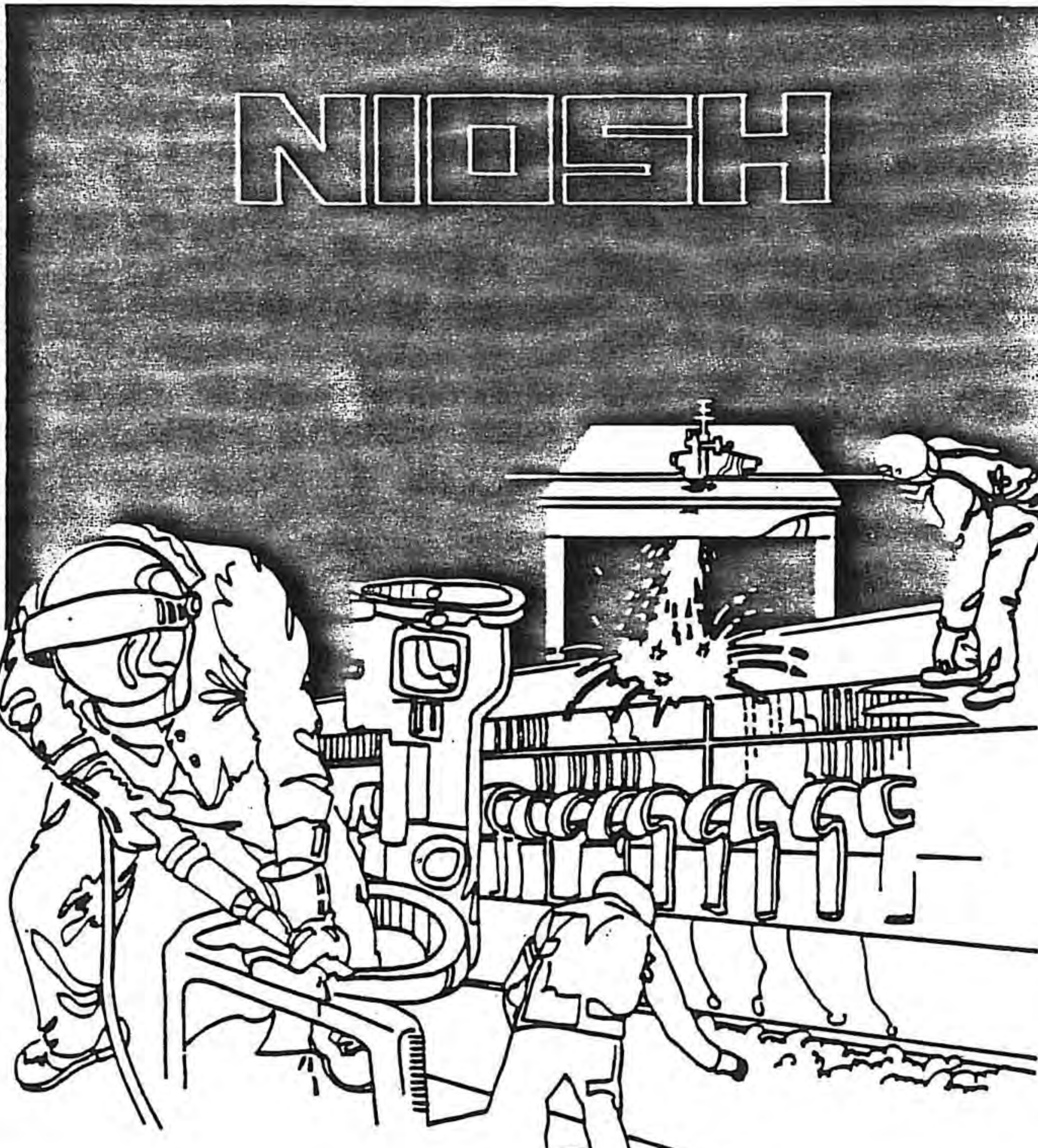
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public Health Service
Centers for Disease Control ■ National Institute for Occupational Safety and Health



Health Hazard Evaluation Report

HETA 84-510-1691
ROCKWELL INTERNATIONAL,
ROCKY FLATS PLANT
GOLDEN, COLORADO

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

HETA 84-510-1691
MAY, 1986
ROCKWELL INTERNATIONAL, ROCKY FLATS PLANT
GOLDEN, COLORADO

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I. SUMMARY

In August 1984, the National Institute for Occupational Safety and Health (NIOSH) received a request to evaluate exposure to beryllium among production machinists, metallurgical operators, and chemical operators at the Rocky Flats Plant in Golden, Colorado. A worker in the beryllium shop had recently been diagnosed as having berylliosis.

On November 8 and December 13, 1984, a NIOSH physician and an industrial hygienist visited the plant to discuss the evaluation and to present a talk on the hazards of beryllium to workers and management. On January 21 and 22, of 1985, a followup evaluation was conducted. This evaluation included breathing zone air monitoring, pulmonary function testing, and medical questionnaires administered to all workers on all three shifts. Additional trips were made by the NIOSH physician on February 5 and March 1, 1985 to complete the medical interviews. On November 13, 1985 after the NIOSH industrial hygienist had received security clearance, another environmental survey was conducted and all 8 workers on the day shift in the beryllium shop were monitored for exposure to beryllium.

Thirty-three breathing zone air samples were collected for beryllium analysis by NIOSH with assistance of the Department of Energy and Company personnel on January 21 and 22, 1985. Six of the sample results exceeded the (NIOSH) evaluation criterion of 0.5 ug/M^3. These samples had measured beryllium concentrations, of 7.2, 0.60, 0.60, 0.69, 0.92, 0.57 ug/M^3. The average level of all 33 samples was 0.4 ug/M^3. Sixteen of the samples were below laboratory detection limits of 0.2 ug/filter. Thirty-three samples were collected at fixed stations on all the machines machining beryllium. All of these samples except one, which had a level of 0.5 ug/M^3, were below the evaluation criterion of 0.5 ug/M^3. These samples were collected on whatman 41 filter paper. One of the reasons for low concentrations was due to the poor collection efficiency of this filter. The average concentration for fixed station samples was 0.06 ug/M^3 with 13 of the samples less than the detection limit of 0.5 ug/filter.

NIOSH personnel could not enter the beryllium shop until proper security clearance was obtained. After a security clearance was obtained, the NIOSH industrial hygienist took environmental breathing zone air samples on all 8 workers and the foreman in the beryllium shop on November 13, 1985. Of the nine breathing zone samples taken, seven exceeded the evaluation criteria of 0.5 ug/M^3. The levels were 1.2, 2.1, 0.6, 1.5, 1.9, 0.4, 0.5, 0.8 and 0.08 ug/M^3.

Medical evaluation showed that most of the current beryllium workers had normal pulmonary function. Mean values as a percent of predicted and standard deviations were: forced vital capacity (FVC), 91.9 $\pm$ 17.9; one-second forced expiratory volumne (FEV_1), 94.7 $\pm$ 12.8; ratio of FEV_1/FVC, 77.5 $\pm$ 9.4; and maximal mid-expiratory flow (MMEF), 71.0 $\pm$ 30.1. Only 2 current beryllium workers had a severity code other than "0". Neither had worked in the beryllium shop for more than a year and the more severely affected had only recently started, but gave a history of pulmonary disease.

There were no statistically significant differences in pulmonary function data among ex-beryllium and current beryllium workers. The diagnosis of beryllium disease in the index case appears to have been made after an adequate medical evaluation.

After the initial evaluation, arrangements were made to have x-rays of all forty-three workers in this study read by two "B" readers. Only the one worker with known beryllium disease had an abnormal x-ray reading, which was recognized by both "B" readers. Chest x-rays of twenty-two other workers who had abnormal x-ray readings listed by the medical department were read by the "B" readers as described in the text of this report. An additional 55 x-rays with normal readings or no readings listed were also read by the B readers. The B readers pointed out the need for better film quality but otherwise their conclusions did not differ excessively from the listed readings.

On the basis of environmental data, it was concluded that a health hazard existed at the time of the investigation from over-exposures to beryllium in the beryllium shop. On the basis of the medical evaluation, it was concluded that a health hazard also existed in the past, as evidenced by the development of berylliosis in the index case. No additional cases of berylliosis were identified among currently exposed workers. Recommendations for either eliminating or controlling the beryllium hazard are included in this report.

Keywords: SIC 9711 (National Security) beryllium, beryllium disease, pulmonary function

II. INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) received a request in August 1984 from the United Steelworkers of America Local 8031 to evaluate workers in the beryllium shop of the Rocky Flats Plant operated for the U.S. Department of Energy by Rockwell International. The interest in beryllium exposure was due to a worker in the beryllium shop developing beryllium disease. A complete medical evaluation of this index case had been performed at the Cleveland Clinic, Cleveland, Ohio. A complete environmental and medical evaluation of the current Rocky Flats beryllium workers was performed during the months of November and December of 1984, and January, February, March, and November of 1985. Environmental and medical data from these visits have been presented to and discussed with both union and management.

III. BACKGROUND

The Rocky Flats Plant is located between Golden and Boulder, Colorado. For about the last 30 years this plant has been involved in the production of materials used for the National Defense. The area where this study took place included the milling and machining of beryllium alloyed metals. Since the NIOSH investigators were not cleared to visit such areas, a special tour was provided for NIOSH staff during the Christmas vacation period. During the subsequent hazard evaluation, company and union officials made periodic checks on the NIOSH equipment and reported to the NIOSH investigators. Management collected samples identical to those collected by NIOSH. All workers were monitored and provided with pulmonary function testing and medical questionnaires. In the meantime, the Department of Energy was in the process of getting adequate clearance for the NIOSH investigators to enter this area on the followup investigation. This clearance was obtained in Autumn of 1985 and a followup environmental investigation was performed by a the NIOSH industrial hygienist on November 13, 1985. On this visit all 8 beryllium workers and the foreman were monitored for beryllium exposure.

IV. ENVIRONMENTAL DESIGN AND METHODS

A. Environmental

On the first industrial hygiene visit on January 21 and 22, 1985, all workers on 3 shifts were monitored for beryllium exposure. Thirty-Three breathing zone air samples were collected on AA filters using vacuum pumps operated at 1.5 to 2.0 liters per minute. Each machine in the beryllium shop is equipped with a fixed Station air sampler. The fixed station samples were collected on whatman number 41 filters at a flow rate of 50 liters per minute. All samples were analyzed using (NIOSH) Method 7300. In November 1985, all 8 workers and the foreman on the day shift were monitored for beryllium exposure.

B. Medical

The initial medical evaluation consisted of: 1) review of the Department of Energy report on the investigation into the cause of the one case of beryllium disease; 2) interviews and pulmonary function testing on all 28 workers in the beryllium area and the 5 in the exclusion area; 3) interviews and some pulmonary function testing on 10 other workers who identified themselves as having worked with or been exposed to beryllium. The pulmonary function tests--forced vital capacity (FVC), one-second forced expiratory volume (FEV_1), maximal mid-expiratory flow (MMEF)--were administered by the industrial hygienist (certified in pulmonary function testing) using an Ohio Medical Products Model 822 Spirometer. Predicted values based on sex, race, age, and height were calculated by a Model 200 Spirotech computer utilizing the formulae of Knudson, et al.[1]

Interview results and pulmonary function tests were evaluated using analysis of variance among three groups; current beryllium workers, past beryllium workers, and others. Data were also grouped by current cigarette smokers, ex-cigarette smokers, and non-cigarette smokers.

In addition, the company physician was interviewed. Information on the availability of the lymphocyte transformation test for beryllium sensitivity was obtained. A list of about 1400 self identified beryllium exposed workers who had showed up for chest x-rays was obtained from the company physician.

After the initial evaluation at the plant arrangements were made to have 120 company x-ray films read by two "B" Readers independently. The NIOSH physician correlated the readings and had the B Readers do a joint reading to reconcile differences where their readings did not agree. The films were selected as follows: X-rays for all 43 of the workers in this study were referred for reading. Of the list of 1356 workers who had previously voluntarily had chest x-rays because of concern about beryllium, 29 were in the beryllium NIOSH study. A sampling of the other 1327 was also referred for reading: all 22 workers with abnormal X-ray readings; all 33 workers with no X-ray reading recorded on the list; and 22 of remaining 1272 workers with normal or negative X-ray readings. The B Readers utilized the International Labour Office/International Union Against Cancer (ILO,U/C) 1971 classification of pneumoconioses as recorded on the forms (Form CM-933, Rev. Mar. 1979) used the the U.S. Department of Labor for black lung benefits.

V. EVALUATION CRITERIA

A. Environmental

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy).

In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the evaluation criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH Criteria Documents and recommendations, 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLV's), and 3) the U.S. Department of Labor (OSHA) occupational health standards. Often, the NIOSH recommendations and ACGIH TLV's are lower than the corresponding OSHA standards. Both NIOSH recommendations and ACGIH TLV's usually are based on more recent information than are the OSHA standards. The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH-recommended standards, by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is legally required to meet those levels specified by an OSHA standard.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

	Environmental Exposure Limits 8-Hour Time-Weighted Average (TWA)
Beryllium	0.5 ug/M^3 NIOSH 2.0 ug/M^3 OSHA

ug/M^3 = micrograms of substance per cubic meter of air.

B. Medical

The pulmonary function tests included measurements of forced vital capacity (FVC), one-second forced expiratory volume (FEV_1), maximal mid-expiratory flow (MMEF), and calculation of the ratio of FEV_1/FVC. FVC measures the total amount of air one can force out of his lungs after breathing in as deeply as possible. FEV_1 measures the amount of air one can breathe out in the first second. The MMEF measures the flow rate of the expired air between the time when 25% of the FVC has been expelled until the time when 75 % of the FVC has been expelled. The FVC can be impaired by restrictive lung disease, such as pulmonary fibrosis. FEV_1 and MMEF can be impaired by cigarette-related lung damage or some other conditions causing obstruction to air flow. Any condition that impairs FVC usually impairs FEV_1, but the reverse is not necessarily true. Conditions that impair FEV_1 do not necessarily impair FVC. The FEV_1/FVC ratio is also used to help evaluate obstructive lung disease.

In interpreting the results, the best test results are used. They are compared to "predicted values" which take into account age, height, sex, and race.[1] Pulmonary function is considered "normal" if the best FEV_1 and the best FVC are each 80 percent or more of their respective predicted values and the FEV_1/FVC ratio using the best values is 70 percent or more. Interpretation of the MMEF is more difficult as there is wide variation among apparently healthy individuals. The MMEF is of more value in following an individual over time. The computer calculates the allowable range for the MMEF for the particular individual. As a rough guide, MMEFs as low as 50% of predicted may be within the acceptable range. The computer then screens the results of the three tests and the ratio of FEV_1/FVC for low values and assigns a "Severity Code". A "0" code represents acceptable results. Codes of "1" or higher represent results which may have clinical significance.

The International Labour Office/International Union Against Cancer (ILO,U/C) 1971 classification of pneumoconioses is a standard method of reading chest x-rays which show pneumoconioses[2]. To be considered qualified to read x-rays using this scheme, an individual has to take special training, pass a qualifying test, and have a set of standard x-rays with which he can compare the films he is reading. Besides evaluating possible fibrosis (of most interest when evaluating occupational exposures to dusts) and other abnormalities, the B reader also grades the quality of the x-ray. A quality notation of 1 represents a good film, a 2 represents a film of marginal quality, and u/r represents a film which is unreadable using the ILO,U/C classification. In comparing the B reader readings with those previously given for the films, most emphasis was given to fibrosis and findings of current clinical significance. Minor differences in the reading of conditions with no current clinical significance was given less emphasis. Note, also, not all fibrosis in the lungs is due to pneumoconiosis.

C. Toxicological

Beryllium[3,4,5] can cause both acute and chronic effects by both respiratory and skin exposure. Soluble beryllium salts are irritating to the mucus membranes of the eyes, nose, throat and bronchi, and can cause a chemical pneumonia. Dust of insoluble beryllium compounds or metal can cause chemical pneumonia and/or pulmonary edema. On skin contact soluble beryllium salts can cause an irritative dermatitis. If insoluble beryllium salts or beryllium metals become implanted in the skin, they will form an ulcer, which will not heal until the beryllium is removed.

Beryllium can cause allergic sensitization. This can show up as an increased and more persistent reaction to beryllium exposures. Swelling may be marked after eye exposure. In addition, granulomas can develop in the lung after exposure to beryllium containing dusts (beryllium disease). This can progress, or even develop, after exposure has ceased. Early symptoms include some shortness of breath and a non-productive cough. This will usually progress to loss of appetite, fatigue, weakness, malaise, and weight loss. The usual course of beryllium disease is progressive with remissions and exacerbations. The ill effects can be ameliorated by chronic steroid therapy. It is not common practice to skin test for beryllium sensitivity because of the danger of causing sensitization by the test.

In addition, NIOSH considers that beryllium should be treated as a carcinogen, as it has caused cancers in several species of animals, including monkeys, by several routes of administration. Review of the Beryllium Case Register and other studies have suggested that beryllium can cause an increase in bronchogenic cancer in man.

VI. RESULTS AND DISCUSSION

Environmental

On January 21 and 22, 1985, the environmental portion of the evaluation was performed. Thirty-three workers in the beryllium shop wore personal monitoring pumps and filters. A total of 33 breathing zone air samples were collected and analyzed for beryllium. Six of these samples exceeded the evaluation criteria. These samples contained 7.2, 0.57, 0.92, 0.69, 0.60, 0.60 ug/M^2 beryllium. The average level was 0.06 ug/M^3 with 16 of the 33 samples below the detection level of 0.2 ug/filter. All exposures were collected on machinists that were milling Beryllium. Thirty-five fixed station air samples were also collected and analyzed for beryllium. All of these samples except one were below the evaluation criteria. Thirteen were below the detection limits of 0.5 ug/filter. The highest level was 0.5 ug/M^3, and the average concentration was 0.06 ug/M^3.

During 1984 and 1985, NIOSH personnel could not enter the beryllium shop until proper security clearance was obtained. After a security clearance was obtained, the NIOSH industrial hygienist took environmental breathing zone air samples on all 8 workers and the foreman in the beryllium shop on November 13, 1985. Of the nine breathing zone samples, seven exceeded the NIOSH evaluation criteria of 0.5 ug/M^3. The levels were 1.2, 2.1, 0.6, 1.5, 1.9, 0.4, 0.5, 0.8 and 0.08 ug/M^3. These exposure levels are presented in table VII.

MEDICAL

A. Initial Evaluation

Tables I and II present age distribution, length of employment, length of exposure to beryllium, and pulmonary function results arranged by beryllium exposure and by cigarette smoking status respectively. Most of the current beryllium workers had normal pulmonary function. Mean values stated as percent of predicted with standard deviations were: forced vital capacity (FVC), 91.9 $\pm$ 17.9; one-second forced expiratory volume (FEV_1), 94.7 $\pm$ 12.8; and maximal mid-expiratory flow (MMEF), 71.0 $\pm$ 30.1 ratio of FEV_1/FVC, 77.5 $\pm$ 9.4;. Of the 28 current beryllium workers, only 2 had a severity code other than "0". Neither had worked in the beryllium shop for more than a year and the more severely affected had only recently started, but gave a history of pulmonary disease.

Although the pulmonary function results for the ex-beryllium workers were slightly lower on the average than results for the current beryllium workers, the difference between groups was not great enough and the variability within each group was great enough, to prevent these from being statistically significant differences. Three of the seven ex-beryllium workers who had pulmonary function testing had severity codes greater than "0". All were smokers or ex-smokers. Other than the index case of beryllium disease, neither of the other two had had more than minimal beryllium exposure and one gave a history consistent with chronic bronchitis.

The current beryllium workers were statistically significantly younger than the ex-beryllium workers (36.6 $\pm$ 8.7 yrs. vs. 46.0 $\pm$ 10.7), and had worked with beryllium and in the plant for a shorter period of time (1.6 $\pm$ 1.6 yrs. vs. 6.0 $\pm$ 8.5; and 3.0 $\pm$ 1.5 yrs. vs. 13.1 $\pm$ 13.4 respectively).

When arranged by smoking status, no significant differences in beryllium exposure or length of time in the plant were noted between the groups. Those who had never smoked cigarettes were younger than the rest (34.2 $\pm$ 6.7 yrs. vs. 41.7 $\pm$ 10.9), and had higher MMEFs (87.3 $\pm$ 14.5 % of predicted vs. 67.5 $\pm$ 29.2).

The diagnosis of beryllium disease in the index case which prompted this investigation appears to have been based on a sound medical evaluation done at the Cleveland Clinic, Cleveland, Ohio. However, discussion with the Rocky Flats Medical Department determined that although the chest X-rays taken at the plant were read by radiologists, they were not read by a "B Reader" certified in reading pneumoconioses.

B. X-ray Review

The B readers commented on the poor quality of many of the x-rays which they felt was due to technique rather than the equipment because some of the films were of excellent quality. Figure I graphically depicts film quality by the month the films were taken. As can be seen most of the films taken in November 1984 were of good quality. August and September 1984 were also good months. It would appear that during periods of particularly heavy workload either the extra help required or the extra practice afforded the staff was beneficial to x-ray quality.

In comparing readings of the x-rays by the radiologist used by the company and the B readers engaged for this study, one can divide the 120 x-rays into three groups: 47 on which no reading was given on the company supplied list; 50 on which a normal or negative reading given on the list; and 23 on which mention of some abnormality was made on the list (not necessarily of current clinical significance). Each of these three groups can be subdivided into whether the workers were a part of the Beryllium study group ("Be" workers) seen by NIOSH or not.

Of the 47 workers for which the company list gave no reading, 14 were a part of the Beryllium study group and 33 were taken from the list of concerned workers who had reported for x-rays. By and large the Be workers who had no x-ray reading were not on the list. Four (4) had their last x-ray before June 1984 (April 1980 being the oldest), and 7 had their x-ray in 1985. Of the 14 films 13 were negative and one showed some changes of no current clinical significance. Of the 33 non-Be workers 28 had negative films, 2 showed changes of no current clinical significance, and 2 showed changes of possible clinical significance. One of the latter did require reconciliation between the B readers. None of the films even suggested pneumoconiosis.

Of the 50 workers for which the list gave a negative or normal reading, 28 were a part of the Beryllium study group and 22 were taken from the list of concerned workers who had reported for x-rays. Of the 28 Be workers' films, 26 were again read as negative, one was read as showing changes of no current clinical significance, and one showed changes of possible clinical significance (not pneumoconiosis, but a poor quality film). Of the 22 non-Be workers 19 had negative films (one required reconciliation between the B readers), 2 showed changes of no current clinical significance, and 1 film was judged unreadable on reconciliation. Considering that the primary concern of the physician reading an x-ray is to identify deviations from "normal" which suggest current clinical problems the 3 films in which the B readers identified changes of no current clinical significance does not indicate an important difference in film reading.

Only one of the workers in the Beryllium study (the index case) had an abnormal x-ray reading, and this was recognized by all readers. The 22 other workers who had abnormal x-ray readings listed can be subdivided into three groups: 11 in whom the initial reading involved fibrosis of possible current clinical significance; 6 who showed other changes of possible current clinical significance; and 5 who had changes which did not seem of current clinical significance.

Of the 11 x-rays listed as showing some fibrosis, 9 were judged of poor quality by the B readers and 7 required reconciliation reading. On the two films of good quality no reconciliation between the B readers was necessary. One was read as showing a gradable minimal diffuse fibrosis and the other as showing some atelectasis in an abnormally shaped chest. Of the 9 poor quality films, 3 were read by the B readers as showing some fibrosis, 2 as showing other possibly clinically significant abnormalities, 3 as showing changes of no current clinical significance, and 1 as negative.

Four of the 6 films listed with possibly clinically significant findings were of good quality, but 3 still required reconciliation between the two B readers. (One of the two poor quality films also required reconciliation.) Of the 6 films, 2 showed fibrosis (one of no current clinical significance), 2 showed other changes of possible current clinical significance, 1 showed changes of no current clinical significance, and 1 was read by both B readers as negative (a poor quality film with only an "iffy" reading in the list).

Of the 5 remaining films listed with changes of no current clinical significance, 4 were read as such by the B readers. (One poor quality film required reconciliation.) On the last film, which was of good quality, the two B readers agreed with each other on first reading but differed from the listed reading. As the correct orientation of the film was crucial importance, the B readers reviewed the film to be certain of the orientation. Correctly oriented the reading was confirmed as one of possible current clinical significance rather than a change of no current clinical significance.

Although it is desirable to have fibrosis indicative of a possible pneumoconiosis read by a B reader so the extent of the problem can be judged more readily, it appears for this set of x-rays the major benefit has been the rating of film quality. Considering that B reader review of the negative or normal films showed very little and the reading of abnormal films did not show excessive differences, it is unlikely that having B readers read all the old films will show anything more.

VII. CONCLUSIONS & RECOMMENDATIONS

1. Personnel in monitoring should replace the stationary sampling stations to give a more accurate account of the workers' exposure.

2. All beryllium parts that are mechined should be under adequate exhaust ventilation.

3. Medical monitoring should be conducted of beryllium exposed workers, in accordance with the recommendations outlined in reference 6, which is reproduced in this report as an appendix. In addition to the recommendations contained in reference 6, all chest X-rays obtained in accordance with those recommendation should be read by a B-reader. Particular emphasis should be placed on quality control in obtaining the chest X-rays, so that all X-ray films are of adequate quality for interpretation.

VIII. REFERENCES

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IX. AUTHORSHIP AND ACKNOWLEDGMENTS

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X. DISTRIBUTION AND AVAILABILITY

Copies of this report are currently available upon request from NIOSH, Division of Standards Development and Technology Transfer, Information Resources and Dissemination Section, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days the report will be available through the National Technical Information Service (NTIS), Springfield, Virginia. Information regarding its availability through NTIS can be obtained from NIOSH, Publications Office at the Cincinnati address. Copies of this report have been sent to:

1. Rockwell International, Rocky Flats Plant
2. U.S. Department of Labor/OSHA, Region VIII
3. NIOSH, Region VIII
4. Colorado Department of Health

For the purpose of informing affected employees, a copy of this report shall be posted in a prominent place accessible to the employees for a period of 30 calendar days.

TABLE I

Age, Length of Service, and Pulmonary Function Test Results by Current and Past Status Regarding Working with Beryllium

Rockwell International, Rocky Flats Plant
Golden, Colorado

January 21 - 22, 1985

	Current Beryllium Workers		Ex-Beryllium Workers		Other Workers		Total Workers	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Number	28		9		6		43	
Age	36.6	± 8.7	46.0	± 10.7	38.0	± 11.8	38.7	± 10.1
Years in Plant	3.0	± 1.5	13.1	± 13.4	8.7	± 10.4	5.9	± 8.2
Number	28		9				37	
Years working with Beryllium	1.6	± 1.6	6.0	± 8.5			2.7	± 4.7
Yrs. since working with Beryllium			3.0	± 5.0				
Number	28		7		2		37	
FEV_1 (% of Predicted) (Normal - 80% or greater)	97.9	± 16.3	86.7	± 10.5	105.5	± 6.4	96.2	± 15.6
FVC (% of Predicted) (Normal - 80% or greater)	99.3	± 12.0	89.3	± 6.4	104.5	± 3.5	97.7	± 11.5
Ratio of FEV_1/FVC (%) (Normal - 70% or greater)	79.1	± 8.0	77.6	± 8.3	81.5	± 9.2	78.9	± 7.9
MMEF (% of Predicted) (Normal - probably better than 50%)	77.0	± 26.0	68.4	± 28.0	80.0	± 29.7	75.6	± 26.0

S.D. = Standard Deviation

Statistically Significant Differences
Analysis of Variance

	F Value	Probability of Chance	Difference in Means	L Value (95% Confidence)
Age:	$F_{(2,40)}=3.35$	p=0.046		
Beryllium Workers vs. Ex-Beryllium Workers			- 9.4	± 9.3
Years in Plant	$F_{(2,40)}=7.40$	p=0.0026		
Beryllium Workers vs. Ex-Beryllium Workers			- 10.1	± 7.0
Beryllium Workers vs. Rest of Workers			- 7.9	± 5.9
Years in Beryllium	$F_{(1,35)}=7.19$	p=0.012		
Beryllium Workers vs. Ex-Beryllium Workers			- 4.4	± 3.3

TABLE II

Age, Length of Service, and Pulmonary Function Test Results by Cigarette Smoking Status

Rockwell International, Rocky Flats Plant
Golden, Colorado

January 21 - 22, 1985

	Current Cigarette Smokers		Ex-Cigarette Smokers		Non-Cigarette Smokers		Total Workers	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Number	16		10		17		43	
Age	41.0	± 9.5	42.8	± 13.3	34.2	± 6.7	38.7	± 10.1
Years in Plant	4.8	± 6.7	8.9	± 11.5	5.2	± 7.2	5.9	± 8.2
Number	13		8		16		37	
Years working with Beryllium	1.6	± 1.4	2.9	± 5.1	3.5	± 6.0	2.7	± 4.7
Number	2		3		4		9	
Years since working with Beryllium	0.2	± 0.1	6.2	± 7.7	1.9	± 3.4	3.0	± 5.0
Number	15		7		15		37	
FEV_1 (% of Predicted) (Normal - 80% or greater)	91.9	± 17.9	90.7	± 14.4	103.0	± 11.5	96.2	± 15.6
FVC (% of Predicted) (Normal - 80% or greater)	94.7	± 12.8	96.4	± 8.7	101.2	± 11.4	97.7	± 11.5
Ratio of FEV_1/FVC (%) (Normal - 70% or greater)	77.5	± 9.4	75.0	± 9.7	82.2	± 9.2	78.9	± 7.9
MMEF (% of Predicted) (Normal - probably better than 50%)	71.0	± 30.1	60.1	± 27.9	87.3	± 14.5	75.6	± 26.0

S.D. = Standard Deviation

Statistically Significant Differences
Analysis of Variance

	F Value	Probability of Chance	Difference in Means	L Value (95% Confidence)
Age: Non-Smokers vs. Smokers & Ex-Smokers	$F_{(2,40)}=3.24$	p=0.050	- 7.7	± 7.7
MMEF: Non-Smokers vs. Smokers & Ex-Smokers	$F_{(2,34)}=3.40$	p=0.047	+ 21.8	± 21.6

TABLE III

Breathing Zone Air Concentration of Beryllium in the Beryllium Shops at Rocky Flats Plant, Golden, Colorado
January 21, 1985
Evening Shift

Sample #	Job	Location Machine	Sampling Time	ug/m^3 Be
5	Machinist	010-035	3:52 - 11:12	0.57
4	Machinist	010-036	3:54 - 11:11	0.46
3	Machinist	009-007	3:55 - 11:14	0.46
2	Machinist	003-020	3:56 - 11:15	0.46
1	Machinist	003-025 Rover	3:57 - 11:14	0.92
8	Foreman	Rover	3:59 - 11:16	*
6	Machinist	009-008	4:00 - 7:30	*
9	Machinist	010-034	4:35 - 11:16	*
7	Machinist	010-035	4:47 - 11:13	0.69
	Evaluation Criteria NIOSH			0.5
	Laboratory Limit of Detection ug/Filter			0.2

TABLE IV

Breathing Zone Air Concentrations of Beryllium in the Beryllium Shops at the Rocky Flats Plant, Golden, Colorado
January 21-22, 1985
Graveyard Shift

Sample #	Job	Location	Sampling Time	ug/m^3 Be
11	Machinist	009-008	11:47 - 6:47	*
12	Machinist	all areas	11:48 - 7:10	*
13	Machinist	009-007	11:42 - 7:08	0.29
15	Machinist	004-219	11:40 - 7:07	*
16	Machinist	010-035	11:45 - 6:44	0.60
17	Machinist	004-220	11:47 - 6:45	*
24	Machinist	010-34(excusion)	11:30 - 7:10	*
25	Machinist	003-020	11:30 - 7:07	0.32
27	Machinist	003-013	11:34 - 6:42	*
	Evaluation Criteria NIOSH			0.5
	Laboratory Limit of Detection ug/Filter			0.2

TABLE V

Breathing Zone Air Concentration of Beryllium in the Beryllium Shops at the Rocky Flats Plant, Golden, Colorado
January 22, 1985

Sample #	Job	Location Machine	Sampling Time	mg/m^3 Be
19	Be Machinist	010-036	7:34 - 2:47	0.27
21	Be Machinist	009-008	7:35 - 2:42	*
34	Be Machinist	024-002	7:37 - 2:41	*
33	Be Machinist	003-026	7:40 - 2:43	0.28
26	Be Machinist	009-007	7:41 - 2:44	0.60
22	Be Machinist	010-035	7:41 - 2:51	0.20
29	Be Machinist	003-024	7:41 - 2:46	7.2
18	Be Machinist	003-013	7:43 - 2:50	0.23
28	Be Machinist	004-219	7:44 - 2:45	0.31
20	Be Machinist	003-020	7:45 - 2:53	*
23	Be Machinist	Deburring	7:47 - 2:49	*
14	Be Machinist	Metal Productions	7:47 - 2:51	0.48
30	Be Machinist	Bldg. 444	7:49 - 2:47	*
38	Laundry	Laundry	8:18 - 1:10	*
32	Laundry	Laundry	8:19 - 1:11	*
	Evaluation Criteria NIOSH			0.5
	Laboratory Limit of Detection ug/Filter			0.2

TABLE VI

Fixed Station Beryllium Samples Taken in the Beryllium
Shops at Rocky Flats Plant, Golden, Colorado
January 22, 1985

Head #	Sampling Time	Air Volume M^3	ug/m^3 Be
13	7:30 - 2:00	19.5	*
14	7:30 - 2:00	19.5	*
15	7:30 - 2:00	19.5	0.5
16	7:30 - 2:00	19.5	0.3
17	7:30 - 2:00	19.5	0.03
18	7:30 - 2:00	19.5	*
19	7:30 - 2:00	19.5	*
20	7:30 - 2:00	19.5	*
21	7:30 - 2:00	19.5	*
22	7:30 - 2:00	19.5	*
23	7:30 - 2:00	19.5	0.03
24	7:30 - 2:00	19.5	0.15
25	7:30 - 2:00	19.5	0.04
26	7:30 - 2:00	19.5	0.03
27	7:30 - 2:00	19.5	*
28	7:30 - 2:00	19.5	*
29	7:30 - 2:00	19.5	*
30	7:30 - 2:00	19.5	*
31	7:30 - 2:00	19.5	*
32	7:30 - 2:00	19.5	0.03
33	7:30 - 2:00	19.5	0.04
34	7:30 - 2:00	19.5	0.10
35	7:30 - 2:00	19.5	0.05

TABLE VI (Con't)

Head #	Sampling Time	Air Volume M^3	ug/m^3 Be
36	7:30 - 2:00	19.5	0.05
37	7:30 - 2:00	19.5	0.10
38	7:30 - 2:00	19.5	0.05
39	7:30 - 2:00	19.5	0.10
40	7:30 - 2:00	19.5	0.15
41	7:30 - 2:00	19.5	0.05
42	7:30 - 2:00	19.5	0.20
43	7:30 - 2:00	19.5	*
44	7:30 - 2:00	19.5	0.05
45	7:30 - 2:00	19.5	0.10
46	7:30 - 2:00	19.5	0.03
47	7:30 - 2:00	19.5	0.03
Evaluation Criteria NIOSH			0.5
Laboratory Limit of Detection ug/Sample			0.5

TABLE VII

**Breathing Zone Air Concentrations of Beryllium (Be)
in the Beryllium Shop at
Rocky Flats Plant,
Golden, Colorado
November 13, 1985**

Sample #	Location	Job	Sample Time	ug/M^3 Beryllium
16	Beryllium Shop	Machinist	7:17a - 3:22p	1.2
12	Beryllium Shop	Machinist	7:17a - 3:06p	2.1
18	Beryllium Shop	Machinist	7:21a - 3:26p	0.6
11	Beryllium Shop	Machinist	7:23a - 3:22p	1.5
17	Beryllium Shop	Machinist	7:27a - 3:10p	1.9
20	Beryllium Shop	Machinist	7:28a - 3:20p	0.4
19	Beryllium Shop	Machinist	7:33a - 3:34p	0.5
8	Beryllium Shop	Machinist	7:35a - 3:20p	0.8
13	Beryllium Shop	Foreman	7:40a - 3:15p	0.08
Evaluation Criteria				0.5
Laboratory Limit of Detection ug/sample				0.03

FIGURE I

Film Quality by Date Taken as Reported by "B" Readers.
Chest X-Rays of Beryllium and Other Workers

Rockwell International, Rocky Flats Plant
Golden, Colorado

```
Month & Year     0 1 2 3 4 5 6   8  10  12  14  16  18  20  22  24  26  28  30
  of X-Ray       |         |         |         |         |         |         |
                 |XXIIIIII |         |         |         |         |         |
Before June 1984 |XX    II |   4     |         |         |         |         |
                 |XXIIIIII |         |         |         |         |         |
                 |         |         |         |         |         |         |
                 |XXXXIIIIIIIIIIIIII |         |         |         |         |
 June 1984       |XXXX            II |   9     |         |         |         |
                 |XXXXIIIIIIIIIIIIII |         |         |         |         |
                 |         |         |         |         |         |         |
                 |XXXXXXXXXXXXIIIIIIIIIIIIIIIIIIIIIIIIIIII         |         |
 July 1984       |XXXXXXXXXXXX                          II  20     |         |
                 |XXXXXXXXXXXXIIIIIIIIIIIIIIIIIIIIIIIIIIII         |         |
                 |         |         |         |         |         |         |
                 |XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXIIIIIIIIIIIIIIIIIIII         |
 August 1984     |XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX                  II  26     |
                 |XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXIIIIIIIIIIIIIIIIIIII         |
                 |         |         |         |         |         |         |
                 |XXXXXXXXXXIIIIIIII |         |         |         |         |
 September 1984  |XXXXXXXXXX      II |   9     |         |         |         |
                 |XXXXXXXXXXIIIIIIII |         |         |         |         |
                 |         |         |         |         |         |         |
                 |XXIIIIIIII         |         |         |         |         |
 October 1984    |XX      II   5     |         |         |         |         |
                 |XXIIIIIIII         |         |         |         |         |
                 |         |         |         |         |         |         |
                 |XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXIIIIIIIIIIII
 November 1984   |XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX          II 30
                 |XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXIIIIIIIIIIII
                 |         |         |         |         |         |         |
                 |XXXXIIIIII         |         |         |         |         |
 December 1984   |XXXX    II   5     |         |         |         |         |
                 |XXXXIIIIII         |         |         |         |         |
                 |         |         |         |         |         |         |
                 |XXXXXXXXXXIIIIIIIIIIII       |         |         |         |
After 1984       |XXXXXXXXXX          II  11   |         |         |         |
                 |XXXXXXXXXXIIIIIIIIIIII       |         |         |         |
                 |         |         |         |         |         |         |
                 0 1 2 3 4 5 6   8  10  12  14  16  18  20  22  24  26  28  30
                 |
Totals                              XX     62     II     57    Grand Total  119
  # with only 1 quality notation            3             3                   6
```

1 = Good quality
2 = Marginal quality
u/r = Unreadable

XX = 1-1,1-2,1-blank
II = 2-2,2-u/r,2-blank,1-u/r

One u/r-blank reading is excluded from this tabulation.

FIRST DRAFT
END OF TELECOMMUNICATIONS SESSION

THE TOXICOLOGY OF BERYLLIUM

Irving R. Tabershaw
Editor

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CHAPTER VII

Medical Control

Robert N. Ligo

The primary objective in the control of the various forms of beryllium disease is the prevention of their occurrence by keeping workers from being exposed to toxic doses of beryllium. In achieving this objective, the chief reliance should be on good engineering controls.

Medical control measures are designed to keep individuals with certain types of problems from entering the work force of a plant where exposure to beryllium occurs. Medical control also consists of monitoring workers in such plants to insure that if cases of the various forms of beryllium disease do occur they are discovered early and appropriate action is taken.

A comprehensive pre-employment history and physical examination should be performed on all worker applicants. This should include a 14" x 17" chest roentgenogram, and pulmonary function tests. One of the principal purposes of this examination is to identify individuals who should not work with beryllium. The conditions for which applicants are usually excluded include the presence of chronic respiratory disease or potentially disabling organic heart disease such as mild congenital anomalies. There is no evidence that persons with these conditions are more prone to develop chronic beryllium disease than persons who do not have these conditions. However, because of possible difficulties in distinguishing pre-existing respiratory disease from chronic beryllium disease these persons are usually excluded from working in beryllium plants. In addition applicants with chronic dermatitis are usually excluded from assignment to areas where exposure to the soluble salts of beryllium may occur.

To work with toxic substances, adequate intelligence and a normal regard for one's own health and that of co-workers is required. Applicants lacking these qualities should be excluded.

An important function of the medical staff, in an industry where beryllium exposures occur is to discuss, in some detail, with each new employee, the nature of beryllium-related health problems, the necessity for exposure control and the medical and industrial hygiene monitoring programs. The employee should be instructed to report promptly instances where possible overexposure has occurred or where symptoms or signs of beryllium disease are suspected.

Periodic examinations of beryllium workers are necessary. Baseline information should be obtained during the pre-employment examination. The time intervals between examinations will vary depending on the nature of the exposure. These examinations should include review of health status to include history of intermittent illness, surgery and accidents, measurement of body weight, determinations of vital capacity and chest roentgenograms. The results of each examination should be carefully evaluated, and compared with results obtained in previous examinations, with special attention to changes in weight, chest films, and pulmonary function. Appropriate follow-up and treatment procedures should be instituted as necessary.

Individuals who have had known or suspected overexposures that might produce beryllium disease should be examined immediately and daily for the first week after exposure, then at weekly intervals for a month. If symptoms of lower respiratory tract disease develop the patient should be kept under close medical supervision until all danger of pulmonary edema has passed. During the period of close observation the worker should be removed from further exposure to beryllium.

A suggested program for medical control is outlined below. It should be emphasized that detailed implementation will vary from industry to industry. Evaluations and decisions which involve medical judgments should not be arbitrary but should take into account the multiple factors at play.

BASIC MEDICAL PROGRAM

I. Physical examinations

A. Schedule

1. Pre-employment

2. Periodic

At intervals determined by likelihood and degree of exposure, but at least once a year. In areas known to have produced acute pulmonary manifestations, examinations as often as once weekly may become necessary.

3. Termination, at time of cessation of employment, unless a periodic examination has been done within one month.
4. Special examinations as directed by symptoms or known exposure.

B. Scope

1. Preplacement examination
   a. Complete medical history
   b. Complete occupational history, with specific reference to previous beryllium exposures
   c. Physical examination, by systems
   d. Weight and height
   e. Chest roentgenogram – 14" x 17" postero-anterior
   f. Vital capacity determination
   g. Urinalysis and blood count*
   h. Blood chemical profile with special attention to indications of liver or kidney dysfunction*
2. Periodic and termination examination
   Same as preplacement with substitution of interval history.

C. Physical standards for employment

1. The following can be considered disqualifying for employment involving exposure to beryllium.
   a. Pulmonary fibrosis by chest X-ray or biopsy
   b. History of acute lower respiratory tract disease due to beryllium
2. In concordance with the established medical policy of a particular company and subject to the judgement of the examining and review physicians, the following findings *may* be considered as potentially disqualifying an applicant from employment involving potential exposures to beryllium.
   a. History of repeated respiratory infections
   b. Recently treated tuberculosis
   c. Bronchial asthma
   d. Repeated hay fever
   e. Organic heart disease
   f. Acute or chronic disease of the liver
   g. Acute or chronic disease of the kidney
   h. Dermatitis
   i. Vital capacity more than 25% below normal standards for height and age - cause undiagnosed

*These tests are suggested as "good practice." There is no evidence that beryllium disease is precipitated by prior hepatic or renal disease.

The management of individuals who develop symptoms or signs suggesting beryllium disease should be in the hands of an informed physician. The following can serve as general guidelines:

Any employee who develops a cough, pain or tightness in the chest, anorexia, weight loss, shortness of breath, should be kept under close medical surveillance until the symptoms have disappeared or until the cause has been established to be something other than beryllium. Those with acute upper respiratory tract involvement only should be removed from beryllium exposure, treated as necessary and after recovery returned to their jobs depending on engineering control in areas where the exposure levels are below the threshold limit value.

Individuals with acute lower respiratory tract involvement or other beryllium related diseases should be removed from beryllium exposure and given appropriate treatment. If a diagnosis is made of beryllium disease, experience dictates permanent exclusion from further occupational exposure to beryllium.

Individuals with dermatitis or conjunctivitis attributed to beryllium should be removed from exposure, treated as necessary, and returned to their jobs on recovery if the threshold limit value can be maintained. If the problem is recurrent, the worker should be transferred.

In all diagnosed or suspected cases, there should be prompt investigation of the work areas by an industrial hygienist to determine the source and level of probable exposure. If unsatisfactory conditions are found, they should be corrected.

Individuals who are not regular employees (such as outside contractors), but who may be called upon to work in areas where beryllium exposures are likely, should have a chest roentgenogram as a matter of record. Further, those in charge of such workers should be adequately briefed on the potential existence of beryllium exposure if uncontrolled.

At all stages of a medical control program, visits to the physician should be used for personal indoctrination of the employee in the basic health problems associated with beryllium and how to protect himself and others.

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