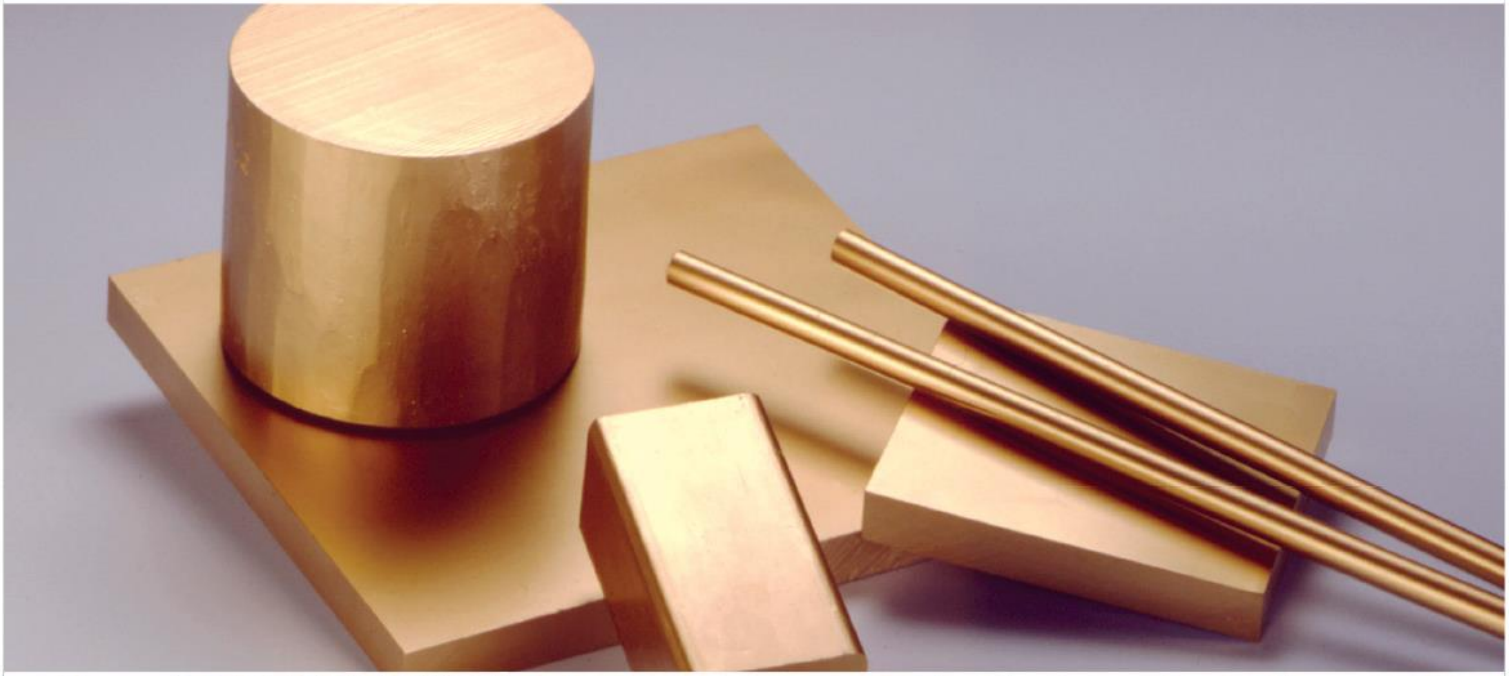
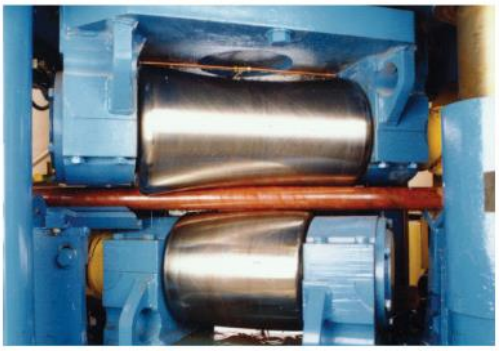
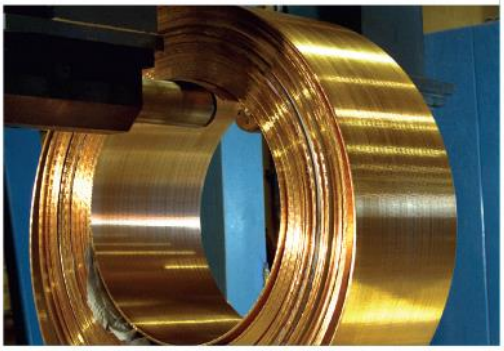
Be⁴ Responsible

Beryllium Product Stewardship

BERYLLIUM-CONTAINING MATERIALS







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Beryllium Science & Technology Association

BERYLLIUM SCIENCE & TECHNOLOGY ASSOCIATION
A VOLUNTARY BERYLLIUM PRODUCT STEWARDSHIP PROGRAM
BE RESPONSIBLE
MAY 2016

RATIONALE

Over the years the beryllium industry has worked to advance the science of beryllium health and safety to better protect beryllium workers, family members and the general public. It is expected the customers and users of beryllium containing materials will benefit from the creation of a Voluntary Beryllium Product Stewardship Program (Be Responsible) that formally engages workers, trade unions and governmental authorities in a cooperative arrangement that seeks to continuously improve worker safety during the production and processing of beryllium-containing materials.

Recent studies have added considerable clarity as to what protective methods are reducing the risks associated with occupational exposures to beryllium. These studies have resulted in the development of a Beryllium Worker Protection Model which can form the basis for a Product Stewardship Program (Be Responsible) as an effective means to providing greater protection to workers. With such a program, greater risk reductions can be achieved at lower costs through a proactive voluntary program than can be achieved by regulations or restrictions.

The industry has the technical resources to effectively support Be Responsible and will actively seek and encourage buy-in from downstream users toward achieving a much higher level of worker protection. The industry is prepared to work with member state authorities in jointly offering technical assistance particularly to small businesses that may not have the technical resources available to them. The program envisions a commitment toward continued working collaboration with trade unions, authorities, customers, downstream users, trade associations and other interested stakeholders.

This product stewardship program is directed to the processing and use of beryllium metal and beryllium containing alloys. It is well known that beryllium is a naturally occurring element and as a result, there are exposures in many industries not served beryllium industry. BeST does not have expertise in regards to exposures due to naturally occurring beryllium and takes no position on whether this program is appropriate or needed for the many industries having such exposures.

USES, BENEFITS, AND CRITICAL APPLICATIONS OF BERYLLIUM

Because of its unmatched combination of qualities, beryllium has become an important material for a wide range of commercial and governmental applications. Attachment 1 - Uses of Beryllium Beryllium brings unrivalled benefits to society Attachment 2 - The Benefits That Beryllium Brings To Society and is the material of choice in critical application where failure is not an option. Attachment 3 - Critical Applications of Beryllium.

80% of the beryllium used goes into copper beryllium alloys, that are used to exploit an unmatched combination of physical properties to produce highly reliable components of systems that protect lives and where failure could be either life-threatening or would provide lower performance and reduced quality of life.

POTENTIAL HEALTH EFFECTS FROM EXPOSURE TO BERYLLIUM

Beryllium metal, copper beryllium (CuBe) and other beryllium containing alloys, in solid form and as contained in finished products, presents no special health risks. Most manufacturing operations, conducted properly on well-maintained equipment, are capable of safely processing beryllium metal and beryllium-containing alloys. However, like many industrial materials, beryllium containing materials may present a health risk if handled improperly. The inhalation of dust, mist or fume containing beryllium can cause a serious lung condition in some individuals. The degree of hazard varies, depending on the form of the product, how it is processed and handled, as well as the amount of beryllium in the product.

The Beryllium Science & Technology Association (BeST) has prepared a Beryllium Safety Bulletin Overview (Attachment 4) that briefly describes the health hazards associated with exposure to beryllium, the main sources of exposure and the general control measures.

Manufacturers and distributors of beryllium products prepare safety data sheets (SDS) or product specific Safety Information Sheets that provide additional environmental, health and safety guidance that should be read and understood before working with alloys containing beryllium.

EVALUATING WORKPLACE EXPOSURES TO BERYLLIUM

The amount of beryllium dust or other airborne beryllium particulate released in the processing of a beryllium product determines the extent of exposure control needed to protect workers. To determine the levels of beryllium exposures in a given workplace, the collection of air samples is necessary. Measurements may be made both of the beryllium concentrations encountered by individual workers and of the levels in work areas. An industrial hygienist or other qualified professional should be used to establish a sampling plan. The primary supplier, member state authorities and BeST can provide references or assistance as needed.

The air-sampling survey will identify concentrations expressed as micrograms of beryllium per cubic meter of air ($\mu g/m^3$). The employer must compare the beryllium levels found in the survey with the legally enforceable limits imposed by the standard adopted for occupational exposure to beryllium by each member state. Besides serving as an index of compliance, the survey results will, if exposure measurements are made at individual operations, show where to concentrate control efforts. A well-designed control program strives to reduce exposure to as low as reasonably achievable, not merely reduce it to some numerical maximum. The Beryllium Science & Technology has developed an Exposure Assessment Strategy Tool that can be used as a guide and also as a training tool. (Attachment 5). In addition, the European Chemicals Agency (ECHA) has developed a more complex guide that can also be used Occupational Exposure Estimation .

CONSIDERATIONS FOR SPECIFIC OPERATIONS

Best has developed safety practices for specific operations as detailed below. In addition, BeST has developed communications on the results of case studies performed on specific operations where copper beryllium (CuBe) alloys are processed that provide the reader with information on exposure and exposure control options such as work practice, administrative and engineering controls.

Machining Copper Beryllium Alloys
Drilling, Boring, Milling, Turning, Tapping, Reaming, Sawing, etc.

Copper beryllium is a ductile metal that machines easily, generally producing large chips and turnings. Processes that generate large particles are usually performed in an open shop environment with no special ventilation or housekeeping practices required. Machining processes that do generate small particles must be controlled with appropriate work practices and engineering controls. Best has prepared a Safety Bulletin "Safety Practices for Machining Copper Beryllium Alloys" for use by end users Attachment 6. Additionally, a more detailed guide for machining copper beryllium alloys for use by end users is offered in Attachment 7.

Benching
Sanding, grinding, buffing, lapping and polishing

These machining processes are capable of generating small particles. These processes must be controlled with appropriate work practices and engineering controls. BeST has prepared a Safety Bulletin "Safety Practices for Sanding, Grinding, Buffing, Lapping and Polishing Copper Beryllium Alloys" for use by end users Attachment 8. BeST has also prepared a case study report on benching operations Attachment 9.

Stamping Copper Beryllium Alloys

Copper beryllium alloys are stamped into a variety of shapes, sizes and designs for use in electrical and electronic equipment. The manufacturing operations commonly associated with precision stamping can safely process copper beryllium alloys. The latest scientific evidence indicates that airborne beryllium exposure levels experienced at precision stamping operations are not sufficient to adversely affect health. Special controls are not required during the precision stamping, die repair, and inert atmosphere heat treating of copper beryllium alloys. Best has prepared a Safety Bulletin "Safety Practices for Precision Stamping Copper Beryllium Alloys" for use by end users Attachment 10. BeST also has developed a case study report on stamping Attachment 11.

Welding (A Special Case)

Welding or cutting (with a gas flame or electric arc) indoors, outdoors, or in confined spaces, involving beryllium-containing base or filler metals must be done using local exhaust ventilation and airline respirators unless atmospheric tests under the most adverse conditions have established that the workers' exposure is within the acceptable concentrations. In all cases, workers in the immediate vicinity of the welding or cutting operations shall be protected as necessary by local exhaust ventilation or airline respirators. BeST has prepared a Beryllium Safety Bulletin for safety practices for welding on copper beryllium alloys Attachment 12.

Casting and Alloying

Safe foundry practices must be employed when working with beryllium alloys. Furnace ventilation is required to capture fume and particulate generated during melting operations. The configuration and extent of ventilation must be designed for the specific application. One type of melting furnace, for example, may by its very design create little air contamination, while another may require more sophisticated engineering controls. Implicit in all foundry operations are the difficulties of handling molten metal and drosses plus the cutoff and finishing operations that are usually involved. BeST developed an overview of safety practices for copper beryllium foundry operations Attachment 13.

The importance of controlling airborne beryllium contaminant from drosses in an alloy foundry cannot be overlooked. Chemical analysis has shown that drosses frequently carry higher

concentrations of beryllium than the alloys originally melted. Dross, moreover, is easily airborne, a characteristic which intensifies the need for appropriate management and control.

Ram Electrical Discharge Machining (EDM)

Ram EDM uses spark erosion to remove metal. When sufficient voltage is applied, the dielectric oil ionizes and controlled sparks melt and vaporize the work piece. As the metal melts and vaporizes, metal fumes are emitted. To control visible fuming and potential exposures, a properly designed ventilation system is recommended when conducting EDM on beryllium-containing alloys. BeST has developed a case study report on an EDM operation Attachment 14.

Computer Numerically Controlled (CNC) Lathe on Copper Beryllium Alloys

A CNC Lathe involves digitally automated machining of a rotating part mounted onto a chuck. CNC Lathe operations are generally performed in enclosed machining centers with a flooding of machining fluids. These machining centers allow for a variety of complex machining operations such as boring, turning, cutting, drilling and routing. The water soluble machining fluids are used to lubricate and cool the cut and to flush away the resulting swarf. This containment and flooding of swarf in the enclosed machining centers minimizes the release of particulate. BeST has developed a case study report on a CNC operation Attachment 15.

CONTROLING WORKPLACE EXPSOURES

Facilities handling beryllium-containing materials in ways which generate particulate are encouraged to use engineering and work practice controls, including personal protective equipment, to control potential worker exposure. Exposure controls to keep beryllium work areas clean and keep beryllium particulate out of the lungs, off the skin, off of clothing, in the work process, in the work area and on the plant site must be evaluated and implemented as appropriate. It remains the best practice to maintain levels of all forms of beryllium exposure as low as reasonably achievable, and continue to work to improve exposure control practices and procedures.

The primary instruments for exposure reduction are engineering controls. Of these, local exhaust ventilation, which captures contaminants at the point of release, is the most useful. Valuable, and often essential, supplements to engineering measures are work-practice controls. An illustration is prohibiting compressed air for cleaning and providing vacuum-sweeping equipment equipped with a high efficiency filter. An effective housekeeping program to prevent accumulations which might become airborne and the development of written standard operating procedures (SOP's) that specify safe handling practices are work practices that are absolutely required.

Wet processing is often an effective means of controlling the generation of airborne particles. Care must be given to prevent splashing or misting that could carry alloy particles away from the operation. Inadequate coolant flow or high tooling speeds may necessitate the need for additional containment or ventilation controls. Machining lubricant should be filtered and changed frequently to reduce the accumulations of particulate.

Still another type of exposure control is the respirator. For a number of reasons, it is the least preferred in the hierarchy of controls. Improper fit may not provide adequate protection and respirators can be uncomfortable. The best practice is to confine the use of respirators to operations for which satisfactory engineering of work-practice controls have not been developed, to maintenance work, to emergency situations, and to operations awaiting the results of exposure measurement.

BeST developed a Sources of Exposure Tool that characterises risk potential by operation and addresses specific operational concerns. The tool can also be used as a training aid (Attachment 16).

MEDICAL SURVEILLANCE OF WORKERS

Employer should follow the requirements established by the respective member states regarding occupational health surveillance. However, BeST recommends any worker who exhibits signs or symptoms of exposure to beryllium metal be evaluated by a physician having expertise in chronic lung diseases.

BERYLLIUM WORKER PROTECTION MODEL

The Beryllium Worker Protection Model developed over time and is the heart of Be Responsible and is based on eight elements that are to be embraced by management and workers alike.

Keep Beryllium	
➢ Out of the lungs	➢ Work areas clean
➢ Off the skin	➢ Off of the clothing
➢ At the source	➢ In the work area
➢ On the plant site ;	➢ Workers prepared

It is obvious that keeping beryllium out of the lungs is of utmost importance. However, it is difficult to reach definitive conclusions regarding the contribution of each of the other model elements toward disease prevention. It is likely that the use of all elements has contributed to and reinforced the success in the others. The comprehensive nature of exposure control rather than quantitative achievement in any one component drives this model.

This model is demonstrating that industrial hygiene concepts developed for the control of general toxins in relatively high concentrations (mg/m^3) need significant modification when applied to very low concentrations (< 1 µg/m^3) of airborne particles. The application of this model may also prove useful in controlling exposures to other materials with low occupational exposure limits or with materials where health risks are suspected, but yet to be defined (nanoparticles). It is understood that this model is not a one size fits all approach and that end users may need all or only part of this model in their workplace.

The success of this model supports the hypothesis that exceptional beryllium safety performance can be achieved by a combination of operating manager ownership of safety, a disciplined use of the beryllium worker protection model and active worker involvement.

The eight operational goals are defined below and further described in Attachments 17 – 25.

Keep Beryllium Out of the Lungs

The main goal of the Beryllium Worker Protection Model is to Keep Beryllium Out of the Lungs. Keeping beryllium-containing particles out of the lungs will ultimately prevent chronic beryllium disease (Attachment 17).

Keep Beryllium Work Areas Clean

One of the corner stones of the Beryllium Worker Protection Model is Keeping Beryllium Work Areas Clean. The goal is to have work areas clean and shipshape which means areas are visibly clean, well lit, orderly and free of clutter. When work areas are disorganized, cluttered and dirty, it is more difficult to control worker exposure to potentially hazardous materials. Having all surfaces painted and visually attractive will make it easier to determine when surfaces are not visibly clean (Attachment 18).

Keep Beryllium Off of the Skin

Keeping beryllium off of the skin is highlighted to avoid beryllium-containing particles entering the skin through cuts, abrasions and rashes. Beryllium-containing particles on the skin can also result in inhalation exposure due to hand and arm contact with the face (Attachment 19).

Keep Beryllium Off of the Clothes

Keeping beryllium off of the Clothing is emphasized because beryllium-containing particles and solutions on clothing can be a source of worker exposure and a major path way in which beryllium is carried out of the work area (Attachment 20).

Keep Beryllium at the Source

Keeping beryllium at the source is the first line of defense in controlling worker exposure. The idea is that if beryllium-containing particles are not produced by the process or are captured and never leave the source, then the particles cannot become airborne to reach the lungs of workers (Attachment 21).

Keep Beryllium in the Work Area

Keeping beryllium in the work area is the second line of defense in controlling worker exposure as well as exposure to others. The goal is to make sure beryllium-containing particles and solutions do not spread from beryllium work areas to work and support areas where beryllium work is not performed (Attachment 22).

Keep Beryllium on the Plant Site

Keeping beryllium on the plant site is the third line of defense in controlling worker exposure as well as exposure to others. When beryllium-containing particles leave the plant site on people and things such as personal items, clothing, laundry, tools, products or equipment, potential exposures to others can result (Attachment 23).

Keep Beryllium Workers Prepared

Keeping beryllium workers prepared is how the other elements are accomplished. If managers have prepared themselves and their organizations to manage beryllium operations and tasks, and workers know and have the skills to work properly, maintain equipment, recognize breakdowns or upset conditions, and take preventive actions, and are motivated to do so consistently, experience has shown that beryllium exposure can be controlled to desired levels, and CBD can be prevented.

BeST has developed an employer's guide that concentrates on what is needed for protecting workers (Attachment 24). BeST has also developed a training module for workers that provides information that workers need to know to work safely with beryllium containing materials of the worker protection model and what they need to know about protection (Attachment 25).

KEY FEATURES OF VOLUNTARY BERYLLIUM PRODUCT STEWARDSHIP PROGRAM

Recommended Exposure Guideline (REG)
Be Responsible adopts a daily REG of 0.2 µg/m³ 8-hour TWA and recommends that exposure levels be maintained reliably below the REG. The daily REG is not theoretical or an extrapolation, but has been substantiated in a number of workplace studies. Even with the daily REG, Be Responsible encourages reducing exposures to the lowest level that is feasible and practical. It is also recommended that a short term REG of 2.0 µg/m³ over 15 minutes be utilized as a tool for keeping workers protected from high exposures. The short term REG is based primarily upon the findings of a study conducted in Europe at the Atomic Weapons Establishment in the UK.

Control Measures
The Beryllium Industry has developed Safety Practices for operations processing beryllium containing products that are most frequently performed in the EU. However, users should examine available engineering and process control technologies and employ practicable methods to reduce ambient beryllium concentrations, where appropriate. It is expected that engineering and process controls may be ineffective in many applications hence respirator use may be required. Be Responsible focuses on protecting the employee first with respiratory protection rather than waiting for the implementation of improved engineering or work practice controls.

Be Responsible is generally premised upon reducing beryllium exposures using all available methods. In most instances, the application of engineering and work practice controls should be able to reduce exposure levels for most operations and tasks to levels below 0.2 µg/m³. It is recognized there are processes such as; melting, powder handling and arc furnace operations that, even with extensive engineering controls, have exposure potentials exceeding 2.0 µg/m³. The 0.2 µg/m³ recommendation as an engineering and work practice control limit is a useful benchmark in this regard; however, where it is feasible to reduce workplace concentrations to levels below 0.2 µg/m³, it is prudent to do so.

Exposure Evaluations
It must be noted that the REG is based on the closed faced filter cassette total sampling method (CFC) as is used in the United States and many other countries. Some member states measure exposures to beryllium and other metals using the inhalable sampling method. This method collects much larger particles and therefore generally gives results 2-3 times higher than that of the CFC. The world's largest producer of beryllium products (Materion) sponsored the most comprehensive sampling method comparison study ever conducted. The study concluded a conversion factor of 2.89 was appropriate for the copper beryllium operations most commonly conducted in Europe.

Training – Be Responsible will provide and disseminate beryllium health and safety training information consistent with the evolving science relative to protecting workers.

Product Research – Be Responsible will continue to encourage and promote research on beryllium health and safety. The research will attempt to identify specifically the preeminent casual factors that lead to or increase the risk of chronic beryllium disease. In this regard, it is

expected that the influences of chemical form, surface area, particles size and particle number will continue to be evaluated. Because CBD is a granulomatous lung disease confined primarily to the alveolar region of the lung, it has been proposed by some scientists that CBD is not caused by particles greater than 10 μm in diameter, which are unable to deposit in the tracheobronchial region of the lung. Some researchers suggested the dose-response relationship between beryllium exposure and CBD might be obscured by CFC measurements. It was observed that the particle size characteristics varied depending on the type of beryllium process. For process areas that were associated with a size distribution of particles greater than 5 μm, there were fewer reported cases of CBD and sensitization compared to process areas that measured the greatest distribution of particles less than 5 μm. Therefore, sampling respirable particles may be a better predictor (exposure metric) for CBD than CFC method of airborne beryllium particles. There are no studies that would validate the use of the inhalable sampling method.

It has also been suggested that CBD may be linked to genetics and the advances in genetic research may alter or refine existing practices. While many aspects of the etiology of CBD are still unclear, researchers have identified a genetic marker that appears to significantly increase the probability that a worker will develop CBD. Future research is needed as it could benefit workers who are highly susceptible to avoid beryllium exposure in the workplace.

Consumer Products – Beryllium, in consumer products, has a very low potential for causing consumer health or environmental risk. While the general population is exposed to beryllium in soils, water and foodstuffs on a daily basis, the most predominant source of airborne beryllium is from the combustion of coal. Uses in consumer applications do not pose exposure risks because either the beryllium-containing part or structure is not easily accessible or the part remains as a solid structure through its useful life. Materion has conducted a number of studies in electronic scrap recycling process. The studies have shown that beryllium exposure profiles present little risk, if any, to workers. The Beryllium Science & Technology Association (BeST) will monitor end use applications for beryllium containing products so that health and end of life exposure risks continue to be minimal.

Waste Minimization and Disposal – Be Responsible will include waste minimization and scrap recycling initiatives designed to reduce quantities of waste produced per unit of product and to increase recycling rates where feasible.

Evaluation –Be Responsible calls for a partnership with authorities, trade unions and trade associations to meet periodically to review the latest available information on beryllium and the overall effectiveness of this Program. The members of BeST agree to share and discuss significant developments in the scientific and medical assessment of beryllium products. It is anticipated that member state authorities will provide summary information on inspections and an assessment of overall compliance and to make the information gained through this Program publicly available.

SUMMARY

The members of BeST believe that this product stewardship program addresses the key components necessary to achieve a high degree of safety for workers in the primary beryllium industry through downstream users of beryllium-containing materials. BeST recognizes that substantial uncontrolled workplace exposure to beryllium can present a potential health and safety hazard to employees. This program is intended to minimize any such potential hazard. BeST recognizes that it is prudent to adopt beryllium exposure controls where feasible and

necessary, and that compliance with Be Responsible will reduce potential health risks in places of employment and other activities involving beryllium manufacturing or use. Further, BeST and regulatory authorities recognize that Be Responsible is an appropriate vehicle for encouraging the continued reduction of beryllium workplace exposures, at both manufacturing and end-user facilities, and that there are engineering controls, work practices and personal protective equipment readily known and available to implement the provisions of the Program. It is clear to the parties involved with this initiative that innovative, out of the box thinking, coupled with the total involvement of the workforce sets the stage for a firm commitment to eliminate CBD.
the workforce sets the stage for a firm commitment to eliminate CBD.