

REPORT DOCUMENTATION PAGE 1. REPORT NO. IWS-37.7 2.

PB81226003

4. Title and Subtitle
Industrywide Study of Beryllium Production Facilities

5. Report Date
July, 1973

7. Author(s)
Donaldson, H. M.

6. NA

8. Performing Organization Rept. No.
NA

9. Performing Organization Name and Address
NIOSH, Environmental Investigations Branch, Division of Field Studies and Clinical Investigations

10. Project/Task/Work Unit No.
NA

11. Contract(C) or Grant(G) No.
(C) NA
(G)

12. Sponsoring Organization Name and Address
Same as Above

13. Type of Report & Period Covered
Industrywide Study

14. NA

15. Supplementary Notes
NA

16. Abstract (Limit: Worker exposures to beryllium (7440417) (Be) were surveyed in an industrywide study of four Be facilities in 1968 through 1970 and 1971 thru 1972. In the 1968 survey, general area, gross, and respirable dust samples were collected. In 1970, mainly personal respirable samples were collected and some general area gross and respirable dust samples were analyzed. In the 1971 through 72 surveys personal respirable, personal gross, and the Atomic Energy Commission (AEC) sampling methods were used. In facility A, Be concentrations ranged from 0.08 to 166.8micrograms per cubic meter (cu m) in the 1968 and 1970 surveys. In the 1971 and 1972 surveys, concentrations ranged from 0.13 to 76.4 micrograms/cu m. In facility B during the 1968 through 70 survey concentrations ranged from 0.01 to 1.29 micrograms/cu m. In facility C during the 1968 and 1970 surveys, concentrations ranged from 0.1 to 237.0micrograms/cu m. In facility C the 1971-72 Pennsylvania State survey concentrations ranged from 0 to 582.0micrograms/cu m and during the NIOSH concurrent survey, concentrations ranged from 0 to 1146.0micrograms/cu m in facility C. In facility D during 1968 and 1970, concentrations ranged from 0.1 to 136.0micrograms/cu m and in 1971 through 1972 concentrations ranged from 0.1 to 136.0micrograms/cu m. The author concludes that in facility A, Be concentrations by AEC methods generally were within the 2microgram/cu m standard. Facility C exceeded the OSHA standard regardless of the sampling method used. It is feasible to operate Be facilities at the specified exposure standards (AEC method).

17. Document Analysis a. Descriptors

Field-Study, Region-3, Metallic-dusts, Air-sampling, Work-environment, Standards, Air-contaminants, Air-quality-control

b. Identifiers/Open-Ended Terms
c. COSATI Field/Group

18. Availability Statement
Available to the Public

19. Security Class (This Report)
NA

21. No. of Pages
3

20. Security Class (This Page)

22. Price

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IWS-211
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INDUSTRYWIDE STUDY
OF
BERYLLIUM PRODUCTION FACILITIES

Harry M. Donaldson

Environmental Investigations Branch
Division of Field Studies and Clinical Investigations
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

July 1973

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U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

ACKNOWLEDGMENT

With the exception of sample data collected in Phase II by the personnel of the State of Pennsylvania Department of Environmental Resources, all sampling was done by personnel of the Division of Field Studies and Clinical Investigations listed below:

Howard E. Ayer
John M. Dement
Roy M. Fleming
Richard A. Lemen
Jeremiah R. Lynch
Harold J. Mangin
Clinton V. Oser, Jr.
Patrick J. Shuler
Roger E. Schmid
Kenneth M. Wallingford
Robert B. Weidner
Ralph D. Zumwalde

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A B S T R A C T

The purpose of this paper is to present a detailed industrial hygiene report on an industrywide beryllium study which was conducted for the United States Public Health Service by the Division of Field Studies and Clinical Investigations, National Institute for Occupational Safety and Health (previously Bureau of Occupational Safety and Health). The report includes information on the origin of the study, the methods used in conducting the study, the results of the study and recommendations for future investigations and/or actions relating to occupational health standards for beryllium. The study included coverage of four beryllium facilities, each having somewhat different processing operations (e.g., beryllium copper alloy production, beryllium oxide and ceramic production, beryllium metal production, and beryllium fabrication).

ENVIRONMENTAL INVESTIGATIONS

Introduction

The study of beryllium facilities by the Bureau of Occupational Safety and Health (BOSH) and subsequently the National Institute for Occupational Safety and Health (NIOSH) had its conception in the mid-nineteen sixties as a result of the discovery of outplant cases of beryllium disease in the Reading, Pennsylvania area. These cases were diagnosed in people who had never worked in the beryllium industry. The discovery of these outplant cases, which were in the vicinity of a beryllium facility, was mainly the result of the investigations conducted by Jan Lieben, M.D., Chief of Occupational Health for the State of Pennsylvania^{1 2}. Lieben attributed the cases to the fact that beryllium ambient air levels in and around the Reading area were in excess of the $0.01 \mu\text{gBe}/\text{m}^3$ (monthly average) recommended as the maximum acceptable level of exposure by the Atomic Energy Commission (AEC)³. As a result of the diagnosis of cases of beryllium disease in this area, the beryllium facility was recognized as the obvious contaminating source.

Due to these beryllium disease cases and the possible legal problems connected with them, the company requested Lieben to invite the United States Public Health Service (USPHS) to conduct an epidemiological study in the Reading, Pennsylvania area to substantiate his work. Lieben did not feel that this was necessary; therefore, the company directly approached the USPHS. The USPHS indicated they were interested in conducting such an epidemiological study; however, they could not conduct such a study since this was an intrastate situation. This position was changed and subsequent investigations were initiated by the USPHS, when in 1967, another company having beryllium facilities in another State requested a similar study, thereby resulting in an interstate situation.

At the initiation of these investigations in 1968, the USPHS had had very little experience in working with beryllium, since nearly all previous industrial hygiene work had been under the direction of the AEC. The only study conducted formerly by the USPHS resulted in the Fairhall report,⁴ published in 1943, which concluded erroneously, on the basis of animal experiments, that there was little or no toxicity associated with beryllium. The USPHS study initiated in 1968 never took on the dimensions that the company originally requesting the study envisioned. Since the population living near the plant in Reading, Pennsylvania was never studied as had been done in the Lorain,

Ohio study in the early forties, where outplant beryllium disease cases were found²⁰. The 1968 USPHS study was an epidemiological study among a population of beryllium workers and the scope of this study was explained to the companies involved prior to its initiation.

The protection of workers associated with the handling of beryllium is based on an airborne beryllium exposure level of $2 \mu\text{gBe}/\text{m}^3$, daily weighted average (DWA), as postulated by Eisenbud and Machle in 1948.⁵ The measurement of adherence to this standard in the past has been by monitoring beryllium levels using an electroflux vacuum cleaner system appropriately converted to an air sampler. DWA worker exposures are calculated using the results obtained with samplers located in areas representative of breathing zone and general work area concentrations. This method of monitoring (hereafter identified as the "AEC" method) was documented in 1956 and made an integral part of the sales contracts between the AEC and its beryllium suppliers.³ A summary with slight modifications of this method is presented in NIOSH's criteria document on beryllium⁶.

Compliance with the $2 \mu\text{gBe}/\text{m}^3$ DWA standard, as measured by this sampling method, resulted in bringing beryllium facilities under control for the prevention of occupational disease. Also, it was found that after such control, beryllium disease which did occur could usually be associated with violations of the standard and in many cases rather

gross violations. Available medical data which show decreases in beryllium disease are correlated with the 2 ugBe/m^3 standard of exposure as measured by the AEC method.⁷

The environmental aspects of the USPHS study consisted of three phases with investigations into four beryllium facilities. These four facilities include (1) a plant that produces beryllium metal, beryllium oxide, beryllium oxide ceramic, and beryllium copper alloys (Plant A), (2) a beryllium fabrication facility (Plant B), (3) a plant that produces mainly beryllium metal and subsequently fabricates it (Plant C) and (4) a plant that has as its major production beryllium copper alloys (Plant D). The processing operations at these types of facilities are described in The Metal Beryllium, published in 1955 by the American Society for Metals, Cleveland, Ohio.⁸

Details of Environmental Investigations

Phase I: 1968 and 1970 Investigations

The purpose of this portion of the overall study was to conduct an industrywide survey of the medical and environmental aspects of the beryllium industry. These investigations were conducted initially by the Bureau of Occupational Safety and Health and all four of the facilities included in this report were surveyed.

Only those portions of the survey dealing with the environmental data are included herein. Tables I-IV present a summary of the data which were collected utilizing both personal and general area sampling for gross and respirable quantities of airborne beryllium.

In the 1968 investigations, general area gross and respirable dust measurements were obtained utilizing Hi-Vol samplers,⁹ and both personal gross and respirable dust measurements were made with the Cassella pump and its associated collection equipment,¹⁰ which was worn by the individual worker throughout the normal working day.

In the 1970 investigations, the major emphasis was on personal respirable sampling.^{11 12} Some general area gross and respirable dust sampling utilizing Hi-Vol samplers also was conducted.

In both the 1968 and 1970 investigations, the pumps that were utilized to collect the personal respirable samples were not fitted with the flow straightener (dampener) that is currently recommended for such sampling.¹³ The exposure levels obtained utilizing the "undampened" pumps were lower than those obtained if "dampened" pumps had been used. Also, the sample flow rate for the collection of the personal respirable samples was 2.0 l/min. compared to the now recommended 1.7 l/min., which

is needed for the respirable samplers to more nearly simulate the Los Alamos upper respiratory retention curve for man.¹⁴

In establishing the above sampling strategies for the survey, the researchers largely ignored the previous work and sampling procedures of the AEC as well as the sampling procedures being utilized in the facilities being surveyed.

There probably is no argument to the fact that personal sampling is the most practical way to obtain a DWA worker exposure. The AEC method of sampling, for example, excludes worker exposures on other than routine type jobs. Also, personal respirable sampling should be the best approach to the determination of a worker's actual exposure since it is a measure of that portion of the dust that could penetrate to the lungs. However, even though the personal respirable technique is the most desirable and that mainly relied upon in the 1968 and 1970 investigations, the results of these surveys are difficult to interpret because samples were not collected utilizing the AEC method. Medical data are all correlated with the AEC method and there is at present no way to convert from one method to another; therefore, the data are nearly impossible to relate to specific worker health hazards. There is, however, some information that can be obtained from the data. Some of the major points are :

1. The production worker sampled at Plant A (Table 1) in the

oxide furnace area appeared to be exposed to exceedingly high beryllium levels (maximum levels of $166 \mu\text{gBe}/\text{m}^3$ gross and $9.3 \mu\text{gBe}/\text{m}^3$ respirable); however, in reality this is not the case since the worker was wearing a fresh air mask and should have had essentially no exposure at all.

2. Maintenance workers may occasionally be subjected to extremely high exposures as is shown by the personal respirable concentrations measured in Plant A (Table I), i.e., a mean of $3.3 \mu\text{gBe}/\text{m}^3$ but one value was $58.5 \mu\text{gBe}/\text{m}^3$.

3. High exposure levels in the alloy production area of Plant A (Table I) were noted; however, available medical information indicates that there have been no cases of beryllium disease diagnosed in workers in this area since the plant began operation in 1953.¹⁵

4. The environmental data collected at Plant B (Table II), as would be expected for a well-controlled machine shop, indicated very low exposure levels of beryllium. For example, the personal respirable, general area gross dust, and general area respirable samples averaged over both the 1968 and 1970 investigations were 0.078, 0.238 and 0.030, respectively.

5. The average airborne beryllium levels in the beryllium metal production areas of Plant C (Table III) for both the 1968 and 1970 investigations were quite high; therefore, there is a potential for beryllium disease in the workers involved in these areas. For example, the average personal gross dust, personal respirable, general area respirable, and general area gross dust concentrations were 45.6, 2.31, 4.36 and 28.0 $\mu\text{gBe}/\text{m}^3$, respectively.

6. Beryllium exposure levels in the alloy production areas of Plant D (Table IV) were high; however, it is questionable whether this is significant since beryllium copper alloys do not appear to have the same toxicity as other beryllium products.¹⁵

Phase II : State of Pennsylvania Contract

Following the 1968 and 1970 surveys, a contract was let (1971-1972) with the State of Pennsylvania Health Department for the purposes of evaluating sampling techniques for beryllium and asbestos. For the portion of the contract dealing with beryllium, sampling was conducted at the plants identified as C and D in this report. The sampling techniques utilized included personal gross and respirable (dampened pumps at 1.7 l/min)¹³, general area respirable

and gross dust procedures. Data were not collected using the AEC method of sampling; therefore, the data collected during the contract are of limited value in correlating with beryllium disease since they do not relate to the accepted sampling method. The data, however, can probably be utilized as a guide in evaluating the effectiveness of the controls at the facilities.

As can be seen in Tables III and IV, the exposure levels were quite high in many areas of the facilities. For example, the average personal gross dust concentrations in Plant C in the powdering area, decontamination-utility-maintenance area, and process development laboratory area were 60, 43 and 123 $\mu\text{gBe}/\text{m}^3$, respectively, while the average personal respirable concentrations were as high as 4.46 $\mu\text{gBe}/\text{m}^3$ in the attrition mill area. These data for Plant C, even though none represent the AEC method of sampling, do reflect from a relative standpoint that the facility was "out-of-control" during the sampling period.

This survey was designed specifically to evaluate sampling methods and the sampling devices used appeared to work adequately.

Phase III : 1971 and 1972 Investigations

Concurrently with the sampling being done by the State of Pennsylvania, surveys also were being conducted in Plants A and C by the Division of Field Studies and Clinical Investigations, NIOSH, for the purposes of (1) finalizing the beryllium study, (2) determining the need and feasibility for operating a beryllium facility at $2 \mu\text{gBe}/\text{m}^3$, and (3) comparing different methods of sampling in order to be able to determine the practicality of establishing a conversion factor between exposure levels determined by the AEC method and the personal respirable and personal gross dust methods. This latter purpose was to help establish a more practical sampling technique.

On the basis of previous work, it was decided that Plants A and C (beryllium production facilities) would be best suited for this type of survey since health problems associated with high levels of airborne beryllium would more likely occur in beryllium metal operations than in alloy plants.^{15 16} The exposure levels at Plant A were measured utilizing personal respirable ("dampened" pumps at 1.7 l/min.),¹³ personal gross and the AEC sampling methods. At Plant C, the same three sampling methods were used except the pumps used for collecting the personal respirable samples were "undampened". At Plant C, however, the AEC sampling method was restricted to the beryllium metal powder handling area.

As is shown in Table I, Plant A was found (based on the AEC method results) to be, with minor exceptions, in compliance with the $2 \mu\text{gBe}/\text{m}^3$ standard. Plant C (Table III), however, was out of compliance with the $2 \mu\text{gBe}/\text{m}^3$ standard in the beryllium processing-powdering area regardless of which sampling technique is utilized.

Plant A has not generated beryllium disease as a result of exposures at the levels documented herein, while Plant C has had recently diagnosed cases of beryllium disease which were probably generated at airborne beryllium levels similar to those determined in Plant C during all three phases of this study.¹⁷ It is obvious that at airborne beryllium levels such as those found at Plant C, the chances of generating beryllium disease are increased. Likewise, the lower levels found at Plant A, which has been operating at these lower levels for several years, would not be expected to generate such cases except under unusual circumstances.

These Phase III investigations also indicate that not only is it feasible to operate beryllium metal facilities essentially at levels of $2 \mu\text{gBe}/\text{m}^3$ (AEC method), but that it is now being done.

With regard to the sampling techniques used for collecting data at Plants A and C, the ratios between the numerical results of various sampling methods are given below:

<u>PERSONAL GROSS</u>	<u>AEC (AREA)</u>	<u>PERSONAL RESPIRABLE</u>
10	4	1

These Ratios correspond to actual sample values as follows:

<u>PERSONAL GROSS</u>	<u>AEC (AREA)</u>	<u>PERSONAL RESPIRABLE</u>
5 $\mu\text{gBe}/\text{m}^3$	2 $\mu\text{gBe}/\text{m}^3$	0.5 $\mu\text{gBe}/\text{m}^3$

Even though over 1000 samples were collected at Plants A and C, the data are probably too limited to produce reliable statistical comparisons among the three sampling methods. Also, since each operation in the facilities is dynamic, any relationship between the techniques will to some degree be a matter of judgment. The collection of these data and the practicality of using the personal monitoring technique over the AEC method hopefully will serve as the impetus for determining the actual relationship between the techniques for future sampling purposes.

Summary and Conclusions

1. The worker exposures to beryllium as measured by the AEC method of sampling are the only levels that have been associated with medical responses. 7,17
2. From a practical standpoint and in order to measure personal exposure directly, the personal method of sampling is far more advantageous than the AEC method.
3. Personal respirable sampling probably is more representative of the health related aspects of beryllium since this technique measures that portion of the dust that could reach the lungs; however, the actual relationship of worker exposures determined by this method to health hazards has not been determined.
4. The AEC method,³ which measures a worker's DWA exposure from results obtained with samplers located in areas representative of breathing zone concentrations and general work area concentrations, does not measure exposures for such workers as maintenance employees, decontamination workers, or other workers performing non-routine tasks.

5. In general, beryllium exposure levels in a well-controlled machine shop will be below the $2 \mu\text{gBe}/\text{m}^3$ DWA standard (AEC method).

6. A beryllium metal production facility can be expected, if well-controlled, to have beryllium exposure levels at or near the $2 \mu\text{gBe}/\text{m}^3$ DWA standard (AEC method).

7. Beryllium oxide-metal production facilities with operational areas grossly in violation of the $2 \mu\text{gBe}/\text{m}^3$ DWA standard tend to generate beryllium disease,¹⁷ while in general, the converse is true for those areas which have been in compliance.⁷

8. With an appropriate and acceptable experimental design, a reliable relationship between worker exposure levels determined by the AEC method, personal respirable, and personal gross sampling probably can be determined.

DISCUSSION OF SAMPLING PROCEDURES

As has been discussed in the previous section, the beryllium standard under which beryllium facilities were to have been controlled in the past is the $2 \mu\text{gBe}/\text{m}^3$ DWA as postulated by Eisenbud and Machle⁵ in 1948.

As such, this exposure level (TLV) was adopted by the American Conference of Governmental Industrial Hygienists (ACGIH) in the mid-1950's. Subsequently, the Occupational Safety and Health Administration (OSHA) adopted a beryllium standard of $2 \mu\text{gBe}/\text{m}^3$, which applies to an eight-hour weighted average exposure of an individual worker, with a maximum ceiling concentration of $25 \mu\text{gBe}/\text{m}^3$ for 30 minutes. In promulgating the standards, OSHA referred to the ANSI standard Z 37.29-1970,¹⁸ which has as a basis a very general and non-specific method of sampling for beryllium, and which cannot be interpreted as the AEC method upon which the $2 \mu\text{gBe}/\text{m}^3$ standard is based. As best as can be determined, OSHA is utilizing a personal gross dust technique in its monitoring program¹⁹ which is similar to the techniques mentioned in the previous section of this report.

To further complicate this situation, NIOSH has recommended to OSHA in the beryllium criteria document⁶ the same standards ($2 \mu\text{gBe}/\text{m}^3$ DWA and a ceiling value of $25 \mu\text{gBe}/\text{m}^3$ for 30 minutes); however, the sampling method recommended is specifically the AEC method. Therefore, it is evident that confusion exists as to the meaning of the $2 \mu\text{gBe}/\text{m}^3$ eight-hour standard and the ceiling standard in regard to the methods by which beryllium exposures are to be determined.

As has been mentioned previously, the practicality of personal sampling from the standpoint of monitoring the individual worker is OSHA's reason for using this monitoring technique. If any validity, however, can be found in the results of the surveys conducted in Phase III, monitoring with the personal gross dust technique will give exposure levels at least twice as high as those that would be obtained by utilizing the AEC method.

Since it is necessary that OSHA have an acceptable yet practical sampling technique, a valid determination of the relationship between the three mentioned sampling techniques is needed. Even more important than the relationship between the AEC method and the gross personal technique is the relationship between the AEC method and the personal respirable technique since the latter better reflects the dust exposures that probably would cause beryllium disease. This technique also would make sampling for beryllium consistent with techniques for silica, coal dust and nuisance dusts. Until such time as a relationship is established between the AEC method and personal sampling methods, and until such time as sampling methods for the collection of beryllium samples are standardized, the environmental health standard of $2 \mu\text{gBe}/\text{m}^3$ for beryllium cannot effectively be enforced.

RECOMMENDATIONS FOR FUTURE ENVIRONMENTAL INVESTIGATIONS

1. A study should be developed to ascertain the relationship between the beryllium sampling techniques presently available, i.e., the AEC method, personal respirable sampling and personal gross sampling. If the results of such a study provide data that allow a relationship between the sampling methods to be derived, the appropriate modifications to the presently recognized beryllium standard should be considered and the acceptable sampling technique specified as a standard method. Use of the personal gross dust sampling method (OSHA method) would, based on the data discussed herein, place on a beryllium production facility certain undue hardships that cannot be supported from a medical standpoint. This is due to the fact that engineering feasibility does not as yet exist to reduce worker exposure levels to $2 \mu\text{gBe}/\text{m}^3$ as measured on a personal gross basis.

If the study does not determine that a statistically sound relationship exists between the three sampling techniques, it probably would be expedient to attempt to make a technical judgment on the relationship because the situation that presently exists is not workable. It should be remembered that this type of situation is continually occurring in the industrial hygiene field in many areas

of monitoring and that new, practical and representative sampling techniques must be developed in some instances over a period of time that does not allow for associated collection of health data. Prime examples of this are the recent changes from impinger counting to gravimetric (mass) and fiber counting techniques. The fact must not be overlooked that when a new sampling procedure is introduced, it has to be continually re-evaluated in light of current medical data.

2. It is recommended that the study of sampling techniques be conducted through a contract negotiated by NIOSH with a well-controlled, integrated beryllium metal production facility with appropriate NIOSH contract monitoring because of the extensive amount of sampling that would be required, from a monetary, manpower and feasibility standpoint it could be much better handled in this manner than by a NIOSH monitoring team or by a private or State contractual agreement that would require much time to be spent at the facility and in analytical determinations. It is estimated that this study would involve approximately 24 man months of work over a period from six months to one year. The beryllium metal production facility that would be utilized should be able to handle the sampling with existing personnel and analytical expertise. NIOSH would conduct all the statistical analyses of the collected data.

It is unnecessary to include other beryllium facilities such as machine shops, etc., in this study since the sampling of an integrated beryllium metal production facility will afford the opportunity to monitor practically all types of beryllium handling operations. Also because of the economic incentives involved in salvaging beryllium chips for resale, it is expected that these other operations would be under control.

3. In order to evaluate the effectiveness of established beryllium standards, it is recommended that the beryllium case registry with which NIOSH will soon be involved, be used as one source for determining the need for further industrial hygiene surveys. For example, as beryllium disease cases are reported to the registry, such surveys may be conducted, after investigation of the individual's work history, to determine from a research standpoint why the disease occurred.

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A P P E N D I X

TABLES SHOWING RESULTS OF AIR SAMPLES TAKEN
BY
VARIOUS SAMPLING METHODS IN FOUR BERYLLIUM PRODUCTION FACILITIES - 1968-1972

Table I - Plant A

Table II - Plant B

Table III - Plant C

Table IV - Plant D

TABLE I-PLANT A

OPERATION	TYPE OF SAMPLE	PHASE II: 1970 AND 1970 SURVEYS			PHASE III: 1971 AND 1972 SURVEYS			MEAN CONCENTRATION $\mu\text{gSe}/\text{m}^3$
		NO. OF SAMPLES	CONCENTRATION $\mu\text{gSe}/\text{m}^3$		NO. OF SAMPLES	CONCENTRATION $\mu\text{gSe}/\text{m}^3$		
			Range	Mean		Range	Mean	
Beryl Furnace	PRD				4	0.34- 1.31	0.83	0.83
	PG				4	0.29- 4.17	1.61	1.61
	AEC						0.72	0.72
Ore Processing Operator	PRD				2	0.53- 0.57	0.55	0.55
	PG				2	1.32- 2.26	1.79	1.79
	AEC						0.74	0.74
Thickener-Hydroxide Operator	PG	2	0.45-17.74	9.1	1	0.13	0.13	6.11
	AEC						1.60	1.60
	PRU	9	0.08- 0.45	0.23				0.23
	HI Vol R	2	0.29- 0.42	0.35				0.35
	HI Vol G	2	1.80- 3.14	2.47				2.47
GC Salt Operator	PRD				4	0.19- 0.85	0.43	0.43
	PG				3	1.02- 1.91	1.46	1.46
	AEC						1.28	1.28
Oxide Furnace Operator*	PRD				3	1.12- 8.03	3.52	3.52*
	PG	1	166.8	166.8	3	4.02-11.7	7.58	47.4*
	AEC						0.88	0.88*
	PRU	5	0.43- 9.29	3.19				3.19
Beryllium Metal Wet Plant Sludge Operator	PRD				5	0.26- 1.24	0.72	0.72
	PG				4	1.69- 5.51	2.90	2.90
	AEC						0.99	0.99
Evaporator Operator	PRD				2	0.39- 0.59	0.49	0.49
	PG				1	1.18	1.18	1.18
	AEC						2.42	2.42
Fluoride Furnace Operator	PRD				3	0.18- 0.73	0.48	0.48
	PG				3	1.23- 2.18	1.67	1.67
	AEC						0.92	0.92
Reduction Furnace Operator	PRD				3	0.78- 1.32	0.99	0.99
	PG				3	1.74- 2.65	2.16	2.16
	AEC						1.37	1.37
Melts Crusher Thru Pebble Inspection	PRD				3	0.13- 2.87	1.05	1.05
	PG				4	0.52- 2.75	1.59	1.59
	AEC						10.2	10.2
Miscellaneous Powder Handler	PRD				1	0.15	0.15	0.15
	PG				1	2.85	2.85	2.85
	AEC						1.02	1.02
Vacuum Cast Operator	PRD				6	0.18- 2.11	0.79	0.79
	PG				6	0.30- 7.24	3.66	3.66
	AEC						2.86	2.86
Chipping Lathe Operator	PRD				7	0.16- 1.62	0.53	0.53
	PG				7	1.31-15.14	5.16	5.16
	AEC						2.96	2.96
Scrap Reclamation**	PRD				6	0.33- 5.98	1.28	1.28
	PG	1	5.45	5.45	6	1.70-33.3	9.50	8.92**
	AEC						1.11	1.11**
	PRU	1	1.71	1.71				1.71
	HI Vol R	1	0.12	0.12				0.12
	HI Vol G	1	1.69	1.69				1.69
Attrition Mill Operator	PRD				11	0.21- 1.11	0.81	0.81
	PG				9	1.22-19.03	5.88	5.88
	AEC						1.45	1.45
Attrition Mill Load Man	PRD				3	0.15- 0.60	0.30	0.30
	PG				3	1.13- 4.21	2.44	2.44
	AEC						1.42	1.42
Compact Load Operator* (Preparation & Strip)	PRD				2	3.45- 7.83	5.64	5.64*
	PG				2	14.4-76.4	45.40	45.40*
	AEC						2.25	2.25*
Compact Load Operator* (Powder Preparation & Die Loading)	PRD				4	1.09-19.9	7.56	7.56*
	PG				3	1.45-23.5	13.80	13.80*
	AEC						1.69	1.69*
Sintering Furnace Operator	PRD				9	0.15- 5.58	0.62	0.62
	PG				8	0.23- 5.65	1.60	1.60
	AEC						1.39	1.39
Sintering Welder*	PRD				1	0.96	0.96	0.96*
	PG				1	217.40	217.40	217.40*
	AEC						0.51	0.51*



Table I (continued)

OPERATION	TYPE OF SAMPLE	PHASE I: 1968 AND 1970 CONVEYS			PHASE III: 1971 AND 1972 CONVEYS			MEAN CONCENTRATION $\mu\text{gBe}/\text{m}^3$
		NO. OF SAMPLES	CONCENTRATION $\mu\text{gBe}/\text{m}^3$		NO. OF SAMPLES	CONCENTRATION $\mu\text{gBe}/\text{m}^3$		
			Range	Mean		Range	Mean	
Sintering Machining Operator	PRD				17	0.15- 0.53	0.25	0.25
	PG				15	0.18- 2.64	1.67	1.67
	AEC						0.51	0.51
Press Operator	PRD				4	0.16- 0.69	0.30	0.30
	PG				4	0.48- 8.26	2.69	2.69
	AEC						0.58	0.58
Iso Press Operator	PRD				2	0.16- 0.51	0.33	0.33
	PG				2	2.61- 7.10	4.96	4.96
	AEC						0.41	0.41
Machine Operator (Ceramics)	PRD				9	0.16- 0.34	0.24	0.24
	PG	2	0.31- 7.98	3.99	8	0.67- 4.99	2.35	2.68
	AEC						2.90	2.90
	PRU	17	0.07- 5.41	0.88				0.88
	Hi Vol G	1	1.33	1.33				1.33
Kiln Operator	PRD				3	0.32- 0.82	0.49	0.49
	PG				2	0.81- 5.36	3.09	3.09
	AEC						0.74	0.74
Control Laboratory	PRD				10	0.17- 2.03	0.52	0.52
	PG				10	0.32-18.68	4.41	4.41
	AEC						0.42	0.42
Machine Shop (Maintenance)	PRD				41	0.10- 0.37	0.23	0.23
	PG	2	0.74- 1.77	1.25	43	0.16- 6.8	1.51	1.50
	AEC						0.20	0.20
	PRU	21	0.08-58.5	3.29				3.29
	Hi Vol R	1	0.18	0.18				0.18
Laundry Operator	PRD				1	0.29	0.29	0.29
	PG				1	0.87	0.87	0.87
	AEC						1.04	1.04
Arc Furnace Charge Man	PRD				4	0.18- 1.04	0.47	0.47
	PG				4	1.95-10.55	4.68	4.68
	AEC						2.85	2.85
Arc Furnace Crew Chief	PRD				1	0.49	0.49	0.49
	PG				1	4.86	4.86	4.86
	AEC						2.01	2.01
Arc Furnace Helper	PRD				3	0.32- 0.93	0.59	0.59
	PG				3	1.28-19.9	8.07	8.07
	AEC						2.03	2.03
Mixer	PRD				2	0.17- 0.84	0.50	0.50
	PG				2	4.64-16.3	10.47	10.47
	AEC						2.05	2.05
Ajax Furnace Operator	PRD				14	0.17- 0.80	0.41	0.41
	PG				14	0.12-18.43	2.25	2.25
	AEC						0.57	0.57
Beryllium Metal Production	PG	19	0.18-25.8	6.30				6.30
	PRU	46	0.06- 3.26	0.65				0.65
Technical Research & Development	PG	2	0.31- 7.18	3.75				3.75
	PRU	3	0.09- 2.64	0.97				0.97
Inspection and Quality Control	PG	2	0.26-18.42	9.34				9.34
Hygiene and Safety	PG	1	0.28	0.28				0.28
	PRU	7	0.11- 2.57	0.98				0.98
Alloy Production	PG	5	0.81-17.5	9.0				9.0
	PRU	9	0.08- 4.29	0.96				0.96
	Hi Vol R	2	3.97- 3.97	3.97				3.97
	Hi Vol G	2	32.3 -62.7	47.50				47.50
Alloy Products	PG	5	0.1- 4.68	3.40				3.40
	PRU	7	0.1- 9.3	1.55				1.55
Stock Room Shipping & Receiving	PRU	2	0.09- 0.09	0.09				0.09

Symbols: PRD : Personal Respirable Dampened Pump Sample
 PG : Personal Gross Sample
 AEC : Atomic Energy Commission Sampling Method
 PRU : Personal Respirable Undampened Pump Sample
 Hi Vol R: Hi Volume Pump Collecting Respirable Sample
 Hi Vol G: Hi Volume Pump Collecting Gross Sample
 * : Fresh Air Mask Worn
 ** : Fresh Air Mask Worn On Some Operations

TABLE II-PLANT B

OPERATION	TYPE OF SAMPLE	PHASE I: 1968 AND 1970 SURVEYS		
		NO. OF SAMPLES	CONCENTRATION $\mu\text{gBe}/\text{m}^3$	
			Range	Mean
Tool Assembly	Hi Vol R	4	0.016-0.078	0.045
	Hi Vol G	5	0.049-0.119	0.078
Machine Shop	PRU	75	0.05 -0.99	0.078
	Hi Vol R	5	0.01 -0.046	0.030
	Hi Vol G	3	0.05 -0.65	0.238
Technical Research & Development	PRU	25	0.05 -1.29	0.032
	Hi Vol R	3	0.01 -0.09	0.041
	Hi Vol G	2	0.01 -0.02	0.015
Inspection & Quality Control	PRU	4	0.05 -0.28	0.232
Production	PRU	1	0.05	0.05
Hygiene & Safety	PRU	4	0.05 -0.66	0.212
Maintenance	PRU	5	0.05 -0.8	0.116

Symbols: PRU : Personal Respirable Undampened Pump Sample
 Hi Vol R: Hi Volume Pump Collecting Respirable Sample
 Hi Vol G: Hi Volume Pump Collecting Gross Sample

TABLE III-PLANT C

OPERATION	TYPE OF SAMPLE	PHASE II: 1968 AND 1970 SURVEY		PHASE III: STATE OF PENNSYLVANIA COMPLIANCE (1971-1972)			PHASE III: 1971 AND 1972 SURVEY			MEAN CONCENTRATION $\mu\text{g}/\text{m}^3$
		NO. OF SAMPLES	CONCENTRATION $\mu\text{g}/\text{m}^3$	NO. OF SAMPLES	CONCENTRATION $\mu\text{g}/\text{m}^3$		NO. OF SAMPLES	CONCENTRATION $\mu\text{g}/\text{m}^3$		
					Range	Mean		Range	Mean	
Ore Thru Sintering	PRD			15	0.09- 2.46	0.53			0.53	
	PG			16	0.39- 21.1	4.34	16	0.4 - 13.8	1.88	
	PRU						16	0.0 - 0.66	0.24	
	HI Vol R	1	0.1	0.1					0.1	
	HI Vol G	1	1.38	1.38					1.38	
Hydride Production	PG	1	2.94	2.94					2.94	
	PRU	9	0.07- 1.4	0.47					0.47	
	HI Vol R	1	1.71	1.71					1.71	
Beryllium Metal Production	PG	6	0.49-130.5	45.6					45.6	
	PRU	54	0.06- 43.8	2.31					2.31	
	HI Vol R	10	0.17- 30.2	4.36					4.36	
	HI Vol G	10	0.74-237.9	28.0					28.0	
Attrition Mill	PRD			16	0.05- 14.8	4.46			4.46	
	PG			16	2.9 - 74.7	58.0	11	0.7 - 1146.0	160.00	
	AEC								49.4	
	PRU						11	0.4 - 17.9	3.06	
Powder Maker	PRD			11	0.11- 11.0	4.43			4.43	
	PG			11	2.57-261.0	60.1	6	2.5 - 43.1	26.8	
	AEC								6.4	
	PRU						6	0.8 - 4.45	3.68	
Die Handler	PRD			13	0.19- 10.8	2.03			2.03	
	PG			13	1.37- 38.6	12.65	5	2.97- 91.8	25.0	
	AEC								3.1	
	PRU						5	0.97- 7.67	3.4	
Chipping Lathe Operator	PRD			7	0.65- 6.23	2.52			2.52	
	PG			7	4.2 - 29.4	11.38	3	3.7 - 2889*	9.2*	
	AEC								4.6	
	PRU						3	0.11- 1.40	0.92	
Press Operator	PRD			9	0.15- 22.5	1.74			1.74	
	PG			9	0.49- 23.2	4.80	6	0.74- 2.70	1.56	
	AEC								1.3	
	PRU						6	0.0 - 0.33	0.15	
Foreman	PRD			9	0.15- 11.6	1.74			1.74	
	PG			9	0.42- 18.7	3.66	1	3.30	3.30	
	AEC						1	0.66	0.66	
	PRU									
Machine Shop	PRD			20	0.11- 1.07	0.51			0.51	
	PG	4	0.17- 4.5	1.55	20	0.80- 5.20	2.29	8	0.67- 3.78	2.36
	PRU	21	0.07- 3.7	0.56				8	0.0 - 0.42	0.15
	HI Vol G	1	0.50	0.50					0.50	
Decontamination Utility Maintenance	PRD			31	0.28- 58.0	3.28			3.28	
	PG			31	0.63-582.0	43.35	12	1.9- 35.9	8.07	
	PRU	13	0.10- 1.20	0.19			12	0.0- 19.7	2.20	
Chip Process Operator	PRD			15	0.72- 4.03	2.17			2.17	
	PG			15	4.10- 98.0	32.4	8	1.14-118.9	26.40	
	AEC								6.50	
	PRU						9	0.16- 2.28	0.90	
Wet Plant Fluoride Reduction Plant	PRD			43	0.0 - 5.16	0.98			0.98	
	PG			43	0.21- 29.0	3.62	29	0.57- 9.53	2.69	
	PRU						29	0.07- 2.74	0.56	
Process Development Laboratory	PRD			16	0.31- 13.4	1.87			1.87	
	PG			16	1.20-183.4	123.0	4	0.16- 5.06	2.06	
	PRU						4	0.0 - 0.44	0.27	
Vacuum Furnace Operator	PRD			14	0.8 - 4.23	1.75			1.75	
	PG			13	0.3 - 56.5	15.7	9	1.35- 9.79	5.6	
	PRU						9	0.0 - 1.19	0.55	
Technical Research & Development	PRU	4	0.06- 3.1	0.63					0.63	
Inspection & Quality Control	PG	3	0.29- 1.59	1.00					1.00	
	PRU	4	0.07- 0.1	0.08					0.08	
Hygiene & Safety	PG	1	2.49	2.49					2.49	
	PRU	8	0.11- 0.51	0.2					0.2	
Stock, Shipping & Receiving	PRU	1	0.05	0.05					0.05	

Symbols: PRD : Personal Respirable Dampened Pump Sample
PG : Personal Gross Sample
AEC : Atomic Energy Commission Sampling Method
PRU : Personal Respirable Undampened Pump Sample
HI Vol R : HI Volume Pump Collecting Respirable Sample
HI Vol G : HI Volume Pump Collecting Gross Sample
* : Excluded one high value

TABLE IV-PLANT D

OPERATION	TYPE OF SAMPLE	PHASE I: 1968 AND 1972 SURVEYS			PHASE II: STATE OF PENNSYLVANIA CONTRACT (1971-1972)			MEAN CONCENTRATION $\mu\text{gBe}/\text{m}^3$
		NO. OF SAMPLES	CONCENTRATION $\mu\text{gBe}/\text{m}^3$		NO. OF SAMPLES	CONCENTRATION $\mu\text{gBe}/\text{m}^3$		
			Range	Mean		Range	Mean	
Oxide Production	PRD				17	0.3- 16.4	3.08	3.08
	PG				17	2.0-136.0	37.42	37.42
	PRU	1	2.74	2.74				2.74
Pickling & Plating	PG	4	0.34- 5.42	1.70				1.70
	PRU	8	0.12- 0.42	0.24				0.24
	Hi Vol R	1	10.53	10.53				10.53
Foundry	PRU	7	0.26- 1.05	0.50				0.50
	Hi Vol G	1	7.91	7.91				7.91
Alloy Production	PRD	33	0.1 - 26.9	3.22				3.22
	PG	7	0.14-136.0	21.35	32	0.1-125.0	26.16	25.30
	PRU	39	0.14- 19.3	1.40				1.40
	Hi Vol R	5	0.56- 8.87	3.30				3.30
	Hi Vol G	4	0.27- 42.6	14.90				14.90
Rod Wire & Extrusion	PG	3	0.37- 0.38	0.38				0.38
	PRU	14	0.07- 0.84	0.24				0.24
	Hi Vol R	1	2.29	2.29				2.29
	Hi Vol G	1	2.88	2.88				2.88
Hot Mill	PG	2	0.26- 0.42	0.34				0.34
	PRU	13	0.10- 0.70	0.41				0.41
Cold Mill	PG	12	0.14- 0.41	0.30				0.30
	PRU	19	0.07- 0.42	0.21				0.21
	Hi Vol R	2	0.07- 0.19	0.13				0.13
	Hi Vol G	3	0.04- 0.16	0.08				0.08
Annealing & Heat Treating	PG	1	0.28	0.28				0.28
	PRU	9	0.10- 0.30	0.21				0.21
	Hi Vol R	1	0.06	0.06				0.06
	Hi Vol G	2	0.08- 0.82	0.45				0.45
Tool Assembly	PRU	3	0.07- 0.27	0.14				0.14
Machine Shop	PG	1	0.34	0.34				0.34
	Hi Vol R	1	0.08	0.08				0.08
	Hi Vol G	1	0.8	0.8				0.8
Technical Research & Development	PG	1	0.35	0.35				0.35
	PRU	7	0.12- 0.36	0.22				0.22
Alloy Products	PRD				48	0.1 - 5.00	0.69	0.69
	PG				46	0.1 - 6.50	3.53	3.53
Hygiene & Safety	PRD				3	0.6 - 12.0	4.23	4.23
	PG				3	6.4 - 19.5	12.43	12.43
	PRU	1	0.07	0.07				0.07
Maintenance	PRD				7	0.1 - 1.5	0.26	0.26
	PG	3	0.32- 0.33	0.32	7	0.5 - 29.1	2.94	2.15
	PRU	3	0.07- 0.5	0.32				0.32
Lunch Room	PRU	1	0.19	0.19				0.19

Symbols: PRD : Personal Respirable Dampened Pump Sample
 PG : Personal Gross Sample
 AEC : Atomic Energy Commission Sampling Method
 PRU : Personal Respirable Undampened Pump Sample
 Hi Vol R: Hi Volume Pump Collecting Respirable Sample
 Hi Vol G: Hi Volume Pump Collecting Gross Sample

HEALTH AND SAFETY SECTION OF THE SALES CONTRACT
BETWEEN ATOMIC ENERGY COMMISSION AND ITS BERYLLIUM SUPPLIERS

(Contract No. AT(11-1)-462)

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 $2 \mu/m^3$, but is less than $5 \mu/m^3$, 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 $5 \mu/m^3$, the operation in question will be halted until the necessary improvements can be accomplished. A daily average concentration exceeding $2 \mu/m^3$ 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 $2 \mu/m^3$ have been accepted by the Commission.

- b. In the event that a single air sample shows a concentration in excess of $25 \mu/m^3$ within the operating area, but is less than $100 \mu/m^3$ (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 $100 \mu/m^3$ 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 $25 \mu/m^3$. In no case will concentrations above $25 \mu/m^3$ be permitted to exist for a period exceeding 60 days without the specific

HEALTH AND SAFETY SECTION OF THE SALES CONTRACT
BETWEEN ATOMIC ENERGY COMMISSION AND ITS BERYLLIUM SUPPLIERS
(continued)

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 $0.05 \mu/m^3$, the plant will be expected to inform the AEC of specific procedures which will be undertaken to reduce the air-borne concentration. In the event that the concentration exceeds $0.05 \mu/m^3$, operations will be immediately halted and the necessary corrections made to reduce the average concentration to below $0.01 \mu/m^3$. In any event, concentrations above $0.01 \mu/m^3$ 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.

HEALTH AND SAFETY SECTION OF THE SALES CONTRACT
BETWEEN ATOMIC ENERGY COMMISSION AND ITS BERYLLIUM SUPPLIERS
(continued)

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.
- 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 m³/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.

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION
SAMPLING DATA SHEET

Substance:

Beryllium and beryllium compounds

Standard:

8-hour average: 2 $\mu\text{g}/\text{m}^3$
Ceiling: 5 $\mu\text{g}/\text{m}^3$ (30 min.)
Peak: 25 $\mu\text{g}/\text{m}^3$

Analytical Method:

Atomic absorption
Detection limit: 0.02 $\mu\text{g}/\text{filter}$

Sampling Equipment:

Personal sampling pump plus unweighed 37mm Millipore type HA filter. Either 2- or 3-piece filter cassette may be used. Sample at 1.5 lpm with cassette face cap on and small plug removed.

Sample Size:

For ceiling limit evaluation, use 30 minute samples. Minimum of 60 minutes for measurement of 2 $\mu\text{g}/\text{m}^3$ limit. Longer samples up to full shift are preferred. Sampler battery recharge required after 4 hours.

Blank:

With each batch of samples submit one filter which is subjected to exactly the same handling as for the samples except that no air is drawn through it. Label this as a blank.

Shipping:

The cassettes in which the samples are collected should be shipped in a suitable container, designed to prevent damage in transit.

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