ENGINEERING A NEW RELIABLE ALPHA-CONTAINING FILTERED EXHAUST GAS SYSTEM

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Abstract

A reliable exhaust system was designed to ventilate gloved enclosures in an existing building which was modified to provide for the safe handling of kilogram quantities of alpha-emitting materials. The new exhaust system was designed especially for this purpose, and as a separate system, it relieved the existing overtaxed exhaust systems which could not be economically upgraded to perform the same function. The arrangement of components and the features incorporated in the new system provide many improvements in reliability and maintenance not found in other systems of this type. The more significant events experienced during the design, fabrication, and installation of this system, beginning with the design criteria and ending with an objective critique for the benefit of others, are discussed herein.

Introduction

The Radiochemical Pilot Plant (Building 3019) at Oak Ridge National Laboratory (ORNL) was originally built to accommodate radiochemical operations on a pilot-plant scale in which beta-gamma sources of radiation were encountered. However, the original function of this facility has been modified by a growing use of work space and support systems for operations involving alpha-emitting materials. After 20 years of facility operation during which numerous system alterations were made, the decision was reached to install a new exhaust ventilation system that would meet the current and expected future needs of the facility.

At the time this decision was reached, the existing facility had two forms of filtered exhaust systems, but neither was adequate to provide the particular service necessary to support large-scale handling operations involving alpha-emitting materials in a manner consistent with current safety regulations. The existing cell ventilation system, which exhausted shielded cells and fume hoods and provided some space ventilation, furnished high flow under low suction conditions (gage pressure of about 2 in. H_2O). The second system provided low flow under high suction conditions, and it can best be described as suited only for process ventilation of vessels and restricted enclosures where open chemical operations are conducted or where high suction does not create an unsafe condition. Although this second system had been adapted to serve some glove boxes, the existing ducts were inadequate for greatly increased flows. The flow reserve in the system was less than 200 cfm, which was far from meeting the projected needs of the facility. Changes to such systems are costly and difficult to keep reliably safe from imploding forces resulting from the high suction pressure (about 35 in. H_2O).

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With the present facility personnel as operators, the new alpha enclosure ventilation system will be extended to serve various building areas as the changes planned for different research programs are realized. The criteria established for the design of the new system were developed to attain suitable service provisions of the type and quality foreseen for current and future alpha enclosure ventilation needs.

System Design Criteria

The goal of the system design criteria was maximum safety for gloved enclosure operations and for the environment; the key being reliable trouble-free system operation. A basic design premise was that reliability is best attained by engineering simplicity and another was that human error is a greater threat to safety than material or equipment failure. This philosophy underlies the approaches taken to implement the criteria into an integrated system design. Some points of the criteria characterize only this system, while other points reflect the application of long-standing practices. Significant points of the criteria are outlined as follows.

1. The system shall be designed and sized to operate with an ultimate airflow rate of 3000 cfm. Initial operation shall be at a rate as low as 600 cfm, with periodic increases as other branch connections are put into service under future programs.
2. A negative pressure of 4 in. H_2O shall be maintained with a high degree of service continuity in each branch duct.
3. Protection shall be provided to safeguard each branch duct against excessive negative pressure.
4. Two physically separated and separately testable HEPA filter stages shall be provided to filter all effluent before release to the atmosphere. The first stage shall be within the building confinement limits and be applied individually to each branch duct.
5. Fire barriers shall be provided upstream of each of the three second-stage HEPA filter housings to intercept any burning debris that might result from a breakthrough of the first-stage filters.
6. The total system airflow and the flow in each individual branch duct shall be continuously monitored.
7. The system shall be instrumented so that an on-duty operator can quickly determine the status of the system at an existing central station in the building.
8. The system ducts shall be metal with minimal leakage, and they shall be incapable of collapse by fan suction or exposure to weather.
9. The system shall be tested upon completion of construction to demonstrate performance compliance with the design criteria.
10. The recommendations given in USAEC Report ORNL-NSIC-65[1] shall be used as a guide.

Arrangement of System Components

Various desirable features, the selection of which was at the option of the designer, were considered for their relative value in adding safety and reliability to the system. These features (in descending order of judged desirability) were (1) an alternate (electrical) power source, (2) standby fan(s), (3) vacuum relief devices to limit suction in the system, (4) multiple filter paths for second-stage HEPA filters, (5) manual dampers rather than automatically operated damper devices, (6) inertia wheels for fan units to provide better changeover performance, (7) independent electrical power controls for each fan, (8) two backflow preventer dampers in series on discharge of each fan, (9) alarms to detect and signal abnormal flow and/or pressure conditions, (10) dual duct system (physically separated) upstream of fans, (11) fire suppression system for second-stage HEPA filters, and (12) fans rigidly connected to ducts and foundation framing without isolating devices.

The selections were made on the basis of which feature would provide operation that would be simple to maintain and regulate. Previous experience strongly indicated the selection of such items as manual adjustment of flow-pressure conditions; three equal-size fans in parallel operation; welded stainless steel ducting rather than coated metal ducting in which flanged joints would be required, thereby jeopardizing leak-tightness; and normal and alternate sources of power, both being electric so that all fan units can be equal and the operation of on-line units can be continued rather than having to start an idle unit. Where failure of a single component could jeopardize system function, it was considered necessary to include a redundant item (of equal size). Although it provides only a single path in many places, the ductwork was judged unworthy of full redundancy because there are no normally moving parts and the failure risk was considered to be low.

The final selection and arrangement of system components are illustrated schematically in Figure 1. Note that the first testable stage of HEPA filters is located within the limits of the building confinement, as is the vacuum relief device which acts as a safety device against excessive suction pressure within the branch. All of the components of the system beyond the first-stage HEPA filters are located outside the main building, where they are exposed to the weather and do not have the added protection afforded by the building in confining any leakage of contaminating particles.

The first-stage HEPA filters for one branch duct are shown in Figure 2. Each of two single-filter housings contain a 24 × 24 × 11 1/2 in. HEPA filter. This branch is designed to handle a flow rate of 600 cfm without shutdown during filter changes since one filter is allocated for standby duty, permitting DOP testing before being returned to service. Both the first- and second-stage HEPA filters are introduced into and removed from the system by a bagging process which preserves system containment.

Three existing multiple-filter housings were available for this project. These housings were outdoors and had connecting stainless steel ducts and manual shutoff dampers (single-blade design). Since these housings were only 4 years old and had been subjected to very light service, the decision was readily made to incorporate them and the associated ducting, dampers, and insulated stainless steel steam coil in the new ventilation system. The filter housings had coated carbon-steel exterior surfaces and stainless steel clamping linkage. The dampers and ducts were round with gasketed and bolted flanged joints. Some 60 ft of 20-in.-OD stainless steel duct was reused on the downstream side of the fan units where the pressure is low and leakage is less critical. Utilization of this existing equipment reduced the expected cost of the project.

Design and Procurement of System Components

A design condition which greatly influenced the sizing of various system components arose from the need to use some existing equipment (gloved boxes) with limited strength and the desire to minimize the main duct suction pressure. The branch duct suction pressure of -4 in. H_2O stipulated in the system

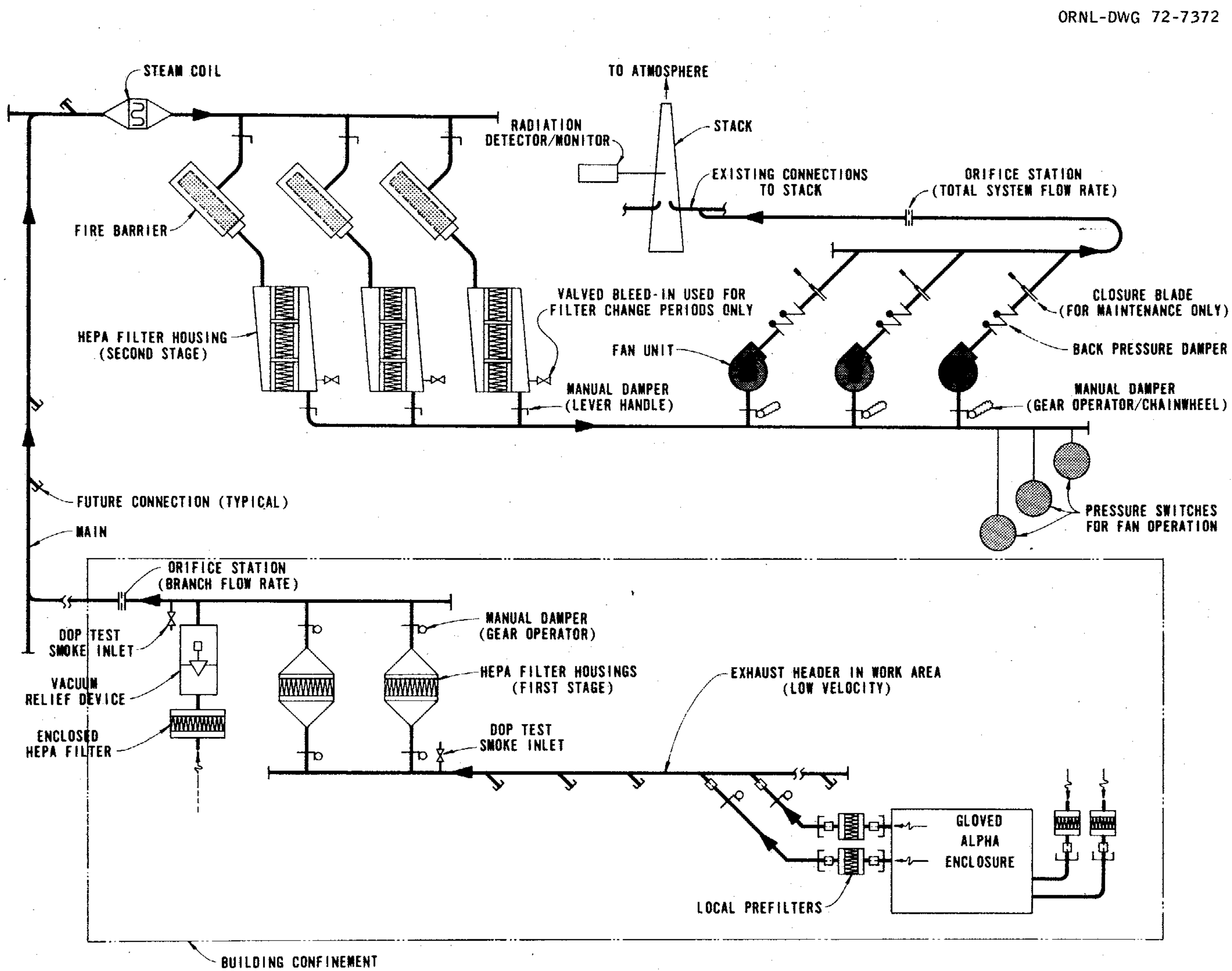

Figure 1. Schematic Airflow Diagram for Alpha Enclosure Ventilation System.

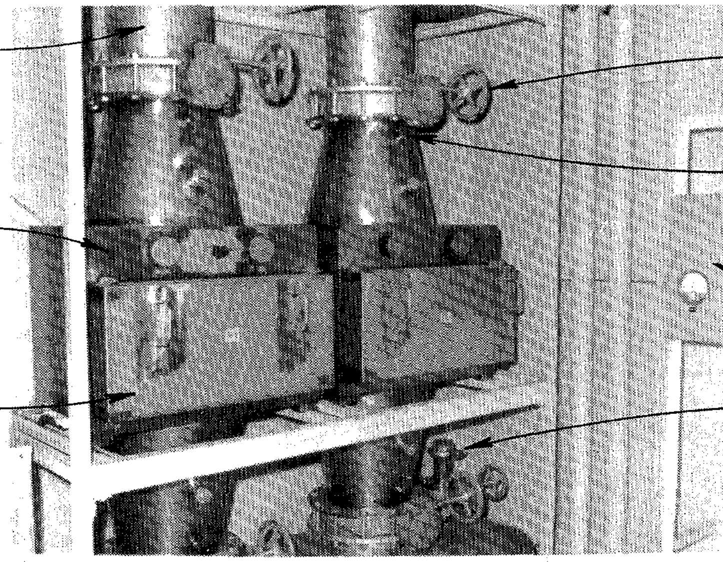

Figure 2. First-Stage HEPA Filter Housing Arranged for Parallel Airflow With One Unit On-Stream and One On Standby.

design criteria was a compromise value set to establish a balance between the ability to move air through each branch, accounting for the airflow resistance of filters, ducts, etc., and the need to not subject existing gloved enclosure and space ducting to pressures that could cause imploding forces. A branch suction pressure greater than -5 in. H_2O was to be avoided by having a vacuum relief device on each branch duct. This value was set as a design goal because the existing gloved boxes and enclosures had been designed to withstand a pressure differential of only 6 in. H_2O (not including the gloves). The weakest portions of such enclosures are the window panels. These pressure settings influenced the pressure gradient throughout the remaining portions of the system, and the pressure profile for the entire system, based on a total design level airflow of 3000 cfm, is illustrated in Figure 3. Note that the minor variation in pressure throughout the main ducting results in nearly the same suction pressure at each service connection.

The site conditions for this project eliminated consideration of a fixed-price construction contractor because of the interrelationship between areas of the facility in continuous operation and the possible exposure of workers to known areas of contamination. The resulting cost-plus-fixed-fee (CPFF) construction arrangement permitted a great deal of flexibility in execution of the work.

Equipment Specifications for Advance Procurement

To save construction time and help assure quality control, detailed procurement specifications were prepared for each significant item of equipment. Specifically, these items were the stainless steel ducting, low-pressure valves used as dampers, fan units, first-stage filter housings, and the emergency generator. The job site was investigated closely, critical space areas were carefully measured, and layout decisions were made to allow precise detailed drawings of the stainless steel ducting to be made for procurement purposes. This information permitted the close calculation of system airflow resistances, thereby providing accurate data for the specification of fan performance. The emergency generator was then sized. The equipment specifications were completed and advance procurement was begun with the intent of receiving the items prior to their need during construction.

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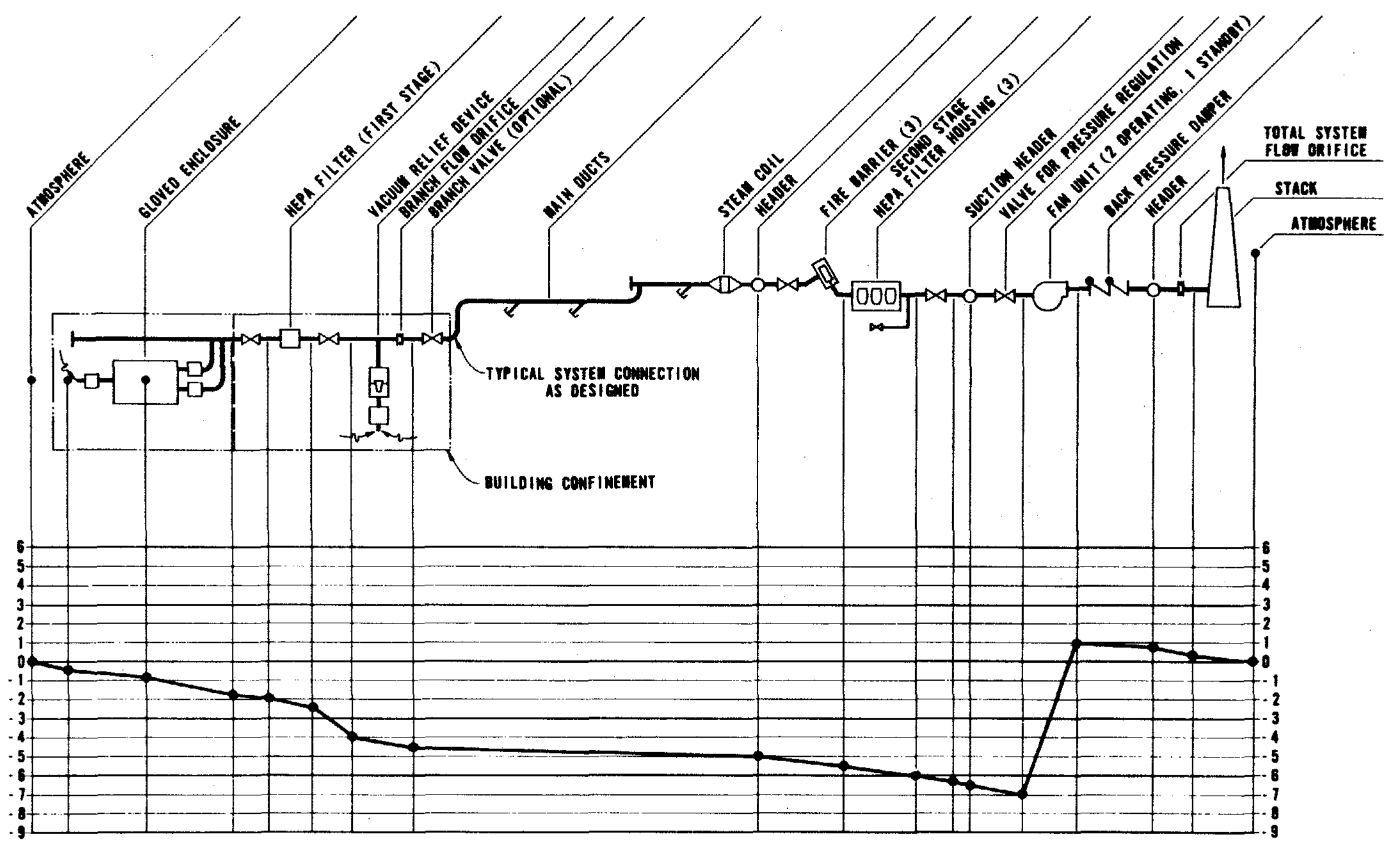

Figure 3. Pressure Profile for 3000-cfm Flow Rate in Alpha Enclosure Ventilation System.

Particular coverage was given in the specifications to performance testing and inspection to clearly establish the technical requirements for all participants and to assure that the item delivered would meet the intended requirements. An example of the type of specification used is presented in Appendix A.

Fans

An arrangement (AMCA Arrangement 8) of three equal-size fan units in parallel operation was chosen for its dependability and ease of servicing. Each fan is sized for an airflow rate of 1500 cfm (50% of the system design capacity) against a static pressure of 8 in. H_2O. Each is powered by a 10-hp (1750 rpm) electric motor. During initial operation of the alpha enclosure ventilation system, only one fan will be needed on-stream to meet the system requirements for airflow and pressure, leaving the other two fans for standby service. Later, as more system connections are made, two fans will be required on-stream and the third will be used for standby service.

The provision of an inertia wheel (flywheel) for each unit was stipulated in the procurement specification to enhance the coast-down time and to virtually eliminate any interruption to the system suction during fan changeover. This feature has been demonstrated and judged very desirable for critical process operations. The direct-connected inertia wheel was sized to utilize all excess capacity of the 10-hp motor over that required for the air-wheel load (approximately 3 hp).

It was also stipulated in the procurement specification (Appendix A) that at design conditions, the peak-to-peak vibration displacement of the fan should not exceed 1.5 mils in any plane. This condition permits direct bolting of the fan to inlet and outlet ducts and to the platform framing, thereby eliminating the need for flexible sleeves and vibration isolators which are subject to deterioration in outdoor service. Failure of a sleeve or isolator could permit major inleakage which would grossly impair the performance of the fan. Experience has proved that this type of failure is not unusual for outdoor fan installations.

A very simple scheme is used to bring fans in or out of system service either manually or automatically. The operator selects the fan or fans required for on-stream service by setting three individual pressure switches, using knobs at the instrument face where the header suction condition is indicated. A loss of suction pressure in the main suction header causes the fans to automatically start in the order established by the pressure switch settings. If by accident, the operator resets the switches in a manner that causes all three fans to be run at the same time, only minor pressure fluctuations will result at the branch connections as compared with the conditions during operation of one or two fans. The airflow path from the suction header through the fan and back-pressure dampers was designed to be essentially identical for each fan so that the performance of each operating fan is the same as that of the others. This feature assures that fan performance during an emergency period will be equal to that during normal periods of operation and it assures equal loading under any combination of parallel operation. Manually adjustable dampers (valves) with high-ratio gear (chain wheel) operators are provided between the main suction header and each fan suction, and the blade position in these three valves is kept the same. They are adjusted in unison to set the suction level in the main header. The blade position will remain unchanged for long periods, and it is readjusted only when significant changes in airflow rates, such as those occurring when a new connection is added to the system, are made.

Normal and Alternate Power

The arrangement of the system requires a reliable power source to serve all three fan units and the three pressure switches that control fan operation. The normal power is supplied by the ORNL plant power distribution system (TVA source), and the alternate power is supplied by a diesel-engine-driven emergency generator (100 KW continuous). This unit and other electrical apparatus, such as transfer switches, are housed in a separate fire-resistant structure which provides compartmental separation for the generator and the power circuitry for each fan. The emergency generator house with its compartmented areas is shown in Figure 4. Each area of this structure is accessible only from the outside via individual doors. The 285-gallon underground fuel supply tank and the anti-syphon fuel piping to the engine are not shown in Figure 4.

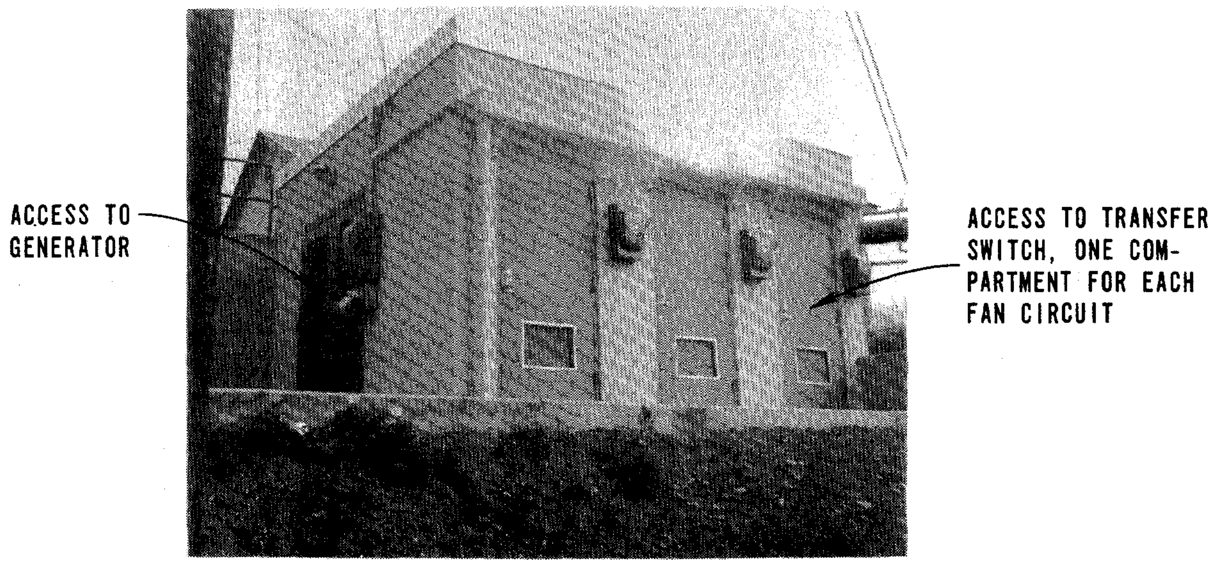

Figure 4. Compartmented Emergency Generator House.

The wiring for each fan unit is isolated from that for the other fans so that if one fan circuit fails as a result of an electrical short, fire, etc., the other circuits will remain operable. The power and control wiring from the transfer switches to the fan motors is routed in separate underground conduits that are encased in concrete. A schematic diagram of the power wiring to the three fans is illustrated in Figure 5.

The emergency power generator was sized to start all three 10-hp fan motors simultaneously should this inadvertently be called for. Normal start-up would include only one or two fans. The control wiring allows any one fan (whose automatic transfer switch opens its contacts) to demand start-up of the emergency generator upon loss of its normal power supply. The time required for operation of the emergency generator from zero-speed to full load is about 12 seconds. This period is easily bridged by the flywheel coast-down time of the fans, providing excellent continuity of system suction pressure during the transition.

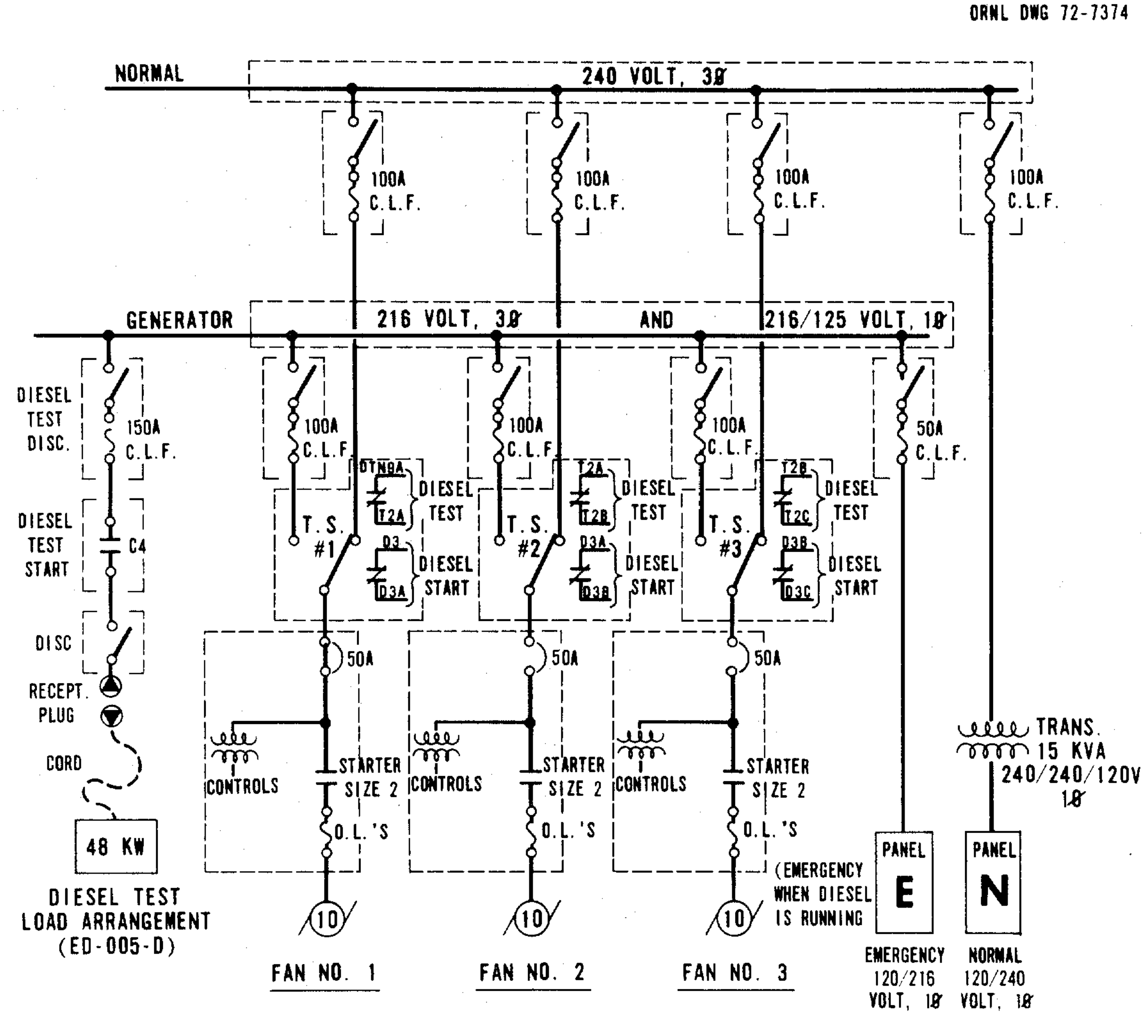

Figure 5. Schematic Diagram of Power Wiring for Fans.

Ducting

All ducting was fabricated from type 304L stainless steel with welded joints being used wherever reasonable. Separate drawings of the ducting were prepared for procurement purposes, and they provided the fabricator with virtually all of the necessary details, including dimensions, fit allowances for field adjustments, flange details, end preparations, etc. The drawing notes accompanying the details for the stainless steel ducting are presented in Appendix B.

Low velocities were purposely employed in the duct design to create a near uniform suction pressure throughout the system. The branches were sized to accept a normal flow of 600 cfm at a velocity not over 1000 fpm. Since these branches are downstream of the first-stage HEPA filters, normal dust loading is almost nil and any particles will be of a submicron size. Therefore, the conveying velocity was not a problem, but the need to minimize the system resistance resulting from duct airflow was a prime concern. The outside diameter of the initial branch ducts was selected as 12 3/4 in., yielding a velocity of approximately 700 fpm with an airflow of 600 cfm. The velocity in the mains was limited to 2000 fpm for the expected normal flow rates to insure low pressure losses, as was illustrated in Figure 3.

The thicknesses of the duct material, based on data given in USAEC Report ORNL-NSIC-65,[1] were selected so that stiffening would not be required and the ducting could be safely tested at a negative gage pressure of 15 in. H_2O. The outside diameters of the suction ducts vary from 12 3/4 to 20 in., and the wall thicknesses vary from 14 to 12 gauge (USS). The pressure for strength testing of the ducting upstream of the fans was set at 12 in. H_2O (positive), but this upstream ducting and equipment are also capable of withstanding a negative differential pressure of 15 in. H_2O without permanent deflection. The ducting downstream of the fans is open to the stack at all times and is therefore exposed only to positive pressure. The wall thickness of the downstream ducts was set at 16 gauge to reduce material, handling, and welding costs.

Since the ducting through the second-stage HEPA filters serves as an extension of the primary (enclosure) containment, limiting duct leakage was of special concern. A major portion of this ducting is located outdoors and maximum containment is necessary to both hold in contaminating materials and hold out air and moisture. The criteria for leakage limits were not exact, so the method of leak testing by which the leak rates for various duct sections were to be determined was stated on the design drawings. The final leak-rate testing was to be performed after a soap-bubble test of all joints under a positive pressure of 6 in. H_2O. These tests are detailed in Appendix C. Leak-rate testing of an outdoor duct system to prove tightness to a close tolerance ($\leq$ 0.1% volume/minute) is costly and time consuming. The testing conditions must be carefully defined, and the acceptance terms must be clear in advance.

To limit leakage, welding is the preferred method of joining duct sections. Since quality welds made in the field are more costly than those made in the shop, economical field installation calls for as few field welds as possible. Belled joints requiring a single external fillet weld were therefore used where possible for field welds. This was done by planning the piece details and setting the sequence of installation. Where a weld joint could not be used, the next preference was a clamped flange with a full-face neoprene gasket of one-piece construction. Gasketed and bolted flange joints were used only where it was necessary to fit existing equipment, such as the filter housings, and for the fan connections where vibration was a greater possibility. The clamped flange with a full-face gasket has proved to be superior to the bolted and gasketed flange in that it has less leakage, costs less, and is easier to install. The various types of joints employed throughout the alpha enclosure ventilation system are illustrated in Figure 6.

Physical barriers were provided for exposed ducts on roof areas to protect them against accidental abuse, puncture, or displacement resulting from other activities in the area. Two methods of affording this protection are shown in Figure 7.

Fire Barriers

Since the issuance of the criteria for new plutonium facilities[2] by the USAEC Division of Construction, new and inventive ways of providing acceptable protection for HEPA filter banks against fire, heat, water, and burning debris have been studied. Acceptable methods for providing fire-suppression equipment are not defined by these criteria.[2] They therefore did not greatly influence the design of this system. Through necessity, a method of providing fire protection for this new system was devised, and it involves the use of Neva-Clog* in cylindrical form to act as a barrier for burning debris should

*Trademark of Multi-Metal Wire Cloth, Inc., 501 Route 303, Tappan, New York, 10983.

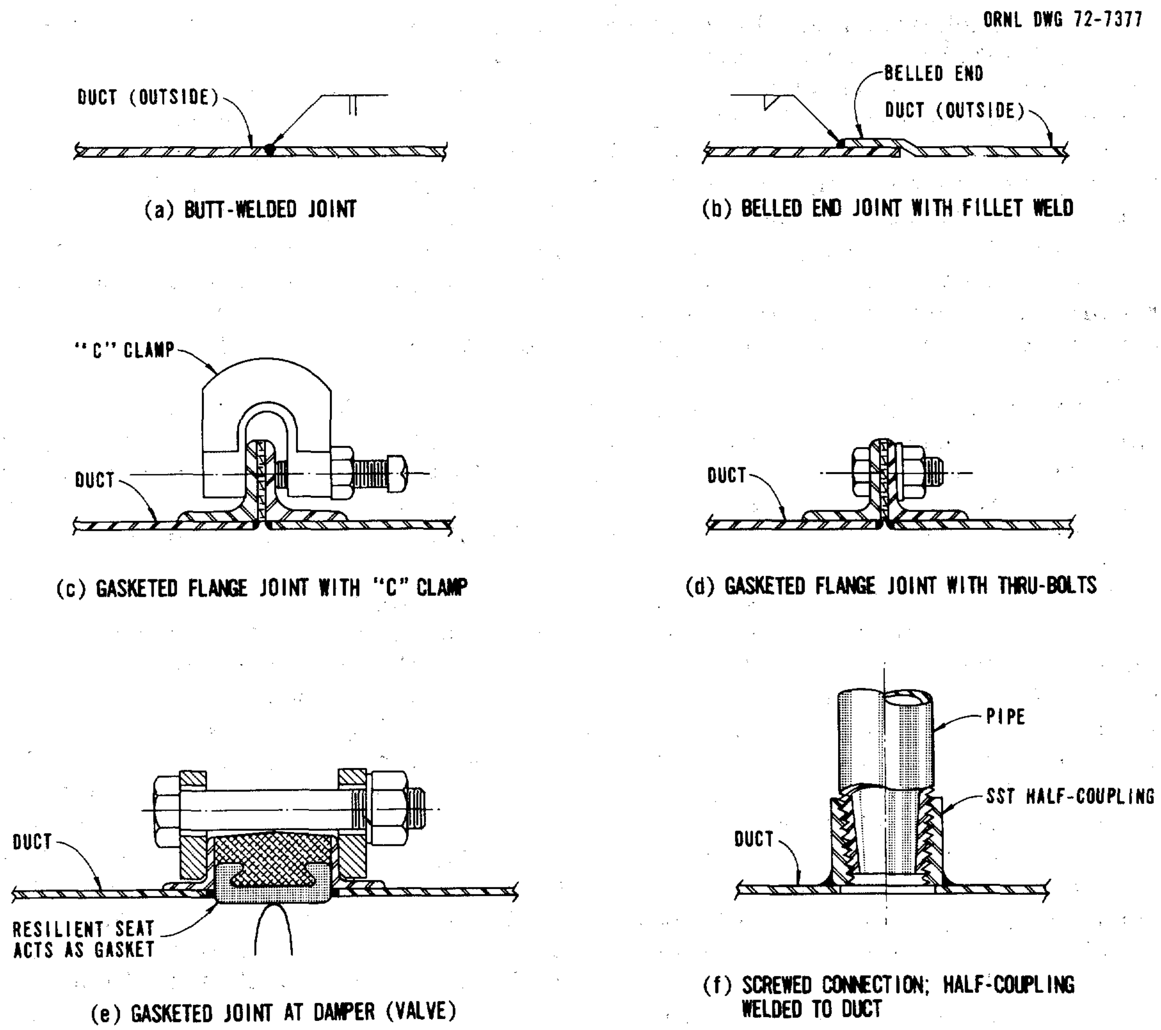

Figure 6. Types of Duct Joints Used in Alpha Enclosure Ventilation System.

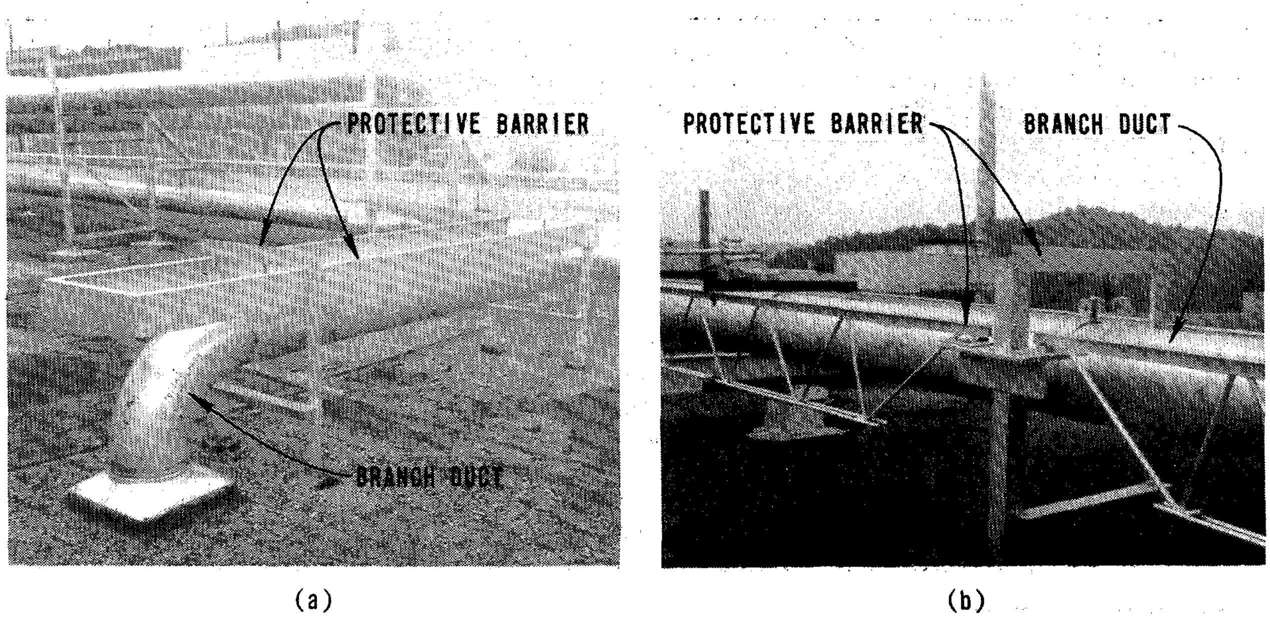

Figure 7. Protective Barriers for Exposed Ducts in Traffic Areas.

any be conveyed toward the second-stage HEPA filters. The barrier is located in the ducting downstream of the first-stage HEPA filters and the heating coil where it is free of dust loading and moisture droplets. Three such barriers are used in the system; one for each of the three second-stage HEPA filter housings. The installation details for a barrier are illustrated in Figure 8, and the exterior of a barrier with the inspection window uncovered is shown in Figure 9.

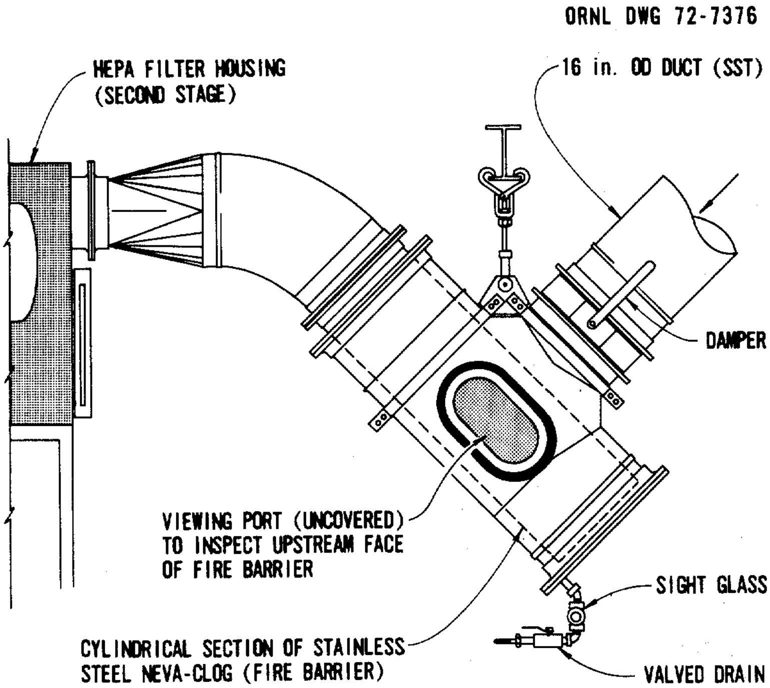

Figure 8. Typical Fire Barrier Installation Upstream of Second-Stage HEPA Filter Housing.

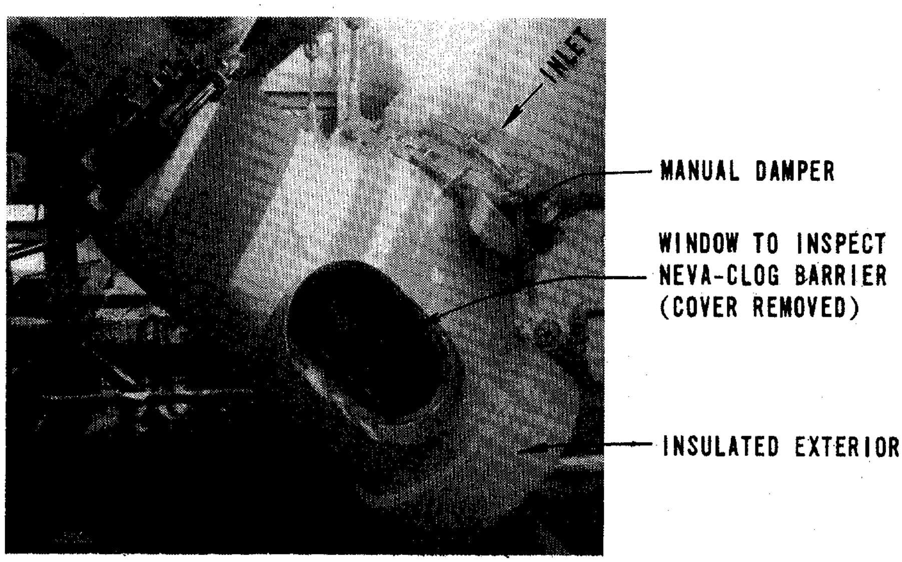

Figure 9. Exterior View of Typical Fire Barrier With Inspection Window Uncovered.

Note the insulation around the fire barrier shown in Figure 9. This is to prevent condensation in the fire barrier or ducting when the temperature of the air is raised well above the dew point by the steam coil. A superficial air velocity through the Neva-Clog was selected as 100 fpm at a design airflow of 1500 cfm so that the pressure drop will be low (< 0.25 in. H_2O, dry) and DOP smoke can pass when the HEPA filters are tested in place. The cylindrical section of stainless steel Neva-Clog is removable for cleaning or replacement if such is needed.

Back-Pressure Dampers

Each fan discharge has two single-blade back-pressure dampers arranged in series. It was necessary to have two such dampers in series to provide a degree of reliability comparable to that for other items with moving parts. This redundancy prevents the failure of one damper from allowing bypassing at the idle fan(s) and negating the suction in the system. As shown in Figure 10, the back-pressure dampers on each fan discharge are oriented at a 45° angle with the viewing window turned toward the operator's station, thereby permitting the operator to determine at a glance whether a damper blade is intact on its seat or freely moving on the passing airstream. These dampers are inspected for seating and freedom of movement during periodic start-up testing of the fans.

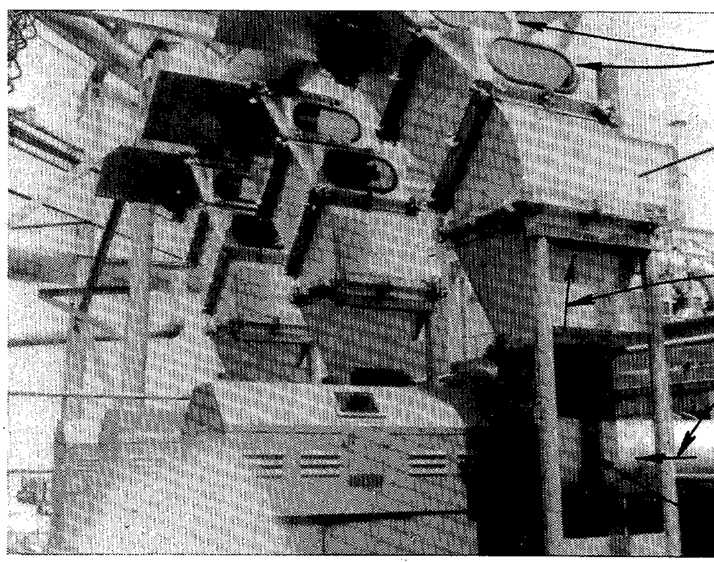

Figure 10. Orientation of Back-Pressure Dampers on Each Fan Discharge.

Vacuum Relief Device

The condition of excessive suction in the ducts and space headers is potentially more dangerous than the loss of suction in the system. Excessive suction can impose forces on enclosures that could rip off a glove or cause a viewing panel to cave in, thereby destroying the integrity of the containment. Most enclosure structures at ORNL are designed to withstand a negative pressure of 6 in. H_2O, but the gloves are depended upon to withstand a pressure differential of no more than 4 in. H_2O.

A self-contained vacuum relief device for each branch duct is incorporated in the design for the alpha enclosure ventilation system to guard against excessive suction. To meet the requirements of this function, the device must remain fully closed (no airflow) until a condition of excessive suction ($\geq$ 4.5 in. H_2O) occurs. The device must then open and relieve the condition by emitting filtered room air. The airflow capacity of the device must equal or exceed the normal airflow in the branch duct before the negative pressure in the duct reaches 6 in. H_2O. The device must also fully recover (reseal) after the condition of excessive suction has been relieved to preserve system containment, and it must be free to repeat its function an indefinite number of times. An additional requirement was direct gravity action without springs, periodic adjustments, or complicated moving parts that might stop reliable opening and closing.

A search for a commercially available item that would meet all of these requirements proved fruitless. A unit sized for an airflow of 600 cfm was designed, a prototype was built, crudely tested, and found to be short of the needed capacity. The design was altered and a second unit was built and later tested as part of the initial system performance tests. The capacity of this unit was sufficient but the flow was not stable. The one moving part of the device would pulsate and produce violent pressure surges in the ducting; a totally unacceptable condition that did not appear as a problem during the original testing. An effective correction was made by using a sealed fluid-filled cylinder to dampen the movement of the one moving part. This permitted smooth operation without adding any load to alter the unseating differential pressure setting of 4.5 in. H_2O.

The installation arrangement of the vacuum relief device with an enclosed 24-by-24-in. HEPA filter at the bottom on the inlet path is shown in Figure 11. When the vacuum relief device opens, it bleeds air directly into the branch duct downstream of the first-stage HEPA filters. This arrangement does not affect the filters and allows this penetration to be independent of any valves that could overcome its function of relieving excessive suction pressure. The

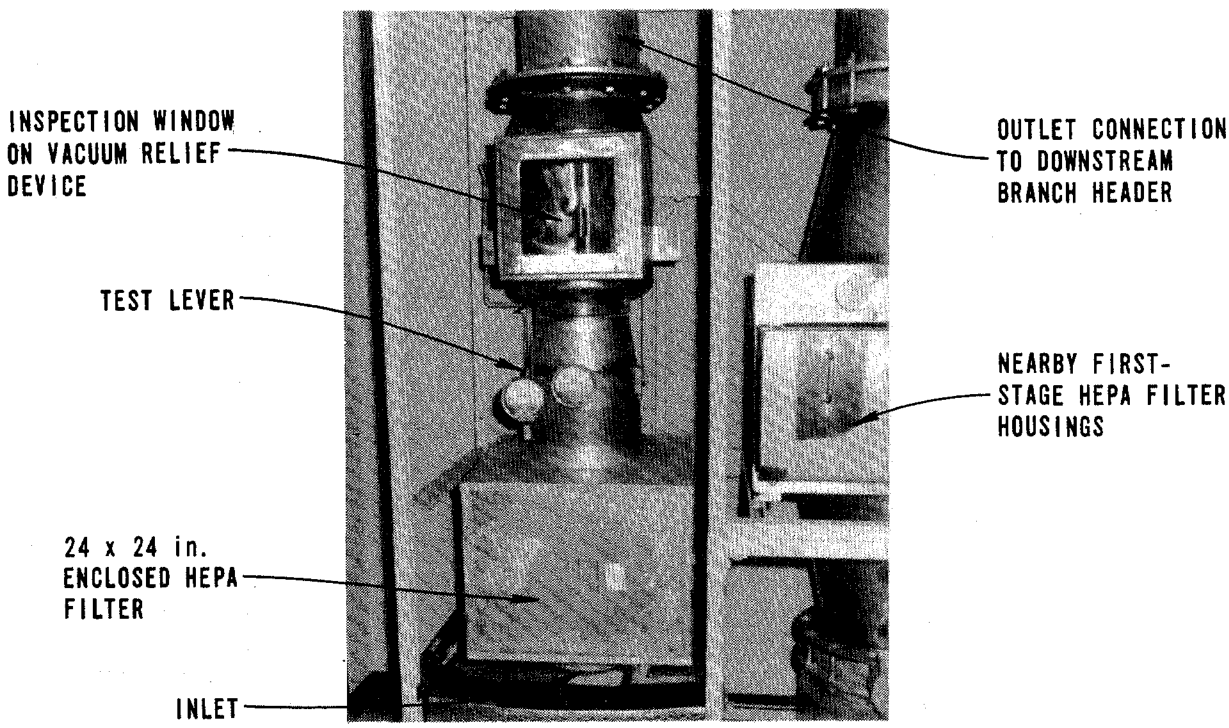

Figure 11. Installation of Vacuum Relief Device to Limit Suction Pressure in a Branch Duct.

vacuum relief device is periodically tested by means of an integral hand lever to determine whether the moving part is free to open and return to its sealed position (by gravity).

In-Place Testing of HEPA Filters

Permanent connections are provided to permit separate DOP smoke testing of each stage of HEPA filters. Valved ports (3-in. size) are provided for smoke inlets, and 1/2-in. connections are provided for the upstream and downstream sampling points on each filter path, as is shown in Figures 1 and 2. The ORNL safety requirements dictate separate tests for each stage of HEPA filters with 99.95% minimum collection efficiency demonstrated for each. Testing is required by schedule at 6-month intervals for this system, or following each filter change, or for any reason that might make the filters suspect. These requirements made worthwhile the provision of permanent connections in the system for convenient and safe testing. All of the HEPA filters in the system will be DOP tested during each routine test to provide the best correlation of results. The life of the second-stage HEPA filters is expected to exceed 4 years. The life expectancy of the first-stage HEPA filters is more dependent upon the local operations served, but it should average over 1 year where the prefilters are kept effective.

Installation and Testing of System

All fan units, stainless steel ducting, dampers, first-stage HEPA filter housings, and the emergency generator were procured in advance so that they would be delivered in ample time for use by the installation contractor. However, not all of these items were received by their promised delivery dates, and the installation work was sequenced largely by the availability of new items of equipment. Since the generator house was in a separate area and its construction involved the use of "ordinary" materials, it was the first to be started.

The new stainless steel ducting was received in a single lot, and since a large portion of it was to be installed on the building roof, this phase of the installation was accomplished with little difficulty. Relatively few welds were to be made in the field, and the prefabricated portions of the ducting were quickly positioned, welded, and inspected.

Reuse of some existing ducting involved the additional problems of decontamination and the wearing of protective clothing by workers. All workers performing welding operations on existing steel also had to be protected from subsurface contamination, and Health Physics surveillance was continuous throughout all phases of the construction period.

The late receipt of new equipment and a holdup for higher priority work involving the replacement of ducting in another nearby existing exhaust system delayed construction of the alpha enclosure ventilation system, and the pressure and leak-rate testing of the system could not be started until work on all sections of the system had been completed. Once all of the duct sections were installed and an effort was made to start the testing in accordance with the design requirements, several things became very obvious. First, the time remaining before the onset of cold weather was too short to perform all of the specified tests. All of the joints were to be individually soap-bubble tested, and then by isolating sections, all three regions of the system were to be pressure and leak-rate tested separately in accordance with specific design instructions (Appendix C).

Second, several major leaks became obvious as soon as attempts were made to pressurize the ducts. The reused steam coil leaked profusely at each tube entry to the casing. This problem was not anticipated during the design stage of the project. The original insulation on the coil headers had obscured this condition, and after decontamination, the stainless steel coil was placed in storage for later reinstallation. Welding all of the tube entries was not practicable, and delivery time for a new stainless steel coil was many weeks. It was therefore decided to seal all of the tube joints by using a heat-resistant silicone sealant (Dow-Corning 90-102 Aerospace Sealant*). Two unsuccessful attempts at sealing were made before the leakage was reduced to a rate that permitted any meaningful testing of the ducting.

Rather than a definition of the amount of leakage that could be tolerated, the particular testing method to be used had been specified. This approach was selected because of the fixed budget of time and funds. A typical pressure delay curve representative of the final test results for the Section-1 ducting, which included all ducting upstream of the reused filter housings (about 540 ft^3 of volume), is illustrated in Figure 12. Because the leakage

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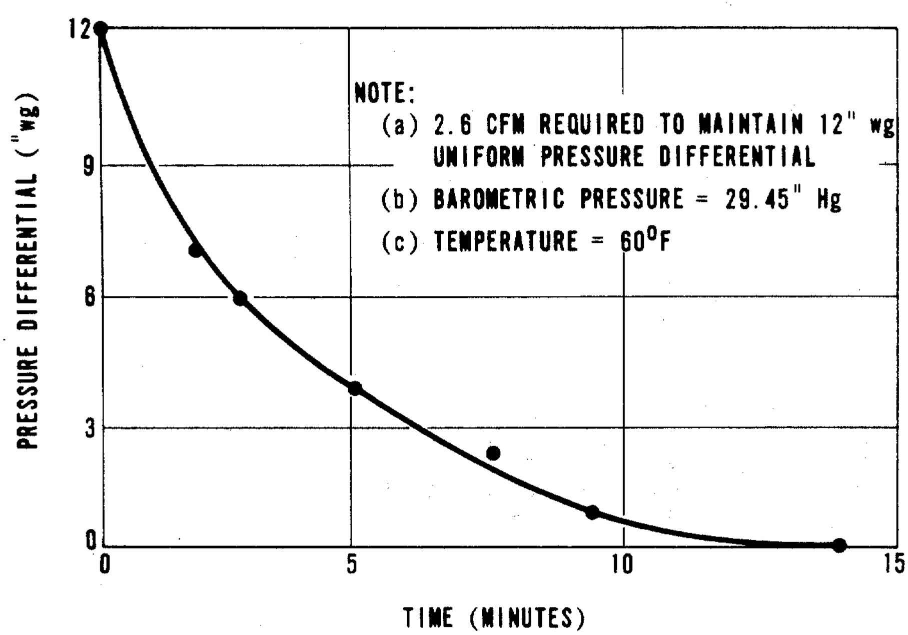

Figure 12. Typical Leak-Rate Test Pressure-Delay Curve for Ducting Upstream of Second-Stage HEPA Filters.

was so severe, the method of leak-rate testing used by the field forces partially deviated from that planned (Appendix C). The leakage anticipated for the Section-1 ducting was in the order of 1 ft^3 per 1000 ft^3 at a differential pressure of 6 in. H_2O since the majority of the joints were welded. Careful soap-bubble testing did not reveal any visible leaks in the ducting itself, and it was concluded that all the leakage was occurring at the reused steam coil where sealing had been attempted.

*Trade name of Dow-Corning Company, Engineering Products Division, Midland, Michigan.

Other reused parts also leaked heavily. The single-blade 20-in. dampers leaked at the stem packings and at flanges, and the reused second-stage HEPA filter housings leaked at the covers and flanges. The severity of internal leakage (bypassing the blade) in the reused dampers forecast another problem unanticipated by the designer. During a filter change, the plastic bagging would be too taut to safely handle because the static pressure in that region of ducting would be about 6 in. H_2O. For best performance, bagging should not be subjected to differential pressure in excess of 1/4 to 1/2 in. H_2O. As a corrective measure, under a construction deviation, new 3-in. valved bleed-in ports were added to the clean side of each filter housing, as shown in Figure 13. When HEPA filters are to be changed in one of the housings, the bleed-in port for that housing is equipped with two enclosed 12-by-12-in. HEPA filters, the main dampers are closed, and air is bled in through the new 3-in. filtered port to compensate for the main damper leakage. This reduces the negative pressure in the filter housing to an appropriate level for filter-change bagging operations and interim inspection of the bags, both of which require removal of the filter housing access cover.

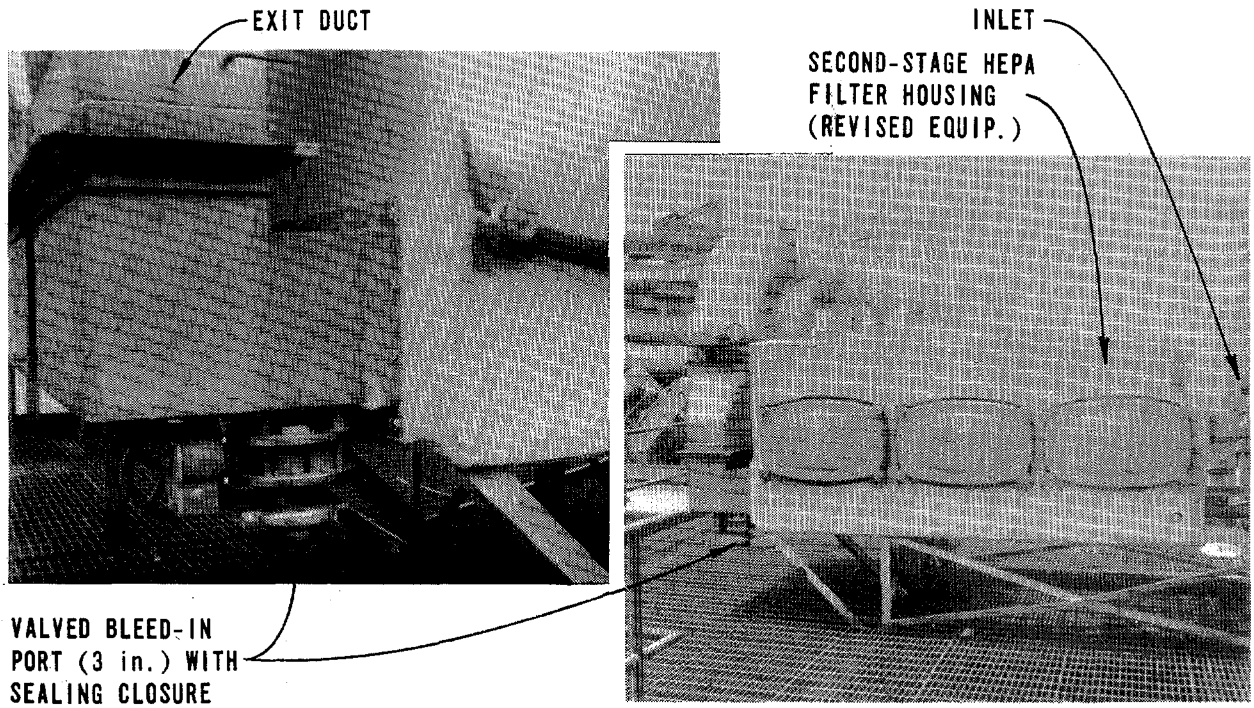

Figure 13. Valved Bleed-In Port at Second-Stage HEPA Filter Housing.

Once installed, the emergency generator was scheduled for field performance testing by the Seller. After a time loss caused by minor problems and the replacement of several parts, the testing was performed in accordance with the procedure prepared by ORNL. The portable dummy load used in the test of the generator is shown in Figure 14.

After successful testing of the emergency generator, the electrical power and control systems were tested in accordance with a step-by-step procedure in which the load characteristics and time response of the generator were documented for automatic start-up operation with one, two, and three fans. The response of the emergency generator to maximum loading (simultaneous start-up

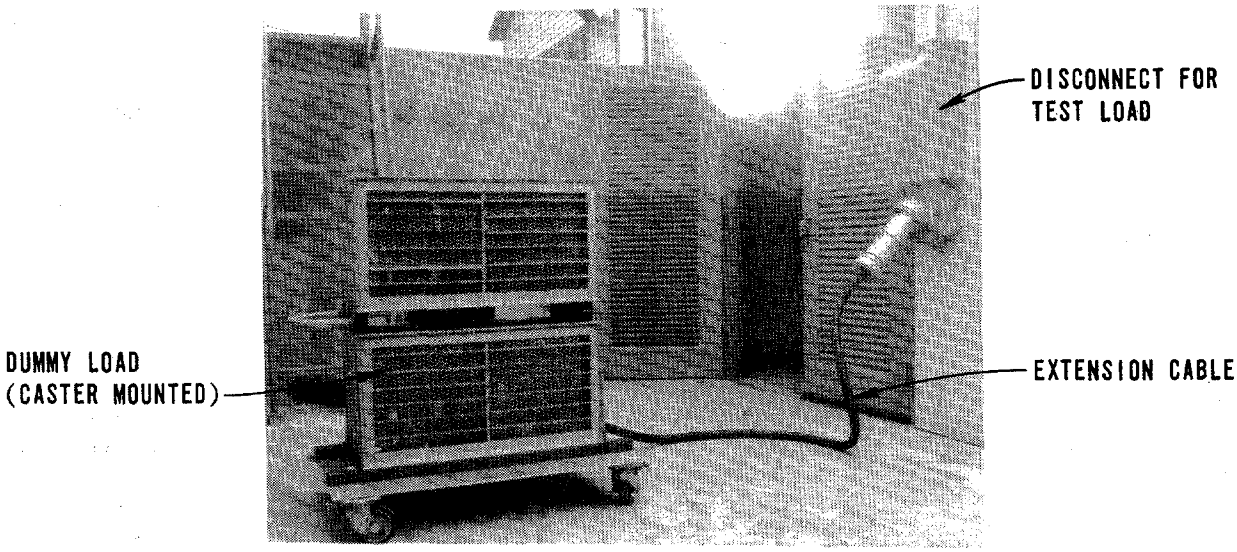

Figure 14. Portable Dummy Load Used for Periodic Testing of the Emergency Generator.

of the three 10-hp fan motors) is illustrated in Figure 15. The voltage dip remained within the specified limit for safe operation, and the generator accepted the total load. Start-up from signal to full load (1750 rpm) required 12 seconds. After de-energization, fan coast-down times from full load to zero speed were consistently measured at over 4.5 minutes.

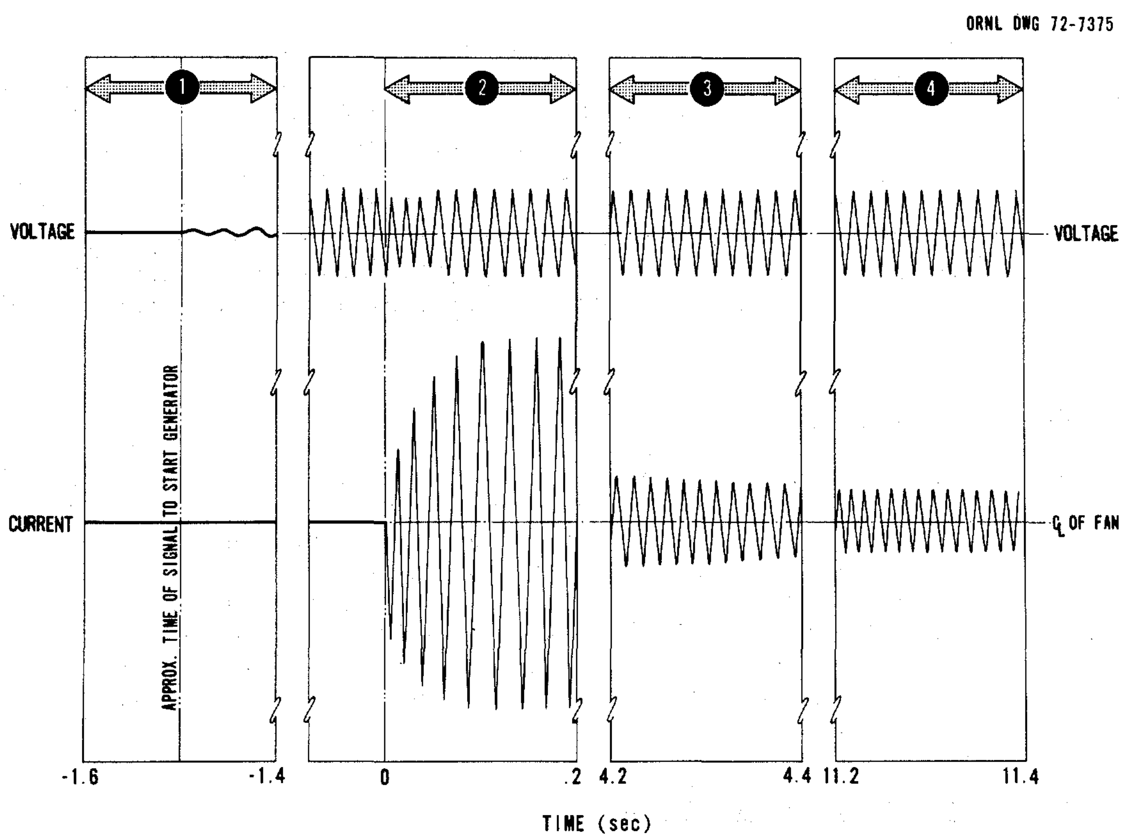

Figure 15. Response of Emergency Generator to Simultaneous Start-Up of Three 10-hp Fan Motors.

Critique

A number of problems were encountered during work on this project, some of which were foreseen at the time of design while others arose without warning. This experience improved our understanding of the needed approach to such a project, and it is related here for the enlightenment of those who may profit by it.

Criteria

All of the project criteria goals except one proved to be realistic and beneficial. The one compromising condition was created by the design strength limit (6 in. H_2O) of the existing gloved alpha enclosures. This limitation established the maximum allowable suction pressure at the enclosures, thereby requiring that the vacuum relief device open at a lesser suction pressure to fulfill its function as a safety device. This compromise will be reflected in a reduced life for the first-stage HEPA filters. A suggested improvement would be to require that all enclosures (not including the gloves) be designed and tested to withstand a maximum differential pressure of 12 in. H_2O. This would make the enclosures, as well as the rest of the system, easily capable of withstanding the total head of the fans. The threat of implosion would be greatly reduced, and dependence upon the vacuum relief devices for other than glove protection would also be reduced.

Reliability Value of Items

No source of information has been determined to give the relative merits of one feature or system component over another with respect to reliability. Beyond the demands of the basic system criteria, the various features and items to be included in the alpha enclosure ventilation system were rated by the designer in accordance with his own experience and judgment. The choice of features was directly related to cost as well as the need to achieve a level of reliable operation commensurate with the desired safety. The reliability factor of individual items is not distinct enough to allow the designer to say that "this is necessary for this particular system, and that feature is going too far".

Reuse of Existing Equipment

Additional construction time and some unexpected costs were incurred by reuse of the existing filter housings, valves, and steam coil. It was intended that the quality and performance of the reused equipment equal that of comparable new equipment. The initial assessment of the condition of these items failed to disclose their inadequacies. Closer inspection during the planning phase would have flagged all of the features which required expenditure of additional time and money. The experience in this case emphasizes the need for careful inspection and evaluation of equipment to be reused in the early stages of the project.

Equipment Specifications and Procurement

The formal specifications for advance procurement of new equipment were prepared principally to improve fabrication and testing control for quality assurance reasons. However, it was still necessary to work closely with prospective bidders to be certain that the requirements were clear. For example, the procurement specification for the three fan units required individual testing of each unit rather than testing of one unit representative of the purchased lot. This feature required detailed explanation.

The detailed drawings prepared for procurement of the new stainless steel ducting were a definite asset to the project. Time was saved in procurement of the ducting, and the need for field modification of pieces was almost eliminated. Although accurate field work is essential for the proper detailing and dimensioning of all pieces, the same data are also useful to the construction forces and for any later changes that must be made to the system.

Testing

Detailed instructions for field testing of the entire system of stainless steel ductwork (Appendix C) were provided. The soap-bubble testing of all external surfaces of the ducting for leaks was successfully performed in a straightforward manner. However, performance of the pressure and leak-rate tests was complicated by labor jurisdictional matters. This experience points up the need to give more consideration to work responsibilities and the procedures involved when the testing methods are selected.

The visual soap-bubble testing method seems to surpass all others for effective leak detection in metal ducting and housings. Less skill and experience are needed by the workmen, and with care, soap-bubble testing can be performed both indoors and outdoors with equal efficiency. In contrast, leak-rate testing must be performed by people familiar with the procedures involved and can be time-consuming. Good leak-rate precision is difficult to maintain when the components are outdoors since small atmospheric changes (sunshine versus cloudy skies) can adversely affect the results.

Another problem encountered during the testing program was brought about by the vacuum relief device. The tests performed by ORNL on the initial vacuum relief device yielded erroneous results because the actual conditions to be experienced in the system were not correctly simulated in the test mock-up. The need to test the unproved device was foreseen, but not enough thought and effort were devoted to the actual testing. When the new ventilation system became operable, testing of both the first- and second-generation vacuum relief devices revealed the same pulsating conditions once the conic section of the device was unseated by suction force. This condition was corrected by the installation of a small hydraulic cylinder, used like a dashpot, to dampen any pulsating movement of the conic section within the vacuum relief device. This stabilized the unseating movement and did not impose an additional loading that would affect or alter the pressure setting.

Operating Experience

The alpha enclosure ventilation system has been operated continuously since March 1972. Because of the limited airflow needed for initial operation of the system, only one fan is required for on-stream operation, leaving the other two for standby service. Similarly, only one of the three second-stage HEPA filter housings is needed on-stream, leaving the other two on standby. After initial start-up of the system, excessive vibration was experienced by fan units 2 and 3. One at a time, while the remaining fans were in continuous service (one on-stream and one on standby), the fans were vibration tested by ORNL forces. The fans were dismantled, the rotating parts were balanced, and the fans were then reassembled, balance tested, and returned to service. Operation of the system has been uneventful since the fan vibration problems were corrected, and the pressure conditions throughout the system have proved to be very close to the design values.

A series of meetings was held to familiarize the operating personnel with the operation of the alpha enclosure ventilation system. The operating personnel had witnessed much of the initial performance testing and assisted in correction of the fan vibration problem. The on-duty operators perform routine checks of the system status and log information relative to flow, pressure, fan operation, generator tests, etc. System maintenance and routine testing (filters, generator) are scheduled as part of a plant-wide service under a computerized program.

References

1. C. A. Burchsted and A. B. Fuller, "Design, Construction, and Testing of High-Efficiency Filtration Systems for Nuclear Application," USAEC Report ORNL-NSIC-65, Oak Ridge National Laboratory, Nuclear Safety Information Center, January 1970.
2. "Minimum Criteria for New Plutonium Facilities," United States Atomic Energy Commission, Division of Construction, April 1971.

APPENDIX A

PROCUREMENT SPECIFICATION	No. XSP-378
	Date 3-3-71
Oak Ridge National Laboratory Operated by Union Carbide Corporation, Nuclear Division	Page 1 of 5

SPECIAL EXHAUSTER ASSEMBLY

1. SCOPE

1.1 This specification covers a special exhauster assembly for outdoor unsheltered continuous duty service in an exhaust ventilation system where continuity of operation is paramount. Seller shall provide a complete and tested assembly.

2. REFERENCES

2.1 Air Moving & Conditioning Association (AMCA) Standard 210-67 - Test Code for Air Moving Devices.

2.2 AMCA Standard 211A - Certified Ratings Program for Air Moving Devices.

2.3 AMCA Standard AS2406 - Fans - Designation of Direction of Rotation and Discharge.

2.4 AMCA Standard 2408-69 - Operating Limits for Centrifugal Fans.

2.5 AMCA Standard AS2404 - Fans - Arrangements of Drive.

2.6 NEMA - National Electrical Manufacturers Association.

3. REQUIREMENTS

3.1 Exhauster assembly shall include a centrifugal fan unit (SWSI) of all-welded steel construction with special width wheel, shaft coupling, 10 horsepower electric drive motor, inertia wheel, guard/weather cover, and integral base for all components. Assembly shall be Arrangement 8 (AMCA AS2404), direct-drive with fan arranged for counterclockwise upblast discharge (AMCA AS2406).

3.2 The following features and/or performance is required.

3.2.1 Exhauster (fan) shall deliver 1500 SCFM (+50; -0) of clean air, 0.075 lb/cu. ft density, against an external static pressure of 8" wg. Suction load on fan shall be equal or be greater than 75% of total external load. Maximum fan operating speed shall be 1800 rpm. Wheel shall be a backwardly inclined non-overloading high-efficiency type keyed to the drive shaft and fixed with two or more set screws. Design operation for this fan unit shall fall in the mid-zone of optimum performance with maximum horsepower demand requirement occurring at less than design airflow rate. Stable operation shall be assured at any pressure/flow relationship (at operating speed) from 50 to 100% of wide open volume.

3.2.2 The electric drive motor shall be 10 horsepower, 1800 rpm maximum, squirrel-cage polyphase induction type, NEMA C design, continuous rated, service factor 1.15, ball bearings, splashproof with all openings screened to prevent insect entry, Class F insulation. Motor shall operate on 440/220 volts, 3 phase, 60 Hertz electrical power.

3.2.3 The assembly shall include an inertia device (flywheel) that will provide coasting power for the fan when normal electric power to motor has been stopped. The size of this device shall be such that, together with the directly-connected moving parts (i.e., fan-wheel, shaft, coupling(s), and motor), it shall utilize as near as possible the starting and running capacity of the 10 horsepower motor without exceeding the electric motor rating for either mode. This inertia device shall not require field adjustment or resetting. The device shall be directly connected with the other rotating parts so as to produce one rotating mass. The device may be arranged inside or outside the fan housing, or on the opposite end from the fan via a double shaft motor.

3.2.4 Fan unit shall have gas-tight construction. This shall include, as minimum treatment, flanged inlet and outlet connections, drive shaft seal, gasketed joints (if any) in the housing (scroll), and screwed or flanged and gasketed joints for any penetration to the interior of the housing.

3.2.5 The fan housing (scroll) shall have a bottom drain (threaded half-coupling and closure plug) of Series 300 stainless steel, 3/4" NPT minimum size.

3.2.6 All bearings (except in electric motor) shall be heavy-duty ball type of standard manufacture. Rated capacity of bearings (based on 60,000 minimum hour life) shall exceed the maximum working load for this particular service. The outdoor operating environment will vary with ambient conditions from -10°F to +130°F.

3.2.7 The exhauster assembly shall have all moving parts and pieces statically and dynamically balanced. At operating (design) speed and load, within the range of 1200 to 3600 cpm vibration frequency, the peak-to-peak vibration displacement shall not exceed 1.5 mils in any plane. It is the intention of the Company to install and operate this assembly without vibration isolators and with gasketed and bolted connections to adjoining ducting on inlet and outlet of the fan. An IRD Model 600B Vibration Analyzer will be used by the Company to confirm balance performance.

3.2.8 Shaft coupling(s) shall be flexible type constructed of rust-resistant materials. Selection shall be based on a rating having a minimum service factor of 2.

3.2.9 The exposed parts of the assembly exclusive of fan (i.e., shaft(s), coupling(s), and electric motor) shall be enclosed in a removable combination metal safety guard and weather cover. A small (4" × 6" minimum) viewing window shall be provided on each side to allow an observer to view rotation of the inertia device (or coupling) without removing any part. The viewing windows shall be glazed with safety plate glass 1/4" thick. The cover shall be designed for convenient handling either as a single unit or in parts not weighing more than 60 pounds each.

3.2.10 An integral base shall be furnished for the unit to consolidate the mounting of all components and ensure alignment and balance. The base shall be constructed of carbon steel with mounting holes (and bearing areas at the holes) arranged for support from the bottom. The base shall not contain pockets or recesses that do not drain rainwater.

3.3 All metal surfaces (exterior or interior) of the assembly that are subject to weathering or rusting shall be protected by paint. Painting shall be equal to PPG Industries Ironhide Red 8-2 Metal Primer (2 coats) and Lavax Machinery Enamel, Yellow 23-78 (2 coats), applied as recommended by PPG Industries for surface preparation and application.

3.4 Maximum overall dimensions for the assembly are as follows.

Length = 6'-6"; Width = 3'-2"; Height = 3'-2".

3.5 Materials - Items not specifically specified elsewhere in this specification shall be the manufacturer's standard construction and finish.

4. TEST AND ACCEPTANCE

4.1 A performance test shall be performed by the Seller to determine fan characteristics over a full range of static pressure/airflow/horsepower relationships, all at operating speed. Data shall be recorded and plotted for convenient analysis. Seller shall furnish Company with certified copies of these test records.

4.2 Frequency/displacement vibration tests shall be performed by the Seller on the completed exhauster assembly. This testing shall determine displacement data (in mils) for two specific points for three different planes at operating speed for frequencies of 600, 1000, 1200, 1800, 2400, and 3600 cpm. The two (2) specific points for measurement shall be: (1) outer corner of the discharge flange on the fan unit, and (2) the assembly base at a mounting hole opposite the end supporting the fan unit. Data shall be recorded and tabulated for convenient analysis. Seller shall furnish Company with certified copies of these test records.

4.3 Seller shall provide the Company written notice of test dates seven (7) days (minimum) in advance of testing (4.1 and 4.2). Company reserves the option to witness the testing of this equipment.

4.4 Final acceptance shall be at installation site, Oak Ridge, Tennessee.

5. DOCUMENTATION

5.1 Documents to be furnished by the Seller are listed on the attached Company Form UCN-3296 Manufacturer's Data Requirements.

Page 5

MANUFACTURER'S DATA REQUIREMENTS

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE CORPORATION
NUCLEAR DIVISION

POST OFFICE BOX X
OAK RIDGE, TENNESSEE 37831

WORK REQUEST	K-0992A-A1
SPEC. NUMBER	XSP-378
REQ. NUMBER	
P. O. NUMBER	

ITEM:

SPECIAL EXHAUSTER ASSEMBLY

	Three Copies, With Bid	Three Copies for Company Approval Before Fabrication	Copies With Order, As Noted; One Copy to be Packed With Equipment	REMARKS
1. Dimensional sketches and/or catalog data showing assembly being proposed.	3			
2. List and sketches of components including materials of construction.	3			
3. Proposed method(s) and location of testing.	3			See 4.1 and 4.2.
4. Certified drawings for assembly and each major component.			3	
5. Certified Bill of Materials.			3	
6. Operating and Maintenance Instructions, Spare Parts List(s).			3	
7. Certified test reports (airflow performance and vibration).			3	See 4.1 and 4.2.

DRAWING NUMBER	ITEM NUMBER

UCN-3296
(3 9-68)

APPENDIX B

Drawing notes accompanying stainless steel ducting details prepared for procurement. Reference: ORNL Drawing H-20327-EG-044-D.

General Notes

1. All metal shall be stainless steel Type 304L meeting requirements of ASTM A240, A371, except as may be noted on drawings. SST materials shall be identified by type, gauge, and heat number. Mill certification of material properties shall be provided. Drilling of round flanges shall correspond to ASA B16.5-150 lb. Gauge thicknesses refer to USS gauge.

2. Ducting shall be joined by welding using the gas metal arc process, or gas tungsten arc process (Type 308ELC Electrode - no flux) by welders and procedures qualified according to ASME Code, Section IX and this type of welding process and materials. Welds shall produce completely airtight joints, (see Note 5 below). Backup tape or strips shall not be used.

3. All welds and heat affected zones shall be visually inspected with 4X magnifying lens after cleaning. By this method of examination welds shall be determined to be free of cracks, and porosity shall not exceed 10 visible surface pores in any 6-inch length. Defects shall be repaired.

4. Gaskets shall be 1/8" thick, one-piece, made from new solid neoprene sheet (Durometer 40-50) to provide full face coverage of the flange and be neatly cut to fit flush with the interior wall of the duct.

5. Each part shall be leak-tested and proven free of leaks when inflated to 6" wg air pressure. A soap-bubble solution shall be used to determine leak-tightness. Leaks found that cause a visible bubble (with 4X lens) within 5 minutes after soaping shall be repaired by welding, and retested. Seller shall certify each piece has been tested to be leak-free according to this test method before shipment.

6. Completed parts shall be cleaned (degreased), rinsed, and dryed before packaging for shipment. End openings, flanges and nipples shall be protected with wooden closure pieces and skids that protect the metal against warpage, abrasion dirt, and moisture during subsequent storage and shipment to Company.

7. Individual pieces shall be marked on top surface with part numbers according to the drawings.

8. Shop welded joints may utilize plain (butt) or belled end welded joints at girth connections and fittings. Longitudinal joints (seals) shall be full, penetration welds that are smooth, even, and uniform. Belled end joints shall be in accordance with detail on the drawing.

9. Quality Assurance - Seller shall utilize a quality verification program that fulfills the requirements of AEC-RDT Standard F 2-4T.

APPENDIX C

Reference ORNL Drawings H-20327-EG-049-D and H-20327-EG-050-D.

General Notes for Alpha Ventilation System Installation and Testing

1. Stainless steel ducting and fittings (except for instrument lines, Note 12 below) shall be furnished by the Company and installed by CPFF contractor. Special exhauster assemblies (3), backdraft dampers (6) with adjacent SST duct fittings on the discharge side the exhausters, and 16" SST valves (3) shall be furnished by the Company and installed by CPFF contractor. Pressure/leak testing, as required below, shall be performed by CPFF contractor.

2. Design, material, and workmanship associated with this project is required to achieve quality assurance level III control. Quality verification shall be pursued by all participants. Mill certification of all SST materials shall be furnished, including welding rod. The Company (Inspection Engineering) will verify the acceptability of all welds and maintain records of same.

3. Advance approval shall be obtained from Building 3019 supervisor to discontinue, alter, or disconnect any existing service that is operable. Specifically the changeover of ventilation service for Cells 1, 2, and 3 shall be accomplished by the Company when requested.

4. Before entry and at the time of penetration into an existing system, it is required that ORNL Health Physics personnel survey the work area and determine the extent of personnel protection required of workers. HP recommendations shall become a valid requirement. Routine monitoring of workmen shall be in accordance with HP instructions. Any work on existing pieces (e.g., modifying 20" SST duct) off-site shall be approved by HP personnel, including any work procedure imposed. HP shall determine the advisability of discarding the existing HEPA filters in the 3 SGN caissons (by ORNL) before construction starts.

5. Structural Steel

   a. Material and Fabrication

      (1) Structural steel shapes, plates, bars, etc., shall conform to ASTM A36.

      (2) High strength steel bolts shall conform to ASTM A325. All bolt holes shall be 13/16" for 3/4" bolts, except as noted.

   b. Fabrication and Erection

      (1) The American Institute of Steel Construction "Specification for the Design, Fabrication and Erection of Structural Steel for Buildings," seventh edition, and the AISC "Code of Standard Practice" (1969) shall govern this work unless otherwise indicated on the drawings. Bolted connections shall be in accordance with AISC endorsed "Specification for Structural Joints using ASTM A325 Bolts."

(2) All welding shall be performed by qualified welders and in accordance with the requirements of the AISC specifications, Part 5, Section 1.17, Welds.

c. Painting

Prime all new miscellaneous and structural steel with one shop coat Pittsburgh ironhide inhibitive red 8-2. Finish with two coats of Pittsburgh Metaleaf aluminum paint No. 22-3.

6. It is necessary that the planned alignment and uniform slope(s) be maintained in the erection of stainless steel ducting. It is essential the SST duct not rest or bear on any edge or surface not identified as a hanger or connection on the drawings. Work plans and installation sequence of SST duct pieces must confirm all dimensions as true in the field before any cuts are performed on furnished pieces. Planned allowances of extra length have been made so the installer can accurately size each straight run and make a minimum number of field cuts and welds. All pieces shall be joined by welding except where specifically indicated otherwise on the drawings; exceptions by written approval in advance of the installation only. All fitting and welding of pieces is expected to be done on-site. In the event supplementary SST materials are required they shall conform to the original requirements set for like items being furnished by the Company. Their use and pedigree shall be approved prior to coming to the job site.

7. Drawings indicate the positioning of duct (dimensionally) when ambient temperature is 70°F. Compensations (at a rate of 9.2×10^{-6} in./in./°F) shall be made to allow for an installation temperature other than 70°F. Clearances for ducts must respect an expansion/contraction range of +140°F maximum/+70°F neutral/-10°F minimum ambient temperature.

8. During storage on the job-site and during installation all SST ducting and system components like housings, instruments, tubing shall be protected from dirt, oil, or water to control the ultimate cleanliness of the system's interior. Any water, dirt, or <u>tools</u> shall be meticulously removed and the inside surfaces installed free of any foreign matter visible to the eye.

9. Particular care shall be exercised during construction to preserve the watertightness of the roof. Temporary protection shall be used during the installation of supports on the roof when the roof is penetrated. Final closure of penetrations shall provide complete water seals that do not pocket water that can freeze and strain the seal.

10. The existing steam heat coil shall be relocated in the new 20" main duct as indicated on Drawing EG-059-D. The steam and condensate piping shall be reconnected from the same points with comparable materials as now used. The control valve sensing bulb shall be reconnected at the same coupling. A mercury actuated dial thermometer shall be provided downstream from the steam coil in a 3/4" NPT half-coupling. Thermometer shall be: American Cat. No. 4 1/2-6071EM-T3-U7 1/2, 7 1/2" insertion, 0-250°F range, Type 71 well with lagging extension (304 SST).

11. Flanged and gasketed joints, as indicated by the drawings, for SST ducting are of two types. (A) Where existing flanged duct pieces are being reused the joint shall be made up using 304 SST cap screws with 410 SST lock washers (internal) and brass hex-nuts. Gaskets shall be one-piece solid sheet neoprene, 1/8" thick, 40-50 Durometer hardness, with hole pattern prepared in the shop. (B) At the back pressure dampers and at new joints as indicated by the drawings, flanged connections shall be made using a full-face one-piece solid sheet neoprene gasket, 1/8" thick, 40-50 Durometer hardness, without any hole punchings. These connections shall be made tight using C-clamps (Grinnell Fig. 86 No. 2), see detail and schedule on drawings.

12. Pressure sensing lines at the fan platform area shall be made using Type 304L stainless steel tubing (0.035" wall thickness), ASTM A269 and Type 316 stainless steel fittings, compression type, Swagelok. Lines inside enclosure(s) or directly at instruments ($<$ 2 ft) may use brass fittings, compression type. Threaded joints at instruments, valves, etc., shall be doped with Teflon tape. Sensing lines must slope uniformly to control any condensation to a prepared low point having a drain opening that is normally sealed via a fitting. Support for lines shall be made using P1000 Unistrut and tubing clamps.

13. Field Welding - Stainless Steel Ducting - Welding procedures, welding procedure qualifications, and welders qualifications shall be prepared in written form and submitted to the Company and be approved by the Company in writing before field welding shall be started. Field welds, where indicated on drawings, for SST ductwork shall be made in accordance with ORNL WPS 302 (for 304L SST), except inert gas backup is not required for belled-end joints. Welds shall produce completely airtight joints (see Note 15 below). Backup tape or strips shall not be used.

14. Weld Inspection - Stainless Steel Ducting - All welds and heat affected zone shall be visually inspected with 4X magnifying lens after cleaning. By this method of examination welds shall be determined to be free of cracks, and porosity shall not exceed 10 visible surface pores in any 6-inch length. Defects shall be repaired. The Company shall approve all welds individually. Weld inspection reports shall include the record of welder, inspector, and approver with dates for each weld.

15. Field Testing - After completion of all installation, field welding, and inspection the entire system of stainless steel ductwork (SST) and instrument lines shall be pressure and leak tested as follows.

    a. Preparation to Test - The ducting shall be tested in three sections, one at a time, in the order given; then Sections 2 and 3 suction tested together. Section 1 - Beginning in the second level filter roof of 502 facility and embracing all SST ducting on the building roof to a point terminating at the inlet of the three existing SGN filter housings. Temporary closures shall be made at each housing inlet (bolted and gasketed blind flanges). Section 2 - including the three existing filter housings and existing 20" ducting, new suction header, three fans and six back-pressure dampers. Section 3 - discharge header and 20" SST ducting to the existing duct connection at the 3020 stack base. Section 3 for testing purposes shall be limited to the last bolted flange joint before the stack connection. Visual inspection only shall be used from the last flange to and including the stack connection.

b. Pressure Testing - The closed sections system of ducting shall be subjected to a total positive pressure of 12 inches wg, being applied in two steps (first to +6 inches wg, then to +12 inches wg). After the first step to 6 inches wg is made all areas of the ductwork shall be visually inspected to seek out any obvious deficiency that requires correction, if the first step shows no defects needing correction, then the second step shall be made to inflate the duct to 12 inches wg (total). The 12 inches wg head shall be maintained on the duct system for 30 minutes. All areas of the duct shall be inspected and determined to have no visible deformation. Any area having any change in shape, or detectable leakage, shall be marked with tape and identified to the Company.

NOTICE: The contractor shall exercise extreme caution to prevent abnormal pressure of ductwork during testing. A water manometer indicating duct pressure and a water column relief device (for relief at pressures $>$ 15" wg) to safeguard against overpressure shall be continuously employed during the test period with an attendant assigned and informed about emergency procedures.

c. Initial Leak-Rate Testing - With dry weather prevailing and after successfully completing the above pressure test the ducting shall be leak-rate checked by: 1) temperatures during total leak-rate test period shall not vary more than 10°F (± 5). Inflate ducting to 12 inches wg positive pressure, measuring with an inclined water manometer made of clear 3/8" ID plastic tubing and scale, and the source of air disconnected and its penetration sealed. Record atmospheric temperature and pressure and period of time recorded in seconds for the ducting to deflate from 12 inches wg to 6 inches wg as indicated on the water manometer. 2) This temperature and timing period shall be repeated twice more by re-inflating the duct to 12 inches wg before each run. If the first time period exceeds two hours (with the air temperature constant, (± 5°F) runs two and three may be terminated after a one-hour period with manometer readings recorded; however, the duct must be purposely deflated to 6 inches wg or less to precondition for subsequent testing before inflation to 12 inches wg is started thus ensuring a significant pressure cycle on the duct.

d. Soap-Bubble Testing for Leaks - After completing work on initial leak-rate timing tests the ducting shall be inflated to 6 inches wg minimum (12 inches wg maximum) while all welds are soap-bubble tested for leaks. Leaks found that cause a visible bubble within three minutes after soaping shall be repaired by welding and retesting (except at gasketed joints). Gasketed joint leaks shall first have joint tightened to eliminate the leak. If unsuccessful, the joint shall be disassembled (after deflating duct), pieces inspected for defects until apparent trouble has been determined, corrections made, joint reassembled, ducting inflated to 6 inches wg and the joint(s) retested with soap solution. If this effort is unsuccessful in repairing the leak, the Company shall direct the nature of further effort. Each such occurrence shall be recorded in writing (giving pertinent details) and delivered to the Company. Soap solutions shall be prepared daily as needed, and periodically tested on test leaks (once each hour) to prove bubbles can easily be formed and retained. Soaped areas shall be protected from wind and sun to prevent rapid drying. After soaping operations are completed, the surfaces so wetted shall be rinsed with clean clear water and brushed, and then wiped dry.

e. Final Leak-Rate Testing Sections 1 and 2 Combined - After successful completion of soap-bubble testing the ducting shall again be given leak-rate timing tests in a manner similar to "c" above except ducting shall be deflated to 8 inches wg negative pressure. This testing shall cover the range from -8" wg to -2" wg. Times and temperatures shall be separately recorded with pressure and then promptly reported to the Company in one written report. Section 3 shall not be given a final leak-rate testing comparable to Sections 1 and 2.

f. All temporary closures shall be removed, joints remade, inspected, and condition reported to the Company.

DISCUSSION

LOYSEN: What is the approximate cost per cfm of this installation?

FULLER: I can't identify it too closely. I can tell you that the total cost of the project was about $214,000. However, I should qualify that by saying that this cost included many things. For example, the ducting cost about $22,000, plus installation cost which was very low. Leak testing was one of the costly items that we experienced. A little more than we had expected, certainly.

WASTE ENCAPSULATION AND STORAGE FACILITY VENTILATION SYSTEM*

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Abstract

This paper describes the design for the ventilation and filtration requirements for Hanford's Waste Encapsulation and Storage Facility--design that complies with the highest standards of quality assurance and licensability.

The encapsulation and underwater storage of the isotopes cesium-137 and strontion-90 is a part of the management program at Hanford for the safe disposition of radioactive wastes. It has been necessary to design a special facility to handle the large quantities of these materials at high production rates (30 megacuries of strontium-90 and 30 megacuries of cesium-137).

The air-handling and air-cleaning systems in this facility are essential to operation of the encapsulation facility. The building's atmosphere is maintained at negatively zoned pressures varying from -0.05 inch to -1.5 inch water gauge in the working areas.

Introduction

The goal of the Hanford Waste Management Program** is the isolation and safe storage of hazardous isotopes for extended periods of time. The specific program described here is the fractionization of long-life radionuclides strontium-90 and cesium-137 from the stored and currently generated liquid wastes. These isotopes are purified and concentrated into solid forms and doubly encapsulated in the Waste Encapsulation Facility (Figure 1). The isotopes will be stored as cesium chloride and strontium fluoride. The facility can process 30 megacuries each of the isotopes per year. Processing will be on a batch basis of 200 batches per year strontium and 70 batches per year cesium.

A batch of cesium will generate about 9,000 Btu/hr; a batch of strontium will generate about 3,500 Btu/hr. Heating sources within the processing cells consist of isotope decay heat, special lighting, and process heat losses. While one function of the cell ventilation system is to provide a suitable ambient for equipment and machinery, the ultimate purpose is to provide airflow patterns and pressure differentials to establish safe working conditions in the operating areas.

General Functions of the Heating and Ventilating System

- Controls the temperature and cleanliness of the air within the facility

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* Work performed under USAEC Contract AT(45-1)-1698

** Atlantic Richfield Hanford Company is the AEC's prime operating contractor for waste-management programs at Hanford.

- Controls the spread of airborne contamination within the facility by maintaining the proper area pressure levels
- Eliminates the release of airborne contamination to the environs by filtration
- Provides cell cooling under all operating conditions
- Provides ventilation and cooling under periods of electrical power failure
- Includes a sampling system for the exhaust filters and stack to measure air quality

Cell Functions (Refer to Figures 2 and 3)

The facility houses seven hot cells of approximately 8 ft by 8 ft by 13 ft high. For personnel protection, the walls are made of high-density 235-lb-per-ft^3 concrete, 35 in. thick. Cells are fitted with leaded-glass viewing windows and two heavy-duty remote master slave manipulators.

Cell A, a man-entry cell, is used for second generation waste handling.

Cells B and C are strontium processing cells. Cell B is a wet chemistry cell; Cell C is a mechanical cell where the strontium fluoride powder is placed in a capsule and the capsule seal-welded.

Cells D and E are a double cell used for cesium processing. This cell also consists of a wet chemistry side and a mechanical side.

Cell F is a cleaning cell consisting of four ultrasonic cleaning tanks and a check station for determining the cleanliness of the capsules.

Cell G is the final packaging cell. Capsules are placed in a second container that is seal-welded and leak-checked. The containers are then passed on to the interim storage area. Cell G is a man-entry cell.

Ventilation System Descriptions (Refer to Figure 2)

The overall facility is divided up into four ventilation systems.

K-1

The K-1 system covers the operating areas that could become radioactively contaminated. This system provides outside air to the area on a once-through basis. The air is prefiltered with an 80% NBS filter consisting of an automatic renewable media filter and a replaceable extended surface cartridge. The air is then preheated (steam), cooled with chilled water, and distributed to areas by centrifugal supply fans through reheat coils to meet the space temperature requirements. Air is exhausted through a filtration system consisting of a bank of 8% NBS prefilters and a bank of 35% NBS replaceable extended surface cartridge-type secondary filters, in two banks of high-efficiency filters (HEPA) in series. This filter bank is designed for contact maintenance and manual replacement of the filter media. The two exhaust fans will operate alternately for backup service. Both fans can be operated on emergency power to provide airflow during power outage.

Two 100-ton refrigeration units supply the facility with chilled water for cooling. These units are also on emergency power.

K-2

The K-2 system is for the service areas completely isolated from potential contamination such as the mechanical equipment room, lunchroom, and change room. Outside air is provided to the spaces on a once-through basis. The air is pre-filtered with an 80% NBS filter consisting of automatic renewable filter media and a replaceable extended surface cartridge. The air is then conditioned and distributed to the space by centrifugal supply fans at the desired temperature. The air is exhausted to atmosphere by power roof ventilators and through ducts to a common stack.

K-4

The K-4 system is a capsule storage area. This system provides outside air to the area on a once-through basis. The air is prefiltered with an 8% NBS filter and a 35% NBS renewable extended surface cartridge filter, conditioned, cooled with a rotary evaporative cooler, and distributed. A centrifugal fan provides the system motivation. This system exhausts through the K-1 filtration system.

Figure 2 shows the plan of the first floor and indicates the layout of the cells and their relationship to the service and storage area. The cells have higher negative air pressure with respect to the canyon and the operating areas; the canyon has a higher negative air pressure with respect to the operating areas. These conditions are maintained to insure flow from lesser levels of contamination to higher levels.

K-3 (Refer to Figure 4, Simplified Flow Schematic of this System)

The K-3 system ventilates the canyon and the process cells providing out-side air on a once-through basis. The air is prefiltered with an 80% NBS filter consisting of an automatic renewable filter media and a replaceable extended service cartridge. The air is then preheated and reheated with steam, cooled with chilled water, and distributed to the canyon by a centrifugal supply fan to meet the canyon temperature and humidity requirements. The canyon has a negative air pressure in relationship to the service areas and the K-1 system. It acts as a supply plenum for the cells. Two operating conditions are possible for the K-3 air system.

K-3 Routine Operation. During routine operations, air is routed through each cell on a once-through basis with the major airflow bypassing the cell. Air to the cells is filtered by HEPA filters and cooled with chilled water to insure a maximum cell operating temperature of 120°F. Air is exhausted from the cell through a HEPA filter. The combined exhaust air from all cells plus a bypass from the canyon is routed via a plenum to the final filtration system consisting of two replaceable filtration banks. The replaceable banks consist of a 35% NBS extended service filter and two banks of HEPA filters in series. Each of the replaceable filters is designed to handle 6,500 cfm.

Two exhaust fans are installed and will operate alternately for backup service. Both fans can be operated on emergency power to provide airflow during power outage.

K-3 Non-Routine Operation. The second condition, or non-routine operation, is with a cell cover block removed. The system, to insure downflow from the canyon area, is balanced so that the bypass air enters the open cell at a face velocity of about 100 ft per minute while maintaining airflow to the other cells. This air bypasses the cell supply filters and coils, and is exhausted through an unfiltered opening to the main exhaust plenum and the final filtration system. When a cell cover block is removed, the canyon bypass air damper closes and allows for 100% of the K-3 system air to pass through the cells. Under both routine and non-routine conditions, the canyon supply air of 6,500 cfm is maintained. A cell is placed in a non-operating condition and is essentially decontaminated before the cover blocks are removed.

The air in the K-3 system is filtered and cooled prior to discharge of each cell. Both the volume and temperature of the air is controlled to maintain the cell negative pressure and temperature. Each cell has dual air supply systems consisting of ducts, valves, filters, coolers, and control instrumentation. Approximately 250 cfm of air can be supplied through each system; normal requirements are approximately 125 cfm. The supply system to a cell consists of a butterfly valve, HEPA filters, a cooling coil, and all the necessary control instrumentation. The function of the inlet HEPA filter is two-fold: 1) it eliminates particulates entering the cell from the canyon and 2) prevents the backflow of contamination from the cell to the canyon should a major pressure surge or upset occur. Chilled water is supplied to the cooling coils reducing the air temperature so that the discharge air from the cell is less than 120°F. In actual operation, the cell airflow will be 125 cfm at an inlet temperature of 50°F with a cell outlet temperature of 120°F. The exhaust air will filter first through an incell replaceable HEPA filter and discharge into the exhaust plenum. The plenum is sized to handle all the air for the K-3 system. Filters, valves, and ducts are sized to minimize pressure drops in order that differential pressures between areas can be maintained.

The system is designed so that, with a cell cover block off, airflow to the cell will be at 100 ft per minute face velocity. This provides about 5,000 cfm to a cell exhaust system. This additional air is not filtered and flows directly into the cell exhaust plenum via a bypass. This operation is assumed to be infrequent; it would be for the removal of process equipment or to do some major work within the cell. It is not anticipated as part of the routine operation. Chemical processing of strontium or cesium would not be carried on with a cell cover block off.

Design Conditions

The design of the facility ventilation system (K-1, -3, and -4) is considered Class I; this class is defined as follows:

- Those structures, systems, and equipment whose failure could cause an uncontrolled release of dispersible plutonium or radioactivity to the environs; or those structures and components vital to the safe shutdown of the process or system

The building ventilation system was designed to withstand an earthquake of 0.25g horizontal force and 0.125g vertical force without loss of integrity of the system.

Remotely Replaceable Filter

This system is typical for the design of a hot cell facility, including the backup systems. An important feature of this filtration system is the replaceability of the final filter.

The approximate size of the exhaust filter assembly is 5 ft wide by 16 ft long by 7 ft high; its weight is 7,000 lb (Figure 5). The current fabrication cost is $18,000, which includes two replaceable 24-in.-diameter duct connectors (wedges) at $5,000 each. The fixed part of the connector (saddle) costs approximately $8,000. The jumpers for connecting pressure taps and samplers would be reused and would be an additional cost in the first filter installation.

Figure 6 is an instrument schematic for the replaceable filters. The instrumentation includes pressure taps across each filter, isokinetic samples across each filter, moisture monitor, a radiation element, and a temperature element in addition to ports for inserting air measurement instrumentation for system balancing. Not shown is the permanent instrumentation and controls located in the ducts and exhaust stack. The sampling system continuously monitors for radiation as a check of the filter efficiency. In addition, the stack contains a radiation monitor, which gives an independent check of air quality prior to discharge.

The replaceable filter system is designed for a clean pressure drop of 3 in. wg and has an allowable buildup of an additional 3 in. wg. The filter housing is constructed of Type 304L stainless steel. Design allows independent verification that the filters have been installed without damage. The various sections of the housing are flanged and bolted. The efficiency of the filter assembly will be tested prior to placement in the system. The filter assemblies are contained inside an underground concrete structure. The shielding requirement of the concrete presupposes a 5,000 curie source of strontium-90 on the first bank of HEPA filters. It is anticipated that the filters will normally be replaced because of pressure drop rather than radiation. The filter assemblies could be manually disassembled for contact replacement of the filters.

The 24-in.-diameter duct connectors (wedge connectors) operate on the same principle as the disc in a large gate valve (refer to Figure 5). The fixed end of the connector (saddle) has an upper flange containing two aligning and sealing studs. The wedge is set into the saddle and the studs engage captive nuts. The connector is sealed by tightening the captive nuts and forcing the wedge to seal against the replaceable gasket. Removal of the wedge is just as simple an operation as is the placement. The captive nuts are disengaged. A third fixed nut on the wedge is engaged, which reacts with the fixed flange of the saddle and forces the wedge away from the seat and seal. After both wedges have been disengaged, a crane can lift the filter assembly. Care is taken to lift it straight up so as not to distort the wedges or the saddle. This design includes a strong back or lifting beam so that a uniform force is applied for lifting the assembly out of the saddles. Figures 7, 8, and 9 are construction photos of the wedge connectors and the filter housing.

In summary, the system described here will provide efficient and thorough air cleaning and ventilation in a potentially hazardous environment requiring many remote operations. The quality of the air exhausted from the facility's stack will be at a level permitting recycle.

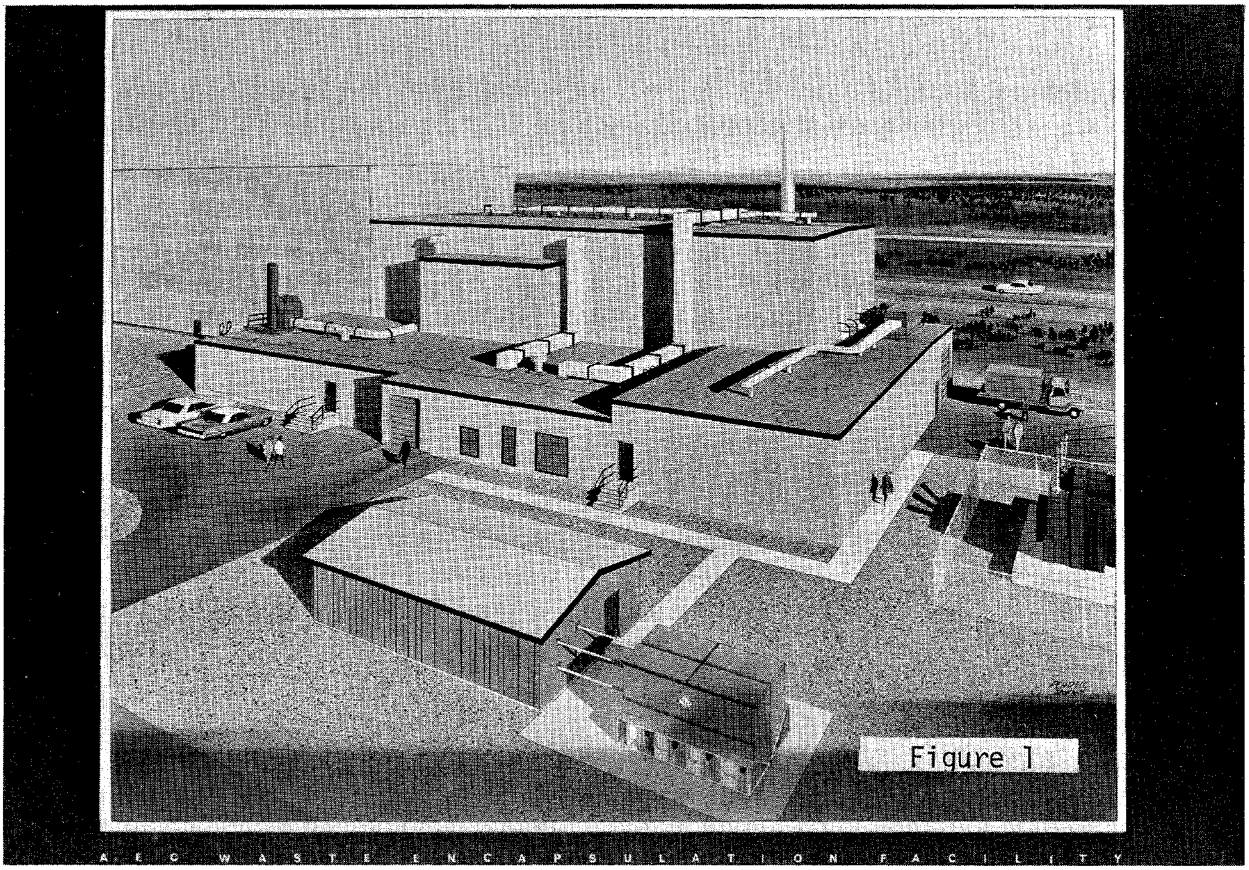


Figure 1

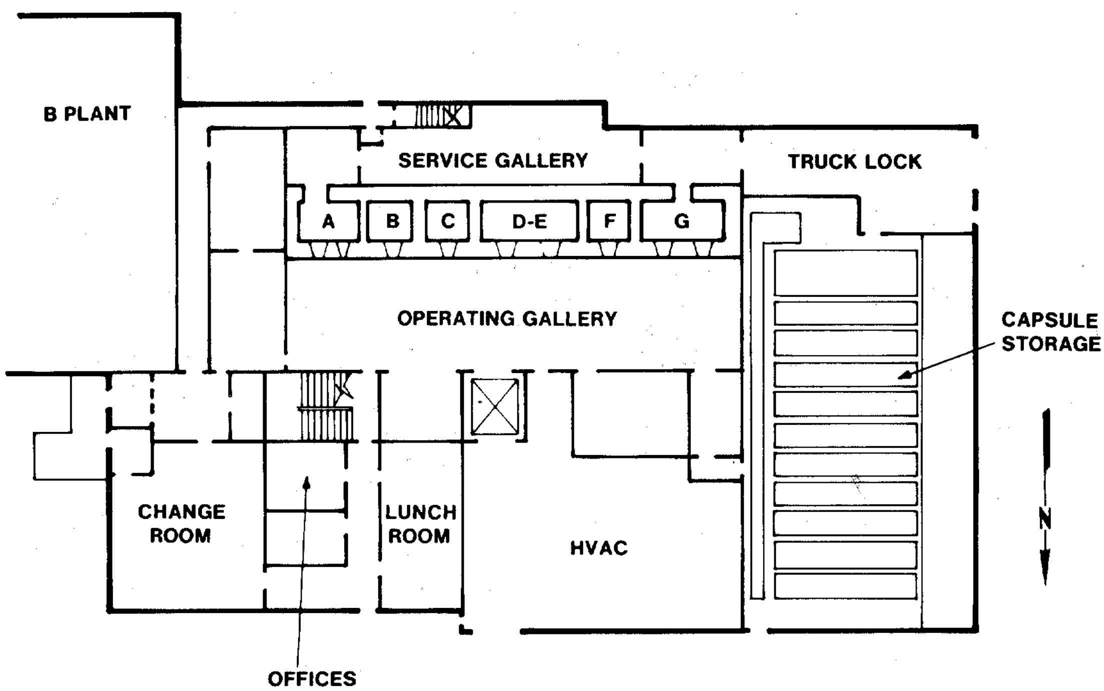
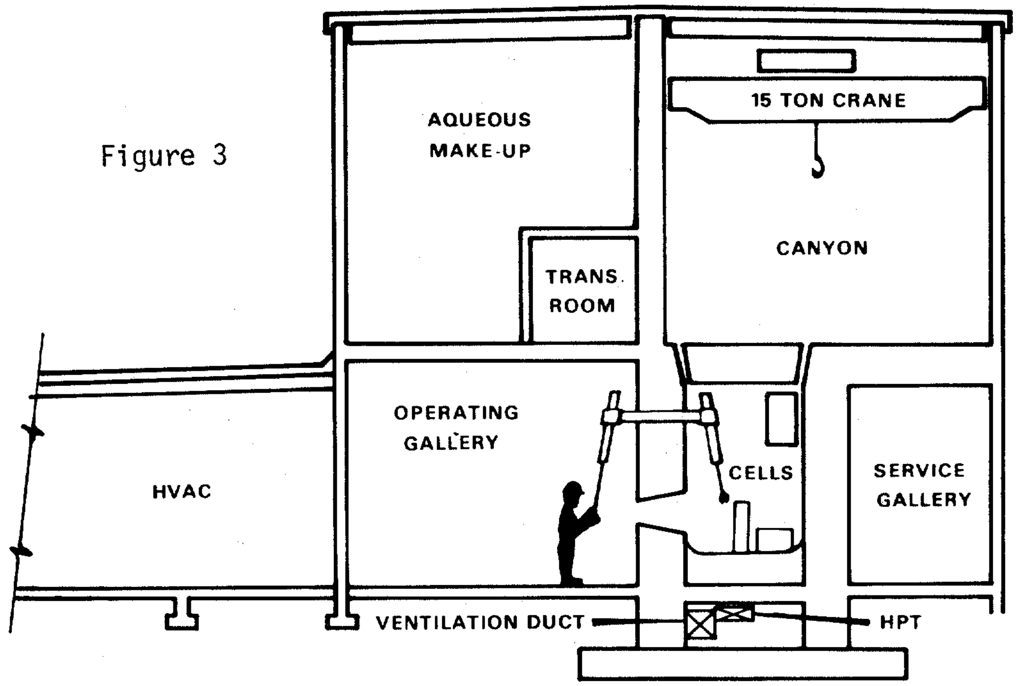


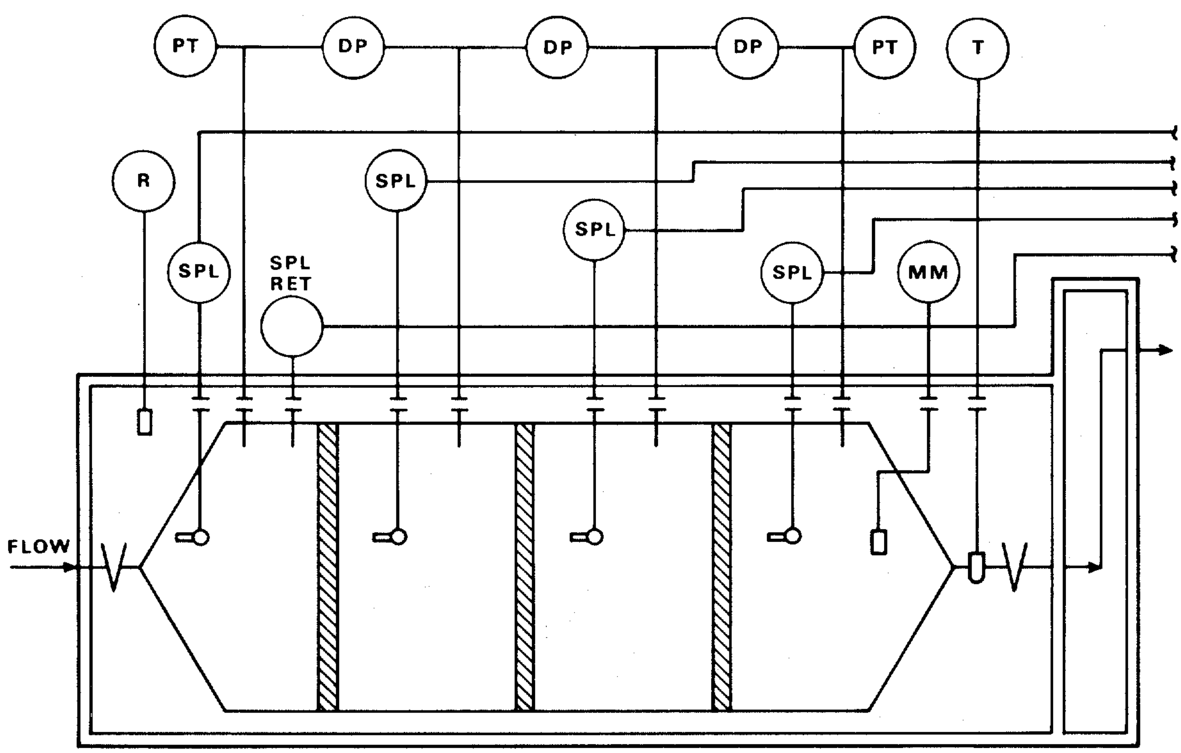
Figure 2

Figure 3



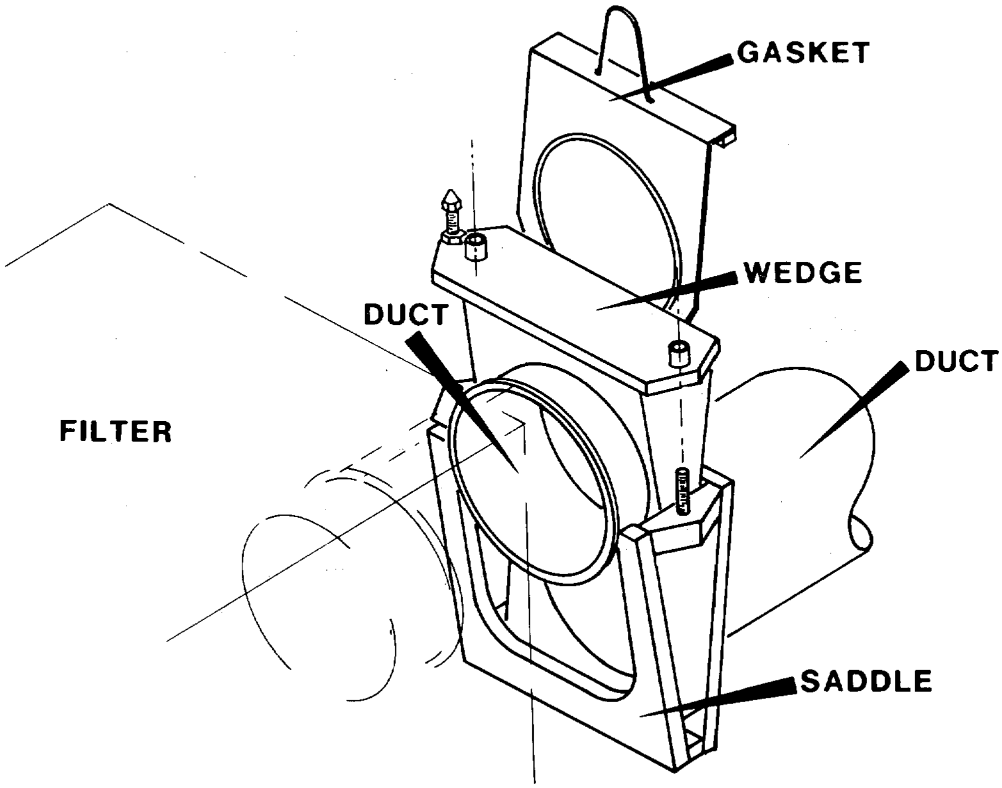
CELL EXHAUST SYSTEM K3

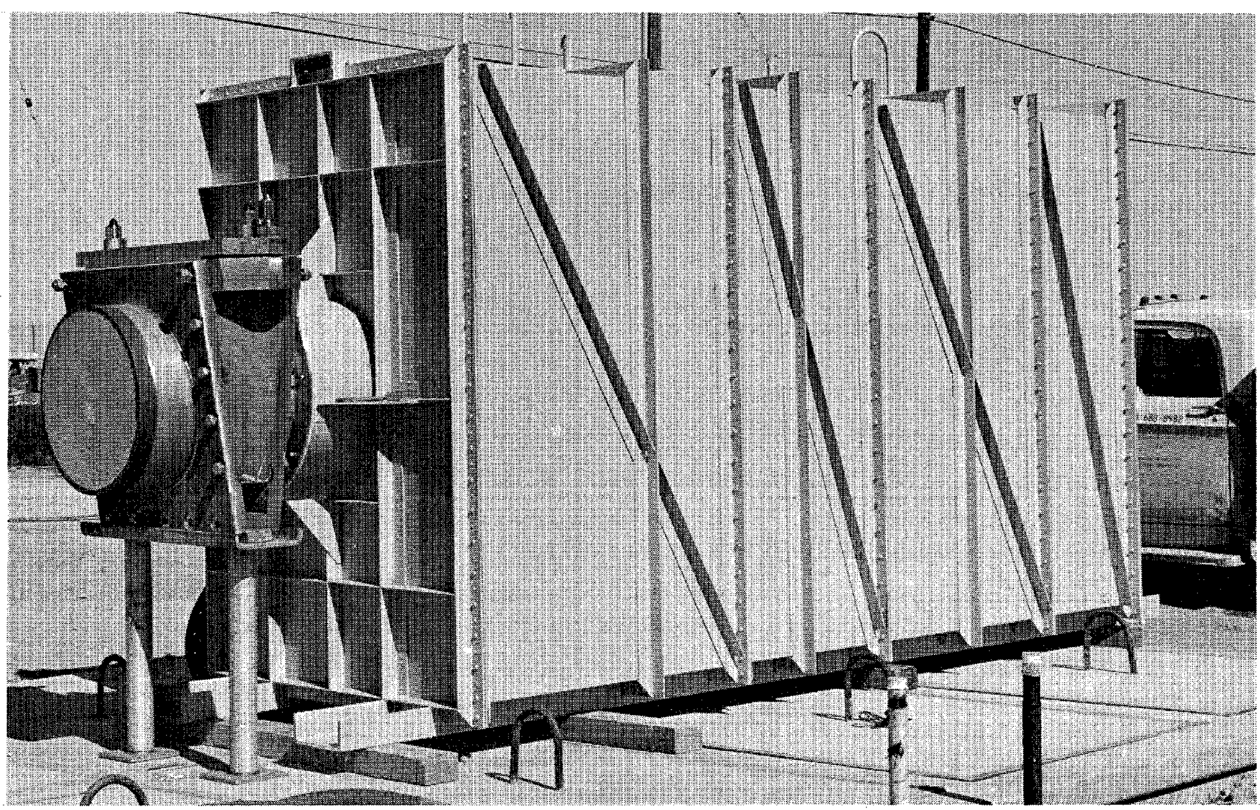
Figure 4



REMOTE DUCT CONNECTER

Figure 5





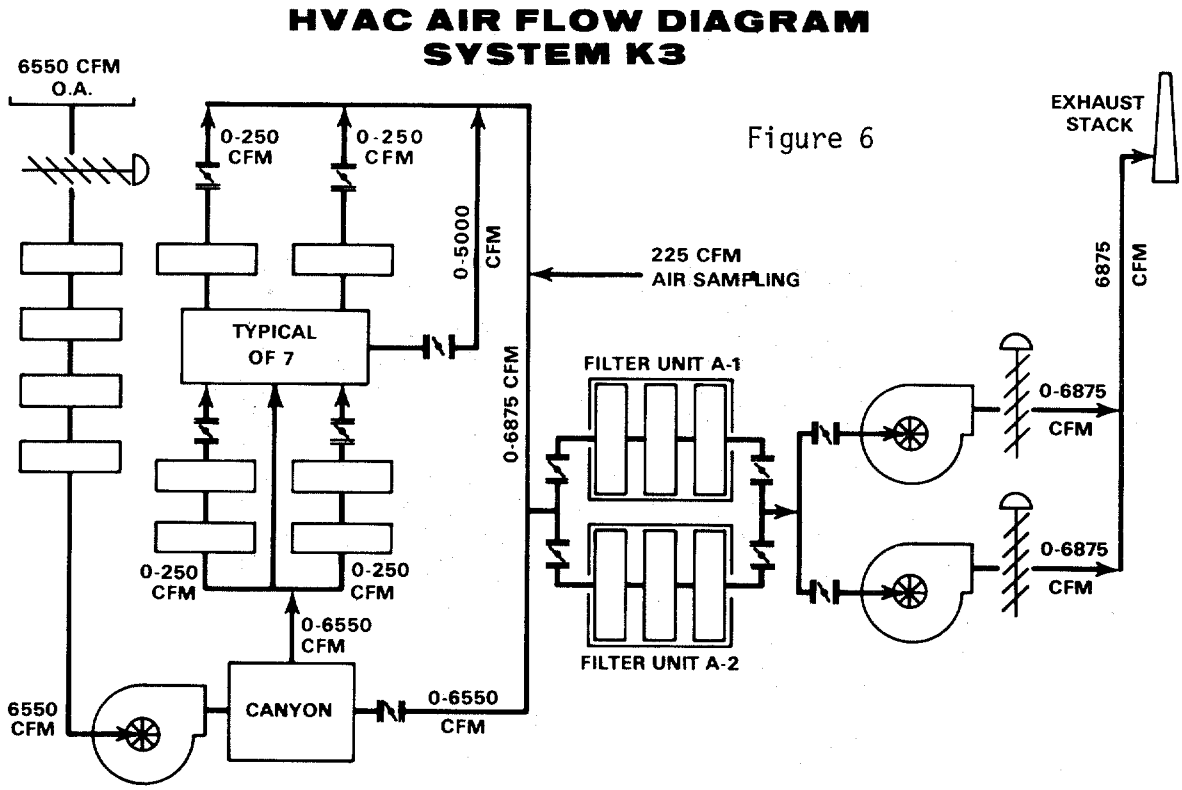


Figure 6

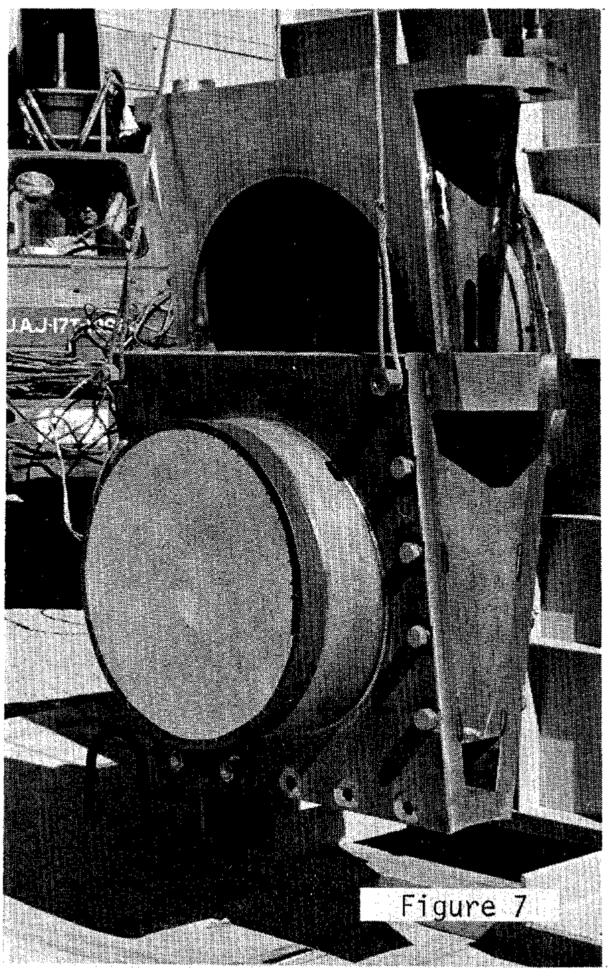


Figure 7

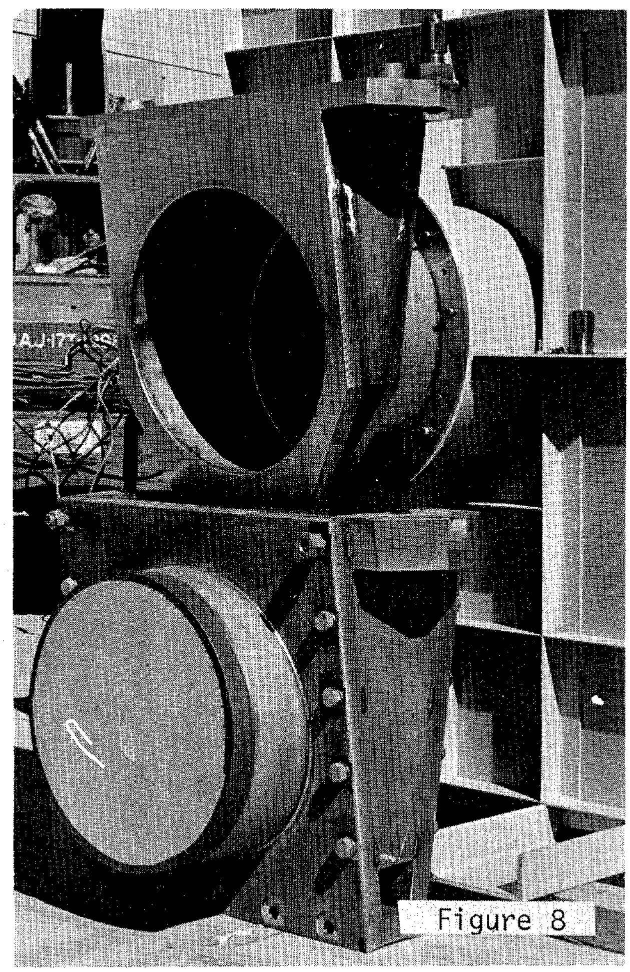


Figure 8

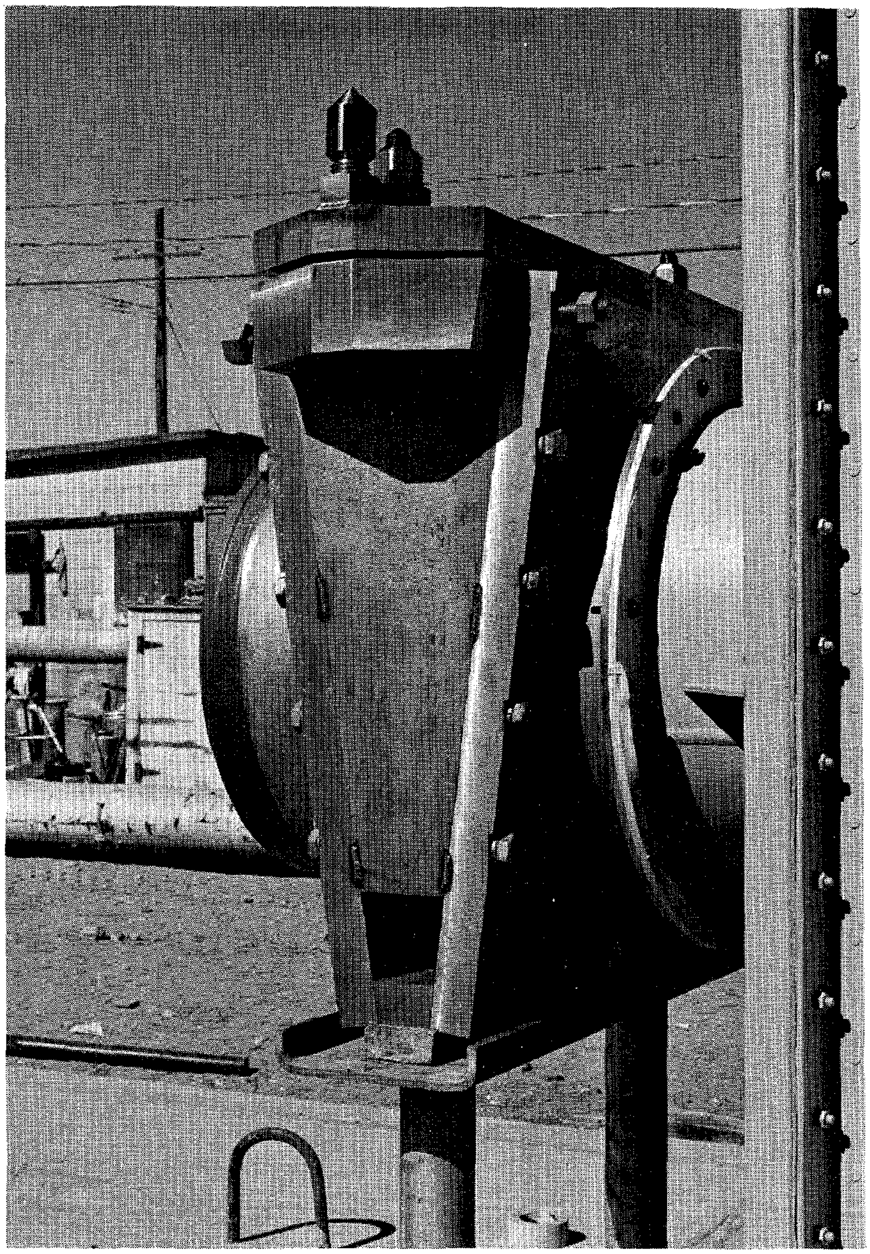


Figure 9

DISCUSSION

MURROW: You said that the system was designed for a 0.25 "g" earthquake. Did you find data on a rotating fan indicating that it would withstand such forces while rotating?

CALDWELL: I cannot answer that question, but those who did our calculations have the information.

FULLER: I would like to ask if you have a total cost for your ventilation system.

CALDWELL: The total ventilation system will run about $900,000 on a $12,000,000 facility. That includes the control instrumentation, the chilled water system, and the evaporative cooler; the whole thing.

JOHNSTON: What kind of fire protection do you have in that filter system, if any?

CALDWELL: The final filtration system (A-1 and A-2 of the schematic we showed) does not have a fire protection system, per se. However, each of the cells has its own fire protection system. We've calculated, or postulated, that a fire would be within the cell. Using administrative controls, etc., calculations indicated that a fire would not penetrate to the remote filters. The cells themselves have all kinds of fire detection and protection systems.

CHAIRMAN'S CLOSING REMARKS:

This session was kind of a polyglot thing. We got a glimpse of the wave of the future; that is, the HTGR, and some of the new problems associated with it. We had another look at a rather old technology; the silver reactor for iodine removal. However, it is in the last two papers that I think we saw the end of one era and the beginning of another. I think Mr. Fuller's duct exposed on top of the building is probably the last new such duct which will ever be discussed in these meetings, and Mr. Caldwell's concern with seismic phenomena is the sort of thing that will receive a great deal more attention in these meetings in the future.