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Author(s): Gerald C. Langner
Kathryn L. Creek
Richard G. Castro

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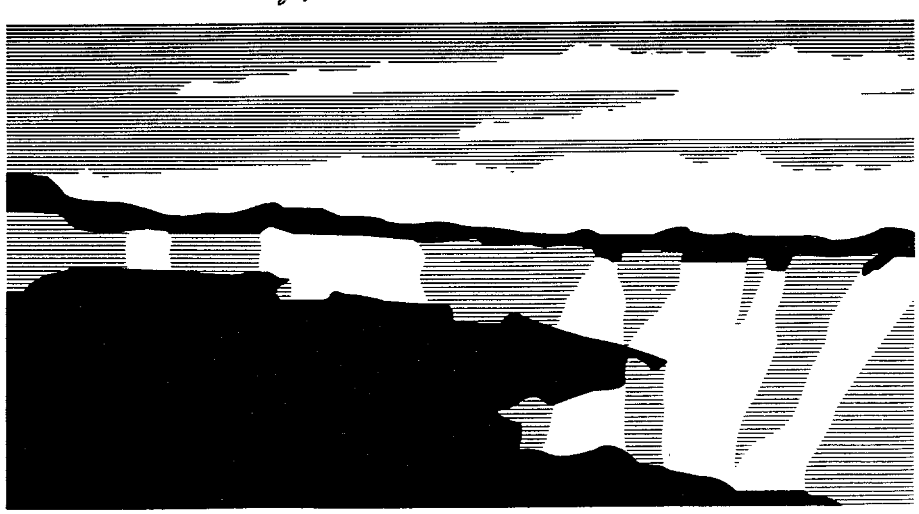

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Control of Beryllium Powder at a DOE Facility

G.C. Langner, K.L. Creek, R.G. Castro
PO Box 1663
Los Alamos National Laboratory
Los Alamos, NM 87545

INTRODUCTION

Beryllium is contained in a number of domestic and national defense items. Although many items might contain beryllium in some manner, few people need worry about the adverse effects caused by exposure to beryllium because it is the inhalable form of beryllium that is most toxic. Chronic beryllium disease (CBD), a granulomas and fibrotic lung disease with long latency, can be developed after inhalation exposures to beryllium. It is a progressive, debilitating lung disease. Its occurrence in those exposed to beryllium has been difficult to predict because some people seem to react to low concentration exposures whereas others do not react to high concentration exposures. Onset of the disease frequently occurs between 15 to 20 years after exposure begins. Some people develop the disease after many years of low concentration exposures but others do not develop CBD even though beryllium is shown to be present in lungs and urine. Conclusions based on these experiences are that their is some immunological dependence of developing CBD in about 3-4% of the exposed population[1], but the exact mechanism involved has not yet been identified[2]. Acute beryllium disease can occur after a single exposure to a concentration of greater than 0.100 mg/m3 (inhalation exposure); it is characterized by the development of chemical pneumoconiosis, a respiratory disease. The acute effect of skin contact is a dermatitis characterized by itching and reddened, elevated, or fluid-accumulated lesions which appear particularly on the exposed surfaces of the body, especially the face, neck, arms , and hands. Small particles of beryllium that enter breaks in the skin can lead to the development of granulomas and/or open sores that do not heal until the beryllium has been removed. Our interest is only airborne beryllium, which is found in areas that machine or produce beryllium.

Early studies of acute beryllium disease led to adoption and implementation of the present exposure standard forty five years ago, which is 0.002 mg/m^3. This is the limit advocated by The American Conference of Government Industrial Hygienists (ACGIH) Threshold Limit Value-Time Weighted Average and the OSHA Permissible Exposure Limit. This value represents the time weighted average concentration for a normal 8-hour workday and a 40-hour workweek, to which nearly all workers may be exposed, day after day, without adverse effect. This limit was established (adapted) by the Atomic Energy Comission to reduce or eliminate the acute form of beryllium disease and it has proven to be effective. However, beginnning in 1984, over 50 new cases of the CBD disease have been identified; the majority of them in the Department of Energy (DOE) facilities. As a result, the Industrial Hygiene (IH) community increased its scrutiny of current practices, and exposure minimization, the lower the better, is now being considered. Our interest in this area is both historical and current. Beryllium has been processed and machined at Los Alamos National Laboratory (LANL) for many years. Research operations include production of beryllium and beryllium aloy powders and plasma spraying. It is the powder operation that caught our interest and led to the study and plans described below.

WORK

Brief Description of Plasma Spraying Process[3]

The plasma spraying technique for applying coatings to materials developed out of the need for new materials and composites for high temperature wear and corrosion resistance of components used in the aerospace industry. It is a complex procedure that has as many as 50 parameters that affect the quality of the applied coating to the substrate material. It is easiest to think of the process as one that coverts powdered materials to a molten state and sprays this molten material onto the part to be coated. To produce the molten material, an electric arc is discharged across an electrode gap in which a gas to be converted to a plasma, and a carrier gas containing injected powder, has been introduced. Energy from the arc is transferred to the gas thus forming a plasma. The carrier gas, which contains the powder, experiences a transfer of energy and momentum from the plasma which subsequently melts the powder. The carrier gas and plasma gas are most commonly inert gases (Ar, He). This gas-to-plasma transformation occurs in a torch which contains a water-cooled cylindrical anode made from high conductivity copper. The cathode is conical in shape and is made from thoriated tungsten. The plasma generating gas and the powder carrier gas are introduced into the electric-arc discharge region through two different injection ports. The molten and partially molten powders which are contained in the plasma jet are subsequently deposited on the surface to be coated.

Two very important qualities that can affect the resulting coating properties are the melting characteristics of the injected powder feed stock and the rapid solidification that occurs when individual droplets impact a surface. Many difficult processing parameters can influence these qualitites, which include among others: the operating pressures, the types of plasma generating gases, the torch to substrate distance, and substrate temperature. In many cases, by optimizing and controlling the temperature and velocity of the impacting particles, high quality coatings can be achieved. A review of the effect of various parameters on the spraying of beryllium can be found in reference 3.

Sampling

We devised a method of sampling that would enable us to determine the amount of beryllium a worker could be exposed to, or a task would generate, and the steps of the task that produced the highest concentration of airborne beryllium. Following standard industrial hygiene (IH) techniques, a sampling train that ended with collection of particles on a filter was attached onto one lapel of a worker's personal protective clothing. A tube that led to a Laser Induced Breakdown Spectroscopy Monitor (LIBS), a real-time technique [4], was attached to the other lapel. Short duration side-by-side samples were thus obtained.

We collected side-by-side-samples using both the LIBS monitor and standard industrial hygiene technique. Sampling events occurred during various operations: cleaning the spray chamber, spraying parts, and conducting equipment repair and troubleshooting. Industrial hygiene samples were collected on filters using pre- and post-calibrated pumps operating at approximately 3.5 Lpm. These samples were analyzed using inductively coupled plasma technique according to the National Institue for Occupational Safety and Health (Method 7300) [5].

The portable LIBS monitor was equipped with a focused high-powered Q-switched neodymium:yttrium-aluminum garnet (Nd:YAG) laser. The laser beam induced a dielectric breakdown of air and formed a plasma spark in the sample stream drawn from operator's breathing zone. Beryllium particles in the region of the spark were vaporized and the resulting vapor exicited. A fiber-optic cable focused on the sample port collected the light emitted by the excited beryllium when it decayed to lower energy state. The light was directed to the entrance slit of a small spectograph tuned to the most intense beryllium line at 313.1 nm. In this work, a photomultiplier tube detected the beryllium emission and an analog-to-digital processor located inside the computer integrated the signal and digitized the resulting voltage. The resulting signals were stored in the computer's memory. Laser repetition was 10 hertz and a sample interval was 30 seconds. The sum of all the 30-second intervals provided a temporal exposure profile that was used to identify steps of the beryllium operation that are associated with peak personal exposures. Use of this instrument allowed real-time capability to identify which steps of the process contributed the most to the exposure levels experienced by the workers.

From the standard technique we saw that airborne beryllium concentrations were above standard limits and needed further control. Using the relative peaks and lows of real-time data, the investigators correlated work practices and control measures. This data was also used to identify potential areas or work steps of increased airborne concentation. From the LIBS data we saw that steps contributing to higher airborne concentration included: cleaning parts with a spray mist from a cleaning bottle, opening the chamber door, working deep within the chamber (leaning into the chamber), removing the plasma spray torch, and wiping/cleaning surface parts. Lower airborne concentrations were caused by: repair of equipment (after it was cleaned), vacuuming the inside of the chamber, and installation of parts within the chamber. Another event that contributed to airborne beryllium was the activity of personal after their protective clothing became contaminated. Activities such as lifting arms or slightly patting a dirty surface would suspend particles in the air.

As we acquired air samples using the dual sampling technique, it became apparent that existing engineering controls were not adequate, and that individual styles of work by the operators contributed to potential airborne beryllium concentration. Servicing the plasma spray chamber seemed to contribute significantly to the problem.

Observations by IH personnel within the plasma spray laboratory showed that workers received some degree of beryllium contamination on their protective clothing during servicing of the plasma spray chamber. Of course, engineering controls and personal protective equipment/clothing, including respirators, were used while performing this task, but we became concerned about the concentration of respirable dust near the operator and the degree of contamination being generated throughout the shop. We also observed that there were some operations that we knew contributed greatly to the soiling of protective clothing, e.g. leaning into the chamber to retrieve the plasma spray torch. Other steps of the operation were suspected to contribute to potential contamination.

The plasma spray laboratory as well as other areas of beryllium operatons are now being redesigned with additional engineering controls for beryllium particles.

PROPOSED ENGINEERING UPGRADES TO BERYLLIUM PLASMA SPRAY CHAMBER

Analysis of sampling results and current spray chamber design and engineering controls quickly led to the conclusion that we had to deal with two different aspects of work, each aspect having well defined boundaries. One aspect included the standard operation of the plasma torch within a vacuum chamber, and placement within and removal of samples from within the chamber. The other aspect included servicing and cleaning of the chamber. Consideration was also given to other sources of beryllium contamination such as the beryllium hoppers.

It was determined that with proper engineering design, control of hazards of both aspects of operation could be met by the following features (these are in addition to the already existing engineering controls mentioned earlier).

1. The plasma spray chamber will be augmented with a glove box for placement and removal of plasma sprayed parts, and for control of contamination during the maintenance of the plasma spray torch.
2. A small ante-room will be constructed on the exit of the plasma spray chamber.
3. Engineering upgrades will be completed so that the beryllium powder hoppers will be in a breakout hood.

Details of the engineering controls include construction of an 4.00" exhaust port on the back of the spray chamber which will be connected to a high pressure pick-up. A cyclone separator will remove approximately 85% of the particulates from the air before exhausting the air through the HEPA exhaust system. High pressure, pulsed gas nozzles will be installed inside the spray chamber to fluidize the oversprayed beryllium powder prior to exhausting and cleaning the chamber. Chamber exhaust will occur through exhaust ports that will be redesigned for the existing plasma spray chamber.

The entrance door to the spray chamber will be redesigned to include an ante-chamber with glove ports and an isolation door between the main spray chamber and the ante-chamber. The ante-chamber will be used for the maintenance of the plasma torch and for the transfer of parts in and out of the spray chamber. To position the plasma torch in the anti-chamber, the Y axis on the plasma torch X-Y manipulator will be extended. A translation table will be designed to allow the extension of plasma sprayed samples into the ante-chamber. These features will reduce the frequency of entry into the spray chamber. The potential will still exist for transferring the contamination within the plasma spray chamber to the ante-chamber. For this reason, ports for a vacuum cleaner hose will be located within the ante-chamber. In addition, a water line will be added to the ante-chamber with an outlet so that the ante-chamber and parts can be rinsed prior to opening the chamber door. Figure 1 shows the layout of the ante-room, glove box, and spray chamber. It also shows the proposed exhaust train from the cyclone separator to the HEPA filter.

A buffer area between the beryllium powder laboratory and remainder of the building will be provided by an air lock room. A 55 gallon drum with attached hood will be available to place soiled protective clothing prior to entering the air lock room or change room from the powder laboratory side. An emergency safety shower will be provided within the powder laboratory, and soft sided glovebags will be used to enhance maintenance efforts. Figure 2 shows the general layout of the powder laboratory. Other control features will include the wiping or washing of parts versus spraying of parts with mist, use of pressurized air, all parts will be cleaned prior to manipulation, and personal protective clothing will be worn including full face respirators.

CONCLUSIONS

Careful analysis of operating practices in the beryllium plasma spray laboratory were enhanced by detailed monitoring of personnel performing nominal tasks within the laboratory. Without the availability and use of a LIBS monitor, we could not have easily identified those practices that caused short term, high exposure situations. Use of the LIBS results with results from standard industrial hygiene sampling techniques allowed engineers to identify procedures and practices that can be controlled by proper design of the work area. We were fortunate that a building upgrade was being designed at approximately the time our results were available. The decision to upgrade the facility was influenced by the proposed expanded scope of beryllium work to be performed at Los Alamos. We feel the proposed facility design will greatly increase our ability to control airborne exposure to personnel and contamination of the work area. We intend to carefully monitor both the personnel working under the new procedures and processes during the operation of the upgraded beryllium plasma spray facility.

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   Brush Wellman, Inc.

   Department of Energy
   - Albuquerque, NM
   - Oakland, CA
   - Oak Ridge, TN
   - Rocky Flats, CO
   - Washington, DC

   EG&G Rocky Flats, CO

   Inhalation Toxicology Research Institute

   Lawrence Livermore National Laboratory

   Los Alamos National Laboratory

   Manufacturing Sciences Corporation

   Martin Marietta Energy Systems

   ORISE

   Pantex

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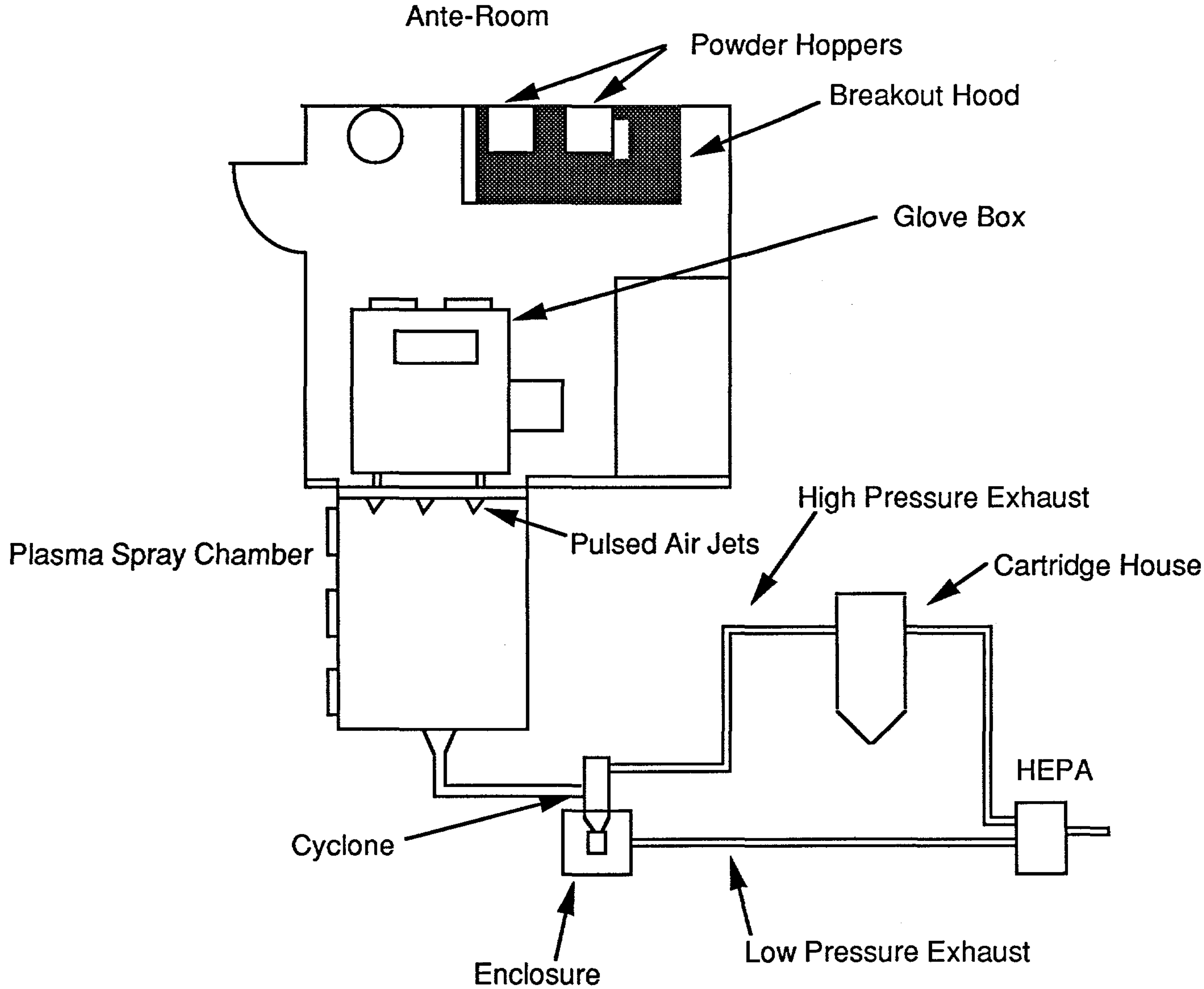

Figure 1

DETAIL OF ANTE-ROOM AND EXHAUST TRAIN

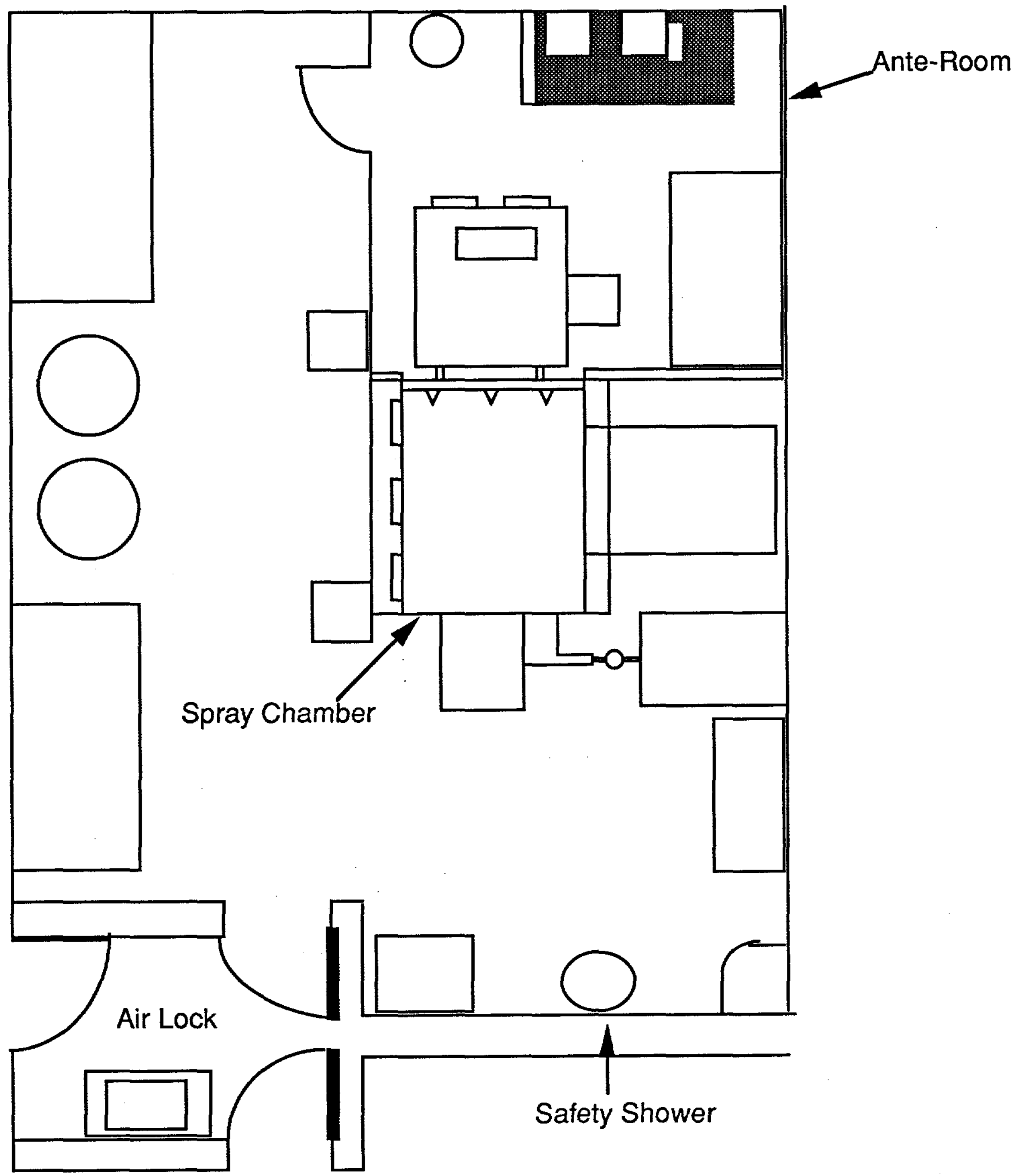

Figure 2

BERYLLIUM POWDER LABORATORY LAYOUT