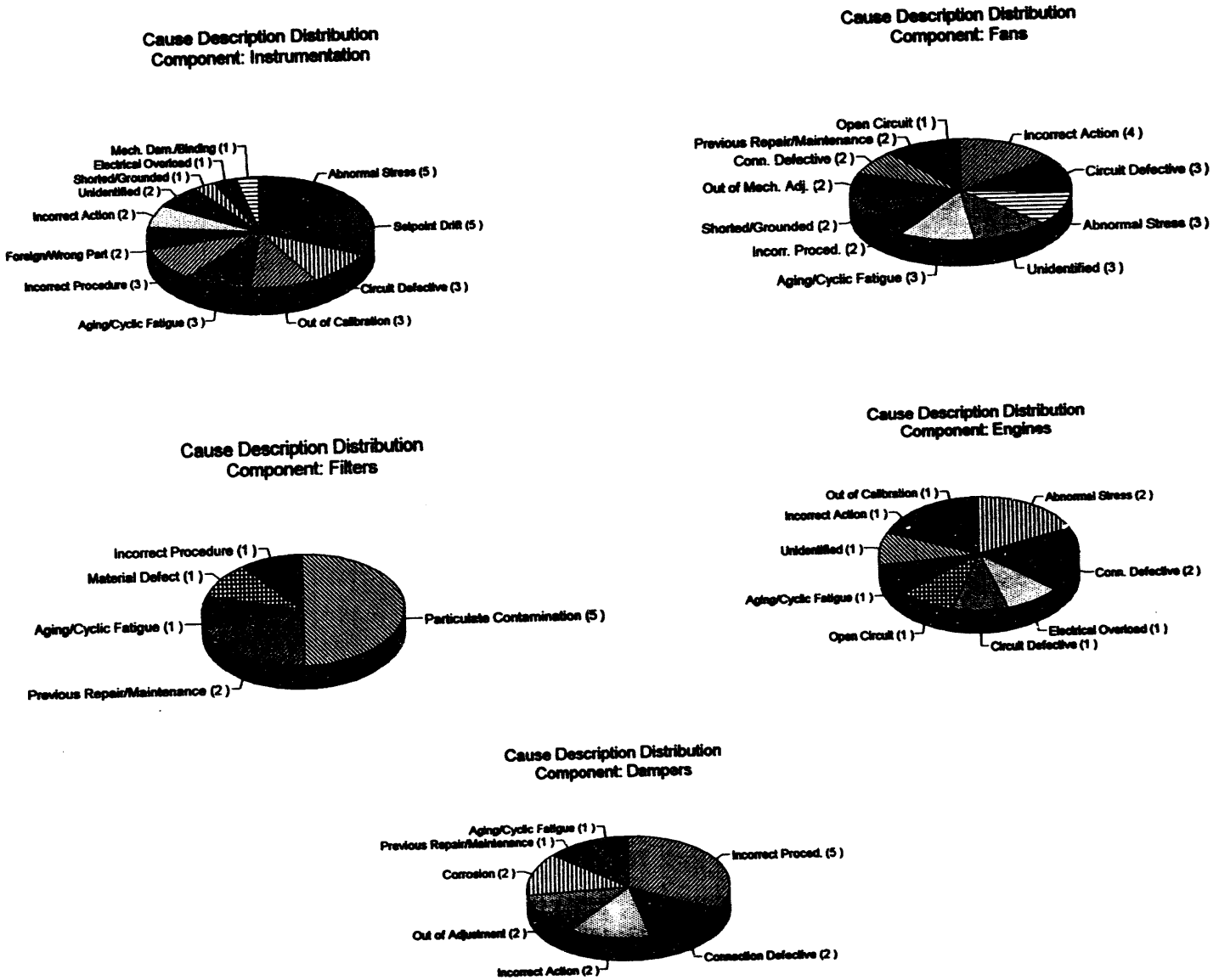


Figure 3.5 Breakdown of the Major Component Failure Cause Descriptions

The "1991-1081" did not specifically state that the cause of failure was aging/cyclic fatigue; however, this judgment was based on the OR's reference to "worn rotor bearings in the fan hub". In addition, the investigation into the fan failure also identified worn belts which needed replacement. These descriptions led to the classification of the failure cause as aging/cyclic fatigue.

In the "1992-0013" event, the "Description of Cause" narrative specifically identifies "wear-out of the bearings over time, due to the continuous use of the fan".

The third event, 1992-0062, specifically cites "fatigue" as the cause of bearing failure.

Incorrect Action-Fans

The fan failure events identified as "Incorrect action" can be found in ORs:

- SR--WSRC-FBLINE-1992-0003
- SR--WSRC-FBLINE-1992-0009
- SR--WSRC-HBLINE-1992-0029

In both **FB-Line** events the "south glovebox exhaust fan switch" was inadvertently moved to an incorrect position; the cause of this mistake was not clearly identified. In each case the switch was found in the "OFF" position instead of the expected "MANUAL" position. There is speculation in both cases that the cause of the mispositioning was one of the following: 1) it was bumped by an air hose, 2) vibration in the panel, and 3) intentionally moved by unauthorized, unidentified personnel.

The final resolution of these two events was to install switches for both the "north" and "south" glovebox with "stiff" detent positions to preclude accidental mispositioning. This resolution is satisfactory for items 1) and 2); however, if the mispositioning was intentional, a more thorough fix would have been to install a switch requiring a supervisory keylock.

In the **HB-Line** event, a planned activity, involving "Canyon exhaust fan switching", resulted in the actuation of a low vacuum alarm interlock, which, in turn, shut down the **HB-Line Air Supply**. This event is classified as "incorrect action" because the Power Department personnel who were conducting the test did not inform **HB-line** personnel of the activity, which affected the **HB-Line** ventilation system. The OR states that"... had **HB-line** personnel been notified of the situation, the activation of the *Canyon Exhaust Tunnel Low Vacuum Interlock* would have been anticipated, and considered a planned activity". The corrective action to issue a standing order for **H-Canyon** personnel to notify **HB-Line** personnel when *Canyon Exhaust System* configurations are made will minimize the potential for reoccurrence.

Unidentified

This failure cause description is used for those events were there was inadequate information to determine an exact cause or to infer one. The code "XX" was used in the database to identify such fan-related ORs:

- RFO--EGGR-PUFAB-1992-0138
- RFO--EGGR-PUFAB-1992-0147
- RFO--EGGR-PUFAB-1993-0053

In most cases, ORs classified as "unidentified" lack sufficient causal information because they are "10-Day" reports or "10-Day Updates", and the investigation is ongoing.

Among the other failure causes were defective circuits (2), mechanical misadjustment (2), incorrect procedure (2), and previous repair/maintenance (1).

Instrumentation/Control

In addition to fans, instrumentation and controls (I&C) were identified as the affected components in 31 OR events (Fig. 3.3). The more prevalent failure causes for the I&C-related events were the following:

- Abnormal stress,
- Setpoint drift,
- Out of calibration,
- Defective circuits.

One recurring instrumentation/control problem at the Rocky Flats Analytical Operations Facility was identified as the Process Air Programmer (PAP). A description in the ORs indicates that the PAP is an electro-mechanical device used to isolate and subsequently restart, the safety-related ventilation equipment. There were several ORs involving PAP-related problems (**RFO--EGGR-ANALYTOPS-1991-0159, 1005, 1006,1058**). As indicated, the PAP serves an extremely vital function, yet according to information reported in one OR (**RFO--EGGR-ANALYTOPS-1991-1006**), there were no approved test or maintenance procedures available to adequately test its function. The OR further states that surveillance requirements for the PAP were not established until 1987, and it was not until much later that procedures were developed to implement them. From 2/91 through 9/91 there were several PAP-related ORs, identifying some degree of inoperability, as well as spurious, but proper actuation, which either isolated selected fans, or shut them down. During this period, one OR mentions (**RFO--EGGR-ANALYTOPS-1991-1058**) that incorrect setpoints used for the PAP-supervised, F302B glovebox fan, caused a surveillance test to fail. During the test, the fan did not actuate at the required setpoints as stated in the procedure. Later, it was identified that the setpoints used for F302B had no documented Design Basis. The OR further states that an engineering evaluation found that these setpoints would not allow the exhaust plenum fans of the glovebox to operate properly because they would not actuate in the proper sequence, based on the incorrect setpoints. The corrective action statements identified in this OR, and the other referenced ORs, indicates that procedures were being developed to maintain and test the PAP. Several additional ORs after 9/91 identified situations where the PAP functioned as designed isolating and restarting, selected ventilation equipment, given that the parameter setpoints were met. With its critical function for the continuous operation of safety-related ventilation equipment, and its historical background of problems, the PAP is a focal point for follow-up investigation, and should be included in any planned inspections of the Analytical Operations Facility at Rocky Flats.

Abnormal stress also was an identified causal factor for instrumentation related events, mostly attributed to external phenomena. Two examples were **RFO--EGGR-ANALYTOPS-1992-0005**, and **SR--WSRC-FBLINE-1992-0057**.

In the "ANALYTOPS" event, a "freeze-stat" sensor responsible for controlling supply fans F-1 and F-2 in the supply-plenum was exposed to temperatures below its setpoint of 35°F. This situation tripped fans, as well as causing the loss of effluent Selected Air Alpha Monitor (SAAM) #17 which lost its vacuum system when the supply fans were tripped. The primary cause for this event was a lack of adequate control over the air temperature in the plenum where the sensor was located; the temperature was supposed to be controlled by a combination of airflow and temperature-control dampers. No reason was given in the OR for this improper operation of the system.

In the FB-LINE event, high winds were believed to have caused a pressure transient which, in turn, simulated a loss of differential pressure across the operating fan, thereby tripping the "J" interlock. The severe storm conditions (55 mph winds) were believed to have affected the readings on a manometer (2-10) which references static pressure in the room air exhaust duct. Corrective actions were planned to investigate alternative means for tripping the "J" interlock.

Dampers

Ventilation system **dampers** were identified among the top five leading affected components, mostly due to incorrect configuration. In tabulating cause descriptions, this was identified mainly as "Incorrect procedure". Dampers were either left in the wrong position, or they were put into positions that were not consistent with the design basis of the particular facility, based on a procedure which did not adequately identify the correct position. Among the remaining six failure causes, no one particular cause was involved in more than a single event. Some examples of damper-related ORs are discussed below.

In the event described in **SR--WSRC-HCAN-1992-0009**, the lack of a developed procedure to adjust selected dampers to reduce radioactivity levels in a particular airlock caused the inadvertent pressurization of an adjacent room. This pressurization resulted in air reversal causing air to flow from one room to another where personnel were monitoring air flow into the room without the proper respiratory protective equipment. The OR states that..."a review of a procedure may have made up for the inadequate administrative control of assuring that during adjustment to a primary ventilation control system, personnel in the vicinity will be in the necessary respiratory protective equipment..." At the time of the incident, the particular room had 2000 d/m transferable alpha contamination/0.1 m^2, which was the basis for attempting to adjust the damper.

An incorrectly worded procedure was the cause cited in **SR--WSRC-FBLINE-1992-0046**. The procedure required that the test was performed twice to ensure proper function. The steps in the procedure which verified the acceptance criteria for closure of the dry cabinet supply dampers was correctly stated for the first test, but was incorrectly stated for the second test. While carrying out the test, the individual monitoring it inadvertently used the correct acceptance criteria from the first test for the second test. The resolution to this event included 1) revising the procedure, 2) retesting the interlock using

the revised procedure, and 3) revising the design basis documents and drawings to reflect as-built conditions for the ventilation systems and ventilation interlocks. The last item has been identified as a recurring problem in our OR ventilation review. Situations indicative of incorrect design documents and drawings will continue to pose a problem unless site specific programs are initiated to review their impact on a facilities mission.

Filters

The filters associated with ventilation systems serve a vital function in controlling the spread of radioactive particulates and radioactive gases. From our review, filters were the fourth most frequently affected component. Their failure causes were identified as 1) particulate contamination (4 events); 2) previous repair/maintenance (2); 3) aging/cyclic fatigue (1); 4) material defect (1); and, 5) incorrect procedures.

The expected failure mode for filters is particulate contamination. At some point in the filters service life it becomes sufficiently "plugged" with particulates that it no longer satisfies a given performance criteria for flow or ΔP. This was the failure cause in four of the ORs reviewed:

- RFO--EGGR-ANALYTOPS-1991-1086
- RFO--EGGR-ANALYTOPS-1991-1104
- RFO--EGGR-ANALYTOPS-1992-0057
- RFO--EGGR-ANALYTOPS-1991-0093

In each instance, the air flow velocity through the "B" boxes failed to meet the minimum face velocity of 150 linear feet per minute. The direct cause was attributed to dirty filters restricting air-flow through. From information provided in the ORs, the affected filters had not been replaced for 18 months.

As discussed earlier in the section on Preventive Maintenance, according to the information in the ORs, the root cause for these events was attributed to ..."inadequate management direction in implementing a routine filter replacement program..." The decision to curtail filter changeout as a part of the overall curtailment of plutonium operations resulted in the current situation. A corrective action given in the associated ORs indicates that the Rocky Flats Systems Engineering Department would recommend the required frequency of changeout of the filter. The recommendation was to be made on a case-by-case basis, given the priority associated with the boxes and the Building 559 start-up.

The resolution to these events, described in these ORs, seems to have adequately identified the problem, the deficient surveillance procedures, as well as justifying the continued planned maintenances on selected, "prioritized" gloveboxes. No reason was proffered as to why these filters had not been changed on a regular basis in the past, other than those already indicated in the ORs. One would assume "good engineering practice" for any system is routine maintenance and testing, especially for replaceable parts, such as filters.

Another identified failure causes for filters was material defect. This event (RFO--EGGR-774OPS-1991-1003) describes the failure of several HEPA filters (13 of 45) in the Building (Bldg.) 774 Recirculation Plenum (FP-201). The filter plenum was required to

have a stage efficiency of 99.95%; testing indicated an efficiency of 97.90%. Further testing identified the failed filters through individual testing. A visual inspection of the failed filters revealed "...a physical separation of the paper membranes from their plywood frames..." The OR identifies the manufacturer of the failed filters as a one-time supplier (Delta Filter Corporation). Also discussed is the thorough investigation that identified all Delta Filters sitewide. The implications to the DOE complex as a whole is one that might be investigated in the future, or, at least, a generic notification of these filter failures could be made to all facilities that use HEPA filters from this particular manufacturer.

Two events had failure causes associated with a previous repair/installation (**ORO--MMES-Y12METLPRP-1991-1014** and **SR--WSRC-FBLINE-1992-0029**). In the Y12 event, it was speculated that during the changing of **"dynel roughing filters"** dislodged some process material containing uranium. The OR indicates that there was **no specific maintenance procedure** covering the filter changes: the process was identified as a joint effort between Operations and Maintenance. This event typifies a situation where an approved procedure may have prevented the occurrence of an unusual event.

In the other maintenance-related filter event, a bank of HEPA filters did not pass a "delayed" post-maintenance DOP test. The failure was attributed to maintenance performed two days before the test. It was believed that the filters were improperly seated or misaligned when they were installed, and that post-maintenance testing could not be undertaken on that day due to other scheduled work. The OR goes on to state that "...DOP testing of HEPA filters should be performed immediately following a filter replacement because of increased vulnerability to problems or unexpected effects on the system as a result of the configuration changes and associated activities..."

Engines

The last major component identified was Engines, or more specifically, diesel generators. Eleven events were attributed to diesel failures with no failure cause more dominant than any other. In most cases, the diesels are dedicated, portable units for specific ventilation fans. As indicated previously, it is not clear from the information provided in the ORs whether adequate PM and surveillance is being performed in these units. Refer to the section on Wearout/Aging for a discussion on diesel engines and associated problems and potential resolutions.

NA-Category

Also included as part of the total group are ORs where the affected component was deemed not applicable (NA), based on a review of the event. These events included a loss of power to a site due to severe weather storm (lightning and hail), an audit of a facility's operation safety requirements (OSRs), and a failed survey of facility's ventilation patterns.

In the loss of on-site power event (**ALO-LA-LANL-ESHSUPT-1991-1566**), fume hood ventilation was lost when power was interrupted to buildings TA-55 and OH-1. An evaluation of the incident by facility representatives indicated that neither building required emergency back-up power "...based on the low frequency of loss of power events, and also because the samples under analysis do not contain sufficient radioactivity to justify continuous power".

The second "NA" event involves the audit of a facility's OSRs (**ID--ROCK-SMC-1991-0001**). The event describes three areas of concern with regard to the facility OSRs:

1) OSR criteria are no longer valid due to modifications in the facility or process,

2) lack of clearly defined requirements precludes determining the level of compliance for directed ventilation air flows, and

3) failure to meet the presently stated OSR criteria for selected-radiation monitoring equipment.

The final NA event (**SR--WSRC-FBLINE-1993-0008**) involved the failure of a ventilation pattern survey. The survey found air flow patterns that were opposite of design patterns under certain conditions. The irregular patterns involved rooms that were normally unoccupied, and those which had respiratory requirements. The evaluation by the facility manager/designee indicates that "...air balance work was underway to stabilize the air flow in the affected area..." There were no entries in the "corrective action" field, nor in the "final evaluation and lessons learned field". Due to the vague write-up, we could not assign the responsibility for the OR event to any particular component or system. This seemed to be a case of inadequate configuration control on the part of the facility with respect to the existing design bases. There were no stated component failures, nor were there any references to operating procedures that were not followed properly in the OR. This OR typifies those events where inadequate knowledge or familiarization with the existing design basis is identified as a factor in the operation or maintenance of a ventilation system. It also typifies those ORs in the ORPS database that lack sufficient detailed information.

Field Offices/Facilities

Figure 3.6 shows the distribution of unusual event, ventilation-related ORs by field office. The facility-specific breakdown is included as Figure 3.7. More than 80% of all of these ORs were reported by either the Rocky Flats field office (52%), or the Savannah River field office (29%); a more detailed facility breakdown is given in Figure 3.8 for these two field offices. The facilities at Rocky Flats with the largest number of ventilation-related, unusual event ORs were the Analytical Operations (ANALYTOPS), and the Plutonium Fabrication (PUFAB) facilities (82% of RFO ORs). The Savannah River facility with the highest contribution to the ORs reviewed is the F-Canyon Beamline (40% of SR ORs).

While the mere frequency of ORs is not in itself a sound basis for determining which facilities should be chosen for detailed site visits, it provides a focal point for further review. Still, several questions come to mind when comparing gross numbers for one facility versus another. For instance, is the facility with the larger number of ORs doing a better job of reporting, or are they not performing as well? Does one facility have more stringent TSRs than another, leading to more excursions outside the safety basis? How does the subjective aspect of classifying an OR as an "off-normal" event versus an "unusual" event add to the discrepancy in reporting ORs between facilities. It was seen that some of the "off-normal" events discussed in the Nuclear Safety Weekly Summary Reports were more important, from a safety viewpoint, than some ORs that were classified as "unusual". Should such inter-facility comparisons even be considered since most of the systems are so diverse? The

answers to these and other questions should determine where to focus available resources in an effort to provide some bases for follow on evaluations. Both the Rocky Flats and Savannah River sites meet the criteria of frequency, as well as severity in those areas concerning the reliable operation of the safety-related ventilation systems, to warrant emphasis in any initial evaluations.

3.3 Significant Findings

Based on our overall review, we identified several generic areas for potential follow-on work:

- Inadequate/Improper Preventive Maintenance
- Procedural Deficiencies
- Management of Wearout/Aging

These areas provide a common basis for the follow-on review, and inspection of DP ventilation systems and facilities. Nearly all the facilities reported ORs where each of these areas was identified as a problem at some point or another. The specific examples of the previous section help to narrow the focus to specific facilities, and components, as well as those areas recommended in the general discussions of industry standards and practices (Section 4) There were no design-specific details provided as part of these recommendations, other than those discussed in generalities in Section 2, and in citing of the specific examples of Section 3. Primarily, this lack of specificity reflected the fact that all of our initial OR reviews were done without the benefit of facility specific, design-related documentation. Therefore, the compilation of such facility-specific documentation would be an initial activity for any additional reviews or evaluations.

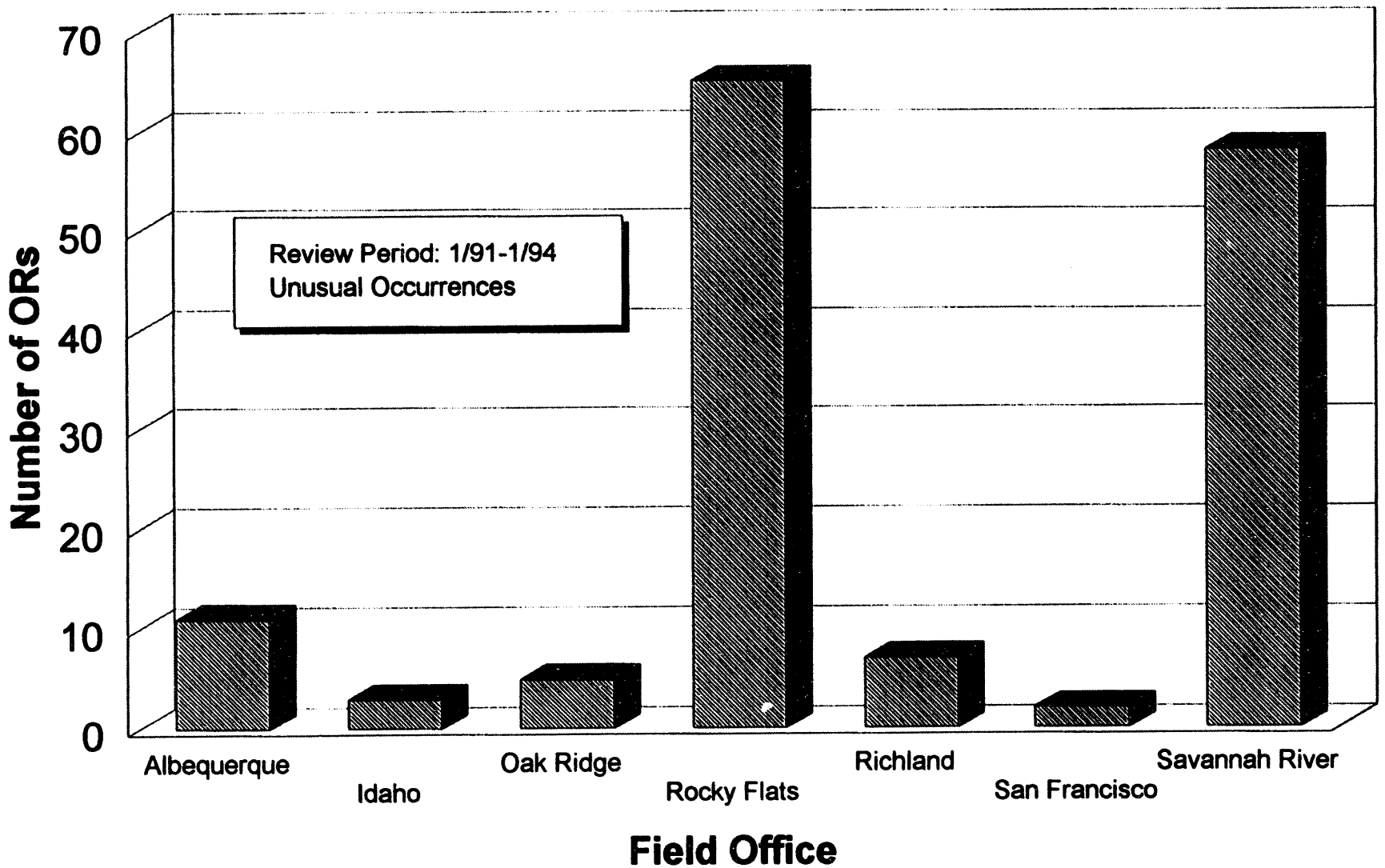
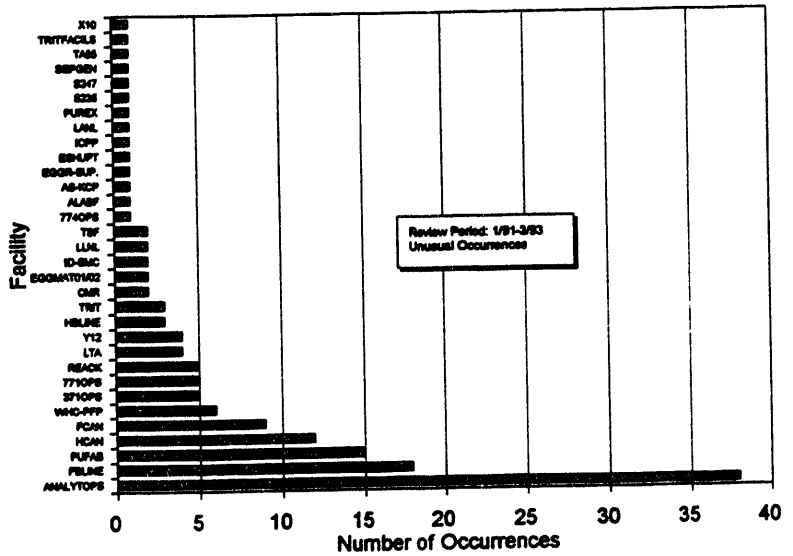
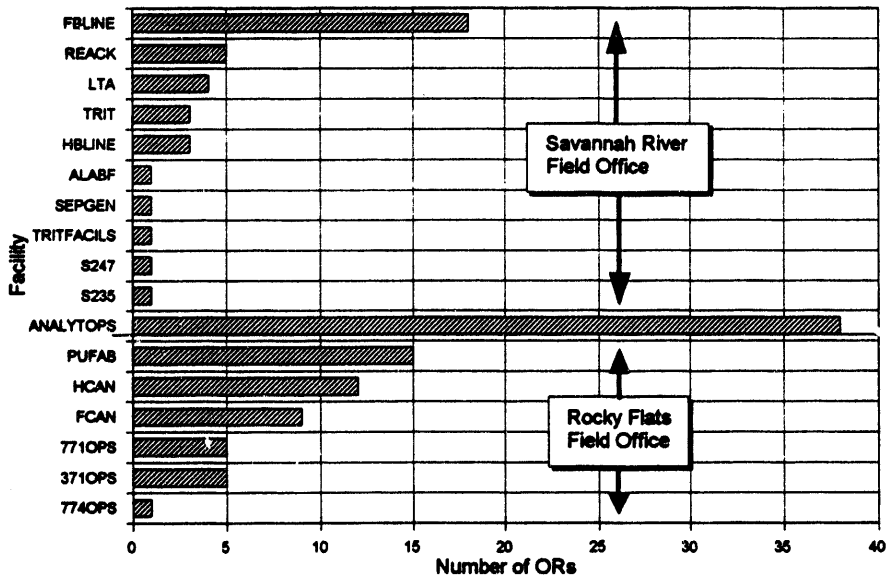


Figure 3.6 Distribution of Ventilation-Related ORs by Field Office



Acronym	Facility Name	Field Office
371OPS	371 Operations	Rocky Flats
771OPS	771 Operations	"
774OPS	774 Operations	"
ALABF	F-Area Analytical Laboratory	Savannah River
ANALYTOPS	Analytical Operations	Rocky Flats
AS-KCP	Allied Signal - Kansas City Plant	Albuquerque
CMR - LANL	Chemistry & Metallurgy Research	"
EGGMAT01	EG&G Mound Applied Technologies - Tritium Facility	"
EGGMAT02	EG&G Mound Applied Technologies - Plutonium Facility	"
ESHSUPT - LANL	Environment, Safety and Health Support	"
FBLINE	FB-Line	Savannah River
FCAN	F-Canyon	"
HBLINE	HB-Line	"
HCAN	H-Canyon	"
ICPP	Idaho Chemical Processing Plant	Idaho
LLNL	Lawrence Livermore Nat. Lab. (BOP)	San Francisco
LTA	Laboratory Technical Area	Savannah River
PFP	Plutonium Finishing Plant	Richland
PUFAB	Plutonium Fabrication Pyrochemical Operations	Rocky Flats
PUREX	PUREX	Richland
REACK	K-Reactor	Savannah River
S235	235-Puff	"
S247	Building 247-F	"
SEPGEN	Seperations General Facilities	"
SMC	Specific Manufacturing Capability	Idaho
SUPPORT	Support Services	Rocky Flats
TA55	Plutonium Processing & Handling Facility	Albuquerque
TRIT	Tritium Facility	Savannah River
TRITFACILS	Tritium Facilities, WX5	Savannah River
TSF	Tritium Salt Facility	Albuquerque
X10CHEMTEC	Chemical Technology	Oak Ridge
Y12SITE	Y-12 Site	Oak Ridge

Figure 3.7 Distribution of Ventilation-Related Occurrence Reports by Facility



Acronym	Facility Name	Field Office
FBLINE	FB-Line	Savannah River
FCAN	F-Canyon	"
HBLINE	HB-Line	"
HCAN	H-Canyon	"
LTA	Laboratory Technical Area	"
REACK	K-Reactor	"
SEPGEN	Separations General Facilities	"
S235	253-Puff	"
S247	Building 247-F	"
TRIT	Tritium Facility	"
371OPS	371 Operations	Rocky Flats
771OPS	771 Operations	"
774OPS	774 Operations	"
ANALYTOPS	Analytical Operations	"
PUFAB	Pu Fabrication Pyrochemical Ops	"
SUPPORT	Support Services	"

Figure 3.8 Ventilation-Related ORs at Savannah River and Rocky Flats

4. COMPARISON TO DOE ORDERS AND INDUSTRY STANDARDS

Since one of the primary objectives of this report is to provide guidance to those responsible for the operation or oversight of Ventilation systems, either within DOE itself, or by the site contractors outside DOE, this section of the report is devoted to consolidating those requirements and recommendations on inspection, test, and maintenance of ventilation systems and components both from existing DOE orders and from available technical information as embodied in the codes and standards with respect to ventilation systems applicable to various commercial and nuclear industries.

To facilitate this effort, the relevant information is shown at the end of this section in Table 4-1, "Comparison of DOE and Industry Standards for Ventilation System Components." Sections 4.1 and 4.2 below provide a detailed discussion of the information provided by each source.

4.1 DOE Orders and Standards

There are several DOE orders whose requirements are applicable to the design, operation, maintenance, inspection and test of ventilation systems in an overall sense. Those orders are the following:

- DOE 4330.4B, "Maintenance Management Program,"
- DOE 6430.1A, "General Design Criteria,"
- DOE 5480.5, "Safety of Nuclear Facilities,"
- DOE 5480.23, "Nuclear Safety Analysis Reports,"
- DOE 5480.22, "Technical Safety Requirements,"
- DOE 5480.19, "Conduct of Operations Requirements for DOE Facilities," and
- DOE 5700.6C, "Quality Assurance."

DOE Order 4330.4B, "Maintenance Management Program," recommends a graded approach for DOE nuclear facilities to determine the depth of detail required and the magnitude of resources to be expended for each maintenance program element described in the order. For each nuclear facility, the maintenance program must be described in a Maintenance Implementation Plan (MIP), which must address the 18 elements in the sequence and format of Chapter II.

Many of the deficiencies identified in these analyses and in the OEWS fall within the 18 elements. System-specific guidance for maintenance management is not within the scope of this order. However, there are several DOE Standards which are intended to be example guidelines for the implementation of the order and for the development of maintenance programs that are applicable to a particular facility. These standards include the following:

- DOE-STD-1050-93, "DOE Standard - Guideline to Good Practices for Planning, Scheduling, and Coordination of Maintenance at DOE Nuclear Facilities." (Ref. 19)

- DOE-STD-1051-93, "DOE Standard - Guidelines to Good Practices for Maintenance Organization and Administration at DOE Nuclear Facilities." (Ref. 20)

- DOE-STD-1052-93, "DOE Standard - Guidelines to Good Practices for Types of Maintenance Activities at DOE Nuclear Facilities." (Ref. 21)

- DOE-STD-1053-93, "DOE Standard - Guidelines to Good Practices for Control of Maintenance Activities at DOE Nuclear Facilities." (Ref. 22)

Of particular interest for improving the performance of ventilation systems is DOE-STD-1052-93, which defines Predictive Maintenance as follows:

¶ 2.13- Predictive Maintenance - Predictive maintenance activities involve continuous or periodic monitoring and diagnosis in order to forecast component degradation so that "as-needed" planned monitoring may be performed prior to SSC (structures, systems, and components) failure. Not all SSC conditions and failure modes can be monitored; therefore, predictive maintenance should be selectively applied. Reliable predictive maintenance is normally preferable to periodic internal inspection or equipment overhauls.

Further discussion is provided in § 3.4, **Guidelines**, as follows:

¶ 3.4.4 Predictive Maintenance

3.4.4.1 - ....In addition, corrective maintenance efficiency may be improved by directing repair efforts (manpower, tooling, parts) at problems detected using predictive maintenance techniques.

3.4.4.4 - Selection of Predictive Maintenance Techniques

This paragraph outlines some of the predictive maintenance techniques that may be used. The following techniques are particular useful for rotating equipment found in ventilation systems, such as fans, dampers, and motors:

- **Vibration Monitoring and Diagnostics** - These techniques are particularly useful for rotating equipment such as fans and motors. Measurements of displacement, velocity, and acceleration are analyzed to diagnose problems such as worn bearings, poor shaft alignment, or improper balance.

- **Lubricating Oil Analysis, Ferrography, and Grease Analysis** - These techniques are used to detect lubricant breakdown and abnormal wear at an early stage. They can be particularly useful again for rotating equipment such as fans and

  - **Lubricating oil analysis** monitors oil viscosity, moisture content, "additive" package content, and the presence of contaminants.

- **Ferrography** monitors the presence within the oil of metal wear products and other particulates. Trending and analyzing the amount and type of wear particles present in a machine's lubrication system may pinpoint where degradation is occurring.

- **Grease Analysis** monitors changes in the lubrication properties of grease as indicated by the color, odor, and consistency. Measurement of penetration is sometimes used to assess consistency. Grease analyses are often performed on samples obtained from motor-operated valves. For ventilation systems, such analyses could be applied to motor-operated dampers.

- **Bearing Temperature/Trending Analyses** measure and trend temperatures of machinery bearings. Increases in bearing temperature may indicate wear due to loss of lubrication, excessive vibration, or intrusion material into rotating assemblies. These analyses often are performed together with vibration monitoring and lubricating oil analysis/ferrography programs.

- **Infrared Thermography** measures the infrared radiation emitted by a source as its surface temperature varies. Infrared surveys are performed on heat-producing equipment such as motors, circuit breakers, batteries, load centers, and insulated areas to monitor for high resistance, loose connections, or insulation breakdown. For ventilation systems, this technique can be applied to the fan motors and circuit breakers, and also to the ventilation ductwork to pinpoint air leakage locations.

- **Motor-operated Valve Testing** measures and analyzes key motor-operator parameters such as running current, voltage, stem thrust, limit and torque switch set-points, and valve stroke times, and depending on the system configuration, sometimes can allow verification that the valve operates as designed under actual system conditions of temperature, flow and pressure. For ventilation systems, such testing could be applied to critical motor-operated dampers.

- **In-Leakage Detection** is based detecting the presence of helium to locate pathways for the ingress of contaminants into piping systems. For ventilation systems, it could be applied to test the integrity of ductwork and filter housings.

- **Insulation Resistance (Meggering)** is a technique to measure leakage currents in electrical insulation, thereby monitoring degradation of such insulation for motors, generators, and cables.

- **Polarization Index** is a measure of the mechanical integrity of insulation as represented by the ratio between one-minute and 10-minute readings for insulation resistances.

- **Electric Circuit Monitoring** measures the condition of an electrical circuit to aid in fault location. Basic measurements are taken such as inductance, capacitance, and resistance. Distance is measured through time domain reflectometry. Electric circuit monitoring is effective in determining the condition of electrical connections, contacts, terminations, and the location and extent of moisture damage and damage to insulation.

- **Performance Monitoring** includes measurements of such indicators as pressure, temperature or flow differentials. For ventilation systems, pressure differential is an important indicator for filters, while flow measurement is useful for monitoring fan performance.

In addition, this standard contains three appendices, E, F, and G, each of which provides an example of a procedure that implements techniques proven to be successful in selected applications. Appendix E pertains to vibration monitoring, Appendix F to lubricating oil analysis, and Appendix G to infrared monitoring (thermography).

Although not discussed specifically in DOE-STD-1052-93, it should be noted that applications of Expert Systems and/or Neural Networks are increasing in industry. Such applications may be particularly useful when combined with predictive maintenance techniques. The process of building an expert system has been described as knowledge engineering. This process typically involves a special form of interaction between the expert-system builder, called the knowledge engineer, and one or more human experts in some problem area. The knowledge engineer "extracts" from the human experts their procedures, strategies, and rules of thumb for problem solving, and builds this knowledge into the expert system. The result is a computer program that solves problems in much the same way as the human experts. (Ref. 23)

Neural networks are computer-based simulations of living nervous systems, which work very differently from conventional computing systems. Neural networks are more closely related to parallel processing systems than to the sequential processing systems of conventional processing systems. They are sometimes referred to as massively parallel processors. Neural networks are both a rival and a companion to expert systems. The former are good at recognizing patters very quickly, and essentially are self-organizing and self-programming like the human brain.

A good example of an application of a neural network is as a blower motor checker. Siemens, the German electrical equipment maker, tried to detect noisy blower motors for car heaters by having people listen to all of the motors. However, the people became tired and bored. Conventional approaches did not have much more success than using people. By applying a neural network to check all blower motors, they have achieved a greater than 90% accuracy in detecting the noisy motors. (Ref. 24)

Failures of ventilation system components at the DOE DP facilities due to both equipment malfunctions and human errors have been identified previously in Section 3. Therefore, it may be useful to apply, at least on a trial basis, some combination of predictive maintenance techniques with either an expert system or a neural network, or both, at a selected facility to determine if significant improvement in system performance can be realized.

Table 4-1 Comparison of DOE and Industry Standards for Ventilation System Components

COMPONENT	DOE ORDER 6430.1A	NFPA 801	NRC R.G. 1.52	ASME N509	ASME N510	NFPA 90A	NFPA 45A	AIHA Z9.5	ACGIH INDUSTRIAL VENTILATION
Air Sampling Device								§4.13.5.2 IST @ ≤1 mo. per experience or mfr. recommendation. Include sensing element, zero drift, signals, alarms, controls.	
Air Pollution Control Equipment								§4.14.4 ISI @ ≤1 wk. as required. Tests & repairs per mfr. recommendations or regulations.	
Filters:						B-3.1 Renew or clean @ 2× original ΔP or per mfr. recommendation.		§4.14.2 All air filters to have ΔP gauges, which to be read @ 1 wk., or other interval based on experience. If ΔP ≥ rated max., change filter at first opportunity. Recirc. air filters ISI/IST per §4.12.3.1, i.e. Inst. for Env. Sci. "Rec. Pract. for Laminar Flow Clean Air Devices", except provisions are mandatory.	
-HEPA	§1550-2.5.5 IST per UL 586, ASME N510, ERDA 76-21; Filter assemblies to comply with ASME N509			§4.1 - Minimum efficiency 99.97% for 0.3 µm diam. particles. Table 9-1 & §5.6.5.2 Visual inspection.	Table 1 & §5 - Visually inspect before each test series. Table 1 & §8 Airflow distribution test across each filter bank to verify uniform flow @ design flow rates, at acceptance and surveillance. Table 1 & §10 In-place leak test at acceptance & after each adsorber replacement & ≥ once/ operating cycle. Table 1 & §9 Air-aerosol mixing uniformity test (Dioctyl phthalate DOP test) to verify uniform mixing in flow upstream of HEPA filter bank to be			§4.12.3.2 alarm when ΔP of primary or secondary filter ≥0.1 in. WG than rated loaded ΔP.	

Table 4-1 (Cont'd)

COMPONENT	DOE ORDER 6430.1A	NFPA 801	NRC R.G. 1.52	ASME N509	ASME N510	NFPA 90A	NFPA 45A	AIHA Z9.5	ACGIH INDUSTRIAL VENTILATION
–Absorption					Table 1 & §8 - Airflow distribution test across each adsorber bank to verify uniform flow @ design flow rates, at acceptance and surveillance. Table 1 & §8 - Air-aerosol mixing uniformity test (Dioctyl phthalate DOP test) to verify uniform mixing in flow upstream of adsorber bank to be tested, after installation or any major modification or repair. Table 1 & §11 - In-place leak test at acceptance & after each adsorber replacement & ≥ once/operating cycle.			Panel or cartridge adsorbers to be installed in series & IST of space between sampled periodically based on experience OR IST of samples @ time intervals from experience as per §4.12.4.1.	
–Carbon Bed Adsorbers				§4.1 - Required for removal of iodine and iodine compounds.	Same as above.			§4.12.4.1 IST of samples @ time intervals from experience. §4.14.3 recirc. adsorbers tested per §4.12.4 @ ≤1 mo. per experience.	
–Sand									
–Glass Fiber									
–Prefilter				§5.3.1 - Rating 45% avg. atmospheric dust-spot eff. per ASHRAE Std. 52. Airflow capacity ≥ HEPA filter of same filter frame face area.					
–Postfilter				§5.3.1 - Rating 95% avg. atmospheric dust-spot eff. per ASHRAE Std. 52. Airflow capacity ≥ HEPA filter of same filter frame face area.					

Table 4-1 (Cont'd)

COMPONENT	DOE ORDER 6430.1A	NFPA 801	NRC R.G. 1.52	ASME N509	ASME N510	NFPA 90A	NFPA 45A	AIHA Z9.5	ACGIH INDUSTRIAL VENTILATION
–Automatic Filter Electrical Equipment, Drive Motors, Gear Reductions						B-3.5 ISI @ 6 mos.			
Scrubber									
Demister or Moisture Separator				§4.1 - Required when entrained water droplet conc. may be >1 lbm water/1000 CFM air-flow.					
Mounting Frame				Table 9-1 & §4.6.4 test pressure(s) & tolerance. §5.6.5.3 Shop test of each HEPA and adsorber frame leakage ≤0.1% of rated flow.	Table 1 & §7 - Optional pressure leak test as part of total bank leakage during HEPA filter bank and adsorber bank in-place leak tests				
Process Vessel Vent System									
Condenser									
Distribution Baffle									
Duct					Table 1 & §6 - leak test and structural capability test after installation or any major modification or repair.	B-4.1 ISI @ 3 mos. or increase interval to suit conditions. Clean as required.			
Duct Damper Bypass									
Housing					Table 1 & §6 - leak test after installation or any major modification or repair and at least once every 10 years.				
Plenum						B-5.1 ISI @ 1 mo. or increase interval to suit conditions. Clean as required.			
Outside Air Intake						B-6.1 Conditions at outside of air intake to be inspected during ISI of ducts.			

Table 4-1 (Cont'd)

COMPONENT	DOE ORDER 6430.1A	NFPA 801	NRC R.G. 1.52	ASME N509	ASME N510	NFPA 90A	NFPA 45A	AIHA Z9.5	ACGIH INDUSTRIAL VENTILATION
Fire Suppression System		§2-5 ISI, IST, PM per NFPA codes					§6-14.6 ISI fixed extinguishing systems protecting filters @ 3 mos. Clean nozzles as required.		
Fire Damper		§2-5 ISI, IST, PM per NFPA codes				B-2 ISI @ 2 yrs.		§4.14.1.4 NOT used in laboratory hood exhaust systems per NFPA 45.	
Ceiling Damper						B-2 ISI @ 2 yrs.			
Smoke Damper		§2-5 ISI, IST, PM per NFPA codes				B-2 ISI @ 2 yrs.			
Tornado Damper									
Emergency Bypass Damper								§4.14.1.1 test by control signal and observe damper movement for full range of design operation.	
Other Dampers								§4.14.1.2 ISI damper, drive linkage, actuator visually. Operate actuator enough to observe proper movement.	
Exhaust Stack									
Fans/Blowers/Motors/ Controls	§1300-3.5 locate in uncontaminated area; §1550-2.5 specific fan requirements				Table 1 & §8 - Airflow capacity test to verify that design airflow can be achieved with fan as furnished, under actual field conditions at max. & min. filter ΔP, at installation & after any major modification or repair.	B-7.1 ISI fans/motors @ 3 mos. Clean/ lubricate as required. B-8.1 Fan controls ISI/IST @ 1 yr. B-8.2 Auto shutdown devices IST @ 1 yr.	§6-14.5 ISI fans/motors/ components @ 1 yr. ISI fan belts @ 3 mos. when no air flow detectors provided or no air flow tests performed. ISI double sheaves & belts @ 6 mos.	§4.14.7 §4.14.7.1 - ISI visually @ 1 per wk.: abnormal noise/ vibration, bearing noise, motor high temp., lubricant leakage, etc. §4.14.7.2 - V-belt drives stopped and inspected @ 1 per mo.: belt tension, belt wear or cracking. §4.14.7.3 - Blowers, drives, other critical machine elements to be lubricated at intervals and with lubricants per mfr. recommendations.	§6.4.2 Bearings for proper operating temperature (greasing on established schedule). Ex.essive vibration of bearings or housing. Belt drives for proper tension and minimum wear. Correct coupling alignment. Fan impeller for proper alignment and rotation. Impeller free from excess wear or material accumulation.
Coils					Table 1 & §14 - Air heater performance test at ≥ once/operating cycle.	B-4.3 Clean as required when ducts are cleaned.			

Table 4-1 (Cont'd)

COMPONENT	DOE ORDER 6430.1A	NFPA 801	NRC R.G. 1.52	ASME N509	ASME N510	NFPA 90A	NFPA 45A	AIHA Z9.5	ACGIH INDUSTRIAL VENTILATION
Heat Removal System									
Instrumentation:									
-Pressure Transmitters/Alarms								§4.13.5.1 instrumentation & measurement per ANSI/ ASHRAE 41.3. Calibration ≤6 mos. before use, or any potential damage, since last calibration. Accuracy for 0.1 in. WG = 10%; 0.5 in. WG = 5%.	
-Velocity Transmitters/Alarms								§4.13.5.1 accuracy for 50 FPM = 10%; ≥100 FPM = 5%.	
-Temperature Transmitters/Alarms								§4.13.5.1 instrumentation & measurement per ANSI/ ASHRAE 41.1. Calibration ≤6 mos. before use, or any potential damage, since last calibration. §4.14.7.6 - For critical service equipment ≥100 HP, temperature sensors should be considered.	
-Flow Transmitters/ Alarms							§6-14.1 ISI/IST air flow indicators/alarms @ installation/modification & @ 1 yr. intervals. §6-14.3 IST lab hood face velocity profile or exhaust air quantity @ any adjustment to ventilation balance.		
-Vibration Monitors								§4.14.7.6 - For critical service equipment ≥100 HP, vibration sensors should be considered.	
-Radiation Monitor									
-Critically Safe Drain System									

Although all of the DOE orders mentioned apply to ventilation systems, the order which contains the most specific requirements for ventilation systems and is therefore the most relevant to the operation of building ventilation systems is DOE Order 6430.1A.

DOE Order 6430.1A, "General Design Criteria," as its name implies, provides general design criteria for the acquisition of DOE facilities and establishes responsibility and authority for the development and maintenance of those criteria. This order references numerous industry standards for design bases, and provides some guidance on maintenance, including surveillance, inspection, and test requirements.

In particular, Division 11, "Equipment," ¶ 1160, "Enclosures," § 1161-1, "General Considerations," defines **enclosures** as physical barriers, such as cubicles, gloveboxes, fume hoods, or conveyor tunnels that, together with their ventilation and operating systems, prevent the release of radioactive or other hazardous material into the work space or the environment. Accordingly, their structural and confinement integrity shall be primary design consideration. Unless more specific guidance is provided to the design professional on the location, size, fume composition, and operating schedule for enclosures, the primary reference source shall be the ACGIH Industrial Ventilation Manual.

In § 1161-4, "Ventilation," the detailed design requirements for enclosures are specified, such as that the ventilation system shall maintain a minimum negative differential pressure of 0.3 in. W.C. inside the enclosure (except open-face hoods) compared to the operating area, and that perchloric-acid fume exhaust systems shall comply with NFPA 45, Chapter 6 (Ref. 25).

Safety class items of the ventilation system shall be supplied with emergency power. The system shall be designed to automatically ensure inflow of air through a credible breach in the enclosure system. Minimum inward air velocity shall be 125 ± 25 linear ft/min, or as determined from guidance provided in the ACGIH Industrial Ventilation Manual. Other requirements pertain to the location of HEPA filters, minimizing the spread of fire, overpressurization protection, and specific requirements concerning hoods.

Division 13, "Special Facilities," ¶ 1300, "General Requirements," specifies that the criteria in Division 13 apply to all non-reactor nuclear facilities and to explosives facilities and that reactors and their safety systems shall be sited and designed according to DOE Order 5480.6 (Ref. 26).

Special facilities include:

- Non-reactor nuclear facilities
- Plutonium processing and handling facilities
- Plutonium storage facilities
- Uranium processing and handling facilities
- Uranium enrichment facilities
- Un-irradiated enriched uranium storage facilities
- Uranium conversion and recovery facilities
- Irradiated fissile material storage facilities
- Reprocessing facilities

- Tritium facilities
- Fusion facilities
- Explosives facilities
- Laboratory facilities (including hot laboratories)
- Radioactive solid waste facilities
- Radioactive liquid waste facilities

Other special facilities are emergency preparedness facilities, occupational health facilities, communications stations, document storage vaults and rooms, and secure offices and conference rooms.

§ 1300-3, "Safety Class Criteria," specifies the following for maintenance and testing of special facilities:

1300-3.5 Maintenance

"The design shall consider the maintainability factors peculiar to the specific equipment to be used in the facility. Facility design shall provide for routine maintenance, repair, or replacement of equipment subject to failure.

Safety class items shall be designed to allow inspection, maintenance, and testing to ensure their continued functioning, readiness for operation, and accuracy. **Ancillary equipment, such as pumps, blowers, motors, compressors, gear trains, and controls, shall be located in an area least likely to be contaminated.**

The design of equipment that must be located within confinement systems shall allow for in place maintenance or replacement.

The capability shall be provided for the maintenance of contaminated equipment that cannot be repaired in place. This capability shall include the necessary provisions for confinement, ventilation, and waste control.

The design of all process equipment shall include features to minimize self-contamination of the equipment, piping, and confinement areas. The design of process equipment shall also include features to minimize the spread of contamination out of local areas.

1300-3.6 Testing

The design shall include provisions for periodic testing of monitoring, surveillance, and alarm systems. In addition, the design shall provide the capability to test periodically, under simulated emergency conditions, safety class items that are required to function under emergency conditions.

All systems for which credit is taken to meet the criteria of Section 1300-1.4.2, Accidental Releases, shall be in-place testable in terms of pressure, filtration or removal efficiency, alarm capability, leak resistance, and the like. Safety class items shall be designed to be testable on a regular schedule.

The facility design shall allow for routine in-place testing of HEPA filtration systems as outlined by ASME N510 (Ref. 27)."

The DOE Order goes on to specify the objectives of Confinement Systems in 1300-7:

1300-7 CONFINEMENT SYSTEMS

1300-7.1

Confinement systems shall accomplish the following:

- Minimize the spread of radioactive and other hazardous materials within unoccupied process areas
- Prevent, if possible, or else minimize the spread of radioactive and other hazardous materials to occupied areas
- Minimize the release of radioactive and other hazardous materials in facility effluents during normal operation and anticipated operational occurrences
- Limit the release of radioactive and other hazardous materials resulting from DBAs,including severe natural phenomena and man-made events in compliance with the guidelines contained in Section 1300-1.4.2, Accidental Releases

1300-7.2 General

Confinement capabilities, including confinement barriers and associated ventilation systems, shall maintain a controlled, continuous airflow pattern from the environment into the confinement building, and then from non-contaminated areas of the building to potentially contaminated areas, and then to normally contaminated areas...."

The order continues with some general prescriptions for confinement systems regarding design basis accidents (DBAs),and then states that:

"Because the number and arrangement of confinement systems that shall be required for a specific nuclear facility design cannot be predicted, these general criteria describe a conservative confinement design that uses three principal confinement systems. In general, the primary confinement system consists of the process enclosures and their ventilation system. In special cases where the processes require the use of corrosive or noxious materials, the process system

shall be totally enclosed (i.e. pipes and vessels) and provided with its own ventilation and off-gas cleanup system. In such cases, the process system shall be treated as the primary confinement system. The secondary confinement system consists of the barriers that enclose the areas that house the primary confinement and the system that ventilates those areas. These areas may be referred to as operating areas or operating area compartments. The tertiary or final confinement system is the building structure and its ventilation system...."

The remainder of the 1300 section gives the specific requirements for confinement systems for each of the special facilities such as Plutonium Processing and Handling Facilities, Uranium Processing and Handling Facilities, Tritium Facilities, and other facilities.

For example, for a plutonium storage facility (PSF), under general requirements for confinement systems, § 1305-5.1 specifies that exhaust ventilation systems shall be provided with HEPA filtration to minimize the release of plutonium and other hazardous material through the exhaust path. In addition, inlet ventilation systems also shall be provided with either HEPA filtration or fail-safe backflow prevention to minimize the release of plutonium and other hazardous material through the inlet path.

Other requirements are specified in Section 1550, "Heating, Ventilating and Air-Conditioning Systems," such as in § 1550-2.5, "Air Handling and Air Distribution Systems." For example, ¶ 1550-2.5-3, "Fans/Motors," specifies that:

"Fans shall be designed and specified to assure stable, non-pulsing aerodynamic operation in the range of operation over varying speeds. Air handling units and fans in sizes over 1 HP shall use belt drives. Fans with motors of 10 HP or less shall be designed with adjustable motor pulley sheaves to assist in air balancing of systems. Fans with motors greater than 10 HP shall use fixed (non-adjustable) drives that can be adjusted by substituting fixed motor pulley sheaves of different diameters. Supply air handling units and return air fans in variable-air-volume systems shall control capacity through the use of variable-speed drives, inlet vanes, or scroll bypass dampers. All fans shall comply with AMCA Standard 210 (Ref. 28), ASHRAE Standard 51 (Ref. 29), and ASHRAE Equipment Handbook (Ref. 30).

Fans shall be located within the ductwork system according to the requirements of AMCA Publication 201 (Ref. 16) and ACGIH Industrial Ventilation Manual. The design professional shall consider the use of variable-speed drives on fans in variable-air-volume systems where the supply fans are larger than 5 BHP. Motors shall be sized according to properly calculated BHP fan requirements and shall not use oversized fans and motors to meet future capacity needs unless so directed by DOE project criteria.

The design professional shall consider the selection of fan construction materials based on corrosion resistance and cost. Spark-resistant construction

shall be used where required by NFPA. All fans and accessories shall be designed and specified to meet all smoke and flame spread requirements of NFPA 255 (Ref. 32)."

Other components under this section include air-handling units, coils, air cleaning devices, such as HEPA filters and fire protection for such filters, filters for air handling systems serving inhabited spaces, air-cleaning devices for special applications, such as for heavy dust loadings or nuclear or toxic applications, and ductwork systems.

The general requirements for air-cleaning devices are specified in § 1550-2.5.5:

"Air cleaning equipment for ductwork installation shall be **easily removable, serviceable, and maintainable.** Air cleaning equipment shall have face velocities as recommended by the filter manufacturer and the design manuals recommended above to achieve maximum efficiency and pressure drop...."

"High-Efficiency Particulate Air Filters"

HEPA filter assemblies shall comply with ASME N509 (Ref. 33).

HEPA filtration systems shall be used to minimize the release of particulate contaminants such as carcinogens, infectious agents, radioisotopes, or highly toxic materials when determined by safety analysis to be necessary.

The design professional shall design for a location that facilitates in-place testing of HEPA filters, with particular attention given to plenum hardware provisions that allow for testing of the HEPA filter bank without requiring the testing personnel to enter the plenum. Utility services shall be extended to the plenum location (e.g., electrical receptacles and compressed air) to facilitate testing work. In-place testing design requirements shall meet all the recommendations of UL 586, ASME N510, and ERDA 76-21 (Ref. 34). HEPA filtration systems shall be designed with pre-filters installed upstream of HEPA filters to extend the HEPA filter's life. The design professional may eliminate the installation of pre-filters if an analysis of filtration requirements and consideration of the filter assembly justifies omission."

Section 1550-3, "Testing, Adjusting and Balancing," discusses the requirements for performance tests of the mechanical air distribution and HVAC water distribution systems the associated testing and balancing devices. In particular, § 1550-3.2 specifies that:

"HVAC air and water distribution systems shall be provided with permanently installed calibrated testing and balancing devices and access as needed to accurately measure and adjust water flows or air flows, pressures, or temperatures as required. The design professional shall provide as a minimum the balancing devices in Table 1550-3.2a and Table 1550-3.2b. Test devices shall be located and installed according to AABC Volume A-82 (Ref. 35)."

Section 1550-99, "Special Facilities," § 1550-99.0, "Non-reactor Nuclear Facilities-General," sets out the specific requirements for the non-reactor nuclear facilities described above. This section has many of the same requirements for confinement ventilation systems described for Division 13, Section 1300 which were discussed previously.

The above discussion shows that requirements for ventilation systems appear in several different sections of DOE Order 3460.1A and, in some cases, what appears in one section may be more restrictive in another section. For example, concerning HEPA filters, § 1300-3.6 on testing specifies that:

> **"The facility design shall allow for routine in-place testing of HEPA filtration systems as outlined by ASME N510."** (See Ref. 27).

While § 1550-2.5.5 states that:

> **"In-place testing design requirements shall meet all the recommendations of UL 586, ASME N510, and ERDA 76-21."** (See Refs. 12, 27 & 34)

In any case, requirements for maintenance and test are specified for the major portions of confinement ventilation systems, such as HEPA filters and fans and blowers.

4.2 Industry Standards

Standards for ventilation systems are published by several different professional organizations. For the DOE DP facilities in question, the following are the most appropriate standards:

1. NFPA 801, "Recommended Fire Protection Practice for Facilities Handling Radioactive Materials," - 1991 Edition. (Ref. 36).

2. NFPA 802, "Recommended Fire Protection Practice for Nuclear Research Reactors," - 1988 Edition. (Ref. 37).

3. NFPA 803, "Recommended Fire Protection Practice for Light Water Nuclear Power Plants," - 1988 Edition. (Ref. 38).

4. NFPA 45, "Standard on Fire Protection for Laboratories Using Chemicals," - 1991 Edition. (Ref. 25).

5. ANSI/ASHRAE 62-1989, "Ventilation for Acceptable Indoor Air Quality," including ANSI/ASHRAE Addendum 62a-1990. (Ref. 39).

6. ANSI/AIHA Z9.5-1992, "American National Standard for Laboratory Ventilation." (Ref. 40).

4.2.1 NFPA 801

NFPA 801 Chapter 5 is dedicated to "Special Radiation Facilities and Equipment." Such facilities include hospitals, fuel-fabrication facilities, fuel-reprocessing facilities, hot cells, glove boxes, hoods, and caves, and also laboratories, ovens, and furnaces. NFPA 801 Section 3.9 "Heating, Ventilating, and Air Conditioning," states that ventilation of a nuclear facility involves balanced air differentials between building areas, comfort ventilation, and heat removal from areas where the equipment generates heat. This also includes fire area isolation and smoke removal equipment, as well as equipment for filtering radioactive gases. The ventilation system should be arranged such that the area containing dispersable radioactive materials remains at an air (or other atmosphere) pressure less than adjoining areas of the facility before and during any fire incident, including during and following any actuation of fire protection systems.

NFPA 801 goes on to specify that the ventilation should be designed in accordance with the following standards:

- NFPA 90A, "Standard for the Installation of Air Conditioning and Ventilating Systems." (Ref. 41).
- NFPA 90B, "Standard for the Installation of Warm Air Heating and Air Conditioning Systems." (Ref. 42).
- NFPA 91, "Standard for Exhaust Systems for Air Conveying of Materials." (Ref. 43).
- NFPA 204M, "Guide for Smoke and Heat Venting." (Ref. 44).

With respect to testing, inspection, and maintenance, NFPA 801 Section 2-5, specifies that:

- Upon installation, all fire protection systems should be inspected and tested in accordance with the applicable National Fire Codes.
- All fire protection systems and equipment should be periodically inspected, tested, and maintained in accordance with the applicable National Fire Codes.
- Tests, inspections, and maintenance should be documented, recording written procedures, results, and follow-up actions. Specific acceptance criteria should be provided for each operation.

There are no direct requirements for testing, inspecting, and maintaining of ventilation systems in NFPA 801. However, other NFPA standards and the standards of other professional societies do suggest or require specific maintenance programs, which include the test and inspection intervals for particular components. Table 6-1 compares the various requirements from each applicable standard.

4.2.2 NFPA 90A

Appendix B of NFPA 90A is entirely devoted to maintenance (see Ref. 41). This appendix is not part of the NFPA document but was included for information only. In view of the importance of maintenance to the safe, reliable operation of the ventilation systems, the appendix from NFPA 90A[1] is included in this report. Relevant portions of the NFPA Appendix B pertaining to test, inspection, and maintenance intervals are highlighted:

B-1 General

B-1.1 Beyond the scope of this standard lies the important responsibility for the maintenance of equipment. This includes periodic checks of the detection and control equipment, damper and motor operation, and cleaning of ducts, plenums, dampers, and filters. **Owners should develop a greater awareness of the life and property protecting abilities of these systems and establish a planned maintenance schedule.**

Failure to maintain proper conditions of cleanliness in air duct systems and carelessness in connection with repair operations have been important contributing causes of several fires which have involved air conditioning systems. The following recommendations apply, in general, to the period of operation of the system; systems operating only part of the year should be given a thorough general checkup before starting operation and again after shutting down.

B-1.2 The interval of testing and maintenance will vary widely depending on duration of system operation, condition of fresh air, amount of dust in return air, and other factors. The intervals given in this standard are intended to be maximum and should be shortened if system conditions warrant.

B-1.3 Inspection Form. The use of an inspection form to assist in obtaining a thorough inspection is recommended. The form should be made up to fit the system or systems involved, listing the items needing attention. However, it is suggested that provision be made on the form for equipment location, **inspection frequency, due date, inspection date,** inspector, and record of discrepancies found.

B-2 Fire Dampers, Smoke Dampers, and Ceiling Dampers.

Each damper should be examined **every two years** to see that it is not rusted or blocked, giving attention to hinges or other moving parts. Remove fusible links (where applicable), operate damper to verify that it fully closes, check latch (if provided), and

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lubricate moving parts if necessary. It is desirable to operate dampers with normal system airflow to assure that they are not held open by the air stream.

B-3 Filters.

B-3.1 All air filters should be kept free of excess dust and combustible material. **Unit filters should be renewed or cleaned when the resistance to air flow has increased to two times the original resistance or when the resistance has reached a value of recommended replacement by the manufacturer.** Provide a suitable draft gauge for the purpose. If the filters are of the automatic liquid adhesive type, sludge should be regularly removed from the liquid adhesive reservoir.

B-3.2 When renewing filters, care must be taken to use proper type and size and to avoid gaps between filter sections, mounting frames, or hardware. Damaged filter sections or media should not be used.

B-3.3 Filters designed and manufactured to be thrown away after use should never be cleaned and reused.

B-3.4 Care should be exercised in the use of liquid adhesives. Use of an adhesive of low flash point would create a serious hazard.

B-3.5 Electrical equipment of automatic filters should be inspected **semiannually**, observing the operation cycle to see that the motor, relays, and other controls function as intended. Drive motors and gear reductions should also be inspected at least **semiannually**, and lubricated when necessary.

B-4 Inspection and Cleaning of Ducts.

B-4.1 Inspections to determine the amount of dust and waste material in the ducts (both discharge and return) should be made **quarterly**, except that if after several inspections such frequent inspection is found unnecessary, the interval between inspections may be adjusted to suit the conditions.

B-4.2 Cleaning should be undertaken whenever inspection indicates the need.

B-4.3 Cooling and heating coils should be cleaned, if necessary, at the time of cleaning the ducts. Thorough cleaning of ducts may require scraping, brushing, or other positive means. Vacuum cleaning may not remove dust of an oily or sticky nature, or heavy accumulations in the elbows or seams. The amount and kind of dust and dirt will depend greatly on the occupancy and the arrangement of the duct system. Additional access doors or panels may be required for complete cleaning of duct systems.

B-5 Inspection and Cleaning of Plenums.

B-5.1 Apparatus casing and air handling unit plenums should be inspected **monthly**, except that if after several inspections such frequent inspection is found unnecessary, the interval between inspections may be adjusted to suit the conditions.

B-5.2 Ceiling cavity, raised floor, and duct distribution plenums should be inspected similar to ducts, beginning with **quarterly** inspections and adjusting frequency to suit dirt buildup conditions.

B-5.3 Cleaning should be undertaken whenever inspection indicates the need, especially in common plenums serving more than one fan or system. Where plenum chambers being used for storage are found, arrangements, such as keeping the doors locked, should be made to prevent such usage.

B-5.4 Repair Work.
Great caution should be exercised in the use of open flames or spark emitting devices inside of ducts or plenum chambers, or near air intakes.

B-6 Outside Air Intakes.

B-6.1 Conditions outside the outside air intake should be examined at the time of inspection of the ducts. Items to be noted are: (a) accumulations of combustible material near the intake, (b) presence of buildings or structures which may present an exposure to the intake allowing smoke and fire to be drawn in, and (c) operating condition of any automatic damper designed to protect the opening against exposure fire.

B-6.2 If accumulations of combustible material are noted, they should be **immediately** removed, and arrangements made to avoid such accumulations. Inspections should thereafter be made more frequently. If newly erected exposures are noticed, consideration should be given to the protection at the intake to see that it is adequate.

B-7 Fans and Fan Motors.

B-7.1 Fans and fan motors should be inspected at least quarterly, and cleaned and lubricated when necessary. Care should be exercised in lubricating fans to avoid allowing lubricant to run onto the fan blades. Fans should also be checked for alignment, and to see that they are running freely.

B-7.2 The alignment of fan belt drives should be checked since improper alignment can cause motor overheating as well as premature belt failure.

B-8 Controls.

B-8.1 Fan controls should be examined and activated **at least once a year** to assure that they are in operable condition.

B-8.2 All automatic shutdown devices should be tested **at least once a year.** Special care should be given to smoke sensing devices and fittings to assure that they are clean and properly calibrated in accordance with manufacturer's instructions.

4.2.3 NFPA 45[2]

NFPA 45, Chapter 6, is dedicated to Laboratory Ventilating Systems and Hood Requirements. Section 6-14, Inspection, Testing, and Maintenance, specifies the following:

6-14.1 Laboratory hoods, laboratory hood exhaust systems, and laboratory special exhaust systems shall be inspected and tested. When installed or modified and **at least annually thereafter,**. The following inspections and tests, as applicable, shall be made:

a) Visual inspection of the physical condition of the hood interior, sash, and ductwork;

b) Airflow indicator systems;

c) Low airflow and loss-of-airflow alarms at each alarm location;

d) Face velocity;

e) Verification of inward airflow over the entire hood face;

f) Changes in work area conditions that may affect hood performance.

6-14.2 Deficiencies in hood performance shall be corrected or:

a) The activity within the hood shall be restricted to the capability of the hoods; or

b) The hood shall not be used.

6-14.3 Laboratory hood face velocity profile or exhaust air quantity shall be checked after any adjustment to the ventilation balance.

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6-14.4 Detectors and Alarms

Air system flow detectors, if installed, shall be inspected and tested **annually**. Where potentially corrosive or obstructive conditions exist, the inspection and test frequency shall be increased appropriately.

6-14.5 Fans and Motors

6-14.5.1 Air supply and exhaust fans, motors, and components shall be inspected at least **annually**.

6-14.5.2 When airflow detectors are not provided or airflow-rate tests are not made, fan belts shall be inspected **quarterly**. Frayed or broken belts shall be replaced promptly. When double sheaves and belts are employed, the inspection frequency shall be permitted to be **semi-annual**.

6-14.6 Fixed fire extinguishing systems protecting filters shall be inspected **quarterly** for accumulation of deposits on nozzles. Nozzles shall be cleaned as necessary.

4.2.4 ANSI/ASHRAE 62-1989 and ANSI/AIAA Z9.5-1992

Two other industry standards are significant for building ventilation systems:

- ANSI/ASHRAE 62-1989 (including ANSI/ASHRAE addendum 62a-1990) "An American National Standard - Ventilation for Acceptable Indoor Air Quality."
- ANSI/AIHA Z9.5-1992 "American National Standard for Laboratory Ventilation."

ANSI/ASHRAE 62-1989, published by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, applies to the environmental acceptability of indoor air and does not deal specifically with ventilation systems or components. It does not have any information about inspection, testing, or maintenance of building ventilation systems.

ANSI/AIHA Z9.5-1992, published by the American Industrial Hygiene Association, is a relatively new standard which specifies requirements for ventilation systems and components including inspection, tests, and maintenance. As noted in its Foreword, the standard was developed to provide one comprehensive set of guidelines for laboratory ventilation. Originally, some standards and guidelines addressed specific topics of laboratory ventilation (such as fume hoods), but there was no single standard presenting most of the common issues. Because of the wide variety of laboratory types and diversity of operations, developing a single set of requirements for laboratory ventilation was a monumental task, taking eight years trying to address the major issues confronting the design of laboratory ventilation. A substantial effort was made to obtain input from an array of laboratory users, equipment manufacturers, designers, engineers, and health and safety professionals.

Although the standard specifies some exact requirements, it is mainly intended to give users enough information to make appropriate decisions for a specific application. The requirements are considered the minimum necessary to ensure worker safety. The guidelines are considered suitable for adoption by any laboratory user of ventilation equipment in the private or public sector.

While the standard does not apply to animal laboratories, explosives laboratories, radioisotope laboratories, laminar flow hoods (not for employee protection), or biological safety cabinets, has some useful requirements generally applicable to inspection, tests, and maintenance of ventilation systems. In view of the recent issue date, September 15, 1992, of the final version, and the general applicability to all types of ventilation systems, some significant portions are presented here.

Of particular interest is Section 4.11.4, "Differential Pressure and Airflow Between Rooms," which states, in part, that:

> ".... although it is true a difference in pressure is the driving force that causes air to flow through any openings from one room to another, specifying quantitative pressure differential is poor basis for design. What really is desired is an airflow velocity (usually 50 to 100 fpm) through any openings; and some openings such as doors are frequently, but not always, open. Therefore, serious attempts to maintain the specified pressure differential require very complex fast-acting and expensive controls. Attempts to design for pressure differential without such controls result either in loss of the pressure differential when doors are open or excessive pressure differentials when doors are closed, sufficient to affect the performance of low pressure fans."

It is useful to note Section 4.12.3, "Filtration for Recirculation," which states that filtration systems for recirculating exhaust air contaminated with toxic particulates shall be filtered through a series of two types of filters:

- a primary high-efficiency filter (85-95% as per ASHRAE Standard 52 {Ref. 45}), followed by

- a high-efficiency particulate filter (HEPA) of 99.97% efficiency for 0.3 micron diameter droplets of dioctylphalate.

Sub-section 4.12.3.1, "HEPA Filter Installation," states that HEPA filters should be tested for leaks (see the Institute of Environmental Science's Recommended Practice for Laminar Flow Clean Air Devices {Ref. 46}) and all leaks repaired or the filter replaced before use.

Sub-section 4.12.3.2, "Filter Assembly Controls," states that the filter assembly should be provided with a damper and instruments and controls that:

- indicate the static pressure differential separately across the primary and secondary filters and the pressure differential across both filters and the damper;

- actuate a damper motor to open the damper from its initial partially closed position when filters are clean, to a full-open position when the filters are fully loaded;

- actuate a signal or alarm when the pressure drop across either the primary or secondary filter reaches 0.1 in. W.G. more than the rated loaded pressure drop.

Also of interest is Sub-section 4.12.4, "Activated Carbon 'Filters'," which states the following:

> "Pellets of activated carbon are available in a number of configurations, some thin panels that resemble filters. Activated carbon may be used in panel form, or as hollow cylinders, or loose in a deep bed. An important characteristic of carbon is that upstream layers become saturated so that downstream layers perform the adsorption function, with the result that "breakthrough" of unabsorbed gas occurs rather quickly without gradual reduction of adsorption efficiency. Production of breakthrough in deep beds can be accomplished by periodic withdrawal of samples from incremental depths of the bed, but this is impractical in the shallow beds used in panels or in cylindrical cartridges. Saturation of active adsorption sites occurs progressively through the layer of carbon and depends on the burden of adsorbate, which typically is variable. Therefore, breakthrough of contaminant on the downstream side of the carbon layer is difficult to predict."

To address the problem of breakthrough, the standard specifies the following:

4.12.4.1 Deep Bed Carbon Absorbers

Deep bed absorbers shall be monitored in one of two ways:

- A reliable and adequately sensitive monitoring instrument shall be installed downstream of the carbon bed. The monitor shall be furnished with a signal or alarm to indicate breakthrough, and shall immediately actuate the bypass damper to atmosphere or to an installed parallel bed that has been regenerated. The sensitivity of the monitoring system shall be a predetermined fraction of the threshold limit value (TLV®) of the contaminant(s) being adsorbed.

- Sampling tubes into the bed shall be furnished at intervals not longer than one-fifth of the bed depth. **Samples shall be withdrawn, at time intervals based on experience, and analyzed to detect presence of contaminants.** When contaminants are detected at the downstream port, the air stream shall be directed to an installed parallel bed that has been regenerated, or to atmosphere.

4.12.4.2 Panel and Cartridge Absorbers

Panel or cartridge absorbers shall be monitored in one of two ways:

- A monitoring instrument should be used as described in 4.12.4.1;
- Two sets of panels or cartridges shall be installed in series. One is the working or upstream filter, which is to be physically separated from the downstream backup filter. **The space between them shall be sampled periodically at intervals based on experience.** When breakthrough is detected on the upstream unit, the system shall be placed on bypass or shut down, and the unit replaced. The sensitivity of the detection method used shall be a predetermined fraction of the TLV of the contaminant(s) being adsorbed. The upstream unit may be removed and replaced with the downstream unit, and a new unit installed downstream.

For comparison, particularly to NFPA 90A Appendix B pertaining to maintenance, ANSI/AIHA Z9.5-1992, Sub-sections 4.13 on Preventive Maintenance and 4.14 on Testing and Monitoring are presented below:

4.13 Preventive Maintenance

Preventive maintenance shall be performed on a **regularly scheduled basis.**

4.13.1 Operations During Maintenance Shutdown

Operations served by equipment being shut down for inspection or maintenance should be discontinued and secured during such maintenance.
NOTE: "Secured" condition will vary from case to case. It might consist of ceasing operation, or require removal from the premises of all flammable or highly toxic materials.

4.13.2 Housekeeping Before and After Maintenance

All toxic or otherwise dangerous materials on or in the vicinity of the subject equipment should be cleaned up before maintenance. Substances designated hazardous waste shall be handled and disposed of in accordance with regulations. Any hazardous materials and other debris shall be cleaned up before operations resume.

4.13.3 Safety for Maintenance Personnel

Maintenance personnel shall be required to use appropriate personal protective equipment (PPE) (such as respirators, goggles or face shields, gloves, and protective clothing) during parts of the work involving potential hazard. If possible, equipment to be removed to the shop should be decontaminated before removal. **Also, a procedure should be established to notify hood users before any maintenance is to be performed so work in the hood can be halted**

during maintenance. If the maintenance activities involve contact with potentially contaminated parts of the system, these parts should be evaluated first by appropriate methods.

4.13.4 Records

Records should be maintained for all inspections and maintenance. If testing involves quantitative values (such as hood throat section) the observed values should be recorded. Inspection forms designed for the several categories of testing should be provided and should include the normal values for the parameters tested.

4.13.5 Test Instruments

4.13.5.1 Air Velocity and Air Pressure Instruments

Pressure instrumentation and measurement shall be in compliance with ANSI/ASHRAE 41.3.{Ref. 32}. Temperature instruments and measurement techniques shall be in compliance with ANSI/ASHRAE 41.1. {Ref. 33}. **All instruments using electrical, electronic, or mechanical components shall be calibrated no longer than six (6) months before use or after any possible damage (including impacts with no apparent damage) since the last calibration.** The accuracy of a scale used for a given parameter shall meet the following requirements:

Velocity - FPM	**Accuracy, %**
50	10
100 and higher	5

Pressure - In. W.G.	**Accuracy, %**
0.1	10
0.5 and higher	5

Instruments that are "primary standard" (e.g. standard pitot tubes, U-tube manometers, draft gauges) - if used with fluids for which they are designed, and tested for leaks - require no further calibration. Pitot-static tube measurements shall be in accordance with ASHRAE's Standard Method for Measurement of Flow of Gas (41.7). {Ref. 49}. Inclined manometers shall be selected so that the nominal value of the measured parameter is at least 5% of full-scale. U-tube manometers shall not be used for pressures less than 0.5 in. W.G. Pitot tubes other than standard shall be calibrated.

4.13.5.2 Air Contaminant Monitors

Air contaminant monitors shall be tested at least **monthly** or more often, if experience or manufacturer's recommendation indicate. Such testing shall include the sensing element, zero drift, and actuation of signals, alarms, or controls.

4.13.5.3 Tolerances of Test Results

Allowable variance from design conditions, or conditions determined otherwise satisfactory, shall be

- for air velocity ±10%;
- for ventilation air pressure or differential pressure, ±20%;
- for pneumatic control system air pressure, ±5%;
- for electronic control system, ±2% of full scale values.

4.13.5.4 Other Test Instruments

Other instruments (such as voltmeters, ohmmeters, and tachometers) shall be checked for function and accuracy against a known source before use.

4.14 Testing and Monitoring

4.14.1 Airflow Controls

4.14.1.1 Emergency Bypass Dampers

Emergency bypass dampers shall be tested by applying the appropriate control signal to the system and observing the damper movement for the full range of designed operation.

4.14.1.2 Other Dampers

Other dampers and associated drive linkage and actuators should be inspected visually, and the actuator operated enough to observe proper movement.

NOTE: This usually will require inspection panels or windows strategically located in ductwork. When open inspection panels are to be avoided for hazard reasons, a pair of nautical-type "port lights" might be useful. They may be opened briefly to clean the inside of the glass and reclosed. One port-light is used for a light; the other for observation.

4.14.1.3 Damper Shaft Integrity; Slide Gates

The inspection panels described in 4.14.1.2 are not required for dampers constructed with the damper blade affixed to the damper shaft so that the blade cannot, under foreseeable conditions of corrosion or vibration, fail to rotate in unison with the shaft, or for flow slide gates.

4.14.1.4 Fire Dampers

Fire dampers shall **not** be used in laboratory hood exhaust systems (ANSI/NFPA 45).

4.14.2 Air Filters

All air filters should be provided with differential pressure gauges. **Gauges should be read at intervals of one week (or at other intervals, based on experience) and inspected visually at the same time.** If the pressure differential equals or exceeds the rated maximum, the filters should be changed at the first opportunity.

NOTE: Recirculation air filters shall be inspected and tested per 4.12.3.1 except that provisions are mandatory. See 4.14.1.1 (emergency bypass dampers).

4.14.3 Recirculation Activated Carbon Beds

Activated carbon beds or panels shall be **tested** per 4.12.4 at intervals no longer than **one month**, based on experience with the particular installation.

4.14.4 Air Pollution Control Equipment

Air pollution control equipment shall be **inspected visually** at intervals no longer than **one week** and, if necessary, at shorter intervals. Specific tests and repairs shall be in accordance with the manufacturer's recommendations or in compliance with applicable regulations.

NOTE: The variety of generic types of pollution control equipment, combined with the many different configurations on the market, makes it inappropriate to set forth specific requirements.

4.14.5 Fume Hoods

If practical, the exhaust flow rate from hoods shall be tested by measuring the flow in the duct by the hood throat suction method (see the Industrial Ventilation manual, Section 9) or by a flow meter. If a flow meter is used, care shall be taken to ensure that the sensing element has not been compromised by chemical action or deposition of solids.
NOTE: Fine dust, for example, might adhere to the throat of a venturi meter and change its inside dimension, which is critical to the measurement.

If flow measurement in the duct is not practical, velocity at the hood face or opening shall be measured at a sufficient number of points to obtain a realistic average velocity, and multiplied by the open area in the plane of velocity measurements to obtain the flow rate.

If the flow rate is more than 10% different from design, corrective action shall be taken.

4.14.6 Room Air Balance

The proper direction and velocity of air movement between laboratory spaces will have different degrees of importance, varying from desirable to important to critical. The degree of importance will vary with many factors, among them the objective assessment of potential health hazard and whether the potential health effects are acute or chronic. Many other factors are involved, varying from the maximum credible accident to protection of sensitive instruments to aesthetics. In a perfume laboratory, for example, unwanted migration of harmless, pleasant odors might be regarded as critical.

The laboratory organization should establish the degree of importance of proper airflow balance as desirable, important, or critical. This classification might vary from one laboratory room or suite to another in the same facility.

4.14.6.1 Critical Air Balance

Monitoring devices shall be inspected and tested at intervals no longer than one week.

4.14.6.2 Important Air Balance

Direction and velocity of airflow shall be tested at intervals no longer than one month.

4.14.6.3 Desirable Air Balance

Direction and velocity of airflow should be tested at intervals not to exceed six months.

4.14.7 Blowers, Motors, and Drives

4.14.7.1 Visual Inspection

Fans, blowers, and drive mechanisms shall be visually inspected weekly. Key observations are abnormal noise or vibration, bearing noise, excessive temperature of motors, lubricant leaks, etc.

4.14.7.2 V-Belt Drives

V-belt drives shall be stopped and inspected monthly for belt tension and signs of belt wear or cracking.

4.14.7.3 Lubrication

Blowers, drives, and other critical machine elements shall be lubricated at intervals and with lubricants recommended by the manufacturer.

4.14.7.4 Critical Service Spares

Preventive maintenance is intended to prevent unplanned breakdowns, but breakdowns will occur. In some cases, delivery time of replacement parts might be long enough to inhibit maintenance resulting from periodic inspection. Maintenance supplies and spares should be planned, taking into consideration the typical factors involved, such as:

- potential health or safety risk of breakdown;
- availability of spares or replacements;
- economic cost of facility out of service.

4.14.7.5 Critical Service Instrumentation

For critical equipment of 100 horsepower or larger, consideration should be given to providing temperature and vibration sensors to give early warning of problems.

4.2.5 ACGIH "Industrial Ventilation - 21st Edition"

The Industrial Ventilation manual has a useful summary of inspection and maintenance requirements for fans in §6.4.2, where it is noted that wear or accumulation on an impeller will cause weakening of the impeller structure and/or serious vibration. If vibrations are severe, damage or failure also can occur at the bearings or fan structure.

Fan rotation often is reversed inadvertently during repair or alterations to wiring circuits or starters. As centrifugal fans do move a fraction of their rated capacity when running backward, incorrect rotation can occur unnoticed in spite of less effective performance of the exhaust system. Scheduled fan inspection is recommended, as follows:

- Bearings for proper operating temperature (greasing on an established schedule).
- Excessive vibration of bearings or housing.
- Belt drives for proper tension and minimum wear.
- Correct coupling alignment.
- Fan impeller for proper alignment and rotation.
- Impeller free from excess wear or material accumulation.

5. COMPARISON WITH REQUIREMENTS FOR VENTILATION SYSTEMS IN COMMERCIAL NUCLEAR POWER PLANTS

In commercial nuclear power plants, there are several systems which are somewhat analogous to building ventilation systems in the DOE DP facilities. These are normally operating building ventilation systems which typically are not safety-related. The safety-related ventilation and air filtration systems generally are on a standby basis for post-accident conditions. In the Standard Technical Specifications, which have not yet been adapted to any currently operating reactors, there are no limiting conditions of operation for the normally operating ventilation systems. Only the standby systems are addressed. Below is a summary description and the requirements for General Electric boiling water reactors (BWRs), BWR/4 type, and Westinghouse pressurized water reactors (PWRs), which together represent the vast majority of the operating nuclear power plants in the United States, as described in the Standard Technical Specifications.

5.1 Standard Technical Specifications

5.1.1 General Electric BWRs

In a BWR, the two major structural limitations to leakage of radioactive materials to the environment are the primary containment and the secondary containment. According to the "Standard Technical Specifications - General Electric Plants, BWR/4," NUREG/CR-1433, Volume 2, (Ref. 50) for GE BWR/4 plants, the primary containment isolates and contains the fission products released from the Reactor Primary System following a design basis accident (DBA) and confines the postulated release of radioactive material. The primary containment consists of a steel-lined, reinforced-concrete vessel, which surrounds the Reactor Primary System, and essentially provides a leak tight barrier against an uncontrolled release of radioactive material to the environment.

The secondary containment contains, dilutes, and holds up fission products that may leak from the primary containment following a DBA. Together with operation of the Standby Gas Treatment System (SGTS), and closure of certain valves whose lines penetrate the secondary containment, the secondary containment is designed to reduce the activity level of the fission products before their release to the environment, and to isolate and contain fission products that are released during certain operations that occur inside the primary containment, when primary containment is not required to be operable, or that occur outside the primary containment.

The secondary containment is a structure that completely encloses the primary containment and those components that may contain primary system fluid. This structure forms a control volume that holds up and dilutes the fission products. It is possible for the pressure in the control volume to rise relative to the environmental pressure, e.g. due to additions from the pump and motor heat loads. To prevent ground level exfiltration while allowing the secondary containment to be designed as a conventional structure, the secondary containment requires the support of the Secondary Containment Isolation Valves (SCIVs) and the SGTS.

There are several ventilation-related systems in both the primary and secondary containments that support the function of the primary containment system following a DBA; their availability is governed by the following Technical Specifications:

5.1.1.1 Primary Containment Ventilation Systems

a) **Hydrogen Recombiners**

Description

The hydrogen recombiner system eliminates any potential breach of primary containment due to a hydrogen-oxygen reaction and is part of combustible gas control required by 10 CFR 50.44, "Standards for Combustible Gas Control Systems in Light-Water-Cooled Reactors," (Ref. 51) and General Design Criterion 41, "Containment Atmosphere Cleanup" (Ref. 52). The system maintains the concentration of hydrogen gas within the containment at or below the flammability limit of 4.0 volume % (v/o) following a postulated LOCA by combining hydrogen and oxygen to form water vapor.

Since the flammability limits would not be reached until several days after a DBA, the system is manually initiated from the main control room typically when the hydrogen concentration reaches 3.3 v/o, and consists of two 100% capacity subsystems. When the primary containment is inerted, i.e. the oxygen concentration is < 4.0 v/o, the system functions only until the oxygen is consumed. Each hydrogen recombiner consists of an enclosed blower assembly, a heater section, a reaction chamber, a direct contact water spray gas cooler, a water separator, and associated piping, valves, and instruments. Each recombiner is powered from a separate Engineered Safety Features bus and is provided with separate power panel and control panel.

The process gas circulating through the heater, the reaction chamber, and the cooler is automatically regulated typically to 150 SCFM by an orifice plate in the cooler, and then is heated typically to 1200°F, at which point the hydrogen and oxygen recombine into water vapor. The water vapor is condensed in the water-spray gas cooler by the associated train of the Residual Heat Removal System (RHRS) and discharged with some of the effluent process gas to the suppression chamber. The majority of the cooled, effluent process gas is mixed with the incoming process gas to dilute the incoming gas before the mixture enters the heater section.

Surveillance Requirements

Two hydrogen recombiners must be OPERABLE in Modes 1 and 2. With one recombiner inoperable, the inoperable recombiner must be restored within 30 days. The 30 day completion time is based on the low probability of occurrence of a LOCA that would generate hydrogen in amounts capable of exceeding the flammability limit, the amount of time available after the event for operator action to prevent exceeding the limit, and the low probability of failure of the operable recombiner. For plants with an NRC accepted alternate hydrogen control system, such as the Primary Containment Inerting System, or one subsystem of the Containment Atmosphere Dilution System, when both recombiners are inoperable, plant operation is allowed for 7 days, in conjunction with verification of alternate

capabilities within 1 hour by administrative means and subsequent constant 12 hour surveillance of the alternate control system. If the completion time cannot be met, the plant must be brought to at least Mode 3 status in 12 hours.

Three surveillance tests are required for the recombiner system, all of which are performed typically at 18 month intervals. This chosen frequency is acceptable from a reliability standpoint because operating experience has shown that the components usually pass the surveillance test then. The following are the system tests:

- A system functional test ensures that the minimum temperature of the heater sheath increases typically to ≥ 1200°F in ≤ 1.5 hours and that it is maintained > 1150°F and < 1300°F for ≥ 4 hours thereafter to assure proper recombiner function and also to assure that significant heater elements are not burned out.

- A visual inspection determines abnormal conditions that could cause credible failures, such as loss of power or blower function, blockage of the internal flow path, and missile impact, which are postulated because the recombiners are mechanically passive, except for the blower assemblies.

- A resistance-to-ground test of each heater phase verifies that the resistance for any heater phase typically is ≥ 10,000 Ω.

b) **Drywell Cooling System Fans**

Description

The Drywell Cooling System (DCS) fans ensure a uniform post-accident atmosphere in the primary containment to minimize the potential for local hydrogen burns due to a pocket of hydrogen above the flammable concentration. The DCS fans are an Engineered Safety Feature (ESF) which are designed to withstand a post-accident environment without loss of function. They employ forced circulation to mix the hydrogen, while the fan coils provide natural circulation by increasing the density of the hot gases at the top of the drywell by cooling them, so causing the cooled gases to gravitate to the bottom of the drywell.

The DCS consists of two 100% capacity subsystems consisting of fans, fan coil units, motors, controls, and ducting, each of which is sized to circulate typically 500 SCFM. The fan-coil units and the recirculation fans are disengaged automatically during a LOCA but may be restored to service manually by the operator from the control room, typically several days after a LOCA since flammability limits would not be reached until several days later.

Each subsystem is powered from a separate emergency power supply. If offsite power is lost, the power supply for all fan-coil units, recirculating fans, and primary-containment water chillers is transferred to the emergency diesel generators, and the fan coil units and recirculating fans are started automatically.

Surveillance Requirements

In Modes 1 and 2, two DCS fans are required OPERABLE to ensure the capability of preventing localized hydrogen concentrations above the flammability limit of 4.0 v/o in the drywell. With one DCS fan inoperable, the inoperable fan must be restored within 30 days. The 30 day completion time is based on the availability of the second fan, the low probability of occurrence of a LOCA that would generate hydrogen in amounts capable of exceeding the flammability limit, the amount of time available for operator action to prevent exceeding the limit, and the availability of the Primary Containment Hydrogen Recombiner System and the Containment Atmosphere Dilution System. For plants with an NRC accepted alternate hydrogen control system, such as the Primary Containment Inerting System, or one subsystem of the Containment Atmosphere Dilution System, when both recombiners are inoperable, plant operation is allowed for 7 days, in conjunction with verification of alternate capabilities within 1 hour by administrative means and subsequent constant 12 hour surveillance of the alternate control system. If the completion time cannot be met, the plant must be brought to at least Mode 3 status in 12 hours.

There are two surveillance test requirements for the DCS fans:

- Every 92 days, each DCS fan subsystem must be operated ≥ 15 minutes to detect any blockage, fan or motor failure, or excessive vibration, and to ensure that all associated controls are functioning properly. The 92 day frequency is consistent with Inservice Testing (IST) program frequencies, operating experience, the known reliability of the fan motors and controls, and the availability of a redundant fan subsystem.

- Typically every 18 months, each DCS fan is operated to verify that the flow rate is typically ≥ 500 SCFM which ensures that each fan can maintain localized hydrogen concentrations below the flammability limit. The 18-month frequency allows this surveillance test to be performed during a plant outage, and also prevents a possible plant transient if the test were performed with the reactor at power. The selected frequency also is acceptable from a reliability standpoint because operating experience has shown that the components usually pass the surveillance test then.

5.1.1.2 Secondary Containment Ventilation Systems

a) **Containment Atmosphere Dilution (CAD) System**

Description

The CAD system maintains combustible gas concentration within the primary containment at or below the flammability limits following a postulated LOCA by diluting hydrogen and oxygen with nitrogen. Oxygen concentration is kept typically < 5.0 v/o, or hydrogen concentration is kept typically < 4.0 v/o.

The CAD system is manually initiated and consists of two independent, 100% capacity subsystems. Each subsystem includes a liquid nitrogen supply tank, ambient vaporizer, electric heater, and connected piping to supply the drywell and suppression chamber volumes. The capacity of each nitrogen storage tank is typically ≥ 4350 gallons, which is adequate typically for 7 days of CAD subsystem operation.

The CAD system operates in conjunction with emergency operating procedures that reduce the pressure in the primary containment periodically during CAD system operation. This combination results in a feed-and-bleed approach to maintaining hydrogen and oxygen concentrations below combustible levels.

(The CAD system is similar in some respects to systems which purge and replace tritium with an inert gas, and mitigate the leakage of tritium from gloveboxes and hoods in DOE DP facilities).

Surveillance Requirements

In Modes 1 and 2, two CAD subsystems are required OPERABLE to maintain oxygen concentration below 5.0 v/o following a LOCA. With one CAD subsystem inoperable, the inoperable subsystem must be restored to operable status with 30 days. The 30 day completion time is based on the low probability of occurrence of a LOCA that would generate hydrogen and oxygen in amounts capable of exceeding the flammability limit, the amount of time available after the event for operator action to prevent exceeding this limit, and the availability of the operable CAD subsystem and other hydrogen mitigating systems.

For plants with an NRC accepted alternate hydrogen control system, such as the Primary Containment Inerting System, or one hydrogen recombiner and one DCS fan, when both CAD subsystems are inoperable, plant operation is allowed for 7 days, in conjunction with verification of alternate capabilities within 1 hour by administrative means and subsequent constant 12 hour surveillance of the alternate control system. If the completion time cannot be met, the plant must be brought to at least Mode 3 status in 12 hours.

There are two surveillance test requirements for the CAD system:

- Every 31 days, the capacity of liquid nitrogen in each liquid nitrogen supply tank is verified to be typically ≥ 4350 gallons to ensure typically that the CAD system can operate at least 7 days post-LOCA. The 31 day frequency is based on operating experience, which has shown that this is an acceptable period to verify the liquid nitrogen supply, and also on the availability of other hydrogen mitigating systems.

- Every 31 days, the correct alignment for manually operated, power-operated, and automatic valves in each of the CAD subsystem's flow paths to ensure that the proper paths exist for system operation. This surveillance does not apply to valves that are locked, sealed, or otherwise secured in position, since such valves were verified to be in the proper position before doing this. Nor does this surveillance apply to valves which cannot be inadvertently misaligned, such as check valves.

Because the CAD system is manually initiated, a valve is allowed to be in the nonaccident position provided it can be aligned to the accident position within the time assumed in the accident analysis.

This surveillance does not require any testing or valve manipulation, only verification that those valves that can be mispositioned are in the correct position.

The 31-day frequency is acceptable because the valves are operated under procedural control, an improper position would only affect a single subsystem, the probability of an event requiring system initiation is low, and the system is manually initiated.

b) **Standby Gas Treatment System (SGTS)**

(The SGTS is the system which most closely matches a typical building ventilation system in a DOE DP facility, the major difference being that the SGTS is a standby system, while the building ventilation systems normally must operate continuously).

Description

The SGTS is required by 10 CFR 50, Appendix A, General Design Criterion 41, "Containment Atmosphere Cleanup," to ensure that radioactive materials which leak from the primary containment into the secondary containment following a DBA are filtered and adsorbed before exhausting to the environment. The SGTS consists of two 100% capacity subsystems, each with its own set of ductwork, dampers, charcoal filter train, and controls.

Each charcoal filter train consists of the following components listed in the order of direction of air flow:

1. A demister or moisture separator;
2. An electric heater;
3. A prefilter;
4. A high-efficiency particulate air (HEPA) filter;
5. A charcoal adsorber;
6. A second HEPA filter; and
7. A centrifugal fan.

The SGTS equipment and components are sized based on an analysis of infiltration and exfiltration through the secondary containment. The internal pressure of the SGTS boundary region is maintained at a negative pressure typically of 0.25 in. W.G. when the system is operating; this is the internal pressure required to ensure zero exfiltration of air from the building when exposed typically to a 10 MPH wind blowing at an angle of typically 45° to the building.

The demister removes entrained water in the air and the electric heater reduces the relative humidity of the airstream typically to < 70%. The prefilter removes large particulate matter, while the HEPA filter removes fine particulate matter and protects the charcoal from

fouling. The charcoal adsorber removes gaseous elemental iodine and organic iodides, and the final HEPA filter collects any carbon fines exhausted from the charcoal adsorber.

The SGTS automatically starts and operates in response to actuation signals indicative of conditions or of an accident that could require it to operate. Following initiation, both charcoal filter train fans start. Upon verification that both subsystems are operating, the redundant system is normally shut down.

Surveillance Requirements

The SGTS is required to be OPERABLE during Modes 1, 2, and 3, during which time a DBA could lead to a fission product release to the primary containment which could leak to secondary containment. With one SGT subsystem inoperable, the inoperable subsystem must be restored in 7 days. The 7 day completion time represents consideration of such factors as availability of the operable redundant SGT subsystem and the low probability of a DBA occurring during this period. If the completion time cannot be met, the plant must be brought to at least Mode 3 within 12 hours and to Mode 4 within 36 hours. These times are reasonable, based on operating experience, to reach the required plant conditions from full power conditions in an orderly manner without challenging plant systems.

During movement of irradiated fuel assemblies in the secondary containment, during core alterations, or during operations with potential for draining the reactor vessel (OPDRVs), when the completion time cannot be met, the operable subsystem should be placed immediately into operation. This is to ensure that no failures that could prevent automatic actuation have occurred, and that any other failure would be readily detected. An alternative action is to suspend immediately any activities that represent a potential for releasing radioactive material to the secondary containment, such as core alterations, movement of irradiated fuel assemblies, and OPDRVs. Suspension of these activities must not preclude completion of movement of a component to a safe position.

When two SGT subsystems are inoperable, any core alterations, movement of irradiated fuel assemblies in the secondary containment, or OPDRVs, must be suspended immediately, but not to preclude completion of movement of a component to a safe position. While in Modes 1, 2, or 3, movement of irradiated fuel assemblies is independent of reactor operation, so that inability to suspend such movement would not be sufficient reason to require a reactor shutdown.

There are four surveillance tests for the SGTS:

- Every 31 days, each SGT subsystem must be operated for typically ≥ 10 continuous hours to ensure that any blockage, fan or motor failure, or excessive vibration is detected and that all associated controls are functioning properly. Operation with the heaters on, with the automatic heater cycling to maintain temperature for ≥ 10 continuous hours every 31 days eliminates moisture on the adsorbers and HEPA filters. The 31 day frequency is based on the known reliability of fan motors and controls, and the known redundancy available in the system.

- At frequencies described in the Ventilation Filter Testing Program (VFTP), the SGT system filter tests are in accordance with Regulatory Guide 1.52, "Design, Testing, and Maintenance Criteria for Post Accident Engineered-Safety-Feature Atmosphere Cleanup System Air Filtration and Adsorption Units of Light-Water-Cooled Nuclear Power Plants." (Ref. 53). The VFTP includes testing the performance of the HEPA filters, efficiency of the charcoal adsorber, minimum system flow rate, and the physical properties of the activated charcoal (general use and following specific operations).

- Every 18 months, each SGT subsystem is verified to start on receipt of an actual or simulated initiation signal. This frequency is acceptable from a reliability standpoint even though the test can be performed with the reactor at power because operating experience has shown that these components usually pass the test at 18-month intervals, and also because the **Logic System Functional Test** (SR 3.3.6.2.6) overlaps this test.

- Every 18 months, it is verified that the filter cooler bypass damper can be opened and the fan started to ensure that the ventilation mode of SGTS operation is available. While this test can be performed with the reactor at power, operating experience has shown that these components usually pass the test at the 18-month frequency, which is based on the refueling cycle. Therefore, the frequency is acceptable from a reliability standpoint.

5.1.2 Westinghouse PWRs

For commercial PWRs, Westinghouse is the predominant supplier of the Nuclear Steam Supply Systems (NSSS). The corresponding standard technical specifications for Westinghouse plants are contained in NUREG/CR-1431, Volume 3 (Ref. 54). The appropriate ventilation systems consist of both containment systems and plant systems. Such containment systems are the following:

- Hydrogen Recombiners (§3.6.8)
- Hydrogen Mixing System (§3.6.9)
- Iodine Cleanup System (§3.6.11)
- Shield Building Air Cleanup System (§3.6.13)
- Air Return System (§3.6.14 for ice condenser containment designs only)

The following are the appropriate plant systems:

- Control Room Emergency Filtration System - CREFS (§3.7.10)
- Control Room Emergency Air Temperature Control System - CREATCS (§3.7.11)
- Emergency Core Cooling System (ECCS) Pump Room Exhaust Air Cleanup System (PREACS) (§3.7.12)

- Fuel Building Air Cleanup System - FBACS (§3.7.13)
- Penetration Room Exhaust Air Cleanup System (PREACS) (§3.7.14)

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Since the above containment and plant systems are essentially analogous to those described previously for BWRs, none of these systems are discussed in detail here.

For most of the above systems, the filters are required to be tested in accordance with the plant's Ventilation Filter Testing Program (VFTP). Since the VFTP is common to both BWRs and PWRs, it is discussed separately in the following section.

5.2 Ventilation Filter Testing Program

The VFTP is a program intended to test the performance of filters used for ventilation systems in both BWRs and PWRs. NUREG/CR-1431, Volume 1, §5.7.2.15, identifies the program as one which shall be established to implement the required testing of the Engineered Safety Feature (ESF) filter ventilation systems at the frequencies specified in the appropriate Regulatory Guide for that system, and also conducted in accordance with Regulatory Guide 1.52, Revision 2, ASME N510-1989, and ASME/ANSI AG-1 (Ref. 55). Specifically, for each of the ESF systems, the following shall be demonstrated:

- An in-place test of the HEPA filters shows a penetration and system bypass typically < 0.05% when tested in accordance with Regulatory Guide 1.52, Revision 2, and ASME N510-1989, at the specified system flow rate, typically ±10%.

- An in place test of the charcoal adsorber shows a penetration and system bypass typically < 0.5% when tested in accordance with Regulatory Guide 1.52, Revision 2, and ASME N510-1989, at the specified system flow rate, typically ±10%.

- A laboratory test of a sample of the charcoal adsorber, obtained in accordance with Regulatory Guide 1.52, Revision 2, shows the methyl iodide penetration less than an acceptable value when tested in accordance with typically ASTM D3803-1989 (Ref. 56) at a temperature of typically ≤ 30°C and greater than or equal to a specified relative humidity. The allowable penetration is defined as [{100% - methyl iodide efficiency for charcoal credited in staff safety evaluation}/{safety factor}] where:
  -Safety Factor = (5) typically for systems with heaters.
  = (7) typically for systems w/o heaters.

- The pressure drop across the combined HEPA filters, the prefilters, and the charcoal adsorbers is less than a specified value when tested in accordance with Regulatory Guide 1.52, Revision 2, and ASME N510-1989 at a specified system flow rate, typically ±10%.

- The heaters dissipate a specified value of wattage, typically ±10%, when tested in accordance with ASME N510-1989.

In a recent information notice, IN 93-06 (Ref. 57), the NRC described the discovery by the staff at the Grand Gulf nuclear plant that there were leakage paths within ventilation system ducting and housings, including fan plenums. These leakage paths reduced the

removal capability, both by adsorption and filtration, for radioactive material of the Standby Gas Treatment System and the Control Room Air Conditioning System in the event of a design basis accident. An opening, or gap, between the fan's hub and the hole in the fan housing could result in air being drawn into the suction plenum of the SGTS downstream of the charcoal adsorber and HEPA filter. The paths were around a motor shaft, through a slotted opening to an actuator for a damper, and at a transition piece of ducting. The ventilation system for the control room also had bypass paths. Air from the area around the fan plenum would be sucked into the ducting and discharged directly into the control room.

Thus, the affected ventilation system ducting serves either as part of the secondary containment boundary or an extension of the environment in the control room. The apparent root cause for the deficiencies, which included missing seals, was a failure to specify a leak-tight construction for the fan housings. The corrective actions taken were to install shaft seals and to rework the other leakage paths to reduce bypass flow.

The NRC noted that many licensees have designed these types of systems to conform with ASME/ANSI N509 and have committed to testing to the standards in ASME/ANSI N510. Testing in accordance with N510 can identify bypass leakage if it is a significant fraction of system flow. Small inleakage rates, such as those at Grand Gulf, can be identified using tracer chemicals, such as SF_6.

5.3 NRC Inspection Procedures

5.3.1 IP 93801 Safety System Functional Inspection (SSFI)

NRC Inspection Procedure 93801 (Ref. 58), which is included as Appendix C, describes the requirements for conducting a Safety System Functional Inspection (SSFI). The objective of a SSFI is to assess the operational performance capability of selected safety systems through an in-depth, multi-disciplinary engineering review to verify that they can perform their intended safety functions. Generic safety significant findings are pursued across the system boundaries on a plant-wide basis.

The intent of the SSFI also is to determine the program-related root cause for identified deficiencies and to analyze their implications on the licensee's quality assurance program.

The procedure gives extensive guidance for all phases of the inspection:

- Inspection Planning
- System Selection
- Inspection Preparation
- Conduct of the Inspection
  - Engineering Design and Configuration Control
  - Operations

- Maintenance

- Surveillance and Testing

- Quality Assurance and Corrective Actions

With the known problems at DOE facilities, such as lack of design documentation and configuration control, it would be expected that application of this procedure at DOE facilities would result generally in numerous findings substantiating was found during the Tiger Team inspections.

5.3.2 Related Procedures

The NRC has in effect other inspection procedures which could be applied to the inspection of ventilation systems at DOE DP facilities. The related procedures include the following:

- IP 93802 Operational Safety Team Inspection (OSTI) **(Ref. ??)**

This procedure is intended to verify that:

- the plant is being operated safely and in conformance with regulatory requirements,

- the organizations that control and support plant operations, i.e. operations, maintenance, surveillance, management oversight, technical support, safety review, quality assurance, and corrective action, are functioning effectively to ensure operational safety, and

- the licensee has properly prepared the staff and the plant for resumption of power operations after an extended shutdown.

- IP 93803 Safety Systems Outage Modifications Inspection **(Ref. ??)**

This procedure is intended to verify that:

- the licensee has appropriate programmatic controls for accomplishing changes, modifications and repairs,

- the licensee is conducting activities related to design changes, modifications, and repairs in accordance with established procedures, commitments, and regulatory requirements,

- the completed modifications have been properly designed, installed, inspected, and tested to ensure the adequate performance of the modified systems and components,

- the design margins of the modified safety-related systems and components have not been reduced, and

- the modified systems and components are ready for safe startup and operation of the plant.

- IP 93804 Risk-Based Operational Safety and Performance Inspection **(Ref. ??)**

The purpose of this procedure is to assess the operational readiness of a commercial nuclear power plant using risk information presented in a reactor plant's site-specific probabilistic risk assessment (PRA), or other generic risk information. The inspection focuses on safety significant components and potential accident mitigation and recovery actions so that:

- plant challenges are minimized,

- safety systems, equipment, and components will be available, reliable, and operable,

- plant operators are capable of recognizing and responding appropriately to plant challenges, and capable of conducting timely and effective accident mitigation and recovery actions, and

- available risk information has been factored appropriately into the reactor plant's programs, procedures, and design.

- IP 93806 Operational Readiness Assessment Team Inspection **(Ref. ??)**

This procedure provides guidance on conducting Operational Readiness Assessment Team (ORAT) inspections for new plants. Results from these inspections provide a major input and basis for determination of startup readiness.

6. CONCLUSIONS

As a result of internal studies conducted by the Office of Defense Programs, as well as through oversight studies by the Office of Nuclear Safety, it is apparent that the Ventilation System has been prone to significant numbers of component failures arising from aging-related failures, inadequate preventive maintenance, personnel errors, inadequate configuration control, and other causes.

This report has focused primarily on the Unusual Occurrence Reports (UORs) filed in the Operations Reporting and Processing System (ORPS) from January 1991 to January 1994 so that significant events and lessons learned can be highlighted with the intention of providing a basis for DOE staff and contractors to compare current practices to industry standards, particularly with respect to testing and maintenance intervals, and to provide guidance for identifying the most effective corrective actions to reduce the frequency and severity of such component failures on the Ventilation Systems. In addition, the requirements of the DOE orders pertaining to ventilation systems were discussed. The requirements of the U.S. NRC for inspection and test of ventilation systems and components of commercial nuclear power plants have been presented for comparison.

The UOR review identified that

- 51% involved hardware failures, and
- 47% involved programmatic or non-hardware deficiencies.

Some examples of the programmatic deficiencies included:

- procedural errors,
- violations of Operational Safety Requirements (OSR),
- configuration management errors, and
- non-conformance situations.

The following programmatic areas were identified as the leading failure cause categories of UOR events:

- Insufficient/Improper Maintenance and Testing
- Incorrect/Inadequate Procedures
- Inadequate Management of Wear Out/Aging

<u>Insufficient/Improper Maintenance and Testing</u>

- Insufficient/improper maintenance UORs included events where there was a failure to follow maintenance procedures, errors reinstalling components or piece-parts, lack of maintenance, as well as personnel errors during maintenance or test activities.

Incorrect/Inadequate Procedures

- Incorrect/inadequate procedure events involved UORs whose procedures did not meet the intent of the existing design nor the mission of the facility in question. These events involved procedures with incorrect information (i.e. misidentification of a fan, or valve), as well as cases where the procedures were not updated to reflect the current design of the system.

  This category also identified those events which fall into the area of configuration management and document control problems as they relate to incorrect or deficient procedures. A number of UORs not reviewed as a part of this study were identified as being related to problems of configuration management, however, these UORs were categorized as off-normal events.

- A cursory review of these reports, as well as the Office of Nuclear Safety Weekly Summary Reports has identified configuration management-related events as a potential area to focus more attention.

Inadequate Management of Wear Out/Aging

- Those events where management of wear-out/aging was identified as a problem involved situations that could most often be traced back to inadequate preventive maintenance (PM) programs which led to the accelerated wear or degradation of components.

The classification of components associated with each failure was also part of the UOR review process. This included both components that were the cause of the failure event, as well as those components that were affected by an identified programmatic deficiency. The top five components for the ventilation-related UORs were:

1) instrumentation and control (I&C)

With respect to the I&C-related events these were attributed to four main cause categories: abnormal stress, setpoint drift, calibration problems, and defective circuits.

2) fans

The fan-events were characterized by causes such as: incorrect action, defective electrical circuits, abnormal stress, and aging/cyclic fatigue. The incorrect action cause category were most often attributed to those events where fans were found to be in an improper operating status with respect to the ventilation system's function. In most of these events the integrity of the facility's negative pressure was of primary concern to maintain the in-flow of any released contamination.

3) dampers

Events involving dampers were dominated by incorrect/inadequate procedure causes. This group includes events where dampers were misconfigured because they were either left in the wrong position, or they were put into positions that were not consistent with the design basis of the particular facility, based on a procedure which did not adequately identify the correct position.

4) diesel engines

Diesel generators (DG) comprised another significant portion of the ventilation-related UOR component population. In most cases the DGs were failing due to abnormal stress or wear-out. Many of the DG events could be attributed to the lack of PM. Also noted in the DG-related UORs was a lack of adequate documentation regarding maintenance records for the DGs likely due to the associated problems regarding ownership, as many of the events noted that the DGs were leased on a temporary basis.

5) filters

Filters identified in the UORs were grouped in the following cause categories: particulate contamination, previous repair/maintenance, aging/cyclic fatigue, material defect, and incorrect procedures. The most commonly described failure mode due to particulate contamination was attributed to the lack of adequate PM for filters. Some events noted that there were no established PM procedures, while others indicated a PM schedule that was not consistent with normal maintenance practice for the type of filters or filters associated with the associated function of removing potential radioactive contaminants.

The following distributions were identified for the various field offices for associated with this UOR group:

- 80% of all ventilation UORs were reported by either Rocky Flats (RFO) 52%, or the Savannah River (SR) 29%, field offices.
- the Analytical Operations (ANALYTOPS) and Plutonium Fabrication (PUFAB) facilities comprise 82% of the RFO events.
- the Savannah River facility with the highest UOR contribution was the FB-Line (40% of SR UORs).

Codes and Standards Review

From reviewing the various codes and standards covering ventilation systems, the following was observed:

DOE Codes and Standards

- The DOE has published several standards related to DOE Order 4330.4B for the management of maintenance. These standards are intended as guidance documents for adaptation by each facility according to the importance of the operational systems and components. In particular, DOE-STD-1052-93 has some very useful information on predictive maintenance techniques. This guidance as related to ventilation systems has been incorporated into Subsection 4.1 of this report.

National Fire Protection Association Standards

- The only standards specifically applicable to DOE nuclear facilities are those published by the National Fire Protection Association (NFPA). In particular, the NFPA Recommended Fire Protection Practices, such as NFPA 801 for facilities handling radioactive materials, NFPA 802 for nuclear research reactors, and NFPA 803 for light water nuclear power plants, are applicable.

- NFPA 801 has the most general application for DP facilities. That standard specifies that the design of ventilation systems should be in accordance with NFPA 90A, "Standard for the Installation of Air Conditioning and Ventilating Systems," NFPA 90B, "Standard for the Installation of Warm Air Heating and Air Conditioning Systems," NFPA 91, "Standard for Exhaust Systems for Air Conveying of Materials," and NFPA 204M, "Guide for Smoke and Heat Venting." There are no direct requirements for testing, inspecting, and maintaining ventilation systems in NFPA 801, but NFPA 90A has an entire appendix devoted to maintenance. (That appendix has been incorporated into Subsection 4.2 of this report).

- NFPA 45, "Standard on Fire Protection for Laboratories Using Chemicals," and ANSI/ASHRAE Z9.5-1992, "American National Standard for Laboratory Ventilation," also contain specific recommendations on maintenance and testing intervals for ventilation components. The most emphasis is placed on ventilation filters, such as activated carbon filters, laboratory hood airflow measurements, and inspection, test, and maintenance of blowers, motors, and drives.

American Conference of Governmental Industrial Hygienists

- The manual "Industrial Ventilation" published by the American Conference of Governmental Industrial Hygienists contains much valuable information about design and test of general and laboratory ventilation systems. It also has some useful recommendations concerning maintenance of fans, motors, and belt drives.

American Society of Mechanical Engineers-

- One of the most important components in Ventilation Systems is the HEPA filter. The major standards applicable to filters are American Society of Mechanical Engineers (ASME) N509 and N510. ASME N509, "Nuclear Power Plant Air-Cleaning Units and Components," pertains to the design, construction, qualification, and acceptance testing of the air-cleaning units and components which comprise the Engineered Safety Feature (ESF) and other high-efficiency air and gas treatment systems used in nuclear power plants. It does not generally apply to inspections, tests, and maintenance of operational systems. Instead, ASME N510, "Testing of Nuclear Air Treatment Systems," specifies the requirements for field testing of ESF and other high efficiency air-cleaning systems for nuclear power plants and other nuclear applications. It forms a basis for developing test programs and detailed acceptance and surveillance test procedures, and specifies the minimum requirements for reporting the results. This standard is cited as one of the primary standards for ventilation systems in DOE Order 6430.1A. ASME N510 is especially cited for testing of High Efficiency Particulate (HEPA) filters and adsorption units such as carbon bed adsorbers. Testing is characterized by an air-aerosol mixing uniformity test, known as the Dioctyl Phthalate (DOP) test.

American Industrial Hygienists Association

- Although ANSI/AIHA Z9.5 does not apply to laboratories or hoods of animal laboratories, explosives laboratories, radioisotope laboratories, laminar flow hoods (not for employee protection), or biological safety cabinets, nevertheless, it does contain much valuable information and recommendations on the inspection, test, and maintenance of laboratory ventilation systems. In particular, it emphasizes that ensuring airflow velocity, usually 50 to 100 ft/min., through a laboratory hood is much more important in achieving adequate ventilation than maintaining a pressure differential between rooms. In view of the difficulty in predicting breakthrough, it also recommends periodic sampling of deep-bed carbon adsorber beds and panel and cartridge adsorbers at intervals based on experience.

Nuclear Regulatory Commission

- The Nuclear Regulatory Commission has several inspection procedures in effect which could be adapted for use in assessing the performance of the ventilation systems in DOE DP facilities. The most relevant of those procedures, IP 93802, "Safety System Functional Inspection (SSFI)," has been included as Appendix C of this report for information purposes.

- Most of the ventilation systems for which the NRC has defined technical specifications are standby systems which would normally operate only under abnormal or emergency conditions. Nevertheless, the surveillance requirements of the technical specifications for the Drywell Cooling System Fans, the Standby Gas Treatment System, and the Ventilation Filter Testing Program could prove useful if adapted to DOE DP ventilation systems.

The following general conclusion can be drawn:

- Of the codes and standards evaluated in this report, it is apparent that there is often a wide disparity in the intervals recommended for inspection, tests, and maintenance. This is particularly true for fans, blowers, motors, and controls. For example, NFPA 45 recommends that in-service inspection of these components occur at 1 year intervals and fan belts at 3 months, while ANSI/AIHA Z9.5 recommends ISI of fans and motors at 1 week intervals with V-belt driven fans being stopped and inspected once per month.

7. RECOMMENDATIONS

Programmatic Deficiencies

The identification of programmatic deficiencies as a large contributor to the overall ventilation OR population requires more attention in the areas of preventive maintenance (PM), more accurate and better developed procedures, and better management of the wear-out/aging of the components which make up the boundaries of the ventilation systems.

In some instances PM programs need to be upgraded to enhance the reliability of their respective systems, while in others a whole new effort needs to be started due to the lack of any formal PM program. In this area the individual sites must use the graded approach to determine the level of effort that will be expended in upgrading or developing a PM program.

In cases where it is warranted, more sophisticated techniques with respect to predictive maintenance (e.g. condition monitoring) may be applicable, while in others simply modifying existing PM frequencies could be enough to meet the goals of higher system reliability, and lessen the frequency of reportable events.

Procedure Modifications

With respect to procedure modifications, an assessment of the existing or updated SAR and associated procedural reviews would be required to determine if the existing mission is consistent with the currently approved procedures, in order that they meet the goals of the design basis.

Some of the more specific recommendations with respect to the review findings involve walking down procedures to determine if the required tasks can be performed within the confines of the work environment without the risk of shutting down or altering the operational status of collocated equipment. This recommendation is provided in response to the number of events where "bumping" of switches and components were cited as the cause for unanticipated operational events. Performing a walk-through of a procedure will allow the procedure writers to incorporate any necessary caution statements within the procedure, as well as identifying the need to introduce any warning tags/signs in the immediate work area. In one particular instance where bumping of switches was a recurring problem, a facility modified a control panel by placing a Plexiglass cover over to prevent any further incidents. These types of actions will assist in lowering the number of accidental shutdowns of facilities and the potential for associated evacuations caused by inadvertent bumping of components.

Management of Wearout/Aging

The management of wear-out/aging will become more attainable given that more emphasis is placed on the area of preventive and predictive maintenance. This effort will provide more reliable components, and better life-cycle management. These efforts will specifically enhance the reliability of components such as diesel generators, fans and associated mechanical components, and remote-actuated dampers. A balance must be struck such that PM activities do not dominate the unavailability of components/systems thereby offsetting their positive intent.

A general rule of thumb would be to adhere to manufacturers recommendations to determine the proper PM intervals, factoring in any environmental or operational stresses which may cause these periods to be shortened. In addition, better documentation must be maintained to provide a more accurate history of critical components and systems such as diesel generators.

Consideration of Off-Normal Events

Due to time and economic constraints this study was limited to the unusual event category (there were no ventilation-related emergency category events). With respect to the off-normal events not reviewed as a part of this effort it is highly recommended that each facility take a careful look at those areas where reported events are dominating the downtime of the facility's operational and safety goals.

Reporting of Occurrences

With respect to the number of occurrences that are being reported by particular sites there are no definitive recommendations provided other than to have each facility examine their reporting responsibilities with regard to those requirements identified in DOE 5000.3B, "Occurrence Reporting and Processing of Operations Information.

Review of Codes and Standards

Revision of DOE Orders

- Through DOE Order 6430.1A, Section 0109, "Reference Codes and Standards," NFPA 45 and NFPA 90A are directly referenced. However, NFPA 801, 802, and 803 are not referenced. Also, since the DOE order was issued in 1989, ANSI/AIHA Z9.5-1992, "American National Standard for Laboratory Ventilation," has been issued. If it is not already underway, consideration should be given to revising the DOE order to reference these standards.

In particular, ANSI/AIHA Z9.5-1992 makes some particularly useful recommendations regarding the monitoring of the velocity of airflow within laboratory hoods as opposed to the differential pressures between rooms and also regarding periodic sampling of deep-bed carbon adsorber beds and panel and cartridge adsorbers at intervals based on experience.

Ventilation System Handbook

- There are numerous codes and standards concerning ventilation systems which are referenced by DOE Order 6430.1A. Many of those standards have not been addressed in this report. If there is no such document, it may be beneficial to establish a Ventilation System Handbook which consolidates all of the applicable portions of DOE Order 6430.1A and the respective portions of the codes and standards for both DOE contractors and assessment personnel. This handbook could be generated by citing key words from the Key Word Index and codes and standards from the Document Index of the DOE order.

Recommended Maintenance Intervals

- In view of the disparity observed for some ventilation system components between the recommended test intervals amongst the industry standards, each facility should judge what is the proper interval based on the observed performance and importance of the particular component. Such judgements should be made with proper consideration of the guidance provided in the DOE standards concerning maintenance, particularly DOE-STD-1052-93.

Performance Enhancement Through Predictive Maintenance/ Expert Systems/ Neural Networks

- Failures of ventilation system components at the DOE facilities due to both equipment malfunction and human errors have been identified in Section 3. As discussed in Section 4, it may be useful to apply, at least on a trial basis, some combination of predictive maintenance techniques with either an expert system or a neural network, or both, at a selected facility to determine if system performance can be improved significantly.

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APPENDIX A
DESCRIPTION OF VENTILATION SPREADSHEET/DATABASE

This appendix gives field descriptions, along with the associated code definitions, for the spreadsheet/database used in the DOE, Defense Programs, ventilation review.

Also included is a printout of the BNL spreadsheet database used in the OR review. For the reader's convenience, two tables are shown, one sorted by component (A.1), the other sorted by occurrence number (A.2).

Field Name

BNL #

A non-specific value used as a place mark for reference.

Occurrence Report #

ORPS generated number for OR designation and referencing.

Field Office

Three letter code to identify the associated field office. Extracted from OR number.

Discovery Date

Date that the event was discovered by facility staff, as reported in OR.

UCNI

Identification of those events in the database that may be UCNI related. Codes used were either: P - possible, N - not UCNI. The determination for UCNI was made by a DOE derivative classifier and included as part of the OR.

Failed Component

Entry of yes - Y, or no - N, to indicate whether a component failure had taken place as part of the OR event. This classification was made as part of the BNL review.

Component Affected

Designation to identify the component which was most affected by the OR event. The majority of the entries in this field are self-explanatory; the following list includes a brief description of those abbreviations that require clarification[1].

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[1]Selected abbreviations excerpted from the NPRDS Reporting Guidance Manual, Chapter 8: Component Codes

ELECON: Electrical conductor, bus bar, wiring.

ICNTRL: Instrumentation, controller. This designation is used for those components which perform feedback control.

INDREC: Instrumentation, indicator/recorder. This designation is used for meters, and recorders. These components do not have a feedback loop, as used in ICNTRL, but merely supply a visual representation of the parameter being monitored.

IXMITR: Instrumentation, transmitter. This designation is used for those components which directly sense a process variable. By electrical or mechanical means, the process variable is converted to an electrical, or pneumatic signal.

The remaining fields include codes that were developed by the Institute for Nuclear Power Operations (INPO) for using in the Nuclear Plant Reliability Data System (NPRDS) database. The subsequent sections were excerpted from the NPRDS Reporting Guidance Manual[20]. Minor editing has taken place to support the context of the ventilation review project.

Failure Detection Code

The Failure Detection Code identifies how the failure was recognized or brought to the attention of the staff. The code selected should be fully supported by, and make sense when compared to, the failure narratives.

For example:

- A control room alarm observed by an operator falls within the definition of detection codes, "Operational Abnormality" and "Audiovisual Alarm." The latter is the correct choice because it is the most specific description of the method of detection.

The field is one character in length, and the entry must be one of the following values:

A - Operational Abnormality -

a failure detected during operation of the component by individuals assigned duties involving the system.

B - In-service Inspection/Testing -

a failure detected during a scheduled in-service inspection or test, such as during inspections or tests required by a governing code or standard (i.e. ASME Boiler & Pressure Vessel Code, Section XI).

C- Surveillance Testing -

a failure detected through routine testing that measures the performance or physical characteristics of a component or system to determine if it meets acceptance criteria, such as calibration checks, trip-point checks, and functional checks; includes mechanical, electrical, and instrumentation tests, as well as routine chemistry samples and analyses.

D - Preventive Maintenance -

a failure detected during preventive maintenance or while installing a design modification--If detected during preventive maintenance testing/surveillance, Code C is to be used because detection was related more to testing than to maintenance work.

E - Special Inspection/Test -

a failure detected during an inspection/test not routinely scheduled or required

F - Audiovisual Alarm -

a failure detected by an alarm that can be seen or heard.

H - Routine Observation -

a failure detected as a result of normal log-taking or log review, daily/weekly inspections, or trend analysis--Usually this would be within the normal duties or job functions performed by the unit's personnel.

J - Incidental Observation -

a failure detected by casual observation or chance witnessing by individuals not assigned duties involving the system.

K - Corrective Maintenance -

a failure detected during the corrective maintenance of some other problem on that component.

Failure Cause Category Code

The Failure Cause Category Code categorizes the known or most reasonable cause of the failure. The code selected should be fully supported by, and make sense, when compared to the failure narratives.

The field is one character in length, and the entry must be one of the following values:

A - Engineering/Design -

a failure attributable to the inadequate design of the component or system.

B - Incorrect Procedure -

a failure attributable to incorrect or inadequate procedures that were followed as written--Category E or F is to be used for failures caused by incorrectly following procedures.

C - Manufacturing Defect -

a failure attributable to inadequate assembly or the initial quality of the responsible component or system.

D - Installation Error -

a failure caused by improper installation of equipment--This code is for original (first-time) installations of components and not reinstallation (after maintenance, for example); Category F is to be used for reinstallation errors.

E - Operating Error -

a failure caused or aggravated by personnel errors while operating the equipment, including failure to follow operating procedures properly.

F - Maintenance/Testing -

a failure resulting from improper maintenance or testing, lack of maintenance, or personnel errors that occur during maintenance or testing on the responsible component or system, including failure to follow maintenance procedures--This category is to be used for errors in reinstalling the component/piece part.

H - Wear Out/Aging -

a failure thought to be the consequence of expected wear or aging--Failures due to faster-than-expected wear are to be coded with the cause of the faster wear, or designated "unknown" if the cause is not known.

J - Other Devices -

a failure attributable to a failure or misoperation of another component or system, including associated devices.

K - Unknown -

a failure for which the cause is unknown or cannot be assigned to any of the preceding categories.

If the cause of the failure could not reasonably be determined, the Failure Cause Category Code "Unknown" (Code K) was selected, along with one or more Failure Cause Description Codes that are the most likely causes of failure.

Failure Cause Description Code

The Failure Cause Description Code identifies the cause of or contributing factors to the failure.

Where a definite cause is not established, codes indicating the suspected cause were chosen and based on the narrative in the "Description of Cause" in the OR.

A maximum of 3 two-character codes were used for this field. At least one code was entered for all of the events. The following valid codes apply:

Mechanical Causes

AB - Foreign/Incorrect Material -

internal environment containing an unanticipated material, such as water, or the use of an unspecified material--Includes air in instrument sensing lines.

AC - Particulate Contamination -

failure due to buildup of suspended solids in fluid systems.

AD - Normal/Abnormal Wear -

loss of function due to a gradual change in configuration or loss of material.

AE- Lubrication Problem -

failure directly attributable to improper or insufficient lubrication.

AF - Weld-related -

weld fracture, crack, or heat-affected zone failure attributable to the welding process.

AG - Abnormal Stress -

material stress attributable to abnormal load, vibration, temperature, pressure, or flow.

AV- Connection Defective/Loose Parts -

loose mechanical parts or fasteners.

AZ - Material Defect -

material type as specified but with integrity compromised due to a flaw or leak.

BB - Mechanical Damage/Binding -

loss of proper mechanical configuration due to excessive forces; or mechanical flaw not attributable to any one subcomponent, component, or part, including unknown mechanical flaws or failures not reproducible.

BC - Out of Mechanical Adjustment -

loss of proper mechanical alignment, movement limits, or configuration not due to damage--Includes loose setscrews, locknuts, mechanical stops, and changes in setpoints of adjustable fixtures.

BD - Aging/Cyclic Fatigue -

time-related degradation of mechanical properties without significant loss of material (as through wear)--Includes radiation damage, embrittlement, and fatigue cracking of material subjected to stress reversals.

BE - Dirty -

loss of function due to deposition of extraneous material on operating surfaces, such as the moving parts of circuit breakers and pilot-valve seats.

BF - Blocked/Obstructed -

loss of flow function due to lodged objects or solids--Includes loss of movement due to mechanical interference other than binding.

BG - Corrosion -

failure attributable to loss of material or buildup of chemical reaction products from electrochemical or stress-aided corrosion.

Electrical/Electronic Causes

AG - Abnormal Stress -

loss of function due to stress-related causes attributable to voltage spikes, oscillations, and other occurrences.

AR - Insulation Breakdown -

loss of electrical circuit integrity, including shorts, arcs, and burned windings, attributable to failure of the insulation itself--If insulation failure was caused by breakdown due to local combustion, overload, and/or electrical fire, a code of AX was used.

AS - Shorted/Grounded -

loss of integrity of electrical circuit due to a shorted or grounded circuit.

AT - Open Circuit -

in operability of electrical circuit due to a break in conductor or contacts not made up.

AU - Contacts Burned/Pitted/Corroded -

in operability of electrical circuit due to degradation of electrical contacts.

AV - Connection Defective/Loose Parts -

loose electrical terminal connection or one containing intermittent contact- or high electrical-resistance.

AW - Circuit Defective -

electrical or electronic circuit fault not attributable to any one subcomponent, component, or part, including unknown electronic faults or failures not reproducible.

AX - Burned/Burned Out -

loss of integrity of electrical circuit, in including insulation breakdown due to local combustion, overload, and/or electrical fire.

AY - Electrical Overload -

loss of function specifically attributable to unanticipated high electrical current.

AZ - Material Defect -

material type as Specified, but with a flaw.

BD - Aging/Cyclic Fatigue -

time-related degradation of electrical properties such as occurs with components like capacitors, resistors, and solid-state devices.

BE - Dirty -

loss of function due to deposition of extraneous material on operating surfaces, such as electrical contacts.

BG - Corrosion -

failure attributable to loss of material or buildup of chemical reaction products from electrochemical corrosion.

Adjustment/Human Related

AA - Foreign/Wrong Part -

part does not belong in responsible component or system--Includes poor designs and misapplication.

AL - Setpoint Drift -

drift attributable to poor stability of control set point--This applies to components that have some type of actuation or trip function at a specific value (trip point, relief valve setting). This code includes changes in the relief-valve set point during operation due to changes in the bleed rate of the pilot-valve seat," but not to changes due to previous repair or mechanical adjustment.

AM - Previous Repair/Installation Status -

inadequate repair resulting from lack of proper action during previous maintenance, installation, or restoration to operational status.

AN - Incorrect Procedure -

failure directly attributable to an inadequate or improper instruction or approved procedure.

BC - Out of Mechanical Adjustment -

loss of proper mechanical alignment, movement limits, or configuration not due to damage--Includes loose setscrews, locknuts, and mechanical stops and changes in settings of adjustable fixtures.

BH - Out of Calibration -

electrical/mechanical outputs not in the specified tolerance within a range of possible operation (transmitters, computation modules). Code AL was used if the failure involved failure of some type of actuation function or trip (instrument setpoint).

BJ - Incorrect Action -

degradation and loss of proper function directly due to human error.

Table A.1 BNL Spreadsheet/Database for Ventilation System ORs (Sorted by Component)

Occurrence Report #	Field Office	Discovery Date	UCNI	Failed Component	Component Affected	Detection Method	Cause Category	Cause Description 1	Cause Description 2	Cause Description 3
ID--WINC-ICPP-1992-0002	ID	01/06/92	N	N	ALARM	J	K	BJ	AA	?
ALO-LA-LANL-TRITFACILS-1993-0007	ALO	11/13/93	N	Y	BATTERY	A	K	AG		
RFO--EGGR-771OPS-1991-1033	RFO	09/18/91	N	Y	BELT	A	F	AD		
ALO-LA-LANL-TSF-1993-0003	ALO	05/12/93	N	Y	BRKR	A	D	AV		
RL--WHC-PFP-1991-1009	RL	06/09/91	N	Y	BRKR	A	F	AM		
SR--WSRC-TRIT-1993-0041	SR	06/11/93	N	Y	BRKR	C	K	AV		
SR--WSRC-HCAN-1993-0096	SR	10/13/93	N	N	BRKR	C	K	AL		
ALO-LA-LANL-CMR-1993-0001	ALO	01/01/93	N	Y	BRKR	A	J	AG	?	
RFO--EGGR-ANALYTOPS-1992-0046	RFO	04/10/92	N	N	CKTBRK	C	F	AG	AN	
ORO-MMES-Y12QUALSER-1991-1007	ORO	12/12/91	N	Y	CKTBRK	A	K	AW		
RFO--EGGR-PUFAB-1992-0372	RFO	12/13/92	N	Y	CKTBRK	C	K	AG		
RFO--EGGR-ANALYTOPS-1991-1099	RFO	12/09/91	N	N	CKTBRK	A	E	BJ		
SR--WSRC-FCAN-1992-0054	SR	08/09/92	N	Y	CKTBRK	C	K	AG		
SR--WSRC-REACK-1992-0159	SR	07/09/92	P	Y	CMPTR	A	A	BF	AN	
RFO--EGGR-ANALYTOPS-1991-1010	RFO	06/22/91	N	N	DAMPER	D	F	BC		
RFO--EGGR-ANALYTOPS-1991-1005	RFO	05/10/91	N	N	DAMPER	C	F	AN	MGT	
RFO--EGGR-PUFAB-1992-0147	RFO	07/20/92	N	Y	DAMPER	B	H	BD	AV	
RFO--EGGR-ANALYTOPS-1993-0129	RFO	08/30/93	N	N	DAMPER	C	J	AV		
SR--WSRC-S235-1993-0004	SR	08/13/93	Y	N	DAMPER	J	B	AN		
RFO--EGGR-PUFAB-1992-0180	RFO	07/20/92	N	Y	DAMPER	B	K	AV	BC	
SR--WSRC-REACK-1991-1179	SR	11/03/91	P	Y	DAMPER	C	F	BG	AN	
SR--WSRC-REACK-1991-1170	SR	10/24/91	P	N	DAMPER	A	B	AN	BB	
SR--WSRC-HCAN-1992-0009	SR	02/12/92	P	N	DAMPER	A	B	AN	BJ	
SR--WSRC-FBLINE-1992-0046	SR	05/13/92	N	N	DAMPER	C	B	AN		
RFO--EGGR-PUFAB-1993-0126	RFO	07/25/93	N	Y	DAMPER	H	J	AU		
SR--WSRC-FBLINE-1991-1030	SR	11/25/91	P	N	DAMPER	C	F	BJ	AN	
SR--WSRC-FBLINE-1992-0013	SR	01/24/92	P	N	DAMPER	E	F	AM	BJ	
RFO--EGGR-371OPS-1993-0028	RFO	04/12/93	N	N	DAMPER	H	K	BC		
ALO-DA-EGGM-EGGMAT02-1993-0018	ALO	10/19/93	N	Y	DAMPER	A	F	BJ	AN	
SR--WSRC-HCAN-1992-0012	SR	03/02/92	N	Y	DOOR	A	A	BC		
SR--WSRC-HCAN-1992-0079	SR	10/07/92	P	N	DOOR	J	A	BD	AN	
SR--WSRC-HCAN-1993-0040	SR	05/17/93	Y	N	DOOR	C	B	AN		
SR--WSRC-FBLINE-1993-0026	SR	06/15/93	Y	N	DUCT	C	K	BJ		
SR--WSRC-HCAN-1993-0095	SR	10/06/93	Y	N	DUCT	J	F	BJ		
SR--WSRC-HBLINE-1993-0016	SR	06/25/93	N	Y	DUCT	H	D	AG	BJ	

Table A.1 BNL Spreadsheet/Database for Ventilation System ORs (Sorted by Component)

Occurrence Report #	Field Office	Discovery Date	UCNI	Failed Component	Component Affected	Detection Method	Cause Category	Cause Description 1	Cause Description 2	Cause Description 3
SAN--LLNL-LLNL-1992-0098	SAN	10/16/92	N	Y	DUCT	J	H	AZ	BG	
RFO--EGGR-ANALYTOPS-1992-0010	RFO	01/17/92	N	N	DUCT	C	E	BJ		
SR--WSRC-LTA-1993-0032	SR	05/10/93	N	N	DUCT	H	J	AC		
SR--WSRC-LTA-1993-0034	SR	05/12/93	N	N	DUCT	H	J	AC		
ALO-KC-AS-KCP-1993-0022	ALO	10/11/93	N	N	DUCT	B	F	BC	AN	
SR--WSRC-SEPGEN-1992-0002	SR	03/13/92	N	N	DUCT	E	A	AN		
RFO--EGGR-ANALYTOPS-1991-1101	RFO	12/12/91	N	N	ELECON	D	B	AN		
RFO--EGGR-771OPS-1992-0012	RFO	01/24/92	N	Y	ELECON	C	K	AW		BD
RFO--EGGR-771OPS-1992-0022	RFO	12/18/92	N	Y	ELECON	A	K	AS		
ALO-LA-LANL-LANL-1993-0005	ALO	05/13/93	N	N	ELECON	A	J	AG		
ORO--MMES-Y12DEFPGM-1993-0045	ORO	08/03/93	N	Y	ELECON	A	F	BJ		
ID--ROCK-SMC-1991-1026	ID	07/25/91	N	Y	ELECON	C	K	AX		
ORO--MMES-Y12SITE-1993-0036	ORO	07/27/93	N	Y	ENGINE	A	F	AW	AM	
SR--WSRC-FCAN-1993-0037	SR	07/11/93	N	N	ENGINE	C	C	AV		
SR--WSRC-FCAN-1993-0021	SR	04/13/93	N	Y	ENGINE	E	D	BJ	AS	
SR--WSRC-FCAN-1993-0010	SR	03/08/93	N	Y	ENGINE	F	J	BH		
SR--WSRC-TRIT-1991-1005	SR	06/01/91	N	Y	ENGINE	A	A	AG	BJ	
SR--WSRC-TRIT-1993-0041	SR	06/11/93	N	Y	ENGINE	C	D	AT		
SR--WSRC-FCAN-1992-0061	SR	09/11/92	N	Y	ENGINE	A	H	BD		
SR--WSRC-HCAN-1992-0016	SR	03/18/92	N	Y	ENGINE	A	D	AV	AA	
SR--WSRC-S247-1993-0012	SR	04/29/93	N	Y	ENGINE	C	K	NA		
SR--WSRC-HCAN-1993-0079	SR	08/18/93	N	N	ENGINE	C	J	AY		
SR--WSRC-HCAN-1993-0047	SR	06/01/93	N	Y	ENGINE	A	B	AG	AN	
RL--WHC-PFP-1991-1023	RL	10/09/91	N	N	FAN	F	F	AM	AB	
SR--WSRC-LTA-1992-0050	SR	10/21/92	N	N	FAN	F	D	AW		
SR--WSRC-FCAN-1993-0045	SR	08/26/93	Y	Y	FAN	A	B	AS		
SR--WSRC-HCAN-1993-0091	SR	09/20/93	N	Y	FAN	C	K	AS		
RFO--EGGR-PUFAB-1993-0093	RFO	05/11/93	N	Y	FAN	F	F	AG	AA	
RFO--EGGR-PUFAB-1993-0053	RFO	03/14/93	N	Y	FAN	C	K	XX		
RL--WHC-PFP-1991-0222	RL	03/18/91	N	Y	FAN	D	A	BC		
ORO-MMES-X10CHEMTC-1991-1004	ORO	06/10/91	N	N	FAN	C	B	AN		
SR--WSRC-FBLINE-1992-0003	SR	01/03/92	P	N	FAN	A	E	BJ		
ALO-LA-LANL-CMR-1993-0023	ALO	07/29/93	N	N	FAN	E	F	AM		
SR--WSRC-FBLINE-1993-0025	SR	06/13/93	Y	N	FAN	F	J	AG		
SR--WSRC-FCAN-1993-0018	SR	04/02/93	N	Y	FAN	F	B	AV	AN	
SR--WSRC-HBLINE-1992-0029	SR	12/23/92	N	N	FAN	A	E	BJ		
SR--WSRC-FCAN-1993-0054	SR	11/01/93	Y	N	FAN	A	F	BJ		

Table A.1 BNL Spreadsheet/Database for Ventilation System ORs (Sorted by Component)

Occurrence Report #	Field Office	Discovery Date	UCNI	Failed Component	Component Affected	Detection Method	Cause Category	Cause Description 1	Cause Description 2	Cause Description 3
SR--WSRC-FBLINE-1992-0009	SR	01/15/92	P	N	FAN	A	E	BJ		
SR--WSRC-FBLINE-1993-0016	SR	04/09/93	N	Y	FAN	F	J	AG		
SR--WSRC-FBLINE-1992-0050	SR	06/11/92	N	N	FAN	F	B	AN		
RFO--EGGR-ANALYTOPS-1992-0062	RFO	06/04/92	N	Y	FAN	A	H	BD		
RFO--EGGR-PUFAB-1992-0138	RFO	06/18/92	N	N	FAN	F	K	XX		
RFO--EGGR-PUFAB-1992-0147	RFO	06/28/92	N	N	FAN	H	K	XX		
RFO--EGGR-771OPS-1993-0004	RFO	01/08/93	N	Y	FAN	B	H	BC		
RFO--EGGR-ANALYTOPS-1992-0013	RFO	01/24/92	N	Y	FAN	H	H	BD		
RFO--EGGR-ANALYTOPS-1991-0102	RFO	02/26/91	N	Y	FAN	A	J	AW		
RFO--EGGR-ANALYTOPS-1993-0071	RFO	05/17/93	N	Y	FAN	C	H	AW		
RFO--EGGR-ANALYTOPS-1993-0011	RFO	02/01/93	N	Y	FAN	F	J	AT		
RFO--EGGR-ANALYTOPS-1991-0094	RFO	02/21/91	N	Y	FAN	A	J	AV		
RFO--EGGR-ANALYTOPS-1991-1081	RFO	11/14/91	N	Y	FAN	H	H	BD		
SAN--LLNL-LLNL-1992-0013	SAN	01/30/92	N	Y	FLTR	C	H	BD		
SR--WSRC-FBLINE-1992-0029	SR	04/30/92	N	N	FLTR	C	F	AM		
RFO--EGGR-ANALYTOPS-1992-0057	RFO	05/21/92	N	Y	FLTR	C	F	AC		
RFO--EGGR-ANALYTOPS-1992-0093	RFO	09/03/92	N	Y	FLTR	C	F	AC		
RFO--EGGR-774OPS-1991-1003	RFO	05/30/91	N	Y	FLTR	C	C	AZ		
SR--WSRC-HCAN-1991-0034	SR	03/08/91	N	N	FLTR	E	B	AN		
SR--WSRC-LTA-1993-0037	SR	05/26/93	N	Y	FLTR	H	A	AC		
RFO--EGGR-ANALYTOPS-1991-1086	RFO	11/22/91	N	Y	FLTR	C	F	AC	AN	
ORO-MMES-Y12METLPRP-1991-1014	ORO	08/21/91	N	Y	FLTR	C	F	AM		
RFO--EGGR-ANALYTOPS-1991-1104	RFO	12/26/91	N	Y	FLTR	C	F	AC	AN	
SR--WSRC-HCAN-1993-0073	SR	07/22/93	Y	Y	GASKET	H	K	BC		
RFO--EGGR-ANALYTOPS-1991-1058	RFO	09/24/91	N	N	ICNTRL	C	B	AL	AN	
SR--WSRC-FBLINE-1993-0037	SR	07/20/93	Y	N	ICNTRL	H	B	BJ		
SR--WSRC-FBLINE-1993-0038	SR	08/04/93	Y	Y	ICNTRL	C	?	NA		
SR--WSRC-FBLINE-1993-0049	SR	11/04/93	Y	Y	ICNTRL	C	?	NA		
RFO--EGGR-ANALYTOPS-1993-0015	RFO	02/05/93	N	N	ICNTRL	F	K	AW		
RFO--EGGR-ANALYTOPS-1993-0007	RFO	01/25/93	N	N	ICNTRL	C	B	AN		
RFO--EGGR-ANALYTOPS-1992-0005	RFO	01/15/92	N	N	ICNTRL	A	K	AG		
RFO--EGGR-ANALYTOPS-1992-0054	RFO	05/16/92	N	N	ICNTRL	A	K	AY		
RFO--EGGR-ANALYTOPS-1992-0037	RFO	03/27/92	N	Y	ICNTRL	E	K	BD	BG	
RFO--EGGR-ANALYTOPS-1991-1065	RFO	10/11/91	N	N	ICNTRL	C	B	AL	AN	
RFO--EGGR-ANALYTOPS-1991-1086	RFO	11/22/91	N	N	ICNTRL	C	B	AL	AN	
RFO--EGGR-ANALYTOPS-1992-0056	RFO	05/20/92	N	N	ICNTRL	C	A	AA		
RFO--EGGR-ANALYTOPS-1993-0018	RFO	02/15/93	N	N	ICNTRL	F	A	AG		AM
RFO--EGGR-ANALYTOPS-1993-0077	RFO	05/27/93	N	N	ICNTRL	C	H	BD		
SR--WSRC-FBLINE-1992-0057	SR	07/01/92	N	N	ICNTRL	F	K	AG		
RFO--EGGR-ANALYTOPS-1993-0078	RFO	05/27/93	N	Y	ICNTRL	A	K	AL		

Table A.1 BNL Spreadsheet/Database for Ventilation System ORs (Sorted by Component)

Occurrence Report #	Field Office	Discovery Date	UCNI	Failed Component	Component Affected	Detection Method	Cause Category	Cause Description 1	Cause Description 2	Cause Description 3
RL--WHC-PFP-1991-1018	RL	09/19/91	N	N	ICNTRL	A	B	AN		
RFO--EGGR-ANALYTOPS-1993-0121	RFO	08/19/93	N	N	ICNTRL	C	K	AL		
SR--WSRC-FBLINE-1992-0060	SR	08/02/92	N	N	ICNTRL	F	J	BH		
RFO--EGGR-371OPS-1993-0005	RFO	01/25/93	N	Y	ICNTRL	F	H	AW		
RFO--EGGR-ANALYTOPS-1993-0055	RFO	04/24/93	N	Y	ICNTRL	A	A	AA		
RFO--EGGR-ANALYTOPS-1993-0030	RFO	03/01/93	N	N	ICNTRL	C	J	BJ	BB	
SR--WSRC-FBLINE-1992-0076	SR	11/23/92	P	N	ICNTRL	F	K	BH		
SR--WSRC-FBLINE-1992-0077	SR	11/22/92	P	N	ICNTRL	F	K	BH		
RFO--EGGR-PUFAB-1991-1006	RFO	04/25/91	N	N	INDREC	F	K	AW	AA	
RL--WHC-PUREX-1991-1012	RL	05/22/91	N	Y	INDREC	E	H	BD	BJ	
RFO--EGGR-PUFAB-1992-0200	RFO	08/01/92	N	N	INDREC	C	B	AN		
RFO--EGGR-PUFAB-1991-1097	RFO	09/23/91	N	Y	INDREC	F	F	AG	AN	
RFO--EGGR-PUFAB-1991-1001	RFO	04/12/91	N	Y	INDREC	E	K	BB		
ALO-DA-EGGM-EGGMAT01-1993-0010	ALO	07/10/93	N	N	INST	F	A	AG	AA	
SR--WSRC-HBLINE-1991-1006	SR	06/10/91	N	Y	IXMITR	A	F	AS	AN	
RFO--EGGR-SUPPORT-1992-0032	RFO	04/23/92	N	Y	MOTOR	A	K	AG		
RL--WHC-PFP-1991-0194	RL	03/07/91	N	Y	MOTOR	A	E	AS		
RFO--EGGR-PUFAB-1993-0013	RFO	01/17/93	N	Y	MOTOR	H	K	AE	BD	
SR--WSRC-REACK-1991-1153	SR	09/24/91	P	Y	MOTOR	A	D	AM	AT	
RFO--EGGR-371OPS-1993-0023	RFO	03/23/93	N	Y	MOTOR	A	H	AD		
RFO--EGGR-PUFAB-1992-0129	RFO	06/10/92	N	Y	MOTOR	F	H	AY	BD	
ALO-LA-LANL-ESHUPT-1991-1566	ALO	08/06/91	N	N	NA	A	K	NX		
SR--WSRC-FBLINE-1993-0008	SR	01/27/93	P	NA	NA	X	X	XX		
ID--ROCK-SMC-1991-0001	ID	01/09/91	N	N	NA	E	K	NX		
RFO--EGGR-ANALYTOPS-1991-1006	RFO	05/25/91	N	Y	RELAY	C	H	BD		
RFO--EGGR-ANALYTOPS-1991-0159	RFO	03/27/91	N	Y	RELAY	C	H	BH		
RFO--EGGR-771OPS-1992-0080	RFO	08/21/92	N	Y	RELAY	B	K	AU		
RFO--EGGR-ANALYTOPS-1991-1077	RFO	11/01/91	N	N	SAAM	E	D	AA		
RFO--EGGR-371OPS-1993-0067	RFO	09/01/93	N	N	SAAM	C	F	BJ		
RFO--EGGR-ANALYTOPS-1991-1078	RFO	11/01/91	N	Y	STMTRAP	A	J	AG	BJ	
ALO-LA-LANL-TSF-1993-0006	ALO	11/15/93	N	Y	SWITCH	A	D	AS	AA	
RL--WHC-PFP-1993-0065	RL	12/26/93	N	Y	UPS	F	?	NA		
ALO-LA-LANL-TA55-1992-0003	ALO	01/07/92	N	N	VALVE	A	F	AM	AN	AM.
RFO--EGGR-371OPS-1992-0099	RFO	12/08/92	N	N	VALVE	A	E	BJ		
SR--WSRC-REACK-1993-0043	SR	02/13/93	P	Y	VALVE	A	H	BD		
RFO--EGGR-ANALYTOPS-1992-0038	RFO	03/30/92	N	N	VALVE	C	D	AA		

Table A.2 BNL Spreadsheet/Database for Ventilation System ORs (Sorted by OR Number)

Occurrence Report #	Field Office	Discovery Date	UCNI	Failed Component	Component Affected	Detection Method	Cause Category	Cause Description 1	Cause Description 2	Cause Description 3
ALO-DA-EGGM-EGGMAT01-1993-0010	ALO	07/10/93	N	N	INST	F	A	AG	AA	
ALO-DA-EGGM-EGGMAT02-1993-0018	ALO	10/19/93	N	Y	DAMPER	A	F	BJ	AN	
ALO-KC-AS-KCP-1993-0022	ALO	10/11/93	N	N	DUCT	B	F	BC	AN	
ALO-LA-LANL-CMR-1993-0001	ALO	01/01/93	N	Y	BRKR	A	J	AG	?	
ALO-LA-LANL-CMR-1993-0023	ALO	07/29/93	N	N	FAN	E	F	AM		
ALO-LA-LANL-ESHUPT-1991-1566	ALO	08/06/91	N	N	NA	A	K	NX		
ALO-LA-LANL-LANL-1993-0005	ALO	05/13/93	N	N	ELECON	A	J	AG		
ALO-LA-LANL-TA55-1992-0003	ALO	01/07/92	N	N	VALVE	A	F	AM	AN	AM
ALO-LA-LANL-TRITFACILS-1993-0007	ALO	11/13/93	N	Y	BATTERY	A	K	AG		
ALO-LA-LANL-TSF-1993-0003	ALO	05/12/93	N	Y	BRKR	A	D	AV		
ALO-LA-LANL-TSF-1993-0006	ALO	11/15/93	N	Y	SWITCH	A	D	AS	AA	
ID--ROCK-SMC-1991-0001	ID	01/09/91	N	N	NA	E	K	NX		
ID--ROCK-SMC-1991-1026	ID	07/25/91	N	Y	ELECON	C	K	AX		
ID--WINC-ICPP-1992-0002	ID	01/06/92	N	N	ALARM	J	K	BJ	AA	?
ORO--MMES-Y12DEFPGM-1993-0045	ORO	08/03/93	N	Y	ELECON	A	F	BJ		
ORO--MMES-Y12SITE-1993-0036	ORO	07/27/93	N	Y	ENGINE	A	F	AW	AM	
ORO-MMES-X10CHEMTC-1991-1004	ORO	06/10/91	N	N	FAN	C	B	AN		
ORO-MMES-Y12METLPRP-1991-1014	ORO	08/21/91	N	Y	FLTR	C	F	AM		
ORO-MMES-Y12QUALSER-1991-1007	ORO	12/12/91	N	Y	CKTBRK	A	K	AW		
RFO--EGGR-371OPS-1992-0099	RFO	12/08/92	N	N	VALVE	A	E	BJ		
RFO--EGGR-371OPS-1993-0005	RFO	01/25/93	N	Y	ICNTRL	F	H	AW		
RFO--EGGR-371OPS-1993-0023	RFO	03/23/93	N	Y	MOTOR	A	H	AD		
RFO--EGGR-371OPS-1993-0028	RFO	04/12/93	N	N	DAMPER	H	K	BC		
RFO--EGGR-371OPS-1993-0067	RFO	09/01/93	N	N	SAAM	C	F	BJ		
RFO--EGGR-771OPS-1991-1033	RFO	09/18/91	N	Y	BELT	A	F	AD		
RFO--EGGR-771OPS-1992-0012	RFO	01/24/92	N	Y	ELECON	C	K	AW		BD
RFO--EGGR-771OPS-1992-0022	RFO	12/18/92	N	Y	ELECON	A	K	AS		
RFO--EGGR-771OPS-1992-0080	RFO	08/21/92	N	Y	RELAY	B	K	AU		
RFO--EGGR-771OPS-1993-0004	RFO	01/08/93	N	Y	FAN	B	H	BC		
RFO--EGGR-774OPS-1991-1003	RFO	05/30/91	N	Y	FLTR	C	C	AZ		
RFO--EGGR-ANALYTOPS-1991-0094	RFO	02/21/91	N	Y	FAN	A	J	AV		
RFO--EGGR-ANALYTOPS-1991-0102	RFO	02/26/91	N	Y	FAN	A	J	AW		
RFO--EGGR-ANALYTOPS-1991-0159	RFO	03/27/91	N	Y	RELAY	C	H	BH		
RFO--EGGR-ANALYTOPS-1991-1005	RFO	05/10/91	N	N	DAMPER	C	F	AN	MGT	
RFO--EGGR-ANALYTOPS-1991-1006	RFO	05/25/91	N	Y	RELAY	C	H	BD		
RFO--EGGR-ANALYTOPS-1991-1010	RFO	06/22/91	N	N	DAMPER	D	F	BC		
RFO--EGGR-ANALYTOPS-1991-1058	RFO	09/24/91	N	N	ICNTRL	C	B	AL	AN	

Table A.2 BNL Spreadsheet/Database for Ventilation System ORs (Sorted by OR Number)

Occurrence Report #	Field Office	Discovery Date	UCNI	Failed Component	Component Affected	Detection Method	Cause Category	Cause Description 1	Cause Description 2	Cause Description 3
RFO--EGGR-ANALYTOPS-1991-1065	RFO	10/11/91	N	N	ICNTRL	C	B	AL	AN	
RFO--EGGR-ANALYTOPS-1991-1077	RFO	11/01/91	N	N	SAAM	E	D	AA		
RFO--EGGR-ANALYTOPS-1991-1078	RFO	11/01/91	N	Y	STMTRAP	A	J	AG	BJ	
RFO--EGGR-ANALYTOPS-1991-1081	RFO	11/14/91	N	Y	FAN	H	H	BD		
RFO--EGGR-ANALYTOPS-1991-1086	RFO	11/22/91	N	N	ICNTRL	C	B	AL	AN	
RFO--EGGR-ANALYTOPS-1991-1086	RFO	11/22/91	N	Y	FLTR	C	F	AC	AN	
RFO--EGGR-ANALYTOPS-1991-1099	RFO	12/09/91	N	N	CKTBRK	A	E	BJ		
RFO--EGGR-ANALYTOPS-1991-1101	RFO	12/12/91	N	N	ELECON	D	B	AN		
RFO--EGGR-ANALYTOPS-1991-1104	RFO	12/26/91	N	Y	FLTR	C	F	AC	AN	
RFO--EGGR-ANALYTOPS-1992-0005	RFO	01/15/92	N	N	ICNTRL	A	K	AG		
RFO--EGGR-ANALYTOPS-1992-0010	RFO	01/17/92	N	N	DUCT	C	E	BJ		
RFO--EGGR-ANALYTOPS-1992-0013	RFO	01/24/92	N	Y	FAN	H	H	BD		
RFO--EGGR-ANALYTOPS-1992-0037	RFO	03/27/92	N	Y	ICNTRL	E	K	BD	BG	
RFO--EGGR-ANALYTOPS-1992-0038	RFO	03/30/92	N	N	VALVE	C	D	AA		
RFO--EGGR-ANALYTOPS-1992-0046	RFO	04/10/92	N	N	CKTBRK	C	F	AG	AN	
RFO--EGGR-ANALYTOPS-1992-0054	RFO	05/16/92	N	N	ICNTRL	A	K	AY		
RFO--EGGR-ANALYTOPS-1992-0056	RFO	05/20/92	N	N	ICNTRL	C	A	AA		
RFO--EGGR-ANALYTOPS-1992-0057	RFO	05/21/92	N	Y	FLTR	C	F	AC		
RFO--EGGR-ANALYTOPS-1992-0062	RFO	06/04/92	N	Y	FAN	A	H	BD		
RFO--EGGR-ANALYTOPS-1992-0093	RFO	09/03/92	N	Y	FLTR	C	F	AC		
RFO--EGGR-ANALYTOPS-1993-0007	RFO	01/25/93	N	N	ICNTRL	C	B	AN		
RFO--EGGR-ANALYTOPS-1993-0011	RFO	02/01/93	N	Y	FAN	F	J	AT		
RFO--EGGR-ANALYTOPS-1993-0015	RFO	02/05/93	N	N	ICNTRL	F	K	AW		
RFO--EGGR-ANALYTOPS-1993-0018	RFO	02/15/93	N	N	ICNTRL	F	A	AG		AM
RFO--EGGR-ANALYTOPS-1993-0030	RFO	03/01/93	N	N	ICNTRL	C	J	BJ	BB	
RFO--EGGR-ANALYTOPS-1993-0055	RFO	04/24/93	N	Y	ICNTRL	A	A	AA		
RFO--EGGR-ANALYTOPS-1993-0071	RFO	05/17/93	N	Y	FAN	C	H	AW		
RFO--EGGR-ANALYTOPS-1993-0077	RFO	05/27/93	N	N	ICNTRL	C	H	BD		
RFO--EGGR-ANALYTOPS-1993-0078	RFO	05/27/93	N	Y	ICNTRL	A	K	AL		
RFO--EGGR-ANALYTOPS-1993-0121	RFO	08/19/93	N	N	ICNTRL	C	K	AL		
RFO--EGGR-ANALYTOPS-1993-0129	RFO	08/30/93	N	N	DAMPER	C	J	AV		
RFO--EGGR-PUFAB-1991-1001	RFO	04/12/91	N	Y	INDREC	E	K	BB		
RFO--EGGR-PUFAB-1991-1006	RFO	04/25/91	N	N	INDREC	F	K	AW	AA	
RFO--EGGR-PUFAB-1991-1097	RFO	09/23/91	N	Y	INDREC	F	F	AG	AN	
RFO--EGGR-PUFAB-1992-0129	RFO	06/10/92	N	Y	MOTOR	F	H	AY	BD	
RFO--EGGR-PUFAB-1992-0138	RFO	06/18/92	N	N	FAN	F	K	XX		
RFO--EGGR-PUFAB-1992-0147	RFO	07/20/92	N	Y	DAMPER	B	H	BD	AV	
RFO--EGGR-PUFAB-1992-0147	RFO	06/28/92	N	N	FAN	H	K	XX		
RFO--EGGR-PUFAB-1992-0180	RFO	07/20/92	N	Y	DAMPER	B	K	AV	BC	

Table A.2 BNL Spreadsheet/Database for Ventilation System ORs (Sorted by OR Number)

Occurrence Report #	Field Office	Discovery Date	UCNI	Failed Component	Component Affected	Detection Method	Cause Category	Cause Description 1	Cause Description 2	Cause Description 3
RFO--EGGR-PUFAB-1992-0200	RFO	08/01/92	N	N	INDREC	C	B	AN		
RFO--EGGR-PUFAB-1992-0372	RFO	12/13/92	N	Y	CKTBRK	C	K	AG		
RFO--EGGR-PUFAB-1993-0013	RFO	01/17/93	N	Y	MOTOR	H	K	AE	BD	
RFO--EGGR-PUFAB-1993-0053	RFO	03/14/93	N	Y	FAN	C	K	XX		
RFO--EGGR-PUFAB-1993-0071	RFO	04/05/93	N	N	X	C	K	BH		
RFO--EGGR-PUFAB-1993-0093	RFO	05/11/93	N	Y	FAN	F	F	AG	AA	
RFO--EGGR-PUFAB-1993-0126	RFO	07/25/93	N	Y	DAMPER	H	J	AU		
RFO--EGGR-SUPPORT-1992-0032	RFO	04/23/92	N	Y	MOTOR	A	K	AG		
RL--WHC-PFP-1991-0194	RL	03/07/91	N	Y	MOTOR	A	E	AS		
RL--WHC-PFP-1991-0222	RL	03/18/91	N	Y	FAN	D	A	BC		
RL--WHC-PFP-1991-1009	RL	06/09/91	N	Y	BRKR	A	F	AM		
RL--WHC-PFP-1991-1018	RL	09/19/91	N	N	ICNTRL	A	B	AN		
RL--WHC-PFP-1991-1023	RL	10/09/91	N	N	FAN	F	F	AM	AB	
RL--WHC-PFP-1993-0065	RL	12/26/93	N	Y	UPS	F	?	NA		
RL--WHC-PUREX-1991-1012	RL	05/22/91	N	Y	INDREC	E	H	BD	BJ	
SAN--LLNL-LLNL-1992-0013	SAN	01/30/92	N	Y	FLTR	C	H	BD		
SAN--LLNL-LLNL-1992-0098	SAN	10/16/92	N	Y	DUCT	J	H	AZ	BG	
SR--WSRC-ALABF-1993-0030	SR	09/22/93	N	NA	X	?	?	NA		
SR--WSRC-FBLINE-1991-1030	SR	11/25/91	P	N	DAMPER	C	F	BJ	AN	
SR--WSRC-FBLINE-1992-0003	SR	01/03/92	P	N	FAN	A	E	BJ		
SR--WSRC-FBLINE-1992-0009	SR	01/15/92	P	N	FAN	A	E	BJ		
SR--WSRC-FBLINE-1992-0013	SR	01/24/92	P	N	DAMPER	E	F	AM	BJ	
SR--WSRC-FBLINE-1992-0029	SR	04/30/92	N	N	FLTR	C	F	AM		
SR--WSRC-FBLINE-1992-0046	SR	05/13/92	N	N	DAMPER	C	B	AN		
SR--WSRC-FBLINE-1992-0050	SR	06/11/92	N	N	FAN	F	B	AN		
SR--WSRC-FBLINE-1992-0057	SR	07/01/92	N	N	ICNTRL	F	K	AG		
SR--WSRC-FBLINE-1992-0060	SR	08/02/92	N	N	ICNTRL	F	J	BH		
SR--WSRC-FBLINE-1992-0076	SR	11/23/92	P	N	ICNTRL	F	K	BH		
SR--WSRC-FBLINE-1992-0077	SR	11/22/92	P	N	ICNTRL	F	K	BH		
SR--WSRC-FBLINE-1993-0008	SR	01/27/93	P	NA	NA	X	X	XX		
SR--WSRC-FBLINE-1993-0016	SR	04/09/93	N	Y	FAN	F	J	AG		
SR--WSRC-FBLINE-1993-0025	SR	06/13/93	Y	N	FAN	F	J	AG		
SR--WSRC-FBLINE-1993-0026	SR	06/15/93	Y	N	DUCT	C	K	BJ		
SR--WSRC-FBLINE-1993-0037	SR	07/20/93	Y	N	ICNTRL	H	B	BJ		
SR--WSRC-FBLINE-1993-0038	SR	08/04/93	Y	Y	ICNTRL	C	?	NA		
SR--WSRC-FBLINE-1993-0049	SR	11/04/93	Y	Y	ICNTRL	C	?	NA		
SR--WSRC-FCAN-1992-0054	SR	08/09/92	N	Y	CKTBRK	C	K	AG		
SR--WSRC-FCAN-1992-0061	SR	09/11/92	N	Y	ENGINE	A	H	BD		
SR--WSRC-FCAN-1993-0010	SR	03/08/93	N	Y	ENGINE	F	J	BH		
SR--WSRC-FCAN-1993-0018	SR	04/02/93	N	Y	FAN	F	B	AV	AN	
SR--WSRC-FCAN-1993-0021	SR	04/13/93	N	Y	ENGINE	E	D	BJ	AS	
SR--WSRC-FCAN-1993-0037	SR	07/11/93	N	N	ENGINE	C	C	AV		

Table A.2 BNL Spreadsheet/Database for Ventilation System ORs (Sorted by OR Number)

Occurrence Report #	Field Office	Discovery Date	UCNI	Failed Component	Component Affected	Detection Method	Cause Category	Cause Description 1	Cause Description 2	Cause Description 3
SR--WSRC-FCAN-1993-0045	SR	08/26/93	Y	Y	FAN	A	B	AS		
SR--WSRC-FCAN-1993-0054	SR	11/01/93	Y	N	FAN	A	F	BJ		
SR--WSRC-FCAN-1993-0065	SR	12/27/93	N	N	X	?	?	NA		
SR--WSRC-HBLINE-1991-1006	SR	06/10/91	N	Y	IXMITR	A	F	AS	AN	
SR--WSRC-HBLINE-1992-0029	SR	12/23/92	N	N	FAN	A	E	BJ		
SR--WSRC-HBLINE-1993-0016	SR	06/25/93	N	Y	DUCT	H	D	AG	BJ	
SR--WSRC-HCAN-1991-0034	SR	03/08/91	N	N	FLTR	E	B	AN		
SR--WSRC-HCAN-1992-0009	SR	02/12/92	P	N	DAMPER	A	B	AN	BJ	
SR--WSRC-HCAN-1992-0012	SR	03/02/92	N	Y	DOOR	A	A	BC		
SR--WSRC-HCAN-1992-0016	SR	03/18/92	N	Y	ENGINE	A	D	AV	AA	
SR--WSRC-HCAN-1992-0079	SR	10/07/92	P	N	DOOR	J	A	BD	AN	
SR--WSRC-HCAN-1993-0040	SR	05/17/93	Y	N	DOOR	C	B	AN		
SR--WSRC-HCAN-1993-0047	SR	06/01/93	N	Y	ENGINE	A	B	AG	AN	
SR--WSRC-HCAN-1993-0073	SR	07/22/93	Y	Y	GASKET	H	K	BC		
SR--WSRC-HCAN-1993-0079	SR	08/18/93	N	N	ENGINE	C	J	AY		
SR--WSRC-HCAN-1993-0091	SR	09/20/93	N	Y	FAN	C	K	AS		
SR--WSRC-HCAN-1993-0095	SR	10/06/93	Y	N	DUCT	J	F	BJ		
SR--WSRC-HCAN-1993-0096	SR	10/13/93	N	N	BRKR	C	K	AL		
SR--WSRC-LTA-1992-0050	SR	10/21/92	N	N	FAN	F	D	AW		
SR--WSRC-LTA-1993-0032	SR	05/10/93	N	N	DUCT	H	J	AC		
SR--WSRC-LTA-1993-0034	SR	05/12/93	N	N	DUCT	H	J	AC		
SR--WSRC-LTA-1993-0037	SR	05/26/93	N	Y	FLTR	H	A	AC		
SR--WSRC-REACK-1991-1153	SR	09/24/91	P	Y	MOTOR	A	D	AM	AT	
SR--WSRC-REACK-1991-1170	SR	10/24/91	P	N	DAMPER	A	B	AN	BB	
SR--WSRC-REACK-1991-1179	SR	11/03/91	P	Y	DAMPER	C	F	BG	AN	
SR--WSRC-REACK-1992-0159	SR	07/09/92	P	Y	CMPTR	A	A	BF	AN	
SR--WSRC-REACK-1993-0043	SR	02/13/93	P	Y	VALVE	A	H	BD		
SR--WSRC-S235-1993-0004	SR	08/13/93	Y	N	DAMPER	J	B	AN		
SR--WSRC-S247-1993-0012	SR	04/29/93	N	Y	ENGINE	C	K	NA		
SR--WSRC-SEPGEN-1992-0002	SR	03/13/92	N	N	DUCT	E	A	AN		
SR--WSRC-TRIT-1991-1005	SR	06/01/91	N	Y	ENGINE	A	A	AG	BJ	
SR--WSRC-TRIT-1993-0041	SR	06/11/93	N	Y	BRKR	C	K	AV		
SR--WSRC-TRIT-1993-0041	SR	06/11/93	N	Y	ENGINE	C	D	AT		

APPENDIX B
RECENT VENTILATION-RELATED REPORTS REVIEWED BY THE OFFICE OF NUCLEAR SAFETY

Operating Experience Weekly Summary (OEWS) reports published by the Office of Nuclear Safety often have provided very useful information about ventilation systems. This appendix lists the OEWS and occurrence reports referenced in the OEWS on selected topics. The OEWS discusses the problems in detail, gives useful guidance, and references related DOE Orders, DOE manuals, and Nuclear Regulatory Commission reports. For a copy of the OEWS, please contact Dick Trevillian (301)903-3074, or Bruce Breslau (301)903-7343.

Inadequate Preventive Maintenance Induced Ventilation System Failures/Shutdowns

NS Weekly Summary Report	OR Number
• Bearing Related Failures	
92-20	RFO-EGGR-PUFAB-1992-0231
93-27	RFO--EGGR-771OPS-1993-0068
93-8	RFO--EGGR-ANALYTOPS-1993-0021
93-8	RFO--EGGR-ANALYTOPS-1992-0084
93-6	RFO--EGGR-PUFAB-1993-0026
"	RFO--EGGR-PUFAB-1993-0022
"	RFO--EGGR-PUFAB-1993-0013
"	RFO--EGGR-PUFAB-1991-1154
"	RFO--EGGR-PUFAB-1992-0231
"	RFO--EGGR-PUFAB-1992-0038
• Drive Belt Related Failures	
93-23	SR--WSRC-RMAT1-1993-0009
"	SR--WSRC-REACK-1993-0096
"	SR--WSRC-FBLINE-1992-0004
"	SR--WSRC-FBLINE-1992-0014
93-18	RFO--EGGR-PUFAB-1993-0086
"	RFO--EGGR-PUFAB-1993-0084
"	ID--EGGR-ATR-1992-0005
"	ALO-LA-LANL-CHEMLASER-1991-1001
93-19	RFO--EGGR-PUFAB-1993-0093

Insufficient Routine Surveillance of Ventilation Parameters

93-25	SR--WSRC-FBLINE-1993-0026

Inadequate Post-Maintenance Testing/Reconfiguration

93-25	RL--WHC-FFTF-1993-0012

Inadequate Work Controls On Safety-Related Ventilation Systems

93-25	SR--WSRC-WVIT-1993-0048
"	RFO--EGGR-ANALYTOPS-1991-1054
"	RL--WHC-TANKFARM-1993-0011
93-19	SR--WSRC-TRIT-1993-0026
93-18	RFO--EGGR-ANALYTOPS-1993-0059
92-34	RFO--EGGR-371OPS-1992-0099

Inadequate Freeze Protection Induced Ventilation System Failures

93-18	RFO--EGGR-ANALYTOPS-1993-0055
"	RFO--EGGR-ANALYTOPS-1992-0005
"	RFO--EGGR-ANALYTOPS-1992-0118

Undocumented, Known, Pre-Conditions Leading to Loss of Ventilation

93-18	RFO--EGGR-771OPS-1993-0045

Unauthorized Alarm Bypasses

93-7	ID--WINC-ICPP-1992-0052

Inadequate Training

93-6	CH-AA-ANLW-EBR-1992-0011

Inadequate Procedure

93-5	RFO--EGGR-ANALYTOPS-1993-0007
93-1	SR--WSRC-HBLINE-1992-0029

Installation Error(s)

93-4	ORO--MMES-X10METCER-1993-0001

Non-Conformance of Installed Equipment

92-34	SR--WSRC-RTF-1992-0015

Component Failures w/o Identified Causes

92-36	ID--WVNS-CSS-1992-0004

Importance of Timely Preventive Maintenance

92-11	RFO-EGGR-ANALYTOPS-1992-0073

HEPA Filter Qualification Requirements

92-30	ALO-LA-LANL-ESHSUPT-1992-0010

Need For Comprehensive Acceptance Test Program

93-29	SR-WSRC-FCAN-1992-0083
93-29	SR-WSRC-FCAN-1993-0034

Failure of Solenoid-Operated Damper Valve

92-36	ID-WVNS-CSS-1992-0004

Need for Facility Walk-throughs After Power Interruptions

92-13	RL-PNL-PNLBOPER-1992-0045

Need for Proper Sequencing in Returning Equipment to Service After Power Failure

92-14	ID-WINC-ICPP-1992-0051
92-14	ID-EGG-TRA-1992-0015
92-14	CH-AA-ANLW-EBR-1992-0010
92-14	CH-AA-ANLW-AL-1992-0003

Inadequate Communication Between Personnel

92-28	RFO-EGGR-7710PS-1992-0099
93-25	CH-AA-ANLW-FCF-1993-0022
92-34	RFO-EGGR-3710PS-1992-0099

Need for Thorough Review of Work Package in Pre-Job Briefings

94-12	RL-WHC-PUREX-1994-0013
93-42	
92-36	

Need to Obtain Proper Authorization Before Changing Configuration of the System or Equipment

93-29	RL-WHC-PFP-1993-0040

Need for Periodic Self-Assessments to Identify Non-Compliance

93-37	ALO-LA-LANL-TSTA-1993-0005
"	ALO-LA-LANL-TRITFACILS-1993-0004
"	ALO-LA-LANL-TSF-1993-0003
"	ALO-LA-LANL-WASTEMGT-1993-0010
"	ALO-LA-LANL-TA55-1993-0044
"	ALO-LA-LANL-SECURITY-1993-0009

Need for Preventive Measures in Confined Spaces to Prevent Switch Bumping

92-18	ALO-AO-MHSM-PANTEX-1992-0050
93-45	SR-WSRC-FBLINE-1992-1020
"	SR-WSRC-FCAN-1993-0031
"	RFO-EGGR-ANALYTOPS-1992-0009
"	RL-WHC-TANKFARM-1993-0011

Importance of Controlling Moisture in Air Systems that Service Safety-Related Systems and Components

93-39	SR-WSRC-TRIT-1993-0016
"	CH-NBL-NBL-1993-0007
"	SR-WSRC-TRIT-1993-0016

Ventilation Air Reversals With the Potential to Spread Contamination

93-41	SR-WSRC-HBLINE-1991-1013
"	RFO-EGGR-3710PS-1992-0053
"	RL-PNL-324-1992-0011
"	SR-WSRC-HCAN-1992-0012
"	SR-WSRC-HCAN-1992-0009
94-07	RFO-EGGR-3710PS-1994-0016
"	RFO-EGGR-3710PS-1994-0018
"	RFO-EGGR-3710PS-1993-0028
"	SR-WSRC-HCAN-1993-0095
94-11	SR-WSRC-HCAN-1994-0033

Need for Procedure for Adequate Field Review in the Design Process for Facility Upgrades

93-25	SR-WSRC-FCAN-1993-0043
"	SR-WSRC-FCAN-1991-1015
"	SR-WSRC-FCAN-1991-1027

Cracking in Ventilation System Ducting

94-07,93-26,93-44	SAN-LLNL-LLNL-1992-0098
94-07	CH-NBL-NBL-1992-0002
"	SR-WSRC-BHLINE-1993-0016
93-44	ORO-MMES-X10CHEMTEC-1993-0016

APPENDIX C
NRC INSPECTION MANUAL PROCEDURE 93801

"Safety System Functional Inspection"

SAFETY SYSTEM FUNCTIONAL INSPECTION (SSFI)

PROGRAM APPLICABILITY: 2515

93801-01 INSPECTION OBJECTIVES

01.01 The primary objective of a Safety System Functional Inspection (SSFI) is to assess the operational performance capability of selected safety systems through an in-depth, multi-disciplinary engineering review to verify that the selected systems are capable of performing their intended safety functions. Generic safety significant findings are pursued across the system boundaries on a plant-wide basis.

01.02 The secondary objective of the SSFI is to determine the program-related root cause for identified performance deficiencies and analyze the implications of these deficiencies on the licensee's quality assurance program.

93801-02 INSPECTION REQUIREMENTS

02.01 Inspection Planning. Prior to the inspection, the team leader shall develop an inspection plan to address, at a minimum, the following points:

a. Background information relative to significant issues between the responsible Regional Office and the licensee, particularly as it may relate to engineering and plant design.

b. Identification of applicable sections of procedure 93801, identification of specific MC-2515 procedures, and any supplemental checklists and inspection elements, as assigned to each individual team member.

c. Selection of the systems and key components to be addressed by the team as initial inspection samples, based upon probabilistic risk assessment (PRA) considerations.

d. Assignments of individual team members to specific functional areas, and expectations regarding the type and timing of information to be provided to other team members, e.g., the recommendations, guidance, data, and requests originated by the engineering office team to the inspectors at the plant.

e. A timetable of events involving team coordination activities, such as site access training, entrance and exit meetings, coordination meetings, conference calls, due dates for issuance of intra-team data, etc.

02.02 System Selection. The SSFI should be performed on one principal safety system. During the planning process, the team leader should select a number of electrical, mechanical, and instrumentation and control components for detailed review. The majority of these components should be from the principal system with the remainder from support systems which are necessary for successful operation of the principal system or from interfacing safety systems served by the principal system.

02.03 Inspection Preparation. After selecting the safety system to be evaluated, the team leader and the engineering design inspectors conduct the pre-inspection trip to the site and engineering offices to assemble the plant procedures, drawings, modification packages, calculations, analysis and other background information. In addition, the inspectors collect all the documentation required for the remaining functional areas such as key administrative procedures. This information is copied, collated, and distributed to the inspection team members for their in-office preparation.

The engineering design inspection begins with the pre-inspection visit. The inspectors will communicate their initial engineering observations to the other team members for followup during the in-office preparation of their respective functional areas. This will include any identification of particularly sensitive areas noticed which warrant onsite reviews in the functional area.

As an option, the site members of the inspection team may accompany the team leader to the site during the pre-inspection visit to assist in reference material collection and to obtain site access training.

02.04 Conduct of the Inspection. After initial arrival on-site, the inspection team should establish contact with the applicable system engineers and conduct a general system walkdown either as a team or individually. The objective of this walkdown is familiarization with the general plant and specific system hardware and layout. A more detailed walkdown will be performed by the operations and maintenance inspectors later in the inspection.

The inspectors assigned to each of the functional areas should develop individual inspection plans to meet the inspection objectives listed in Section 01.01 and the inspection plan of Section 02.01. The inspection plans shall incorporate the following inspection requirements.

a. Engineering Design and Configuration Control

1. Review the design basis and other design documents such as calculations and analyses for the selected system and determine the functional requirements for the system and each active component during accident or abnormal conditions. This review should include verifying the appropriateness of the design assumptions, boundary conditions, and models. This may include

independent calculations by the engineering design inspectors. The review should determine if (1) the design basis is in accordance with the facility's licensing commitments and regulatory requirements, (2) the design bases, analyses, and associated design output documents such as facility drawings and procurement specifications are correct, and (3) if the installed system and components are tested to verify that the design bases have been met.

2. Review the configuration of the selected system as installed in the plant and determine if the drawings which reflect the as-built design and installation match the current design documents and licensing requirements and commitments for the facility.

3. Determine if the as-built and modified system is capable of functioning as specified by the current design documents and licensing requirements and commitments for the facility.

4. Determine if the system operation is consistent with the design documents. Advise the site inspectors of any discrepancies for further review and operations evaluation.

5. Evaluate the licensee's drawing control program, the control and use of design input information, and the adequacy of design calculations from the perspective of modifications made to the selected safety system.

6. Review all modifications made to the original system that could have potentially changed the design basis. Determine if the system meets the design basis and the facility's licensing requirements in the as-modified configuration.

7. Determine if system modifications implemented since initial licensing have introduced any unreviewed safety questions.

8. Review the modification packages for the selected safety system to ensure that all changes to the support elements have been made (pursuant to ANSI N45.2.11), including maintenance requirements and procedures, operating procedures, training documentation and training programs, periodic testing, and procurement documentation and specifications. Identify any discrepancies to the site inspectors for further review and evaluation.

9. Evaluate the interface between engineering and technical support and plant operations.

10. If available, review (usually toward the end of the inspection) the results of the licensee's internal SSFI reviews and technical audits (of the selected system when available).

b. <u>Operations</u>

1. Identify the key components of the system and the components to be evaluated during this inspection.

2. Review the technical adequacy and accuracy of alarm response procedures and operating procedures for normal, abnormal and emergency system operations.

3. Review operator training for the selected system, focusing on the technical completeness and accuracy of the training manual and lesson plans. Ensure that the lesson plans reflect the system modifications and that the licensed operators have been trained on these modifications.

4. Walk-through the system operating procedures and the system P&IDs with the operators. Verify that the procedures can be performed using the main control panel and the alternate shutdown panel and that components and equipment are accessible for normal and emergency operation. If any special equipment is required to perform these procedures, determine if the equipment is available and in good working order. Verify that the knowledge level of the operators is adequate concerning equipment location and operation.

5. Conduct interviews with the operators to determine the adequacy of their technical knowledge of the operation of the system, its role in accident mitigation, Technical Specification surveillance requirements, determinations of operability, etc.

6. Verify the local operation of equipment. Determine whether the indication available to operate the equipment is in accordance with applicable operating procedures and instructions. Verify that the environmental conditions assumed under accident conditions are adequate for remote operation of equipment, such as expected room temperature, emergency lighting, steam, etc.

7. Verify that the support systems and procedures are adequate to support the selected safety system during the event sequences that it is designed to initiate.

c. <u>Maintenance</u>

1. Identify the key components of the system and the components to be evaluated during this inspection.

2. In conjunction with other interested functional areas (such as Operations), conduct an in-depth system walkdown.

3. Witness any maintenance performed on the selected system while the team is onsite.

4. Review maintenance procedures for technical adequacy. Determine if the procedures are sufficient to perform the maintenance task and provide for identification and evaluation of equipment and work deficiencies. Check the procedure content against the vendor manuals to verify that the procedure satisfies the vendor requirements, as determined applicable by the licensee, for maintaining the equipment in proper working order. Verify that important vendor manuals are complete and up-to-date.

5. Review the maintenance program for the selected system to determine if the preventive maintenance (PM) requirements are adequate and comprehensive.

6. Determine if the system components are being adequately maintained to ensure their operability under all accident conditions.

7. Review applicable vendor manuals, generic communications (i.e., Bulletins, Information Notices, Generic Letters, and special studies) and verify that the licensee has integrated and implemented the applicable items into the maintenance program.

8. Review the component history files for the selected components for the past two years; however, a longer interval may be necessary. While reviewing the maintenance history, look for recurring equipment problems and attempt to determine if any trends exist. Select several maintenance activities and verify each for technical adequacy, performance of appropriate post-maintenance testing and satisfactory demonstration of equipment operability.

9. Conduct detailed interviews with the maintenance personnel to determine their technical knowledge of how components are maintained, such as setting limit switches, pump coupling alignments, and breaker maintenance.

10. Determine if maintenance personnel receive adequate training pertaining to the selected safety system and if the degree of training provided is consistent with the amount of technical detail included in procedures.

d. <u>Surveillance and Testing</u>

1. Identify the key components of the system and the components to be evaluated during this inspection.

2. Review and evaluate the technical adequacy and accuracy of all of the Technical Specification surveillance procedures and inservice test procedures performed in the past two years for this system. Attention should be focused on the specific components selected for detailed review.

3. Verify that the system has been tested in accordance with the accident analysis. Determine if the testing adequately ensures that the system will operate as designed under postulated accident conditions. Verify that the surveillance test procedure acceptance criteria are adequate to demonstrate continued operability.

4. Determine if surveillance test procedures comprehensively address required system responses.

5. Evaluate the support systems and plant modifications selected for review by the engineering team to ensure that system design capability as demonstrated by preoperational testing has not been compromised.

6. Review the component history files, looking for indications of adverse trends or recurrent test failures.

7. Review the inservice test records for pumps and valves in the selected safety system, emphasizing the technical adequacy and accuracy of the data. Attention should be focused on the specific components selected for detailed review.

8. Conduct interviews with instrumentation and control technicians, discussing in detail such items as how specific instruments are tested, how valve stroke time testing is performed, and how and where temporary test equipment is installed.

9. Determine if engineering and technical support personnel contribute to surveillance test procedures and if they review test results.

10. Witness any post-maintenance, surveillance, and inservice tests performed on the selected system while the inspection team is onsite.

e. Quality Assurance and Corrective Actions

1. Review the Plant Onsite Safety Review Committee and the Offsite Safety Review Committee meeting minutes for the past six months for items pertaining to the selected system. Identify any discrepancies and unusual operability determinations to the operations and design inspectors.

2. Review the open item tracking system for items pertaining to the selected safety system.

3. Conduct technical interviews with key quality assurance and quality control personnel to determine their technical knowledge and level of involvement in field activities.

4. Review the operational history of the selected system, including licensee event reports (LERs), nuclear plant reliability data system (NPRDS) reports, 10 CFR 50.72 reports, enforcement actions, nonconformance reports, and maintenance work requests, with an emphasis on adequacy of root cause evaluations. Limit the review of work requests to a sample of work requests ready for implementation, with emphasis on hold point identification.

5. Compare the results of the team's assessment of the areas inspected for the selected system with the results of applicable licensee quality verification activities in the same areas (i.e., operations, maintenance, surveillance and testing, engineering design, and design control). In cases where the same findings exist, determine why they have not been corrected. In cases where the team found conditions which were missed by the licensee, determine why the licensee's quality verification activities were not capable of finding these issues.

6. Review the status of the corrective actions for the findings of applicable licensee SSFI reviews and technical audits (of the selected system when available).

03.01 General Guidance. The predominant feature of an SSFI is the use of a deep vertical slice technique to accomplish the inspection objectives. The term "deep vertical slice" refers to the in-depth review of a selected safety system in six functional areas. These areas are operations, maintenance, surveillance and testing, engineering design, design control, and quality assurance and self-assessment. When a weakness in a functional area is identified, the inspection is expanded to determine if a programmatic weakness exists. For example, if the selected safety system is the auxiliary feedwater system and a weakness in motor operated valve torque switch settings is identified by the maintenance inspector, then a preliminary review of programmatic controls for torque switches should be performed. In contrast, a programmatic inspection technique typically examines functional areas by arbitrarily selecting and observing activities in a given functional area across a variety of systems.

The SSFI determines whether the system is capable of performing the safety functions required by the design basis and licensing requirements and commitments, and if the testing is adequate to demonstrate that the system would perform all of the safety functions required. The SSFI verifies that the system maintenance and material condition are adequate to ensure system performance under postulated accident conditions and that the operator and technician training are adequate to ensure proper operations, testing and maintenance of the system. The human factors considerations relating to the selected system (such as accessibility and labeling of valves) and the supporting procedures for the system are reviewed to verify adequacy and to ensure proper system operation under normal and accident conditions. The management controls including procedures are reviewed to verify that the safety system will fulfill the functions required by the safety analysis and that the support systems required for system operation are capable of performing their required functions in the expected accident environments.

The SSFI technique emphasizes the functionality of the selected safety system. The focus of the inspection should be on the system and hardware operation, maintenance, engineering design, design control, surveillance and testing, and quality assurance and corrective actions -- and not on a review of programmatic requirements. The SSFI method has been successful in disclosing specific safety-related hardware, design, or operational problems and issues that call into question the reliance on affected safety systems for continued plant operation. Because the safety systems selected for review are not normally challenged or periodically tested to the outer limits of their design basis, a heightened measure of confidence in system functionality and reliability can be provided by an SSFI evaluation. Based on the safety benefits of the inspection, it is important to correctly select the system for evaluation and to prepare for the inspection prior to arrival onsite.

Past experience with SSFIs has demonstrated that identifying and retrieving the detailed design basis requirements for the selected safety system can be quite difficult and time consuming for the inspection team as well as for the licensee. The difficulty in clearly identifying design basis requirements at older plants is related to the fact that the information often has never been assembled and is typically scattered among the records stored at the plant, the licensee's corporate offices, the A/E's offices, and the NSSS vendor's

offices. Consequently, an effort should be made to provide the licensee with adequate advanced notice regarding the system to be inspected to allow the licensee time to begin collecting the needed documentation.

The licensee is required by 10 CFR 50, Appendix B and 10 CFR 50.59 to fully understand the design basis for all safety systems and the modifications to those systems since initial licensing. As a minimum, the licensee should have documentation available to support any system design changes.

For older plants, it may be difficult for the licensee to retrieve design bases and other design documents such as calculations and analyses. If the selected system has not been modified since initial licensing, the fact that original documents are not available to demonstrate safety system functionality does not in itself raise an operability question. It may be possible to determine operability by licensee surveillance testing, review of pre-operational test data, or other means. However, for systems modified since operating license issuance, the licensee should have a sufficient set of design documents to demonstrate that design margins have not been unacceptably reduced. Therefore, for plants where original design documents are difficult to retrieve, the team should focus on reviewing system modifications and responses to NRC Bulletins and Generic Letters that would require licensees to assess the adequacy of their facility, at least on a topical basis, and which would have required the regeneration of a limited set of design documents.

The inspectors should verify that the as-built configuration of the system is in accordance with the design basis and the licensing basis. In addition, the inspectors should also verify that the current surveillance and testing requirements assure that the system meets its licensing basis and will perform the safety functions.

The facility's licensing basis is the set of regulatory requirements and licensing commitments that form the basis for issuance of the operating license and for the continued safe operation of the facility. The licensing basis is contained in NRC regulations, plant technical specifications, the Final Safety Analysis Report, NRC safety evaluation reports, and licensee commitments such as these in response to NRC generic notifications or to NRC violations. The licensing basis changes with time. For example, as technical specification amendments are issued, the licensing basis is updated.

Inspectors in all areas should be sensitive to the human factors considerations related to the selected system (e.g., accessibility and labeling of components).

03.02 Guidance for Inspection Requirement 02.02. The ideal system for an SSFI is one that is heavily relied upon for accident mitigation and has been significantly modified over plant life. If available, the plant-specific PRA should be reviewed as part of the system selection methodology. The PRA should demonstrate that the system would be involved in the dominant sequences for high core melt frequency. The recommended system is to have been originally designed by the architect engineer (A/E) because systems designed by the nuclear steam supply system (NSSS) vendor are generally subject to more rigid design and modification controls than the A/E-designed systems. Modifications to NSSS vendor-designed systems are typically performed by the NSSS vendor and modifications to A/E-designed systems are often

soley performed by the licensee's engineering staff. Therefore, the potential for compromising the design basis and reducing safety may be greater for an A/E-designed system than for an NSSS vendor-designed system, although an NSSS vendor-designed system is acceptable for evaluations.

Studies conducted by the Office for Analysis and Evaluation of Operational Data also can provide useful data for determining which system to select. In addition, the previous NRC inspection history and licensee self-assessments, including SSFIs, should be considered in selecting the system for review.

03.03 Guidance for Inspection Requirement 02.03. The engineering design inspection begins with the pre-inspection visit to allow beginning the design portion of the inspection two-weeks earlier than the rest of the inspection. This increases the effectiveness of the inspection because it allows the engineering team more onsite review time. This additional time is required because the engineering team must review a considerable amount of design documentation to determine if the system design basis has been maintained throughout the modification process. In addition, this method allows communicating the initial engineering observations to the other members of the team for follow-up during the in-office preparation of their respective functional areas.

During the in-office preparation phase, the following items should be reviewed by each inspector to obtain a detailed working understanding of the system operation and design bases:

a. Final Safety Analysis Report (FSAR) and Updated Safety Analysis Report (USAR).
b. Site-specific administrative procedures.
c. System descriptions and design basis documents (if available).
d. Site-specific training documents for the system.
e. Technical Specification requirements and surveillance test procedures.
f. System piping and instrumentation drawings (P&IDs), one-line diagrams and logic diagrams.
g. Engineering calculations (e.g., equipment sizing and short circuit analysis).
h. Temporary and permanent modifications, including safety evaluations.
i. Relevant regulatory information such as Information Notices, Generic Letters, and special studies that apply to the system.
j. Applicable MC 2515 inspection modules for the assigned functional areas.
k. ANSI standards applicable to the assigned functional areas.
l. Licensee event reports (LERs) for the past 12 months.
m. Inspection reports for the past 12 months.
n. Licensee engineering design guides.
o. Significant nonconformance reports.

Each team member should study the documentation to become as familiar as possible and achieve an in-depth understanding of the selected system (e.g., safety function in all modes of operation, major system flow paths, essential safety features actuation signals, system alignment during accident mitigation, safety interlocks, etc.). The inspectors should become familiar with system hardware, design basis, operation, testing and maintenance requirements, and equipment history. They should also become familiar with the accident sequences that the system is designed to mitigate, as well as the

accident analysis assumptions for the system. Additionally, each inspector should have a working knowledge of the plant's key administrative controls such as the design change process, control of maintenance, and the quality assurance (QA) program.

03.04 Guidance for Inspection Requirement 02.04. The effectiveness of the SSFI method is greatly enhanced if the various inspection team members are able to benefit from each other's inspection efforts. Accordingly, daily team meetings are required to allow the team members to share their findings. Experience indicates that many of the more significant findings originate from team meeting discussions that allow related inspection findings in different functional areas to be pieced together. Through the synergism of team meetings, seemingly unrelated observations in one functional area may lead key inspectors responsible for other functional areas to examine specific issues leading to a broader understanding of problem areas.

03.05 Guidance for Inspection Requirement 02.04a. The design review portion of the inspection should be performed by inspectors with extensive nuclear plant design experience, preferably comparable to the experience gained through previous employment with an architect engineering firm. It is important also that the inspectors performing the design review have a good understanding of integrated plant operations, maintenance, testing, and quality assurance so that they are able to relate their findings to the other functional areas being inspected. To this extent it is recommended that contractor support be used when this specific expertise is not internally available.

In reviewing the functional adequacy of the selected system, the inspector should determine if the design basis is met by the installed and tested configuration. The inspector should understand not only the original purpose of the design, but the manner and conditions under which the system will actually be required to function. For example:

a. For valves: What permissive interlocks are involved? What differential pressures will exist when the valve strokes? Will the valve be repositioned during the course of the event? What is the source of control and indication power? What control logic is involved? What manual actions are required to backup and restore a degraded function?

b. For pumps: What are the flow paths the pump will experience during accident scenarios? Do the flow paths change? What permissive interlock and control logic applies? How is the pump controlled during accident conditions? What manual actions are required to back up and restore a degraded function? What suction and discharge pressures can the pump be expected to experience during accident conditions? What is the motive power for the pump during all conditions? Does vendor data and specifications support sustained operations at low flows?

c. For instrumentation and sensors: What plant parameters are used as inputs to the initiation and control system? Is operator intervention required in certain scenarios? Are the range and accuracy of instrumentation adequate? What is the extent of surveillance and calibrations of such instrumentation?

When comparing the as-built design with the current design basis and the licensing requirements for the selected system, the inspector should consider the following questions:

a. Are the assumptions upon which the original design was based adequate? For example, are service water flow capacities sufficient with the minimum number of pumps available under accident conditions? Are the voltage studies accurate and will the required MOVs and relays operate under end-of-life battery conditions and degraded grid voltages? Are fuses and thermal overloads properly sized? Are current dc loads within the capacity of the station batteries? Is the instrumentation adequate in range and accessibility for operations to control the system under normal and abnormal conditions?

b. Have modified structures surrounding safety equipment, components, or structures been evaluated for seismic 2-over-1 considerations, and have modified equipment components falling under the scope of 10 CFR 50.49 been thoroughly evaluated for environmental equipment qualifications considerations such as temperature, radiation, and humidity?

c. If the as-built documents have been marked for the design changes on an interim basis, have additional measures been taken including document review, approval and safe guarding the marked documents and related papers until the changes have been incorporated on the revised documents.

When reviewing modifications to a safety system, the inspector should verify that marked-up copies of drawings are used for future design change activities until the revised as-built document incorporating all the marked-up changes is officially issued.

03.06 Guidance for Inspection Requirement 02.04b. When reviewing the normal, abnormal and emergency operating procedures, the inspector should assess the technical adequacy of the procedures and determine if the procedural steps will achieve required system performance for normal, abnormal, remote shutdown, and emergency conditions. This should include consideration of operator actions to compensate for shortcomings in design. The inspectors should determine if the system is operated in accordance with the system design and if operations personnel receive adequate training pertaining to the selected system. In addition, the degree of training provided should be consistent with the amount of technical detail included in procedures. In particular, verify that operators are trained on system response, failure modes, and required actions involved in all credible scenarios in which the system is required to function.

The inspector should verify that the emergency, off-normal, and abnormal operating procedures are adequate to handle the most limiting design basis events. Where it is not reasonable for procedures to provide detailed guidance, the inspector should verify that the licensee's training program ensures that the operators are knowledgeable in the areas of concern.

The inspector should verify that the operations personnel have the ability to reference an up-to-date and accurate copy of the control room documents. This is necessary because the controlled drawings may not be revised, unless changes due to modifications are extensive. As an interim measure, some

utilities have marked-up a controlled set of the control room documents to show the design changes. In such situations, the inspector should also verify that revisions of the controlled documents incorporating the marked-up changes are performed in a timely manner following the modification. The timeliness of document revision should be consistent to the safety significance of the modified system. Effects of marked-up design changes should not preclude the document being a useable reference document, i.e., without clutter which could cause difficulty in determining the actual installed configuration.

The inspector should verify that the marked-up changes to the control room drawings have been reflected in changes to the normal, abnormal, and emergency operating procedures as necessitated by the scope of the change.

03.07 Guidance for Inspection Requirement 02.04c. When performing the review of maintenance records, it is essential for the inspector to understand the technical details of how the activities were performed. For example, the inspector should consider whether the closing limit switches were set with the motor-operated valve fully shut or partially open and off the valve seat.

The inspectors should witness as much actual maintenance work as possible during the onsite inspection. These performance observations provide valuable insights into the work quality and capability of maintenance craft personnel that is otherwise difficult to determine.

As part of the detailed system walkdown, the inspectors should analyze the adequacy of the system lineup, accessibility, and indications relative to the most limiting design basis conditions (e.g., degraded power and lighting, single failure, loss of nonsafety indications, and harsh environments). This walkdown should be a very detailed hand-over-hand verification to ensure that the as-built configuration agrees with the P&ID. The following attributes should be considered:

a. Determine if components are accurately labeled and accessible. For example, can the components be operated locally or manually if required and is there health physics or security considerations?

b. Determine if motor-operated valve (MOV) operators and check valves (particularly lift check valves) are installed in the orientation required by the manufacturer. Additionally, a human factors assessment of the component (such as the direction of handwheel rotation for valves installed upside down and the number of turns required for full valve travel) should be made.

c. Determine if the system lineup is consistent with the design and licensing basis requirements. This lineup inspection should include considerations of the normal and backup power supplies, control circuitry, indication and annunciation status, and sensing lines for instrumentation.

d. Determine if manually operated components can be operated under accident conditions (i.e., radiation levels, temperatures, and manpower requirements).

When reviewing the preventive maintenance requirements, the inspector should assess whether the vendor-recommended maintenance task is addressed by the maintenance program. For example, are the PMs current for this system? Are corrective maintenance procedures available for major system components? Are limit and torque switch settings proper? Is the instrument air system adequately maintained to ensure the reliability of pneumatic valves? Are fuse and thermal overload sizes correct and are pipe supports, seismic restraints and shielding being maintained? In addition, the inspector should verify that all the required vendor manuals are available and that the latest revisions and bulletins have been reviewed and incorporated into the maintenance requirements. Special attention should be taken to ensure that the appropriate level of detail and guidance is provided in maintenance procedures, especially at facilities where maintenance is performed in accordance with the "skill of the craft."

03.08 Guidance for Inspection Requirement 02.04d. The review of test records should go beyond a review of the in-service testing and surveillance programs required for Technical Specifications. The inspector should answer the fundamental question of whether the safety system and all included components have been adequately tested to demonstrate that they can accomplish their intended safety functions as defined by their design basis. The inspector should determine if the system components have been adequately tested to demonstrate that they can perform their safety function under all conditions they might experience in an accident situation. Although it is not always possible to test the systems in the exact accident configuration or condition, engineering analysis or similar testing (such as containment spray nozzle smoke tests) should have been performed. The testing of the system to be reviewed should include initial testing and periodic testing. Initial testing can include tests such as manufacturer's bench tests, installation checks, preoperational testing, and startup or power ascension testing. Periodic testing can include tests such as technical specification surveillance tests, post-maintenance tests, in-service tests, and preventive maintenance testing.

When reviewing the technical adequacy of the surveillance and testing procedures, the inspector must ensure that the test procedures comprehensively address the required system responses. For example, the inspector should verify that the test lineup duplicates the accident response lineup and that the check valves are tested to prevent reverse flow. The test should not establish any artificial initial conditions; however, the determination of adequate testing may require consideration of removing all actuator power, including both electrical and pneumatic, for fail-safe valves. In addition, support systems and plant modifications should be evaluated to ensure that the system's functional capability, as demonstrated by preoperational testing, has not been compromised. For instance, the addition of a fire barrier in an emergency core cooling system (ECCS) pump room may compromise room cooling capabilities by altering air flow paths. The inspector should also verify that post-maintenance testing demonstrates that the system functional capability has been maintained. Finally, the inspector should verify that the periodic test adequately confirms the continued operability of the safety system.

03.09 Guidance for Inspection Requirement 02.04e. During interviews with the quality assurance (QA) and quality control (QC) technicians, the inspector should attempt to determine their level of knowledge and involvement in field activities.

When reviewing the operational experience of the selected system, the inspector should attempt to determine the historical reliability of the system and its components based on the review and analysis of the operational experience. The inspector should determine if the licensee has aggressively pursued, identified, and corrected root causes of failures. In addition, the inspector should determine the extent of the maintenance backlog and ascertain if the licensee has a program to identify, prioritize, and perform timely safety maintenance activities.

93801-04 INSPECTION RESOURCE ESTIMATE

04.01 Team Composition. The typical SSFI team composition includes six to seven inspectors (three or four operational and three engineering design) assigned to the following areas: operations, maintenance, surveillance and testing, quality assurance and corrective actions, mechanical system design, electrical system design, and instrumentation and control (I&C) design. A mechanical components design area may also be added. The detailed system walkdown can be done by an additional inspector participating for only part of the onsite activities, or this aspect can be jointly performed by the maintenance and operations inspectors. The engineering design inspection assignments may be modified depending on the particular system selected for inspection.

A full-time team leader without any specific area assignments should have the primary responsibility to provide guidance and coordinate team activities. It is recommended that the team leader have several years of inspection experience. The senior resident inspector for the site being inspected should not normally be assigned as a participating team member; however, their involvement in the inspection process should be encouraged to the extent the resident duties will allow.

The engineering design inspectors should have extensive architect engineering experience within their assigned discipline area. In many cases, it may be necessary to use contractor support to provide this specific expertise. When contractor support is used, the engineering design and design control functional areas are normally assigned to an experienced NRC inspector who functions as the engineering discipline sub-team leader. This inspector works closely with the engineering design engineers and must have excellent communication skills. This assignment is particularly important on inspections where the licensee's corporate engineering offices are not located onsite. A significant potential exists to isolate the design and inspection portions of the team due to the physical separation of the team members. In this case, extraordinary measures, such as daily team teleconferences with follow-up individual conversations or weekly full team meetings, should be taken to ensure full communication between the team members.

04.02 Inspection Duration. The length of the inspection, including a one week preparation, is about eight weeks. The licensee should be notified of the safety systems selected to be reviewed at least two weeks in advance of the pre-inspection visit. This minimum amount of time is necessary due to the difficulty most licensees have experienced in locating and reassembling the design basis documents. During the first week of the inspection, the team leader and the engineering design inspectors visit the site and corporate offices to perform the pre-inspection visit, obtain the required plant

procedures, drawings, and other support information and begin the engineering design inspection. The inspection report preparation will require, at a minimum, an additional two weeks effort for all team members immediately following the inspection exit. A longer period will be required of the team leader to issue the report.

04.03 Inspection Schedule. The following guidance is provided for resource commitments and planning in conducting the inspection from start to finish.

Week 1	Pre-inspection visit by the team leader and the engineering design inspectors to collect necessary background information and relay expectations to the licensee for the remainder of the inspection. Entrance meeting for the design phase of the inspection at the best location, either site or corporate, which will allow access to the licensee's knowledgeable engineers and to review modification packages and calculations.
Week 2	Team leader copies, collates, and distributes background information to all team members.
Week 3	Begin in-office review of design inspection work. Briefings on the preliminary concerns of the engineering design team are performed this week.
Week 4	Entrance meeting at site. The entire inspection team, including design inspectors, begins on-site inspection activities.
Week 5	In-office review of inspection documentation and internal NRC management briefings on preliminary inspection findings and potential operational issues. No on-site or engineering office inspection activities. This period off-site allows the licensee time to review the outstanding concerns and questions identified so far during the inspection.
Week 6	The entire inspection team, including the engineering design inspectors, returns on-site for one week to complete the inspection and follow-up on the outstanding issues and concerns. The pre-exit rehearsal is conducted late Thursday afternoon with the participation of NRC management representatives. The exit meeting is held on Friday morning.
Week 7-8	Inspection report input preparation by the team.
Week 9-11	Report completion by the team leader.

93801-05 ADDITIONAL NRC INSPECTION GUIDANCE

05.01 Based upon the inspection observations, the team leader will be responsible to develop an input for the facility Systematic Assessment of Licensee Performance report. This input will predominately address the Engineering and Technical Support functional area. Consideration should be given to the responsiveness of the engineering organization to plant requirements. Overall conclusions should be drawn with respect to the adequacy of the engineering processes.

05.02 The general guidelines for team inspections are provided in Manual Chapter 2900, "Team Inspections." The following inspection procedures are applicable for reference during the inspection:

35701	-	QA Program Annual Review
37700	-	Design, Design Changes and Modifications
37701	-	Facility Modifications
37702	-	Design Changes and Modifications Program
41701	-	Licensed Operator Training
42700	-	Plant Procedures
61700	-	Surveillance Procedures and Records
61725	-	Surveillance Testing and Calibration Control Program
61726	-	Monthly Surveillance Observations
62702	-	Maintenance Program
62703	-	Monthly Maintenance Observations
62704	-	Instrumentation Maintenance (Components and Systems) Observation of Work, Work Activities, and Review of Quality Records
62705	-	Electrical Maintenance (Components and Systems) Observation of Work, Work Activities, and Review of Quality Records
71707	-	Operational Safety Verification
71710	-	ESF System Walk Down
72701	-	Modification Testing
73051	-	Inservice Inspection -- Review of Program
73055	-	Inservice Inspection -- Data Review and Evaluation

END

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