SESSION VI

VENTILATION CONTROL

Tuesday, August 13, 1974
CHAIRMAN: Robert Yoder

CHAIRMAN'S INTRODUCTORY REMARKS:

In this session there are three papers addressing ventilation control in plutonium facilities, two papers addressing glove box ventilation , and two papers addressing the control of ventilation in nuclear power reactors. In proceeding from sound basic engineering design principles to implementation by construction and operation of ventilation systems, there are numerous conflicts and requirements that beg solution. There are experts who disagree with selected alternatives as well as basic philosophy. Questions regarding performance and control under extreme stress (for example, earthquakes, fires, tornados or explosions) are still being debated and we are awaiting additional confirmative data to demonstrate that the selected controls will function as required. Problems of the recirculation of ventilation air, the need for stacks and energy requirements, particularly as applied to heating, ventilating, and air conditioning, are presenting new challenges to both designer and user.

The design analyses that have been performed will provide some assurance that a system will function under stress, and I have every expectation that the present generation of air cleaning systems will function as designed, but I suggest that our designs must meet our performance expectations and intentions. It will be our inability to understand and anticipate the system performance problems which may cause our greatest dismay when mal-functions occur. The papers in this session, I'm sure, will add to our understanding in this area.

VENTILATION DESIGN FOR NEW PLUTONIUM RECOVERY FACILITY

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I. Abstract

In 1972 the Atomic Energy Commission (AEC) issued revised guidelines on "Minimum Design Criteria for New Plutonium Facilities." With these criteria as guidelines, a new Plutonium Recovery Facility is being designed and constructed at the AEC Rocky Flats Plant.

This report presents the methods by which the confinement of contamination and air treatment are being handled in this facility.

II. Introduction

The new Plutonium Recovery Facility will replace an existing facility of similar nature which was placed into operation in 1952. In 1968 it was determined that the old building would require extensive modification to meet the ever increasingly stringent objectives of a plutonium handling facility. Approval was given to proceed with a new replacement building incorporating the best and latest technology available.

The building structure is designed to withstand the effects of all contemplated natural phenomena and internal accident conditions to provide ultimate confinement of radioactive materials.

The building will be divided into compartments served by various ventilating and air cleaning systems that will confine any potential contamination release to the building structure. Three zones of contamination confinement are incorporated into the design:

1. The primary Zone I confinement consisting of process enclosures; i.e., gloveboxes and storage vaults, and their ventilation and air cleaning systems.

2. The secondary Zone II confinement consisting of the operating area compartments and their ventilation and air cleaning systems.

3. The tertiary Zone III confinement comprising the building structure and its ventilation and air cleaning systems.

Each of these zones will contain associated fire protection systems and environmental sampling equipment. In addition, Zone I will contain back-up filter plenum capacity and a criticality drain system.

III. Description

The minimum design criteria state that the design of the facility will "Protect the public and operating personnel from hazards associated with normal plutonium operations and design basis accident conditions including the effects of natural phenomena pertinent to the site." [1, 2]

Design basis accidents (DBA) are the postulated accidents and resulting conditions for which the confinement structure, systems, and equipment must meet their functional goals.

Confinement Structure (Building).

The above statements make it mandatory that the building structure be designed to provide ultimate confinement of radioactive materials under normal operations and design basis accident conditions. The degree of confinement of radioactive materials shall be sufficient to limit releases to the environment to the lowest practical level.

The guideline in use at Rocky Flats is 6×10^{-14} curies per cubic meter (Ci/m^3).

In order to design such a building, the effects of the natural phenomena, particularly in the area of earthquake and tornadoes, had to be analyzed. A complete review and study of all existing data pertinent to natural phenomena for the site area were undertaken. Leading consultant firms in the field of seismology, hydrology, and tornado studies were contracted for their help and recommendations.

The results of the consultant firm's tornado surveys are in Fig. 1. The original design basis figures are also listed in the table for comparative purposes. The design basis figures will be noted to be conservative and are being used for calculations in the design of the structure.

TORNADO DESIGN CRITERIA

CONSULTANTS RECOMMENDATIONS		ADOPTED CRITERIA
	TORNADO CHARACTERISTICS	
200 MPH	TANGENTIAL WIND SPEED	300 MPH
50 MPH	TRANSLATIONAL WIND SPEED	60 MPH
1.2 PSI	ATMOSPHERIC PRESSURE CHANGE	1.7 PSI
150 FT	RADIUS OF 75 MPH WINDS	220 FT
	MISSILE CRITERIA	
	— 4"x 12"x 12' WOODEN PLANK —	
200 MPH	HORIZONTAL VELOCITY	200 MPH
130 MPH	VERTICAL VELOCITY	130 MPH
	— AUTOMOBILE (3000 LBS) —	
40 MPH	HORIZONTAL VELOCITY	50 MPH

FIGURE 1

The ground rules for the structural design, including loading combinations and construction of critical safety and fire protection items, are in accordance with current editions of pertinent nationally recognized codes and standards as referenced in AECM-6301.

Confinement by Ventilation.

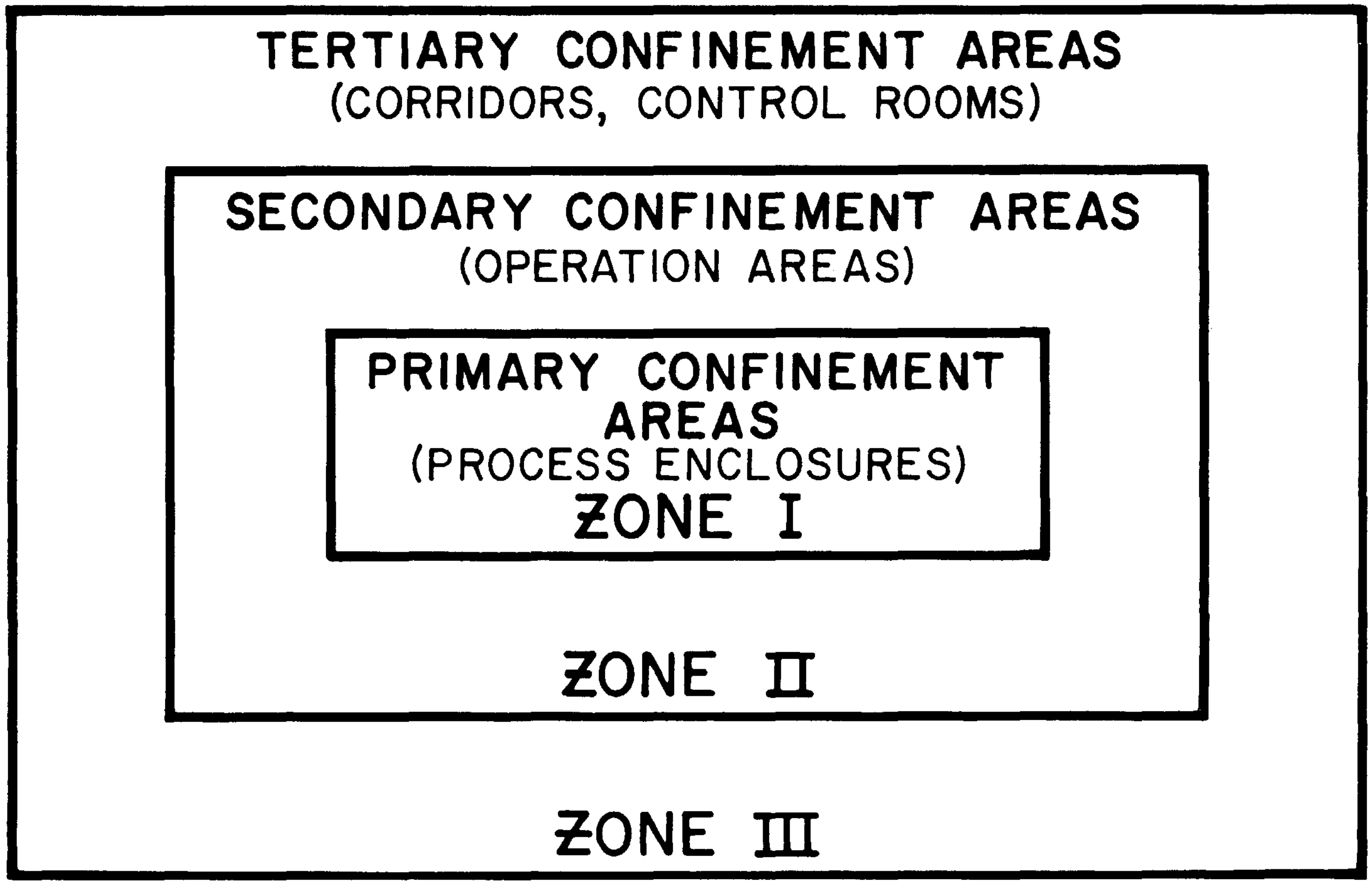
Three phases of contamination confinement are being incorporated in the design of the building as represented by Fig. 2. These are classified as primary, secondary, and tertiary confinement areas. The primary Zone I confinement areas are the process enclosures; i.e., gloveboxes, storage vaults, and canyons and their ventilation systems. Secondary Zone II confinement areas are the operating area compartments, their ventilation systems and the Zone I ventilating system equipment rooms. The tertiary Zone III confinement areas are the building structure, its ventilation system, and the Zone II and III ventilating system equipment rooms.

Primary Confinement Zone I.

The process enclosures are being designed to provide a first stage of confinement during normal operations. All of the production operations will be accomplished inside of gloveboxes, canyons, or vaults and will be remotely controlled from area or process control rooms for each specific operation.

Air Ventilated Systems.

Ventilation for these enclosures will be either by direct ducted air supply or indirect random air supply from the process rooms. Normally the gloveboxes will be provided with indirect supply and the canyons and vaults will have direct air supply. In all cases the air will pass through an intake prefilter and a High Efficiency Particulate Air (HEPA) filter before entering the enclosure. These enclosures are classified as Zone I and will be controlled at a negative pressure of 0.75 inches Water Column ("W.C.) with respect to the process or operating room area, or 1.05" W.C. below atmosphere. The airflow through the enclosures will be controlled to maintain a minimum air change rate of 30 changes per hour. The air will be exhausted through a prefilter and a HEPA filter to a caustic flood type (packed tower) scrubber unit. After being scrubbed, the air will then proceed to a four-stage HEPA filter bank for final cleaning before being discharged to the atmosphere. The air leaving the scrubber should not exceed the limits of 90°F Dry Bulb (DB) and 65°F Dewpoint prior to entering the filter plenum. This requirement will eliminate moisture condensation on the filters and in the plenums.



CONTAMINATION CONFINEMENT AREAS

FIGURE 2

In some areas of the process, the operations require the application of heat which results in corrosive vapors and fog. In these areas, a special hood and collection system will be installed. This saturated air will be exhausted to a liquid trap and a pre-scrubber, (packed-tower type) before being diluted by the air from the enclosures. This stream then will go through the main scrubber and four-stage HEPA filter before discharging to atmosphere. Fig. 3 gives a graphic representation of the primary confinement zone.

The leaving airstreams will be radiometrically monitored at the discharge side of each filter plenum. In order to minimize the number of penetrations from the building to the atmosphere, the discharge ducts are collected and combined so that there are only two exhaust air penetrations from the building. A selective alarm and air monitoring system (SAM) will sample the leaving air at each of the two penetrations. In effect, the air will be radiometrically monitored twice prior to its discharge to the atmosphere.

In addition to the continuous monitoring for radioactive materials, an environmental system for continuous monitoring of chemical pollutants and hydrocarbons will be installed at each of the penetrations to the atmosphere.

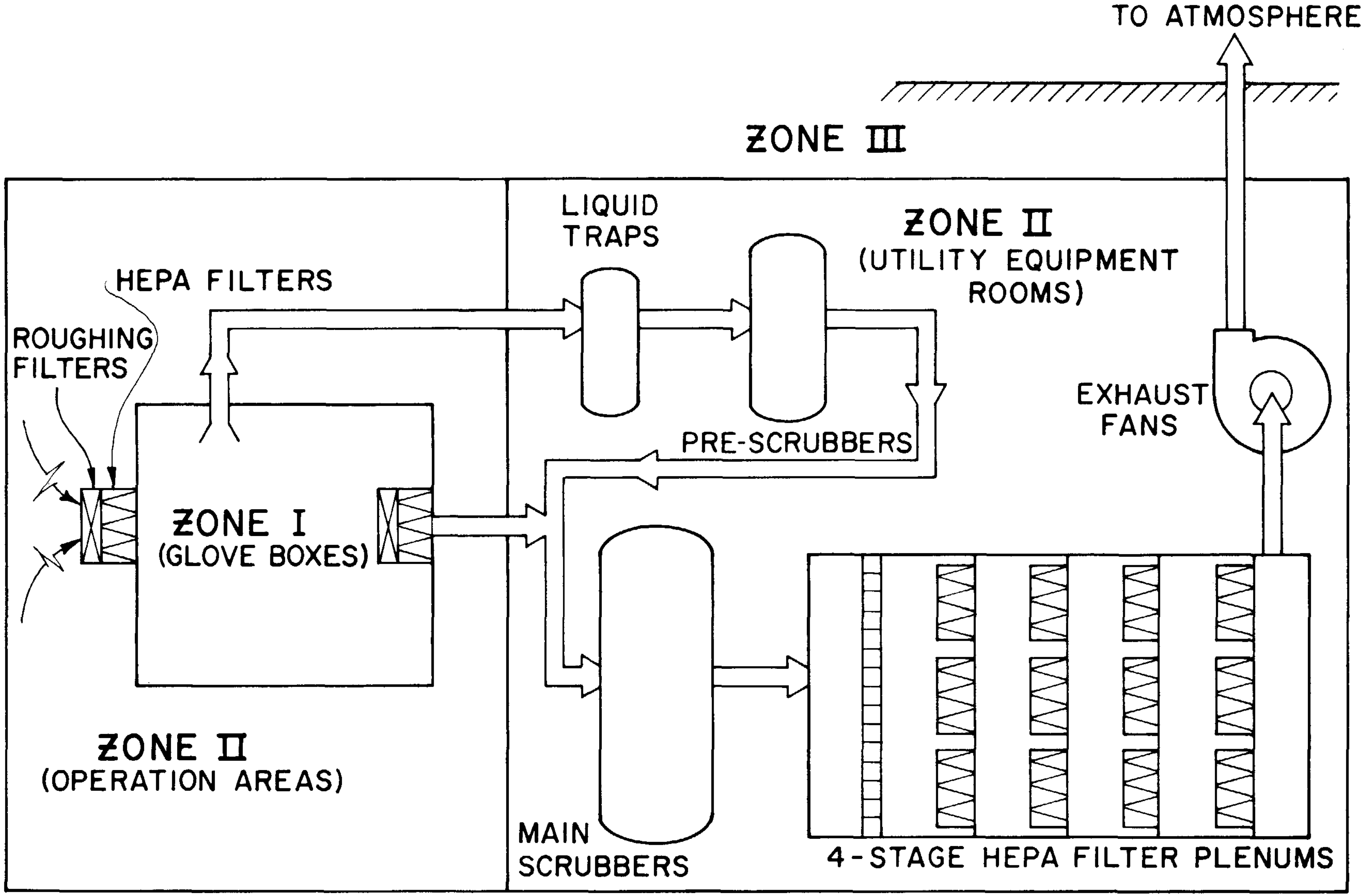
It is of utmost importance in the control and confinement of contamination that the Zone I systems remain operable under any normal or accident condition, even during the design basis earthquake (DBE) and tornado. To achieve this operating capability the controls, exhaust fans, and scrubber systems are to be connected to the emergency generator power source.

Inert Recirculating System.

Some of the operations in the process area do not produce toxic or corrosive fumes and vapors. These operations are classified as "dry chemistry and storage." However, the nature of the material in certain stages of processing presents a potential fire risk. In order to eliminate this potential fire risk, a recirculating inert (nitrogen) atmosphere system is being designed to ventilate these areas.

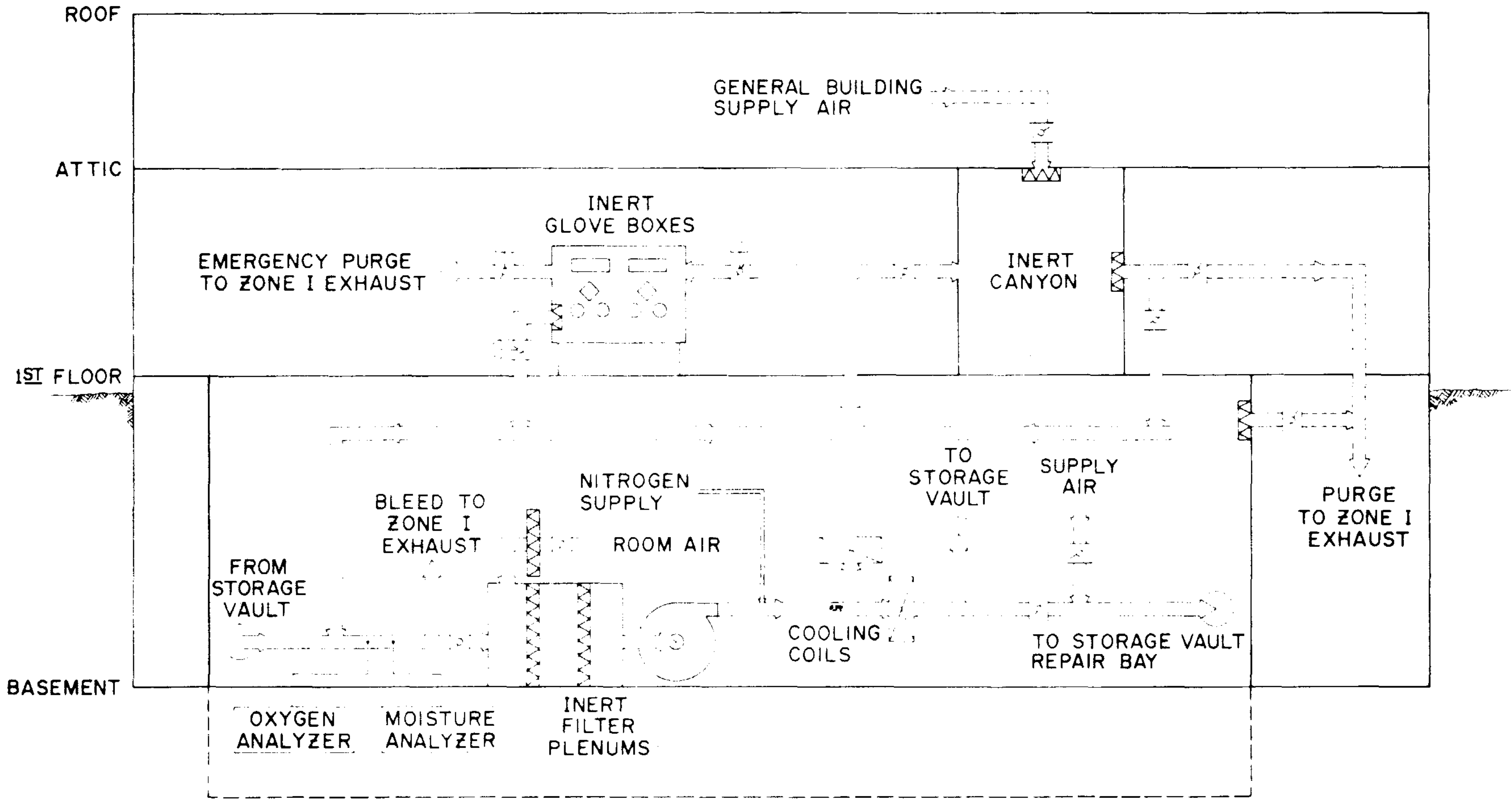
Fig. 4 illustrates the system arrangement and flow patterns.

The inert system will be rather unique in several ways. First, the system will contain two loops: one loop will ventilate the large storage vault area while the second loop will ventilate the glovebox and process canyon enclosures. The storage vault area will have a volume of approximately 5,663 cubic meters (m^3) and require the recirculation of 453 cubic meters per minute (m^3/min.) of nitrogen to maintain proper control. The storage vault loop must have the capability of converting this space from a nitrogen atmosphere to an



ZONE I VENTILATION SYSTEMS

FIGURE 3



NITROGEN INERT VENTILATION SYSTEM

FIGURE 4

air atmosphere within four hours on a demand basis should the vault equipment require maintenance work. The purpose of this conversion capability is primarily one of safety in order to place the workman in an air atmosphere during the period the repair work is being done.

During the period the storage vault is on the air atmosphere, the glovebox and process canyon enclosures must be maintained on a nitrogen atmosphere. Therefore, this system is being designed so the two loops can be operated independently of each other during the conversion period. One loop can be operated on air recirculation while the other loop is maintained on a nitrogen recirculation mode.

The design also includes a process canyon enclosure and an equipment repair bay in the storage vault which must have the same conversion capability as the storage vault area. These ventilation systems are being designed so that these two enclosures can be converted from nitrogen atmosphere to an air atmosphere within 30 minutes time on a demand basis should maintenance work be required. The enclosures can be converted independently and without any upset to the glovebox lines or storage vault.

Basically, the inert system is to be operated at a negative pressure of 0.5" W.C. with respect to process room area, and the oxygen content is to be controlled at about 3% oxygen with a minimum limit of 1%, and a maximum limit of 5% oxygen content. Studies have indicated that quantities of oxygen outside of the minimum and maximum figures listed could contribute significantly to other production problems.

The rate of flow through the storage vault and process canyon will be controlled at five changes per hour. The rate of flow through the gloveboxes will be controlled at 30 changes per hour. These flow rates are based on heat load and mixing characteristics of the enclosures to assure good nitrogen atmosphere at all locations.

The nitrogen will be returned from the enclosures to the filter plenum where it will pass through two stages of HEPA filters and a cooling system before being recirculated back to the enclosures. The filtration system will have a normal operating plenum and a redundant standby filter plenum.

The redundant plenum will act as backup for the normal plenum during periods of filter changing and in-place testing of its filters. The redundant plenum also will act as a normal filtration plenum for the glovebox and process canyon enclosures should it become desirable or necessary to isolate the storage vault from the system. An example of this would be when it is necessary to send personnel into the storage vault for repair of the stacker-retriever unit, and it is necessary to purge the vault area to an air atmosphere for an extended period of time.

It is to be noted that, this being an inert-atmosphere system, no fire protection cooling chambers will be built into these plenums. The system will contain heat detector units, however, to alarm at the fire station and main control room. The system will have the capability of bypassing the nitrogen filter plenums completely and to exhaust into the sprinkler protected filtration plenums of a Zone I system should that need ever arise.

With this capability any purge or release of gases from this system must pass through a fire protected four-stage filtration plenum before being discharged to the atmosphere. This arrangement will assure the prevention of any radioactive release from being discharged to the outside environment.

Secondary Confinement - Zone II.

The operating areas will be divided into several compartments isolated from each other by fire walls, barriers, and corridors. This separation will eliminate the spread of fire or contamination from one area to another.

The operating areas will surround the Zone I enclosures and provide a buffer zone for the Zone III area. In the event a contamination incident occurs which is not contained with the Zone I enclosures, the spread of contamination will be contained within the room area in which the incident occurs.

The ventilation for these operating areas is classified as Zone II. Ventilation for the operating areas will be a direct air supply and return system with the air being supplied near the ceiling and returned from near the floor level. Normally, the air in these areas will be of a breathable quality.

The operating areas will be controlled at a negative pressure of 0.15" W.C. with respect to the Zone III areas or negative 0.30" W.C. with respect to atmosphere. This will provide a positive pressure of 0.75" W.C. with respect to the glovebox or primary confinement enclosures.

The ventilation of the operating areas will be controlled to maintain a constant air change rate of 15 changes per hour or five cubic feet per minute per square foot of floor space, whichever requires the least amount of air to maintain good temperature and confinement control. The supply air inlets to the operating areas will contain HEPA filters which will prevent contamination from being conducted from one operating area to another area via the supply air ductwork, or to the general supply equipment in case of an accidental pressurization for any reason.

The air will be returned from the room area (Zone II) through return grilles containing prefilters to protect the ducts from dust and lint accumulations. The air will then be ducted to the Zone II filter plenum containing fire protection cooling chamber and two stages of HEPA filters.

The filtered air from the Zone II plenum will be combined with the discharge from the Zone III plenums. This air will be ducted to the Zone II basement areas housing Zone I enclosures, such as the Zone I scrubbers and ventilating equipment, to the Zone III basement areas housing the supply air equipment, and to Zones II and III ventilating equipment and electrical equipment. Air supplied to basement Zone II areas is returned by ductwork to the Zone II HEPA filter plenums and the air supplied to the basement Zone III areas will be randomly returned to the supply air units for recirculation to the building. See Fig. 5.

The Zone II system will have the added capability of exhausting 50% of the Zone II air to the atmosphere in case of a noxious fume release within the operating areas that would not be removed by the HEPA filters.

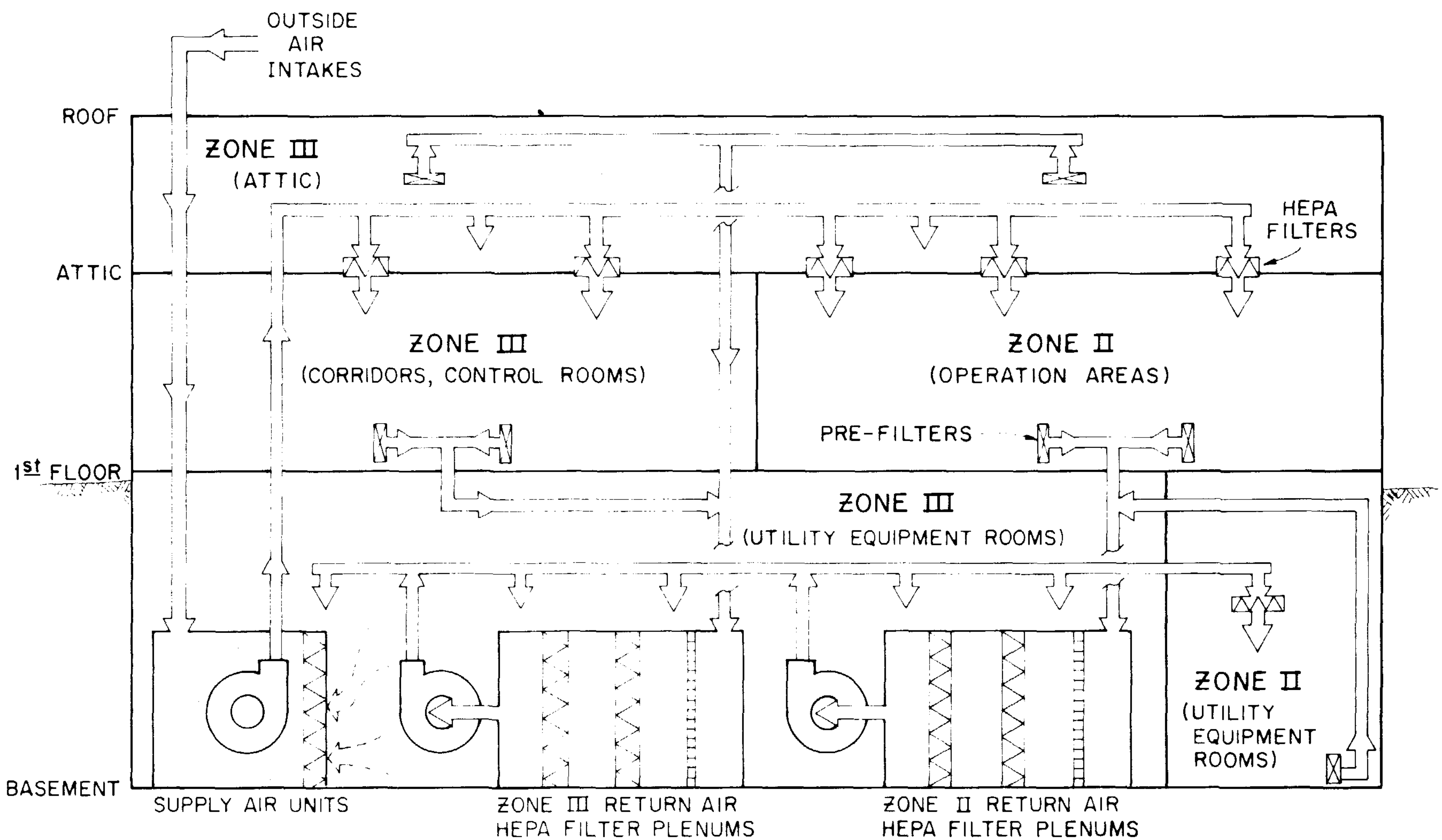
Radiometric monitoring of the airstream for contamination will be done continuously at each filter plenum discharge.

Since this system is not of the importance for continuous operation as the primary confinement system, only that portion of this system required to maintain proper differential pressure control between areas is on the emergency power supply source.

Tertiary Confinement - Zone III.

Surrounding the process or secondary confinement areas will be hallways or corridors for ingress and egress of employees to the respective process areas and process control rooms. The corridors will provide the only route to the building exterior. Each exit from the building contains an air lock section which will help to maintain the pressure differential control during periods of personnel traffic.

The ventilation for these hallways, corridors, and control rooms is classified as Zone III. The ventilation will be a direct air supply and return system with the air being supplied near the ceiling and returned from near the floor level. The areas will be controlled at a negative pressure of 0.15" W.C. with respect to the atmosphere and positive pressure of 0.15" W.C. to the Zone II or secondary confinement compartments. The areas will also be controlled to maintain a constant air change rate of 10 changes per hour or two cubic feet per minute per square foot of floor space, whichever requires the least amount of air to maintain good temperature and confinement control.



ZONE II & III VENTILATION SYSTEMS

FIGURE 5

The air will be exhausted from the corridors and control rooms through return grilles containing prefilters to protect the ducts from dust and lint accumulations. The air will then be ducted to the Zone III filter plenum containing a fire protection cooling chamber and two stages of HEPA filters. The air from the plenum will be mixed with the Zone II return airstream and ducted to the basement utility and mechanical equipment areas.

Monitoring of the airstream for radioactive contamination will be done continuously at each filter plenum discharge.

This system, like the Zone II system, will require only a portion of the equipment to be on emergency power supply source to maintain proper differential pressure control between areas.

As illustrated by Fig. 6, the tendency of air is to flow from non-radioactive zones to moderately radioactive zones to highly radioactive zones. The design of the ventilation systems will assure that proper airflows are maintained at all times.

Ventilation System Protection.

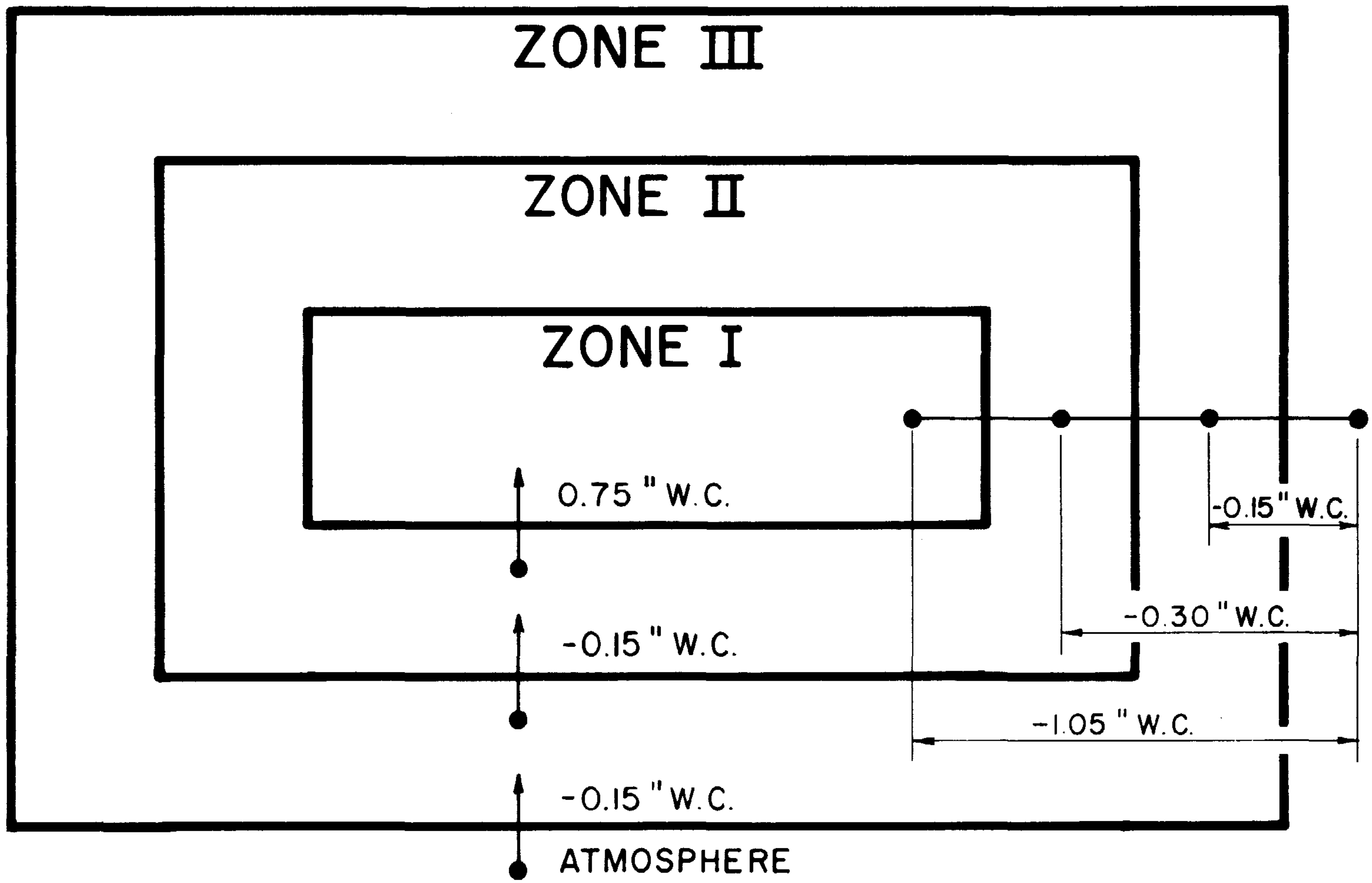
The method by which contamination control is accomplished by the ventilation system has been previously discussed. Now it must be assured that there is no linkage in the facility which will allow a breakdown of this control. Therefore, there must be included in the design ample protection for critical systems which will confine the radioactive materials (1) within the building, (2) within its compartment, (3), if possible, within its enclosure.

Filtration Plenums.

The most vital part of the system is the filtration plenums. These units must be operative under any conditions of accident and must thoroughly clean the air before it is transmitted to the environment or recirculated to the building.

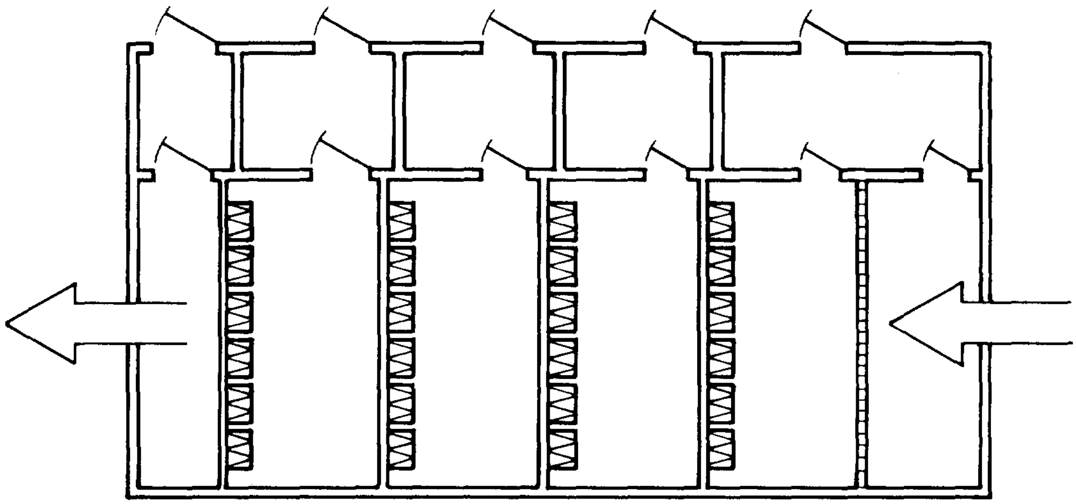
The plenums will all be multistage plenums using four stages of HEPA filtration on the primary confinement area exhaust air and two stages of HEPA filtration on the secondary and tertiary confinement area return air. The number of stages required has been calculated from material loading and particle size determinations observed from previous incidents encountered at the plant.

The configuration of the plenum is illustrated on Fig. 7. These plenums will contain fire protection cooling chambers with mist eliminator sections ahead of the first stage of HEPA filters. These chambers have sprinkler systems which will activate at 190^{o}F inlet temperature and begin discharging water at a rate of one-fourth gallons per minute (gpm) per square foot of filter face area. This is

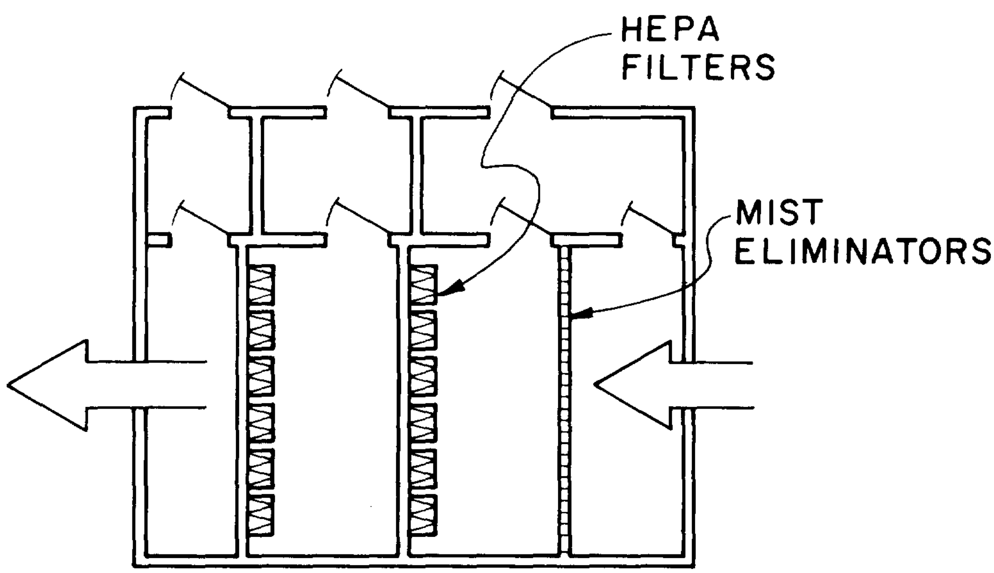


PRESSURE DIFFERENTIAL BY ZONES

FIGURE 6



4 - STAGE HEPA FILTER PLENUM



2 - STAGE HEPA FILTER PLENUM

FIGURE 7

equivalent to about 1.0 gpm per filter unit. Tests at Rocky Flats have demonstrated that this spray cooling chamber can reduce the air temperature to a maximum 140°C or an average of 95°C filter surface temperature with inlet air temperature maximum of 690°C and average inlet air temperature of 335°C.[3] The cooled air then passes through a two-inch thick mist eliminator section made of steel mesh arranged in a herringbone fashion.

A manually operated sprinkler system will be installed between the mist eliminator section and the first stage of HEPA filters for use should additional fire suppression become necessary. Temperature alarms and recordings will be obtained at the plenum inlet, between the first and second stage of HEPA filters and at plenum discharge.

Each Zone I plenum will have an alternate plenum to which the airstream may be transferred in case a problem develops within its assigned plenum. The filtration plenums for Zone I will be cross-connected by ducting and separated by an isolation valve. The plenums and filter capacities are being designed so that each plenum can carry its own load plus the load of the associated system without exceeding the rated capacity of the filters. The transfer of plenums will be made through a key selector switch located in the utility control room.

In order to further protect the filtration plenums handling the air from the primary confinement area, two additional features have been incorporated:

1. Wet chemistry area.

   The gloveboxes, canyons, and vaults will contain HEPA prefilters at each exhaust outlet. The basic function of these filters is to protect the ductwork from accumulations of radioactive dust and debris, and to reduce the amount of loading on the main bank filter face. The installation of scrubbers will be used to cool and clean the air of corrosive and radioactive materials prior to being drawn into the filtration plenum. The scrubber systems were discussed previously in this paper.

2. Dry chemistry and storage areas.

   The installation of an inert gas recirculating system is being incorporated to reduce the fire potential associated with the dry chemical operations and storage of the parts and scrap. The operation of this system was explained under Primary Confinement.

Dedicated Water System.

A water system comprised of water tanks pressurized to 90 pounds per square inch gage (psig) with nitrogen will be installed to serve as a dedicated fire water tank for the Zone I filtration plenums. In case of a loss of the regular fire water main, this tank will supply enough water to protect the filter system for a period of 30 minutes. Our fire department pump trucks would be available within three minutes time from the activation of the fire alarm circuit.

Critically Safe Waste Tank.

Waste water collection tanks will be installed to collect the water from the fire sprinkler systems in the Zone I filter plenums. These tanks will be filled with rashig rings to prevent the possibility of a critical mass being formed from the contaminated material being washed from the airstream and filter face. The plenum drains are being designed to trap the heavier particles of plutonium on the floor of the plenum.

Central Utilities Control Room.

A central control room is being designed into this facility and will incorporate several very new features.

The control room will be located in a hardened structure capable of withstanding the effects of earthquake, tornado, and internal accidents. This structure will be attached to, but separated from, the plutonium building by structural walls. There will be no radioactive material or equipment located or passing through this structural area. The control room will be easily accessible from an outside entrance under adverse building conditions.

The ventilation for the control room will be completely independent of any other ventilation system in the facility. It will contain a separate supply and exhaust system along with its associated controls, air conditioning equipment, and filtration components.

The control system will utilize a computerized data acquisition system. The controls and computer will be optionally powered by an "Uninterrupted Power Source" (U.P.S.) of the rectifier and converter type system with battery floating power. This design will help assure continuous and reliable control, alarm, and data collection under all foreseeable upset conditions within the production or utilities areas.

IV. Discussion

Major changes in design concept were experienced in the area of building structure, ventilation confinement, and filtration protection. The changes were caused primarily by the natural phenomena criteria which required the building structure and all critical operating equipment to remain operational in the event of Design Basis Earthquake (DBE) or Operating Basis Earthquake (OBE) and tornado accident.

The design of this new facility is expected to meet all the demands of the "Minimum Criteria for Plutonium Facilities." The achievement of these designs has not been without problems.

A few of the major problems have been in the following areas of design:

1. Project costs were increased due to substantial increases in caisson substructure, wall thickness, and concrete reinforcing requirements.

2. The tightening of equipment specifications to include certification of seismic design requirements by static and dynamic analysis procedure and by tests has caused numerous problems, as evidenced by a reluctance on the part of suppliers to perform the certification. Manufacturers are not geared for this certification and, consequently, charge high extras to perform the calculations and tests.

3. A factor which has given considerable problems has been the unusually high escalation of costs during the past two years. It is well known that escalation has had a dramatic effect on all costs and we do not foresee any relief in this area for some time.

This unique and complex facility, which has been such a great challenge to many dedicated people, is expected to be in operation by the end of 1976.

References

1. AECM Appendix 6301, Part II, Section H - "Minimum Design Criteria for New Plutonium Facilities."

2. AEC Regulatory Guide 3.12 - "General Design Guide for Ventilating Systems of Plutonium Processing and Fuel Fabrication Plants."

3. D. R. Cartwright, C. M. Johnson, and M. A. Thompson - "Filter Plenum Fire Tests," CRD9403300-109, AEC Rocky Flats Division.

DISCUSSION

BURNHAM: Is it all metal or is it oxide?

OLIVER: It is basically oxide in the chemical recovery-type units.

BURNHAM: And is the high air flow for sweeping the stuff out?

OLIVER: Yes. The 30 air changes in the glove box you are referring to is to keep the glove box cleaned up in a better manner than we have seen them before, and also for temperature control of some of the other areas. The high change rate in the inert box is, of course, for the purpose of getting better mixture.

BURNHAM: And for the operational areas, you said something about 15 changes an hour?

OLIVER: Yes. In the process area we have designed for 15 room air changes per hour, or five CFM per square foot of floor space.

OLSON: I'm concerned with what appears to be superconservatism in some of your designs. Can you tell me why there are 30 air changes per hour for a glove box? That seems rather high. The second question is, why four stages of filtration? What could you possibly get out of using that many filters in series?

OLIVER: We have discussed the 30 air changes per hour a bit. We find from past experience that 30 changes is a very good figure for us to use in the glove boxes. As to why we need four stages of filtration, this has been calculated from past incidents that we have had at the plants. We calculate the number of stages we need for a particular type of system. For example, zone one systems could deposit very high quantities on the filters. We don't expect to ever meet that in this building because we have installed scrubbers and other additional equipment.

OLSON: I notice that you use the 300 mile standard tornado (what the AEC calls a standard tornado). You show a pressure drop of 1.7 instead of 3 PSI. First, why did you drop to 1.7? Why didn't you use the 3 PSI pressure drop? Second, what are you doing to the final filters to protect them from that pressure drop? Is it necessary?

OLIVER: I'll have to get a little help on the tornado. Jack Russell, do you want to answer that point?

RUSSELL: We did an analysis of the effect of the final velocity we anticipated on the filters resulting from negative pressures imposed during the tornado pressure cycle, as described

RUSSELL (cont.): in the criteria, and ducts do require a closure. We are installing an isolation valve to shut off the ducts, using a velocity sensor in the duct. We have determined that you can close a butterfly valve up to 60 inches in half a second, that is to say, in adequate time for tornado protection.

OLSON: Why a reduction in the tornado criteria from 3 to 1.7 PSI?

RUSSELL: That was a result of a study performed by the tornado experts, as shown in the paper, in which they postulated a 200 mile an hour tornado and a 1.2 PSI final negative pressure. A decision was made by the people involved at the time that 1.7 was more realistic than 3.

LIM: You mentioned installation of HEPA filters in supply ducts to zone II. (1) What is the filter face velocity? (2) Have you considered using backflow dampers instead of HEPA filters? (3) What is the basis for the 15 air changes/hr. or 5 cfm per ft^2 for zone II areas? The reason I ask this question is that the fuel recovery and recycling plant we are working on requires more than 200,000 cfm based (preliminary) on 3 air changes/hr. for operating aisles and galleries. So you can see the problem we have if the design is to be based on 15 ac/hr.

OLIVER: Filter face velocity is about 200 fpm. We considered using backflow dampers, but they are not tight enough for our service requirements. Therefore, we went to HEPA filters to avoid contamination spread by reverse flow in the system. We use 15 air changes per hour in production areas and 10 in corridors, aisles, etc. We think three air changes per hour is too low. At less than 10 air changes per hour, it has been our experience that you do not get good contamination control. Kindly keep in mind that we use our corridors as a protective zone III. Therefore, we must keep them under high air flow for good contamination control.

DESIGN OF VENTILATION AND AIR CLEANING SYSTEMS FOR THE NEW LOS ALAMOS PLUTONIUM FACILITY*

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Abstract

The Los Alamos Scientific Laboratory's new plutonium facility will conform to AECM Appendix 6301-Part II, Section H-Minimum Design Criteria for New Plutonium Facilities. The glove box process exhaust air is filtered through three or four stages of HEPA filters. The design of this multi-stage filter installation is shown with a method of in-place testing of each stage individually. A glove box filter holder and the in-place test procedure is described. General room air from plutonium work areas is recirculated at the rate of eight air changes per hour with a 10% fresh air make-up. The filter plenums for the recirculated air are designed to permit in-place testing of each of the two filter stages.

I. Introduction

The plutonium facilities at the Los Alamos Scientific Laboratory (LASL) are used for work on the two major isotopes, ^{239}Pu and ^{238}Pu, of the man-made element plutonium. The programs encompass many phases of plutonium research and development in support of several AEC projects.

The core of the present facilities was constructed in 1944-45 by moving in used warehouse buildings and installing the equipment needed. Over the years there have been revisions to improve the safety and operability. However, following the fire at the Rocky Flats Plant, a review of the facilities indicated that a considerable program of further upgrading was needed to provide for the level of fire protection desired. Subsequently, an ad hoc committee of AEC and contractor personnel developed AECM Appendix 6301 Part II, Section H-Minimum Design Criteria for New Plutonium Facilities which not only establish requirements for fire protection, but also requirements for radiation, health, and safety protection for the worker and protection to the environment. The Fluor Corporation, a California process-engineering firm, was engaged to make a conceptual design of a new facility or a re-do of the existing facility to meet these criteria. Their study concluded that a new facility could be constructed at about the same cost as redoing the existing facility; further, there would be substantially less impact on the operations if a new facility were built. The design of the new LASL plutonium facility has been essentially completed and construction has been started.

*Work supported by the U. S. Atomic Energy Commission.

This paper will be limited to a discussion of the design and procedures that will conform to the Minimum Design Criteria requiring "the filtration system shall be designed to allow reliable in-place testing of high efficiency filters and ease of replacement." The filter systems that will be described are the process exhaust systems for glove boxes and the room air recirculation systems.

II. Process Exhaust

The design of the process exhaust system is most important because of the necessity to confine the high level of contamination. The first step in the process exhaust air cleaning is the filter at the glove box. The criteria requires that "a high efficiency filter be installed as close as practical to the source to minimize the contamination of duct work." It is important that this filter be easily replaced and reliably in-place tested even though the criteria does not permit taking credit for this filter in the calculation of the number of filter stages required for air cleaning.

Figure 1 shows the schematic of the design developed for the glove box filter holder. The 203 mm (8") round HEPA filter will be introduced at the top of the cylindrical holder and pushed into the position as shown using the spacer or pusher. The filter and the pusher each have gaskets at the top and bottom for sealing against the wall of the holder. The design of the gasket permits movement of the pieces while maintaining a satisfactory seal. To replace the filter, a new filter and pusher are introduced at the top of the holder and the old filter and pusher are forced into the glove box for disposal. The top of the holder is tightly sealed.

In-place testing HEPA filters installed inside glove boxes has been limited because of the high level of contamination in the boxes. The connecting of the smoke generator to the glove box and the insertion and removal of test probes can result in the spread of contamination to the room, also, the light scattering chamber of the test equipment may become seriously contaminated. The testing of the filter in the holder shown eliminates many of these problems.

Figure 2 shows a schematic of the in-place test method. The glove box filter will be tested as follows: (1) A temporary cover will be placed over the filter holder opening into the glove box. (2) A temporary duct will be installed on the filter holder outside of the glove box. (3) Air will be drawn through the temporary duct and filter by the process exhaust system. (4) The test aerosol will be introduced into the duct and after a suitable mixing device the initial concentration will be determined. (5) The penetration will be measured downstream of the filter.

The compartmentalization of the new plutonium facility resulted in four separate process exhaust systems of less than .95 m^3/s (2000 CFM) each. Figure 3 shows a schematic of the filter installation process exhaust system. The design consists of two glove box type enclosures connected back-to-back permitting up to four stages of HEPA filters. Each stage will have two 24 x 24 x 12" HEPA filters with space available if required for an additional filter in each stage. The filters will be changed by normal glove box procedures and the contaminated filter will be removed from the glove box by accepted bagging out techniques. This method of changing filters will eliminate complicated procedures required when personnel enter highly contaminated filter plenums.

The figure also shows the arrangement of the permanently installed ductwork that will be used to in-place test each filter stage. Blank flanges are used in the test duct instead of valves to remove the uncertainty that could result from leaky valves during in-place testing. More important is that the positive shut-off of a blank flange will completely eliminate the possibility of bypassing a filter bank through the test ductwork during normal operations.

The 203 mm (8") round test duct will permit in-place testing at approximately the normal rate of flow. Each process exhaust system will have a parallel 100% capacity redundant installation with separate exhaust blowers. One filter installation can be isolated and tested without interruption of the flow in the process exhaust system. The filter installation to be tested is valved off from the process exhaust and by removal of specific blank flanges in the test duct each filter stage can be in-place tested.

Figure 4 shows the flow for testing the first filter stage. The DOP aerosol will be introduced into the test duct and after mixing the aerosol concentration in the challenge atmosphere will be measured. A temporary cover, such as a sheet of plastic, will be used to blank off the 2nd stage to direct the flow into the test duct where the penetration of the 1st stage can be measured.

There is a good chance that the glove box containing the first bank of HEPA filters will become contaminated because the possibly highly contaminated process exhaust will have passed through only the first stage of filters. The test air is, therefore, passed through the fourth stage of filters before being discharged to the atmosphere.

Figure 5 shows the positioning of the valves and blank flanges for testing the 2nd stage of filters. The concentration of the DOP aerosol is measured as before. The flow is directed through the 2nd stage of filters, around the 3rd and 4th stages and the penetration is measured after the blower.

Figures 6 and 7 show the air flow for in-place testing the 3rd and 4th stages of filters. The initial aerosol concentration and the penetration are measured at the same locations as when testing the 2nd stage.

The process exhaust system should satisfy the criteria for reliable in-place testing and ease of replacement.

III. Room Air

The only reference in the AEC Design Criteria to room air that is pertinent to this discussion states, "A partial recirculating ventilation system shall be considered for economic and safety reasons; however, such systems shall be designed to preclude the entry of enclosure exhaust into room air recirculating system."

The room air in the operating area of the LASL new plutonium facility will be recirculated at a rate of eight air changes per hour with an approximate 10% fresh air make-up. The recirculated air will be filtered through two stages of HEPA filters. The air exhausted from chemical fume hoods and the 10% of room air that is not recirculated will also be filtered through two stages of HEPA filters before being discharged to the atmosphere. The compartmentalization of the facility has made it possible to size the room recirculation filter plenums and the room air bleed-off filter plenums for approximately 9.4 m^3/s (20000 CFM) or less. Thus, each compartment recirculation system will have two filter plenum handling 50% of the total compartment air flow. The bleed-off systems will have two filter plenums with each sized for 100% of the required normal air flow.

Figure 8 is a schematic of the typical room air recirculation plenum or a bleed-off plenum. In the actual design, there will be differences in each system, such as cooling coils in the recirculation plenums and not in the bleed-off plenums. But for the purposes of in-place filter testing, the same methods and procedures will be followed. The figure shows the flanged openings with blind covers in place for normal operations. Temporary ducts will be installed on the openings for the in-place testing. The ducts will be 609 mm (24") in diameter allowing testing at approximately 50% of the normal rate of flow.

Two methods of introducing the DOP aerosol to the plenum are contemplated. The first method is to introduce the aerosol by way of a room exhaust duct in the operating area. Figure 9 shows the flow for testing the 1st stage of filters. A temporary cover is placed over the exhaust from the plenum and the flow of air will bypass the 2nd stage through a temporary duct. The penetration is measured after the blower. Figure 10 shows the testing of the 2nd stage with the DOP aerosol introduced in the operating area. The initial concentration and penetration will be measured as before.

Figures 11 and 12 show the testing of the two banks of filters by introducing the DOP aerosol through a temporary duct and recirculating the air in the immediate area of the plenum. The 1st stage of filters is tested by closing valves in the intake plenum and the fan discharge. The DOP will be introduced into the plenum before the 1st stage and the 2nd stage will be bypassed with a temporary duct. The penetration will be measured at the blower discharge. Figure 12 shows the in-place testing of the 2nd stage. The DOP aerosol will be introduced between the filter stages through a temporary duct and the penetration measured at the blower discharge.

Summary

The compartmentalization of the new plutonium facility has made it possible to design HEPA filter installation of an optimum size for ease of in-place testing and replacement. The process exhaust which usually have a high degree of contamination is small enough to make it practical to use glove box type enclosures for the installation. The filter changes can be made without exposure of personnel to high concentration of plutonium and the in-place test procedure is not complicated. The room air and bleed-off filter systems are of such a size that the method of using temporary ducts to accomplish in-place testing of both stages seems very practical.

Glove Box Filter Installation

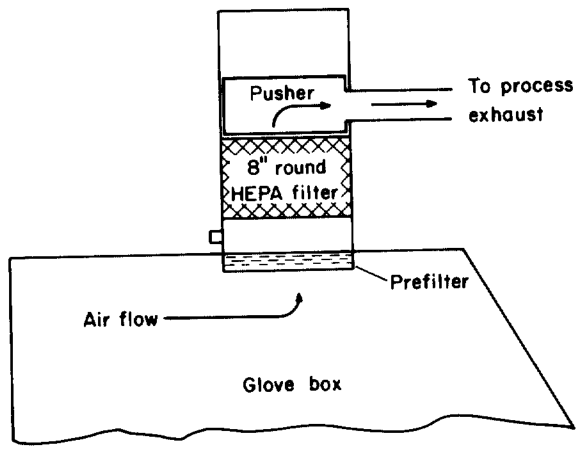


Figure 1.

Glove Box Filter Installation
Filter Test

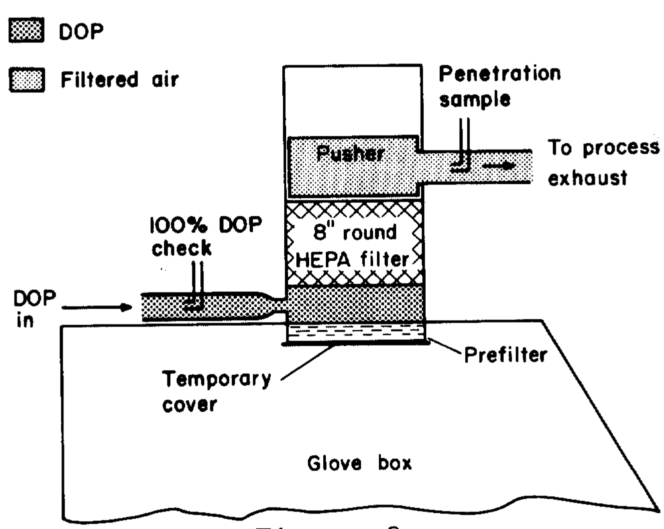


Figure 2.

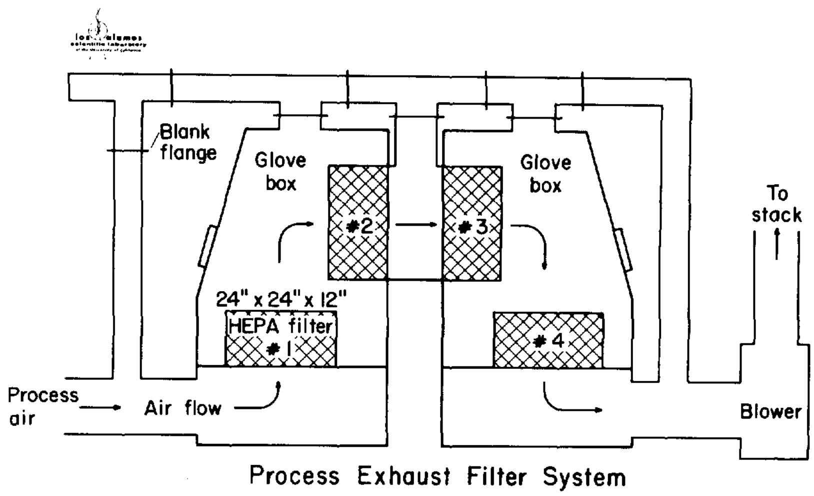


Figure 3.

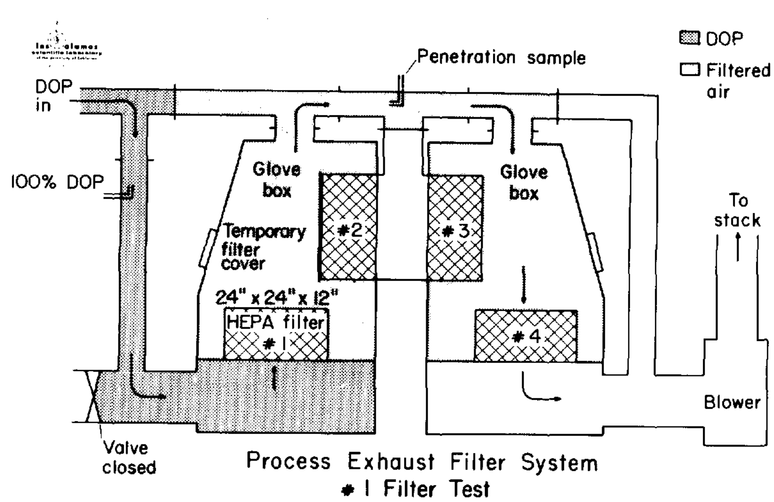


Figure 4.

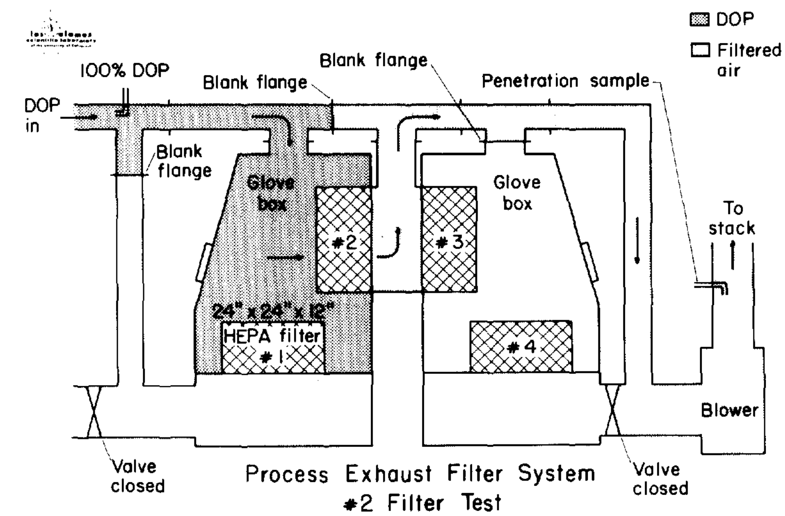


Figure 5.

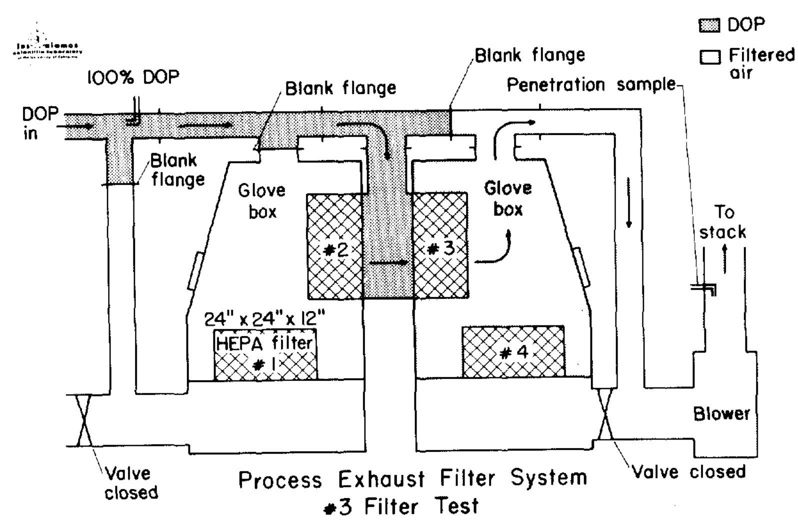
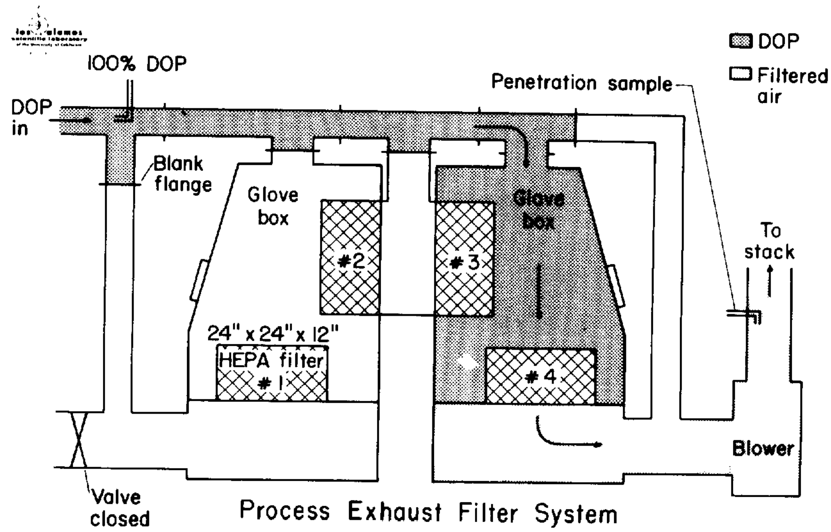
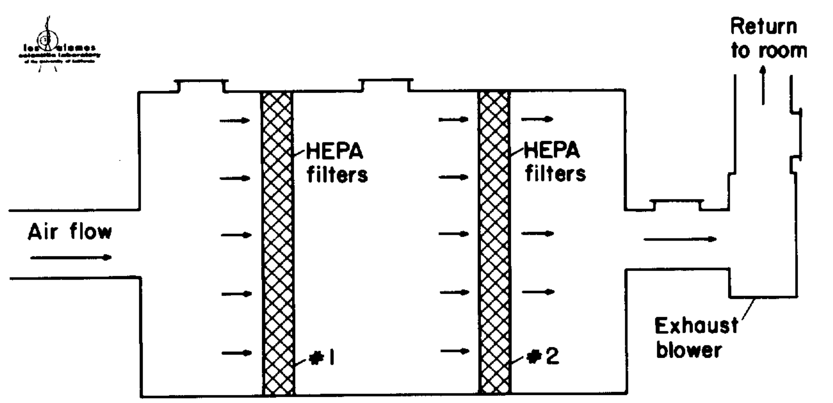


Figure 6.



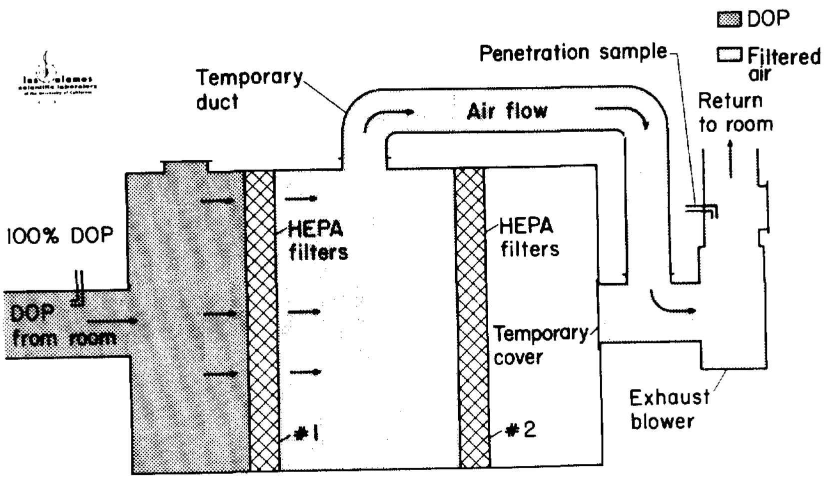
Process Exhaust Filter System
#4 Filter Test

Figure 7.



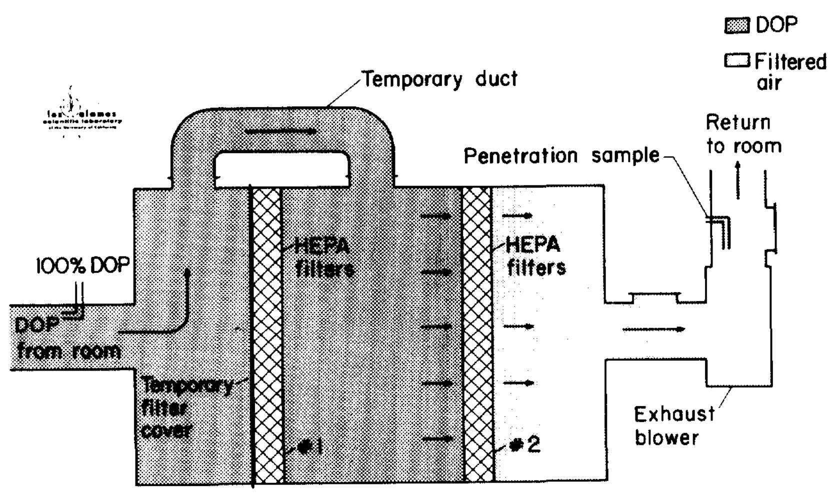
Room Air Filter System

Figure 8.



Room Air Filter System
Filter Bank #1 Test

Figure 9.



Room Air Filter System
Filter Bank #2 Test

Figure 10.

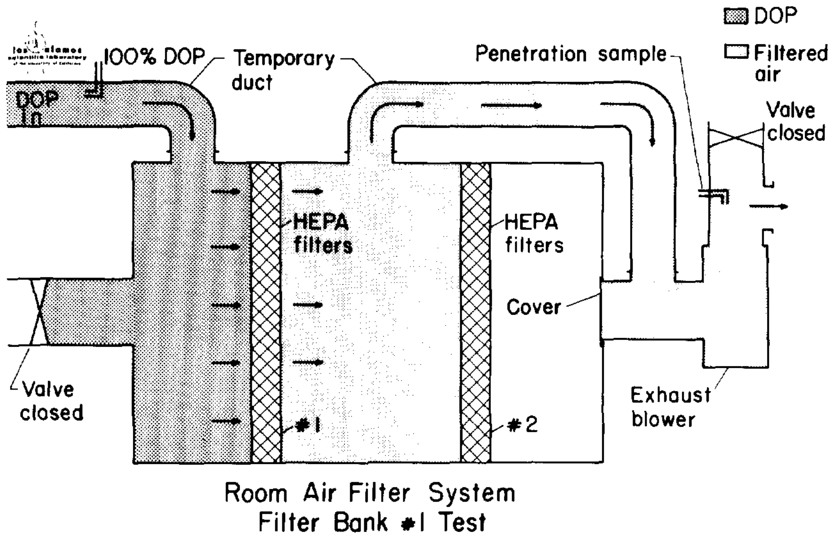


Figure 11.

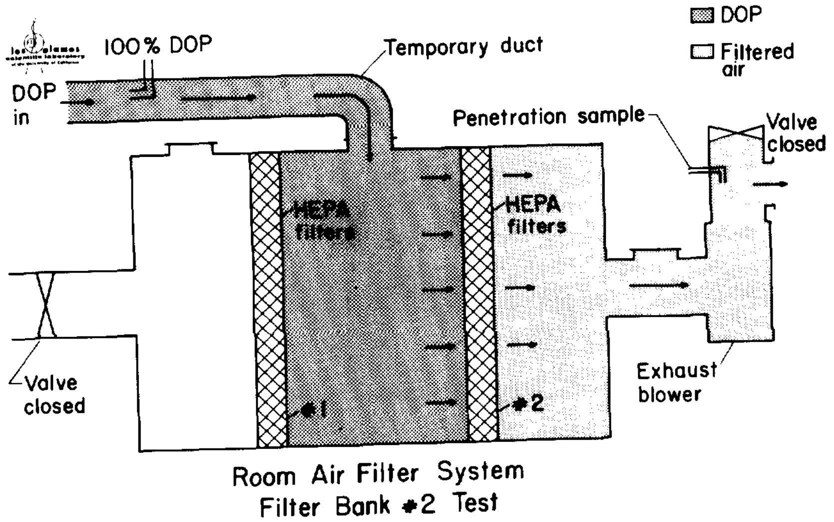


Figure 12.

DISCUSSION

FIRST: Looking at your diagram with the pusher-type changer, I wonder what procedures you might take if you found that your absolute filter didn't pass the test. Is there anything you can do except push it out and put in another or get to it some way and readust the gasket; or whatever else is necessary?

MITCHELL: It would be pushed out and another filter with new gaskets and all would be installed.

FREEMAN: In one of the tests where you are testing the second row of filters, you bypass the first filter and inject the DOP upstream. Isn't there a possibility of contaminating that temporary exhaust?

MITCHELL: Yes, there will be a problem of contamination, but this is a room air system and if it becomes contaminated we will have other troubles. I don't think it's really too serious.

BALSMEYER: I have a simple question relating to glove box testing. You mentioned blind flanges several times. I'm concerned about how you are going to remove them without contaminating personnel?

MITCHELL: The only blind flange that will be exposed to any degree of contamination is the blind flange we contaminated at the first bank of HEPA filters. With the experienced operating group we have, taking out a blind flange isn't complicated. It would not be as much trouble as changing a glove in a glove box. I think it has to be done carefully, but it can be done without really causing any contamination incidents.

DORE: I find it curious that when testing the second and third filters of the process off gas systems, you do not utilize the additional filtration of the fourth filter, but you do use it for the case when you test the first stage of filtration. You have to bypass air, and you're effectively running a test where you could test for contamination at the same time you're examining for DOP. It seems unusual and perhaps a bit risky.

MITCHELL: Other than testing the first stage of filtration, we feel that by the time the process air has gone through two banks of HEPA filters, the contamination should be low enough to permit testing the way we are doing it. Of course, I realize that the best laid plans don't always pan out, so there would have to be some investigation, some checking, before doing this. It isn't always as simple as I might have indicated.

GILBERT: You have an open space between a HEPA filter and pre-filter in the glove box. That is a high-priced round filter versus an $8 square filter. It's a push-through unit into

GILBERT (cont.): the glove box, and, presumably, the pre-filter goes with it. How do you change the pre-filter?

MITCHELL: You change the pre-filter through the box. It's a glass mat filter that can be changed easily from inside the box.

VENTILATION DESIGN MODIFICATIONS AT LOS ALAMOS SCIENTIFIC LABORATORY MAJOR PLUTONIUM OPERATIONAL AREAS*

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Abstract

Major ventilation design modifications in plutonium operational areas at Los Alamos have occurred during the past two years. An additional stage of HEPA filters has been added to DP West glovebox process exhaust resulting in significant effluent reductions. The additional stage of HEPA filters is unique in that each filter may be individually DOP tested. Radiological filter efficiencies of each process exhaust stage is presented. DP West room air ventilation systems have been modified to incorporate a single stage of HEPA filters in contrast to a previous American Air Filter PL-24 filtration system. Plutonium effluent reductions of 10^2 to 10^3 have resulted in these new systems. Modified DOP testing procedures for room air filtration systems are discussed.

Major plutonium areas of the CMR Building utilizing Aerosolve 95 process exhaust filtration systems have been upgraded with two stages of HEPA filters. Significant reductions in effluent are evident. A unique method of DOP testing each bank of HEPA filters is discussed. Radiological efficiencies of both single and two-stage filters are discussed.

I. Introduction

There are presently two major plutonium Research and Development facilities at Los Alamos Scientific Laboratory (LASL), DP West and CMR laboratories. DP West facilities involve glovebox operations with kilogram quantities of ^{239}Pu and multi-one hundred gram quantities of ^{238}Pu. The CMR Building also involves glovebox operations with ^{238}Pu and ^{239}Pu; however, these operations are generally with gram to 100 gram quantities of both isotopes.

The present DP West plutonium facilities were derived from the original D Building at the LASL Technical Area where the first plutonium metal was produced in quantity. It became apparent in the early 1940's that handling of large quantities of plutonium would require design and construction of more extensive facilities to ensure safe operations. The core of the present DP facilities was constructed in 1944-45 by moving in and modifying army warehouse buildings and installing equipment needed for continual operations (1). Since 1945 there have been numerous revisions and upgrading

*Work performed under the auspices of the U.S. Atomic Energy Commission.

of ventilation systems to improve safety, operability, and to reduce radioactive effluents.

The CMR Building construction was completed in 1952. This building is a three-story concrete structure with a full attic and basement which are auxilary to the main floor containing the research and development laboratory modules. It is a winged structure with laboratory wings, each approximately 260 ft long, branching off a 650-ft-long spinal corridor. Research and development activities at the CMR Building include analytical chemistry, physical chemistry, inorganic chemistry, physical metallurgy, and irradiated material examination and handling. As with the DP facilities, there have been considerable ventilation revisions and additions to improve safety and operability; however, since the Rocky Flats Plant fire in 1969, a review of the AEC supported Plutonium facilities indicated that a considerable upgrading program was needed to provide not only the level of fire protection desired, but also ventilation upgrading to protect the environment during normal and postulated accident type conditions. As a result, an extensive program at the LASL was initiated to improve both the DP West and the CMR Building ventilation exhaust system.

Ventilation Systems and Effluent Data

From 1944 to 1959 numerous modifications of the process (glovebox) ventilation systems occurred at DP West. Prior to 1959, the process and room exhaust were combined, and the only filtration was one stage of PL-24 filter media at Building 12. In 1959, the process exhaust was separated from the room exhaust and a combined central process exhaust system installed. High efficiency particulate air filters (HEPA) were installed on each glovebox, either within the glovebox or immediately adjacent in an in-line configuration. During this same modification, a bank of HEPA filters was installed on the combined process exhaust system. Building 12 was then used only as the room air exhaust filter system.

The new process exhaust filter system was designed to handle an air flow of 21,000 cfm and to allow the filters to be changed without disrupting process operations. Since the system was handling air containing radioactive particles and acid fumes, it was necessary that all parts of the system exposed to the exhaust air be stainless steel and all joints and openings be sealed to prevent escape of any air. Figure 1 illustrates the filter system which consists of a filter wheel and housing, a loading dry box, a transfer dry box, and a recovery dry box. Figure 2 shows the filter wheel, which is approximately 7 ft in diameter and 7-1/2 ft long, and is constructed of 1/4-in. thick cold rolled type 304 stainless steel. Figure 3 shows an end view of the filter wheel and the recovery dry boxes. The wheel has twenty-four openings sized to hold the standard 24-in. square HEPA filters. It rotates on two 48-in. diam sleeve bearings which are located at the end of the wheel which is sealed with Garlock seals. The filter wheel assembly is housed in a stainless steel plenum chamber which was shown in the first slide. Twenty-one of the filters are in use at any one time;

the other three being in stand-by position at the transfer box location. The wheel is rotated every 6 to 8 weeks to change location of the filters in the plenum. A complete change of filters is done every year. Contaminated filters are removed from the wheel and moved to the recovery box where they are bagged for recovery. In operation, the contaminated air flows radially in through the filters and the cleaned air flows axially out the center of the wheel to the blowers and exhaust stack. DOP testing of the entire system was done by introducing air jet generated DOP well upstream of the filters and measuring the intake and exhaust concentrations on each side of the filters.

In early 1973, an additional bank of HEPA filters was installed in the process exhaust system. Figure 4 shows Building 324 which houses this final stage of process exhaust at DP West. A duct connects the final filter stage of process from Building 146 (housing the rotary drum) to this final stage of filtration, containing 20-2' x 2' x 1' HEPA filters. This Figure illustrates the intakes and the exhaust ducts with perpendicular flange fitted HEPA filters. Shutoff valves are incorporated on each side of the filter to enhance easy removal and valving off for DOP testing. DOP testing is accomplished by introducing the aerosol at a port in Building 146 and measuring the upstream and downstream concentrations as indicated by the sample probes in the Figure. After initial installation, each filter was individually tested; and finally, the entire system was tested and found to have an overall efficiency of 99.994%.

In late 1972 and early 1973 new room air exhaust systems were installed which is shown in Figure 5. This system contains roughing filters and one bank of HEPA filters. Efficiency testing was accomplished by valving off the intake plenum and introducing DOP through an opening in the plenum airlock. A description of the exact method of DOP testing is better illustrated by Figures shown later in this paper.

Table 1 illustrates the total discharge in curies from 1948 to present[2]. From 1948-1958 both room air and process exhausts were combined. In 1959, Building 146 was constructed to incorporate one stage of HEPA filtered process exhaust. At this time, room and process exhaust were separated. Residual contamination in the previous combined room and process exhaust system (Building 12) led to high room air identified effluent. In 1973 new HEPA filtered room air exhaust systems were installed, and a second stage of HEPA filters was also installed on the process exhaust. Reductions in measured effluent are quite evident. An attempt has been made to estimate the process exhaust first stage radiometric filter efficiency; however, since the intake concentration has previously been used only for operational purposes, and has been taken in an undesirable sampling location, we are reluctant to present this data. Changing bimodal particle size distributions make it difficult to evaluate total system efficiency; however, we are presently trying to quantitate this information.

During the 1950's, the exhaust system of the CMR Building consisted primarily of capillary air washers incorporating coarse glass filaments set at an angle to the air stream. Water from spray heads, oriented in the direction of the air stream, was sprayed over the glass filaments. The air washer served as efficient removers of corrosive fumes, acid mists, and chemical vapors[3]. Water eliminator plates followed the capillaries to protect the downstream dry filter pads against water saturation. The sequence of filtration after the water elimination plates was dry glass fiber filter pads, another wet cell, and a final bank of commercial glass fiber mat filters. The overall radiometric efficiency of this system was considered in excess of 90%.

Over the years, four principal developments have evolved which have led to present determination that a number of the building exhaust systems are inadequate. These are (1) improvements in state-of-the-art filtration methods and materials; (2) programmatic changes resulting in significantly increased research and development efforts involving plutonium; (3) conversion of several general-purpose basement areas to laboratories to meet new or growing programmatic commitments; and (4) increased concern on the part of both the public and the AEC in the control and reduction of potentially harmful effluents to the environment. This latter area is of concern since not only effluents resulting from normal operations but those associated with accidental releases must be considered. Maintenance of the air washers in the early system proved to be a continuing and expensive problem due to high evaporation rates, scaling, and nozzle failure. A program was initiated to replace the unsatisfactory air washers with single banks of Aerosolve 95 filters, which had an efficiency of 80-85% for the removal of 0.3 micron DOP particles. Testing throughout their use indicated that the Aerosolve 95 filters were, in fact, functioning at their specified efficiency. It became apparent that the major wings of the CMR Building where there was work involving plutonium and where the greatest effluent concentrations occurred were Wings 2, 5, and 7. It was also apparent that the effluent concentrations were increasing annually and funds expended to reduce plutonium effluents from these three wings would be most significant for the CMR Building. In early 1972, engineering efforts were begun to design a new ventilation cleanup system for these three wings. Design consisted of roughing filters and two banks of HEPA filters, new plenums, airlocks, and blowers. These new systems became operable in late 1973 and early 1974. Each system consists of two filter banks in series and each bank contains 60-24" x 24" x 12" HEPA filters. A fire screen was installed upstream of the first filter bank and was constructed of wire mesh 2" thick on galvanized steel frames with a pressure drop of 0.15 in H_2O.

All banks of HEPA filters were leak tested after installation. Although leak probing of each filter does not determine the overall efficiency of a system, it is beneficial to locate leaks in the filter housing, filter mounting frames, gasket compression, and other related components before overall system efficiency is measured. Leaks were determined by blowing DOP aerosol between the filters and on welded joints on the upstream side of the filter bank. Penetration of aerosol downstream was measured with a forward light scattering photometer with a 30 ft portable probe and meter.

Figure 6 shows a leak probe test operation where two men introduce the aerosol on the upstream side of the filter and two men scan the downstream penetration. Initially, leaks were found on the joints of the filter housing, frames, and poor filter gasket compression areas. All leaks were repaired, and scanning continued until all leaks were eliminated.

The procedure used for in-place testing of filter system consists of discharging a polydisperse DOP aerosol into a convenient air intake, upstream from the filter bank. For the initial testing, a temporary 30-inch round duct approximately 20' long was used[4].

Figure 7 shows the aerosol generators used for this test which are of the same design that was developed by the Naval Research Laboratory[5]. A total of 6 nozzle type high capacity compressed air aerosol generators were used. A generator operated at 25 psig delivers approximately 24 cfm with a DOP aerosol having a count median diameter of the aerosol of 0.7 micrometer and 95% of its particles less than 1.5 micormeters in diameter[7]. In testing the first filter bank, the 30" duct was positioned in the filter housing air lock shown in Figure 8. The concentration of the unfiltered smoke was determined by drawing a sample from the 30" duct.

The concentration of DOP was measured with a linear readout forward light scattering photometer[6]. Figure 9 depicts the method of testing the first bank of filters. Aerosol is introduced through a sealed opening in the airlock and measured by a sample probe in the introduction duct. Four filters from the second bank are removed and the filtered aerosol is then measured from a sample withdrawn downstream from the first filter bank on the discharge side of the fan. Traverses indicated that the test aerosol was uniformly mixed in the duct. The filtration efficiency of the system was then calculated from the upstream and downstream concentration values. After replacing the four filters in the second bank it was tested in the same manner as the first bank, except that the test aerosol was introduced between the two banks, as shown in Figure 10. The three new systems showed efficiencies greater than 99.97%.

Table 2 illustrates the stack effluent concentrations in curies from 1953 to 1974. There is an apparent increase in effluent concentrations up to 1974.

Table 3 expands the 1973 and 1974 effluent data for all three wings. The asterisks show when the new two bank HEPA filter system was installed. In all cases, we have seen significant reductions.

Table 1

Plutonium in Gaseous Effluent from DP Operation

Year	Room Air Discharge, Ci	Process Air Discharge, Ci	Total Discharge, Ci
1948-9			0.31
1950			0.19
1951			0.027
1952			0.057
1953			0.035
1954			0.022
1955			0.088
1956			0.076
1957			0.074
1958			0.080
1959	0.1750	0.0050	0.18
1960	0.0430	0.0010	0.044
1961	0.0043	0.0030	0.0073
1962	0.0022	0.0020	0.0042
1963	0.0064	0.0008	0.0072
1964	0.0011	0.0010	0.0021
1965	0.0022	0.0003	0.0025
1966	0.0022	0.0003	0.0025
1967	0.0075	0.0003	0.0073
1968	0.0010	0.0008	0.0011
1969	0.0121	0.0009	0.013
1970	0.0030	0.0006	0.0036
1971	0.0125	0.0005	0.0130
1972	0.0550	0.0003	0.0550
1973	0.000001	0.000013	0.000014
1974 (4 months)	0.000001	0.00000008	0.0000011

Controlled soluble 2×10^{-12} µCi/cm^3

Uncontrolled soluble 6×10^{-14} µCi/cm^3

Table 2

CMR Building Gross Alpha Effluent in Curies

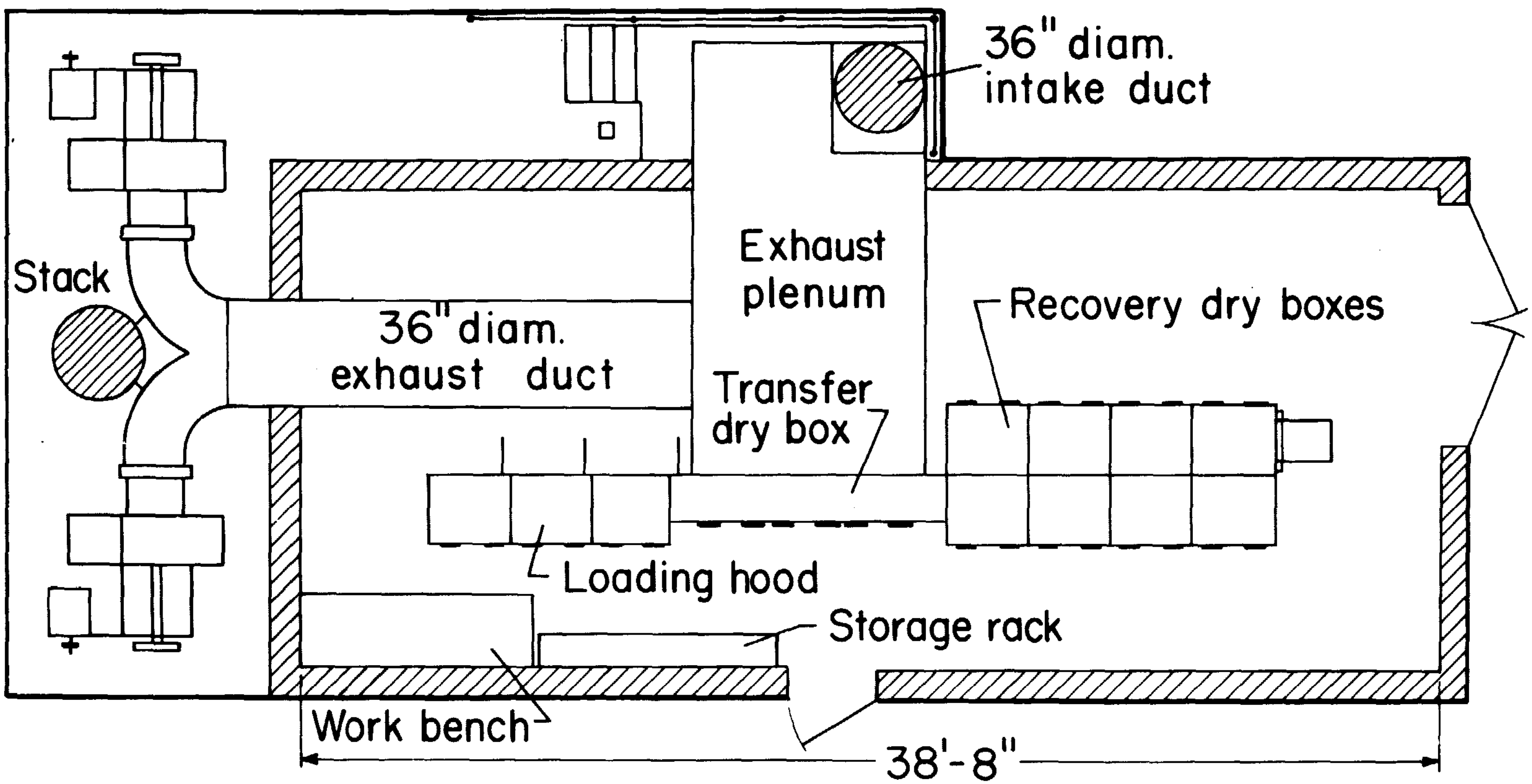
Year	Wing 7	Wing 5	Wing 2
1953	———	———	.000024
1954	.000426	.000337	.000352
1955	.000397	.000374	.000984
1956	.000374	.001151	.000361
1957	.000315	.000183	.000297
1958	.002062	.000316	.000435
1959	.000323	.000151	.000139
1960	.000499	.000953	.000207
1961	.000574	.000400	.000241
1962	.000544	.000139	.000037
1963	.000347	.000042	.000156
1964	.000305	———	.000258
1965	.001053	.000139	.000244
1966	.000627	.000042	.000136
1967	.002992	.000109	.000578
1968	.003201	.000722	.001597
1969	.005251	.003960	.001259
1970	.004100	.003900	.005200
1971	.005300	.002000	.006650
1972	.003290	.001400	.003030
1973	.003698	.001371	.003101
1974	.000017	.000135	.000003

Table 3

1973 and 1974 CMR Building
Gross Alpha Effluent in Curies

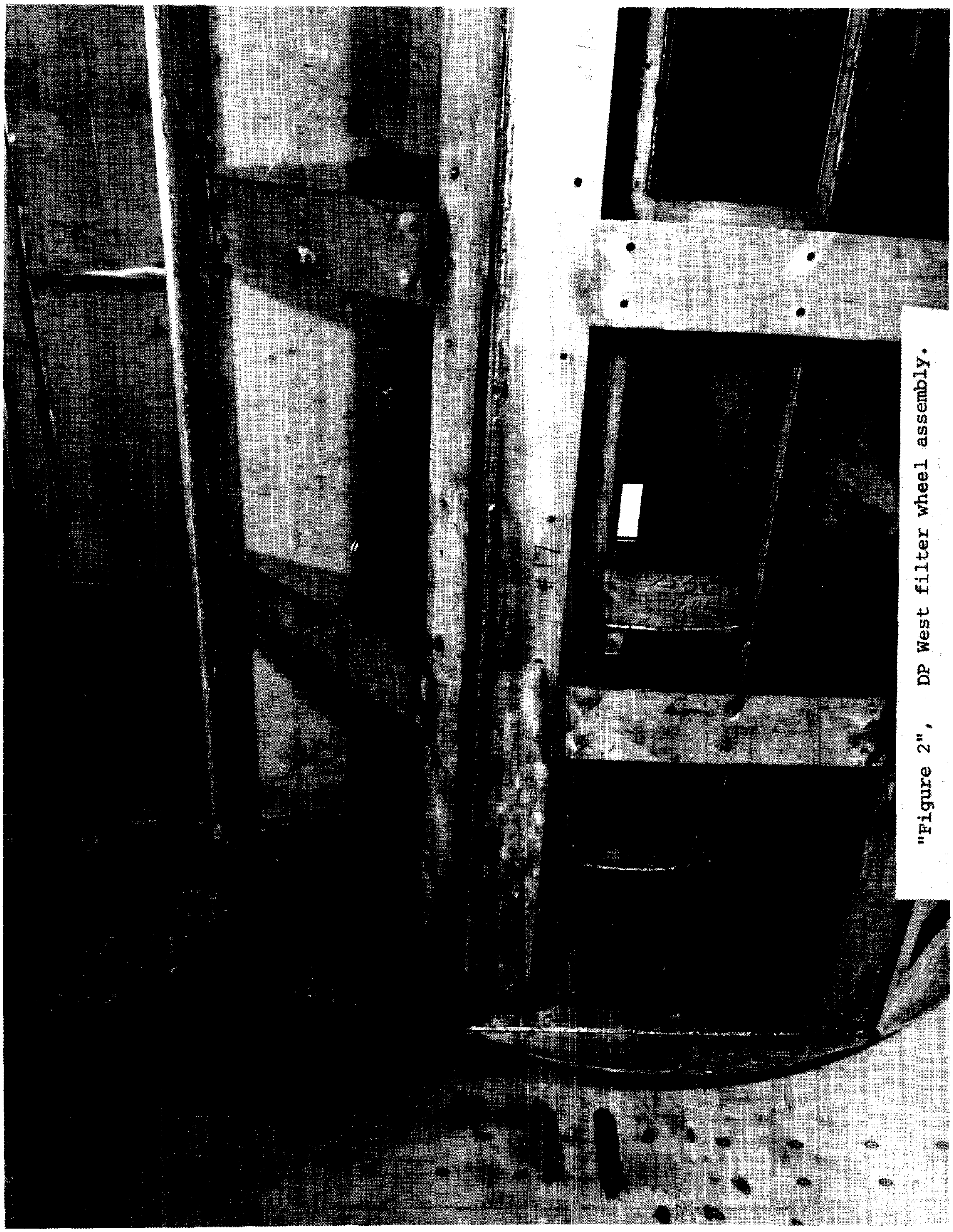
Month	Wing 2	Wing 5	Wing 7
1/73	.000133	.000041	.000521
2/73	.000433	.000273	.000282
3/73	.000108	.000125	.000061
4/73	.000049	.000039	.000338
5/73	.002053	.000279	.000422
6/73	.000029	.000056	.000281
7/73	.000158	.000148	.000080
8/73	.000070	.000068	.000378
9/73	.000049	.000030	.000435
10/73	.000019	.000179	.000379
11/73	.00000009*	.000062	.000416
12/73	.00000000	.000071	.000105
1/74	.00000090	.000134	.000012
2/74	.00000004	.00000010*	.00000040*
3/74	.00000010	.00000007	.00000003
4/74	.00000100	.00000020	.00000003
5/74	.00000043	.00000036	.00000190
6/74	.00000051	.00000046	.00000240

*HEPA Filters Installed.

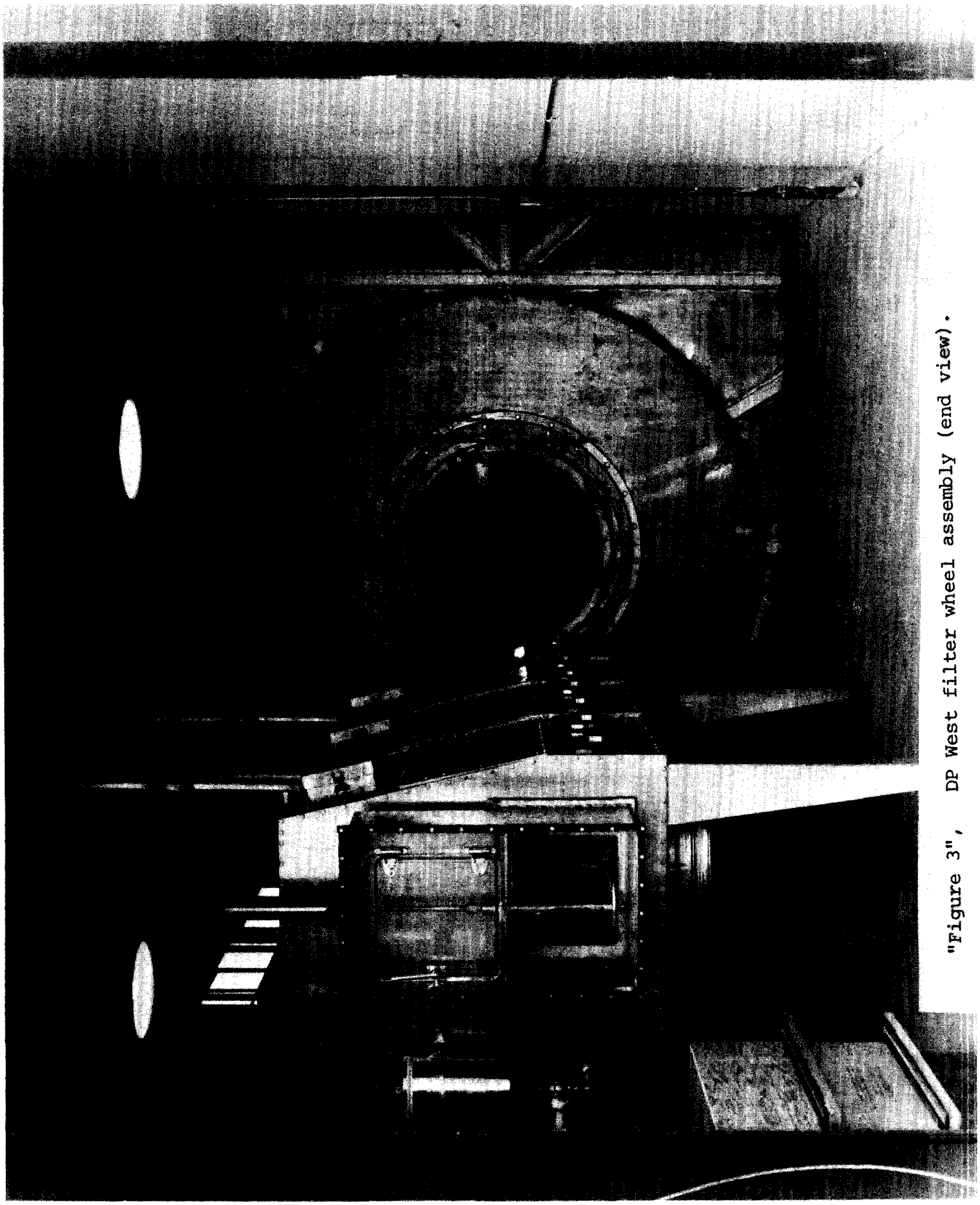


Filter house layout

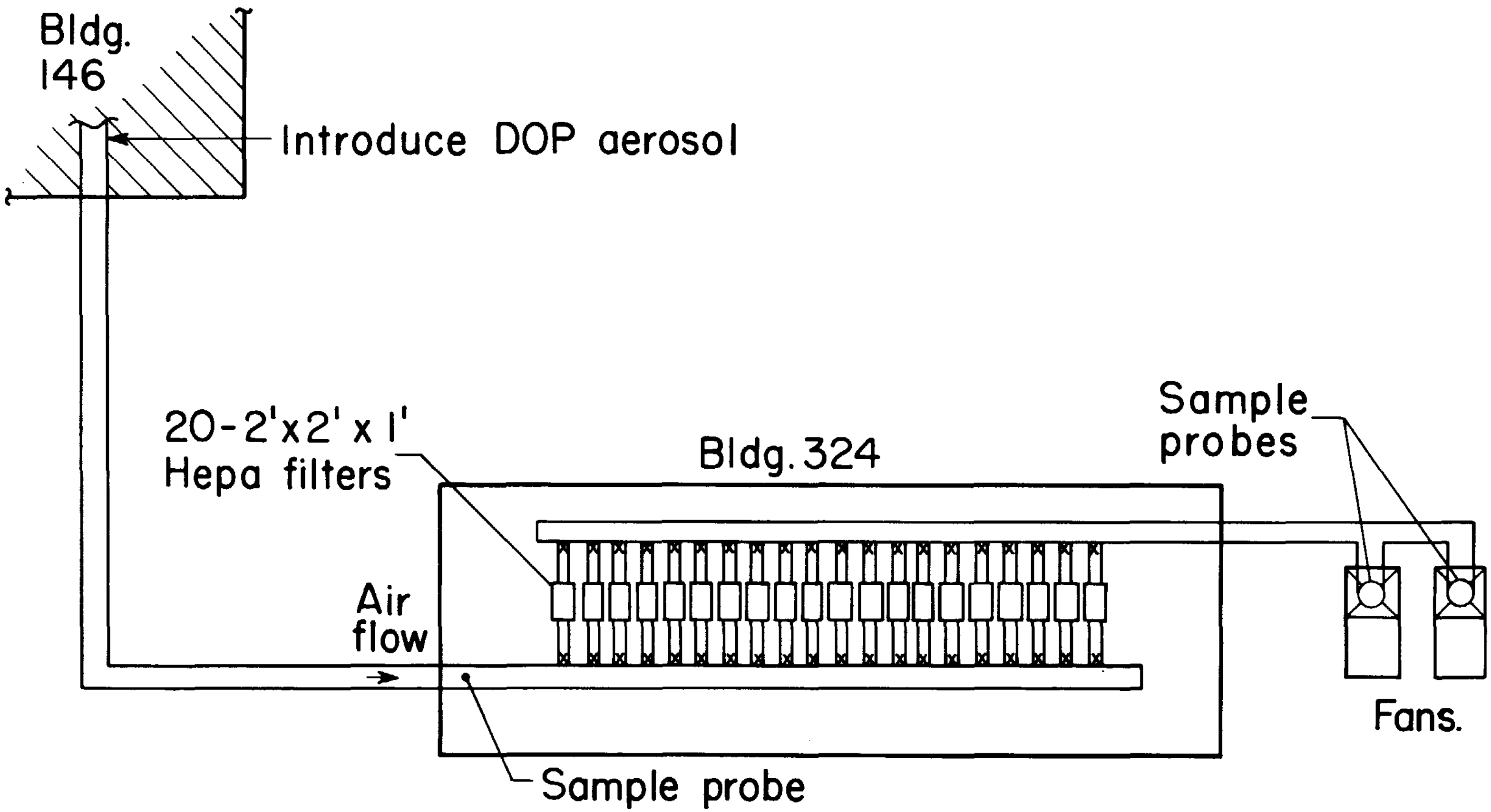
"Figure 1", DP West process exhaust (stage 1).



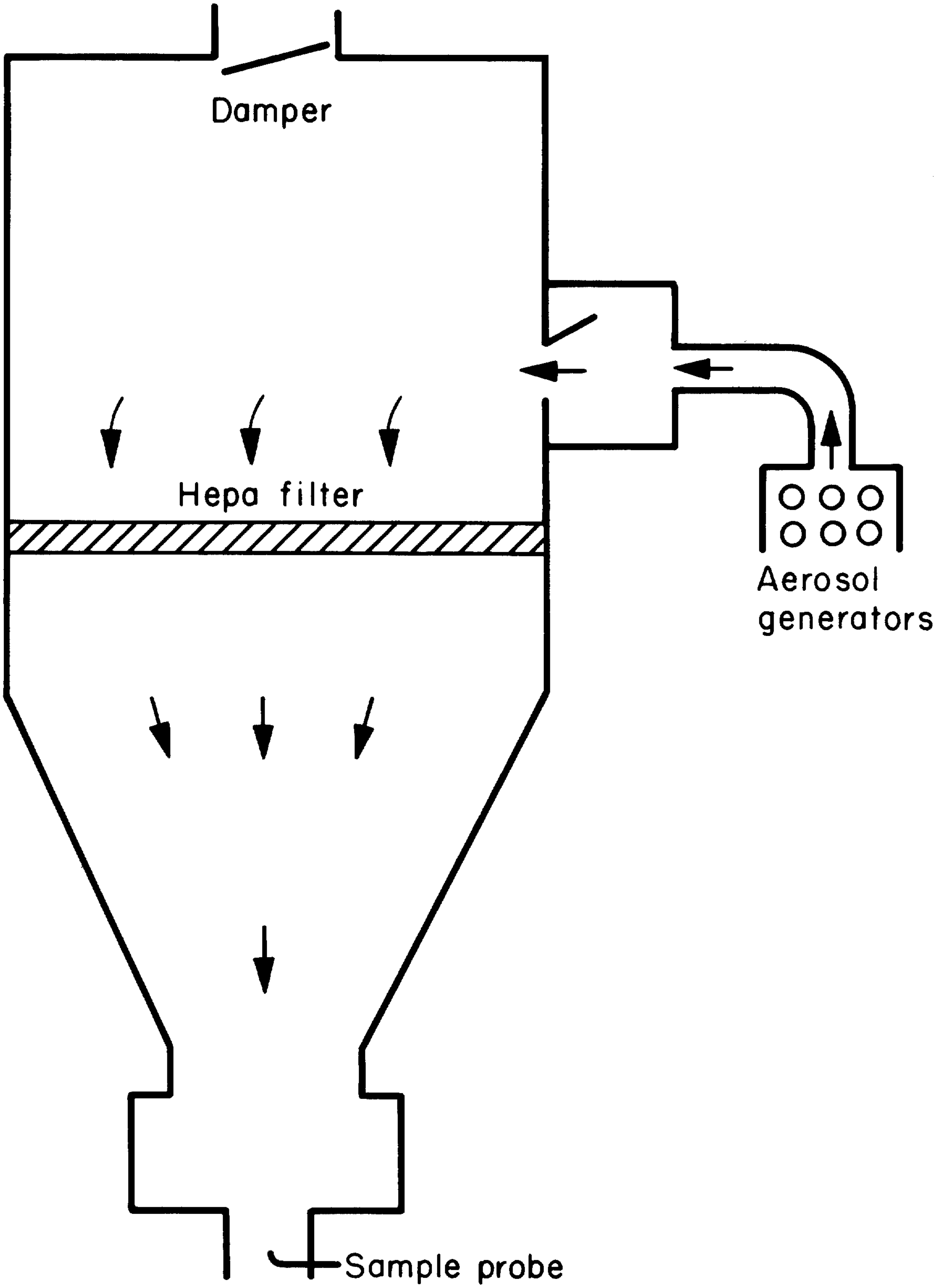
"Figure 2", DP West filter wheel assembly.



"Figure 3", DP West filter wheel assembly (end view).

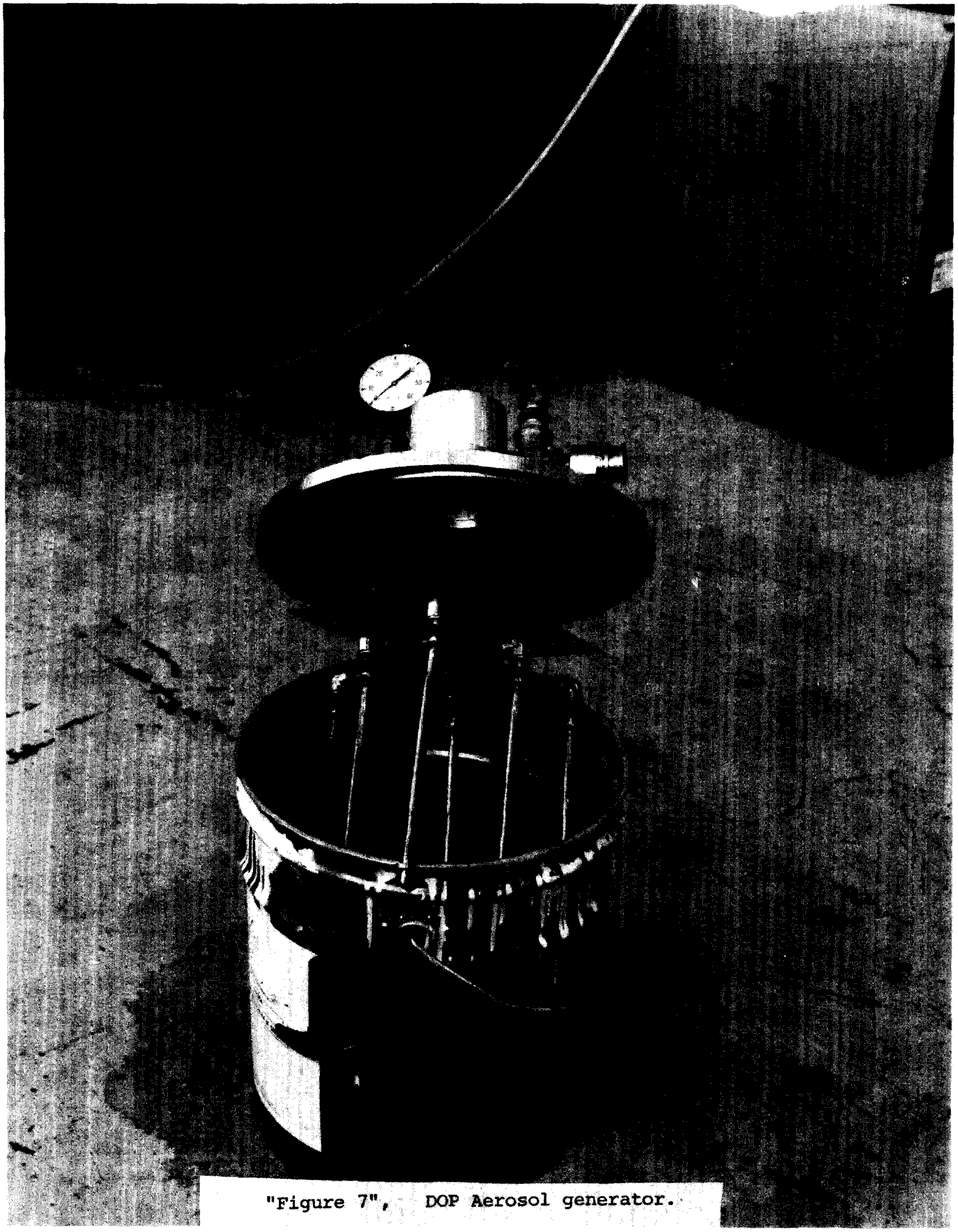


"Figure 4", DP West process exhaust (final stage).



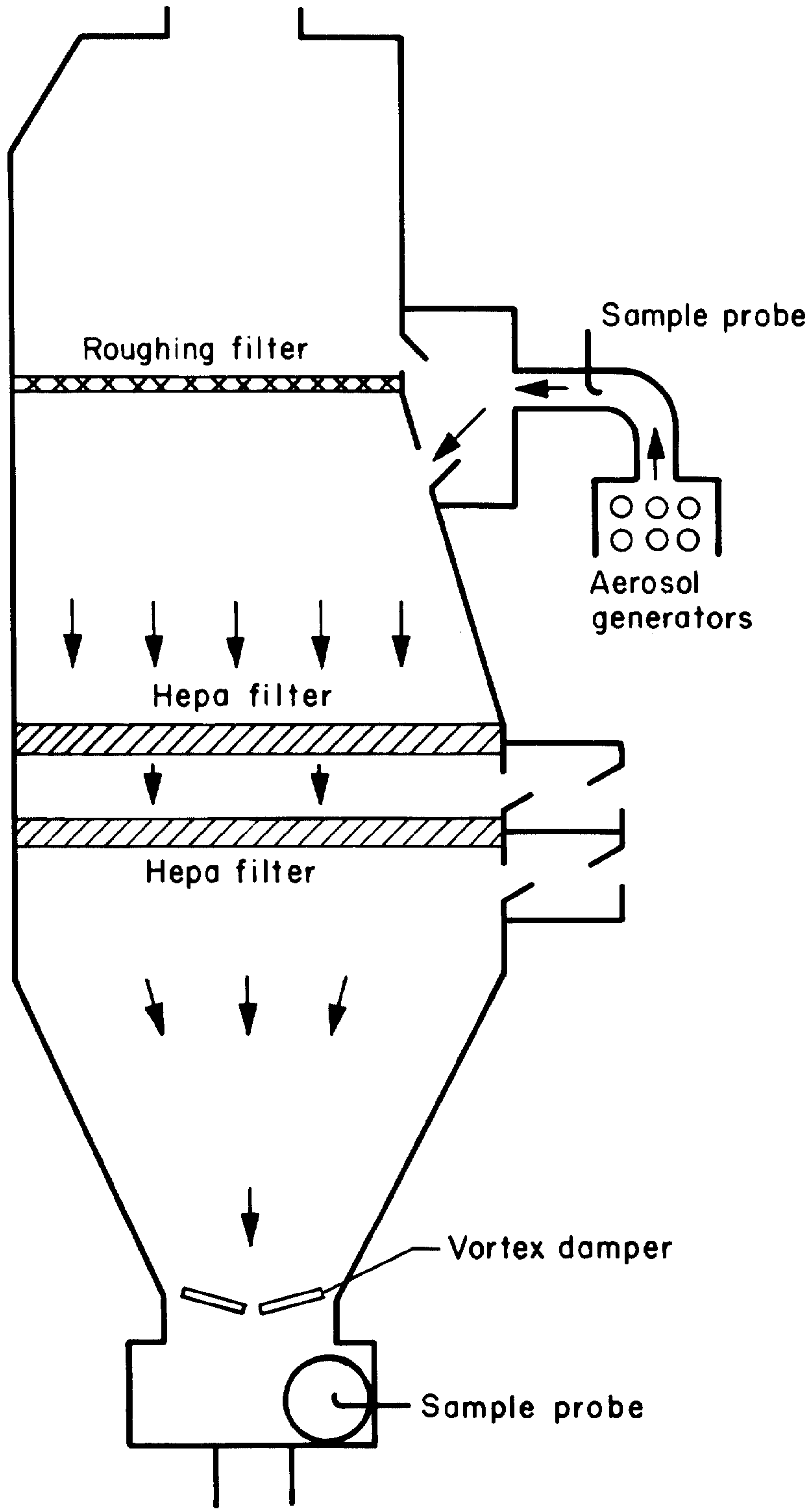
"Figure 5", DP West room air exhaust system.

"Figure 6", CMR Building filter leak probe test.

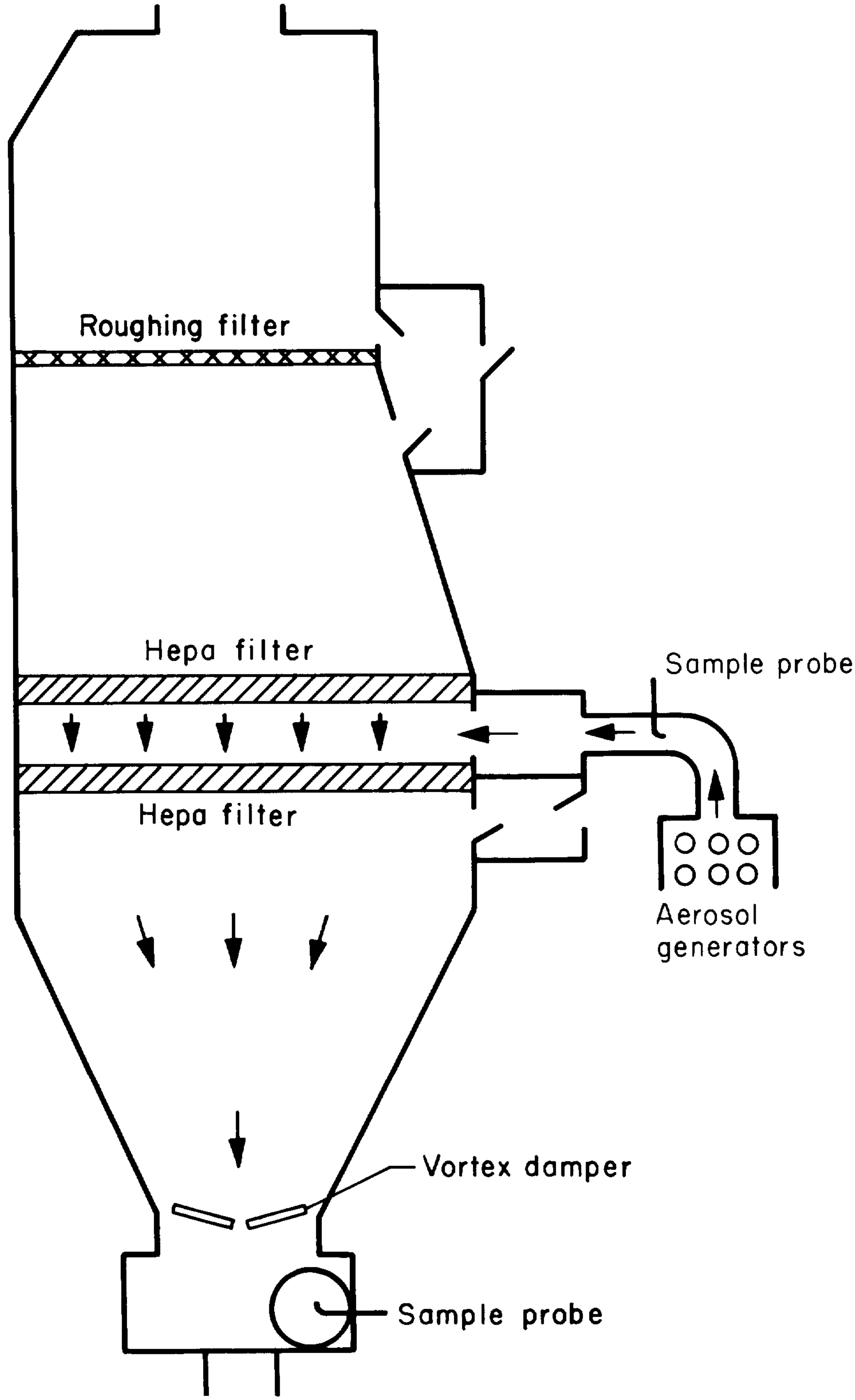


"Figure 7", DOP Aerosol generator.

"Figure 8", DOP Aerosol introduction system.



"Figure 9", DOP Testing of the first stage of filters.



"Figure 10", DOP Testing of the second stage of filter.

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5. Echols, W. H., and Young, J. A., "Studies of portable air-operater aerosol generators," NRL Report 5929 (1963).

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DISCUSSION

HALLIGAN: Would you comment on the distribution of aerosol in that last system?

MITCHELL: When we were doing these tests, we had a man with a portable hose from the light scattering chamber transverse back and forth and up and down through the whole filter plenum. We had a very good distribution across the whole face of the filter plenum.

HALLIGAN: Velocity as well?

STAFFORD: I don't have any answers for that.

A PROPOSAL TO RECIRCULATE GLOVE BOX AND FABRICATION AREA AIR IN A PLUTONIUM FUEL FABRICATION PLANT

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Abstract

Recirculating glove box and fabrication area ventilation systems are proposed for a 40 Te/yr mixed plutonium-uranium oxide fuel fabrication plant. The ventilation design criteria are outlined, features of the fabricating plant relating to the ventilation system are shown and the recirculating systems are described. A method of operating and recirculating systems during unusual situations, energy conservation and system advantages are discussed.

I. Introduction

In 1973 a group was organized at Atomic Energy of Canada Limited to produce a conceptual design for a 40 Te/yr mixed plutonium-uranium oxide fuel fabrication plant. This group included representatives from various divisions within AECL, commercial fuel fabricators and a consulting firm. The following design criteria were proposed.

The ventilation system shall:

1. utilize three self-contained HEPA filters in series on all exhaust filtration systems which release air directly to the environment[1]

2. discharge a minimum amount of air outside the final containment of the plant to reduce the plutonium release potential and to conserve energy

3. require a minimum number of penetrations of minimum size through the secondary containment, since they are the potentially weak points

4. have controlled dampers or valves at all containment penetrations that close automatically when the HEPA filters are threatened.

5. provide ready access to all systems for in-place testing and monitoring

6. have its filters and recirculating systems in service rooms no less elaborate, from a contamination control point of view, than the process area

7. consist of reliable supply, recirculation, filtration and exhaust units designed for continuous operation, but which may be automatically or manually stopped and restarted under certain conditions.

A plutonium-uranium oxide fuel fabrication plant ventilation system based on these criteria is outlined in this paper. Only those features of the proposed plant that relate to the ventilation systems are discussed.

II. Plant

Figures 1 and 2 show the plant layout and cross section. The heavy lines define the secondary containment. The lower level is the service room housing the HEPA filters, recirculating air handling units, cooling system, liquid collection systems and liquid solidification process. It provides access for sampling, monitoring and maintenance for all the service systems. This arrangement precludes the necessity of an attic above the process area and results in one containment area for both liquid and ventilation services. It also allows improved freedom from material handling systems and crane service on the upper level.

III. Glove Box Ventilation System

Figure 3 shows the glove box lines superimposed on the plant layout. For the purpose of this proposal, a ventilation rate of 10 cfm per lineal foot of glove box line was selected. This may not be adequate for some high heat producing processes housed in the line[2]. Two recirculation systems of the same size are proposed for each main fabrication line, one before and one after the furnace. However, more could be used if specific conditioning requirements must be met in certain glove boxes. These systems will probably not exceed 1000 cfm each and can therefore be served by 1100 cfm HEPA filters. Other similar sized recirculating systems will be required for glove box lines used in the analytical, decontamination, maintenance, liquid waste and liquid solidification areas.

Figure 4 is a schematic of two recirculating glove box ventilation systems. Each system has an air conditioning cabinet containing the cooling, dehumidifying, heating, scrubbing and other equipment required for the process line it serves. A constant volume control is provided on the glove box outlet to compensate for filter build-up and the glove box-to-room differential pressure is controlled by the glove box inlet valve. The recirculating system pressure profile is controlled by the constant negative exhaust pressure and a differential pressure control valve at the system inlet. All valves normally close when control pressure is lost. Each recirculating glove box system must be capable of exhausting from its glove box line sufficient air to maintain a face velocity of 0.5 m/s (100 ft/min) over an open 6 in. glove port or an open bag-in-out port.[2]

IV. Glove Box Filter System

A small HEPA filter is provided on the inlet and outlet of each glove box. Each glove box outlet is also provided with a roughing filter located in and changed from inside the box. The recirculating air conditioning unit has a further HEPA filter on its inlet. This prevents contamination of the air conditioning unit if a glove box outlet filter fails and provides additional cleaning.

The main glove box exhaust system for the building has two HEPA filters in series. Thus triple filtration is provided between the glove box and the environment.

V. Room Ventilation System

Figure 5 is a schematic diagram of the recirculating room ventilation systems. The recirculating air conditioning units located in the lower level draw room air through dampers at the ceiling, an HEPA filter and an optional charcoal filter. The air is conditioned and discharged through dampers at the ceiling to the upper level wall or ceiling diffusion system.

Figure 6 is a schematic diagram of the room make-up and exhaust systems. Make-up air is supplied at constant pressure through a shut-off damper from the make-up conditioning unit outside the containment area. This unit also provides make-up air for the glove box system, although it could be drawn directly from the room.

Air is extracted from the room via the fume hoods (see Figure 6). An HEPA filter immediately above the fume hood and a constant volume damper at the floor penetration provide primary filtration and control. Two more HEPA filters in series and a shut-off damper are located before the main exhaust fans and the stack. Should more air need to be exhausted than is required for the fume hoods, additional air may be drawn from the return system (Figure 5), or directly from the room as shown in Figure 6.

Figure 7 shows the entire system.

VI. HEPA Filter Installation

Figure 8 shows a plan and an elevation of a proposed HEPA filter module with a capacity of 5.3 m^3/s (11,000 cfm). At 10 changes per hour of the secondary containment air volume 18 such modules, located in the basement service area, are required.(3) Sixteen of the modules will serve the recirculating room air system and use one HEPA filter and one optional charcoal filter. Two of the modules will serve the fume hood exhaust system and use two HEPA filters in series.

The modules use self-contained filters for the following reasons:

1. The duct connection is simple and reliable.

2. Individual filter units can be pre-tested in a laboratory and retested in situ under identical conditions.

3. Filters can be changed without a bag-out system.

4. Personnel do not enter the ventilation system to change filters.

5. Filters are less likely to be damaged during installation.

The main disadvantage of using self-contained filters is that they require more space than an open bank or grid arrangement. However, this is more than offset by the advantages listed.

VII. Supply, Exhaust and Recirculation System Operation

Normally all systems operate at all times, however, individual units or combinations of units may be allowed to operate all of, part of, or no part of the time that an unusual condition exists. It is intended that an adequate monitoring system be provided with central control of all air handling and filtration systems. Thereby, intelligent operating decisions to cope with unusual situations may be made automatically or manually from outside the secondary containment.

For example, in the case of a glove box fire, the recirculating glove box system exhaust and supply connections are automatically valved off after release of the Halon fire suppressant. The recirculating glove box system continues to operate but may be automatically shut down by a high temperature indication at its HEPA filter. Normally the glove box protection system should cope with all fires in a short time but a fire must be treated as an emergency and the appropriate procedures including evacuation of personnel should begin. However, some glove box pressure rise accompanied by a minor loss of plutonium may be expected, especially if serious clogging of the primary roughing and HEPA filters occurs. This pressure rise can only be mitigated by early detection and rapid and effective suppression. Both once-through and recirculating systems have this problem.

In general, the proposed operating system provides for shutting down and valving off affected subsystems. This protects the HEPA filters from abnormal conditions and minimizes contamination of the environment. Once the incident is under control decontamination proceeds until the room exhaust and recirculation systems have reduced the concentration of contamination in the air to a small fraction of the MPC.

VIII. Shut Down Reliability

A preliminary fault tree of the shut off dampers and controls on one plutonium escape path through the glove box exhaust system is shown in Figure 9.[4] The analysis assumes that the two dampers in series are closed before the HEPA filters are destroyed. A high temperature detected in the glove box line automatically closes damper #1 thereby isolating the affected line from the main exhaust duct and containing the fire and any suspended plutonium. Should a high temperature be detected in the main exhaust duct beyond the first damper, damper #2 automatically closes to isolate the entire system.

For this very preliminary analysis a rate of one fire per year per glove box, in a reference plant made up of five systems of five glove boxes each, or an intolerable 25 fires per year are assumed. However, this intolerable condition still shows a low failure rate of 1.25×10^{-6}.

IX. Energy Conservation

The bulk of the energy required by the fabricating plant within the secondary containment arises from conditioning make-up air and dissipating the internal heat gain. The make-up air in this proposal has been reduced to one air change per hour for contamination control purposes, compared to, say, 10 changes in a once-through system. This results in a considerable reduction in the heating and cooling energy required to condition it. However, the free cooling and the direct discharge of waste heat is reduced when compared to a once-through system.

Table I lists the heating and cooling loads for one change of air per hour for the secondary containment areas. These loads are of considerable magnitude yet represent only one-tenth of the energy required for a 10 air-change once-through building ventilation system.

X. Summary of Advantages of Recirculating Systems

1. Considerable energy can be saved by the use of recirculating room air systems in most climatic regions.

2. A significant reduction in the long-term accumulated plutonium release to the environment via the exhaust system should be achieved by recirculating glove box air.

3. Both recirculating glove box and room air systems can significantly reduce the plutonium release to the environment via the exhaust system during unusual short-term incidents.

4. The recirculation of room air should reduce the problem normally encountered from radon and thoron and their daughter products when monitoring the air for plutonium. They should rapidly collect on the filter and not interfere with routine air sampling to the same extent.(5)

5. The area of relatively weak filter material acting as a secondary containment barrier is reduced to a minimum.

6. The amount of Halon fire suppressant gas required to protect a glove box line with a recirculating ventilation system is much less than that required by a once-through glove box ventilation system.

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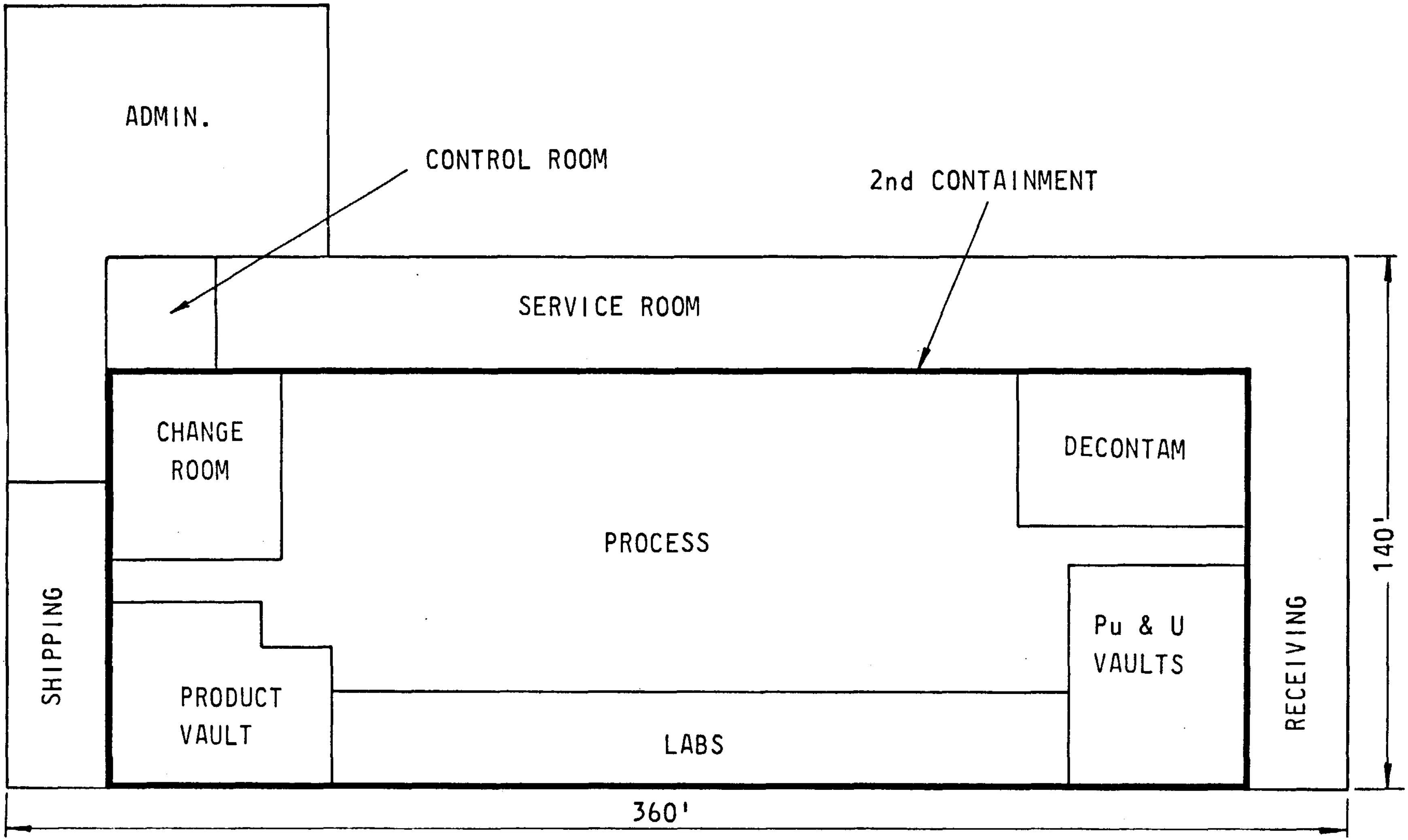

Figure 1 Fabricating Plant 1st Floor Plan

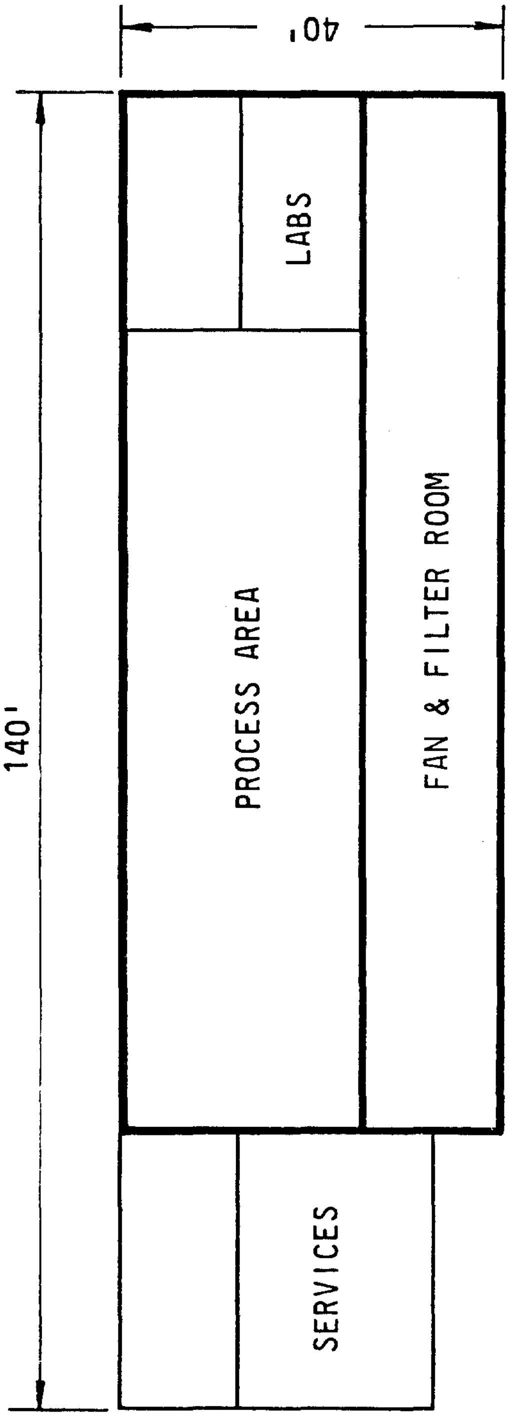

Figure 2 Fabricating Plant Cross-Section

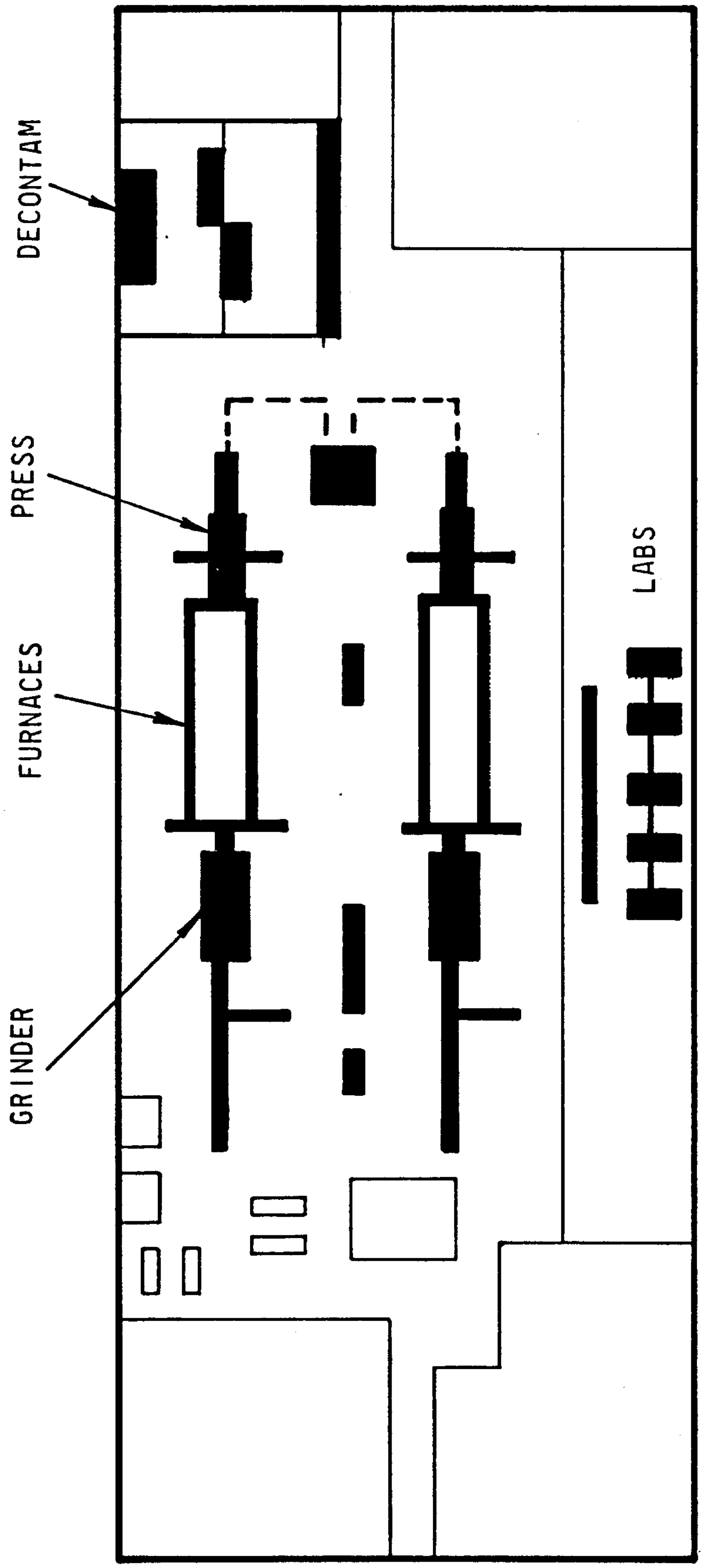

Figure 3 Fabricating Plant Glove Box Lines

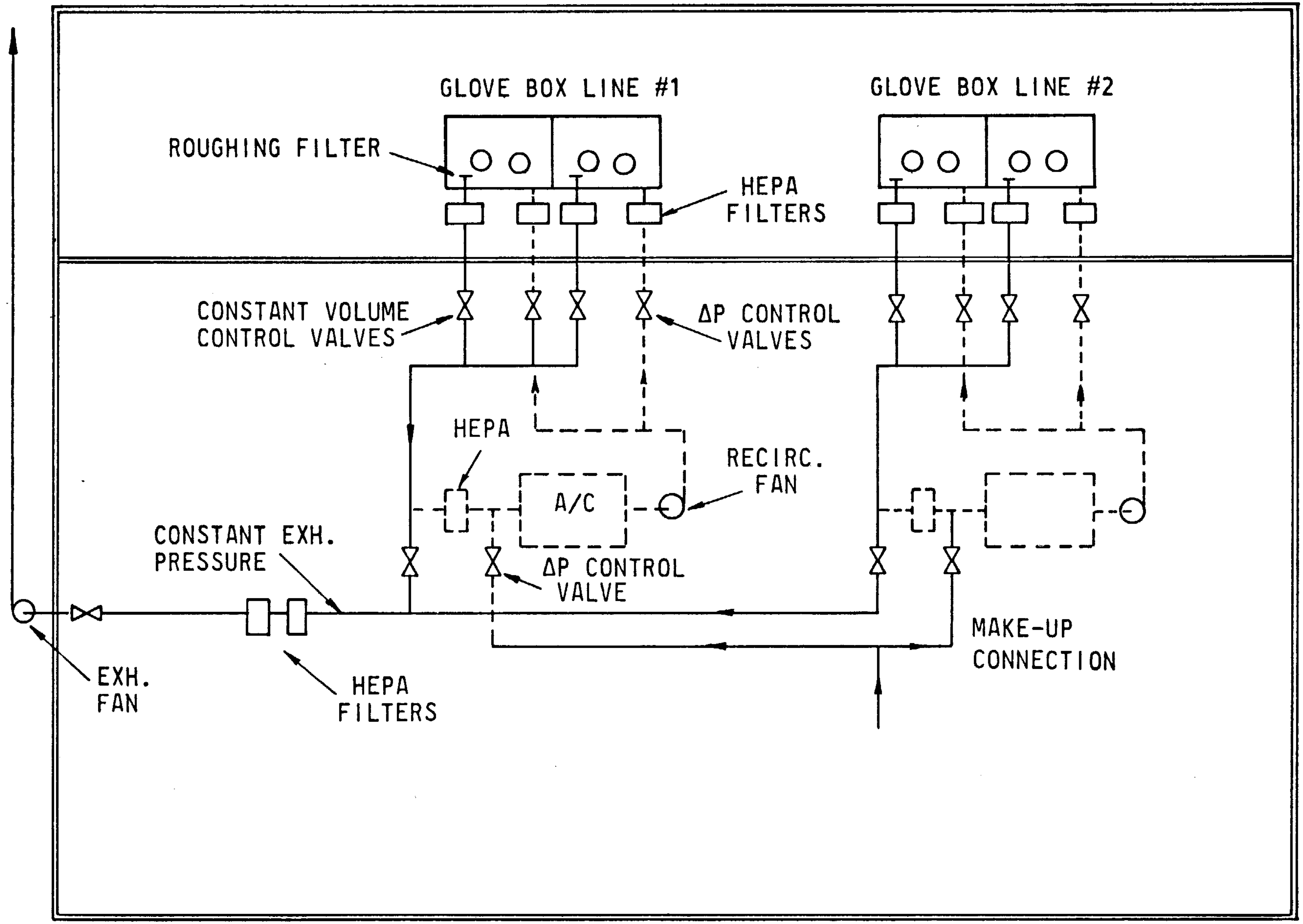

Figure 4 Recirculating Glove Box Ventilation System Schematic

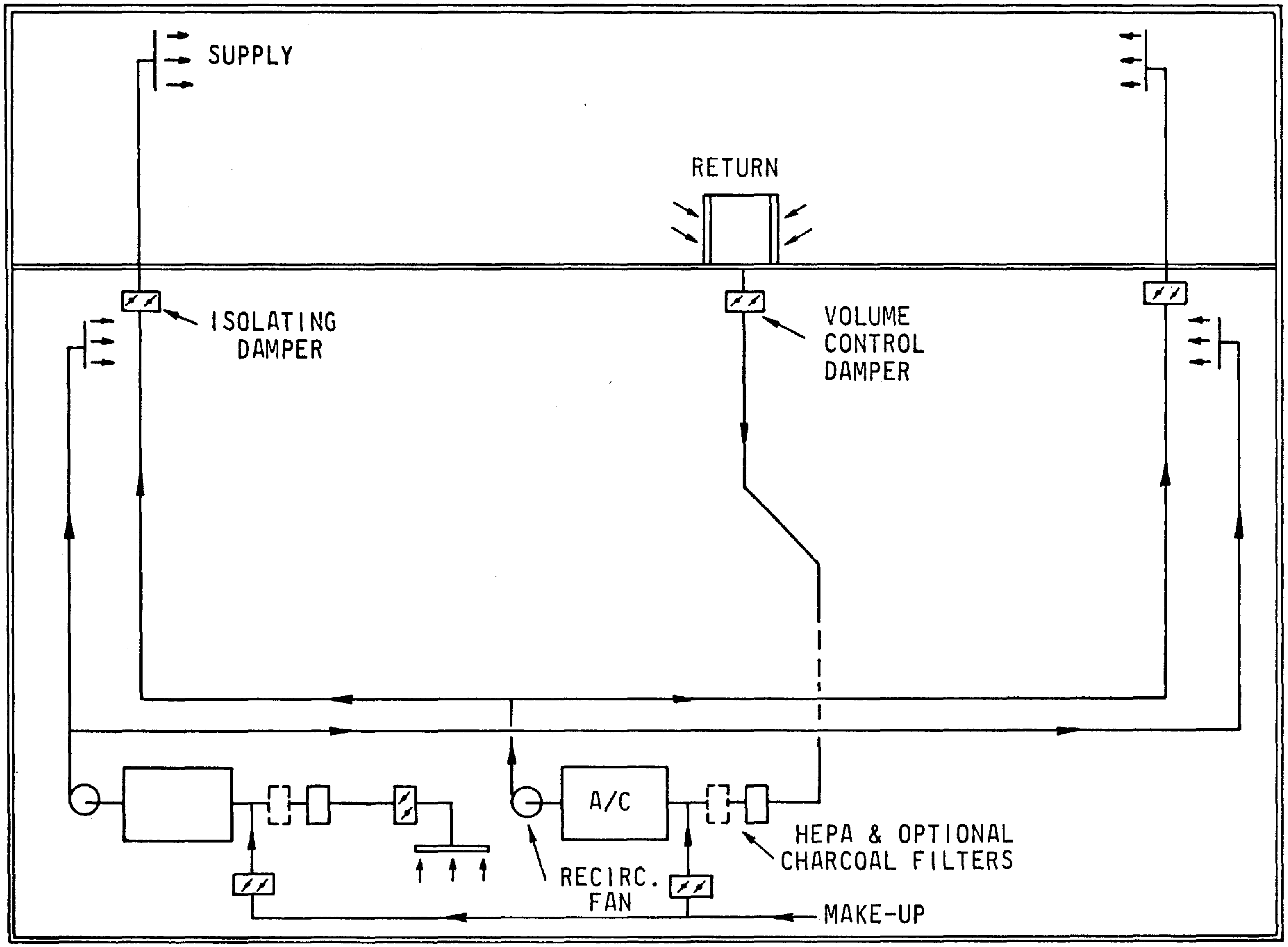

Figure 5 Recirculating Room Ventilation System Schematic

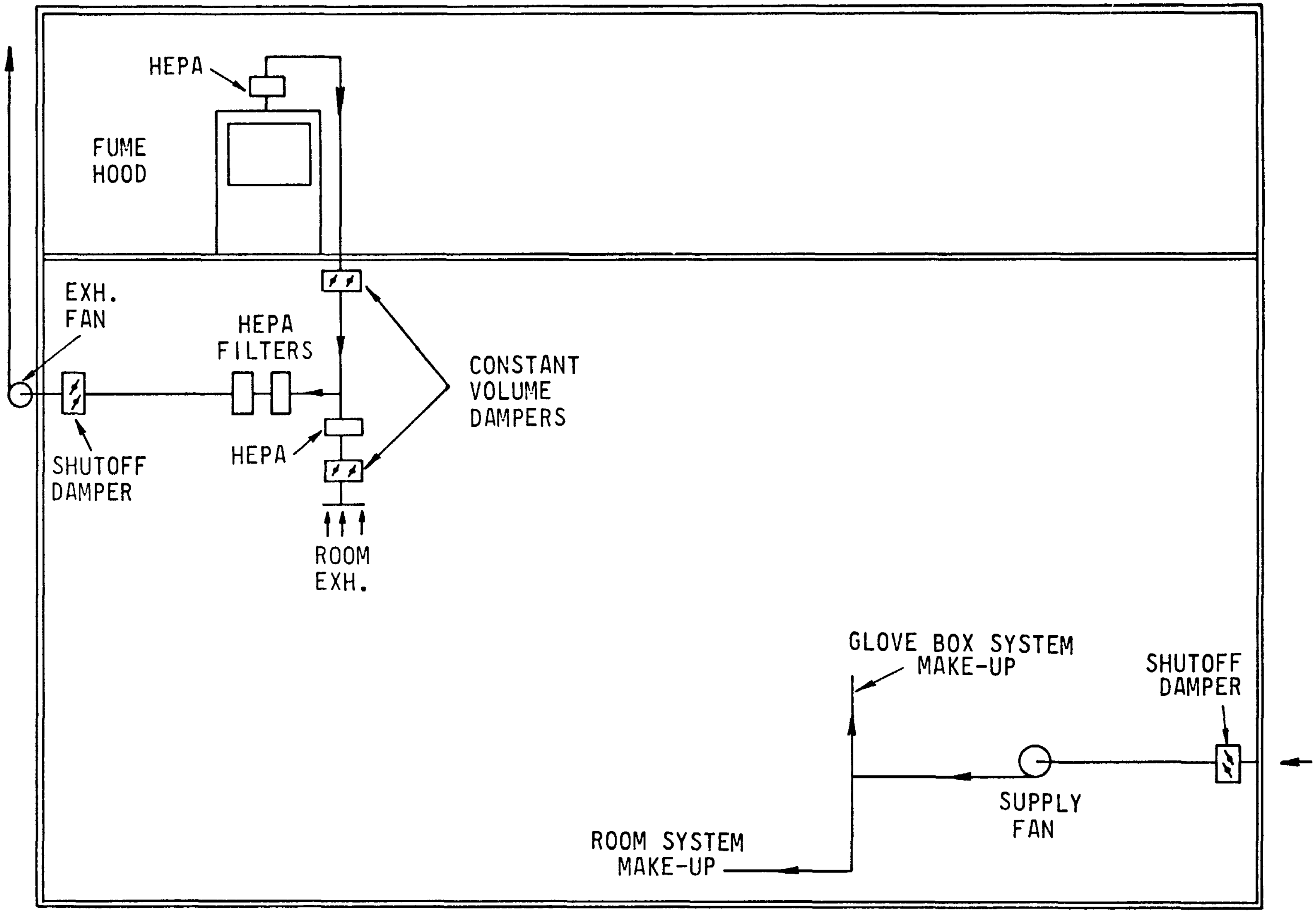

Figure 6 Room Exhaust and Make-up Systems Schematic

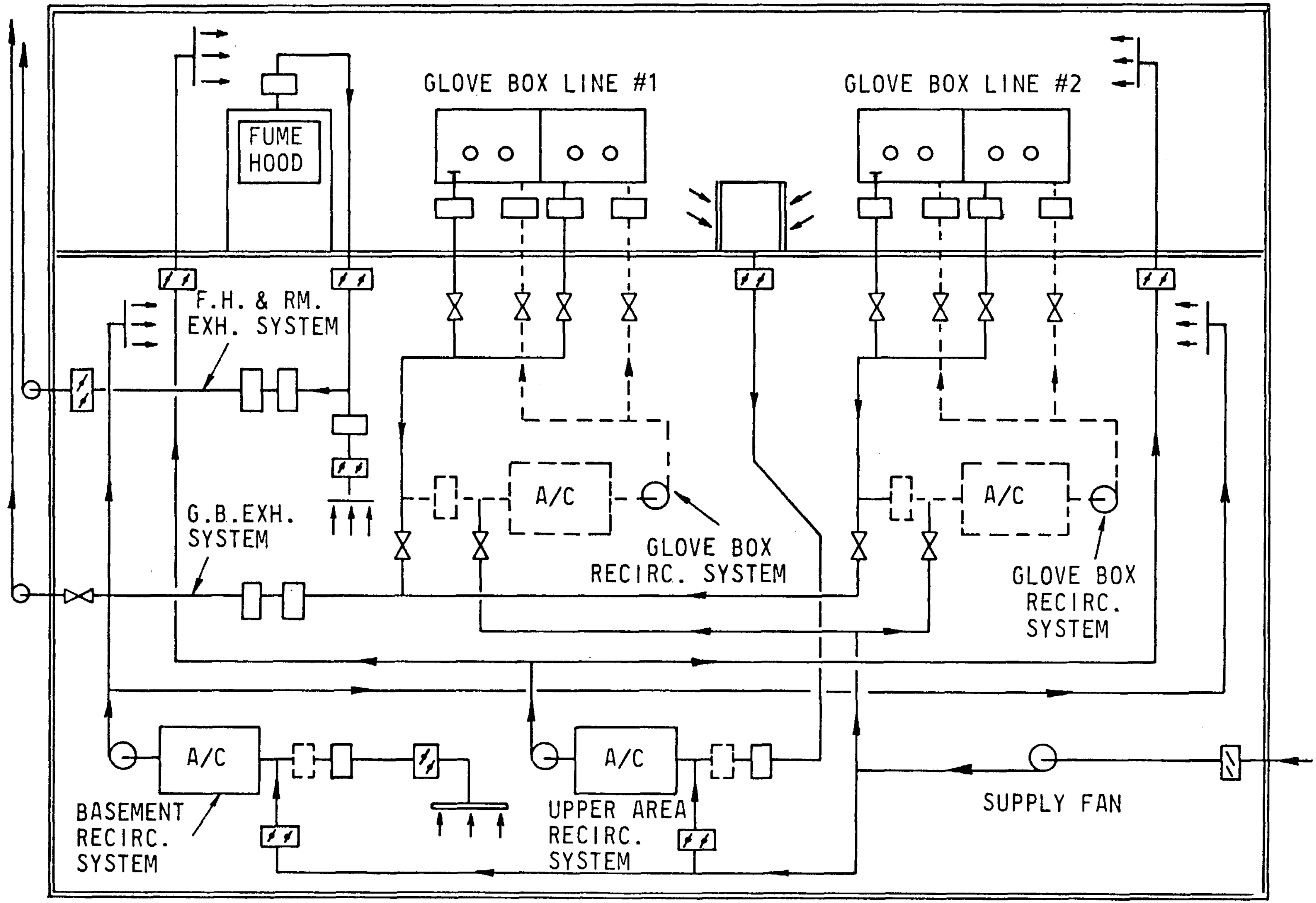

Figure 7 Ventilation System Schematic

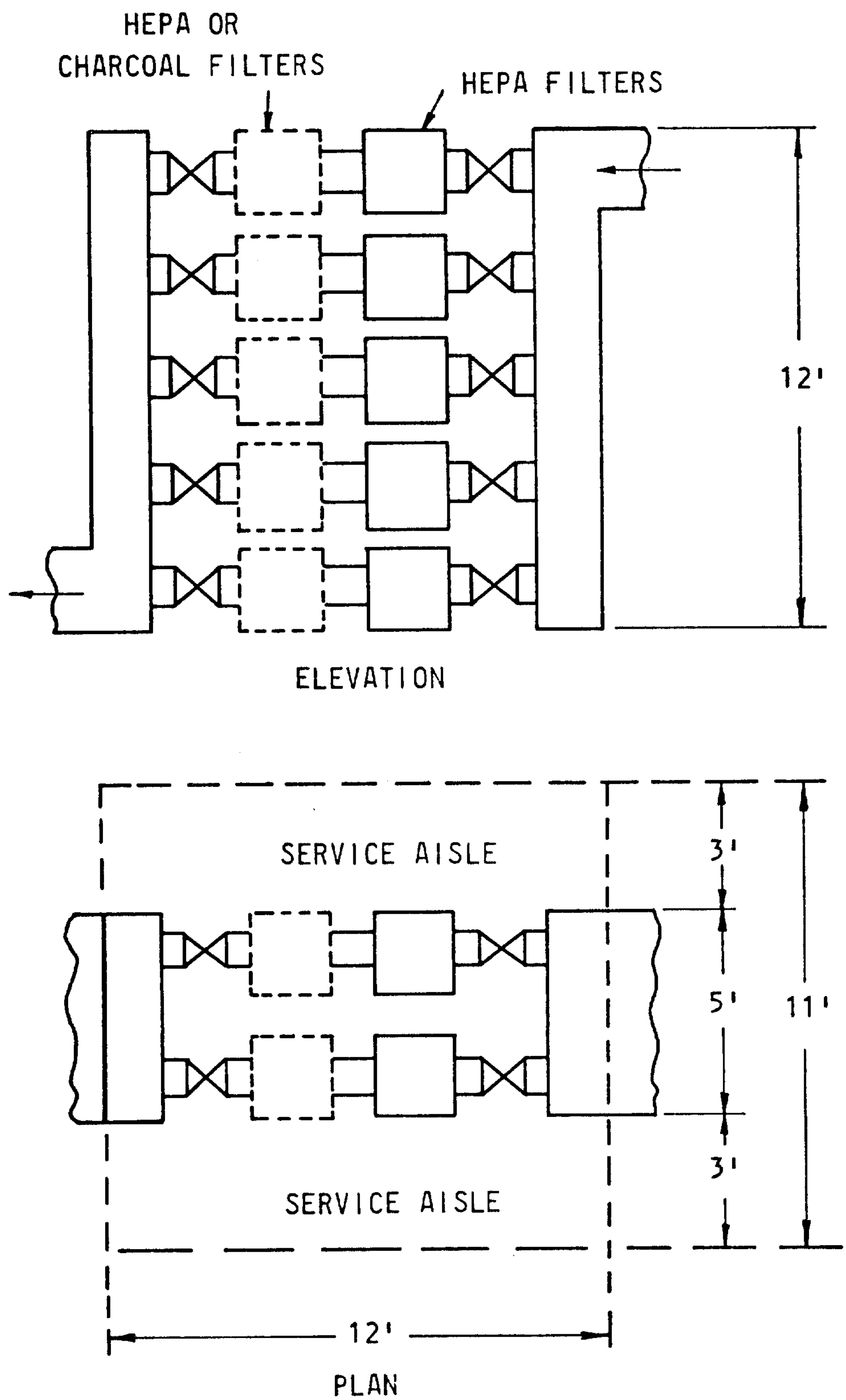

Figure 8 5.3 m³/s (11,000 cfm) Filter Module

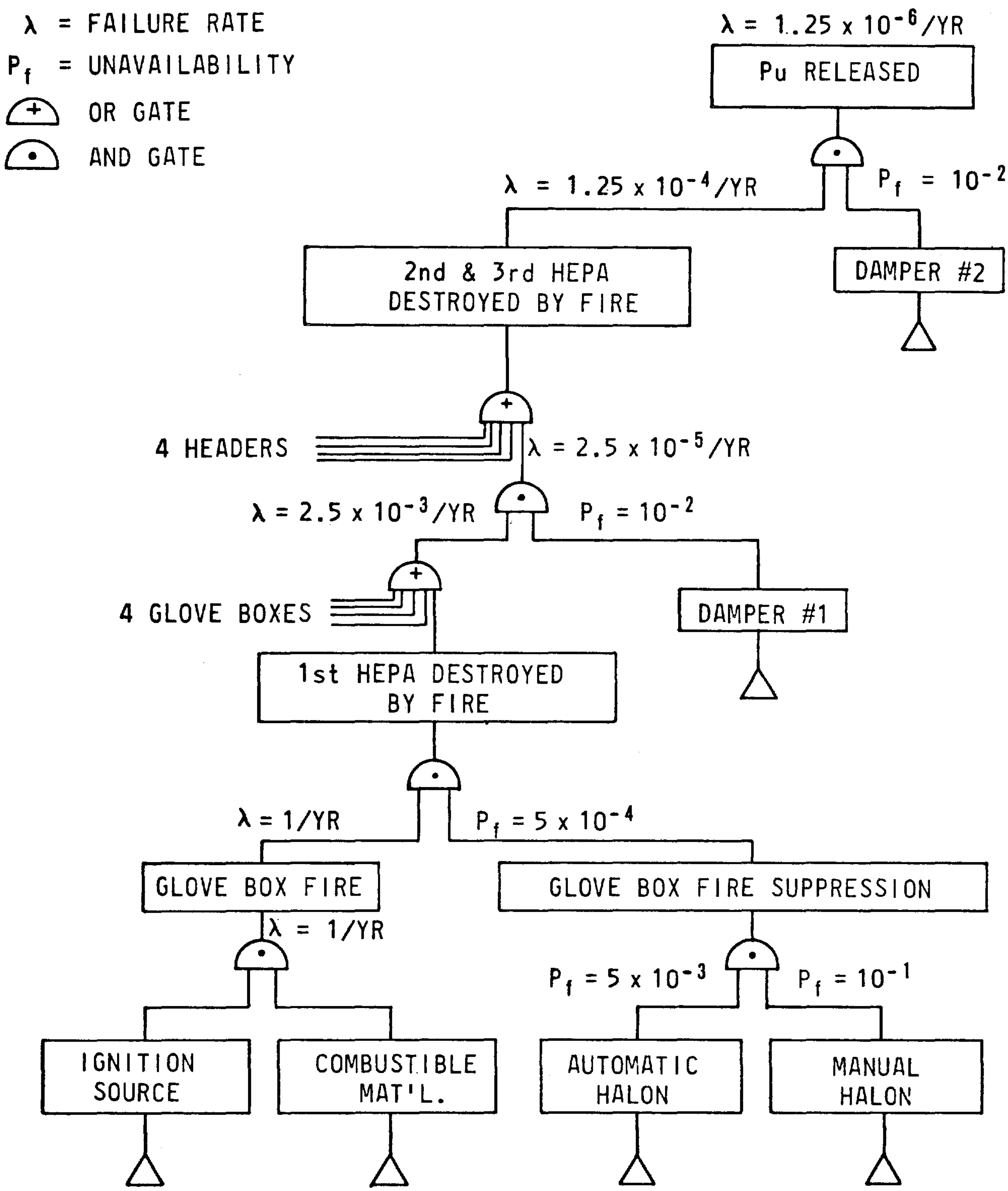

Figure 9 Glove Box Exhaust Damper System Fault Tree

ZONE	AREA		VOLUME		AIR HEATING LD* @ 1 CHANGE/HR x 10^3		AIR COOLING LD @ 1 CHANGE/HR x 10^3	
	METERS²	(FEET²)	METERS³	(FEET³)	JOULES/s	(BTU/HR)	JOULES/s	(BTU/HR)
DECONTAM AREA	222	(2400)	1360	(48000)	25.8	(88)	10.6	(36)
Pu & U VAULT AREA	390	(4200)	2380	(84000)	45.2	(154.2)	18.9	(64.6)
PROCESS AREA	1540	(16575)	9390	(331500)	178.4	(608.6)	74.7	(255.0)
PRODUCT VAULT	334	(3600)	1120	(39600)	21.3	(72.7)	8.7	(29.7)
LAB AREA	418	(4500)	1400	(49500)	26.6	(90.9)	11.1	(38.0)
CHANGE ROOM	209	(2250)	700	(24750)	13.3	(45.4)	5.6	(19.0)
ABOVE LAB AREA	710	(7650)	2165	(76500)	41.2	(140.4)	16.8	(57.4)
NON FISSILE STORE	460	(4950)	1400	(49500)	26.6	(90.9)	10.9	(37.2)
BASEMENT SERVICE AREA	3065	(33000)	12610	(445500)	239.7	(817.9)	100.4	(342.7)
TOTALS	7348	(79125)	32525	(1,148850)	618.1	(2109.0)	257.7	(879.6)

DESIGN CONDITIONS: SUMMER 31.1°C db (88°F) 22.8°C wb (73°F)
WINTER -34.4°C db (-30°F)

* INCLUDES HUMIDIFICATION

TABLE I Secondary Containment Area Heating and Cooling Loads

DISCUSSION

FREEMAN: I notice you have HEPA filters on the fume hood exhaust. For what purposes are your fume hoods used?

PHILIPPI: There is actually very little plutonium work done in fume hoods. I am talking about the process areas. They are largely used for final leak testing of the sheathed fuel. There is talk of going to final welding in a fume hood. There may also be some machining of the welded fuel elements in fume hoods. This is done to prevent plutonium inclusions in the upset at the weld, which is being removed, from becoming a slight contamination problem.

FREEMAN: Then you would rather weld in a fume hood than in a glove box?

PHILIPPI: Definitely so. The only other place that fume hoods are used is in the decontamination area. Once the equipment has been decontaminated to a certain extent in boxes, work may be continued in fume hoods. Certain maintenance procedures will also be done in the fume hoods.

MOELLER: Since I understand that Canada does not have any chemical processing plant, I wonder about the source of your plutonium?

PHILIPPI: Lab quantities are imported. This fabricating plant is part of a study including a reprocessing plant and a plutonium burning reactor.

HAMMERTON: I wonder how many air changes your people have in the room surrounding the glove box?

PHILIPPI: In our laboratories right now, we run approximately 10 air changes per hour and that's why we use 10 air changes on the recirculating system and one air change for fresh air. We are presently installing an analytical line which will have room air recirculating in that ratio of 10 to 1.

VENTILATION SYSTEMS AS AIR CLEANING DEVICES IN NUCLEAR POWER PLANTS - EXPERIENCE AT PALISADES

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Abstract

Experience at Palisades has demonstrated the importance of designing, constructing, testing and operating the ventilation system from the viewpoint of airborne radioactivity control during both normal operation and anticipated operational occurrences. An item of particular concern was the difficulty in maintaining correct non-ducted airflow patterns. Inadequate preoperational testing and system balancing led to marginal ventilation system performance. This condition was further aggravated by extensive plant maintenance and construction activities and, in some cases, by a lack of administrative controls. Following completion of construction of the radwaste addition, it was possible, with minor basic design changes, to adjust and rebalance the entire ventilation system, thus assuring control of airborne radioactivity.

Introduction

In a nuclear plant, the function of the ventilation system goes beyond normal requirements for supply of fresh air and control of temperature. The ventilation system must maintain airborne radioactivity concentrations at acceptably low levels, limit the spread of airborne radioactivity throughout the plant, and minimize leakage to the environment via pathways other than through the prescribed exhaust and filter systems. In addition, the performance of the ventilation system affects the performance of other airborne radioactivity control systems such as filters, adsorbers, monitors, and samplers. Experience at Palisades has pointed up the importance of ventilation in airborne radioactivity control.

The Palisades Plant of Consumers Power Company is located on the eastern shore of Lake Michigan about 15 miles north of the city of Benton Harbor. The plant utilizes a Combustion Engineering pressurized water reactor nuclear steam supply system with an initial plant output of about 700 MWe. By early 1970 basic plant construction was completed, approximately six months behind schedule. However, as the plant chronology in Table I shows, difficulties in obtaining an operating license delayed the first commercial power generation until December of 1971 and full power operation until April of 1973. Figure I shows a view of the plant looking southeast in November 1972 with the radwaste addition and cooling towers under construction.

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Initial Experience

Start-up plans called for a preoperational test procedure to verify the proper functioning of instruments, controls and equipment associated with the HVAC system. Balancing of the system was to be done by the HVAC subcontractor. It became apparent that initial testing was inadequate in at least three areas: (1) Flow rates were not measured for several key vaneaxial fans; (2) non-ducted airflows were not thoroughly checked under various fan lineups; and (3) there was a general lack of flow data throughout the ventilation system as evidenced by the absence of a sufficient number of Pitot probe ports in the ductwork. Because of this lack of flow data, the plant operating staff was not aware of the sensitivity of the ventilation system under certain fan lineups to such things as exhaust hood operation and the position of doors and removable shields.

After initial testing was completed in the summer of 1970 there were no apparent problems with the ventilation system until March 1972 when, almost coincidentally with the increase to 60% power, intermittent airborne activity increases were detected by the continuous air monitors located in the corridors on the 590-foot level of the auxiliary building. Fresh air is supplied to the corridors and should flow from the corridors into the rooms containing potential sources of radioactivity as shown in Figure 2. Radioassay identified the contributing nuclides as Rb-88 and Xe-133 and concentrations were well below the respective maximum permissible concentrations. Considerable time was spent trying to pin down the source of this activity. On one occasion the drainer trap on the C-50B waste gas compressor moisture separator was found to be blowing through. Smoke bomb tests run in the north corridor area indicated that non-ducted airflows were not according to design. However, by this time construction was well under way on an approximately 40,000 square foot addition to the auxiliary building. This construction was necessary to provide floor space for additional gaseous, liquid, and solid radwaste equipment. There were several penetrations from the existing building into the construction area. In addition, temporary blowers and heaters were being used in the construction area. It was concluded that construction activities were the primary source of anomalous non-ducted airflows. An attempt was made to locate and control the sources of activity while at the same time minimizing the influence of construction activities. It should be pointed out that internal and external dosimetry indicated that personal exposures resulting from this airborne activity were minimal.

In December 1972, because of a combination of root valve malfunction and sample line leakage, radioactive noble gas was released to the auxiliary building from Waste Gas Decay Tank T-68C. Again, continuous air monitor readings in the corridor indicated that air was flowing in the wrong direction. Because of this incident a concerted effort was begun to seal construction-related openings as well as practicable. It was agreed that airflow tests would be conducted in the auxiliary building after this sealing had been accomplished.

Ventilation System Testing

Coincidentally with the efforts of the plant staff following the gas leakage incident, an AEC contractor study team arrived on site in early January 1973 to conduct an iodine species sampling program under an agreement with Consumers Power. The team tested the ventilation system using helium injection and downstream helium mass spectrometer detection.[1] Because of anomalies in the ventilation system, they were unable to obtain dependable flow, velocity profile and mixing and dilution measurements.

An airflow diagram showing the principal exhaust fans is presented in Figure 3. At the time of the testing discussed here, the V-68 and V-70 fans were not tied in to the ventilation system since construction of the addition was not complete. At the point where the V-68 and V-70 fans now enter the main exhaust plenum, there was a dilution air inlet damper to maintain plenum differential pressure. Normal mode operation requires the fuel handling and radwaste area exhausters in operation with one of the V-6 fans. Purge mode brings in additional flow from the V-35 containment purge exhaust and both V-6 fans must be in operation with the dilution damper closed.

Principal problem areas identified by the AEC study team and plant staff through early 1973 testing were as follows:

(1) A deficiency in the operating procedure allowed the 32,000 cfm V-10 radwaste supply fan to be operated with only one of the two 16,000 cfm V-14 exhaust fans in operation. In any case, the total supply to the old radwaste area exceeded the design rating of the exhausters by over 3,500 cfm.

(2) Main stack flows were below design values. This was attributed largely to the sticking of back draft dampers on the V-6 exhaust.

(3) As the pressure drop increased across the radwaste area filter plenum (V-14), there was a tendency for the dilution air inlet damper on the main exhaust plenum to supply more makeup air, thus reducing flow from the old radwaste area.

(4) Damper settings had been changed by operating and/or construction personnel.

(5) Construction activities continued to influence ventilation system performance.

In the midst of this testing the unit came off the line on January 16, 1973 for what was to be a 48-day outage to repair steam generator leaks. The operating procedures were corrected and damper maintenance was performed. It was known that the V-68 and V-70 fans would soon be ready for tie-in to the main exhaust plenum, thus eliminating the dilution air inlet damper. The ventilation system was performing as well as could be expected under the circumstances and further testing would await completion of the radwaste addition construction.

Preoperational testing of the radwaste addition ventilation system began in April 1973. By May there was enough confidence in the ventilation system that the AEC study team was invited to return to the site in early July to resume the iodine species sampling program. However, the new ventilation arrangement had problems of its own. In early July, airborne activity was again experienced on the 590-foot level of the auxiliary building as a result of the failure of packing on a charging pump. It was noted at this time that ventilation in the charging pump area had deteriorated significantly compared with flows prior to the tie-in of the V-68 and V-70 fans. It was noted that the removal during maintenance of the shield walls shown in Figure 2 was possibly contributing to this problem. In addition, later testing revealed that a supply duct running through the charging pump area was leaking.

At about this same time the AEC study team arrived on site and, in concert with the plant staff, began testing the ventilation system. They discovered a positive pressure in excess of one inch wg in the main exhaust plenum under both normal and containment purge modes of operation. Subsequent to this discovery a series of meetings was held involving Consumers Power, the AEC study team and our architect-engineer (Bechtel) to discuss ventilation system problems. It was decided that as soon as possible a licensed air balance contractor would be brought on site under Bechtel supervision to rebalance the entire ventilation system and to pinpoint specific problem areas.

Rebalancing and Resolution of Problems

Eastern Air Balance Corporation personnel arrived on site in October 1973. In attempting to meet design requirements, several adjustments were made. Blades on the V-6 fans were reset resulting in a 60% increase in stack flow in normal mode and a 43% increase in purge mode. V-5 fan blades were reset to insure nonducted airflow from the fuel pool area into the containment while in purge mode. The V-8 fans were speeded up resulting in a 17% increase in flow. The final airflow data is given in Table II (Column 1) and can be compared with design flows in Figure 3. Airflow data was taken in the purge mode since plenum back pressure was highest in this mode. The fuel handling and radwaste area fans handled, as a group, approximately 10,000 cfm more in normal than in purge mode. Since it was not possible to obtain a negative main plenum pressure in purge mode and since the plant was down for an extended maintenance outage requiring purging, the main plenum was sealed against air leaks and the access door was reversed to seal on positive pressure.

As a result of this balancing work, main plenum positive pressure in the purge mode was reduced considerably and a negative pressure was achieved in normal mode. Non-ducted airflows were checked and found to be from clean areas to potentially radioactive areas. Non-ducted airflows were found to be sensitive to the operation of turbine building supply fans and roof exhausters. It is necessary to keep exterior doors, doors in the radwaste area, and the common door between the turbine building and auxiliary building shut to maintain proper non-ducted flows. The primary cause for main exhaust pressure fluctuations and stack flow fluctuations was determined to be modulating flow control dampers on the V-68, V-70 and V-14 fans. It was also discovered that the back draft dampers on the V-6 fans were not opening fully on fan start, thus decreasing stack flow.

At this point there appeared to be three possible methods of achieving a negative pressure in the main plenum in purge mode: (1) Replace the V-6 fans; (2) reduce input to the main plenum during purging; and/or (3) construct a discharge evasé on top of the main stack. It was noted that the containment purge supply (V-5) could be reduced to 54,000 cfm and still provide approximately two air changes per hour. The containment purge exhaust (V-35) could then be adjusted to a flow of 60,000 cfm with the 6,000 cfm difference maintaining the relative balance with the refueling floor ventilation system. Since this was the most expeditious means of achieving a negative pressure, it was decided to readjust the V-5 and V-35 fans. In addition, since the main exhaust plenum is quite crowded, it was decided to install vortex breakers on the V-6 fans in order to stabilize flow. Field tests were run with temporary vortex breakers constructed from wood and a definite main plenum pressure drop was noted in purge mode.

Eastern Air Balance returned to the site in April 1974 after the permanent vortex breakers had been installed. In the meantime the pressure control fluctuations had been stabilized by adjusting flow control dampers. The back draft dampers on the V-6 fans had been motorized so that they opened fully on fan start and shut tightly on fan deactivation. New containment purge design flows were closely matched and a main plenum negative pressure was achieved as shown by the data in Table II (Column 2). Non-ducted airflows were observed and recorded and found to be correct. It was again noted that non-ducted airflows are sensitive to door configuration and hood operation.

As a result of this testing, it was decided that the main exhaust plenum should be strengthened structurally. Operator actions in starting and stopping various fans resulted in shocking the main plenum. The problem was caused in part by the elimination of the dilution air inlet damper on the main plenum. In addition, it was necessary to develop a more detailed fan starting procedure.

A further modification to the plant ventilation system is now in progress which will provide independent ventilation to the fan and penetration rooms. This will isolate these areas from the rest of the plant, thus precluding the spread of steam in the event of a postulated high energy line break. The net effect of this change will be to reduce the required V-14 exhaust flow by approximately 4,000 cfm. This modification should further improve ventilation of the old radwaste area.

Summary and Conclusions

Experience with the ventilation system at Palisades has emphasized the need for attention to detail throughout the design, construction, testing and operation stages to assure adequate airflow and correct non-ducted airflow patterns throughout the plant. Strict administrative controls are necessary for doors, exhaust hoods and other openings, such as removable shields. The ventilation system is sensitive to plant maintenance and construction and an attempt must be made to minimize the effect of such activities. In a nuclear plant it cannot be assumed that the ventilation system is functioning properly strictly on the basis of adequate temperature control and fresh air supply. A regular maintenance program coupled with periodic testing, especially for non-ducted airflows, is necessary. Testing and resolution of problems associated with the ventilation system at Palisades have led to a greater awareness of requirements for proper ventilation at a modern nuclear plant. The result is a ventilation system which assures control of airborne radioactivity at the Palisades Plant.

References

1. W. B. Kerr, R. E. McAtee, and L. T. Lakey, "The Evaluation of a Stack Sampling System Using a Helium Mass Spectrometer Leak Detector," Proceedings of the Twelfth AEC Air Cleaning Conference, CONF-720823 (1973).

Table I Palisades Plant chronology.

June 1966	Plant application filed with AEC.
March 1967	AEC construction permit granted.
Nov 1968	FSAR submitted.
Early 1970	Basic plant construction complete.
March 1970	AEC notice of intent to issue operating license.
April 1970	Petition to intervene filed by group of sport fishermen who later gain support from the Sierra Club and Businessmen for the Public Interest.
June 1970	Operating license hearings begin.
March 1971	Consumers Power reaches agreement with intervenors calling for cooling towers and additional radwaste equipment. AEC gives OK to begin fueling and low power testing.
June 1971	License hearings stalled due to emergency core cooling system (ECCS) questions.
Aug 1971	Calvert Cliffs decision necessitates new environmental impact studies.
Aug 1971	Construction begins on radwaste addition to auxiliary building.
Oct 1971	AEC says plant meets new ECCS criteria.
Nov 1971	20% power license.
Dec 1971	First generation of commercial electric power.
March 1972	60% power license.
Sept 1972	Full power provisional operating license issued with limitation to 60% power pending resolution of fuel densification question.
Dec 1972	Increase to 85% power granted.
Jan 1973	Plant down to repair steam generator leaks.
March 1973	Plant back up at 85% power.
April 1973	Fuel densification issue is resolved and 100% power is achieved.
Aug 1973	Plant down again to repair steam generator leaks.

Table II Airflow data.

	Measured Airflow (Cfm)	
	October 1973	April 1974
Purge Mode		
V-68 A&B	27,096-31,763	-
V-70 A&B	4,604-5,637	-
V-8 A&B	9,941	-
V-14 A&B	32,800	-
V-5	60,074	52,410
V-35	66,510	60,498
V-6 A&B	131,000-137,000	135,000
Main Plenum Pressure	+0.23" to +0.49"	-0.45"
Normal Mode		
V-6 A	-	82,000
V-6 B	81,065	85,000
Main Plenum Pressure	-0.20" to -1.15"	-1.25" to -1.35"

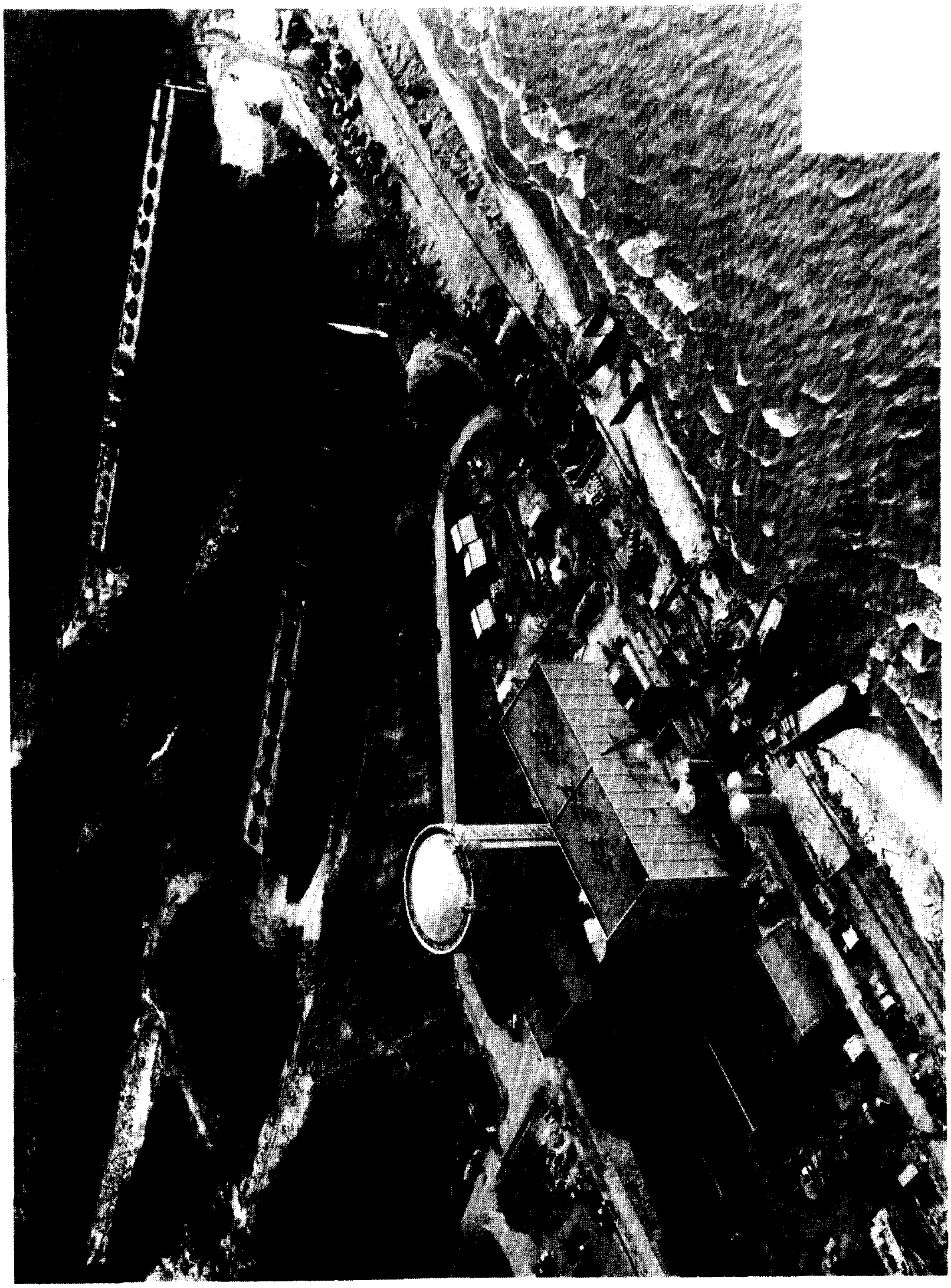

FIGURE 1
PALISADES NUCLEAR PLANT #874
General View
Looking South
GWO 7098 29th November 1972

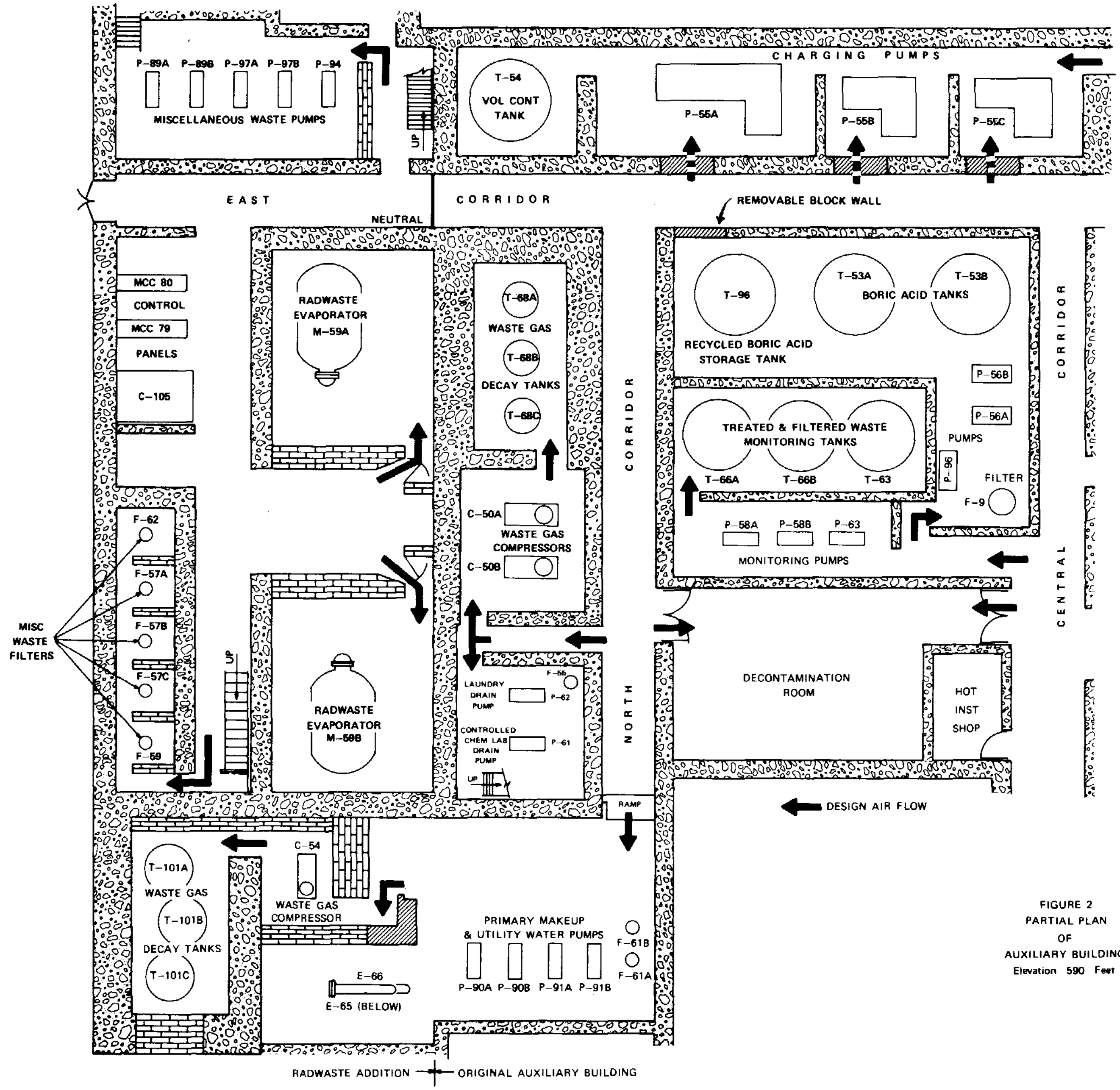

FIGURE 2
PARTIAL PLAN
OF
AUXILIARY BUILDING
Elevation 590 Feet

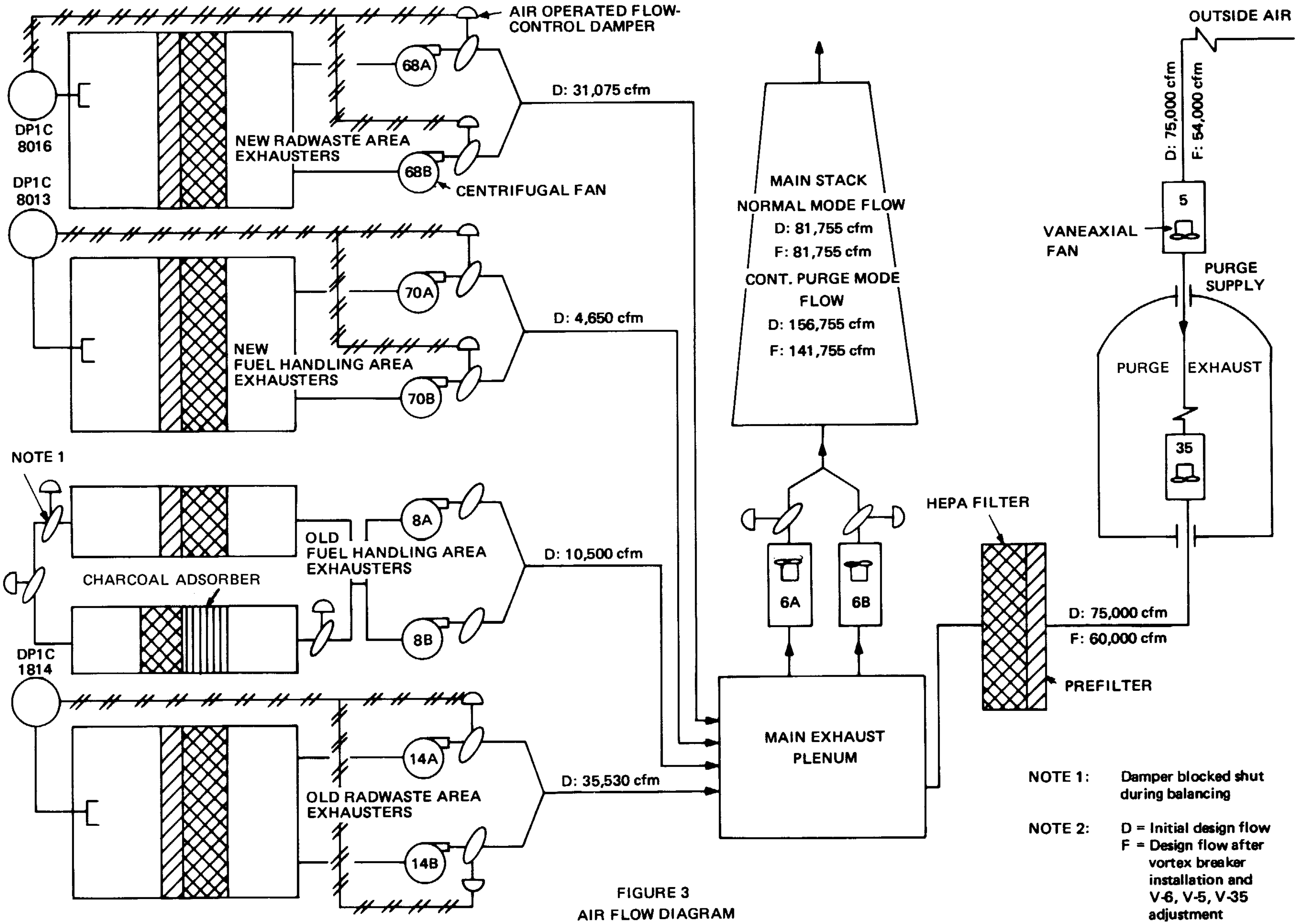

FIGURE 3
AIR FLOW DIAGRAM

DISCUSSION

STEVENS: I am wondering about your preoperational test program. Do you feel that the preoperational test should have pointed out the problem earlier? Did the inadequacies in the pre-op program develop because the test was written poorly or because your review of the results after the preoperational test wasn't what it should have been?

SULLIVAN: I think the test looked good on paper but I think what we need in ventilation system preoperational testing is more involvement on the part of the plant staff. You can't go in and measure flow through the duct work, balance only ducted flows, and expect everything to work. Nonducted air flow patterns must be checked very carefully so that the plant staff knows how the ventilation system is going to respond under different conditions. You can carry this to extremes, obviously. However, you should experiment with the system and get to know it so that when you have an occurrence that can cause problems, you know how the system is going to respond and you know what you need to do to control it.

STEVENS: I agree.

ESTREICH: I notice on your plan of the auxilliary building some rooms had doors and some seemed not to have doors. My concern is that the average velocity into the room may be far less than the thermally-induced velocities and that this could cause the air to puff back out of the room. I wonder if you would comment on that or at least indicate why you have doors on some rooms and not on others?

SULLIVAN: I really can't comment. I am not a ventilation expert. The reason I am concerned with the ventilation system is that I realize it can affect the performance of other systems for which I am responsible, such as filters, adsorbers, radiation monitors, and samplers.

FITZ: With respect to preoperational test programs, our experience indicates that all nuclear plants are usually late and the preoperational test of the ventilation system is limited to a test of the components, i.e. that the fan motors are running, dampers are functioning, etc. The utilities are glad to accept any test result to get on line as soon as possible to begin to produce revenue. My feeling is that there should be more emphasis placed on learning how the ventilation system works and checking that the design conditions are met.

NUCLEAR POWER PLANT CONTROL ROOM VENTILATION SYSTEM DESIGN FOR MEETING GENERAL CRITERION 19

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Abstract

The requirement for protection of control room personnel against radiation is specified in General Design Criterion 19 of Appendix A, 10 CFR Part 50. The evaluation of a control room design, especially its emergency ventilation system, with respect to radiation protection primarily consists of determining the radiation doses to control room personnel under accident conditions.

The accident dose assessment involves modeling and evaluation of radiological source terms, atmospheric transport of airborne activity, and protection features of the control room ventilation system. Some of the assumptions and conservatisms used in the dose analyses are based on the technical review experience of existing or proposed control room designs. A review of over 50 control room designs has revealed a great variety of design concepts, not all of which seem to have been based on radiation protection criteria.

A summary of the basic control room protection requirements, design features, dose acceptance criteria, and an outline of the methods used by the Regulatory staff for accident dose evaluation are presented.

I. Introduction

The General Design Criterion 19 of Appendix A, 10 CFR Part 50, includes a specific requirement with respect to control room personnel protection against radiation under accident conditions. According to Criterion 19, control room design should provide radiation protection such that control room personnel do not receive radiation exposures in excess of 5 rem whole body, or its equivalent to any part of the body, for the duration of the accident.

The assessment of a particular control room design in terms of Criterion 19 doses includes the following considerations:

1. Radiation source term identification and evaluation.

2. Radiation transport, either by airborne contamination or via direct streaming through shielding and other structures.

3. Control room radiation protection with respect to airborne and direct streaming radiation sources.

4. Control room dose calculation models.

A relatively large number of control room designs have been reviewed. As a result, it has been possible to identify and characterize several distinct ventilation system design concepts for protecting control room operators from airborne contaminants associated with postulated accidents. Each concept can be described in terms of its advantages and disadvantages, as well as its performance capabilities for short-term and long-term contamination situations. These attributes, when applied to a specific nuclear power plant configuration, are used to assess the acceptability of a proposed control room ventilation system.

II. Basic Protection Considerations

An accidental release of activity can result in control room operator exposure. The operators can be exposed to external gamma radiation from activity outside the control room. The concrete walls of typical control buildings normally reduce this contribution to acceptably low levels (less than one rem whole body exposure for the worst postulated accidents). Streaming through wall penetrations (e.g., door openings) is normally the only design feature that requires specific review with respect to external radiation.

The operators also can be exposed to both direct and internal radiation from activity buildup within the control room. The exposures consist of whole body gamma and beta skin radiation. If radioactive iodine is present the operators may also be subject to thyroid exposure.

Thyroid exposure is the limiting consideration in most cases. Charcoal filters are installed to remove iodine and thus reduce the thyroid exposure to acceptable levels. The difficulty with respect to iodine protection is the assessment of the level of activity inside the control room as a consequence of various postulated accidents. Aside from estimating source terms and diffusion parameters, the problem centers around the control room design itself, namely the analysis with respect to charcoal filter effectiveness for removing iodine and the determination of control room air infiltration (amount of air entering the control room when it is isolated). These considerations usually have the greatest impact on the outcome of the review of current control room designs. Subsequent sections will discuss these, as well as other considerations in depth.

III. Review of Current Control Room Designs

Since July of 1973 a total of 50 applications, in various stages of review, have been studied to determine control room design adequacy with respect to Criterion 19. It was found that most of the control room emergency systems have very little in common. Very few of the 50 designs are identical. Designs developed even by the same A/E firm differ significantly. For example, there are four basic design categories: once-through filtration, recirculating filtration, bottled air, and dual inlets. Very few of the systems within a category are identical. Equipment capacities, component selection, as well as component arrangements vary. For instance, control room isolation is implemented by a variety of damping devices ranging from slow acting, leaky dampers, to fast acting, leak tight butterfly valves. Charcoal filter flow capacity ranged from 1,000 cfm to

43,500 cfm. Charcoal depths varied from the usual 2 inch depth to as much as 18 inches. Diversity was observed in the use of component redundancy: some designs show duplicate components connected to a common ductwork (component redundancy), whereas others have two completely separate systems (system redundancy).

Much of the observed design variations are caused by differing opinions as to the degree of protection that must be provided. In some cases, one has to conclude that the dose analyses were performed after the ventilation system design had been established. Dose analyses exclusively for the sake of satisfying safety documentation requirements is not a recommended practice. Rather, it should be used as a tool for system design and component selection.

The section on Control Room Dose Evaluation should provide the basis for consistency in evaluating the protective requirements and capabilities of control room ventilation equipment. A consistent evaluating technique in conjunction with an appreciation for good versus poor design details will help reduce the number of design variations and allow for future standardization of these systems. A discussion of the presently proposed concepts should help in achieving this objective. The balance of this section describes the four concepts, their application, and their advantages and disadvantages.

A. Isolation with Filtered Pressurization

In this concept, the control room is automatically isolated upon an accident signal or upon a high radiation signal at the fresh air inlets. The operator has the option of manually initiating emergency pressurization (make-up air being directed through a standby charcoal filter train). Pressurization flow rates between 400 and 4000 cfm are typical. Five percent of the plants reviewed rely on this method of protection.

Isolation is normally sufficient for accidents resulting in an activity release of short duration. Accidents resulting in releases of long duration, such as a LOCA, may require use of the charcoal filters.

Filtered pressurization is relatively ineffective in protecting against iodine. The Regulatory staff allows an iodine protection factor (IPF)* of 20 for charcoal filters that meet Regulatory Guide 1.52 requirements. In most cases, only plants with high stacks (greater than 100 meters) would meet Criterion 19 with this system.

A basic drawback of this type of system is the fact that when the filter is in operation, the unfilterable activity (comprised of noble gases) is being drawn into the control room and contributes to the whole body gamma exposure. Usually the recommendation is made that these systems be modified to allow the filter to be used either in a pressurization or a recirculation mode. This feature adds flexibility to the system as discussed below.

*See Section V-D., the parameter IPF is defined as the ratio of the dose assuming no iodine removal over the dose assuming iodine removal.

B. Isolation with Filtered Recirculated Air

In this concept the control room is automatically isolated and the emergency recirculating charcoal filters started with the same accident or high radiation trip. Control room air is withdrawn, filtered, and returned to the control room. Typical recirculation rates vary from 4000 cfm to 15,000 cfm depending principally upon the leak tightness of the zone serviced by the system and on the calculated activity levels in the unfiltered air. About 40 percent of the plants reviewed proposed this method of protection. The majority of these systems offered the option of manually pressurizing the control room with filtered air. This mode would be selected only if it was determined that contamination is being introduced into the control room within the building housing the control room.

These systems have a much higher potential for controlling iodine than those having once-through filters. IPF's ranging from 20 to over 150 can be achieved. These are designs used mostly for plants having vents located at containment-roof level. A system having a recirculation rate of 5000 cfm and a filter efficiency of 95% would be rated as follows:

Infiltration (cfm)*	IPF**
200	25
100	49
50	96
25	191

In addition to control of iodines, systems with low infiltration rates will provide significant protection against noble gas exposure as discussed in Section V-E.

A design problem common to recirculation systems is the enhanced infiltration from isolation dampers. Typically, these dampers are located on the inlet side of the recirculating fans and may be exposed to several inches of negative pressure. Systems that are designed for low infiltration solve this problem by installing "zero" leakage butterfly valves.

C. Isolation with Filtered Recirculation and Pressurization

This system is essentially the same as the one described in B.

*Calculated values will be acceptable for infiltration rates of 0.06 volume changes per hour or greater (for dose calculation purposes). Smaller infiltration rates will be allowed only if infiltration testing is performed periodically during plant operation. For design purposes infiltration rates less than 0.015 volume changes per hour normally are not considered achievable.

** Within the range of interest, IPF is directly proportional to recirculation flow rate times filter efficiency.

However, the designer has chosen to operate the system in the pressurized mode during long-term accidents and therefore the system must be approved on this basis. About 15 percent of the designs reviewed used this method of protection.

The advantage of pressurization is that it minimizes the amount of unfiltered air entering the control room by infiltration. The leak tightness of the control room then becomes only a secondary consideration. Of course, the disadvantage is that the noble gas exposure will be maximized since outside air is being intentionally admitted to the control room. In most cases, however, the whole body gamma exposure from the noble gases would still remain below Criterion 19 guidelines. The iodine protection factors for this type of system are given below for the case of a 5000 cfm, 95% efficiency filter (flows in cfm):

Make-Up Air*	Recirculated Air	IPF (Assuming No Infiltration)	IPF (Assuming 10 cfm Infiltration)
400	4600	238	159
750	4250	128	101
1000	4000	96	80

The Regulatory staff normally assumes a 10 cfm infiltration rate, notwithstanding pressurization. This is to account for the possibility of backflow of contamination into the control room when doors are opened or closed. This flow would be reduced or eliminated if the design rules out the possibility of backflow by installing devices such as two-door vestibules.

A question that has not been answered satisfactorily as yet, is whether "isolation with recirculation" or "pressurization" is the best continuous mode of operation. This depends primarily on the assumptions as to unfiltered inleakage. The Regulatory staff plans to measure infiltration on a number of actual control rooms to help determine the best operational mode. Isolation with recirculation has the advantage of limiting the entrance of noble gases (not filtrable) and it is also the better approach when the accident involves a short term "puff release." However, with pressurization there is a feeling of more security in that the question of infiltration becomes mute. Also, with the addition of a second charcoal filter in the inlet duct (assuring double filtration of make-up air) the pressurization design becomes very effective against iodine.

*Make-up air should be sufficient to pressurize the control room to at least 1/8 inch water gauge. If the make-up rate is less than 0.5 volume changes per hour, supporting calculations are required to verify it. If the make-up rate is less than 0.25 volume changes per hour, periodic verification testing is required in addition to the calculations.

D. Dual Inlets

This concept utilizes two remotely located inlets. The inlets normally are placed such that any potential release point lies between the two inlets, thus assuring that one of the two inlets is free of contamination. This guaranteed supply of fresh air is used to pressurize the control room for minimizing infiltration. About 35 percent of the plants reviewed proposed dual inlet systems.

The viability of the dual inlet concept depends on whether or not the placement of the inlets assures one inlet free from contamination. This possibility depends, in part, on building wake effects, terrain, and the existence of wind stagnation or reversal. For example, consider a case where the inlets are located at the extreme edges of the plant structures; e.g., one on the north side and one on the south side. It is conceivable that under certain low probability conditions both inlets could be contaminated from the same point source. The designer who is skeptical about this possibility is encouraged to witness a smoke visualization test either in a wind tunnel or at an actual site. These tests show that the complex turbulence patterns set up in and around a group of buildings can result in contamination spreading throughout the complex, upwind as well as downwind of the release point.

If the inlets were to be located several hundred feet outboard of the structure the probability of both being covered probably would approach zero. The staff normally requires at least a once-through charcoal filter for the make-up air in those cases where the inlets are located on or close to the plant structures. Filters usually are not required for plants with inlets 200 feet or more away from any plant structure (provided of course that all potential source points, including toxic material containers, are located such that simultaneous contamination of both inlets is not possible).

The acceptance of a dual inlet system is based primarily on assuring that the inlet selected for operation can deliver pressurization air while at the same time assuring that the closed inlet does not allow any flow. The review involves a careful examination of the ducting and damping of the system. The ducting should meet seismic Category I criteria as well as be protected against missiles. The damping devices (normally butterfly valves) must meet the single active failure criterion. This results in each inlet having a parallel set of two valves in series (4 valves total). When applying the single failure of an active component criterion it should be noted that there must be a guarantee of both flow and no flow in each inlet.

E. Bottled Air

In some plant designs the containment pressure is reduced below atmospheric within one hour after a design basis accident (DBA). This assures that after one hour significant radioactive material will not be released from the plant. This type of design makes it feasible to maintain the control room above atmospheric pressure by use of bottled air. Normally the staff requires periodic pressurization tests to determine that the rated flow (normally about 300 to 600 cfm) is sufficient to pressurize the control room to at least 1/8 inch water gauge. It is also required that the system be composed of several separate circuits (one of which is assumed to be inoperative to account for a possible single failure). The staff also requires at least a once-through filter system for pressurization as a stand-by for accidents of long duration. About five percent of the plants reviewed proposed this method of operation.

IV. Dose Acceptance Criteria

The Criterion 19 dose guideline of 5 rem whole body or its equivalent is used to determine system acceptability. The following specific criteria are applied:

1. Whole body gamma radiation from direct shine radiation of sources external to the control room and from the airborne activity within the control room should not exceed a total of 5 rem.

2. Beta skin dose from airborne activity within the control room should not exceed 30 rem. The dose is evaluated by assuming a 7 mg/cm^2 depth dose (this takes into account the shielding effect of the insensitive superficial skin layer) and a semi-infinite cloud geometry.

3. Thyroid dose from the inhalation of radioactive iodine should not exceed 30 rem. The dose is determined by use of ICRP Publication No. 2 parameters and a breathing rate of 3.47×10^{-4} m^3/sec.

V. Control Room Dose Evaluation

Each of the three dose components;i.e., the thyroid dose due to inhalation of iodine radioisotopes, and the whole body gamma and beta skin doses due to exposure to noble gas radioisotopes, is calculated on the basis of source strength, atmospheric transport,dosimetry, and control room protection considerations, as illustrated in Equations 1 through 3.

$$D_j^I = \frac{C_1 \cdot (X/Q)_j}{IPF} \sum_i^{\text{IODINES}} T_i E_i S_{ji} \qquad (1)$$

$$D_j^\gamma = \frac{C_2 \cdot (X/Q)_j}{GF \cdot PF_j} \sum_i^{\text{NOBLE GASES}} E_i^\gamma S_{ji} + I \qquad (2)$$

$$D_j^\beta = \frac{C_2 \cdot (X/Q)_j}{PF_j} \sum_i^{\text{NOBLE GASES}} E_i^\beta S_{ji} + I \qquad (3)$$

where :

$D_j^I, D_j^\gamma, D_j^\beta$ = the thyroid, whole body gamma, and beta skin dose, respectively, (rem)

j = time interval index, intervals of 0 to 8 hrs, 8 to 24 hrs, 1 to 4 days, and 4 to 30 days are typical

C_1 = 294, dose conversion factor (includes breathing rate of 3.47×10^{-4} m^3/sec

IPF = iodine protection factor, ratio of integrated iodine dose at inlet to integrated iodine dose within control room (see Subsection D)

$(X/Q)_j$ = meteorological factor (see Subsection B) (seconds/meter^3)

i = isotope index

T_i = effective half-life in the body (days)

E_i = effective energy absorbed in thyroid (Mev/dis)

S_{ji} = quantity of isotope released in j^{th} time interval (see Subsection A) (Ci)

C_2 = 0.25, semi-infinite cloud dose conversion factor

GF = geometric factor, converts semi-infinite gamma dose to a finite dose (see Subsection C)

PF_j = purge factor, corrects for slow increase in concentration in the case of a tight, isolated control room (see Subsection E)

E_i^γ = average gamma energy (Mev/dis)

I = symbolic indication of iodine contribution, represents a negligible fraction of dose when iodine filtration is used

E_i^β = average beta energy (Mev/dis)

The major input parameters defined in the equations above are based on the following considerations:

A. Source Term (S)

The source terms should be based on design basis assumptions acceptable to the AEC for purposes of determining adequacy of the plant design for meeting the criteria contained in 10 CFR Parts 50 and 100. For the most part, these design basis assumptions can be found in Regulatory Guides that deal with radiological releases. For instance, when determining the source term for a loss-of-coolant accident (LOCA), the assumptions given in Regulatory Guides 1.3 and 1.4 should be used. Guides 1.5, 1.24, 1.25, and 1.77 should be referenced for the evaluation of other design basis accidents.

In the case of a LOCA, 100% of the noble gases and 25% of the iodines present in the reactor core are assumed to escape to the containment and are initially available for release. The reduction of the amount of material available for release by containment sprays, recirculating filters, or other engineered safety features is taken into account. Reference to the respective Guides should be made for the balance of the assumptions. The source term for each isotope of iodine, xenon, and krypton is calculated in terms of curies released within each time interval of interest. The release rate for accidents of relatively short duration, such as a waste gas decay tank rupture or a main steam line break for a BWR, should be determined in such a way as to maximize control room operator exposure.

B. Meteorology (X/Q)

The term X/Q in Equations 1-3 denotes the degree of dispersion of the activity as it is transported from the point of release to the receptor. The parameter is normally referred to as relative concentration for it can be visualized best as the ratio of the concentration at the receptor (X) to the activity release rate (Q) as shown below:

$$\frac{X\ \mathrm{Ci/m^3}}{Q\ \mathrm{Ci/sec}} = X/Q\ \frac{\mathrm{sec}}{\mathrm{m^3}} \qquad (4)$$

Relative concentration is difficult to determine when both the release point and the receptor are located within or near the turbulence created by a complex of buildings. A number of wind tunnel and field tests (References 1-6) have been performed on specific building configurations. Though these efforts have resulted in usable information for specific situations, general applicability is not possible. In order to provide a basis for evaluation, the staff has formulated an interim position using conservative interpretations of the available data. The procedure consists of first determining the five percentile X/Q(defined as the X/Q value exceeded 5% of the time at the specific site in question). This value is used as the X/Q for the first post-accident time interval. Then the value of X/Q is reduced on the basis of averaging considerations for each subsequent time interval. The detailed procedures are described below.

1. Determination of Five Percentile Relative Concentration

a. In-line, Point Source - Point Receptor

The following relation is used when activity is assumed to leak from a single point on the surface of the containment, or other structure, in conjunction with a single point receptor (e.g., single operating air intake), which is located a distance "x" from the point source (the source and receptor having a difference in elevation of less than 30% of the containment height):

$$X/Q = (3U\pi\sigma_Y\sigma_Z)^{-1} \qquad (5)$$

where:

X/Q = relative concentration at the plume centerline ($\mathrm{sec/m^3}$)

σ_Y, σ_Z = standard deviation of the gas concentration in the horizontal crosswind and vertical crosswind directions, respectively, both being evaluated at distance "x" (m)

U = wind speed at an elevation of 10 meters (m/sec)

3 = wake factor based on Regulatory Guides 1.3 and 1.4

The parameters σ_y, σ_z, and U are determined on the basis of site meteorological data. The data are statistically analyzed to determine that combination of σ_y, σ_z, and U are indicative of the five percentile dispersion condition at the site. Typically, σ_y and σ_z are based on a Pasquill "F" condition (see Reference 7 pages 102 and 103). Five percentile winds speeds of 0.5 to 1.5 meters/sec are typical.

b. Diffuse Source - Point Receptor

The following relation is used when activity is assumed to leak from many points on the surface of the containment in conjunction with a single point receptor:

$$X/Q = [U(\pi\sigma_Y\sigma_Z + \frac{a}{K+2})]^{-1} \qquad (6)$$

where:

$$K = \frac{3}{(s/d)^{1.4}}$$

s = distance between containment surface and receptor location

d = diameter of containment

a = projected area of containment building (m^2)

The above equation is also appropriate in the following cases:

Point source - point receptor where the difference in elevation between the source and receptor is greater than 30% of containment height.

Point source - volume receptor; a volume receptor being exemplified by an isolated control room with infiltration occurring at many locations.

c. Point or Diffuse Source - Two Alternate Receptors

This section applies to those designs having two or more control room fresh air inlets each of which meets the single failure criterion for active components, the seismic criteria, as well as any applicable missile criteria. The design details must assure that the most contaminated inlet is isolated and the least contaminated inlet remains in operation to provide control room pressurization.

(1) Dual Inlets Located on Seismic Category I Structures-The dual inlets are most conveniently placed on the seismic Category I structure contiguous to the control room. The inlets should be located to

maximizethe benefit of the alternate inlet concept. For instance, of the first three locations depicted in Figure 1, only locations B and C would be acceptable, assuming that the containment is the location of the major points of release. Location A would be unacceptable because both inlets can be simultaneously contaminated. With good inlet placement, the relative concentration is calculated by use of Equation (6). In this case the standard deviation parameters are evaluated for the inlet closest to the point of release and with K being set to zero.

(2) Remote Air Intakes-When the dual inlets are placed about 180 degrees apart from the potential release points and each inlet is located well away from any major structure (typically 200 feet or more, see Figure 1, location D), the probability of both inlets being exposed to contamination at the same time is reduced significantly. However, wind shifts and unusual meandering of the wind may still cause simultaneous exposure of both inlets. This would occur infrequently and the contamination level at the operating inlet would be low.

The staff estimates this level of contamination by assuming a plume that spreads out in all directions and is evenly dispersed in the vertical direction. The appropriate equation is:

$$X/Q = 0.16/LUX \qquad (7)$$

where:

L = vertical mixing layer, m

X = distance from source to closest inlet, m

In the cases where activity is released within the wake of the containment, L is taken as the containment height divided by $\sqrt{2}$ (the height is divided by $\sqrt{2}$ to be consistent with the policy of restricting the wake factor to one-half of the projected area of the containment building). It is assumed that the contamination level calculated by Equation (7) will cover both inlets one-half hour per day.

Further adjustments in the X/Q, as discussed in the next section, apply to all methods using Equations (5) and (6), but do not apply in the case of remote air intakes.

2. Determination of (X/Q)j

The five percentile X/Q is used for the first time interval in the calculation (normally 0 to 8 hours after accident occurence). For subsequent time intervals, the X/Q is reduced to account for long term meteorological averaging. Consideration of other factors may require further reduction of X/Q. For instance, an allowance may be considered for the time the operator leaves the plant vicinity. This is defined as the occupancy factor. Typical values for this factor appear in Table 1. Note that the table also presents two other factors involving wind speed and wind direction. These factors account for the effects of changes in wind speed and direction over progressively longer periods of time.

Typically, wind speeds of about 1 m/sec represent the five percentile case whereas speeds of 3 m/sec represent the 40 to 50 percentile case. The staff allows credit for higher wind speeds during long term accidents as indicated in Table 2. The values shown in Column 1 of the table can be used when meteorological data are not available. When available, the factors can be calculated by use of the wind percentiles given in Column 2.

When determining wind speed from site meteorological data, only the wind direction sectors that result in receptor exposure are used. Figure 2 defines the number of 22.5 degree sectors that is considered in obtaining the short term and long term wind speeds. The s/d ratio in the figure is the distance from the building surface to the receptor divided by the diameter or width of the building normal to the direction of the wind. Figure 2 was determined by analyzing the growth of the lines of equal concentration in planes parallel to the ground using results from Reference 2.

Figure 2 also is used to determine the fraction of time the wind is blowing from the sectors in question. The average wind direction frequency F is obtained by summing the annual average wind direction frequency of the sectors in question. Table 3 is then used to evaluate the appropriate wind direction factors. Column 1 of the table is used when F is not available and Column 2 is used when F has been determined.

TABLE 1

EXAMPLE OF FACTORS USED TO CALCULATE EFFECTIVE RELATIVE CONCENTRATIONS FOR SELECTED TIME INTERVALS

Adjustment factors	0 - 8 hrs	8 - 24 hrs	1 - 4 days	4 - 30 days
Occupancy	1	1	0.60	0.40
Wind speed	1	0.67	0.50	0.33
Wind direction	1	0.88	0.75	0.50
Overall reduction	1	0.59	0.23	0.066

TABLE 2

WIND SPEED FACTOR

Time after accident	Column 1 Representative wind Speed Factors*	Column 2 Corresponding wind speed percentile
0 - 8 Hrs	1	5
0 - 24 Hrs	0.67	10
1 - 4 days	0.50	20
4 - 30 days	0.33	40

TABLE 3

WIND DIRECTION FACTOR

Time after	Column 1 Representative wind direction factors **	Column 2 Relations used to estimate wind direction factor when F has been determined
0 - 8 Hrs	1	1
8 - 24 Hrs	0.88	0.75 + F/4
1 - 4 Days	0.75	0.50 + F/2
4 - 30 Days	0.5	F

*Defined as the ratio of the five percentile wind speed to the wind speed appropriate for the time interval in question.

** Defined as the fraction of time the wind is blowing activity toward the receptor.

C. Geometry Factor (GF)

The whole body gamma dose from noble gas radioisotopes is easily evaluated on the basis of immersion in an infinite cloud. Since control structures are usually effective in shielding out most of the gamma radiation from outside the control room, the dose inside the control room is substantially less than what the infinite cloud model predicts. A correction for this effect can be made by using a geometry factor which is a ratio of infinite-to-finite cloud doses, namely:

$$GF = \frac{\text{DOSE FROM AN INFINITE CLOUD}}{\text{DOSE FROM A CLOUD OF VOLUME V}} \quad (8)$$

where V is the control room volume. Taking into account geometric effects and gamma attenuation (using 0.733 Mev as the average gamma energy for noble gases considered in control room dose analyses) by air, it can be shown that Equation (8) becomes:

$$GF = \frac{1173}{V^{0.338}} \quad (9)$$

where the control room geometry is represented by a hemisphere of volume V (cubic feet). Equation (9) is plotted in Figure 3.

D. Iodine Protection Factor (IPF)

As outlined in Section III, there are several control room ventilation-filtration configurations which are used in reducing the iodine radioisotope concentration within the control room atmosphere. Iodine reduction is expressed in terms of the iodine protection factor (IPF) which is evaluated by considering an equilibrium balance between iodine sources and losses within the control room. Figure 4(a) shows a typical configuration, where:

F_1 = rate of filtered outside air intake

F_2 = rate of filtered air recirculation

F_3 = rate of unfiltered outside air infiltration

The balance of activity due to iodine can be written as:

$$\frac{dA}{dt} = A_0F_1(1-\eta) + A_0F_3 - AF_2 + AF_2(1-\eta) - A(F_1 + F_3) \quad (10)$$

where:

A = specific activity within the control room

A_0 = specific activity outside the control room

η = filter efficiency/100

t = time

Under equilibrium conditions the left hand side of Equation (10) can be set to zero and the resulting equation yields the following equilibrium ratio of outside to inside specific activity,

$$\frac{A_0}{A} = \frac{F_1 + \eta F_2 + F_3}{(1 - \eta)F_1 + F_3} \qquad (11)$$

Since dose is proportional to the specific activity, then the iodine protection factor can be expressed as :

$$IPF = \frac{\text{DOSE WITHOUT PROTECTION}}{\text{DOSE WITH PROTECTION}} = \frac{A_0}{A} \qquad (12)$$

The expression for IPF in Figure 4(a) is based on combining Equations (11) and (12).

The iodine protection factor for filtered recirculation with isolation is illustrated in Figure 4(b). It is obtained by letting $F_1 = 0$ in Equation (11).

Figure 4(c) shows a double filtration configuration. The iodine protection factor equation for this system has the same form as Equation (11), with the exception that η in the denominator is replaced by η'. The term $(1-\eta) F_1$ in Equation (11) represents activity inflow after single filtration of contaminated air. With double filtration the same term would normally be written as $(1-\eta)^2 F_1$. However, the effectiveness of two filters in series is limited by Regulatory Guide 1.52. For example, two 2 inch deep charcoal filters each having a η of 0.95 is treated as a single filter of 4 inch depth having a η of 0.99.

Figures 5 through 7 illustrate the dependence of iodine protection factors on F_1, F_2, and F_3, for each of the configurations shown in Figure 4.

Aside from the design, testing, and maintenance criteria given in Regulatory Guide 1.52, the filter designer should review Reference 8 which provides some helpful observations on filter installation and design, based on the field inspection of the filter systems of 23 nuclear plants.

E. Purge Factor (PF)

Control rooms characterized by a high degree of leaktightness can benefit by the relatively slow build-up of activity within an isolated control room followed by a purge of the control room atmosphere at appropriate times after a release.

Given a finite isolation time, a non-equilibrium build-up of activity in the control room, followed by a purge, will result in a lower dose than in the case of instant equilibrium. It can be shown that the ratio of equilibrium to transient doses for an isolated control room followed by a purge is given by

$$PF = 1 - \frac{1}{Rt}(1 - e^{-Rt}) \qquad (13)$$

where

R = air exchange rate, air changes per hour

t = isolation time, hours

Figure 8 shows PF as a function of R and t. Equation (13) is based on the assumption that the control room is immersed in a cloud of constant activity concentration for a period of "t" hours and that immediately after the cloud passes the control room is instantaneously purged of activity. A conservatively large value of "t" should be used, depending on the specific circumstances, since the operator must 1) recognize that the external activity has fallen to a low value and 2) manually initiate control room purging. For a typical control room it is reasonable to assume that several days will elapse before conditions warrant purging.

VI. Control Room Infiltration

Infiltration is defined here as any unintentional inleakage of air into the control room. Pressure differences across the boundary of the control room air space cause infiltration through various leak paths. Typical examples of leak paths include crackage around the perimeters of doors, or duct, pipe, and cable penetrations. Structural joints, damper seals, and miscellaneous discrete cracks or openings are also candidate leakage paths. Good control room design practice minimizes microscopic openings of this type by gasketing, weather-stripping or sealing techniques. However, it should be noted that continuous distributions of microscopic capillaries and pores are possible, as in concrete, for example. Thus, complete elimination of infiltration is not always feasible.

In most cases, the principal cause for pressure differentials is due to "natural" phenomena, such as winds, temperature differences, or barometric variations. Pressure differences also can exist between the control room air space and adjoining enclosures (e.g., mechanical equipment room, turbine building, battery room, etc.) brought about by flow imbalance in the overall ventilation system.

Precise evaluation of control room infiltration is difficult. Although various empirically determined formulas are available for predicting infiltration across individual leak paths of known size and shape, this in itself is of limited value for a realistic assessment of infiltration when the control room is in the design phase. Even after construction, the control room infiltration measurement is difficult since it is sensitive to the combined effect of a number of independent variables. For example, wind direction, building geometry, internal building pressure distribution, air columns (i.e., elevator shafts, stairwells) etc., can combine in a number of ways, resulting in different infiltration rates. Thus, to measure infiltration precisely in a specific case would require many test runs covering the entire range of environmental conditions.

Current practice is to estimate an upper limit on control room infiltration. This can be done on the basis of a gross leakage evaluation. The most direct method is to pressurize an isolated control room and record the pressurization flow rate required for maintaining a constant pressure. In the design phase, the pressurization flow rate can be estimated analytically by taking into account all identifiable leakage paths and applying appropriate pressure-flow rate equations.

The above approach characterizes the control room leak tightness in terms of a gross leakage rate. The calculated or measured gross leakage is used to determine the design basis infiltration rate that will be applied to the evaluation of the radiological consequences of postulated accidents. This rate is determined as follows :

1. The leakage from a control room pressurized to 1/8 inch water gauge is calculated on the basis of the gross leakage data. One half of this value is used to represent the base infiltration rate.

2. The base infiltration rate is augmented by adding to it the estimated contribution of opening and closing of doors associated with such activities as the required emergency procedures external to the control room.

3. An additional factor that is used to modify the base infiltration rate is the enhancement of the infiltration occurring at the dampers or valves upstream of recirculation fans. When closed, these dampers typically are exposed to a several inch water gauge pressure differential. This is accounted for by an additional infiltration contribution over the base infiltration at 1/8 inch water gauge.

It is anticipated that a better understanding and improved methods of evaluation of control room infiltration will be available in the future. An experimental program is planned for precise infiltration measurements of typical control rooms. The program will involve the use of tracer gases in a series of concentration decay measurements under a variety of atmospheric conditions. One of the objectives is to establish an empirical correlation between control room configuration, construction quality, and ventilation characteristics and its infiltration characteristics.

VII. Summary and Recommendations

Acceptance of a control room design with respect to General Design Criterion 19 is measured by its capability for protection against postulated accidents within or in the vicinity of the plant. The Regulatory staff reviews control room acceptability by evaluating radiation source and transport terms, and by applying conservative modeling of the control room ventilation system. A similar approach should be used by A/E firms in conjunction with control room design and equipment selection. This would provide for an earlier establishment of an acceptable control room protection system, as well as reduce the efforts associated with design modifications resulting from Licensing technical review activities.

The approach outlined in this paper should be considered as the first step in establishing standard design specifications of control room ventilation systems. Combined efforts on the part of industry and the government should produce standard designs that are proven and that meet all applicable safety criteria, including Criterion 19.

The following recommendations are made on the basis of the present status of control room protection systems :

1. Consistent evaluation techniques should be employed when determining system acceptability under Criterion 19. This paper should supply much of the methodology required for consistent dose evaluation.

2. Dose analyses should be used as a design tool, at least until such time as the systems have been standardized and approved on a generic basis.

3. The capacity of the charcoal filters should be based on the dose evaluation. The design, installation, and maintenance of the filter systems should be based on recommendations provided in Regulatory Guide 1.52 and Reference 7 (WASH-1234).

4. Careful attention should be given to the placement of fresh air inlets. They should be kept away from exhaust vents or other potential release points of toxic or radiological materials.

5. The structural details of the control room should be such as to limit infiltration when the room is isolated. All penetrations should be sealed, doors should be made leaktight with high quality weatherstripping, low leakage dampers or valves should be used, exhaust fans should be stopped, and the air balance of the entire control building reviewed to assure that inadvertent enhancement of inleakage will not occur as a result of poor system design or operation.

6. All emergency conditions (e.g., fire, smoke, toxic gas,) including radiological releases should be identified and the proposed concepts for control room emergency ventilation systems reviewed against the entire spectrum of postulated events to assure adequate protection.

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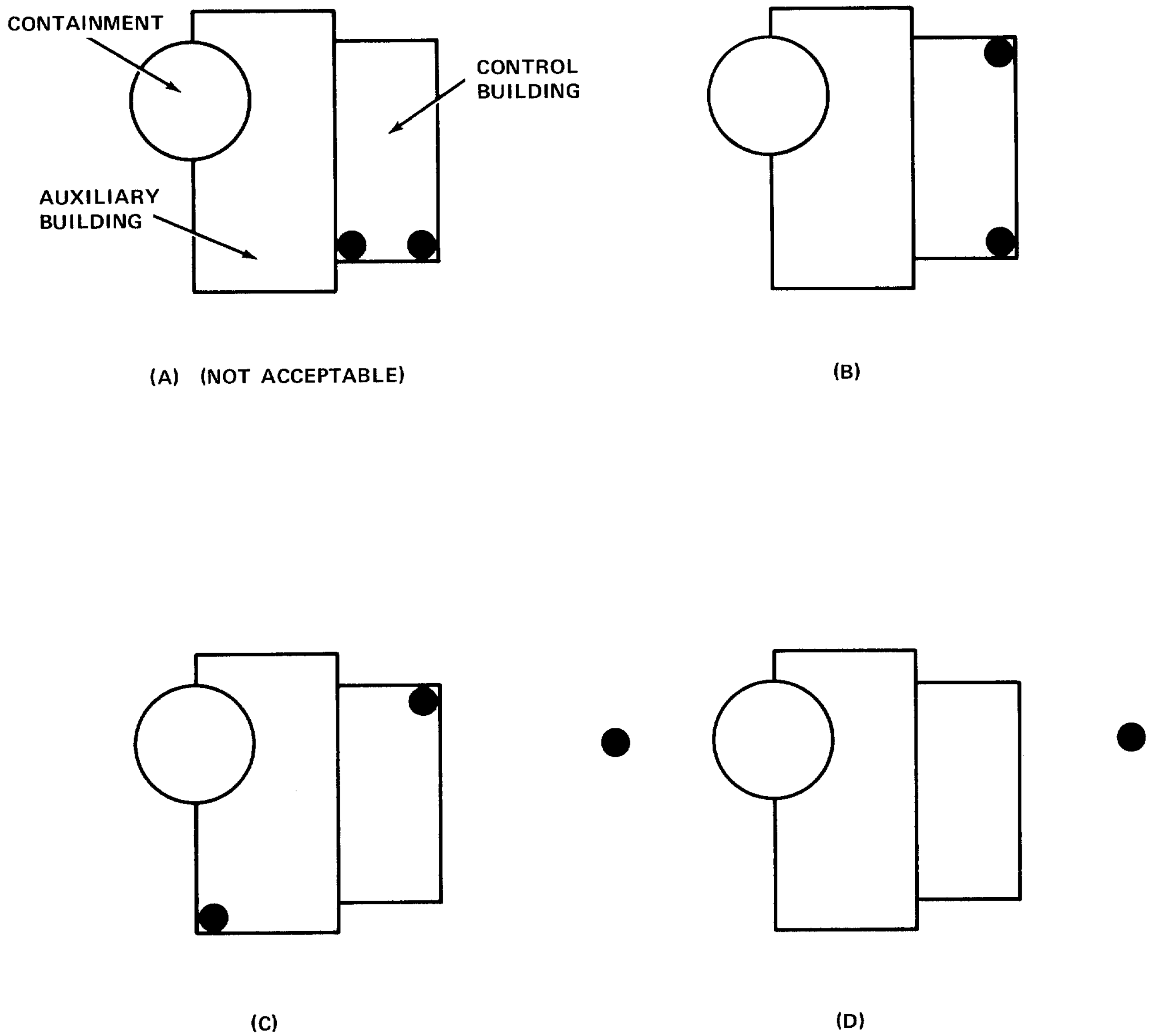


Figure 1   Alternative Locations for Dual Inlets

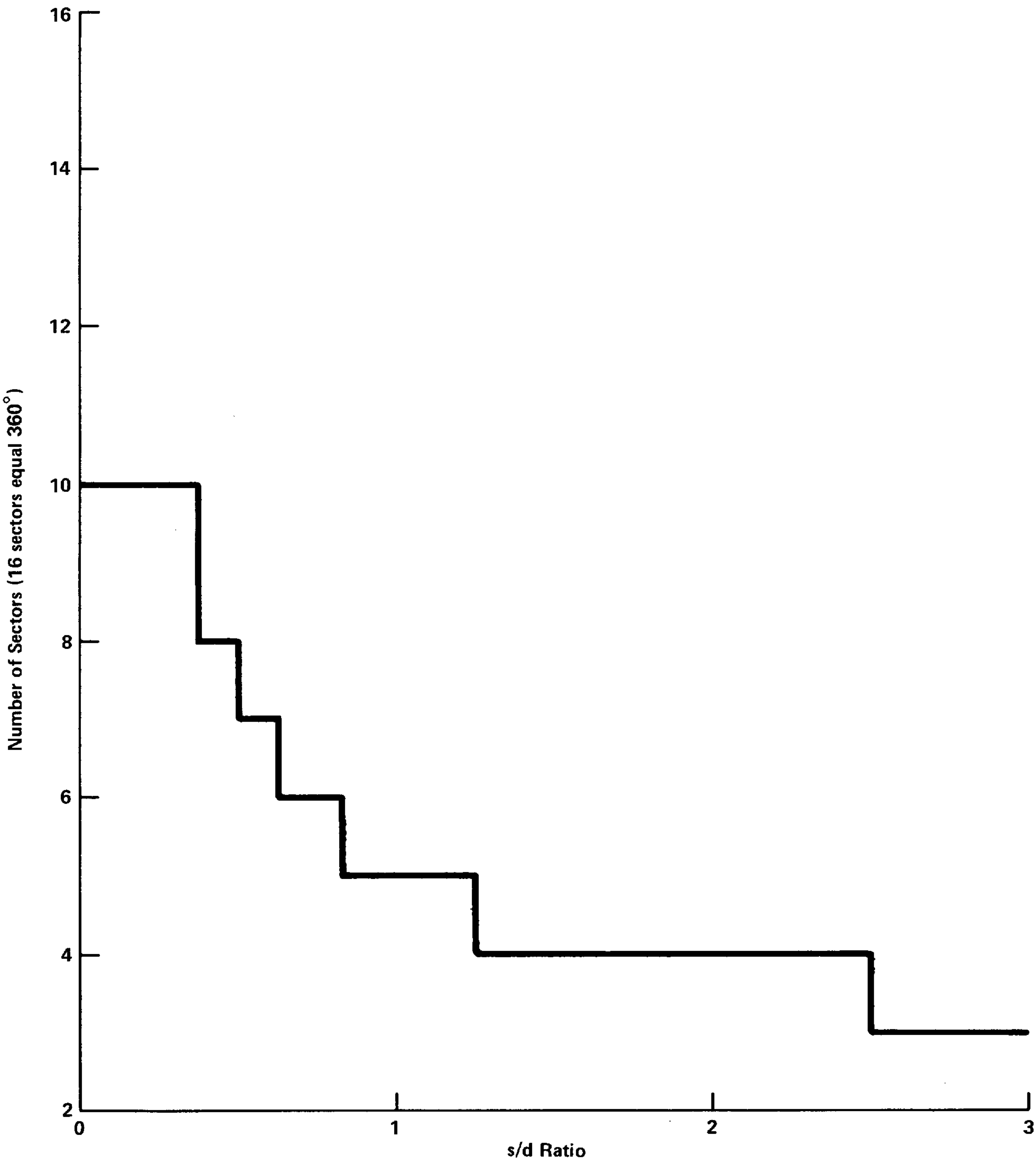


Figure 2 Number of Wind Direction Sectors to be Used in Determining Wind Direction Frequency and Wind Speed

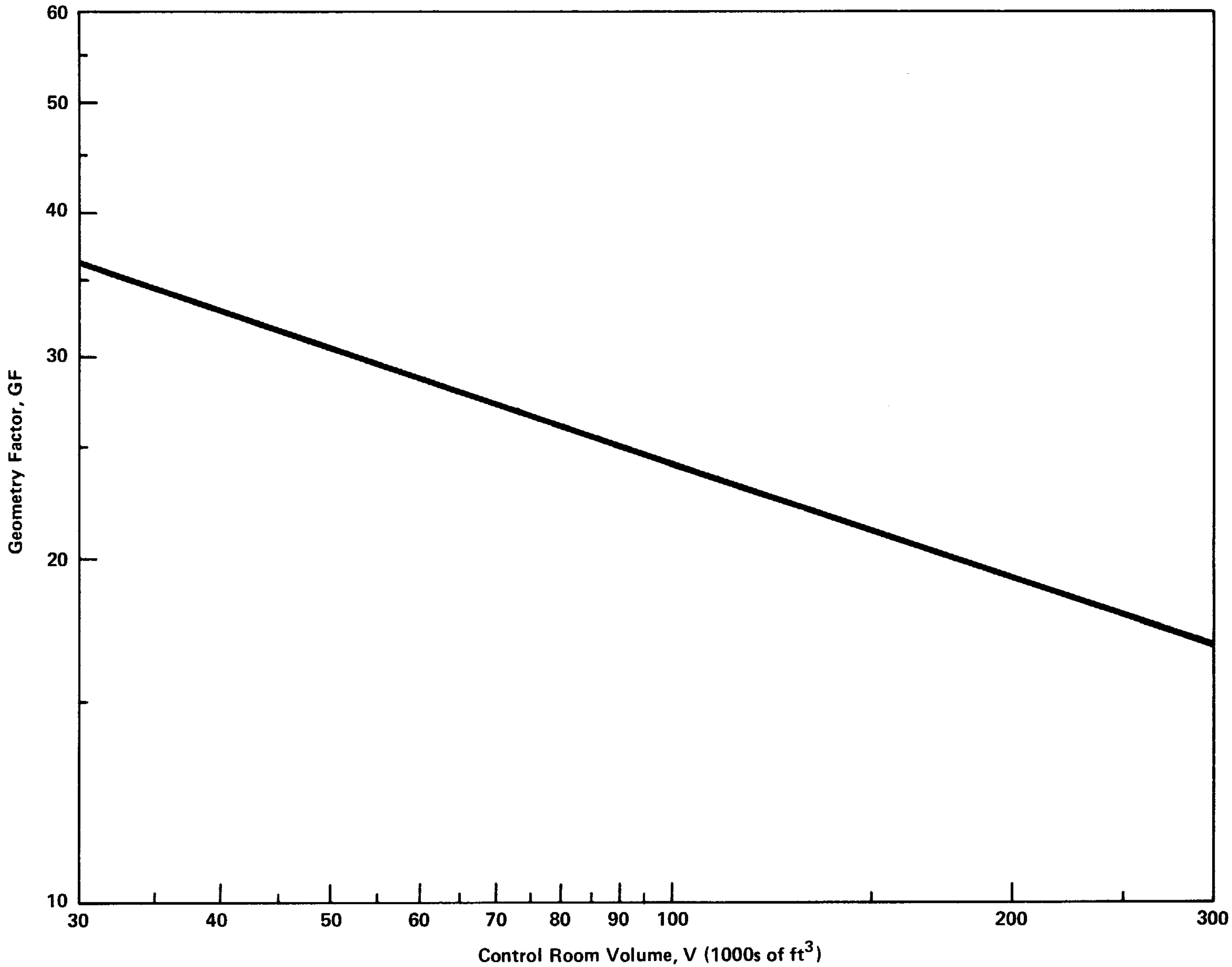
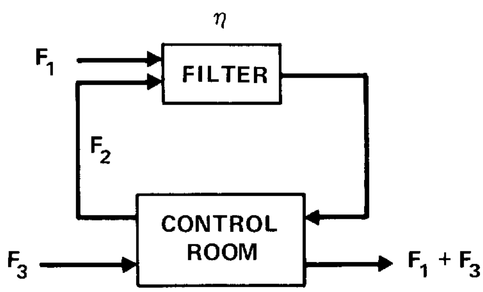
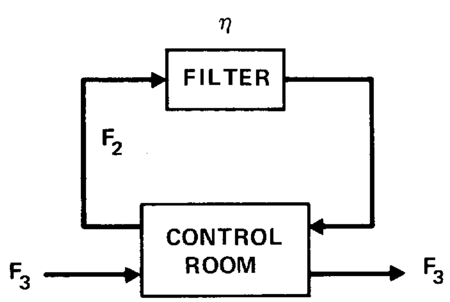


Figure 3 Infinite-to-Finite Cloud Geometry Factor vs. Control Room Volume



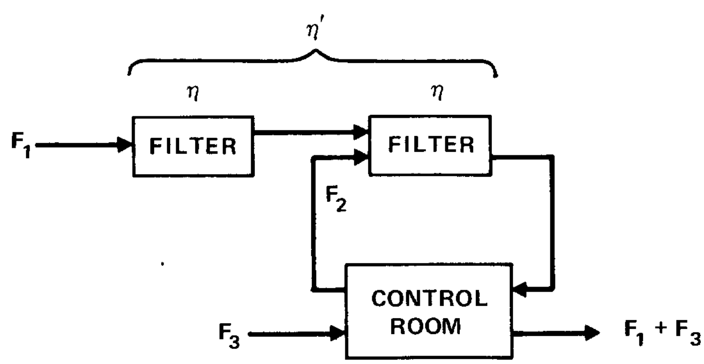
$$IPF = \frac{F_1 + \eta F_2 + F_3}{(1 - \eta)F_1 + F_3}$$

(a)



$$IPF = \eta \frac{F_2}{F_3} + 1$$

(b)



$$IPF = \frac{F_1 + \eta F_2 + F_3}{(1 - \eta')F_1 + F_3}$$

(c)

Figure 4 Selected Control Room Filter Models

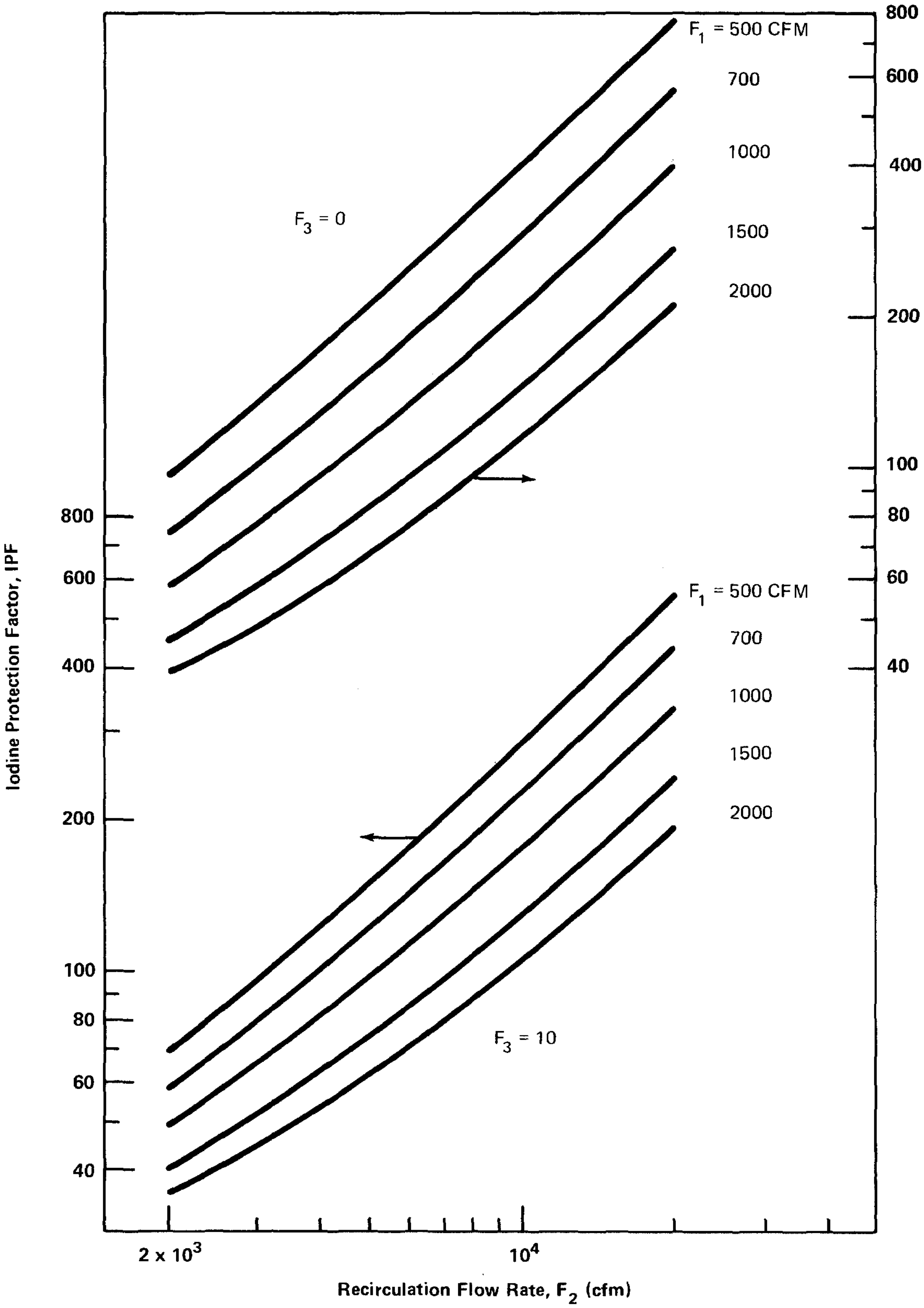


Figure 5 Iodine Protection Factor as a Function of F_1, F_2, and F_3 for a Filter Efficiency of 95%

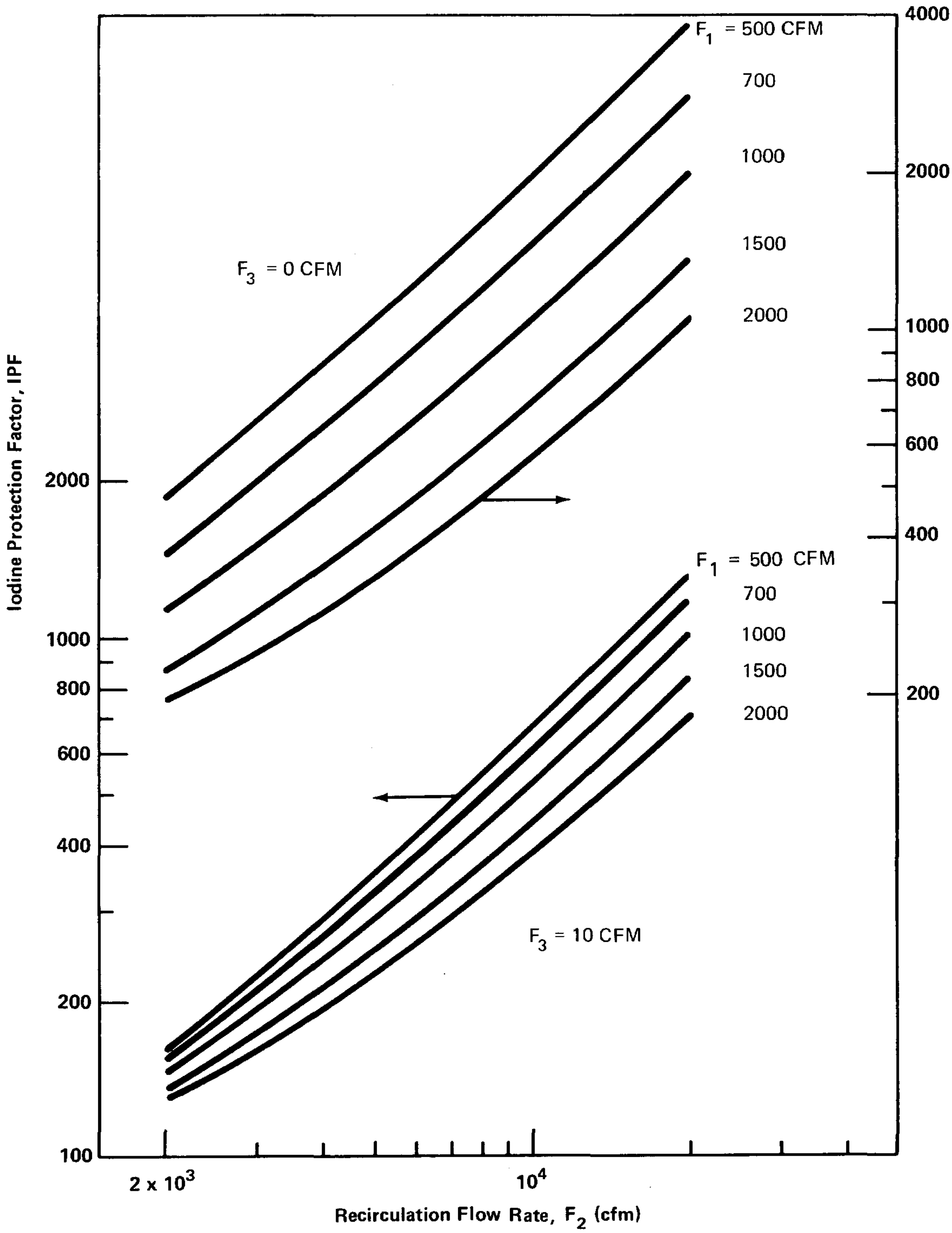


Figure 6 Iodine Protection Factor as a Function of F_1, F_2, and F_3 for a Filter Efficiency of 99%

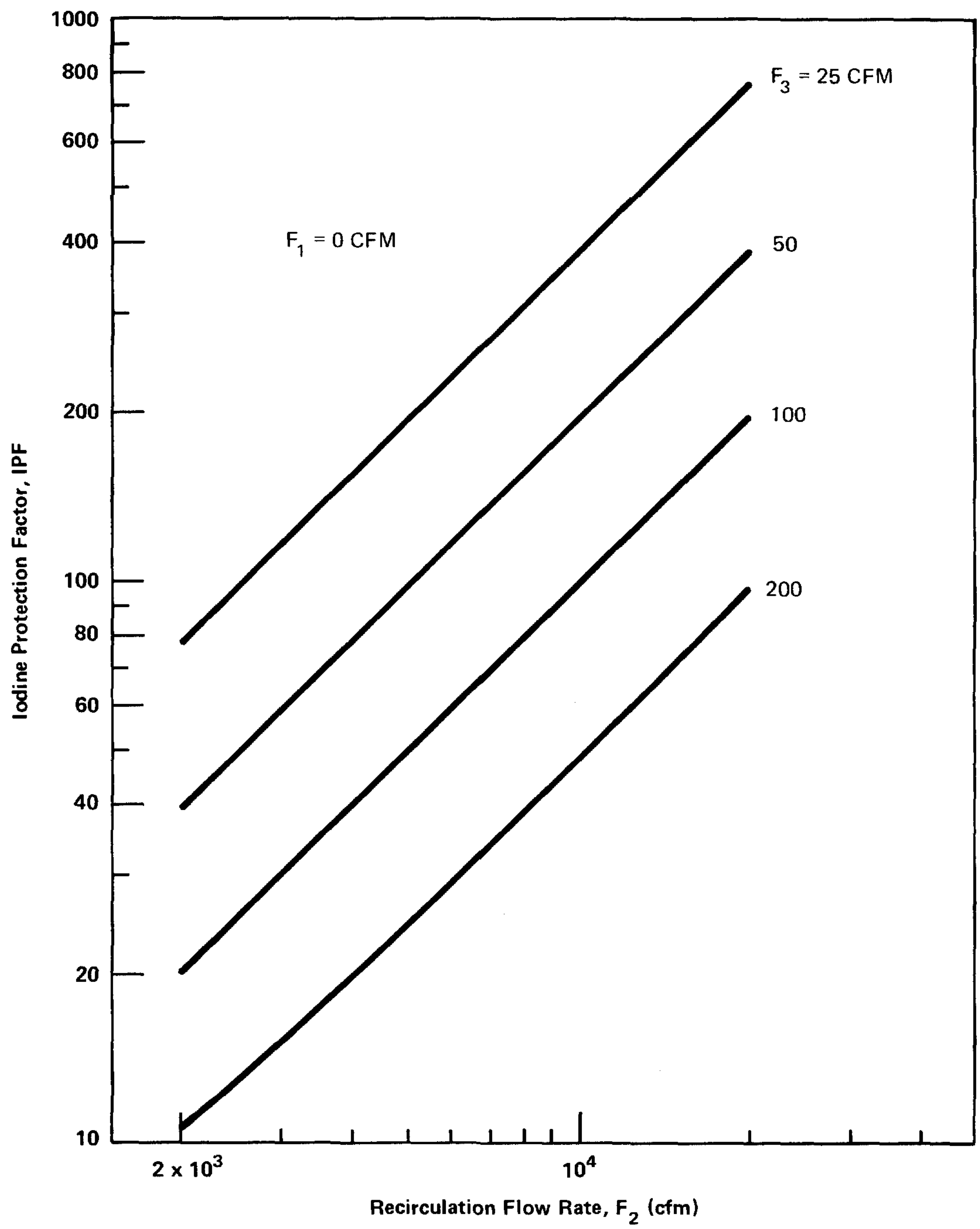


Figure 7 Iodine Protection Factor as a Function of F_2 and F_3 for a Filter Efficiency of 95%

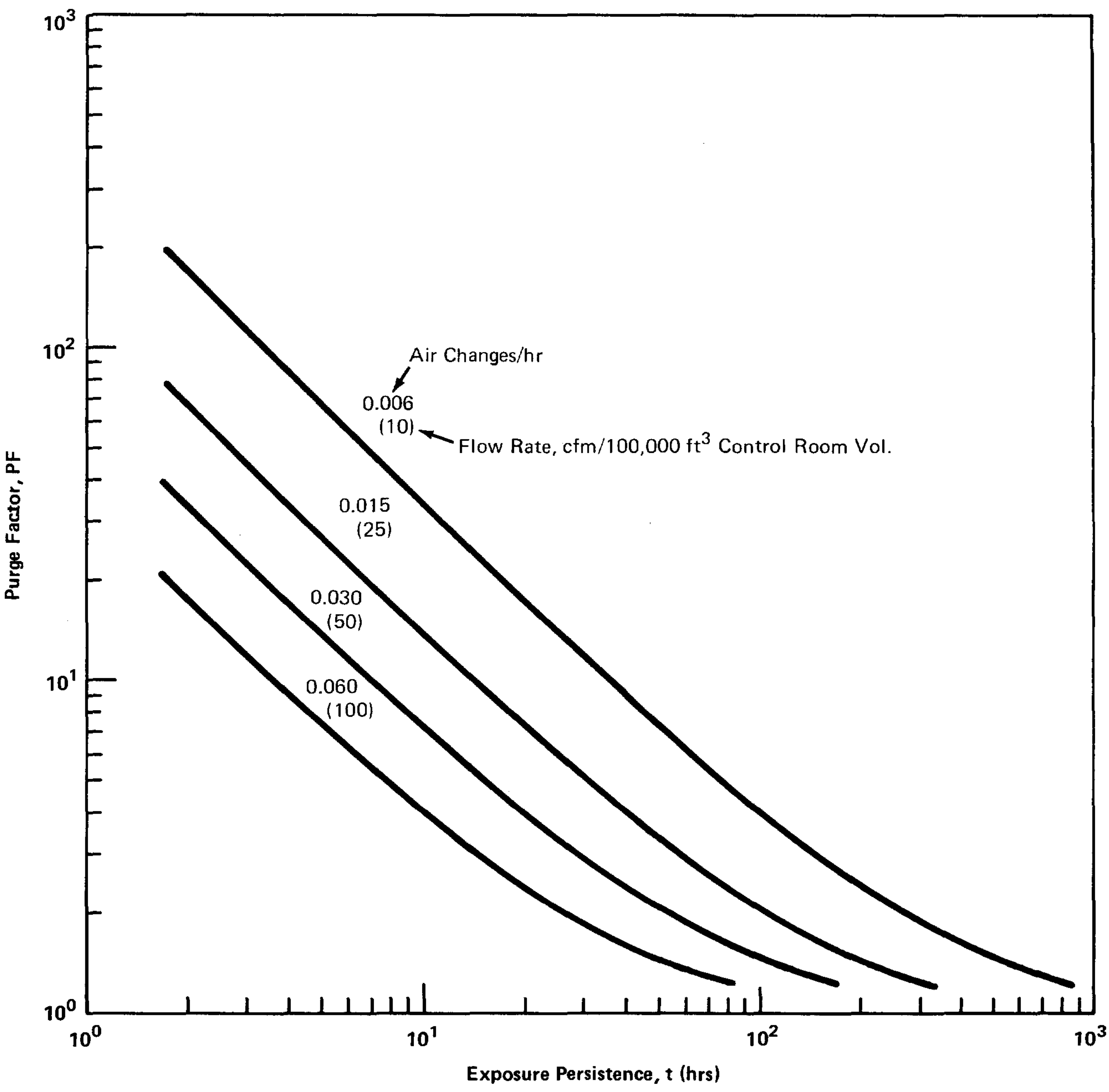


Figure 8 Purge Factor as a Function of Time for Several Infiltration Rates

DISCUSSION

SULLIVAN: This may be a little bit off the subject. Have you seen any designs for the incorporation of devices in control room ventilation systems that take into account possible hazardous chemical releases, namely chlorine?

MURPHY: For chlorine, I think that immediate isolation of the control room is the first defense against such a release. Unfortunately, I think we also have to rely on breathing apparatus for further protection in very severe accidents (we'll call them design basis type accidents) where we assume the entire chlorine car ruptured. We know that charcoal filters can be effective against chlorine. We believe that their use in chlorine accidents will help mitigate most of the lower spectrum of such incidents.

SULLIVAN: The reason I asked the question is that at the Midland Plant, we are going to be supplying process steam to the Dow Chemical Company. Being close to Dow presents some unique problems for us in this respect.

MURPHY: A regulatory guide specifically for the problem of chlorine is now underway and hopefully will be in the public document room within a month or two. This will help to determine the necessary control room protection.

DODDS: Do you have any data that has come out from plants to justify your infiltration assumptions?

MURPHY: To my knowledge there are no data on control room infiltration or infiltration of a similar structure that is so leak-tight. Of course, we know about infiltration for conventional buildings. The National Bureau of Standards, under an AEC contract, will be doing tracer tests on control rooms to determine infiltration rates and, in this way, we will be able to determine whether our present assumptions are valid.

MOELLER: You showed bottled gas being used to pressurize the control room. What is the comparison of the efficiency of using bottled air for that versus using it as a source of individual air supply to the people in the room?

MURPHY: It's much poorer. You see, what we're hoping to do here is to keep a shirt-sleeve environment inside the control room. We might be hurting in terms of whether we used bottled air to pressurize the entire room versus its use in breathing apparatus. However, I think we gain an awful lot in maintaining a shirt-sleeve environment during emergencies.

KOVACH: On the completion of the NBA study, will you consider revising the new guide?

MURPHY: Which guide is this?

KOVACH: Your assumption is based on 10 CFM. I believe the rates are considerably lower.

MURPHY: We will adjust our assumptions to bring them in line with our test findings.

PASSISI: I notice you used the paper of Halitsky as a source. I'm wondering, considering some of the discrepancies in the original Halitsky paper, if you had considered using another dilution model?

MURPHY: We have looked at the applicable wind tunnel tests and all of the field tests that are available to us and we find nothing in all of these tests to show that our modeling is not appropriate. Our position is an interim one. It requires further study, I'm afraid, in terms of both the wind tunnel testing and actual field testing, to determine whether this interim position is far off.

PASSISI: You also made reference to a 95 percent efficient charcoal filter. I wonder if you have considered the removal of particulate iodine by HEPA filters. Are you making an assumption that a certain fraction of the particulates of iodine that would be left in the containment after the initial spray action would be the type of iodine released?

MURPHY: Under most circumstances the iodine that is released to the environment is principally organic and not particulate.

PASSISI: That's contrary to Regulatory Guide 1.4 in terms of the fractions of particulate iodine left after the spray has eliminated the bulk of the elemental iodine. In a PWR with sprays, 40% of the iodine left after the first half hour of spray operation will be particulate.

MURPHY: We usually do not take any credit for the removal of particulate by the HEPA filter, since it usually results in a small dose reduction. It should be noted that the particulate will be reduced to low concentrations after about ten hours of spray operation. The iodine that is subsequently released will be essentially all organic. Nevertheless, an allowance based on HEPA filtration of particulate would probably be acceptable to the Regulatory staff.

AN INERT ATMOSPHERE SYSTEM FOR PLUTONIUM PROCESSING GLOVEBOXES

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I. Abstract

Recent efforts to reduce fire hazards in plutonium processing operations are described. In such operations, the major environmental controls are developed through various kinds of glovebox systems. In evaluating the air-atmosphere glovebox systems, formerly in use at Rocky Flats and many other plants, a decision was made to convert to a recirculating "inert" atmosphere. The inert atmosphere consists of nitrogen, supplied from an on-site generating plant, diluting oxygen content to between one and five percent by volume.

Problems encountered during the change-over included: determination of all factors influencing air leakage into the system, and reducing leakage to the practical minimum; meeting all fire and safety standards on the filter plenum and exhaust systems; provision for converting portions of the system to an air atmosphere to conduct maintenance work; inclusion of oxygen analyzers throughout the system to check gas quality and monitor for leaks; and the use of automatic controls to protect against a variety of potential malfunctions.

The current objectives to reduce fire hazards have been met and additional safeguards were added. The systems are operating satisfactorily.

II. Introduction

In some Atomic Energy Commission (AEC) installations where plutonium processing operations are conducted, the use of an inert atmosphere (nitrogen, argon, helium) has been introduced.

An inert atmosphere system was considered for the Rocky Flats operations during initial design of the plant in 1951, and again in 1961. On both occasions, consideration of economics and of problems of plutonium corrosion in an oxygen-free atmosphere of low humidity, dictated that an air atmosphere be used. The air atmosphere system was typical of others used in AEC operations. Such a system involved introducing room air, or dehumidified air, into gloveboxes. The boxes are operated at a slightly negative pressure (about -0.8 inches water column ["W.C."]). The air is exhausted through a High

Efficiency Particulate Air (HEPA) filter system. Appropriate controls, fire protection equipment, monitoring devices, and other auxiliary systems, are incorporated.

Operations had been successfully carried out under the air systems, except for minor chip fires not considered serious risks. In 1969, an incident occurred which caused the reliability of the systems to be questioned. As a result, a study was initiated to investigate the feasibility of adopting an inert atmosphere.

III. Discussion

Atmosphere.

Determination of the required atmospheric composition was needed because of effects of water vapor, oxygen concentration, and the type of inert gas used, on plutonium combustion. Early studies [1] indicated that, although plutonium is particularly sensitive to water vapor corrosion at very low oxygen concentrations (ppm levels), the protective oxide coating formed at about 0.5% oxygen concentration is nearly as complete as the protection gained in a normal air atmosphere. Therefore, assuming equivalent water vapor conditions, the corrosion to be expected at, say, 1% oxygen concentration, is no worse than at 21% oxygen concentrations.

Studies also indicated that nitrogen, although not truly an inert gas, gave essentially the same ignition protection as argon or helium, within the practical objectives of the program. Actually, it was determined that CO_2 would also be a satisfactory inerting gas, although the oxygen concentration would need to be held about 30% lower to achieve the same ignition protection.

One potential pitfall in the use of nitrogen was recognized in the plutonium nitriding reaction known to take place under certain conditions, creating a powder that could be highly reactive if suddenly exposed to air. A study [2] revealed that plutonium nitride formation is difficult in dry, oxygen-free atmospheres up to about 600°C. In air containing even one-half percent oxygen, the nitride formed reacts immediately to form a plutonium dioxide that acts as a protective coating.

For these reasons, a lower limit of 1% oxygen in nitrogen was placed on the atmosphere to be used in the production gloveboxes. Normal leakage of air into the boxes will assure meeting this limit without any special control system, as noted in later discussions.

The upper limit of oxygen concentration was established by conducting ignition studies on various types of plutonium[3]. Under a given set of standardized conditions, it was found that the ignition temperature of plutonium in air was a fairly predictable function of the specific surface area, as shown in Fig. 1. At surface areas less than one square centimeter per gram (cm^2/g), ignition in air requires fairly high temperatures - higher than normally encountered in routine operations. With powders approaching 100 cm^2/g, however, ignition can occur at temperatures around 100°C.

Turning attention to this area, the effect of decreasing oxygen concentration on the ignition temperature of plutonium powders was investigated (Table I). In order to prevent ignition of 140 mesh filings, an oxygen concentration of less than 1% in nitrogen must be maintained. However, material this fine would not normally exist in the production system at Rocky Flats. For a more realistic test, studies were made on machine turnings with surface areas of around 10 cm^2/g (Fig. 2). For this material, it was found that ignition temperature stayed fairly constant at all oxygen concentrations from 21% down to about 5%. There was essentially no ignition at lower concentrations. Based upon this finding, an upper limit of 5% oxygen in the circulating atmosphere was placed on the project.

Several other points should be mentioned here. Most other materials in the glovebox system, such as wiping paper, Plexiglas®, and oils, do not ignite at oxygen concentrations less than 10%. The 5% level, therefore, provides a fairly comfortable margin to avoid ignition of these materials. Also, "ignition" should not be confused with "extinction." If plutonium chips are ignited in air, they cannot, then, be extinguished by merely lowering oxygen content to 5%. For this, a concentration of probably less than 1% would be required.

Leakage.

The "system" to be inerted was actually a number of different systems, ranging in age from about 14 years down to two years, and designed from several different concepts - both mechanically and for ventilation control. One thing all had in common was that they had been designed for air service. They were designed to operate at around-0.8" W.C. for contamination control. In-leakage of air had been of some concern, of course, but it had not been a major factor in earlier designs. Especially for the older boxes, warpage, deterioration of gaskets, mechanical wear, and other factors had served to increase leakage. The cross-sectional diagram of a typical glovebox in Fig. 3 shows some of the leakage points that might be expected.

Another significant problem was determining the leakage rate to be expected in the operating system after completion. On small systems that can be isolated, leakage rates can be measured fairly easily by using oxygen-rise, pressure-rise, or flow methods. Tests of this sort conducted on individual boxes at Rocky Flats indicated that leakage rates of less than 0.1 (vol/hr-vol) could be attained by careful attention to the box; however, the boxes involved in this

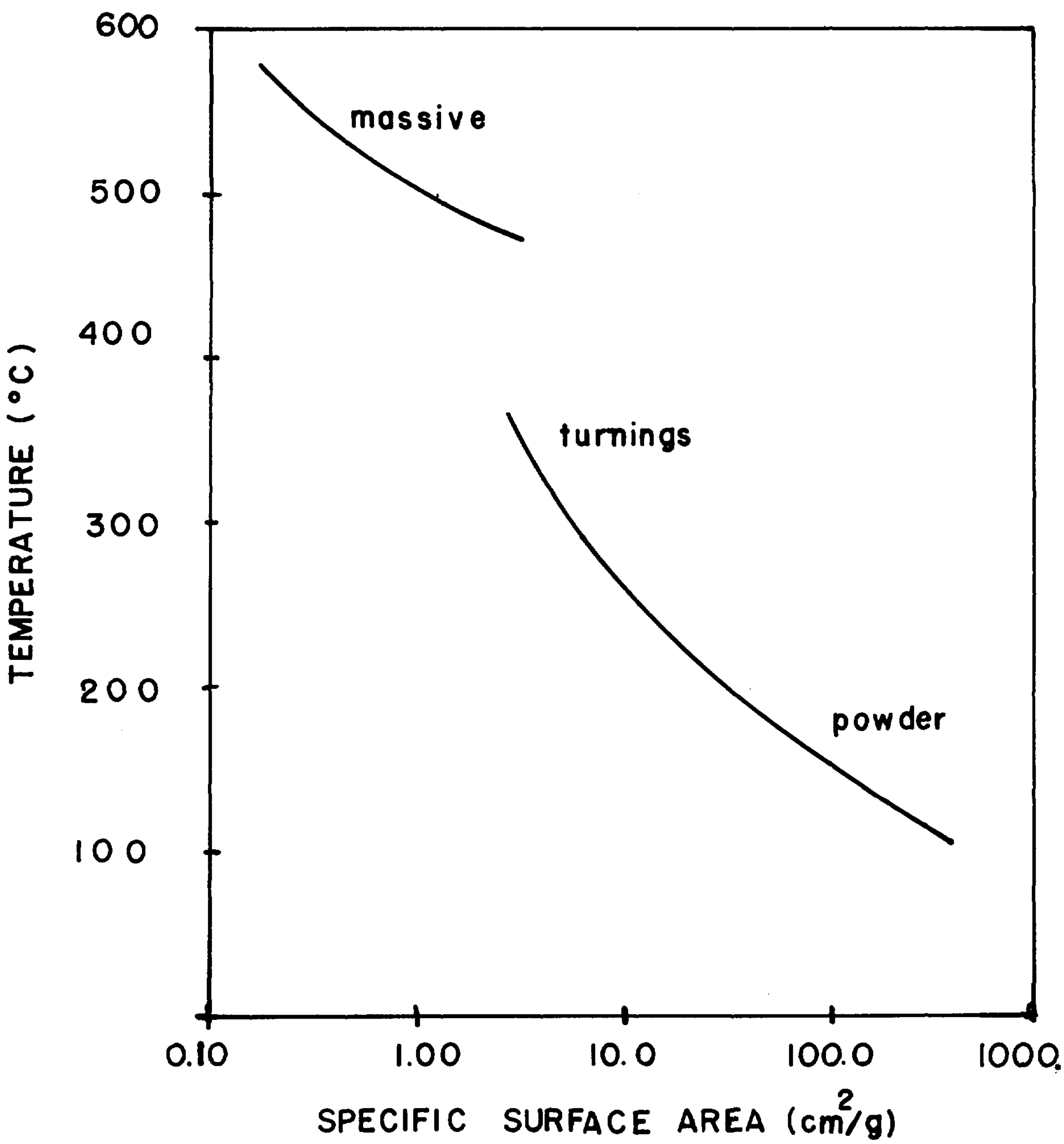


Figure 1. Ignition Temperature of Plutonium in Air

TABLE I

Ignition temperature of 140 mesh 1 wt% gallium alloyed plutonium filings in various concentrations of oxygen.

Oxygen Concentration (vol % O_2)	Ignition Temperature ($\pm 10^{\circ}$ C)
20 ± 1	175
12 ± 1	183
8 ± 1	165
5 ± 1	*170
3 ± 1	*160
< 1	No reaction

Ignition temperature of 1 wt% gallium alloyed plutonium lathe turnings in various concentrations of oxygen.

Oxygen Concentration (vol % O_2)	Ignition Temperature ($\pm 10^{\circ}$ C)
20 ± 1	265
12 ± 1	270
8 ± 1	400
5 ± 1	Slight reaction at 270° C.
3 ± 1	No reaction
< 1	No reaction

* Samples were not completely burned and could be reignited in air after cooling.

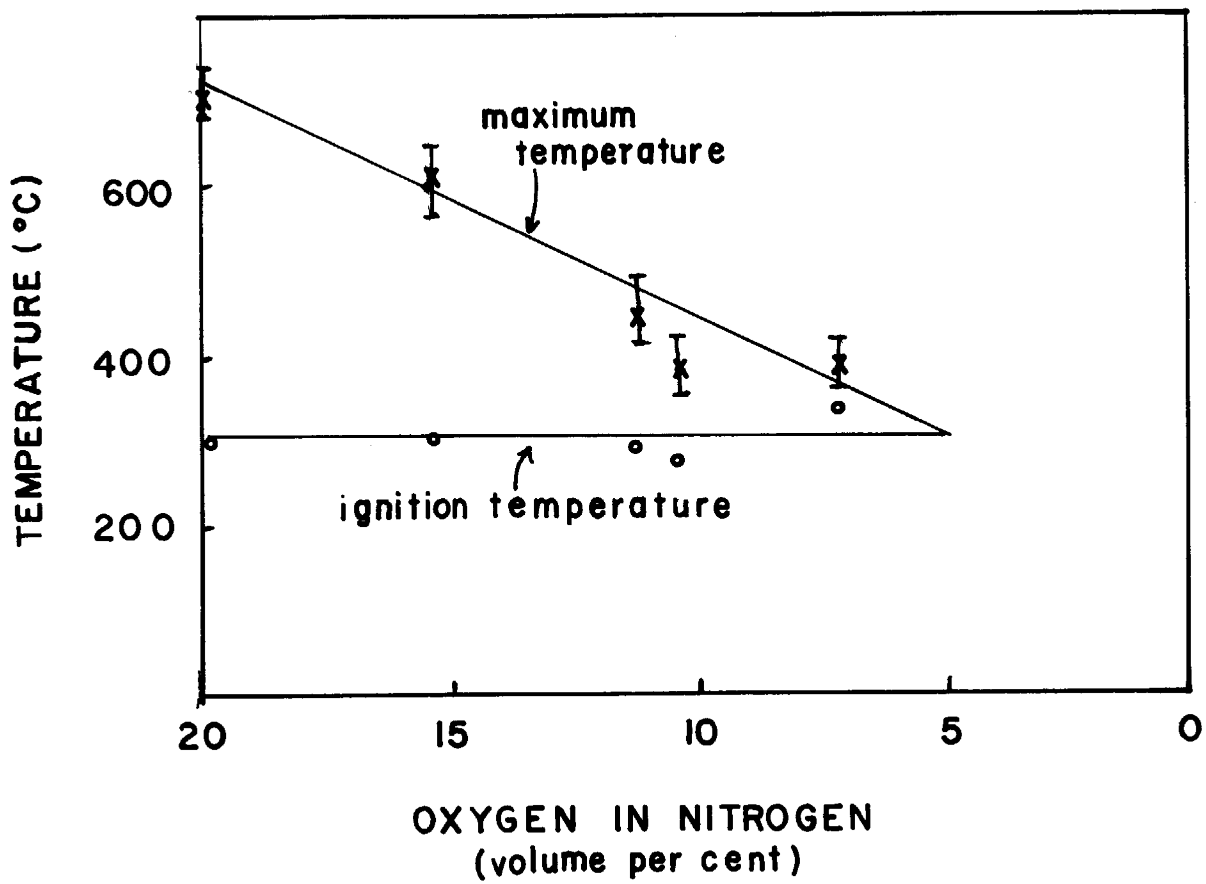
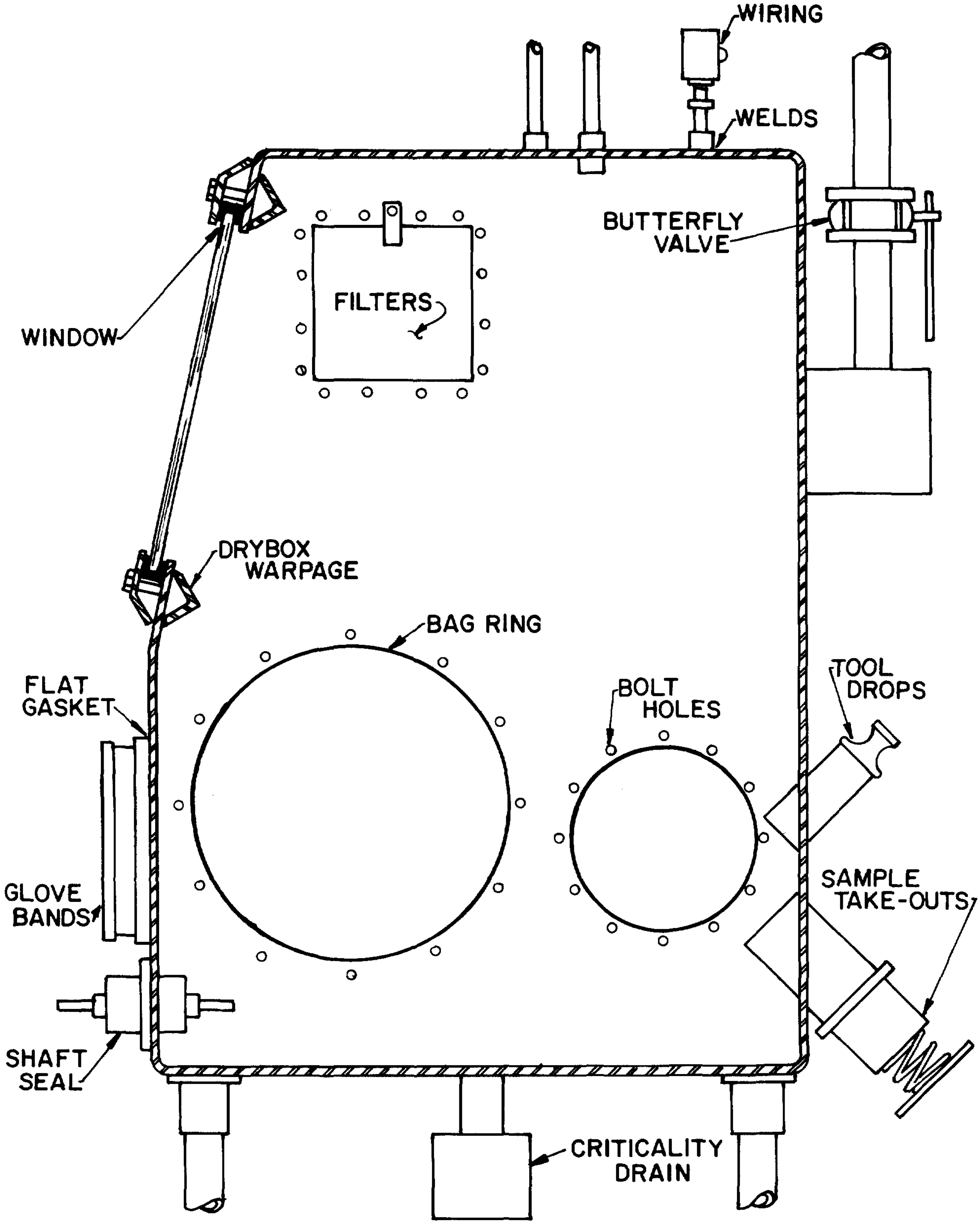

maximum temperature
ignition temperature
TEMPERATURE (°C)
600
400
200
20
15
10
5
0
OXYGEN IN NITROGEN
(volume per cent)

Figure 2

FIGURE 3

STANDARD GLOVEBOX & PROBLEM AREA



testing were all relatively new and tight, and thus conditions were not typical of an old, large system where bag cuts, glove changes, air lock transfers into the box system, and routine processing were being constantly conducted.

Fortunately, major portions of the large system had been provided with a dehumidified atmosphere, and there was a significant water vapor differential between the rooms and the boxes that might be measured to determine an actual operating leakage rate. Use of this technique[4] indicated that the actual leakage factor was frequently above 1.0 (vol/hr-vol). Recognizing that this value could be reduced by both design and operating changes, a value of 0.5 (vol/hr-vol) was used as the design basis, especially for determining the quantity of nitrogen required. Although this was a conservative value, an excess of nitrogen was to be preferred over a deficiency. Actually, an excess of gas is useful since it would be desirable to operate at even lower oxygen concentrations. Because of dilution characteristics, it takes almost twice as much nitrogen to operate at 3% instead of 5% oxygen.

Nitrogen Supply.

Originally, the systems to be inerted contained nearly 100,000 cubic feet of volume, ventilated on a once-through basis at a rate of more than 1,000,000 cubic feet per hour. Providing this amount of nitrogen, simply to replace the air supply, would be costly and would have other disadvantages. The preliminary design, therefore, involved redesigning the ventilation system to recirculate the inert atmosphere, as will be discussed later. Even this concept, with a leakage factor of 0.5, and providing extra capacity for projected growth, a nitrogen supply of 140,000 cubic feet per hour was required.

A number of alternates were considered to obtain this amount.

- Purchase of liquid nitrogen with on-site storage and evaporation
- Nitrogen generation by a combustion process
- Construction of an on-site liquification plant
  - Designed, built, and operated as an AEC plant
  - Designed and built, by a vendor; purchased by AEC
  - Designed, built, and operated by a vendor; gas purchased at the fence.

The last alternate was selected to meet the current requirements. In competitive bidding, Air Products and Chemicals, Inc., was awarded the contract, and now has a plant operating on site. The plant is actually built as two 70,000 standard cubic feet per hour (scfh) units to provide enough gas to continue inert operations, even if one unit goes down for planned, or unplanned, maintenance. In addition, liquid nitrogen - taken from plant production - is stored to provide a supply for at least three days' operation at design rate. Dual, looped transfer lines, to guard against any sort of line failure, are installed underground to deliver nitrogen as a gas to the glovebox systems.

Although the bulk of the gas is used at about atmospheric pressure, the gas is actually supplied at about 120 psig to provide for some high pressure air spindles, pneumatic operators, and control systems that vent into the glovebox systems. All these have been converted from air to nitrogen service.

To date, operation of the nitrogen plant has been excellent.

IV. System Design

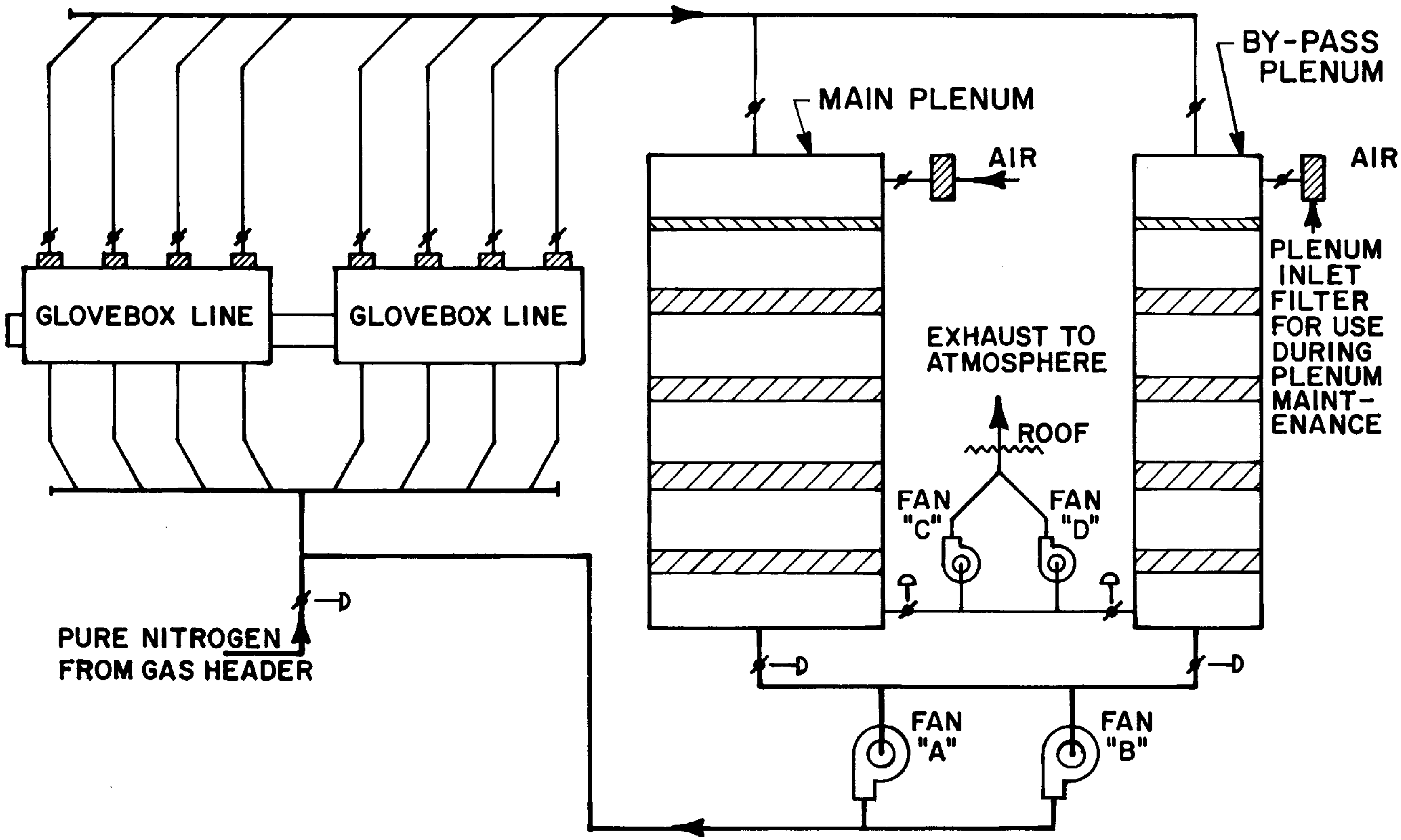
The original project concept entailed converting two systems each in two production buildings from a once-through air atmosphere to a recirculating inert atmosphere. Generally, one of these systems in each building received its air from room air pulled through inlet HEPA filters mounted on the boxes, then through exhaust lines to HEPA filter plenums, which discharged to the atmosphere. In the other systems, dehumidified air was supplied to the gloveboxes from fans and exhausted in a similar manner through plenums to the atmosphere. These two systems were converted to the design shown in Fig. 4 by adding recirculating fans to the plenums, with return headers and supply lines to individual boxes.

In effect, "modifying" the systems entailed new construction throughout, except for the gloveboxes and some supply and return lines. Most of the old equipment did not meet the revised standards for plutonium ventilation systems. The inerting work was, therefore, combined with a project to upgrade the systems through the use of Heat Chambers (water spray cooling units), improved plenum design, fire control systems, Radiation Monitoring monitoring equipment, etc. Much of this work is being discussed in other papers at this conference. Note also that for each inert system, a bypass plenum is provided to allow plenum maintenance, especially filter changing, to be done in an air atmosphere without affecting the integrity of the inert atmosphere.

For each of the systems, a chiller is installed in the recirculating line to remove any of the process heat that might be picked up in one glovebox pass.

FIGURE 4

RECIRCULATING NITROGEN SYSTEMS



In operation, the glovebox pressure continues to be controlled by sensing elements on the return lines, acting through the exhaust fans. As in-leakage of air to the boxes causes oxygen content of the atmosphere to rise, an oxygen analyzer causes the nitrogen control valve to open, thus diluting the oxygen down to the control point. Total system flow is maintained by flow controller, with individual box balancing done manually through butterfly valves at the boxes.

Numerous other control features are built into the systems. Since humidity of the atmosphere is of interest, moisture analyzers are installed which can be used to reset the oxygen control points, thereby changing the humidity level by the introduction of the dry nitrogen.

Although the intent of the project is to eliminate any fire from occurring in the gloveboxes, fire control systems are installed in the event of some malfunction or breach of the system. Each box has a heat detector on the outlet. Each plenum has a heat detector on the inlet which automatically actuates a water spray in the heat chamber portion of the plenum. A further, manually-controlled spray can be used to wet the first stage of filters if needed. In the event that any water spray is introduced into a plenum, interlocks will shut off the recirculating fans and provide maximum system exhaust to prevent introducing moisture to the process.

To check the oxygen concentration in individual boxes which might be diluted in the header by other boxes, each box is connected through a selector device to an oxygen analyzer.

Parallel fans are used on all systems with automatic start capability in the event of need - either flow, or pressure. Interlocks shut off nitrogen supply to the system if both of the exhaust fans fail, to avoid pressurizing the boxes.

Important control functions are located in a control room which has outside access and separate ventilation so that control of the inert systems can be maintained, regardless of conditions around the operating equipment.

Other than changes to the ventilation supply and exhaust lines, modification to the gloveboxes themselves consisted primarily of leakage reduction. External air locks were improved or eliminated. Some internal air locks were added to separate the inert systems where air is still used. Bag ports were removed where possible, or covers provided. Tool drops were improved and sample take-outs eliminated.

V. Construction

Other than normal construction problems, a major difficulty in this project was the requirement for making major changes to operating systems, while continuing to operate the systems for production and without relaxing any of the environmental control standards. This was accomplished by concentrating on one system at a time; building the new plenums with associated heat chamber, fan, ductwork, and controls; then imposing a brief shutdown to tie into the system before removing the old equipment. In cases where inadequate space existed to build the new before removing the old, temporary connecting jumpers were installed to permit using spare equipment while installing the new facilities. Insofar as possible, an attempt was made to check out all portions of the new systems before putting into "hot" service. In particular, all new plenums were thoroughly leak-tested, and the HEPA filters were dioctylphthalate (DOP) tested before being put into service, to assure staying well within release guidelines.

VI. Operation

With some changes, the systems were installed as designed. Although an expansion of the processing gloveboxes had been anticipated, many of them were actually eliminated. In place of the 100,000 cubic feet originally planned for inerting, approximately 60,000 cubic feet are now involved in all the systems. This permitted combination of the two systems in one building into one system by simply interconnecting headers and eliminating one plenum with its fans and controls. In addition, a greater excess of nitrogen was available than originally planned.

Once all equipment was finally checked out and control units were operating properly, the actual changeover to inert atmosphere was fairly smooth. However, one incident occurred after conversion that caused some repiping. Because of a combination of circumstances, some maintenance work being done in one of the gloveboxes caused a flow reversal which forced contamination backward through the recirculating fans, and out the exhaust fans to the atmosphere. In order to prevent a recurrence, the suction for the recirculating fans has been relocated from behind the fourth stage of HEPA filters to the space between the second and third stages. This will assure that even a reverse flow through the fans passes through at least two stages of filters.

The systems have not been operational long enough for extensive leak-checking, and leakage elimination. However, preliminary results indicate that a leakage factor of about 0.3 vol/hr-vol is being realized.

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