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16. Abstract (Limit: 200 words) This project was designed to access data, provide preliminary exposure rankings, and delineate the process for detailing retrospective exposure assessments for beryllium (7440417) among workers at processing facilities. A literature review was conducted, and walk through surveys were conducted at two facilities still in operation. More than 8,000 environmental records were entered into a computer file. Descriptive statistics were then generated and the process of rank ordering exposures across facilities was begun. In efforts to formulate crude indices of exposure, job titles of persons in the NIOSH mortality study were reviewed and categorized for any beryllium exposure, chemical form of beryllium exposure, and exposure to acid mists. Daily Weighted Average exposure estimates were reviewed by job title, across all facilities. The mean exposure at each facility was calculated. The strategy which was developed for retrospective exposure assessment was described. Tasks included determination of the usefulness of the Pennsylvania Workers' Compensation files; cataloguing the numbers of samples available from company sources; investigating data holdings at Oak Ridge National Laboratory; and obtaining records from the Department of Energy Library.					
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Final Performance Report  
Grant No. 1 R03 OH02375-01  
Title: Development of Methods to Estimate Beryllium Exposure  
Carol Rice, Ph.D., Principal Investigator

## I. Description of the Research

The focus of this project was the historical beryllium exposure data contained in files at the National Institute for Occupational Safety and Health (NIOSH). As part of an ongoing study of potential adverse health effects of beryllium exposure among persons employed in processing facilities, NIOSH researchers anticipated the need for exposure assessment to complement a mortality study. Exposure data collected over the years by NIOSH and other agencies, but included in NIOSH archives, had never been computerized. This work was undertaken to access the data, provide preliminary, crude ranked exposures and delineate the process for undertaking a detailed retrospective exposure assessment.

The specific aims were:

1. To computerize all environmental data on beryllium exposures at the processing plants included in the study that were available through NIOSH,
2. To rank exposures by work area and job title, across all plants, and
3. To propose a strategy for reconstructing quantitative estimates of exposures to beryllium.

## II. Results

This project has been conducted in several parts. First, the literature was reviewed to develop a detailed understanding of production processes at each facility. Next, walk-through surveys were conducted at the two plants still in operation. At the processing plants, the availability of additional exposure or supporting information was explored; additional sources of data

were also documented. Concurrently, data in the NIOSH files were computerized. For job titles available from the work records of persons in the NIOSH study, the chemical form of the beryllium exposure and proximity to acid mist operations were reviewed. Issues to be address in a quantitative, retrospective exposure assessment were described.

Each of these activities is detailed below.

### Production Processes

Beryllium is extracted from ore by either the sulfate or fluoride method. In the sulfate process, beryl ore is heated and then water quenched to produce a frit. The frit is heat treated, ground and mixed with sulfuric acid. The ore/acid slurry impinges on a heated surface, forming beryllium and aluminum sulfates. The aluminum sulfate is removed with the addition of ammonium hydroxide. With the addition of sodium hydroxide, beryllium hydroxide is formed. The feed stock for the fluoride method is crushed beryl ore, which is mixed with sodium ferric fluoride, sodium silica fluoride, soda ash and graphite; the mix is formed into briquettes which are sintered, milled and mixed with water to form a slurry. Beryllium hydroxide is precipitated following addition of sodium hydroxide.

The beryllium hydroxide is converted to oxide for ceramic manufacture or further processed to beryllium metal for alloy production. Foundry and/or machining operations complete the production processes.

The chemistry of production processes was detailed in an internal document "Beryllium Production Methods" which is attached as Appendix I. These are summarized below by plant.

## Summary of Individual Plant Processes

### Plant #1

1. Production of Q.M.V. (I-J)\*
2. Metal Machining
3. Ceramic Machining (D-3)

### Plant #2

1. Ore Extraction (Sulphate - C)
2. BeO/Ceramic Production (D)
3. Metal Production (E-I)
4. Fabrication
5. Alloy Production

### Plant #3

1. Conversion of  $\text{Be}(\text{OH})_2$  to BeO (Hi-purity A4-5)
2. Some ceramic production, but majority of BeO is sold
3. Alloy Production
4. Fabrication and Foundry

### Plant #4

1. Ore Extraction (Fluoride - A)
2. Metal Production (E-I)
3. Metal Machining

### Plant #5

1. Ore Extraction (Sulphate - C)
2. Metal Production

\*Number and letter designations refer to Beryllium Production Methods prepared by M. Cornett.

## Walk-Through Surveys

Arrangements were made to visit the two facilities currently in operation: Brush-Wellman, Elmore, OH facility; NGK Metals, Reading, PA. Detailed reports of the visits were completed and are attached; see Appendices II and III.

## Search for Additional Environmental Data and/or Production Information

As part of the walk-through surveys, plant management personnel were queried to determine if additional environmental or supporting information (plant history, engineering control records) might be available. At Brush-Wellman, approximately seven file drawers of Daily Weighted Average (DWA) calculation sheets were located. Descriptive information and some quantitative exposure data were found for the Lorain facility; less environmental data exist for this plant as it burned in 1947, shortly after the original air sampling method was developed. Data for the Luckey plant spanned 1949-1958. The earliest Cleveland site data recorded was 1950. The early data substantially augment that included in the NIOSH files. Additionally, several long-term employees very familiar with plant layout over time were identified.

At the Reading plant, 1960s quarterly DWA and excursion data were reviewed. Some information is available on job classifications. The industrial hygienist from the Hazelton plant has moved to the Reading facility; his notebooks on Hazelton and his recollection are important resources.

Additional sources of data were also explored. None were identified through the Ohio Industrial Commission or the Pennsylvania Department of Natural Resources. The Pennsylvania Workers' Compensation office personnel can retrieve environmental reports from claim files, if the individual's name

is available. This could be a valuable source of early records, if company personnel will list the names of all persons who filed beryllium-related claims.

Because the initial beryllium samples were collected by the Atomic Energy Commission, it was decided to visit the library at the former New York Operations Office (NYOO), now the Department of Energy (DOE). Substantial environmental data and supporting documents were found, as evidenced in the attached inventory of its beryllium files (Appendix IV). Efforts to identify the current location of data forwarded to the Chicago or Cleveland Operations Offices were not productive.

Personnel at Cabot Corporation, a former owner of the Hazelton and Reading plants were contacted to identify whether or not data are held at the corporate office. This search has not been completed.

During the 1960s, a beryllium library was set up at the Oak Ridge National Laboratory. A former NYOO employee recalled that some records were transferred from New York to Oak Ridge. No attempts were made to verify this information.

#### Data Abstraction/Computerization

More than 8,000 environmental records were entered into a computer file. Descriptive statistics were generated and the process of rank ordering exposures across plants was initiated. Further work is needed in this area to merge job titles listed on personnel records with those in the environmental file.

#### Exposure Indices

Two approaches were taken to formulate crude indices of exposure. First, job titles of persons in the NIOSH mortality study were reviewed and categorized for any beryllium exposure, chemical form of beryllium exposure,

and exposure to acid mists. The form was considered important due to the possible varying toxicity of beryllium between the chemical species; acid mist exposure was included because of the potential association with lung cancer.

The results of this effort are shown in Appendix V. A range of types of exposure are noted. While it is virtually impossible to partition measured beryllium exposure into chemical form, a categorical variable for exposure type(s) could be useful in epidemiologic data analysis.

Second, DWA exposure estimates were ordered by job title, across all plants. The mean exposure at each facility was calculated. These values provide ranked exposure categories. An example is shown in Appendix VI. Further work will be required to ensure that the job titles listed in the environmental file are consistent with those on the work histories.

#### Strategy for Retrospective Exposure Assessment

This is one of the few instances in retrospective exposure assessment where the amount of environmental data is substantial. The following steps are proposed for the retrospective exposure assessment.

1. Determine the usefulness of the Pennsylvania Workers' Compensation files by requesting a random sample be searched for environmental records.
2. Catalogue the numbers of samples, by years, available from company sources. Compare with computer file. For areas of overlap, select a random sample of hard data forms to computerize and compare with NIOSH data to evaluate potential biases.
3. Investigate data holdings at Oak Ridge National Laboratory.
4. Obtain records from the DOE Library.

With the completion of tasks 1-4, a decision must be made as to what additional data to computerize.

5. Computerize any additional data.
6. Investigate biases in the data, by sources.
7. Investigate time-trends in exposure data, by task or job.
  - a. Are conversion factors necessary between sampling methods?
  - b. Can apparent changes in exposure be explained by documented process or physical alterations?
8. Describe component tasks for jobs without DWA formulae, or which are documented to have changed over time.
9. Determine quantitative exposure estimates by job, plant and time.
10. Form a categorical variable for chemical form of beryllium exposure, and proximity to acid operations.

### III. Publications

None

### IV. Presentations

"Retrospective Assessment of Beryllium Exposures," C. Rice, D. Seiler, M. Cornett and R. Herrick, American Industrial Hygiene Conference, May 1988 (poster presented by D. Seiler).

Abstracts and visuals attached as Appendix VI.

## Beryllium Production Methods

- A. Conversion of Beryl Ore to Be O Using the Fluoride Extraction Method
- B. Conversion of Be O to Be Cu Alloy
- C. Conversion of Beryl Ore to  $\alpha$  Be(OH)<sub>2</sub> by Sulphate Extraction Method
- D. Be O Ceramic Production
- E. Conversion of  $\alpha$  Be(OH)<sub>2</sub> to (NH<sub>4</sub>)<sub>2</sub> Be F<sub>4</sub>
- F. Conversion of (NH<sub>4</sub>)<sub>2</sub> Be F<sub>4</sub> Salt to Be F<sub>2</sub>
- G. Conversion of Be F<sub>2</sub> to Be Metal Pebbles by Magnesium Reduction
- H. Conversion of Be Pebbles to Vacuum Cast Ingot (Remove Mg Content)
- I. Production of Q.M.V. Powder
- J. Production of Finished Be Metal

## Beryllium Production Processes

### A. Conversion of Beryl Ore to Be O Using the Fluoride Extraction Method

#### Step 1

Input: Beryl ore

Process Step: Beryl ore ground in wet ball mill to 200 mesh and filtered on a rotary filter

Products: Ground ore

Exposure:

#### Step 2

Input: Ground ore, sodium fluosilicate ( $\text{Na}_2 \text{Si F}_6$ ), and soda ash ( $\text{Na}_2 \text{CO}_3$ )

Process Step: The contents are mixed in a mulling type mixer. This mixture is a wet paste (dough-like) which is made into briquettes and put in kiln for sintering ( $750^\circ\text{C}$  for 2 hours).

Products: Sintered bricks of the above mentioned compounds

Exposure: Be dust, beryllium fluoride fume, sodium fluorosilicate

#### Step 3

Input: Sintered bricks

Process Step: The bricks are jaw-crushed and put through a wet-pebble mill. The ground bricks are put into a tank with water and aggitated. The insoluble compounds are allowed to settle out and the water, which contains the soluble Be salt ( $\text{Na}_2 \text{Be F}_4$ ), is drained off. This hot water leaching process is usually repeated three times.

Products: Na<sub>2</sub> Be F<sub>4</sub> solution

By-Products: the solid wastes: SiO<sub>2</sub>, Fe<sub>2</sub> O<sub>3</sub>, Al<sub>2</sub>O<sub>3</sub>.

Exposure: Sodium beryllium fluoride

#### Step 4

Input: Na<sub>2</sub> Be F<sub>4</sub> solution plus caustic soda (NaOH)

Process Step: A small portion of the salt solution is added into a tank, just enough to cover the steam coils and agitator. The caustic soda is added in and some Be is precipitated out and then redissolved into sodium beryllate. The tank is then gradually filled with more of the Be salt solution and the tank contents are kept near boiling during the entire addition. This procedure causes the Beryllium hydroxide (Be(OH)<sub>2</sub>) to precipitate out of solution. The Be(OH)<sub>2</sub> is then filtered in a filter-press of the thorough washing type, washed, and blown dry with air.

Products: Be(OH)<sub>2</sub> (solid)

By-Product: NaF solution

Exposure: Be(OH)<sub>2</sub>

#### Step 5

Input: Be(OH)<sub>2</sub>

Process Step: The Be(OH)<sub>2</sub> is placed in an externally-fired rotary kiln and calcined to BeO by heating to about 1000°C.

Products: Be O

Exposure: Be O, Be(OH)<sub>2</sub>

#### Step 6 (Recycling Step)

Input: NaF solution

Process Step: The NaF solution (from Step 4) is then acidified with sulfuric acid and a 30% ferric solution is slowly added ( $\text{Fe}_2(\text{SO}_4)_3$ ) into the tank with agitation. The  $\text{Na}_3 \text{Fe F}_6$  is precipitated and filtered out, this compound is reused in Step 2. The remaining solution ( $\text{Na}_2\text{SO}_4$ ) is waste.

Products:  $\text{Na}_3 \text{Fe F}_6$  (reused)

By-Products:  $\text{Na}_2\text{SO}_4$  solution (waste)

Exposure:

## B. Conversion of Be O to Be Cu Alloy

### Step 1

Input: Be O, ground carbon, copper chips, dross

Process Step: Weigh out the appropriate quantities of the above mentioned materials and mix them in a rotating mill.

Product: Even mixture of the materials

Exposure: Be O dust, carbon dust

### Step 2

Input: Be O/Cu mixture

Process Step: This mixture is fed into electric arc furnace in 100 lb. batches every 15 mins. Additionally amounts of copper alloy are added in order to dilute to the necessary Be concentration (~3000 lb.). Furnace temperature is about  $1900^\circ$  (Ajax furnace).

Product: Molten mixture

Exposure: Be-Cu alloy fume

### Step 3

Input: Molten mixture

**Process Step:** When contents are melted, the mix is poured into a transfer pot and allowed to cool to 1300°C. Then the contents are poured into another crucible for additional cooling. Within the second crucible, the contents are stirred occasionally and impurities float to surface and are removed.

**Products:** Purified molten alloy

**Exposure:** Be-Cu fumes

#### Step 4

**Input:** Molten alloy

**Process Step:** The molten alloy is cast into ingots graphite molds (usually 3-5% Be)

**Products:** Cu Be ingots

**Exposure:** Be-Cu fumes

#### Step 5 (Recycle Step)

**Input:** Furnace dust (collected by air filters), impurities, and transfer pot cleanings.

**Process Step:** The above compounds are placed in a ball mill and ground for later addition in furnace.

**Product:** Recyclable material

**Exposure:** Be O dust

### C. Conversion of Beryl Ore to $\alpha$ Be (OH)<sub>2</sub> by Sulfate Extraction Process

#### Step 1

**Input:** Beryl ore

Process Step: The beryl ore is crushed and then conveyed to furnace in batches.

Product: Ground ore

Exposure: Dust from ore

### Step 2

Input: Ground ore

Process Step: The ore is melted in an electric arc furnace (melting pt. 1650°C) and the molten ore is poured through a high velocity water jet into a water quench tank.

Products: Particle of quenched ore, called "frit"

Exposure:

### Step 3

Input: Frit

Process Step: The frit is screened to remove large particles which are recycled to melting furnace.

Products: Small particles of frit

### Step 4

Input: Screened frit

Process Step: The frit is then heat treated to increase Be O extraction efficiency

Products: Heat-treated frit

### Step 5

Input: Heat-treated frit

Process Step: The heat-treated frit enters a ball mill which grinds the frit to -200 mesh size. A pneumatic classifier works continuously with the grinder to remove the -200 mesh particles.

Products: -200 mesh particles

Exposure: Dust from ore

### Step 6

Input: 200 mesh ore particles

Process Step: The ground ore is mixed with concentrated sulfuric acid and forms an acid-ore slurry. This slurry is pumped in a small jet where it impacts on the surface of a pre-heated sulphating reactor (250-300°C). The impaction on the hot surface nearly instantaneously yields  $\text{Be SO}_4$ .

Products:  $\text{Be SO}_4$

By-Products:  $\text{SO}_2$  and  $\text{SO}_3$  gases

Exposure:  $\text{SO}_2$  and  $\text{SO}_3$  gases are liberated from sulphating process but are recycled through cyclone separator and packed scrubbing tower because of slight ore content.

### Step 7

Input: Sulphated ore

Process Step: The process material is dumped into water tanks, where the materials enter a leaching and centrifuging system to remove the silica content.

Products:  $\text{BeSO}_4$  solution which also contains high amounts of aluminum.

Exposure:

### Step 8

Input:  $\text{BeSO}_4$  solution

Process Step: The  $\text{BeSO}_4$  solution is continuously blended with ammonium hydroxide ( $\text{NH}_4\text{OH}$ ) and fed into a crystallizer which crystallizes about 75% of all aluminum as ammonium alum. The slurry is fed into a centrifuge where crystals are separated out and washed.

Products:  $\text{BeSO}_4$  solution with reduced aluminum levels

Exposure:  $\text{NH}_4$

#### Step 9

Input:  $\text{BeSO}_4$  solution

Process Step: The  $\text{BeSO}_4$  solution is fed into a beryllating reactor with chelating agents (EDTA and TEM) and dilute sodium hydroxide. The reactants are water cooled to prevent formation of  $\beta$  beryllium hydroxide. The Be in the solution is converted to beryllate and remaining Al is converted to aluminate.

By-Products: Beryllate and aluminate solution

Exposure:

#### Step 10

Input: Beryllate and aluminate solution

Process Step: The solution is continuously transferred to a hydrolyzer which is kept at boiling and causes precipitation of  $\alpha$   $\text{Be}(\text{OH})_2$ . This slurry goes into a continuous centrifuge where  $\alpha$   $\text{Be}(\text{OH})_2$  is separated out and washed.

Products:  $\alpha$   $\text{Be}(\text{OH})_2$

Exposure:

### Step 11

Input: Solution from centrifuge containing some  $\alpha$   $\text{Be}(\text{OH})_2$

Process Step: About 7% of  $\text{Be}(\text{OH})_2$  is too fine to be separated out by centrifuge; therefore, the filtrate is polished by going through a sparkler filter and the filter cake is recycled to the Al crystallization step.

Products: Recyclable material containing  $\text{Be}(\text{OH})_2$  and Al

## D. BeO Ceramic Production

### Step 1

Input:  $\text{Be}(\text{OH})_2$ , sulfuric acid

Process Step: The  $\text{Be}(\text{OH})_2$  is dissolved in sulfuric acid which results in concentrated beryllium sulphate after cooling and crystallization.

Product: Beryllium sulphate crystals

Exposure:

### Step 2

Input:  $\text{BeSO}_4$  crystals

Process Step: The crystals are put in a oxide furnace (batch) that fires @ approximately 900-1500°C resulting in Be O

Product: Be O (can be sold as final product)

Exposure: Be O dust

### Step 3

Input: Be O

Process Step: Be O is milled, pressed, and furnace fired to produce various ceramic products. These ceramics are then machined, if necessary.

Product: Ceramic products

Exposure: Be O dust

#### E. Conversion of $\alpha$ Be(OH)<sub>2</sub> to (NH<sub>4</sub>)<sub>2</sub> Be F<sub>4</sub>

##### Step 1

Input: Be(OH)<sub>2</sub> and/or Be O

Process Step: The Be(OH)<sub>2</sub> is put in a repulper and the material is pulped with ammonium bifluoride. Additionally Be scrap is also dissolved in the NH<sub>4</sub> F<sub>2</sub> solution and added in to the main flow. These reactions yield a (NH<sub>4</sub>)<sub>2</sub> Be F<sub>4</sub> solution.

Product: (NH<sub>4</sub>)<sub>2</sub> Be F<sub>4</sub> solution

Exposure: NH<sub>4</sub>, F

##### Step 2

Input: (NH<sub>4</sub>)<sub>2</sub> Be F<sub>4</sub> solution

Process Step: Add ammonium fluoride solution to raise ammonium fluoride to required stoichiometric level.

Product: (NH<sub>4</sub>)<sub>2</sub> Be F<sub>4</sub> solution with higher ammonium fluoride content.

Exposure: NH<sub>4</sub>, F

##### Step 3

Input: (NH<sub>4</sub>)<sub>2</sub> Be F<sub>4</sub> solution

Process Step: Transfer solution to another tank equipped with carbate plate heaters and heat solution to boiling and add calcium carbonate to precipitate out remaining Al contamination. Then add lead dioxide to precipitate out Mn and Cr. The resultant slurry is filtered through a stainless steel filter screen.

Product:  $\text{NH}_4 \text{ Be F}_4$  solution (purified)

Exposure:  $\text{NH}_4$ , F, Pb

#### Step 4

Input:  $(\text{NH}_4)_2 \text{ Be F}_4$  solution

Process Step: After filtration, the solution is treated with ammonium polysulfide which further precipitates out remaining impurities (Pb, Ni, Cu) as sulphides. This slurry is filtered through sparkler filters to remove the precipitated compounds.

Product:  $(\text{NH}_4)_2 \text{ Be F}_4$  solution (further purified)

Exposure:  $\text{NH}_4$

#### Step 5

Input:  $(\text{NH}_4)_2 \text{ Be F}_4$  solution

Process Step: The solution goes through a polishing filter and another sparkler filter to remove any additional solid impurities. This filtrate is then fed into a continuous salting vacuum evaporator (heat for evaporation from carbate tubes). To maintain smooth operation of evaporation equipment to evaporator cup contents are

continuously pumped into a centrifuge to keep the solid level low within the evaporator. Within the centrifuge the ammonium beryllium fluoride salt is removed and the centrifuge liquor is re-added to the evaporator.

Product: Ammonium Beryllium Fluoride Salt

Exposure:  $\text{NH}_4$ , F

#### F. Conversion of $(\text{NH}_4)_2 \text{Be F}_4$ salt to $\text{Be F}_2$

##### Step 1

Input:  $(\text{NH}_4)_2 \text{Be F}_4$  solution

Process Step: The salt is continuously fed into a gas-fired or electric arc furnace ( $\sim 1000^\circ\text{C}$ ) which decomposes the salt to  $\text{Be F}_2$  (liquid) and ammonium fluoride gas. The  $\text{Be F}_2$  flows to the bottom of the furnace crucible where it is continuously drained through overflow weir into a casting wheel.

Product:  $\text{Be F}_2$  (solid)

Exposure:  $\text{Be F}_2$  gas ---> Traditionally the contents of the furnace crucible were openly dumped into the casting wheel. This created substantial exposure as the  $\text{Be F}_2$  gas that was given off; more recently, this process has been contained and the  $\text{Be F}_2$  exposure has been reduced.

##### Step 2 (Recycling Step)

Input:  $(\text{NH}_4)_2 \text{F}_2$

**Process Step:** The ammonium fluoride gas is collected by wet scrubbers and electrostatic precipitators. This  $(\text{NH}_4)_2 \text{F}_2$  is put into a tank and HF acid is added to ammonium bifluoride solution.

**Product:** Ammonium bifluoride solution which is reused in dissolving step (see E, step 1, above)

**Exposure:**  $\text{NH}_4$ , F

### G. Conversion of $\text{Be F}_2$ to Be Metal Pebbles by Magnesium Reduction

#### Step 1

**Input:**  $\text{Be F}_2$  pellets and magnesium pellets

**Process Step:** The solid raw materials are added to a Be reduction furnace and melted down within a graphite crucible. When the charge is completely liquid, the contents are dumped into a graphite receiving crucible and covered and set aside and allowed to cool and solidify.

**Product:** Metal block containing Be, Mg and F

**Exposure:**  $\text{Be F}_2$  gas, F. The furnace area is usually an area of very high potential hazard exposure; therefore, the furnace area must be equipped with good ventilation system, and the automation allows the operators to only be in the furnace area to change receiving crucibles.

#### Step 2

**Input:** The metal blocks

**Process Step:** Four or five blocks of the metal are added to a stainless steel ball mill for wet milling. This separates the Be metal pebbles from the slag.

Product: Be pebbles

By-Products: Be pebbles, milling solution

Exposure:

### Step 3 (Purification Step)

Input: Milling solution

Process Step: The milling solution is transferred to a tank where MgF crystals settle out and the liquid is added back to the mill operation. This is repeated several times.

Products: MgF crystals

Exposure:

### Step 4 (Purification and Recycling Steps)

Input: MgF crystals

Process Step: Some Be is in the MgF crystals; therefore, HF acid is added to the crystals within a tank and the slurry is agitated. The MgF is then filtered off, washed, and discarded. The filtrate and washings go to step 3. Once the Be content in the milling solution is sufficiently high, the solution is transferred to fresh water and the Be is removed.

Products: Recyclable filtrate and washings

By-Products: MgF crystals (waste)

Exposure:

### Step 5

Input: Be metal pebbles

**Process Step:** Aftr drying the pebbles, they are passed over a magnetic separator which removes steel stars that were added to aid the milling process. The pebbles then go through a float-sink process using ethylene dibromide and mineral oil which serves to separate out the remaining slag. The pebbles are washed with isopropyl alcohol, water, and then dried.

**Product:** Be pebbles (97% pure)

**Exposure:** Ethylene dibromide

#### H. Conversion of Be Pebbles to Vacuum Cast Ingot (Remove Mg Content)

##### Step 1

\*For this operation, a 3000 cycle, 100 Kw induction unit is used for the vacuum furnace, which contains both melting crucible and casting mold within evacuated area.

**Input:** Be metal pebbles.

**Process Step:** The initial charge is placed in the crucible (crucible made of Be O), and mold cover put in place, furnace sealed, pumped down to vacuum, and then power applied. There is a sight glass to monitor melting. When melting nears completion, the sight glass can be removed and additional metal is added, and the vacuum is re-achieved. During the second evacuation, the gases are carefully pumped out, so as to avoid violent evolution of gas that

would cause loss of Be. When out-gassing is complete, the cover on the mold is removed and the crucible contents are quickly poured into the mold (all within vacuum).

Products: Vacuum Cast Be Ingot (99.5% pure), called "billets"  
Exposure: Mg fumes, BeF<sub>2</sub> fumes

I. Production of Q.M.V. Powder

Input: Be billets

Process Step: The billets are "grit blasted," machined into chips in a multiple turning operation and transferred to an attrition mill. The attrition mill grinds the chips into powder which is then sieved to remove Be particles >200 mesh (>200 mesh is returned to mill). This powder is Q.M.V. powder.

Product: Q.M.V. powder

Exposure: Be dust

J. Production of Finished Be Metal

Input: Q.M.V. powder

Process Step: The powder is compact loaded and pressed, and then sintered at about 1000°C. Following sintering, the casing is removed and the oxide skin is machine off.

Product: Finish Be metal

Exposure: Be O fumes, Be dust

INDUSTRIAL HYGIENE WALK-THROUGH  
BRUSH WELLMAN, ELMORE FACILITY  
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## INTRODUCTION

Beryllium production was first begun in 1921 by Charles Brush II in Cleveland, Ohio. By the late 40's, the Atomic Energy Commission (AEC) recognized acute exposure to beryllium caused severe pulmonary disease and thus began to monitor the breathing zone and general air of workers. Today, several researchers have hypothesized that exposure to beryllium is a risk factor for lung cancer. Studies already conducted have suffered from design problems and provide inconclusive of a link between beryllium exposure and cancer. The National Institute for Occupational Safety and Health (NIOSH) has undertaken a cohort study in an attempt to resolve the question of cancer development from beryllium exposure. A preliminary review of available exposure data has been funded by NIOSH to support the cohort study. This work will determine if it is feasible to continue with a more comprehensive retrospective exposure characterization. The first part of the study involves ranking exposure data, available through NIOSH, to job and task title. To gain a better understanding of the beryllium processes and jobs performed by each worker, a plant walk through was scheduled at the Brush Wellman facility at Elmore, Ohio. While at the plant, a historical overview of production in the beryllium industry was given by a member of the company. The second day of the trip consisted of reviewing archived exposure records maintained by Brush Wellman at the St Clair facility at Cleveland, Ohio. Exposure records available at Brush were surveyed and listed to document the materials available for the future comprehensive study.

## PLANT VISITORS

The walk-through survey was conducted by Dr. Carol Rice (Assistant Professor of Environmental Health - University of Cincinnati), Dr. Robert Herrick (NIOSH Representative), Mike Cornett (Graduate Student-UC), Donald Seiler (Graduate Student-UC). The walk-through consisted of viewing the operations in the production of beryllium and its associated products.

## PURPOSE OF VISIT

On November 5, 1987, a walk-through survey of the Brush-Wellman Metal Operations facility was conducted at Elmore, Ohio. The purpose of the visit was to gain an understanding of the current production operations being used in the beryllium industry. A working knowledge of the job performed as a function of job title would also be ascertained. Also, a presentation of the historical production in the industry was provided by a plant representative. On November 6, 1987, a survey of the exposure data records was undertaken at the St Clair facility of Brush Wellman at Cleveland, Ohio. The purpose of this visit was to review archived data and to prepare a categorized list of available company data. This material would be later used in determining the feasibility of a more comprehensive study of exposure.

## COMPANY CONTACTS

The tour of the facility was conducted by Thomas N. Markham, M.D., the Corporate Medical Director for Brush Wellman.

Mr. Martin (last name unknown) conducted the lecture on the historical production in the beryllium industry. Present were two other company officials, which include Mr. Richard Davis, Director of Environmental Affairs, and Mr. Philip R. Wilson, CSP, CIH, Director of Environmental Control.

## HISTORY

The following plant history is taken from the recollections of Martin (last name unknown), a Brush Wellman consultant.

1921

- First work done by Charles Brush II from seed money from his father (Charles Brush I) in the carriage house behind the family mansion.

Late 20's Early 30's

- Start up of the Lorain plant in Lorain, Ohio. Plant conditions were reportably terrible. Workers in the plant reported a blue haze which prevented them from seeing across the room. No formal ventilation controls were used and thus a flour mill like foundry room condition existed due to the dust. The furnace released streams of particles into the air. Windows and roof vents were used to reduce plant dust levels and this increase visibility, however the entire surrounding neighborhood was apparently contaminated. One anecdote involved a woman who lived near the plant would and had to sweep off her porch every morning.

1931

- The Brush Beryllium Company incorporated and transferred beryllium (Be) work from the laboratory to the first manufacturing facility.

- A second company was formed called Brush Instruments which commercialized piezo-electric crystals.

Early to Mid 30's

- Transferred processes to Lorain, Ohio which made metallic beryllium and other compounds (primarily oxides).

Mid 30's

- Reading PA (now NGK metals) Hazelton extruded hydroxide which went to the metal plant at Hazelton and also to Reading.

1937

- 4130 Perkins Ave-Perkins Plant. The building was leased from the AEC to produce beryllium oxide, and beryllium metal but no beryllium copper alloy. Also extraction of ore and hydroxide powder, machining were conducted at Perkins. The building was similar to the MIT hood building, very old and rotting, with a wooden interior and pillars. Particulates were known to accumulate on unpainted and rotted surfaces. Beryllium powder was moved around in glass bottles which when broken contaminated large areas with the powder. The Perkins plant was a continuously changing operation. The plant gained and lost production processes during the course of the plants operation.

Late 30's - Early 40's

-Small production in scope until World War II increased the demand for BeCu, BeO and thus production increased.

- Beryllium toxicity reported in European literature.

- Dr. Van Ostrand of the Cleveland Clinic noticed increased pulmonary problems from workers at the Brush plant (Lorain) and Clifton Products (Painesville). He wrote a paper identifying beryllium and it's salts (BeF, BeSO<sub>4</sub>, BeCl) as one cause.

1940

- New operations were added to the Perkins facility through the 1940's with the exception of beryllium copper production.

1943

- The United States Public Health Service published the Fairhall report which attributed acute berylliosis to the salts (BeF, BeSO<sub>4</sub>, BeCl) and not to beryllium itself.

1946

-Dr. Tabershaw and Dr. Hardy published a report which showed beryllium metal was itself toxic. The chronic disease imitates sarcoidosis which was different from previous reports. Their study was done on fluorescent light plant workers in Salem Mass. The fluoride associated with BeF was not the cause for plumonary disease they detected.

- Saranac symposium resulted in the concensus that beryllium was toxic as an element.

- Products produced
  - BeCu (Commercial products)
  - BeO (Fluorescent Lamp Industry and AEC)
  - Be Metal (AEC only)

1947

- Merrill Eisenbud did studies on exposures at two AEC plants which consisted of: the form of beryllium produced, characterization of the disease, and the concentrations with which workers were exposed. Health and Safety Laboratory (HASL) reports are in the New York office with details on the study. Shilen, head of PA plant, refused to be in study. Plants included Brush-Ohio, Be Corp-PA (two plants in PA), and Clifton Products in Painsville, Ohio.

- Lorain plant personnel reported neighborhood cases (outplant) as well as high number of in plant cases. The case reports resulted in inplant and outplant sampling. Maximum acute standards were set at  $25 \text{ ug/m}^3$  because of a Lorain plant accidental exposure. Eisenbud estimated the exposure of a worker, who developed acute symptoms, to be greater than  $100 \text{ ug/m}^3$ . He then divided the value by four (safety factor) and yeilded an acute value of  $25 \text{ ug/m}^3$ . The chronic MAC (TLV) was determined in the back of a cab. A value of  $2 \text{ ug/m}^3$  was set under the assumption that beryllium is as toxic as other metals on a molar basis. Heavy metals are toxic at  $100 \text{ ug/m}^3$  and have atomic weights around 220. Beryllium has an atomic weight of 9 thus Eisenbud divided  $100 \text{ ug/m}^3$  to get a level of  $4 \text{ ug/m}^3$ . For added safety the value was divided by two and the  $2 \text{ ug/m}^3$  level

was established.

1948

- The Lorain plant burned to the ground (except the kiln). Eventually it became a parking lot after a concrete pad was laid. No exposure data were collected for this plant although high  $\text{mg}/\text{m}^3$  exposure, were thought to occur (86-100  $\text{mg}/\text{m}^3$ ).

- At this point the PA plant used no engineering controls for exposure. They did not acknowledge the toxicity of beryllium. The government needed to decide to buy from the PA plant, since Lorain burned down, or make their own. Brush was commissioned to design a beryllium plant in Lucky, Ohio.

- Dr. John Zelinski's report documented the fire at Lorain. At this point engineering controls were to be implemented in the remaining beryllium plants. Future plants were also to be designed with controls.

1949

- The fluorescent lamp industry stopped using beryllium oxide in tubes which made the AEC the only user of the oxide and metal. At this time Brush was the only producer of the material.

1950

- A Medical Advisory Board was appointed to monitor compliance with the levels established by Eisenbud. They continued to conduct air sampling through 1956.

- Brush was commissioned by the AEC to design a beryllium

facility in Lucky, Ohio. The plant had been a World War II magnesium plant that was obsolete but under the control of the War Board. Available were utilities, water, land, and soon after, an additional building was added. Processes would include ore extraction, oxide and metal production. The plant produced more hydroxide than was needed. Brush then purchased it from the AEC and sold it to fund the building of a foundry in Elmore, Ohio which would produce master alloy.

- Respirable sampling was developed. Appendix D, the standardized method of air sampling used by the AEC in calculation daily weighted averages (DWA), never changed but the implementation of various sampling methods changed periodically. A copy of Appendix D is provided in the appendix.

- The Chester operation was a satellite of the Perkins operation. It operated only as a intermittent machine shop. Employees at Chester were the same employees from Perkins. Low exposures were reportedly encountered.

1953

- The Brush Wellman Elmore facility started up and produced master alloy (BeCu) as a foundry operation exclusively. Beryllium hydroxide was purchased from the AEC to make the alloy. Brush sold privately to compete with the PA company which sold alloy via government contract.

Mid 50's

- The AEC decided two producers of beryllium was necessary.

Since engineering controls had been established at the Be Corp. of America (PA), the AEC agreeded to purchase a yearly amount of product from Brush at Elmore and Be Corp. of America at Hazelton PA. Beryllium copper was produced at Reading PA.

- Extraction was moved to Elmore from Perkins.

- Perkins operations were moved to Lucky and then to Elmore.

1956

- The Medical Advisory Board could not confirm nor deny that Eisenbud's recommended exposure limits protected health thus they were accepted by ACGIH, ANSI, and the state of PA.

1958

- The Lucky plant closed. The Harris paper can be found in the Kettering Workshop which described some of the Lucky plant workers exposure. Harris reported that high levels were recorded in the begining, but came under control with increased ventilation.)

- Sampling strategy set up in Appendix D that was required by the AEC, allowed them to do random sampling audits out of their New York and Chicago offices. Studies were conducted by Breslin and Harris, who succeeded Eisenbud.

- When beryllium was used by Elmore and Hazelton, high concentrations were not allowed by the AEC and thus companies were audited. Hazelton was closed twice and warned once. This sparked a movement to sample respirable instead of total dust

since lower concentrations would result. Why sample total when respirable was the dust of concern? The problem which resulted was that the exposure guideline was based on total dust, not respirable, and respirable results could not be compared with the recommended levels.

1960

- Brush Beryllium began measuring BeCu dusts, by respirable sampling, all other beryllium compounds were measured as total dust.

1960-1968

- St. Clair facility had a machine shop and some research and development (R & D) facilities (still today). Very low exposures were recorded due to good ventilation design. Respirable samples were conducted at this facility. High levels were recorded however in the R & D area. Even to the present, the R & D workers may be exposed to beryllium dusts due to the nature of the work. Cholak's study showed that concentration increased when no ventilation was present. The respirable fraction represented one fifth of the total dust sampled.

1961

- Dr. John Zelinski's paper (see Kettering Workshop) looked at milligram levels of beryllium but found no disease case associations. Cholak validated his findings.

- Machining moved from Perkins to Elmore

- Brush Beryllium began measuring BeCu and beryllium metal by respirable sampling. This allowed for data to be grossly under reported with respirable to nonrespirable dust concentrations being 1 to 10 respectively. Respirable to non-respirable dust samples in the general air were found to be 1 to 20. Also, when a person was 10 ft away from source, the BZ and GA difference was small.

- Types of sampling used were : Stationary by AEC, Brush  
Personal by OSHA  
Paired sampling by  
Donaldson and Wilson

- Study was done at NYU which showed difference in sampling techniques.

1963

-R & D facility moved to Elmore from Perkins

1965

- Perkins operations closed.

1970

- OSHA adopted the 1956 standards set by Eisenbud for beryllium.

1973

- Beryl ore is mined in Utah and sent to Elmore

## DISCRIPTION OF CURRENT OPERATIONS

The Brush Wellman Elmore processing plant is supplied Beryllium Hydroxide ( $\text{Be}(\text{OH})_2$ ) from a plant it operates near the mine in Utah. They also import some of their beryllium hydroxide. The Elmore plant uses three processes which utilize beryllium hydroxide to produce many products. The tour consisted of the following processes: Metallic Beryllium Production, Beryllium Oxide and Ceramics Production, and Beryllium Copper (Master Alloy) and Other Alloy Production. All three processes start with the industry's basic building block, beryllium hydroxide.

### METALLIC BERYLLIUM PRODUCTION

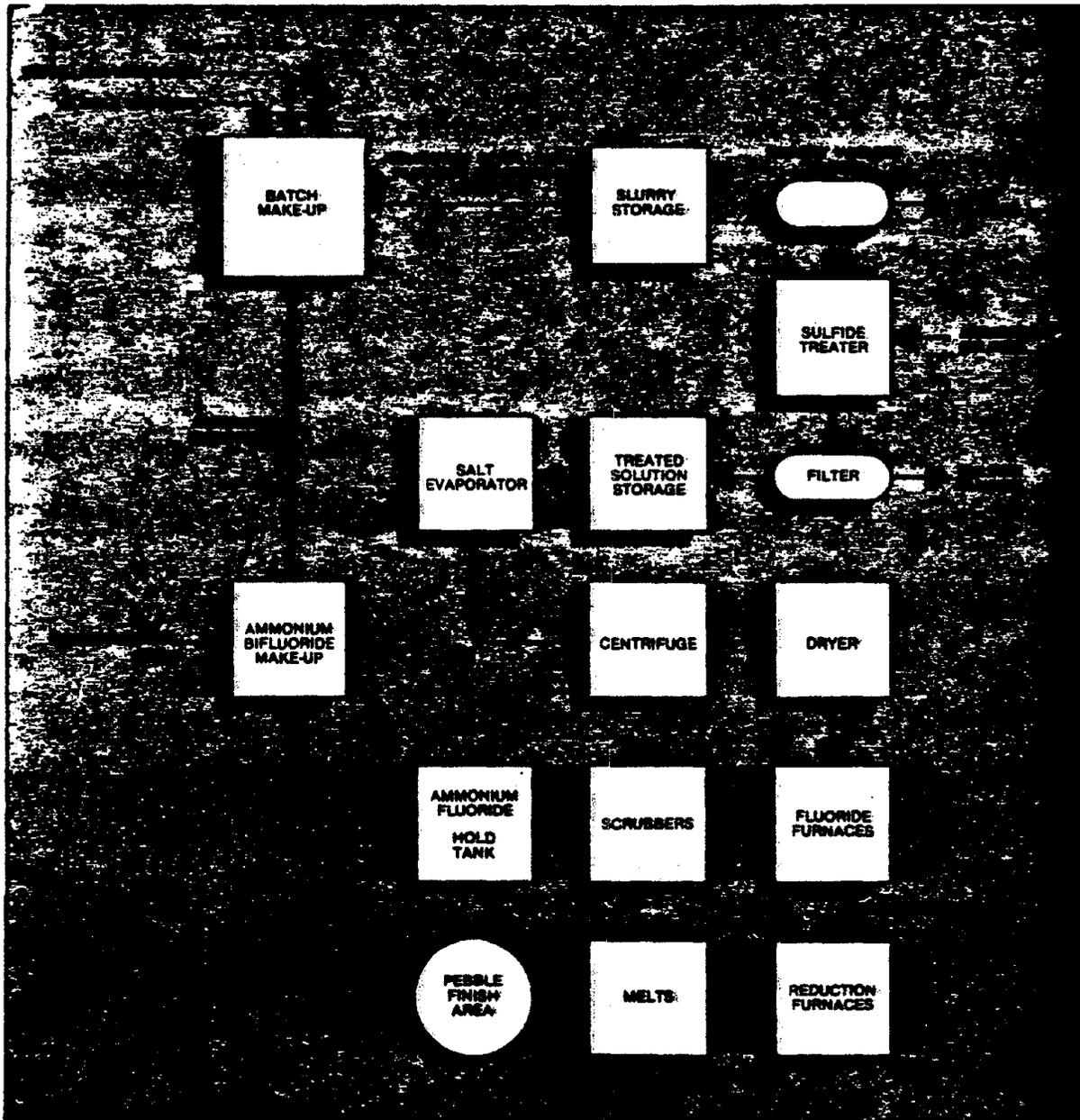
#### A. Beryllium Pebble Production

The first step in the production of pebbles is to combine lime, beryllium hydroxide, recycled materials, and ammonium bifluoride which all are mixed in the batch make-up process. The ammonium bifluoride is made on site by combining ammonium fluoride and hydrofluoric acid. The batch make-up is processed into ammonium beryllium fluoride solution (ABF) and is stored as a slurry. The solution is then filtered in a rotary vacuum and lime sludge is removed. Unwanted impurities like iron, manganese, lead, and zink are removed in the sulfide treater where ammonium sulfide is added. This solution is then filtered and sulfide sludge is removed and stored in a treated solution storage tank. The ABF salt is then transfered into a salt evaporator where it crystalizes by concentrating the solution.

The concentrate is centrifuge and placed in a gas-fired dryer to dry. The ABF salt is then delivered to the fluoride furnaces. Once in the induction furnance, the salt is decomposed at 700-900 degrees C. The process forms ammonium fluoride gas and anhydrous beryllium fluoride. The gas is scrubbed and returned to the ammonium fluoride holding tank.

The molten beryllium fluoride is cooled and appears as a glass like material. The solidified beryllium fluoride is then transfered to the reduction furnace where magnesium is added to reduce the material to beryllium metal. When molten, magnesium fluoride forms allowing beryllium metal to be produced. The mixture is then cooled in a graphite transfer pot to produce a cake composed of unreacted beryllium fluoride, magnesium fluoride, and beryllium pebbles. After the cake is crushed in a hammer mill, and leached with water in a rotary mill, the beryllium metal and magnesium fluoride result. Unreacted beryllium in solution is recycled. The solid material is placed in a tank which contains high-specific-gravity liquid and thus allows beryllium metal to float while magnesium fluoride sinks. Pebbles are collected, and cleaned with a weak acid in a finishing mill and then transferred to the vacuum melting process. On the following page is a flow diagram representing the beryllium pebble production process.

# Beryllium Pebble Production



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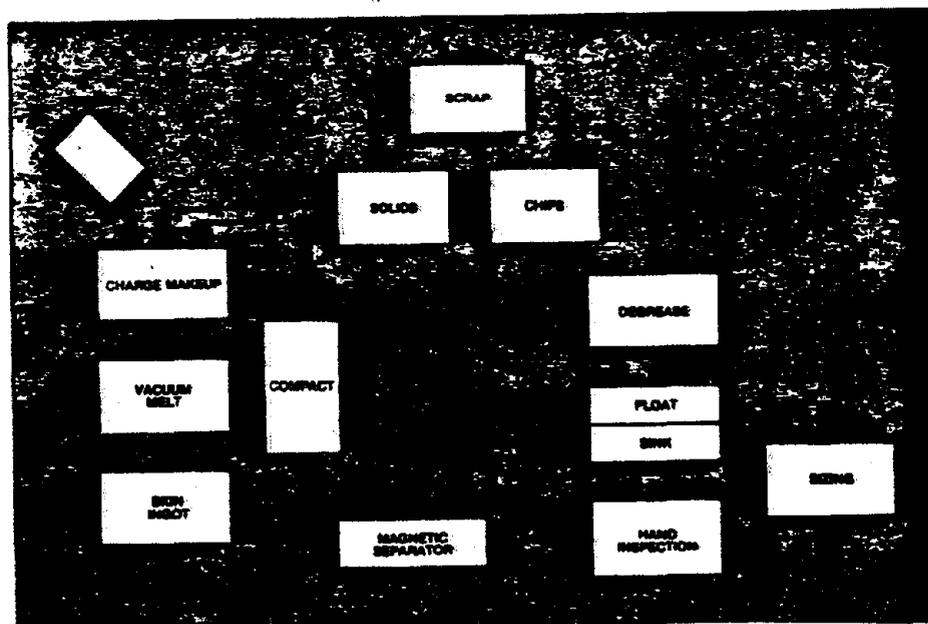


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## B. Vacuum Melting Process

Vacuum melting is a process by which beryllium metal is refined, while controlling the of microalloying constituents. Pebbles are placed in the vacuum melter with scrap solids and chips from the recycling processes. Chips are degreased, floated as the pebbles were, sized, hand inspected, magnetically separated, and compacted before being placed in the vacuum melter. The melter is constructed of a magnesium oxide crucible. The material is then placed under a vacuum and heated to 1300 degrees C. Once molten, the temperature increases and is held while impurities are vaporized. The material is then poured in a graphite mold and solidified forming ingots. The ingot is skinned to remove outer carbon impurities and sent to the chipping operation. The skinned material (bark) is then be recycled. The flow diagram for the process is illustrated below.

# Vacuum Melting



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### C. Beryllium Powder Production

The ingot is placed in a large engine lathe where it is converted to chips except for the last half inch. The chips are removed by vacuum, sized in a cyclone, and stored in drums. The material is ground into powders by three methods : attritioning, impact grinding, and ball mill operation. In attritioning, beryllium chips are ground by one stationary grooved beryllium plate and one moving beryllium plate. The process is conducted in an argon atmosphere to reduce BeO formation, due to the extreme heat. The powder is sized on a vibrating screen for separation and larger particles are placed back into the attritioning mill. Impact Grinding produces a powder which is finer than produced by attritioning. Chips are directed toward a solid beryllium surface by means of a high-velocity air stream. The powder is sized and larger particles are placed back in the impact grinder. To produce the finest powder (10 um), a ball mill is used. Chips are placed in the mill with steel balls and rotated to create the fine powder. The powder is sized in an air classifier (series of cyclones) where larger particles are removed. Beryllium powder production is illustrated on the next page.

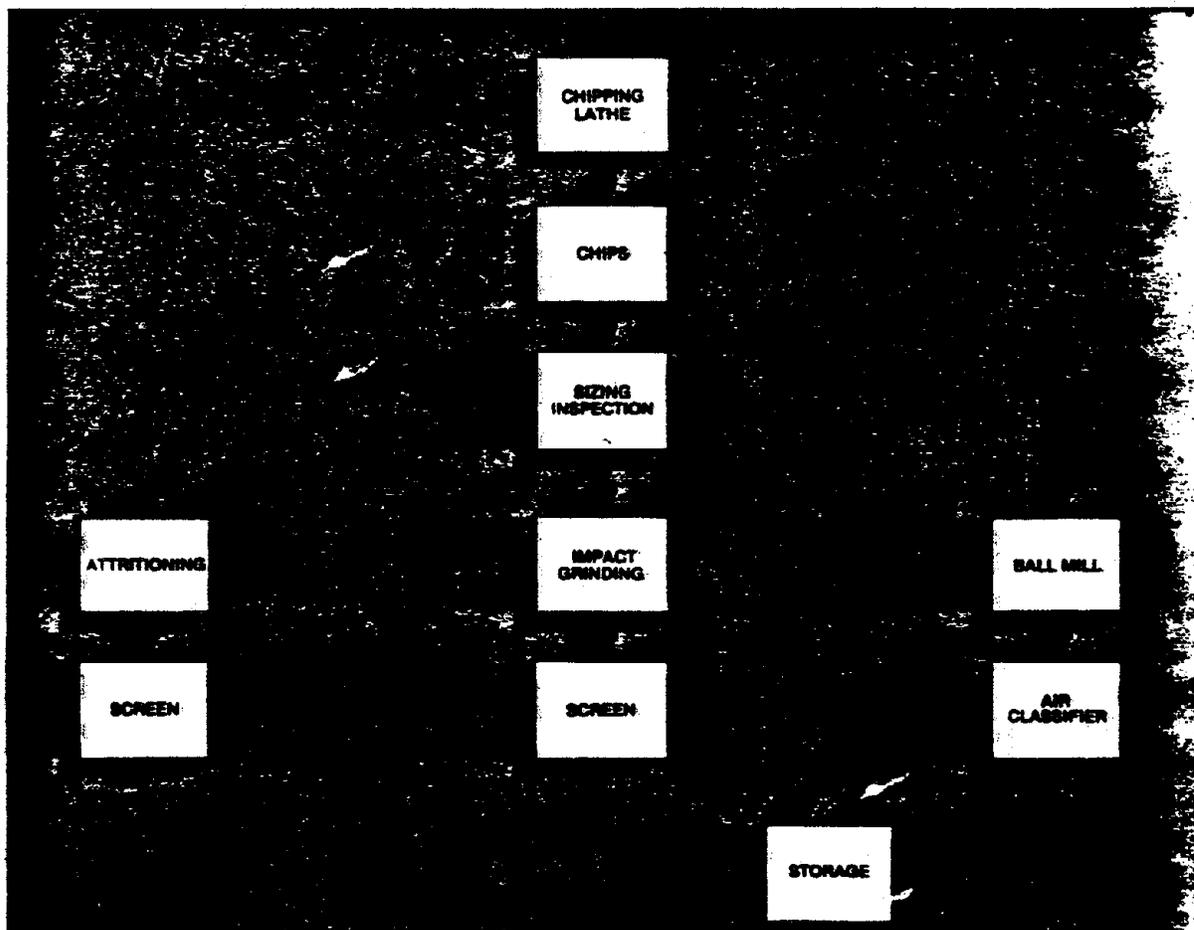
### D. Vacuum Hot Pressing

The three powders produced are mixed in the Elmore plant to form six different types of beryllium metal. The powder is turned into billets in seven vacuum furnaces, five of which use graphite dies and the other two use metal dies. The large metal dies are used for extremely large billets. Stored powder is

blended, screened, and loaded into a die. Within the die, powder is compressed by an upper and lower punch. A vacuum is pulled while heat is applied to the die. Once sintering temperatures are reached, the billet should be 99 % dense and allowed to cool. After checking the density, the billet is skinned and a dye penetrant is used to locate defects. The billet may also be ultrasonically tested to insure a pure, uniformly dense product.

The product is now ready for final machining. A flow diagram for vacuum hot pressing is presented on the next page.

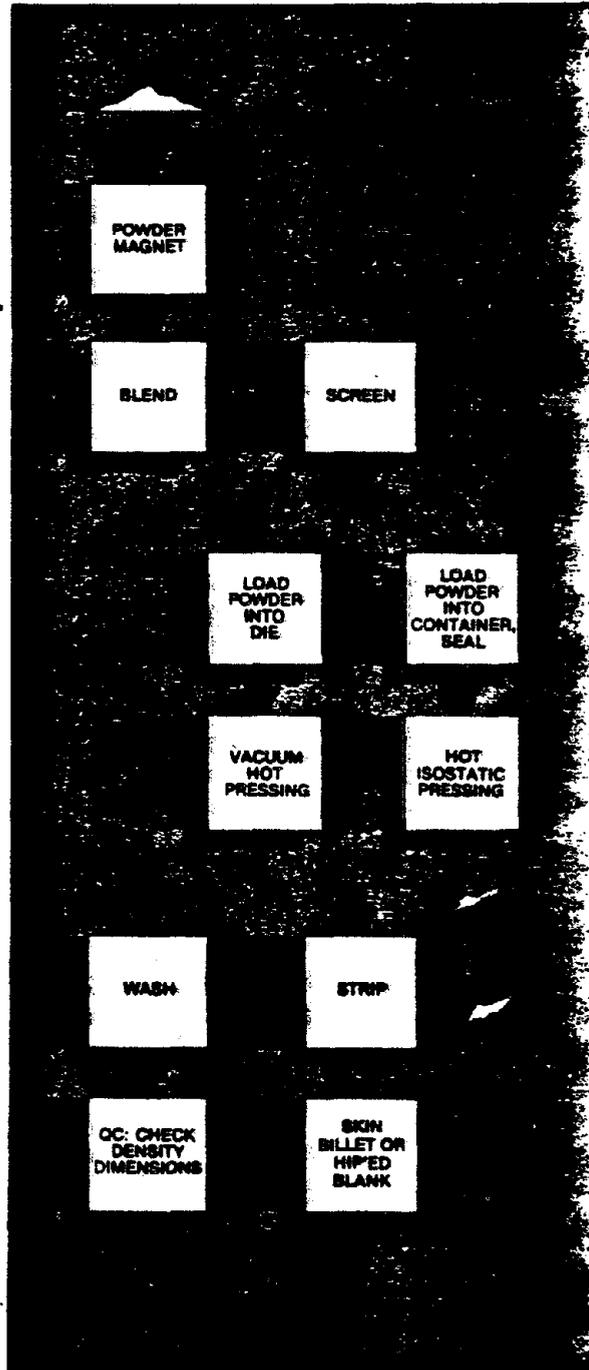
## Beryllium Powder Production



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# Vacuum Hot Pressing



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#### E. Hot Isostatic Pressing

Hot Isostatic Pressing uses powder as does the billet pressing but has the ability to produce near-net-shaped parts. Molds are constructed from welded sheet metal in the form of the usable products. Powder is placed in the mold and isostatic pressure is exerted by argon gas heat to form the powder into a solid. Once fully sintered, the product is near 100 % density. Argon gas is exhausted and the billet is cooled, removed, cleaned, inspected, and sent for final machining.

#### F. Machining

Products which are to be sold are machined at Elmore to approximate the shape of the final product. There is a large number of machining units on site, all of which appear well ventilated. Final metal products are carefully checked for defects and dyed for cracks.

#### G. Rolling and Forming

The Elmore facility also has the ability to roll and form Be metal into foils as thin as 0.0003 inch. Pressing and rolling operations allow Brush Wellman to produce a variety of final products.

### BERYLLIUM OXIDE POWDER PRODUCTION

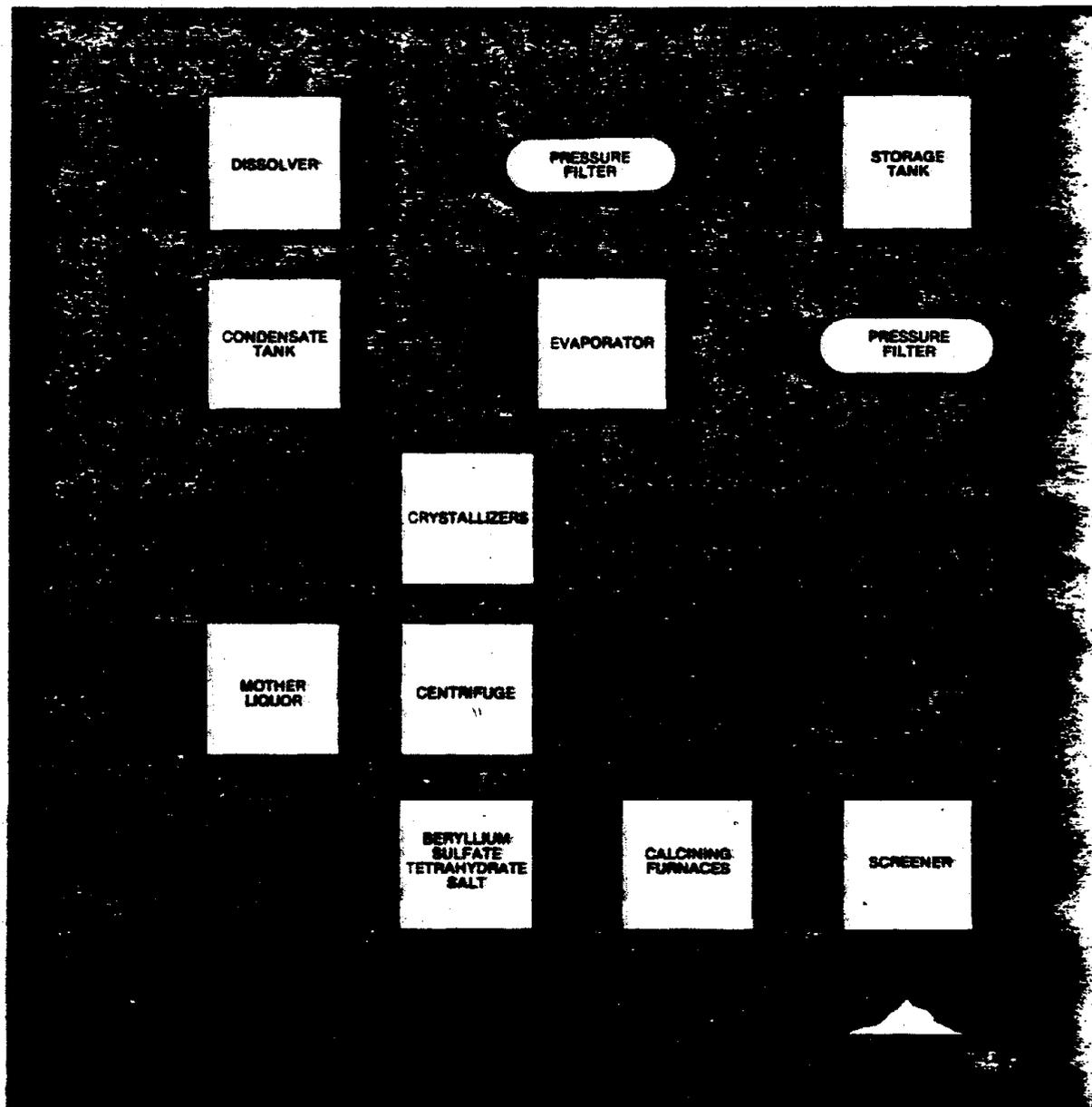
Beryllium oxide powders are used by beryllium ceramics manufactureres to produce ceramic products. The Elmore plant produces two powder sizes (UOX,GCHF) by controlling firing time and temperature. The production process for each powder differs

by these variables, but  $\text{Be}(\text{OH})_2$  is the common starting material. The first step is to dissolve beryllium hydroxide with sulfuric acid in the dissolver to form a sulfate solution. The solution is filtered, evaporated until saturated, and then supersaturated by cooling. The beryllium sulfate tetrahydrate salt crystallizes and is removed from solution by centrifugation. The material is placed in a car-hearth calcining furnace where it is heated to 1430 degrees C. Sulfur dioxide and sulfur trioxide are evolved as gases. Water is also driven off in the process which ultimately results in beryllium oxide production. The powder is screened, checked, and bagged for shipment. A flow diagram for beryllium oxide powder production is on the following page.

#### MASTER ALLOY PRODUCTION - BERYLLIUM COPPER AND OTHER ALLOYS

The Elmore plant's master alloy operation utilizes two arc furnaces to product beryllium copper. The old arc furnace began operation when the Elmore plant first produced beryllium copper. The new furnace was added in 1980 and is able to produce alloy at twice the rate of the old furnace. Alloy production is divided into two operations : Pellet Preparation, Furnace Operations. A series of alloy preparation and machining operations are also undertaken at the Elmore facility.

# Beryllium Oxide Powder Production



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#### A. Pellet Preparation

Beryllium hydroxide serves as the main ingredient of the pellet preparation process. Three hundred and seventy five pound drums are lifted by conveyor and dumped into a rotary calciner. The 1500 degree F calciner converts the material to  $\text{BeO}$ , which is stored in a bin. Baghouse fines from the furnace are also collected in bins. Carbon, which supports the reduction process, and material from the above bins are mixed in a blender and transferred to the mix bin. This mixture along with a lignosulfonate binder form the pellets that are dried at 400 degrees F.

#### B. Furnace Operations

A charge bin composed of Ajax furnace and Master Alloy dross, petroleum coke, copper, and the pellets feed a 8 X 11 foot tall Whiting Arc Furnace. The casting temperature reaches 3400 degrees F before the furnace is tapped and the dross removed. Two railcars collect the master alloy from the furnace and pour 15 and 30 pound pigs which contain 3.8% beryllium. The pigs are allowed to cool. The dross material is recycled with the next batch of pellets. Pigs can then be sold directly or melted and casted into other products at the Elmore facility. The following page contains a flow diagram of the master alloy process.



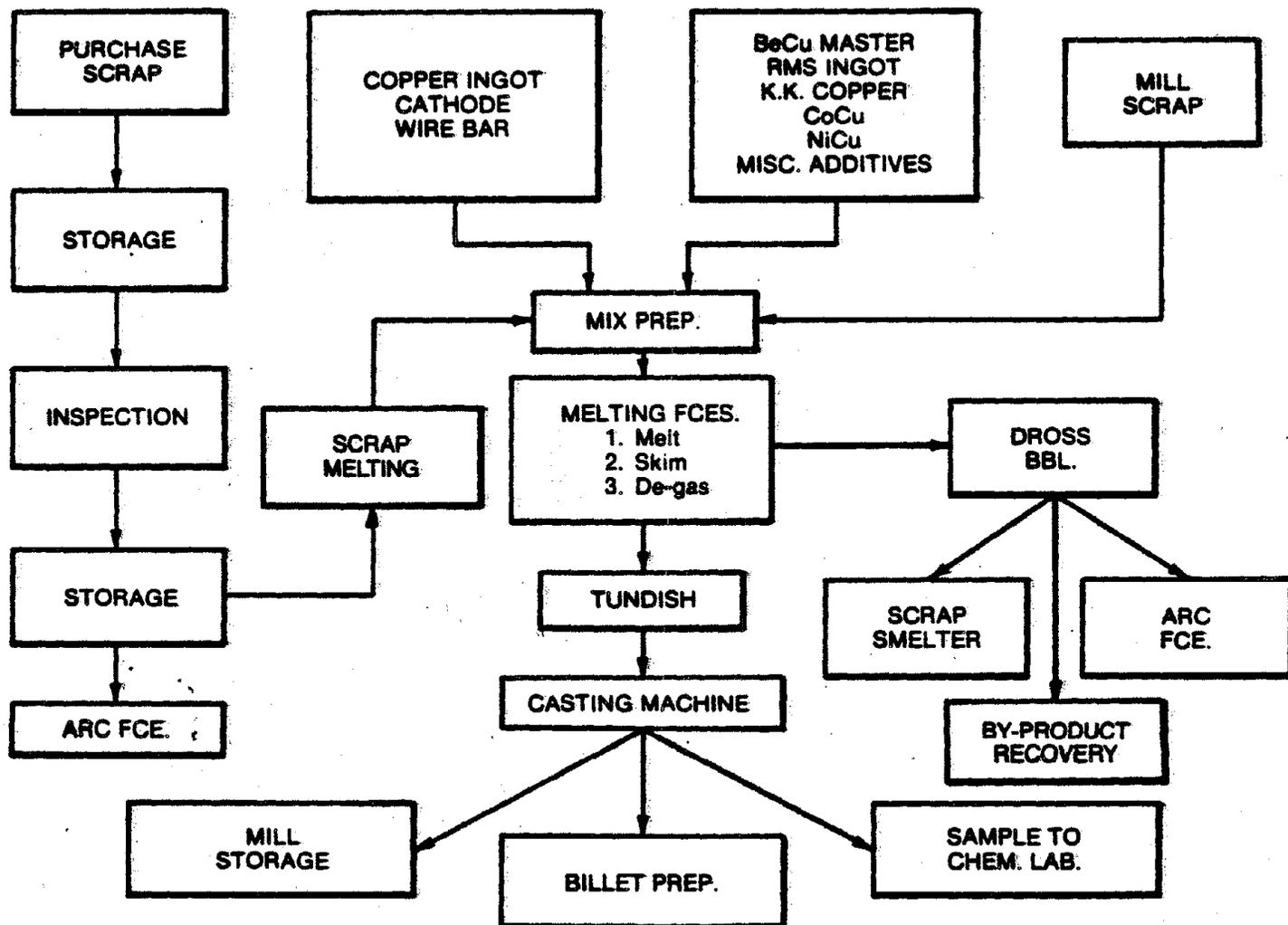
### C. Melting and Casting Production

The melting and casting production operation produces billets which are used to produce final products in the Rod, Bar, and Tube Mill as well as the Strip Platting Process. Along with the copper alloy, nickle and aluminum alloy billets are produced. The mixture which is prepared for the melting furnace consists of ingots from the master alloy process, mill scrap, copper ingots, and material from the scrap melting area. Elmore purchases scrap BeCu products and recycles them in this scrap melting facility. Materials are inspected, sorted, weighed, and melted in a furnace. In the melting furnace the material is melted, skimmed, and de-gased. The furnace is connected to a direct chill casting device which produces billets directly from a water cooled mold. Billets can then be stored or prepared for the extrusion process. Billets are first placed in the homogenization furnace which heats the billet to allow the even dispersal of alloying elements throughout the billet. The billets can then be prepared by sawing into multiple lengths using a band or circular saw. The outer surface may be removed at billet scalping lathe. Rectangle billets may undergo a similar process at a scalping mill or round billets may have a hole drilled in the center by a deep hole drilling machine. A flow diagram is provided on the following page.

### D. Extrusion Operation

The extrusion press produces the materials used in the Rod, Bar, Tube and Wire Mill. After a billet has been properly cast and treated, the round billet is placed in the extruder and

# CASTING PROCESS



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pressed into coils to form materials from as small as 1.25 inches in diameter. An Farrel Extrusion Press is used. As material leaves the extruder, it is water cooled to maintain a uniform size. It is then cut, and coiled for the Rod, Bar, Tube Mill for further processing.

#### E. The Rod, Bar, and Tube Mill

Extruded materials are first placed in the annealing furnace (1200-1900 degrees F) which is part of the Sauder Annealing and Aging Furnace. Extruded products are aged in the aging furnace (475-1200 degrees F). Both furnaces operate by electricity and can be used in air, nitrogen, or nitrogen-hydrogen atmospheres. Next the extruded products are placed in a swager which prepares them for cold drawing. The tip of the product is cut to a smaller size and hardened in this process. Products are cleaned in a three step bulk pickling operation. Materials are dipped in caustic NaOH for 30 minutes, dipped in nitric acid for 5 minutes, and then dipped in a stain inhibitor (BTA). A Lombard Drawbench is used to hydraulically push the material through a die, forming a variety of shapes and sizes. Materials are transferred to a Phillips degreaser which contains perchloroethylene. Then they are cut to various sizes on the Marvel Band Saw. Materials are straightened on either a Sutton Rotary Straightener, Eitel Straightening Press, or Savage Straightening Press. Tubing straightness can be checked by the Straightness Inspection Gauge. To straighten the material, it must be flexed slightly beyond the elastic limit in both compression and tension. The Tandem Wire Mill is used to reduce stock to wire diameters. The device uses

a series of six mill stands and a straightener in order to create a final product. The process flow diagram is provided on the next page.

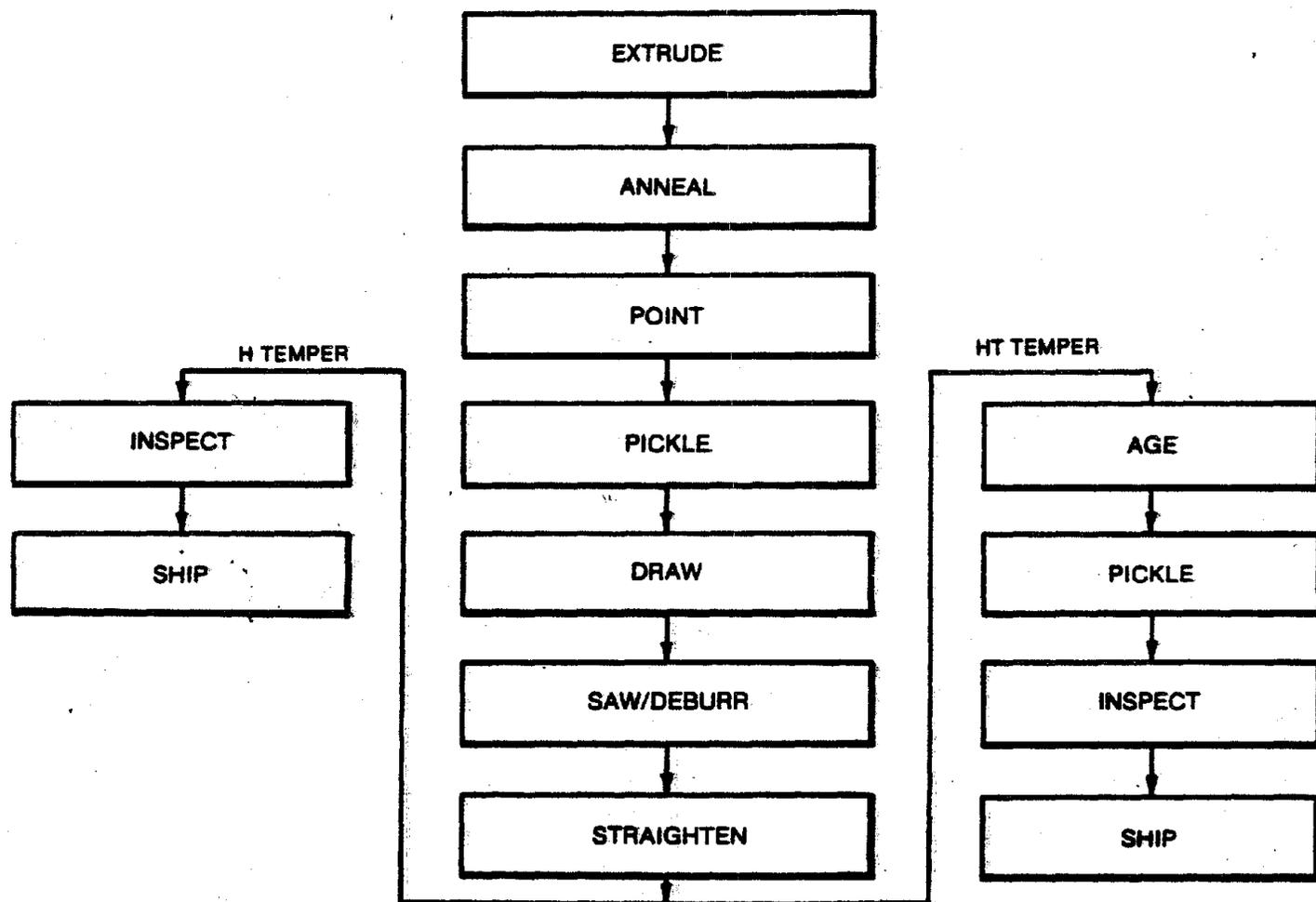
#### F. STRIP AND PLATE PROCESSING

Billets are first heated in the Saunder Car Hearth Furnace to a temperature of 1450 for gold alloy, and 1700 degrees F for red alloy. Billets are then placed in the Reverse Hot Strip Mill where they are subjected to 11 passes before they are coiled. Next on the Weld Line, coils are joined by welding to form 8000 pound coils which also have trimmed edges. At this point the coils are 0.325 inches thick. Coils are then annealed in the Roller Hearth Furnace to redissolve alloy and soften the beryllium copper. The Slab Milling Machine removes scale from each side of the coil before it goes on to further processing. The coil is further processed in a Four-High Cold Rolling Mill which reduces the diameter to 0.090 inches thick in approximately 6 passes. The strip is placed in a roller hearth annealing unit, and has its edges trimmed. Prior to being placed in the pickling line to have the oxidation removed which formed during the annealing operation. Caustic soda removes oils and nitric acid removes scale.

The Z-Mill is used to get very thin gauge materials. Coils then go through a similar process as above. They are cut and trimmed at the Planed Light Gauge Slitter Line, annealed at the Light Gauge Strip Annealing Line, and pickled at the Light Gauge Strip Pickling Line.

The Heavy Gauge Plate Leveler rolls heavy gauge material by

# PROCESS FOR COLD DRAWN ROD, BAR, AND TUBE



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using a series of rolls powered by 200 ton jacks. A plate saw is then used to cut the plates. The Elmore facility also has the capability of electroplating nickel and gold on the surface of its alloy products. Strips run through a dryer and are rinsed before plating. Electrolytic Nickel Anode Bags then plate the nickel, and electrical contacts rinse the strip. After another rinse, the strip is bright pickled and rinsed again. Finally, it is alkaline electrocleaned with NaOH and collected on rolls. The flow diagram for the strip processing is provided on the following page.

#### MISC. OPERATIONS

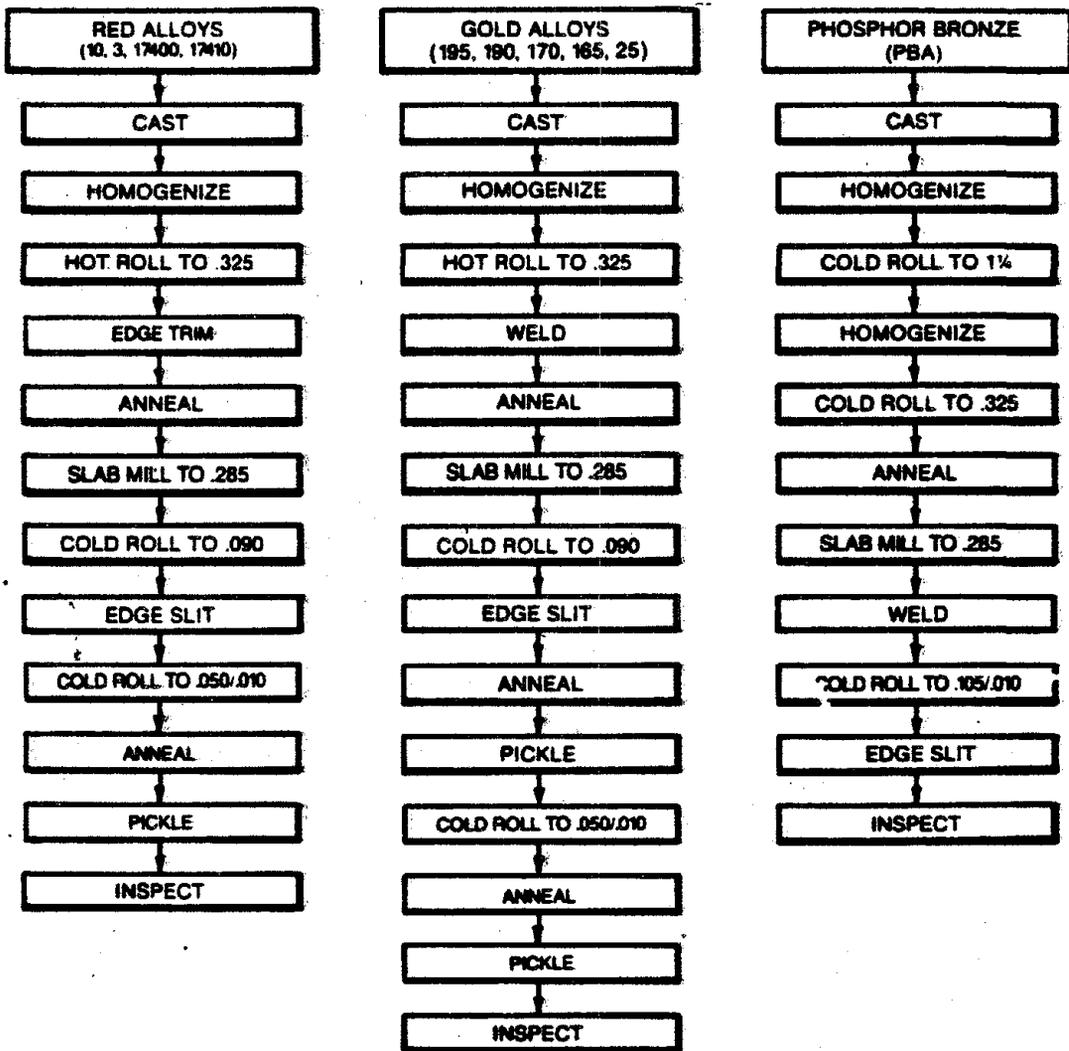
##### A. Laundry Facilities

Clothes worn in the plant are not removed from the facility. Clothes are removed by the employee and segregated into hoppers which are ventilated by large exhaust hoods. Laundry workers wear half face respirators while laundering the clothes. In extremely dirty operations (furnace re-build), clothes are bagged, sealed, and handled specially. The laundry area and workers are sampled for beryllium exposures.

##### B. Solvent Recovery Facility

The Elmore facility has an extensive solvent recovery system that collects waste products and reclaims them. The facility contained very large tanks which were housed in a separate building. Total material waste recovery is being considered as an alternate to hazardous waste disposal of beryllium containing wastes.

## STRIP PROCESSING



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## EXPOSURE RECORD AVAILABILITY AND EVALUATION

On November 6, 1987, Markham, Rice, Herrick, Seiler, and Cornett were met by Mr. R. Davis at the archived files in the St. Clair facility of Brush Wellman in Cleveland. The information available was found to be very extensive for the Lucky and Perkins plants. The Lorain plant had some task data from 1947-1948. The types of data available are included the following information: date, data type (DWA), and the plant sampled. Also included is a copy of the type survey form which was used in much of the field sampling. A large number of these field forms were found in the archives. The Brush Wellman records contain a great deal of useful data dealing with exposure which will prove to be invaluable if a quantitative retrospective exposure assessment is undertaken to compliment the cohort NIOSH study.

Dr. Markham interviewed a worker at the facility (John). John worked at the Chester plant in 1948 and moved to the Perkins plant in early 1949. John did powder work in 1955, small scale extraction, and some ceramic work. John verified that a Chester operation did indeed exist, although only on a small scale.

Dr. Markham then interviewed Mike who started in June of 1949. Mike stated that a full time air sampler, Jim Mowery, was hired by Brush Wellman. Mowery conducted air sampling and analysis at the Perkins plant. At this time it was a small operation with only one machinist and research and some development work on hot press beryllium powder, and re-extraction process. In the mid 1940's - 50's, it was not

## REFERENCES

1. Brush Wellman, Brush Wellman Alloy Division, Elmore Operation discription manual, no data given.
2. Brush Wellman, Producing Defect-free Beryllium and Beryllium Oxide, May 1985.

APPENDIX D

APPENDIX D

HEALTH & SAFETY

A. In-Plant Recommendations

- a. The average in-plant atmospheric beryllium concentration should not exceed 2 micrograms per cubic meter.

If the result of the daily weighted average concentration, computed on a quarterly basis, for any occupation exceeds  $2 \mu\text{M}^3$ , but is less than  $5 \mu\text{M}^3$ , the Contractor will submit plans for necessary corrections for Commission approval and provide all personnel exposed in this area with approved personal respiratory protective equipment. If the daily average concentration exceeds  $5 \mu\text{M}^3$ , the operation in question will be halted until the necessary improvements can be accomplished. A daily average concentration exceeding  $2 \mu\text{M}^3$  will not be permitted to exist for a period exceeding 60 days except with the specific approval of the Commission. This approval will be granted only in the event that satisfactory procedures for reducing the concentration to below  $2 \mu\text{M}^3$  have been accepted by the Commission.

- b. In the event that a single air sample shows a concentration in excess of  $25 \mu\text{M}^3$  within the operating area, but is less than  $100 \mu\text{M}^3$  (and this is to be confirmed within 10 days of the time at which such a sample was obtained) all exposed individuals will be provided with personal respiratory protection approved by the Commission and the Commission will be notified of steps which are being taken to eliminate the high concentration. If the concentration exceeds  $100 \mu\text{M}^3$  in a single sample (and this is to be confirmed within the above time limit) operations will be halted and the necessary corrections made to reduce the air-borne concentrations at this single point to below  $25 \mu\text{M}^3$ . In no case will concentrations above  $25 \mu\text{M}^3$  be permitted to exist for a period exceeding 60 days without the specific approval of the Commission. This approval will be granted only if steps have been undertaken which can be expected to provide a satisfactory reduction in air concentration.

B. Out-Plant Recommendations

In the neighborhood of the plant handling beryllium compounds, the average concentration at the breathing zone level should not exceed 0.01 microgram per cubic meter.

In the event that the maximum average neighborhood concentration at the ground during any calendar month, as determined on a monthly basis, exceeds 0.01 microgram per cubic meter, but does not exceed  $0.05 \mu\text{M}^3$ , the plant will be expected to inform the

B. Out-Plant Recommendations (con't.)

AEC of specific procedures which will be undertaken to reduce the air-borne concentration. In the event that the concentration exceeds  $0.05 \mu\text{M}^3$ , operations will be immediately halted and the necessary corrections made to reduce the average concentration to below  $0.01 \mu\text{M}^3$ . In any event, concentrations above  $0.01 \mu\text{M}^3$  will be permitted to exist for not more than a 60-day period unless specifically authorized by the Commission. Such authorization will be forthcoming only if steps are being taken which are expected to result in a satisfactory reduction in effluent material.

C. Medical Supervision

- a. There should be a medical program, supervised by a physician, to cover all workers exposed to beryllium and its compounds.
- b. If there is any evidence that an individual has chronic beryllium poisoning, such an individual should be excluded from any further exposure to beryllium compounds.

D. Sampling Requirements

In order to insure adequate sampling of breathing air concentrations, the following or equivalent procedures approved by the Commission should be followed:

- a. Each separate plant operation will be broken down into its primary components and the average time per day required for the accomplishment of each component and the number of times it is repeated will be determined. A minimum of 3 breathing zone samples will be taken to evaluate the exposure arising from each such job component in addition to an adequate sampling of the general air so that a complete overall exposure may be arrived at for each plant operator

On the basis of these samples, a daily average exposure will be computed for each operation. The average will be weighted with time by multiplying the average concentration for each job component times the amount of time spent by the operator each day in accomplishing the component. The sum of all of these products divided by the total time per day will yield the time weighted average concentration.

A minimum of 4 such evaluations will be performed each year for each operator.

- b. Representatives of the Commission will be permitted to perform similar surveys at their discretion in order that procedures being followed by the Contractor may be evaluated.

D. Sampling Requirements (con't.)

- c. Determination of the average neighborhood concentration will be made by not less than 3 permanent monitoring stations utilizing air sampling equipment capable of handling an average air volume in excess of 1 M<sup>3</sup>/min. These monitoring stations will sample continuously. Other equivalent procedures may be approved by the Commission. Meteorological data will be obtained to insure that the samples obtained by the monitoring stations can be interpreted in terms of the direction of maximum ground level concentration.

All equipment and procedures employed in the determination of these concentrations must be approved by the Commission prior to operation.

E. Approval of Construction Plans

Prior to construction, a flow diagram plus plans and specifications of hazard control procedures to be followed at each operation will be reviewed by the Commission for adequacy in meeting the very rigid standards necessary for the control of health hazards in beryllium processing. Approval, however, will be based on performance.

F. Reports

Submit such reports as the Contracting Officer may request.

APPENDIX III

Industrial Hygiene Walk-Through  
NGK Metals  
Reading, PA

INDUSTRIAL HYGIENE WALK-THROUGH  
NGK METALS, READING PENNSYLVANIA FACILITY  
FEBRUARY 1, 1988

## TABLE OF CONTENTS

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## INTRODUCTION

Beryllium production was first begun in 1921 by Charles Brush II in Cleveland, Ohio. By the late 40's, the Atomic Energy Commission (AEC) recognized acute exposure to beryllium caused severe pulmonary disease and thus began to monitor the breathing zone and general air of workers. Today, several researchers have hypothesized that exposure to beryllium is a risk factor for lung cancer. Studies already conducted have suffered from design problems and provide inconclusive evidence of a link between beryllium exposure and cancer. The National Institute for Occupational Safety and Health (NIOSH) has undertaken a cohort study in an attempt to resolve the question of cancer development from beryllium exposure. A preliminary review of available exposure data has been funded by NIOSH to support the cohort study. This work will determine if it is feasible to continue with a more comprehensive retrospective exposure characterization. The first part of the study involves ranking exposure data, available through NIOSH, to job and task title. To gain a better understanding of the beryllium processes and jobs performed by each worker, a plant walk-through was scheduled at the NGK Metals facility in Reading, Pennsylvania. While at the plant, a historical overview of production in the beryllium industry was given by a member of the company. Also, a review of the archived exposure records maintained by NGK Metals for both the Reading and Hazelton facilities was conducted. Exposure records available for the two locations were documented for evaluating the feasibility of a future retrospective exposure assessment.

## PLANT VISITORS

The walk-through survey was conducted by Dr. Carol Rice Assistant Professor of Environmental Health - University of Cincinnati, Dr. Robert Herrick, NIOSH Representative, and Donald Seiler, Graduate Student - University of Cincinnati. The walk-through consisted of viewing the operations in the production of beryllium alloy and its associated products.

## PURPOSE OF VISIT

On January 13, 1988, a walk-through survey of the NGK Metals facility was conducted in Reading, Pennsylvania. The purpose of the visit was to gain an understanding of the current production operations being used in the beryllium industry. A working knowledge of the tasks performed as a function of job title would also be ascertained. Also, a presentation on the historical production in the industry was provided by a plant representative. Also, a survey of the exposure data records was undertaken after the plant tour. A review of archived data was conducted and a categorized list of available company data for the Reading and Hazelton facility was composed. This material would be later used in determining the feasibility of a more comprehensive study of exposure.

## COMPANY CONTACTS

The tour of the facility was conducted by David W. Wolfe, P.E., Manager, Industrial Hygiene and Regulatory Compliance

Officer for NGK Metals Corporation, and Bill Heffley, Analytical Chemist for the plant. After the tour of the facility, the group was joined by Leonard E. Velky, the plant Industrial Hygienist; Carolyn Lichtenstein and Niel Roth, epidemiological consultants for NGK Metals.

## HISTORY

The following plant history resulted from the recollections of David Wolf.

1929

- Beryllium Corporation was formed.

1935

- Beryllium Corporation moved to the Reading location.

1941

- Steel Workers are the major union for beryllium employees.

1956

- Beryllium Corporation purchased an old railroad round house in Hazelton, Pennsylvania. The new plant would be involved in ore extraction, oxide manufacturing, and metal alloy production. Jim Bultar was the Industrial Hygienist for the Beryllium Corporation at that time.

1957

- Construction at Hazelton was completed and extraction of pure Beryllium began. The plant was soon shut down to provide better ventilation control of beryllium dust produced, however.

1958

- Hazelton plant re-opened and once again began production.

- The Reading extraction process moved to Hazelton, PA.
- Hazelton workers unionized under the United Mine Workers.

1958 (October)

- Leonard Velkey joined the Hazelton engineering department.

1959 (June)

- Leonard Velkey began Industrial Hygiene sampling, and out side plant monitoring with the NESHAPS network.

Mid 1960

- Leonard Velkey recorded quarterly DWA's and some data on job classification for the Hazelton facility.
- High purity area at Reading facility stopped production and became a storage area for waste copper sulfate.

1961

- Leonard Velkey acted as Industrial Hygienist full time for the Hazelton plant until it closed.

1965

- Hazelton workers joined The Oil Chemical and Atomic Workers Union, OCAW.

1966

- Extraction process at Hazelton was stopped.

1968 (October)

- Beryllium Corporation merged with Kawecki Chemical to form Kawecki Berylco Industries (KBI). (Another possible contact might be Chuck Gerlinger who worked in the industry.)

1977 (July)

- Neil Roth began consulting at KBI. He published his report in OSHA's docket which included exposure values published by Shilen (1954). A copy of this data was provided by Roth

during the walk-through and is shown in the appendix.

1978

- KBI was purchased by Cabot Corporation. Cabot built a new plant in Indiana which never produced a quality product. Corporate problems caused high employee turnover and resulted in lost knowledge.

- Don Robinson became Director of Regulatory Affairs.

1979

- Bill Heffly became Analytical Chemist at the Reading facility, after the closure of the Hazelton plant.

1979 (July)

- Leonard Velkey became the Industrial Hygienist at the Reading facility.

1980

- The Hazelton Plant stopped operation and closed.

- Reading High Purity Area was closed and the operation stopped.

1986 (September)

- NGK Insulators of Japan purchased the plant from Cabot Industries and formed NGK Metals. Many production problems existed at Cabot before the sale to NGK Metals. NGK metals had been producing beryllium metal successfully in Japan, from raw materials purchased from the United States.

- Cabot may have retained some beryllium exposure data. The Reading facility purchases raw materials from the Brush Utah mines and Brazil. BeOH is then sent to the Reading facility where it is calcinated to BeO. Cabot retained a five year lease on two Reading buildings and joined with Cyprus Mineral to produce pure beryllium pellets. NGK metals is currently considering the purchase of a mine in El Paso, Texas.

## DISCRIPTION OF CURRENT OPERATIONS

The primary operation at the current Reading facility is the production of high quality Master Alloy as well as other alloy products (nickel and cobalt) in the form of rods, wire, ingots, and coiled sheets. After Cabot sold the Reading facility to NGK Insulators, Cabot retained a five-year lease on part of the plant to produce pure beryllium pellets. In the mid 1960's, NGK metals discontinued its use of the high purity area. The plant, since that time, has retained a relatively stable staff of approximately 350 production workers. NGK metals currently purchases beryllium hydroxide from the Brush Beryllium Utah mines. The hydroxide is converted to oxide in the calcining room. After hydrogen is driven off, beryllium oxide can then be sold for the production of ceramic products. NGK metals purchases Be Metal from Brush Wellman to produce many alloys in a continuous casting furnace. After bars are cast and cut in 30 foot sections, the bars are taken to the hot mill where the ingots are soaked and rolled. The metal then undergoes an annealing process before it is sent through the bulk cleaning area and finally inspected. These processes are described in more detail in the following section. Also provided in the appendix is a layout of the facility, with identified process locations.

### HIGH PURITY AREA / ARC ROOM

The old high purity area has been shut down since 1980. The

area currently houses drums of copper sulfate in which the sulfuric acid will be recovery when the refining equipment has been installed. unit facility to begin operation. Once the copper sulfate drums have been removed, it is planned to decontaminate the area and remove the machinery in order to set up the new recovery facility. The area has contained asbestos insulation; maintenance personnel had probable exposure to asbestos in the 40's and 50's, while running piping. The asbestos has been removed from this area by outside contractors during the past year. Also housed in this area are two in active, small research and development labs for beryllium aluminum alloy work. Raw material from Brush is brought in by drums. The drum wash is also located in this building.

The adjacent Arc Room houses three furnaces. Two operate at a time while the other acts as a reserve. Enclosures were constructed around the furnaces to control beryllium hydroxide dust during the conversion to beryllium oxide. The hydroxide barrel dumping area is also enclosed, and respirators are required in this area.

#### CONTINUOUS CASTING FURNACE

The continuous casting furnace is composed of graphite and clay packing material. Four ingots can be cast at one time. The furnace is charged with beryllium pebbles, pure copper (Master Alloy production), and scrap ingots which did not pass inspection. Materials are measured by weight in order to

maintain the correct percentage composition of beryllium. It takes approximately 24 hours for the material to melt down and form the liquid alloy. Once the material is ready, the furnace is tapped and the dross is removed. Then the furnace pours up to four ingots of alloy in the continuous caster. As the alloy is being poured, it is water cooled which caused solidification of the ingot. Ingots are then removed by a hoist and layed on a table were they are cut into 30 foot lengths. Furnaces operate seven days per week and three shifts per day. Ingots are then sent to the Hot Mill. Reductions in heat and dust emissions during cutting is accomplished by running water over the saw blade. The casting area is equipped with two large ingot furnaces and two small furnaces for pig pouring. There can be as many a four heats per shift. A nickle alloy is also produced at the Reading facility. Nickel is shipped in hand size briquettes.

#### HOT MILL

In the hot mill, round and square ingots of metal alloy are soaked in furnaces which drives off the remaining hydrogen from the beryllium hydroxide. The square ingots are then transfered to the hot rolling machines were they are reduced to sheets. Final product can be reduced to a thickness of 90 thousands of an inch. The sheets are then transfered to the surface mills for additional finishing and the rough edges are removed. Chips removed in this area are recycled to the cast furnace.

The round billets are turned to remove oxidized material

from the hot mill. Once the ingots have been properly milled, they are sent to the Mill Stock Room.

#### MILL STOCK ROOM

From the mill stock room sheets are further reduced in thickness to customer specifications by the Z-mill (the step before the finishing mill). Here sheets are reduced to 0.010, 0.012, 0.015, and 0.030 thousands in thickness. Then the round and sheet alloy materials are sent through another annealing process (1300 degrees F) which softens the metal to put beryllium in solution with the alloying material. Rounds are surfaced by turning on a mill and transferred to the extrusion mill. Rounds are then extruded in an extrusion mill and reduced in diameter to the size specified by the customer. The alloy materials are hardened in heat treat ovens (700 degrees F) by bringing the beryllium to the surfaces. Once cooled, stock is mechanically cleaned by large brushes of sanding blocks composed of high grit sandpaper.) NGK Metals now uses mechanical cleaning because of the high disposal cost of contaminated nitric acid waste. Materials are then transferred to bulk cleaning tanks for final cleaning and defect inspection.

#### BULK CLEANING

The bulk cleaning facility is composed of either a 5 or 7 strand cleaning process. In the five strand process, alloy is treated with thirty-five percent sulfuric acid at 120 degrees F. Corrosion and remaining beryllium oxide is removed in tanks

which utilize mist suppressors. Alloy is then run through an enclosed tank containing benzotriazol to reduce oxidation of the alloy. After benzotriazol treatment, alloy goes through a sulfuric acid treatment. The first tank in the process contains twenty percent sulfuric acid at 210 degrees F to further remove beryllium oxide, it is followed by a pickling tank containing 15-18 percent nitric acid to remove copper corrosion. A weak sulfuric acid and sodium dichromate solution in a third tank then removes tarnish and gives a bright-finished appearance to the alloy. After a series of hot water cleanings, the material is inspected and sent to shipping and receiving. The seven strand process is identical to the five strand except materials receive a sulfuric peroxide treatment followed by a benzotriazol treatment for corrosion inhibition.

#### MISCELLANEOUS OPERATIONS

##### Water Treatment Facility

The Reading Plant site includes a water treatment facility which handles wastes generated on site. Prior to the mid 1960's, water treatment included the use of lagoons at pre-treatment to creek discharge. In the late 1960's to early 1970's, the system was upgraded to remove chrome from the effluent. This system is no longer used since chrome has been eliminated from the process.

In the current facility, acids are neutralized with lime and the effluent allowed to settle in a series of two settling tanks. The effluent is then pumped to a near by stream. Laboratory

technicians currently operate this facility. Solid materials are landfilled and leachate is monitored by a contract environmental firm.

#### Analytical Laboratory

The analytical laboratory, under the direction of Mr. William Heffley, conducts analyses of the waste treatment streams and plant air samples for beryllium. The wet laboratory is equipped for Intercoupled Plasma (ICP) and Atomic Absorption (AA) analysis. Thirty to 40 air samples are analyzed daily by AA, which include both industrial hygiene and ambient (out plant) air samples. All samples are collected on Whatman filters. All analyses is conducted by one laboratory technician.

#### EXPOSURE RECORD AVAILABILITY AND EVALUATION

On the afternoon of January 13, 1988, Rice, Herrick, Seiler, Velky, Lichtenstein, and Roth archived the files which Leonard Velky maintains for the Reading and Hazelton facilities. Types of data available for each plant were examined and recorded.

#### Reading

The Reading Plant currently has 78 different job classifications. Samples taken include high volume and 10-12 personal samples per month. The plant is also equipped with three emergency high volume samplers set up in the arc furnace, melt and cast, and research and development areas. When a worker

witnesses a visible plume or dust, he/she sounds an alarm and the samplers automatically take a five minute samples. The exposure values are averaged in with the DWA's for the month. Since 1979, three episodes have occurred and thus exposure data for these months may appear higher than normal.

Mr. Velkey had no data prior to 1967 and only a few worksheets from 1967 for the Reading facility. From 1968-1970 data is composed of sparse miscellaneous materials. Data is complete from the second quarter of 1971 to the present. Notebooks have been maintained by quarter and year and are composed of a two-volume set. Volume one contains the raw data for each quarter. Both lapel personal and high volume samples were taken by area and job number designation, with at least three samples per area per job. Also data from emergency situations included. A copy of the raw data sampling sheet is provided in the appendix to the volume. The second volume includes the distribution of the Daily Weighted Averages (DWA's) for each quarter. When exposures were greater than  $2 \text{ ug/m}^3$ , the Chair of the Health and Safety Committee, Health and Hygiene Consultant, and Plant Health and Safety committee were notified. They would then decide on corrective action. It was Cabot's policy to purge data over three years old, but Velkey feels some of the data may remain on microfisch. Also exposure data for the Reading plant may be found in workers compensation files.

#### Hazelton

Mr. Velkey feels much of the Hazelton data has been archived

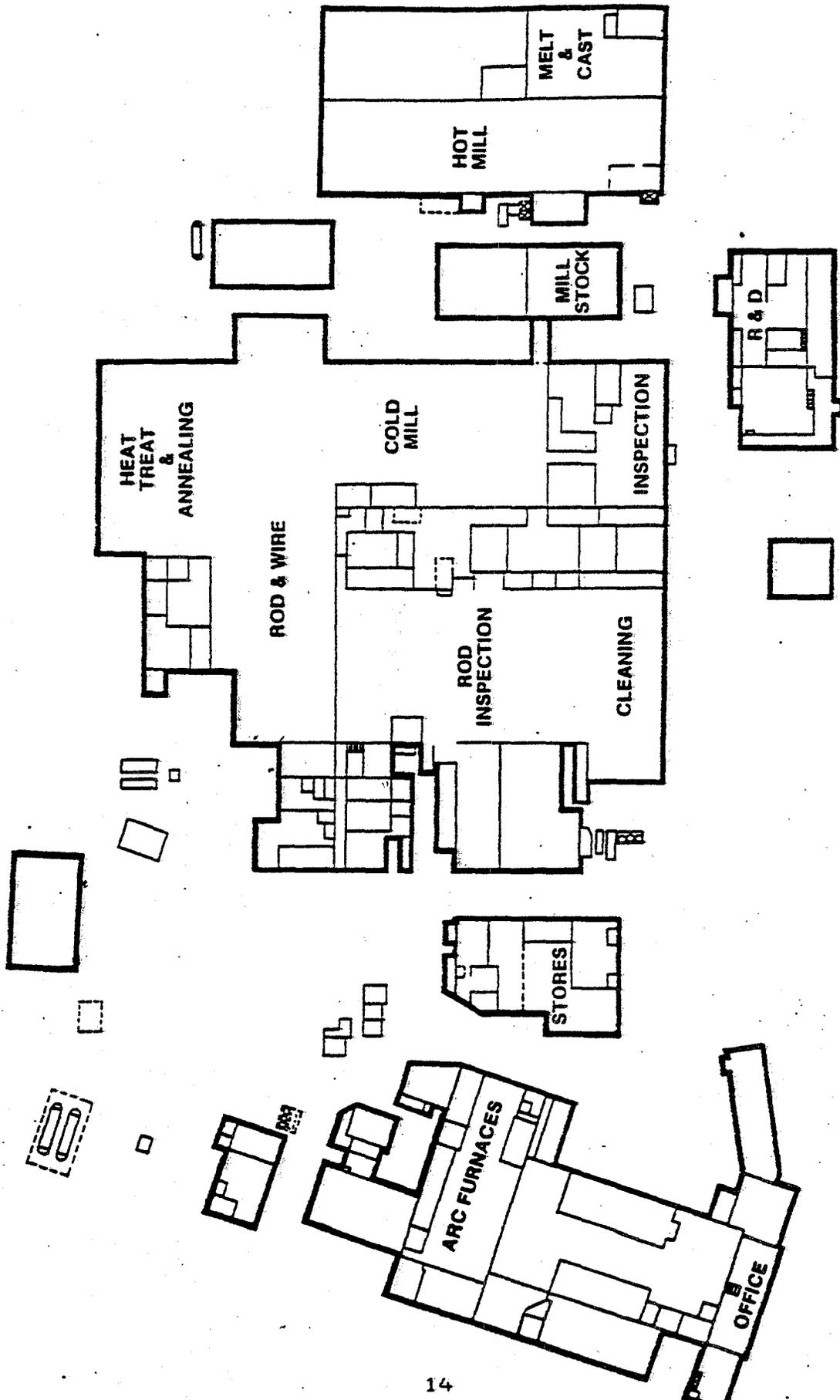
in Boston, Mass. Much of it is composed of personal samples. Job descriptions were done on a quarterly basis for the calculated DWA's. Mr. Velkey had a binder containing lapel versus high volume samples for Hazelton. It includes historical sampling equipment and lapel samples. Data however is very limited for this plant.

Mr. Velkey pointed out some problems with historical methods of sampling. Air sampling pumps were only calibrated approximately once per month. Thus volumes collected were less than correct when considering battery run down problems before the advent of Nickle-Cadmium power sources. He also stated analytical methods were not as good as they are today, when considering improved detection limits of the AA. Sampling practices of previous hygienists are also subject to criticism. Even the type of fabric worn by the employee may bias the detected exposure levels.

From 1970 to present the Reading plant data is very complete. Hazelton data, should be sought and evaluated.

NGK Metals Corporation READING PLANT

APPENDIX





# BERYLLIUM LEVELS IN VARIOUS OCCUPATIONAL DEPARTMENTS: PRE-1950\*

DEPARTMENT	YEAR	NUMBER OF MEASUREMENTS	BE ( $\mu\text{g}/\text{m}^3$ )
1. OXIDE, WET ORE MIXER	1949	2	788
2. OXIDE, BATCH MIXER	1949	1	194
3. OXIDE, BRIQUETTING	1947	2	7
4. OXIDE, SINTER FURNACE	1947	2	0
5. OXIDE, SINTER CRUSHER	1949	3	450
6. RAW BERYL ORE CRUSHER	1947	2	600
	1947	2	680
	1949	4	715
	1947	2	1,300
MEDIAN			680

\*SOURCE: Shilen et al (1954).

APPENDIX IV

Inventory of Beryllium Files  
DOE Library  
New York, NY

Box 1

File Beryllium Corporation Occupational Exposure to Dust of Beryllium  
Materials Berycorp-3 (issued 5/21/51)

Reference to prior 8/49 survey and 5/50  
Distribution of occupation by DWA  
Survey 2/51; contract expired 3/51  
DWA and original sample sheets  
75 samples

File Beryllium Corporation Occupational Exposure to Dust of Beryllium  
materials Berycorp-2 (issued 5/22/50)

Summary 4/50 (operations down 2/50-4/10/50)  
Vacuum cast only  
DWA for furnace operation, sample sheets  
Proposed ventilation drawings  
30 samples

File See above (Berycorp-1 (issued 8/18/49)

Survey 7/49  
Vacuum cast and appurtenant operations  
Reference to (and use of) earlier samples  
One DWA, no original data; ventilation designs

File Comparison of Occupational Exposure to Fluorides in Beryllium and Uranium  
Processing Plants (issued 5/29/51)

Job analysis and original data forms  
Brush-Luckey  
Survey 3/51  
70 samples for fluorides

Bound HASL-Brush-Luckey 9 Occupational Exposure to Airborne Contaminants  
HASL (7/5/57 issued)

DWA, original sample forms

Spiral Bound Occupational Exposure to Airborne Beryllium, Brush Beryllium  
Company, Luckey, Ohio (issued 8/5/58) HASL-48

DWA, original sample forms

Paper Clipped

2/25/54 memo Klevin (Brush) to Harris  
12/53-1/54 Cleveland air samples  
No DWA  
2/54 sampling sheets (typed)  
No DWA

File Quarterly Reports Brush Elmore-1961 (marked Box 6, but in #1)

4/13/62 letter Donaldson to Breslin first quarter  
DWA calc sheets  
10/9/62 letter Donaldson to Breslin third quarter  
DWA calc sheets  
4/23/62 letter Hiser to Siefert  
Changes in DWA formulae detailed

7/5/62 letter Donaldson to Breslin second quarter  
DWA calc sheets; original data forms

Bound Occupational Exposure to Airborne Contaminants Brush Beryllium  
Company, Luckey, Ohio Brush-Luckey 5 (issued 11/18/53)

Survey 8/53

DWA forms, original data

Reference to surveys 6/52, 1/53 and 8/53 (figures showing data)

Bound As above HASL-Brush-Luckey 8 (issued 3/15/57)

Survey 6/56

DWA forms, original data

Reference to surveys, 4/54, 8/53 (figures showing data)

Bound As above HASL-Brush-Luckey 6 (issued 8/16/54) (copied CR)

Survey 4/54

DWA forms, original data

Reference to surveys 8/53, 1/53 (figures showing data)

File Occupational Exposure to Beryllium Dust Brush-Luckey 2 (issued 5/2/50)

Survey date 2/20/50

DWA forms, original data

File As above Brush-Luckey 4 (issued 4/20/53)

Survey date 1/53

DWA forms, original data. 511 samples

Reference to surveys 12/51, 6/52

data graphed

File As above Brush-Luckey 3 (issued 1/31/51)

Survey data 9/12; second semi-annual survey

DWA forms; original data

Reference to February survey, with data graphed

NOTE: Brush-1 is disposal of chemical wastes at Luckey

Box 2 12/1/86

File marked Quarterly Reports, Brush-Elmore 1962

Contents -

Letter Harry Donaldson to A.J. Breslin 7/20/61

DWA Elmore second quarter 1961 calculation sheets

Above target: pebble flotation/insp. 2.1  
sample grinder 3.1  
furnace rebuild 5.4

Letter Harry Donaldson to A.J. Breslin 1/12/62

DWA Elmore fourth quarter 1961 calculation sheets

Above target: sulfate mill op 2.1  
fluoricle furnace 3.0  
reduction furnace 3.0  
melts crusher/patterns on mill 2.7  
vacuum cost 3.2  
sand blast 2.6  
furnace rebuild 4.1

Letter Hisen to Harry Siefert 12/28/61 regarding changes at Elmore  
(copied by CR)

Letter Donaldson to Breslin 10/31/61

DWA Elmore third quarter 1961 calculation sheets

Above target: reproduction furnace 2.3  
melts crusher/ball mill 2.2  
pebble flotation/inspect 2.5

Letter Donaldson to Breslin 4/14/61

DWA first quarter Elmore calculation sheets

Over target: beryl furnace 2.2  
furnace rebuild 2.1

Letter Donaldson to Breslin 1/17/61

DWA fourth quarter Elmore calculation sheets

Over target: powdering  
chip inspection  
scrap reclaim

Data and calculation sheets Be Corp first quarter 1962

Also includes: 3/62, 12/61 and 6/61 summary  
average quarter exposures 59, 60, 61, 62  
face velocity measures 3/31/62

Marked Box 2 12/1/86 (but loose 1/14/88)

File Brush Lorain Outdoor Dust  
Contains BZ data 11/2/51 7 samples

**Marked Box 4 12/1/86 (but loose 1/14/88)**

Clipped together sample sheets Cleveland  
5/53, 3/53, 4/53 (4-5/page 50 pages)  
no DWA

Rubber banded Cleveland sample sheets  
data sheets for 1952  
7-9/52 DWA calculation sheets  
summary memos 8/52, 11/52  
memo, Brush to W. Harris regarding high values at Luckey 12/19/52

File Air samples Cleveland 1953  
data sheets (approximately 600 samples)  
quarters 1-3 DWA calc sheets (incomplete)

Paper clipped Operational Exposure Record Brush, Luckey 1952  
fourth quarter DWA

Paper clipped Operational Exposure Record Brush, Luckey 1953  
first quarter DWA

File Brush Beryllium Co., Luckey  
sample record forms 6/52 - 6/55 (approximately 500)

File Brush Beryllium Co., Cleveland Dust  
3/52 - 3/55 sample record form (approximately 500)

Box 5 12/1/86

Letter Donaldson to Breslin 1/17/61

DWA fourth quarter Cleveland calculation sheets

Above target: do-all saw 2.6

radiac op 2.5

Mention of startup at the Chester Plant (and) the Titan Bldg. across from Perkins

Letter J.E.Kline, Staff Eng., Brush to W.B. Harris NY00 1/2/59

Reference to samples BC8718-BC9550, but data not attached (+5 other samples).

Letter Donaldson to M.B. Powers at Chicago Op. Office (C00) 3/3/59

Reference to 1958 data.

Memo from Gardiner to Breslin 4/10/59

RE: high (72) exposures at Brush Cleveland

Letter Kline to Harris includes data at Cleveland for samples >25 3/10/59 also dated 2/5/59, 6/16/59

Letter M.S. Weinstein to Robert Hiser at Brush 5/1/61

spiked samples

<u>Brush</u>	<u>HASL Expected</u>
6	5
17.4	25
30.3	50
3.9	5
17.0	25
35.4	50
.5	0
1.0	0

Memo G.H. Dugger from Breslin 6/7/61

Preliminary report on HASL survey of /Elmore 4/61  
(copied by CR)

Memo V.C. Vespe to Breslin 10/1/62

Reference to HASL Tech Memo 62-64

T.W. Breakdown 6/11/62

File Occup. Exposure to Be Dust, Brush Cleveland 10/4/50

first semi-annual survey date 8/50

process description

ventilation changes

recommendations

results

results of spiked sample recovery

DWA calculation sheets

Brush Cleveland-1

File Occup. Exposure to Be and Th Dust, Brush Cleveland 5/2/52  
(only 7 people involved in Thorium) Brush Cleveland-2  
see above  
survey 5/52

File Occup. Exposure to Be Dust, Brush Cleveland 3/2/53  
see above  
survey 12/52

File Occup. Exposure to Be Dust, Brush Cleveland 9/15/53  
see above  
survey 7/53

File Occup. Exposure to Beryllium for the 3 months period ending June 30, 1955  
by Kline and Fleming, Brush Cleveland  
average exposures  
DWA calc sheets

File Occup. Exposure to Beryllium for the 3 month period ending March 31, 1955  
by Kline and Fleming, Brush Cleveland  
see above

Booklet Occup. Exposure to Airborne Contaminants, Brush Cleveland 11/55  
(issued) 4/55 (survey date)  
operations  
results  
comparison with 7/53 and 12/52 NY00 survey  
DWA calc sheets  
lab sheets  
see above

Booklet 8/56 (issued) 3/56 (survey date)

Spiral bound HASL-76 Brush 11/59 (issued) 7/59 (survey)  
see above

Spiral bound HASL-81 Elmore 2/60 (issued) 9/59 (survey)  
see above

Spiral bound HASL-Tech Memo Elmore 61-3 (7/20/61) (issued) 4/61 (survey)  
see above

Spiral bound HASL 102 Elmore (issued) 10/60 6/60 (survey)  
see above

Spiral bound HASL-98 Cleveland 9/60 (issued) 8/60 (survey)  
see above

Spiral bound HASL-52 Cleveland 11/58 (issued) 7/58 (survey)  
see above

File Comparison of Occupational Exposures to Fluorides in Beryllium and  
Uranium Production Plants by Klevin 5/29/51  
occupational fluoride [ ] at Brush  
table and DWA calculation sheets

Box 6 12/1/86

File Brush Elmore 61-

6/62 DWA calc forms (in clipped group of papers)

3/17/58 facility map

12/19/58 proposed equipment layout-sinering area

scale maps

8/23/57 equipment layout-mfg

3/5/58 equipment list

1960 listing of BZs and GAs (copies attached CR)

**Marked Box 6, but loose**

**File** Be Corp. Hazelton Air Sample Data 1962  
data for 3/62, 4/62, 2/62, 1/62, 4/62, 5/62  
1" thick  
see attached example  
no DWA

**File** Brush-Elmore Air Sample Data - 1962  
entire year  
(carbon copy)  
cover internal AEC memo notes deteriorated conditions  
no DWA  
1" thick

**File** Beryllium Hazelton  
12/57 (approximately 100 samples) 1/58 (approximately 100 samples)  
8/57-12/57 (300 samples)

**File** Beryclo Reading  
7/49 memo B.S. Wolf to F.M. Belmont, Dir. Prod. Div.  
describes conditions (see copy CR)  
reference to Beryl-Corp Temple, PA??  
data 6/49 (approximately 15) 7/49 (approximately 15 Temple) 8-9/49  
(approximately 15 Reading) 9/49 (3 Reading) 10/49 (approximately 10  
Temple)

Box #7 12/1/86

File Brush Be Records Before 1950

Memo S. Warren from and to B.S. Wolf 8/19/48

reference to Keho request for inplant exposure data

News article 10/21/48 and press release 10/20/48

describes installation of air filters and outplant monitor stations

American Air Filter process description; vent recommendations 12/18/47  
(copy CR)

Letter Eisenbud to Sawyer at Perkins Ave. 5/15/48

reference to clothing study

9/30/49 NOTE: Beryllium Health Hazard Control, Luckey Plant at this date, proposed inplant sampling stations not yet set for routine use  
Schedule of Equipment Installation at Lorain to Reduce [ ] of Beryllium in Plant Neighborhood 1944 - 1948

plant schedule 1/29/48 - 2/3/48

changing technique 2/5/48

summary of Be Co Run, starting 3 AM 1/28/48

1/16/48 production process description

stapled DWA formula background information  
together air data  
(copied recommendations  
CR)

Lorain Plant recap 1/48 - 8/48

includes notes on work practices and source/chemical form of emissions

File Waste Disposal 1949 - 1952 Brush

Memo to file from W.B. Harris

"recent survey in Luckey...indicated high exposures in the sulfate mill, heat treat; backing step and the hydroxide one strip." Other trip notes.

File Brush Luckey 1950

12/14/50 memo MacIntyre to W. Harris

BZ sample LKI 2937 12/5/50 26.6  $\mu\text{g}/\text{m}^3$

Hi-Frey Fluoride furnace, ventilation dust plugged

Drum BeF removed from discharge hood

12/15/50 memo MacIntyre to W.B. Harris

BZ LKI 2982 12/9/50 55.4

pebble

BZ LKI 3003 12/11/50 29.3

pebble leacher

reasons given

12/22/50 memo Thomas A. Brush from Harris

Summary of December samples

11/3/50 memo F. Thomas to H.W. Shaffner

summary of NY00 semi annual survey results

11/20/50 memo MacIntyre to Harris  
GA LKI 2748 38.7  $\mu/m^3$  vac cast pour

Similar memos MacIntyre to Harris  
10/11/50, 10/26/50, 9/19/50, 9/27/50, 8/1/50, 8/16/50, 8/18/50,  
8/23/50, 7/20/50, 7/25/50, 6/2/50, 6/29/50

8/22/50 memo Thomas to Velton at Cleveland regarding Luckey  
ventilation changes as of 7/28/50

8/25/50 memo Thomas to Harris regarding vent changes at Luckey with  
appendix from Curry.

8/25/50 memo Quigly of AEC to file  
Contrast management commitment to H and S at Luckey and Cleveland

7/17/50 letter to Kjellgren regarding production change at Luckey

5/16/50 memo Sawyer to Schaffner  
Mentions red and fluted filters; the latter have higher ash content  
Luckey did own analysis; if too many samples they were sent to  
Cleveland.

Undated description Evacuation of Be Producing Plant includes procedures  
exposed individuals.

5/18/50 memo Eisenbud to Smith, Director Special Materials Division  
results of exposure survey at Luckey (Brush-Luckey 2). All exposures <2  
except hydroxide 3X allowed included recommendations.

5/18/50 memo Thomas to Harris regarding furnace incident 5/15/50 (see  
undated above) ammonium fluoride  
4 samples taken: range .22-2.86  
planned installation of emergency ventilation 6/1/50

4/5/50 memo Harris to Eisenbud  
High concentrations: hydroxide, melts crush, lunch room

4/5/50 memo Harris to Vilton, Field Operator, Cleveland  
Asking to be placed back on mailing list for sample data (had been  
getting stuff through 1949).

4/5/50 memo Harris to Velton regarding melts crushing  
"It is my belief that any thing that can be crushed by means of a  
sledge hammer, can also be crushed mechanically." Reference to high  
levels at melts crushing and hydroxide.

4/5/50 memo Harris to Velton  
Requests information on exposures at Luckey

5/1/50 weekly report Thomas to Harris  
Reference to changes in hydroxide.

5/7-14/50 report Thomas to Harris  
Vent changes vacuum cast and metal plant

4/2/51 report Thomas to Harris  
Documents incorrect resp choices at Luckey

3/12 report Thomas to Harris  
Air sampling data doing filtration trial run.

4/19/50 letter Wolowicz to Harris  
Method of calculating exposure data linked to charge accounts number,  
because number hours each worked in each area is known.

Next report will be more extensive due to fuller operation.

Exposure data attached, with DWA calculation.

4/20/50 memo Velton to Smith  
Changes at Luckey  
Reference to 3/30/50 letter regarding R&D at Cleveland.

4/20/50 memo Schaffner to Sawyer  
Sample LKI 869  
Attached documentation of level

3/8/50 memo from E.J. Keho to Chapman at Cleveland AEC  
Report of fire and recommendations  
Detailed description of furnace area

3/10/50 memo Thomas to Harris  
Luckey inspection report

3/30/50 memo Thomas to Harris  
Regarding ventilation changes

3/10/50 Report of Air Sampling etc. by Wolowicz  
Two sample results reported

3/13/50 letter Schaffner to Harris  
High levels at high frequency furnace

3/3/50 sample results form

3/20/50 letter Harris to Schaffner  
Requesting data

2/9/50 memo Thomas to Harris  
Results of 12/49 air sampling

2/9/50 memo Eisenbud to Smith  
Results of 12/49 air sampling

1/24/50 memo Tabershaw to file  
Regarding 1/13/50 trip to facility with recommendations  
Employee handbook attached  
Clothing/shoe policy attached  
Chemox respiratory project attached

1/16/50 memo Breslin to Harris  
Results of 12/49 sampling

File Brush Cleveland, 1954

Miscellaneous data sheets and correspondence (Cleveland)  
1954 sampling sheets (N approximately 20)  
Correspondence documenting changes  
More 1954 samples (N approximately 100)

2/25/54 comparison of NY00 and Brush BZ samples  
More 1954 samples (N approximately 20; also N approximately 50  
Thorium)

File Brush-Luckey, 1957-53

1/9/57 memo C.B. Sawyer Examination, Air Sampling Results shows metal  
prod and Be in air  
1/11/51 cover letter from Sawyer, Brush Chair  
1/12/57 memo Harris to Thomas  
Recommends use of respirator filters as sampling media  
2/1/57 Eisenbud to Belmore memo  
List of departments  $<5 \mu\text{g}/\text{m}^3$  during second semiannual survey  
2/21/57 Plant Management Comments to Recommendations in pages 18-21 of  
Occupational Exposure Report by Frank A. Thomas, Jr. 1/31/57  
3/1/57 memo Schaffner to Thomas  
Respiratory sampling implemented as supplemental method  
3/8/57 memo by Botts on rotameter calibration errors  
3/9/57 letter MacIntyre to Harris regarding high levels  
Similar letters - 4/12/51, 5/20/51, 6/18/57, 9/24/51, 9/24/57,  
9/24/51, 9/24/57, 9/24/57, 9/24/57  
3/14/57 memo Thomas to Harris  
Results of sharples filter test  
3/19/57 Eisenbud to Belmore memo  
Results of March plant survey  
3/28/57 memo Harris to Moore, Engineering and Construction  
Regarding proposed construction at Luckey  
5/1/57 memo regarding Fabrication and Installation of Fluoride  
Wheel Hoods  
5/4/51 memo regarding Fabrication and Installation of Bird Salt Chute  
5/25/51 memo Harris to Smith  
Continued high levels at remelt  
5/22/51 memo The Relocation of the Public Leacher Unit  
6/4/57 memo Ventilation of the Beryllium Production Furnace  
6/4/57 memo Vacuum Furnace Ventilation  
6/5/51 letter Thomas to Welton regarding engineering changes  
6/6/51 memo Thomas to Botts regarding respiratory sampling  
6/6/51 memo Thomas to Schaffner regarding furnace ventilation  
6/6/51 memo Thomas to Schaffner regarding sprinkler plate washing

6/8/51 letter Botts to Harris air levels in high frequency furnace  
6/28/51 memo Botts to Schaffner regarding air levels  
7/5/51 letter Sargent (Cleveland AEC) to Schaffner  
Regarding ventilation in Cleveland plant  
8/7/51 letter Thomas to Schaffner  
Quarterly reports OK; replaces bi-monthly  
9/25/51 memo Harris to Belmore  
Summary of bi-monthly air data  
10/19/57 memo Harris to Sargent (Cleveland AEC)  
High exposure levels  
3/4/52 memo Harris to File  
Trip report with recommendations/observations  
4/8/52 letter Brody (AEC) to Schaffner  
Comments on Harris' 2/52 trip  
4/18/52 letter Brody to Schaffner  
Application for test production proposal  
5/15/52 memo Harris to Sargent (Cleveland AEC)  
Summary of first quarter report  
7/18/52 memo Wolowicz to Brush/AEC  
Regarding air levels following Substitution of Bird Centrifuges  
7/21/52 memo Albert to Eisenbud  
Reference to high maintenance exposures  
Reference to Versene exposure  
7/22/52 memo Wolowicz to Brush/AEC  
Review of inplant samples during first half of July 52  
8/12/52 memo Harris to Sparks  
Regarding Danco Heater Blower Study  
9/12/52 memo Wolowicz to Brush/AEC  
Review of 8/52 data  
10/30/52 memo Harris to Sparks regarding Luckey inspection  
10/30/52 memo Harris to File regarding Luckey inspection  
12/12/52 memo Harris to Sparks  
Summary of 1952 Brush and AEC data  
10/2/53 memo Breslin to Harris  
Luckey shutdown schedule

File Brush-Luckey, 1949

12/21/49 memo Harris to Eisenbud  
Trip report to Luckey plant  
12/19/49 letter Harris to Schaffner  
Regarding sample number system for the plant  
12/27/49 letter Schaffner to Harris  
Regarding sample number system  
11/3/49 memo Eisenbud to Roboff (AEC)  
Request for permanent air sampling stations at the plant  
9/23/49 memo Harris to File regarding sulphating step  
8/3/49 memo Ryan to File regarding construction inspection at Luckey  
8/26/49 letter Ryan to plant regarding respirator purchase  
8/18/49 memo Eisenbud to File  
Trip report with some air data  
7/25/49 memo Ryan to file  
Construction report with anticipated start-up dates  
5/26/49 memo Kehoe to Bertino regarding respirators for plant

3/10/49 memo Harris to File  
Pre-construction meeting with company personnel  
4/6/48 memo Eisenbud to File  
Description of pilot plant  
3/30/48 memo Giaccio to Eisenbud  
Brush nearing start-up of pilot plant

NOTE: Search for other references to Keho and charge to Kehoe.

File Brush Lorain

6/29/48 letter Schaffner to Eisenbud  
List of present and past employees at Lorain  
5/27/48 Name, SSNo. employment date

File Brush Drawings

Luckey floor diagram (copy CR)  
(also many figures for reports)

File Brush-Cleveland, 1947-1949

12/3/47 letter Eisenbud to Sawyer  
Refers to 92 plant samples submitted to Rochester for analysis  
7/10/47 table  
1935-1946 content of Be in various alloys  
12/3/47 memo Schaffner from and to Bass  
BeO sales 1939-1947  
12/17/47 letter (blessing (Cottrell) to Sawyer  
Estimated exhaust volumes  
12/31/47 memo Eisenbud to Roboff (AEC)  
Ventilation requirements  
4/9/48 memo Smiley to Wolf  
Prep of U alloys for Cleveland plant  
8/26/48 letter Wolf to Kjellgren  
Modifications at the Lorain plant  
9/30/48 memo regarding notes for BeCu ventilation program  
10/11/48 letter Wolf to Kitson (Brush)  
Regarding health hazards of alloys of Uranium  
11/3/48 memo Wolf to Roboff (AEC)  
Air levels at Perkins and Chester 6-10/48  
11/16/48 letter Sawyer to Kjellgren  
Machining/melting/crucible construction ceased at 4301 Perkins  
Ave.  
12/20/48 memo Harris to Eisenbud  
Efficiency of pilot plant collector, Cleveland  
12/27/48 memo Harris to Wanta (Brookhaven)  
Estimates of plant emissions  
2/9/50 letter Harris to Sawyer  
Regarding several high exposures at Luckey  
3/18/49 letter Eisenbud to Rapprich (Brush)  
Reference to film badgers  
5/12/49 memo Blatz to Files  
Details radiation program at Cleveland  
Specifies U consumption to date

6/15/49 memo Wolf to Delmore  
Reference to sample collection 5/25 at Lorain and during test run  
of BeF; DWA given  
Reference to review of Brush data for Perkins powdered metal  
operations  
9/23/49 letter Sawyer to Eisenbud  
Health controls at Cleveland  
Reference to 18 samples collected daily  
10/13/49 letter Harley to Vinci (Brush)  
Analytical method  
10/25/49 letter Harley to Sawyer  
Results of analysis of spiked samples  
10/26/49 letter Eisenbud to Sawyer  
Outlines AEC H&S program, including sampling details (copy CR)  
10/31/49 letter Eisenbud to Sawyer  
Details of in plant monitoring with sampler locations (copy CR)  
11/8/49 letter Kelly to Admiral Mather USN  
Proposed decontamination program for Lorain

File Brush Cleveland, 1950-1952

2/21/50 letter Harris to Sawyer  
Report of Brustin trip with 3 sample results (others not attached)  
2/3/50 memo Breslin to Eisenbud  
Trip report, referenced by Harris 2/21  
Memo includes data  
3/30/50 letter Velton to Kjellgren regarding vent changes proposed  
3/30/50 letter Velton to Kjellgren  
Remedial action before start-up is allowed (following shut down)  
3/28/50 memo Harris to Eisenbud regarding proposed vent changes  
3/5/50 memo Thomas to Eisenbud  
Specifies of BeCl incident at Cleveland  
4/5/50 Harris to Velton memo requesting Cleveland reports  
5/18/50 Harris to Velton memo  
Comments on high exposures among samples taken 5/5-10  
5/18/50 letter Eisenbud to Velton  
Summary of Luckey air sampling program  
9/11/50 letter Sawyer to Velton  
Interpretation of "average" by Luckey personnel  
5/8/50 letter Sawyer to Eisenbud regarding engineering changes  
6/19/50 Plant Manager's memo #15  
Shows distribution of all reports: 3 copies to Velton  
6/30/50 memo Eisenbud to Ryan - 1 copy to thomas  
Summary of (high vs. low/acceptable) samples at Luckey  
All words  
6/21/50 Letter Sawyer to Eisenbud regarding work practices change  
6/6/50 letter Velton to Sawyer confirming all laundry done at Luckey  
6/6/50 letter Velton to Sawyer reference to Luckey (2) survey  
7/28/50 letter Harris to Velton regarding engineering designs  
7/28/50 memo Harris to File regarding engineering design  
7/7/50 memo Eisenbud to Ryan  
Word summary of April-June samples  
7/5/50 memo Harris to Velton  
Suggested improvement

8/31/50 letter MacIntyre to Harris regarding high levels

8/23/50 memo Harris to Eisenbud  
 Regarding ample analytical methods/results

8/1/50 letter Velton to Dodds regarding engineering proposal

8/31/50 15 air sampling records

9/5/50 letter Sawyer to Harris regarding respirator samples

9/18/50 letter Harris to Sawyer regarding respirator samples

9/7/50 letter MacIntyre to Harris regarding clothes washing procedure

8/29/50 memo Vinci to Sawyer regarding % recovery from filters

8/31/50 memo Settevendemi to Sawyer regarding % recovery from filters

9/5/50 letter Sawyer to Harris regarding % recovery from filters

10/16/50 memo Harris to Eisenbud  
 Evaluation of the air sampling program

10/30/50 memo Vinci to Settevendemi  
 DWA calculation guidelines

2/9/51 letter Kitson to Harris  
 Numbers of samples collected (no results)  
 1 DWA sheet

1-2/57 DWA formula sheets, results of respirator samples  
 Production

12/7/50 Medical meeting at Luckey, minutes

12/4/50 memo Botts to Schaffner regarding vent requirement at Luckey

2/21/51 Plant comments to recommendations by Thomas 1/31/51

3/19/51 letter Schaffner to Velton regarding 2/21/51 comments

3-4/51 No DWA due to insufficient operations

4/9/51 letter Kitson to Harris regarding routine reports

5/1/51 letter Botts to Velton tabulation of number of samples

6/11/51 memo Sargent to Morgan regarding uprod change

7/5/51 memo Thomas t Schaffner regarding decon of Cleveland warehouse

7/19/51 memo Harris to File regarding Cleveland level of activity

7/23/51 letter Sargent to Kjellgren regarding needed changes

1/16/52 memo Harris to Sargent regarding proposed ventilation

1/18/52 memo Harris to Sargent regarding machine shop changes

6/17/52 memo Sargent to Files regarding anticipated engineering  
 changes

6/20/50 memo Beaver to Sawyer regarding laundry procedures/Be  
 contamination of clothing

File Brush-Luckey Reports

5-6/51 DWA (Total approximately 25/date; no task data)

1-5/50 DWA

6-7/50 DWA

8-9/50 DWA

10-11/50 DWA

12/50-1/51 DWA

2-3/51 DWA

7-12/54 DWA

1-6/54 DWA

1-2/51 DWA

1950/1951 graph of exposures in: high frequency furnace  
fluoride furnace  
reduction furnace  
wet metal plant  
hydroxide department

5-6/51 DWA Cleveland

Marked Box #7 but loose

Memo to W.B. Harris, Chief, IH Branch, US AEC from A.M. MacIntyre, Prod Coordinator Brush (Luckey) 11/15/50 BZ sample LKI 2704 at Be metal sample grinder 10/10/50  $27.2 \mu\text{g}/\text{M}^3$  "for the past month an upward trend" "previous samples within the limits" "due to increased activity." "Grinder will be moved to an enclosure" "resp are worn by all employees."

Letter to Harris from MacIntyre 11/16/50 "new ball mill to eliminate the melts crusher will not be completed for 3 mos." Fresh air masks installed 10/10/50 "because of high Be content in BZ taken in the melts crusher room."

12/19/50 Eisenhard report of Luckey visit 12/6-7

"Production had maintained at satisfactory levels for some time." Noted the following poor work practices:

- 1) excessive use of rubber hose to transfer tank contents
- 2) excessive splashing of frit at beryl furnace (a condition arising since last inspection)
- 3) storage of large amounts of BeOH and sulfate in damaged drums with poorly fitting covers
- 4) leaks at pumps, valves, flanges
- 5) careless handling of HF
- 6) many serious leaks in ventilating equipment

Each person gets freshly laundered clothes daily; free work shoes.  
Under study: ways to reduce frequency of clean clothes

Mr. Schaffner has a 5-man crew devoted entirely to decon.

Schaffner proposed a reduced sampling schedule.

20 outplant  
.80 BZ 50 GA  
25 process  
10 stack  
15 duct  
10 fluoride Total = 210  
BeO operates 6-days week  
metal dept. going to 6-day week about 1/1.

Sample collection should be over 5 days.

Memo to E.C. Sargent, Area Manager, Cleveland from R.J. Smith, Acting Director, Production Division, NY 7/11/51

"Eisenbud...that Brush is engaged in the firing of BeO crucibles at their Lorain plant. Eisenbud advises that in 1949 there was an agreement...that we would not permit the performance of any further AEC Be work at the Brush Lorain Plant."

Handwritten note: "this was discontinued in April or May."

Memo to W.B. Harris from A.R. Picot 1/14/50 Closeout Survey at Brush Lorain. Survey 2/7/50 to check on "residual contamination remaining in plant as a result of a cancelled contract involving tracer work with 48 day HF 181." Two shipments, each less than 50 mc received. One never opened and will be returned to New Brunswick. Other contained 6 capsules approximately 5  $\mu$ c each on 1/16. Five were not used and will be sent to New Brunswick. The other was used only in the hot lab and flushed down the sink. No floor/furniture contamination. Glassware <1 mr/hr.

Memo to File from J.H. Harley, Chief, NY00 Lab. regarding Lorain

Laboratory results

<u>Added</u>	<u>Found</u>	
15 $\mu$ g	9.6	
7	7.2	
25	2.2	
30	0	
0	0	
.75	5.6	suggestions made.

In a file marked Employees Examined Beryllium Corp.  
Work hr 5/25/48 including previous employment  
Current assignment 4/19/48; 7/21/48, 7/30/48, 6/8/48, 6/10/48,  
6/1/48, 6/3/48

Lorain City Citizens' Meeting on Beryllium Health Program  
4/9/48 in file marked Beryllium Corporation Correspondence

Same File notes on a possible home case from clothes washing.

Same File letter to Dr. C. Dustan, Columiba SPH, from Otto Englehart,  
Pres. Be Corp. 4/13/48

Perkins Plant layout 12/2/47 in same file.

12/3/47 Second floor, Perkins File marked Reports, Field-Dustan.

APPENDIX V

Form of Potential Beryllium Exposures for Selected Job Titles  
Potential for Exposure to Acid Mists

Rating for Job Titles Supplied by NIOSH  
Plants 1-7, NIOSH Study

Plant 6 -

Job Title	Department	BE Exp	Chemical Form	Acids Y/N
SALESMAN		N	-----	N
FURNACE HELPER		Y	?	N
FURNACE OPERATOR		Y	?	N
ROD MILL HELPER		Y	BeCu	N
STENO "A"		N	---	N
BRIQUETTE MAKER		Y	Beryl	N
SYSTEMS ANALYST		N	---	N
MFG SYS COORDIN.		N	---	N
MFG SYS COORDIN.		N	---	N
STRAND PLATER		N	---	Y
PRODUCT SPECILST		N	---	N
SR. RESEAR METL.		Y	ALL FORMS	N
SECT. MGR R & D		Y	ALL FORMS	N
HELPER NIT		?	?	?
CARPENTER		Y	ALL FORMS	Y
EXT. PRESS HELP		Y	Be	N
SCRAP RECLM HLP		Y	Be, BeCu	N
TAP DROSS HNDL		Y	BeCu, Be	N
STRND H.T. FURNA		Y	BeCu, Be	N
ARC FURNACE OP		Y	Be	N
INGOT POURER		Y	BeCu	N
MELT & CAST HLPR		Y	Be	N
GENERAL LABOR		Y	ALL FORMS	Y
ROLLING PLNT OPR		Y	BeCu	N

Plant 6

Job Title	Department	BE Exp	Chemcial Form	Acids Y/N
PAINTER "A"		Y	ALL FORMS	Y
SURF & GAUG INSP		Y	ALL FORMS	Y
CALCINE OPERATOR		Y	BeOH, BeO	N
EXT PRESS OPERAT		Y	Be ALLOY	N
SCRAP HANDLER		Y	Be ALLOY	N
DET FURN HELPER		Y	Be	N
HEATER HELPER		?	?	?
FURNACE OPERATOR		Y	?	N
COLD MILL HELPER		Y	Be ALLOY	N
RESEARCH ASST		Y	ALL FORMS	Y
SECRETARY		N	---	N
COST ACCNT. "A"		N	---	N
SUPV COST DEPT.		N	---	N
MAIL CLERK		N	---	N
SCHED EXPEDITOR		N	---	N
SHEET METL WORK		Y	ALL FORMS	Y
FLOATER		Y	ALL FORMS	Y
SINTER FURN OP		Y	BeOH, BeO	N
DIE ASSEMBLER		Y	BeO	N
HYGIENE ASST.		Y	ALL FORMS	Y
YARD MAN		N	---	N
PLUMBER		Y	ALL FORMS	Y
SLITTER HLPR		?	?	?
HELPER		?	?	?

Plant 6

Job Title	Department	BE Exp	Chemical Form	Acids Y/N
SCRAP HANDLER		Y	Be ALLOY	N
JANITOR		Y	ALL FORMS	Y
FLOORMAN		Y	ALL FORMS	Y
CUT-OFF-MAN		Y	BeCu	N
ROUGHER HELPR		Y	ALLOY DUST	N
COLD MILL HELP		Y	Be ALLOY	N
PRECISION MOLD		Y	Be POWDER	N
FARELL MIL HLP		?	?	?
MOLDER		Y	Be POWDER	N
H.G. ANNEL HLP		Y	Be FUME	N
MELTNG FUR HLP		Y	Be FUME	N
STRP WELD HELP		Y	Be FUME	N
MECH CLEAN HLP		Y	ALLOY DST	N
EXT PRESS HLPR		Y	ALLOY DST	N
BULK ANNEL HLP		Y	Be ALLOY	N
FURNAÇE HELPER		Y	Be	N
CLASS "C" OPER		N	---	Y
SCARFER		Y	Be Dust	N
CLEANING OPERA		Y	ALLOY DST	Y
CHIEF CLEANER		Y	ALLOY DST	Y
FLOATER		N	---	Y
SCREW DOWN OP		?	?	?
CRANE OP POUR		Y	Be, BeCu	N
MAINT MECHAN "A"		Y	ALL FORMS	Y

Plant 6

Job Title	Department	BE Exp	Chemical Form	Acids Y/N
LEACH OP ASST.		Y	Be	Y
INSIDE TRUCK DR PACKER		Y	ALL FORMS	Y
		?	?	?
ELECTRICIAN		Y	ALL FORMS	Y
ELECTRICIAN "B"		Y	ALL FORMS	Y
PLUMBER "B"		Y	ALL FORMS	Y
LAUNDERER		Y	ALL FORMS	N
AJAX FUR HELP		Y	BeO, Be	N
STORES CLERK		Y	Be	N
KEYPUNC OP "B"		N	---	N
LABORER		Y	ALL FORMS	Y
BERYL FL HELP		Y	Be, BeFL	N
PERSONNEL SUPV		N	---	N
ASST MGR		N	---	N
CLERK-TYPIST		N	---	N
FURN REPR ASST		Y	ALL FORMS	N
MIXER OP		?	?	?
RESEARCH MGR		N	---	N
PROCES TECH "B"		Y	ALL FORMS	Y
STRAND ANNEL OP		Y	Be FUME	N
CUT-OFF MAN		Y	Be	N
PLUMBER "A"		Y	ALL FORMS	Y
STORE CLERK		Y	Be	N
CLASS "B" OP		N	---	Y

Plant 6

Job Title	Department	BE Exp	Chemical Form	Acids Y/N
HOT ROLL HELP		Y	Be FUME	N
SCREW DOWN OPR		?	?	?
POURER		?	?	?
PROCS METALURGST		Y	ALL FORMS	N
DESIGN DRAFTSMN		Y	ALL FORMS	Y
GENER CLERK		N	---	N
PROD CNT CLRK		Y	ALL FORMS	Y
ASST PURCH AGENT		N	---	N
PURCHASING AGENT		N	---	N
SALES CORRESPOND		N	---	N
ACCOUNTANT		N	---	N
METALLOGRAPHER		Y	ALL FORMS	N
STENOGRAPHER "A"		N	---	N
CERAMIST		Y	BeOH, BeO	N
CORP IND REL MGR		N	---	N
DRAFTSMAN		Y	ALL FORMS	Y
PROCS CONSLT MET		Y	ALL FORMS	Y
QUALTY CONT TECH		Y	ALL FORMS	N
LAB ASSISTANT		Y	ALL FORMS	N
FOREMAN FAB DEPT		Y	ALLOY DST	N
MASTR ALLY FOREM		Y	BeCu ALLY	N
ORDER CLERK		N	---	N
OILER		Y	ALL FORMS	Y
AJAX HELPER		Y	BeO, Be	N

Plant 6

Job Title	Department	BE Exp	Chemical Form	Acids Y/N
RECEPTIONIST-PBX		N	---	N
WAREHOUSEMAN "B"		N	---	N
METALLURGIST		Y	ALL FORMS	N
MGR OF ALLY DEPT		Y	Be ALLOY	N
TELEPHONE OPERAT		N	---	N
STATIONARY ENGR		Y	ALL FORMS	N
SCARF MACH OP		Y	Be	N
FORGE		Y	Be ALLOY	N
TYPIST B KEEP		N	---	N
PROJ ENGINEER		Y	ALL FORMS	Y
CLERK "C"		N	---	N
ASST. SALES MGR		N	---	N
LIBRARIAN		N	---	N
WAREHOUSMN HELP		N	---	N
SALES ENGINEER		N	---	N
ASST CLERK		N	---	N
HYGIENE ASST		Y	ALL FORMS	Y
PRESS OPR HELP		Y	Be ALLOY	N
SINT FURN OP		Y	Be	N
TECHNICIAN		?	?	?

Plants 4 & 5

Job Title	Department	BE Exp	Chemcial Form	Acids Y/N
CARPENTER HELPER	MAINTENANCE	Y	ALL FORMS	Y
FURN OPERATOR	HI-FIRED	Y	BeO, BeOH	N
TECHNICIAN	CERAMICS	Y	BeO	N
MACHINIST	MACHINE SHOP	Y	Be	N
TOOL MAKER	MACHINE SHOP	?	?	?
LAB ASSISTANT	METALLURGY	Y	ALL FORMS	N
LAB ASSISTANT	CERAMICS	Y	BeO, BeOH	N
MAINTEN HELP	CERAMICS	Y	BeO, BeOH	N
TOOL GRIND "A"	MACHINE SHOP	Y	Be, ALLOY	N
COMBO WELDER	MAINTENANCE	Y	ALL FORMS	N
OPERATOR	MFG	?	?	?
PRODCT HELPER	ROLL & EXTRU	Y	Be	N
PRODCT HELPER	MACHINE SHOP	Y	Be	N
SYST PROGRMER	SPECIAL FABR	Y	Be	N
ACCT. CLERK		N	---	N
SR TECHNOLOGIST		?	---	?
SALES ENGINEER		N	---	N
SR PROGRAMMER		N	---	N
ACCOUNTANT		N	---	N
COMPUTER OPERT		N	---	N
LABORER	LUCKEY-MAINT	Y	ALL FORMS	Y
PRODUCTION HELP	METAL OXIDE	Y	BeO	N
OPERATOR	MILL	?	?	?
GRINDER C	CERAMIC MFG	Y	BeO	N

## Plants 4 &amp; 5

Job Title	Department	BE Exp	Chemcial Form	Acids Y/N
PRODUCT GRIND	CERAMIC MFG	Y	BeO	N
CERAMC INSP.	CERAMIC ENG	Y	BeO	N
Q/A INSPECT.	CERAMIC ENG	Y	BeO	N
LIBRARIAN		N	---	N
DIST SALES MGR		N	---	N
PROGRAM ANALYST		N	---	N
STAFF TECH		?	?	?
SALES COORD.	BE METAL SLS	N	---	N
MGR CUST SERVC	BE METAL SLS	N	---	N
MGR SALES ADM		N	---	N
SUPV SALES ADM		N	---	N
GEN CLRK SALES		N	---	N
SALES ORD CORRES		N	---	N
STAFF ENGINEER	ENG CONSTUCT	Y	ALL FORMS	Y
MGR	PLANT ENG	Y	ALL FORMS	Y
TECH WRITER		N	---	N
STENO CLERK	ALLOY SALES	N	---	N
TECH RPT WRITER	PROCESS DEV	N	---	N
PERSONNEL ASST	PERSONNEL	N	---	N
EDITOR	PERSONNEL	N	---	N
LAB ASSISTANT	R & D	Y	ALL FORMS	Y
TECHNICIAN	MARKET DEVLM	N	---	N
TECHNICIAN	PROD ENGINER	Y	ALL FORMS	Y
MGR SPECIAL PROJ	BE METAL	Y	ALL FORMS	Y
KEY-PUNCH OPER	TABULATING	N	---	N

Plants 4 & 5

Job Title	Department	BE Exp	Chemical Form	Acids Y/N
LEAD MAN	MACH SHOP	Y	ALL FORMS	N
MACHINE TOOL OP		Y	ALL FORMS	N
JOURNEY MACHNST		Y	ALL FORMS	N
TOOL CRIB ATTND	MACHINE SHOP	Y	Be, ALLOY	N
JANITOR	PLNT MAINTNC	Y	ALL FORMS	Y
PBX OPER & RECP	ACCOUNTING	N	---	N
TELEPHON OPR PBX	ACCOUNTING	N	---	N
TELEPHON OPR PBX	ORE SERVICES	N	---	N
SALES ENGINEER	ALLOY SALES	N	---	N
CLERK TYPIST	ACCOUNTING	N	---	N
SECRETARY		N	---	N
PROD HELPER	POWD & SINT	Y	BeOH, Be	N
LAYOUT DRAFTMN	PLT ENG	Y	ALL FORMS	Y
MAT HAND TRUK OP	PROD CONTROL	Y	ALL FORMS	Y
INVENT CONT CLRK	PROD CONTROL	Y	ALL FORMS	N
S R. CLERK	RECORD CLRK.	N	---	N
TRACER LATHE OPR	MACHINE SHOP	Y	Be	N
METALLURGIC ASST	METALLURGY	Y	ALL FORMS	N
RADIOGRAPH INSP.	TECHN Q/C	Y	ALL FORMS	N
TECHNICIAN	CERM ENG DEV	Y	BeO	N
OPERATOR	METAL OXIDE	Y	BeO	N
LIQUID OPERATION	BE HYDROXIDE	Y	BeOH	N
DRAWBENCH OP	ALLOY	Y	Be	N
STRAND PICKLNG O	ALLOY	N	---	Y
CHEMICAL OP	BE HYDROXIDE	Y	BeO	N

Plants 4 & 5

Job Title	Department	BE Exp	Chemical Form	Acids Y/N
MACHINE OP	BE METAL	Y	Be	N
WELDER "B"	CONSTRUCITON	Y	ALL FORMS	Y
RESEARCH ENGINR		Y	ALL FORMS	Y
SHP & RECIVNG		Y	ALL FORMS	N
ANALYST	CHEM LAB	Y	ALL FORMS	N
DECON ASST.	MAINTENCE	Y	ALL FORMS	Y
SR. CLERK	PROD CONT	N	---	N
STAFF ENGINEER	R & D	Y	ALL FORMS	N
STAFF ENGINEER	FAB ENGN	Y	Be	N
MACHINIST	MFG	Y	Be	N
CLERK-TYPIST	RECORDS	N	---	N
CLEANING PERSON	SALES	N	---	N
TECH WELDER	R & D	Y	Be	N
CLERK TYPIST	CHEMISTRY	N	---	N
PROPERTY CUSTODN		Y	Be, ALLOY	N
TECH "C" AIR SMP	CRYSTALIZING	Y	ALL FORMS	Y
MAINT MECHANIC	MAINTENANCE	Y	ALL FORMS	Y
CLERK	ACCOUNTING	N	---	N

## Plants 3

Job Title	Department	BE Exp	Chemical Form	Acids Y/N
MACHINIST	MFG METAL OX	Y	ALL FORMS	N
JANITOR	OFFICES-PLANT	Y	ALL FORMS	Y
LAUNDRYMAN	MFG-LAUNDRY	Y	ALL FORMS	N
MAINT HELPER	GEN MAINTENC	Y	ALL FORMS	Y
ELECTRICIAN	GEN MAINTENC	Y	ALL FORMS	Y
PROD HELPER	METAL OXIDE	Y	BeO	N
LABORER	MFG MAINT	Y	ALL FORMS	Y
ENGINEER	ENGINEERING	Y	ALL FORMS	Y
DETAIL DRAFTSMN	ENGINEERING	Y	ALL FORMS	Y
LABORER DECON	HEALTH & SAFT	Y	ALL FORMS	Y
PROD HELPER	BE EXT & BeO	Y	ALL FORMS	N
FLOOR INSPECTOR	ENGINEERING	Y	ALL FORMS	Y
PRODUCTION HLP	BE MFG ADMIN	Y	ALL FORMS	N
STEND CLERK	MFG METAL OX	N	---	N
LABORER DECON	CENTRAL MAINT	Y	ALL FORMS	Y
MAINT MECHANIC	FACILT ENGIN	Y	ALL FORMS	Y
LAB ASST "	ENGINEERING	Y	ALL FORMS	N
MAINT MECHANIC	MFG MAINT	Y	ALL FORMS	Y
LABORER	FACILT ENG	Y	ALL FORMS	Y
ENGINEER	ALLOY	Y	ALL FORMS	Y
OPERATOR	METAL OXIDE	Y	BeO	N
OPERATOR	BE METAL	Y	Be	N
INSTRU REPAIRMN		Y	ALL FORMS	Y
GRINDER "C"		Y	Be	N

Plants 3

Job Title	Department	BE Exp	Chemical Form	Acids Y/N
PRODUCTION OPR		?	?	?
PURCH DIRECTOR	PURCHASING	N	---	N
PURCHAS AGENT	PURCHASING	N	---	N
FOREMAN BE METAL		Y	Be	N

PLANT 1

Job Title	Department	BE Exp	Chemical Form	Acids Y/N
MAINT HELPER	MAINTENANCE	Y	ALL FORMS	Y
PAINTER	MAINTENANCE	Y	ALL FORMS	Y
LAB	LABORATORY	Y	ALL FORMS	N
FURNACE OPER	SINTERING	Y	BeO, BeOH	N
FURNACE OPER	BE METAL	Y	Be	N
FURNACE OPER	BE OXIDE XTL	Y	Be, BeO	N
ROTARY	BE O	Y	BeO	N
ROTARY	CRYSTALLIZING	Y	BeO, Be	N
ROTARY	MAINTENANCE	Y	BeO, Be	N
ROTARY OPR	ROTARY	Y	BeO, Be	N
OXIDE INSPECTOR	GC INSPECTOR	Y	BeO, Be	N
OXIDE INSPECTOR	BE METAL	Y	BeO, Be	N
WELDER	MAINTENANCE	Y	ALL FORMS	Y
FUR & XTL OPR	Be METAL	Y	Be	N
FUR & XTL OPR	SINTERING	Y	BeO, Be	N
LAB ASST	BeO LAB	Y	BeO	N
ELECT HELPER	MAINTENANCE	Y	ALL FORMS	Y
CLERK	ENGINEERING	N	---	N
CLERK	Be COPPER	N	---	N
DRAFTSMAN	ENGINEERING	Y	ALL FORMS	N
INV CONT CLERK	LAB	Y	ALL FORMS	N
MILLWRIGHT		Y	Be, ALLOY	N
CARPENTERS HELP	MAINTENANCE	Y	ALL FORMS	Y

PLANT 2

Job Title	Department	BE Exp	Chemcial Form	Acids Y/N
PRODCTN HELPER		Y	ALL FORMS	?
JANITOR		Y	ALL FORMS	Y
CLERK - TYPIST		N	---	N
MAINT MECHANIC		Y	ALL FORMS	Y
STEND - CLERK	MAINTENANCE	N	---	N
LAB TECHICIAN		Y	ALL FORMS	N
LABORER		Y	ALL FORMS	Y
BeO ENGINEER	Be METAL	Y	BeO, Be	N
WELDER		Y	Be	N
ELEC HELPER		Y	ALL FORMS	Y
INV CONTRL CLRK		N	---	N
ENGIN TRAINEE	ENGINEERING	Y	ALL FORMS	Y
ACCOUNTNG CLERK		N	---	N
DETAIL DRAFTSMN	ENGINEERING	Y	ALL FORMS	Y
CHEMICAL OPR	BASIC Be	Y	BeOH, Be	N

PLANT 7

Job Title	Department	BE Exp	Chemical Form	Acids Y/N
FLOURIDE OPERAT		Y	BeOH, Be	N
MAINT LABORER		Y	ALL FORMS	Y
DECON LABOR		Y	ALL FORMS	N
VAC FURN HELPER		Y	BeO	N
ENG PROCESS DEV		Y	ALL FORMS	Y
FLOURIDE HELPER		Y	BeOH, Be	N
ATT MILL OPER		Y	Be DUST	N
HIGH PURITY OP		Y	BeOH, BeO	N
LEACH HELPER		Y	Be	N
REDUCT HELPER		Y	BeFL	N
SINTER MIX HELPR		Y	BERYL	N
CHIP PROCESS OP		Y	Be DUST	N
AREA FOREMAN		?	?	?
MACHINIST "C"		Y	Be DUST	N
UTILITY MAN		Y	ALL FORMS	Y
MACHINIST "B"		Y	Be DUST	N
MACHINIST "A"		Y	Be DUST	N
PRESS OPERATOR		Y	BeO	N
VACUUM HELPER		Y	BeO	N
FELT & DRYING OP		?	?	?
SCRAP RECLAIMER		Y	BeCu DUST	N
MILL HELPER		Y	Be DUST	N
MACHINE OPERATOR		Y	Be DUST	N
DECON LABORER		Y	ALL FORMS	Y

PLANT

Job Title	Department	BE Exp	Chemcial Form	Acids Y/N
DIE HANDLER		Y	BeO	N
CHIP PROCESS OP		Y	Be DUST	N
JANITOR		Y	ALL FORMS	Y
PRECIPITATION OP		Y	BeOH	N
FURNACE REP HELP		Y	ALL FORMS	N
SPENT SALT EVAP		Y	Be	N
GEN LABOR POOL		Y	ALL FORMS	Y
UTILITY MAN		Y	ALL FORMS	Y
WT & S OPERATOR		?	?	?

APPENDIX VI

Retrospective Assessment of Beryllium Exposures

Poster Presentation  
American Industrial Hygiene Conference  
May 1988

# AMERICAN INDUSTRIAL HYGIENE CONFERENCE

## JOINT ACTIVITIES IN INDUSTRIAL HYGIENE

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RETROSPECTIVE ASSESSMENT OF BERYLLIUM EXPOSURES. Rice, C., Institute of Environmental Health, University of Cincinnati, 3223 Eden Avenue, Cincinnati, OH 45267-0056; Seiler, D., Cornett, M., Institute of Environmental Health, University of Cincinnati, 3223 Eden Avenue, Cincinnati, OH 45267-0056; Herrick, R., National Institute for Occupational Safety and Health, 4676 Columbia Parkway, Cincinnati, OH 45226.

Beryllium exposure has been associated with the development of nonmalignant respiratory disease since the 1930s. More recently, the question of a causal association between exposure to beryllium and its compounds and the development of cancer has been raised. Several epidemiologic studies of workers suggest an association between beryllium exposure and lung cancer but are limited by methodologic problems including use of duration of employment as a surrogate measure of exposure.

The National Institute for Occupational Safety and Health (NIOSH) has initiated a retrospective cohort mortality study of beryllium-exposed workers in order to resolve the methodologic challenges to the previous studies. Approximately 10,000 individuals fulfill the cohort definition at seven processing plants. A nested case-control study of lung cancer will be conducted to evaluate if exposure to beryllium is related to disease development.

In collaboration with NIOSH, the University of Cincinnati investigators have reviewed the environmental data collected by the U.S. Public Health Service, NIOSH and the Atomic Energy Commission. The results of approximately 6,000 air samples have been computerized and the process by which exposures have been ranked across all job titles in the seven plants is detailed. These ranked exposure estimates are being used by NIOSH for an initial analysis of the case-control study.

The available data illustrate a number of interesting aspects of retrospective exposure assessment. Several sampling methods have been used over the years for the collection of beryllium; therefore, conversion factors are needed to unify the exposure data. Much of the data is reported as mean values of the collected samples, which complicates the statistical treatment. Throughout the processing of beryllium, exposure to other materials or different forms of beryllium may exist.

A strategy to reconstruct quantitative estimates of exposures to beryllium is presented, which accommodates these characteristics of the data set.

### Topic Preference:

- Occupational Epidemiology
- Occupational Medicine
- Joint Activities in Industrial Hygiene

I Prefer:  Platform  Poster  No Preference

Papers may be assigned to Poster Sessions if time is not available in the Platform Sessions. The Technical Program Co-chairmen will make final decisions of papers assigned.

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SUBMIT ABSTRACTS TO THE ABOVE ADDRESS BY OCTOBER 16, 1987.

## INTRODUCTION

Beryllium exposure has been associated with the development of nonmalignant respiratory disease since the 1930's. More recently, the question of a causal association between exposure to beryllium and its compounds and the development of cancer has been raised. The development of lung cancer in rats and monkeys exposed to beryllium has been demonstrated. Some human epidemiologic studies suggest an association between beryllium exposures and lung cancer but are limited by methodologic problems including use of duration of employment as a surrogate measure of exposure.

The National Institute for Occupational Safety and Health (NIOSH) is conducting a retrospective cohort mortality study of employees at six beryllium processing facilities. The work presented here complements the mortality analysis by providing data on exposure.

BERYLLIUM PRODUCTION

BERYL ORE

IMPORTED ORES

UTAH MINES

BERYLLIUM HYDROXIDE  
Be(OH)<sub>2</sub>

BERYLLIUM ALLOYS  
(Cu, Ni, Al)

BERYLLIUM OXIDES  
AND CERAMICS

METALLIC BERYLLIUM

FABRICATED FORMS

Bar            Wire  
Rod            Strip  
Ingot          Tube  
Plate          Billet

FABRICATED FORMS

Beryllia ceramics  
Bare, Metallized  
Beryllium Oxide  
powder

FABRICATED FORMS

Rod            Bar  
Tube           Foil  
Powder

APPLICATIONS

Tooling Dies  
Safety Tools  
Bearing Sleeves  
Overseas Cable  
Housings  
Welding Components

APPLICATIONS

Resistor cores  
Traveling Wave Tubes  
Laser Tubes  
Circuit Chip Carriers

APPLICATIONS

Missile Parts  
Aircraft Brakes  
Inertial  
Guidance Parts  
Rocket Nozzles  
Space Optics  
Weapon Parts

METHODS OF BERYLLIUM HYDROXIDE PRODUCTION

BERYL ORE (4-5% Be)  
 $\text{BeO}_3\text{Al}_2\text{O}_{18}$

FLUORIDE METHOD

Ore Crushed in Mills  
(200 Mesh)

Simpson Mix Muller  
Blend of Sodium-Silico-fluoride  
Soda Ash, water, and oil mix)

Compact into Briquettes  
and Sinter in furnace

Hammer and Ball Mills  
(100 Mesh)

Powder and Hot Water mixed to  
form slurry -- Collect liquor

Ammonium-Persulfate added to remove  
Manganese --  $\text{Na}_2\text{BeF}_4$  Remains

Liquor Heated and Caustic Soda  
Added Yields Precipitation of  $\text{Be}(\text{OH})_2$   
filtered and Dried

SULFIDE METHOD

Ore Crushed in Mills  
( 1 inch diameter )

Ore fused in  
Beryl Furnace

Molten Material Poured  
into Water to Form Frit

Rotary Kiln Heat Treats  
and Dries Frit

Frit Crushed in Ball Mill  
( 325 Mesh )

Powder mixed with  $\text{H}_2\text{SO}_4$  to  
Form Slurry in Sulfating  
Mill.  $\text{BeSO}_4$  and  $\text{AlSO}_4$   
in Solution

$\text{AlSO}_4$  Removed with  
Addition of Amonia

Sodium Hydroxide added to  
Yield  $\text{Be}(\text{OH})_2$  which is  
Removed by Centifugation  
and Dried

TYPICAL WORKER EXPOSURES IN BERYLLIUM PRODUCTION FACILITIES

Job Title	Department	Be Exp	Chemical Form	Acids Y/N
FURNACE OPERATOR	SINTERING	Y	BE DUST	N
OXIDE INSPECTOR	BE METAL PROD	Y	BeO, Be	N
INDUSTL HYGIENST	SAFETY	Y	ALL FORMS	Y
INGOT POURER	BE-CU PROD	Y	BeCu FUME	N
EXTRUSION PRESS	METAL FABRICA	Y	BE	N
ROLLING PLANT OP	METAL FABRICA	Y	BE	N
COMBO WELDER	MAINTENANCE	Y	ALL FORMS	Y
MAINTEN HELPER	CERAMICS	Y	BeO, Be(OH) <sub>2</sub>	N
MGR CUSTOMER SERV	BE METAL SALE	N	-----	N
MANAGER	PLANT ENGINEE	Y	ALL FORMS	Y
PERSONNEL ASSTNT	PERSONNEL	N	-----	N
LAB ASSISTANT	R & D	Y	ALL FORMS	Y
JANITOR	PLANT MAINTEN	Y	ALL FORMS	N
STRAND PICKLING	ALLOY DIV	Y	Be, ALLOYS	Y
CHEMICAL OP	BE HYDROXIDE	Y	Be(OH) <sub>2</sub>	N
METALLURGIC ASST.	METALLURGY	Y	ALL FORMS	N
DECON ASSISTANT	MAINTENANCE	Y	ALL FORMS	Y
CLERK TYPIST	RECORDS	N	-----	N
TECH "C" AIR SMPL	CRYSTALIZING	Y	ALL FORMS	Y
LAUNDRY PERSON	MFG-LAUNDRY	Y	ALL FORMS	N
ELECTRICIAN	GENERAL MAINT	Y	ALL FORMS	Y
FLOOR INSPECTOR	ENGINEERING	Y	ALL FORMS	Y
PURCHASING AGENT	PURCHASING	N	-----	N
PAINTER	MAINTENANCE	Y	ALL FORMS	Y

THE SPECIFIC AIMS

- \* Computerize environmental records
- \* Rank exposures by job title across plants
- \* Develop strategy for reconstructing quantitative exposure estimates

## MATERIALS AND METHODS

- \* Computerize 8,400 environmental records
  - Daily Weighted Average (DWA)
  - Individual Samples
    - Hi-Volume
    - Personal filter
    - Personal cyclone
- \* Describe available data
- \* Detail available data to explore conversion factors
- \* Develop uniform job titles
- \* Identify chemical form of potential exposures
- \* Rank DWA exposures across plants
  
- \* Identify additional sources of data

MEAN DWA EXPOSURES BY JOB TITLE AND PLANT IDENTIFIER

Job Title	Plant	Mean	Range	Number
Air Sampler	2	2.3	2.3 - 2.3	1
	3	1.9	0.7 - 2.8	18
	4	1.2	1.0 - 1.3	3
Alloy Arc Furnace Charger	2	4.0	1.1 - 17.2	13
Alloy Arc Furnace Crew Chief	2	1.1	1.0 - 1.2	4
Ceramic Press	2	0.5	0.2 - 0.9	18
Be Chip Process	3	4.1	1.6 - 6.5	15
Fabrication Foreman	3	3.8	1.3 - 8.0	14
Fabrication Supervisor	3	2.7	1.2 - 4.7	5
Fluoride Furnace Helper	3	2.3	0.4 - 4.9	19
Laundry Operations	2	1.6	0.8 - 2.7	5
	3	2.3	0.5 - 9.0	18
	4	0.6	0.4 - 0.8	3
Rod and Wire	5	0.7	0.3 - 1.6	17
Sinter Mixing	3	2.0	0.3 - 4.9	14
Sinter Mix Helper	3	2.3	0.4 - 5.0	13

## FUTURE INVESTIGATIONS

- \* Acquire additional data
- \* Describe component tasks of jobs without DWA formula
- \* Determine usefulness of data from various sampling methods
- \* Investigate time-trends in exposure measures
- \* Evaluate data
- \* Determine exposure estimates, specific for Job title, Plant, Time, Chemical Form

PHOTOGRAPHS USED AT THE SAN FRANCISCO IH CONFERENCE

1. Chemical Storage Area
2. Beryllium Oxide Drying Ovens
3. Copper Alloy Rolling Plant
4. Beryllium Billets
5. Beryllium Refining
6. Machine Shop
7. DWA High Volume Sampler
8. Beryl Ore Feed Hopper
9. Barrel Filling Operation
10. Beryllium Copper Alloy Ingots
11. Strand Pickling
12. Furnace Operation

SOURCE OF SUPPORT

This project was supported by grant R03 OH02375 from The National Institute for Occupational Safety and Health of The Centers for Disease Control.