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DESIGN CHARACTERISTICS FOR FACILITIES WHICH PROCESS HAZARDOUS PARTICULATE

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Design Characteristics for Facilities Which Process Hazardous Particulate

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ABSTRACT

Los Alamos National Laboratory is establishing a research and processing capability for beryllium. The unique properties of beryllium, including light weight, rigidity, thermal conductivity, heat capacity, and nuclear properties make it critical to a number of U.S. defense and aerospace programs. Concomitant with the unique engineering properties are the health hazards associated with processing beryllium in a particulate form and the potential for worker inhalation of aerosolized beryllium. Beryllium has the lowest airborne standard for worker protection compared to all other nonradioactive metals by more than an order of magnitude. This paper will describe the design characteristics of the new beryllium facility at Los Alamos as they relate to protection of the workforce. Design characteristics to be reviewed include; facility layout, support systems to minimize aerosol exposure and spread, and detailed review of the ventilation system design for general room air cleanliness and extraction of particulate at the source.

INTRODUCTION

The new Beryllium Technology Facility (BTF) is designed to support the Beryllium Technology mission assigned to Los Alamos National Laboratory (LANL) by the Department of Energy (DOE). The mission is to maintain and enhance the beryllium technology base and establish the capability for fabrication of beryllium powder metallurgy components. The facility is undergoing a complete reconfiguration through a decontamination and decommissioning (D&D) project which has removed all equipment and building support systems including, ventilation, electrical, and plumbing. The construction phase will reconfigure the building layout and install new HVAC, electrical, plumbing systems, and seismic upgrades to meet current requirements and provide a state-of-the-art beryllium facility. Equipment installation and hook-up to building systems will follow the construction phase.

The BTF has a total square footage of 16,000 of which 13,000 square feet will be converted to beryllium operations. The remaining 3,000 square feet will remain operational for general metallurgical activities but will not come under the beryllium operations envelope.

This document summarizes the most significant facility design characteristics and as they pertain to protection of workers from beryllium exposures and therefore Chronic Beryllium Disease (CBD). References to peer reviews, design meetings, and the use of outside consultants are provided where their influence provided safety related design input. Los Alamos conducted three independent reviews by recognized experts in ventilation design and beryllium operations:

- Independent review of the ventilation system design by D. Jeff Burton, PE, CSP, CIH [1].

- Peer review by the United Kingdom Atomic Weapons Establishment personnel at Cardiff and Aldermaston [2].
- Peer review by Brush Wellman [3].

DESIGN INTENT

The design intent is to incorporate the best design features from lessons learned throughout the beryllium community and those design characteristics recommended by the American Conference of Governmental Industrial Hygienists (ACGIH) [4] for hazardous operations with particulate. The general design concept conveyed to the Architectural & Engineering firms throughout the design phase was for the facility to have the appearance and cleanliness of a surgical operating room. The flooring and walls of the facility are covered with a hard epoxy finish, which is easily cleaned, and therefore the facility will not resemble conventional metallurgical facilities and will have a much cleaner environment. The facility will also feature, room pressurization control, temperature control, and the ability to adapt equipment design modifications/changes with the building support systems. The design goal is to minimize beryllium aerosols through capture and extraction at the point of generation. Therefore the ventilation system design is critical for the protection and safety of personnel.

Beryllium aerosols are best controlled at the source of generation and the facility design supports:

- a flexible and robust HVAC system to accommodate various equipment enclosure designs and extraction of beryllium particulate at the generating source
- a layout which separates higher hazard operations
- a beryllium analytical laboratory to ensure quick turn-around of Industrial Hygiene (IH) data
- an access restricted facility to limit the exposed population
- waste minimization through laundarable cloths, filtration, collection, and recycle of metal waste streams

In general, local exhaust pick-up of particulate at the point of generation will be the primary means of contaminant control. The enclosure fitted to the particular piece of equipment will provide the secondary measure of control.

FACILITY LAYOUT & GENERAL DESIGN FEATURES

The 1st floor operations area, which contains all process areas, is shown in figure 1. The facility is separated into operation areas and support areas. Operation areas are areas where beryllium is characterized or processed to change its form. Support areas are those areas that support the exposure monitoring, hygiene and access of personnel. Additionally, a few offices and a storage area are located in this facility, but access to them is from a separate entrance. The operation areas are segregated such that the more hazardous operations, as determined by previous process knowledge and Industrial Hygiene data, are isolated from the lower hazard operations. The operation areas include:

- **Inspection** - Beryllium components are inspected for dimensional tolerances, density, and cracking. Components are nondestructively inspected, measured, and returned for further processing. Only solid and clean components enter this room and leave unaltered. The room requires precise temperature control to ensure reproducible dimensional inspection. Only general room ventilation (changed 15 times per hour) is provided due to the low hazard.
- **Metallography** - Specimens are prepared for metallography and transmission electron microscopy (TEM). Metallography requires diamond saw cutting, mounting, grinding, and polishing. The polished specimens are then etched, viewed and/or photographed directly with polarized light. TEM specimens are chemically thinned and/or thinned with an ion mill. All polishing, grinding, and cutting operations are done wet and have local ventilation.

- **Alloy Development** - This area provides for alloy preparation/characterization and contains a small arc melting chamber, furnaces, and a Differential Scanning Calorimeter/Differential Thermal Analysis (DSC/DTA). All operations are contained within sealed vessels and beryllium exposure potential only occurs during loading and unloading. Vessel design will incorporate ventilation to provide airflow away from the operators.

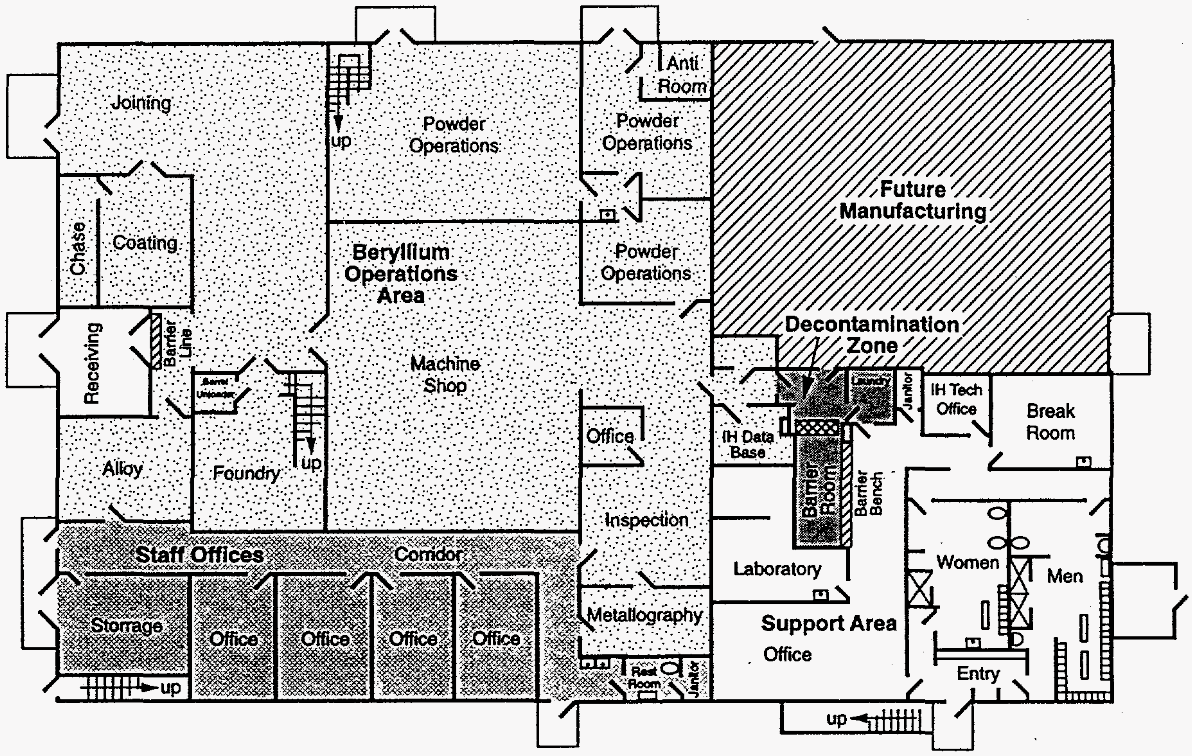

Figure 1 First floor layout of BTF showing operation areas, decontamination zone, support areas, offices, and future manufacturing.

- **Joining** - Components are joined utilizing Gas Metal Arc (GMA) welding, Electron Beam (EB) welding, and brazing furnaces. Parts are also heat treated in the brazing furnaces. The principle purpose of this area is the assembly of components, and there are no metal removal processes. All operations are contained within sealed vessels and beryllium exposure potential only occurs during loading and unloading. Vessel design will incorporate ventilation to provide air flow away from the operators.
- **Coating** - Physical Vapor Deposition (PVD) is utilized to deposit beryllium coatings onto various substrates. The process utilizes an evaporative vacuum environment in an enclosed vessel. The operation is contained within a sealed vessel and beryllium exposure potential only occurs during loading and unloading. Vessel design will incorporate ventilation to provide airflow away from the operators.
- **Machine Shop** - The machine shop will support development work, including parts, tensile bars, chemical samples, metallography samples, and various development tooling and fixtures. Beryllium and beryllium alloys will be machined. Machines include lathes, mills, saws, and electrical discharge machining (EDM). Each machine will have a ventilated enclosure that is negative to the room and the machine chips generated will be extracted at the tool-work interface.
- **Foundry** - Scrap and recycle beryllium is vacuum induction melted and cast. Special alloy compositions are also melted and cast for development work. The system is comprised of a melt/cast chamber, vacuum system, power supply, and a glovebox. The glovebox is used to prep crucibles and

molds in addition to removal of castings from molds. The potential for particulate exposure is higher when loading, unloading and cleaning the furnace. Ventilation, which draws air away from the operator during loading and unloading, is provided. The foundry operations are completely isolated from the other operation areas due to the higher potential for exposure. Included in the foundry area is a ventilated (down draft) room for opening and inspecting containers of beryllium. This area will also be used to service portable HEPA filtered vacuum cleaners.

- **Powder operations** - The powder operation area supports the manufacture, handling, and consolidation of beryllium powder. The area is separated into three individual rooms for atomization and powder handling, plasma spray, and support equipment for sealing and outgassing of containers. These operations have been determined to have the highest airborne contamination levels from previous IH monitoring data and therefore are separated by an airlock to control the spread of any contamination. The equipment in this area is being redesigned to incorporate the best controls for aerosol containment.

Support areas as described here include those areas that support the beryllium health and safety envelope and an exposure minimization program.

- **Receiving and shipping dock** - The dock area supports segregation of in-coming and out-going articles from the process areas. The room pressures are controlled to ensure airflow into the operations area and therefore minimize the spread of any contamination.
- **Analytical Lab** - In-house Industrial Hygiene (IH) analysis of air and surface samples was made a requirement to provide timely feedback to operations personnel. Previous DOE beryllium operations were typically not concentrated in one facility and IH samples were sent to a central analysis laboratory where beryllium samples competed with other samples for analysis. The result was a several day lag time between sample submittal and results reported back to operations personnel. This feature was identified as needing improvement in lessons learned from throughout the DOE complex and therefore was included to support the quick turn-around feedback to workers. This feedback ensures that housekeeping has been adequate and allows for timely corrective action. The in-house IH sample analysis planned for the new beryllium facility has two components:
    - Inductively Coupled Plasma (ICP), and
    - Laser Induced Breakdown Spectroscopy (LIBS).

  The ICP Lab located within the facility will be dedicated to beryllium sample analysis and will provide same day sample analysis for both air and surface samples. The lab is pursuing American Industrial Hygiene Association (AIHA) accreditation to ensure the accuracy and precision of our sample analysis.

  The LIBS instrument is a developmental instrument that can provide real time surface and air analysis. This instrument will be used throughout the facility to monitor housekeeping and operations. Conventional IH sample analysis and the LIBS will be used in tandem to build a database to increase our confidence in the LIBS instrument. All operations will be monitored full time during start-up to ensure the adequacy of engineering controls.
- **Housekeeping & Laundry facilities** - There are separate janitors closets to allow for segregation of housekeeping operations which support beryllium process areas, support areas, and office areas. The janitors closet on the beryllium operations side is also equipped to be a decontamination shower if necessary. Laundry facilities are contained within the facility to preclude the shipment of contaminated articles beyond the facility envelope. Laundarable clothing as opposed to disposable clothing will be utilized whenever possible to minimize the disposable waste streams.
- **Access area & Change/shower rooms** - The facility is designed to <u>**limit access**</u> to only authorized beryllium workers. There is only one entrance to the beryllium operations area which is through the change/locker room. Here workers change from their street clothes to modesty clothing, then cross a barrier where clean coveralls and booties are donned and the worker logs into the facility. Exit from the Beryllium process and support areas is only allowed through the change room. When exiting the beryllium process area, an air down wash area with supply air overhead and a grated floor is provided for removal of coveralls and booties. This laminar-like top down flow is designed to keep

beryllium particulate, which could be resuspended during coverall removal, out of the workers breathing zone. The removed articles of clothing are stored in ventilated drums or containers until washing. The core of authorized beryllium workers will include operations personnel, IH and Lab support personnel, and dedicated janitorial and maintenance crews.

- **Mechanical rooms** - There are two mechanical rooms located on the 2nd floor that contain the majority of plumbing and HVAC equipment.

In addition to the support areas, two types of support equipment, located within the facility, will support the concept of exposure minimization, an electronic communications network, and a supplied air breathing system. Electronic communications has been provided throughout the facility to support the limited access design concept and limit material removal from the facility. For general data transfer, computer terminal lines are provided throughout the facility. This will eliminate the need to carry paper in and out of the facility. For communication and announcements throughout the facility an intercom system is provided. Closed circuit television is also provided so that public or programmatic access to view operations can be provided remotely, without exposure to non-beryllium workers.

A supplied air breathing system has been included in the facility design for maintenance and decontamination operations, which may require the highest in personal protective equipment. Although the facility is designed with engineering controls to hold airborne beryllium concentrations well below the Personal Exposure Limit (PEL), and under normal operating conditions no respiratory personal protective equipment will be required, this system will ensure personnel protection in non-routine situations. Supplied air breathing lines are provided in the powder operations area, foundry, machine shop, outside near the industrial dust collector, and in the mezzanine by the exhaust filter plenums.

HVAC SYSTEM

The HVAC system is the primary engineering control for beryllium aerosols in the facility and consists of these three main systems:

- Supply air system
- General room and hood exhaust air system
- High pressure exhaust system for particulate extraction and recovery

These three systems work together to meet the design criteria of a surgical operating room and ensure a clean operating environment. The systems are tied together through the facility management system (FMS), such that settings for room pressures, airflow rates, room temperature control, and emergency situations such as power loss or fire, are monitored and the system is appropriately adjusted via the programs in the FMS. For example, the HVAC system provides a constant volume supply and variable volume exhaust, to provide precise pressure control between zones/rooms. Documentation of the FMS start-up sequence of operations, normal operating conditions, and response to system interruptions will be provided in the commissioning report at the completion of construction. Building commissioning is a necessary function that must take place for a critical facility such as this.

The following will describe the design of each system, discuss how they are controlled by the FMS, and how they act as a unit through the FMS. The discussion follows the airflow from:

1. outside the building
2. through the supply ventilation system and into the rooms
3. from the rooms into the general exhaust ductwork and enclosures
4. through the exhaust system and out the stack

Figure 2 is a schematic showing the integration of all three systems.

Supply air system

A once-through ventilation system was chosen for the process and support areas of this facility as recommended by the ACGIH Ventilation Manual [4]. While not an energy efficient system, this system assures that there will not be any build-up of airborne contaminants over time. Design features that reduce the overall energy consumption of operating this type of system are discussed latter in this section. The segregated office area uses a recirculation system with fresh air according to American Society for Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE) acceptable Indoor Air Quality (IAQ).

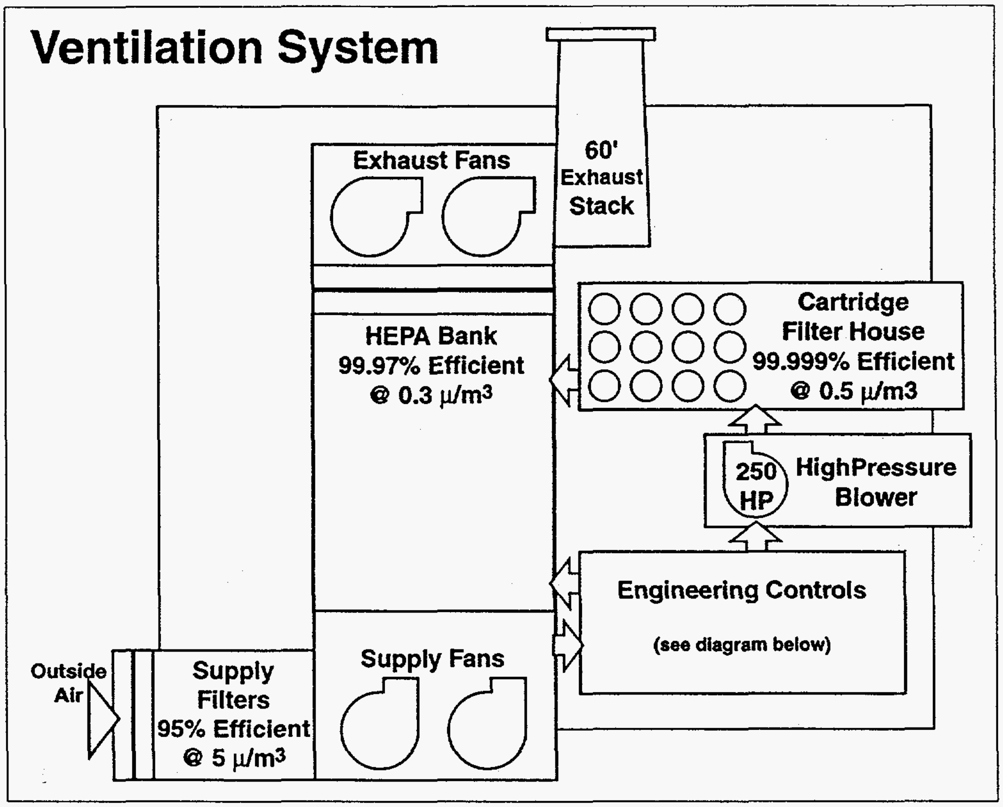

Figure 2 Schematic representation for integration of the supply air, exhaust air, and high pressure systems with the filtration systems.

Air enters the building air handling unit (AHU) through a large louvered opening. The air passes through two stages of filtration. The first stage uses 30% efficient 2" thick throwaway filters to remove large airborne objects. The second stage uses 95% efficient extended media filters that remove up to 95% of particles over 5μ in size. This level of filtration is equivalent to that used for a Class 100,000 clean room. The pressure differential across each stage of filtration is monitored by the FMS. When the pressure reaches a pre-determined set point, the FMS will alert the facility operator that the filters need to be replaced.

Airflow through the second stage of filters is controlled by 2 sets of dampers installed in parallel. These dampers divide the filter bank into two equal sections and are included to provide for filter change-out without shut down of the entire facility ventilation. When a filter change is indicated by the FMS, the variable frequency drive (VFD) on the supply air fans is reduced to 50% of normal operating supply air and one set of the dampers is closed for change out of the corresponding filters. When ½ the filters have been changed, the closed damper is opened and the other damper is closed to complete the filter change-out. During this maintenance operation the facility general ventilation system is running at ½ capacity and the following critical ventilation zones remain fully operational; powder operations, analytical lab, change room, machine shop, foundry, and support areas. Noncritical areas (alloy development, coating, joining, metallography, and inspection) are cordoned off and remain non-operational during this maintenance operation. The 50% operation mode occurs when the second stage supply air filters are changed, the general exhaust system filters are changed or if one of the supply air fans goes down. The damper positions are controlled either by the FMS or a manual switch located at the dampers. The FMS will automatically close the supply air dampers in the event of a power loss. The manual switch is used during maintenance to close the damper and cannot be overridden by the FMS, although the FMS will alarm indicating the damper is closed.

A velocity pressure measurement station is located in the supply air unit to monitor the total airflow in cubic feet per minute (CFM) entering the building. This data is sent to the FMS and is used in balancing and troubleshooting the entire system.

A temperature control section follows the filtration and damper section of the AHU. First in line is a heat recovery coil (HRC). The heat recovery system is comprised of a closed, run around loop, which prevents any possible cross contamination of the air streams. In this system, heat is transferred from the exhaust air stream to a water/glycol solution via a HRC located in the exhaust ductwork. Another HRC located in the AHU then transfers the heat from the water/glycol solution to the supply air stream. A pump circulates the water glycol solution through this loop. All coils are located down stream from the filters to ensure minimal maintenance requirements. A temperature probe is located down stream from each of the HRC's.

The preheat coil (PHC) is located down stream from the HRC. It was designed with sufficient capacity for heating the entire building in the event the HRC is inoperable. This coil has redundant pumps so that loss of a pump does not shut down the facility. The system uses hot water as opposed to steam for more precise temperature control and reduced maintenance (lessons learned at LANL). A temperature sensor located down stream from the PHC sends a signal to the FMS which controls the flow of hot water through the heating coil. A freeze stat is located down stream from the heating coils and is used as a safety sensor. The freeze stat is set at 40^0 F and is interlocked with the supply fan so that if the heating coils fail, the supply fan is shut down and the inlet dampers closed. This is to prevent freezing of the coils should the heating system fail in winter.

The cooling coil (CC) is controlled by the FMS and its temperature control sensor is located after the supply fans. The FMS reads temperatures throughout the building and determines which zone requires the most cooling to maintain its temperature set point. The FMS controls the CC or HRC/PHC to deliver that temperature air. The temperature in the other zones is then controlled by terminal heating coils to ensure the proper temperatures are maintained throughout the facility. This is the most economical system that meets the temperature control requirements of this facility.

The supply fans have variable frequency drives (VFD) and both are required for full operation of the facility. There is approximately 50% redundancy in the supply fans. The fans are controlled by the FMS which adjusts the VFD according to a static pressure probe located downstream in the main supply air duct. Dampers are located in front of each fan and close if that fan goes down. This prevents air from circulating in the fan section and ensures maximum throughput of air into the building.

A duct detector (photoelectric smoke detector) for fire detection is located downstream from the supply fans and is interlocked with the fans to shut them down. The duct detector is also hard wired to the fire control panel and the fire station.

A deionized water mist humidifier maintains a humidity of at least 25-30%.

Each zone within the facility has a supply air valve (venturi) which controls the airflow into that zone as shown in figure 3. A pito tube is located at the air entrance to the valve and measures total pressure. The pito tube is connected to the FMS and adjusts the control arm on the supply valve electronically to maintain a constant volume of flow. The supply air enters each room or zone via diffusers located at the ceiling or at approximately 12' in high bay areas. These diffusers can be manually controlled to either diffuse the air or focus its flow straight down. During the start-up of operations, these diffusers will be adjusted to provide the optimal flow patterns for each work location.

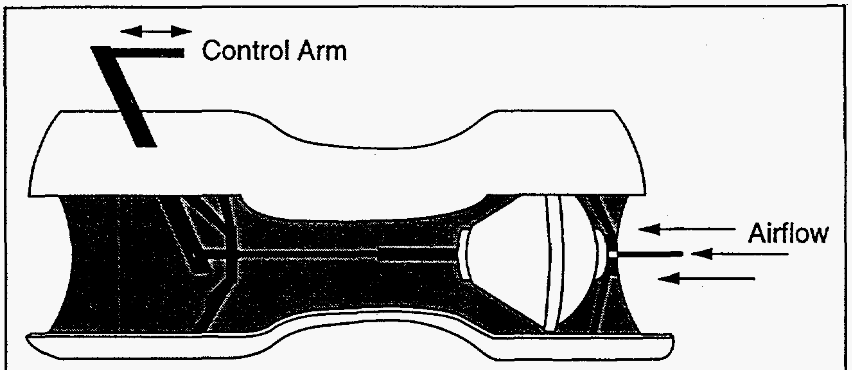

Figure 3 Schematic of a venturi air valve showing the control arm adjustment for the cone and the airflow direction.

General room and hood exhaust

The room air is exhausted through ventilation ductwork openings located at the corners of each room, approximately one foot off the floor. This flow pattern (top down) is designed to prevent beryllium from being held in the workers breathing zones. The exhaust duct is sized to provide an inlet velocity at duct of 500-750 ft/min. When the vertical run of duct reaches the main exhaust ductwork, the velocity increases to a transport velocity of 2000-3000 ft/min. These inlet and transport velocities help to ensure that captured aerosols are transported downstream to the HEPA filters and that the ductwork remains clean and free of particulate buildup. The relatively low inlet velocity of the general room exhaust, points to the importance of aerosol capture at the source and regularly scheduled housekeeping and mopping. A velocity pressure probe located in the main exhaust duct, downstream of the HEPA filters, measures the entire exhaust air volume leaving the facility. This data is sent to the FMS and is used in maintaining the balance between the supply and exhaust systems.

All exhaust air exits through two identical parallel plenums for final HEPA filtration. Nuclear grade bag-in/bag-out plenums were selected to ensure a high quality product was procured and this type of plenum has all of the contamination control features needed. Filters can be changed-out from the plenum without breaching the integrity of the system. In-place efficiency testing of the HEPA filters can also be performed. At the entrance to the HEPA plenums and aft of the HEPA filters are bubble tight dampers. These dampers are used to isolate the exhaust filters during any maintenance. When HEPA filter plenum maintenance is indicated by the FMS, one plenum is isolated and the other maintained operational. During maintenance, the facility goes to 50% operational status and the critical operation areas maintain their operational status and the noncritical areas are shut down, similar to the previously described status during supply filter changes. Following the HEPA filter plenum entrance damper is a fire screen to protect the HEPA filters from possible fire or spark damage. The pressure differential across each stage of filtration is monitored by the FMS and the reading is displayed locally. When the pressure reaches a pre-determined set point, the FMS will alert the facility operator that the filters need to be replaced.

The heat recovery coils (HRC) and a temperature sensor are located aft of the HEPA plenum dampers as described earlier.

The general room exhaust system also provides the exhaust for the hoods in the facility. Process hood exhaust drops (6" and 8" diameter capped drops) are provided throughout the facility with ample redundancy to ensure optimization of engineering controls and operational flexibility. The process hood exhaust is used to ventilate equipment enclosures which are maintained at a negative pressure with respect to the room. This local ventilation when placed properly provides airflow away from operators when equipment is accessed for part removal or setup. Control dampers maintain process hood and equipment exhaust air volumes. The control dampers are preset to a constant flow rate and self adjust as the system static pressure varies. The 125 ft/min face velocity used for design purposes conforms to the LANL standard for chemical hoods and was confirmed in a visit to the UK [2] as within the optimum velocity range to control and capture aerosols.

A booster fan was provided for the down draft glove box in the foundry area. This exhaust air also feeds into the general exhaust system. The booster fan was required to ensure adequate through-put of air for the down draft glove box. The down-draft glove box was designed at Rocky Flats from lessons learned in dealing with fine particulate in an enclosed, non-ventilated glove box. The down draft prevents the suspension of fine particulate in the glove box, improves the operator's field of view, and reduces cleanup requirements. The air is pulled from the room through HEPA filters located on top of the glove box, down through a grated work surface, into a drop out chamber, through pre-filters, and finally through in-line HEPA filters. There is a static pressure probe located before the HEPA filter just described which is monitored by the FMS. This static pressure probe information controls the speed of the variable frequency drive (VFD) exhaust fan to ensure the proper flow in the glove box. The pressure differential across this HEPA filter is monitored by the FMS and the reading is displayed locally. When the pressure reaches a pre-determined set point, the FMS will alert the facility operator that the filters need to be replaced. This fan is also interlocked with the general exhaust system fans. If the general exhaust system fans both fail, then this booster fan shuts off.

Finally, the high velocity process exhaust system feeds into the general exhaust system upstream of the HEPA plenum. This system and its function will be discussed separately due to its importance for extraction of beryllium particulate and aerosols at the point of generation.

Aft of the HEPA filter plenums and HRC's are the exhaust fans and exhaust make-up air duct. Additional make-up air is required to maintain the stack velocity during HVAC maintenance operations. The exhaust velocity and volume is measured at the stack and is required to be maintained within a specific range by NESHAPS and the State of New Mexico air permit. Continuous sampling of the exhaust air stream also takes place in the stack. During HVAC maintenance operations, the supply air is reduced to 50% and therefore make-up air into the exhaust is needed to maintain the required velocity up through the stack. This velocity is maintained by the adjustment of three dampers in the exhaust make-up air duct. The FMS which monitors stack velocity and the status of fans throughout the facility, automatically adjusts the make-up air dampers to maintain the required velocity.

The exhaust fans are located outside the facility and are sized to provide 100% redundancy. Only one fan operates at any given time with the other fan on standby. The 100% redundancy is provided because the fans are exposed to variable weather conditions including temperature and humidity swings, which will create more maintenance requirements. The fans have variable frequency drives (VFD). The operation and frequency drives are controlled by the FMS with input from the other systems to balance the entire system. The FMS will cycle the non-operational exhaust fan on a regular basis to ensure its operational status. Changeover will be scheduled to occur during non-work shift hours. Additionally, isolation dampers controlled by the FMS open and close for each exhaust fan depending on its operational status.

High velocity exhaust for particulate extraction

The high velocity exhaust or high pressure system is used to capture particulate and aerosols at the point of generation and remove them from the operating environment. The high pressure system was reviewed by Jeff Burton [1] and Brush Wellman [3] and was designed to include redundancy and operational flexibility. The machining operations at Rocky Flats and at Cardiff used low volume/high velocity

(VLHV) capture technology with a 1 ½" diameter pipe. The BTF facility systems use an inlet velocity at the nozzle of 11,000 - 14,000 ft/min and a nominal flow rate of 150 cubic feet per minute (CFM). The system designed for use in the beryllium facility allows use of slightly modified capture methods and also incorporates a higher flow rate option. The modified capture method will utilize a 1 ½" diameter pipe with an inlet velocity of 10,000 - 12,000 ft/min and a nominal flow rate of 150 CFM. The high volume option utilizes a 4" diameter pipe with inlet velocities of 4,500 - 6,000 ft/min and nominal flow rates of 400 - 500 CFM. Figure 4 shows that the advantage of the high flow rate option is to allow higher capture velocities with the exhaust inlet at the same distance from the point of generation. The larger exhaust inlet area also makes the placement of the inlet less critical.

For machining operations, a minimum capture velocity of 500 fpm should be maintained as recommended by ACGIH Industrial Ventilation. At capture distances of 2" and 3" the high volume flow (4" diameter duct) easily exceeds the 500 fpm capture velocity, but the LVHV 1.5" diameter duct does not maintain the 500 fpm capture velocity beyond approximately 2 inches. Also shown in figure 4 is the advantage of adding a flange to the exhaust inlet. The solid lines depict the constant velocity contours associated with an inlet without a flange. The dashed lines depict the constant velocity contours with the addition of a flange. Note that the flange extends the capture area which maintains a minimum capture velocity of 500 fpm.

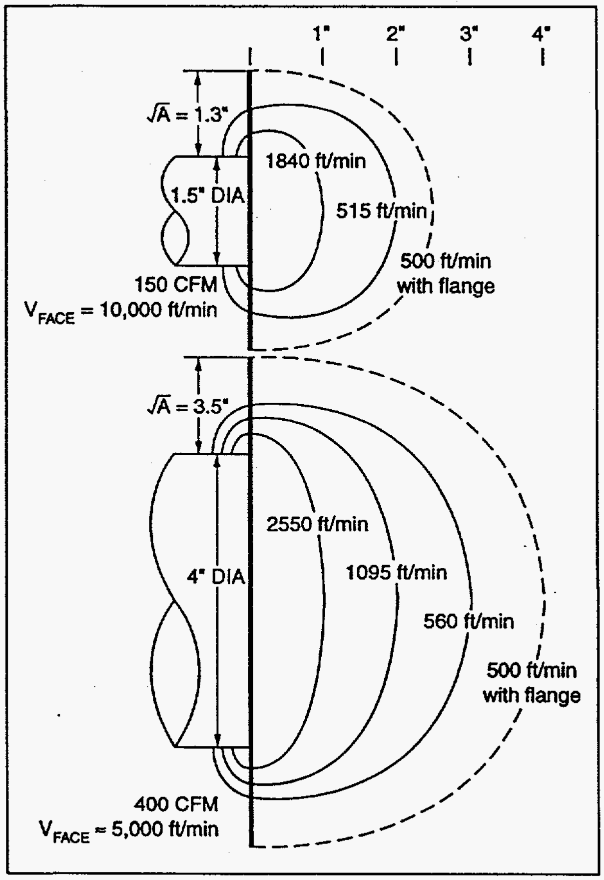

Figure 4 Schematic representation of the particulate capture area for two different exhaust tube configurations and flow rates.

The high pressure exhaust system was designed to accommodate both the LVHV design as well as the high volume design in order to meet the various equipment needs. The LVHV method has a capture area which is directly in front of the nozzle and is smaller in size. This puts more stringent requirements on operator placement of the nozzle. Typically machine chips fly off at angles and not directly in front of the machine tool and therefore the new nozzle designs should capture more of the machining chips. Another advantage of the high flow rate design is that now only one system is required to maintain the negative pressure within the enclosure. The conventional design does not move a high enough volume of air and will require additional hook-up to the general ventilation system. Minimizing the use of the general ventilation system for equipment enclosures ensures cleaner ductwork and provides a cleaner engineering design. The high pressure system has two components for the collection and recovery of particulate:

- A cyclone separator used to capture the majority of particulate
- A dust collector which is 99.999% efficient @ 0.5μ

Each machining operation and operation which generates particulate has its own dedicated cyclone separator. These cyclone separators are rated at 85% efficient capture for 40-100 micron particulate and will capture the majority of particulate. The independent separators also provide for convenient segregation of scrap and easy recycle. Hoppers at the bottom of the separators are designed to be emptied into bottles without breaching the integrity of the system. The piping that connects the cyclone separators to the dust collector is also uniquely designed for the beryllium facility. In a Brush Wellman peer review [3] the need for fire detection and elimination of all spark sources in the ducts was noted to prevent possible beryllium fires. The piping that carries the particulate to the dust collector is grounded to prevent the build-up of static electricity and reduce the potential for sparks. Also, this system is made from segments that are flanged and fastened together mechanically, eliminating the need for welding operations when segments need to be replaced. The piping layout also provides long radius elbows to eliminate excessive wear and minimize "dead spots" where particulate could build-up.

The dust collector is designed for hazardous materials and is rated 99.999% efficient at 0.5μm. The collector unit has three compartments and was sized so that operations and filtration can continue on two while one compartment is off-line for maintenance. The dust collectors have independent pressure sensors which detect when the filters are loaded and automatically provide 100 psi pulsed air to clean the filters. The pulsed air provides for drop-out of the filter build-up into collection containers. The pulsed air is provided by an oil free compressor to maintain the cleanliness of our recycle product. Design specifications indicate that the filter change-out cycle is 5 years. Hoppers at the bottom of the dust collector are designed to be emptied into barrels without breaching the integrity of the system.

The effluent from the dust collector is then piped into the general exhaust system upstream of the HEPA filter plenum for final filtration and release out the stack.

ALARMS

There are two types of alarms in the facility, fire alarms and ventilation alarms. The fire alarms are located per fire code requirements and the ventilation alarms are located according to the hazardous nature of the operations.

There are four components to the fire protection system:

- A building wide sprinkler system that activates thermally when temperatures above 212^0F are detected at the sprinkler heads. This system consists of two flow switches, zone 1 is for the first floor and zone 2 is for the second floor.
- Photoelectric smoke detectors located in the HVAC duct system. The detectors are located on the discharge side of the supply fans and in front of the HEPA filters.
- Three thermal detectors in the dust collector system.
- And manual pull stations throughout the facility

The duct and dust detector alarms were included as part of the peer review recommendations of both the United Kingdom [2] and Brush Wellman [3]. All components connect to the central alarm panel which alarms the building and sends a signal to the LANL central alarm station for fire department response. In addition, included in the sprinkler water supply is a tamper indicator that sends an alarm to the central station should the supply be shut off.

The ventilation system is a vital safety system and therefore has alarms incorporated to protect workers within the facility. The general ventilation alarms are controlled by the FMS. The FMS not only activates alarms throughout the facility but also records the cause, alarm point location, and associated down times. At the entrance to the facility is a ventilation alarm panel. This alarm panel has an audible horn and status light. If the ventilation system goes down the horn sounds for 60 seconds and a red light is activated. Under normal operations a green status light is visible. The alarm condition at the panel can only be changed via a keyed manual rest button in the cabinet. Visual and audible alarms are also located throughout the facility in the following critical areas; men's and women's change rooms, primary change room, emergency shower room, barrel unloader room, foundry, powder operations areas, machine shop, and receiving dock. The high pressure system used for extraction of particulate at the source of generation also has alarms at each piece of equipment in the event of a low flow situation. These will detect not only a blower malfunction but also an obstruction in the exhaust line.

SUMMARY

Beryllium is a unique material which is critical to a number of U.S. defense and aerospace programs. The manufacture and processing of beryllium must be carefully controlled to prevent the inhalation of aerosols which can result in worker development of Chronic Beryllium Disease. The new BTF at Los Alamos National Laboratory was designed using the lessons learned throughout the Beryllium community to provide a state-of-the-art facility with the best possible engineering controls.

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