U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public Health Service
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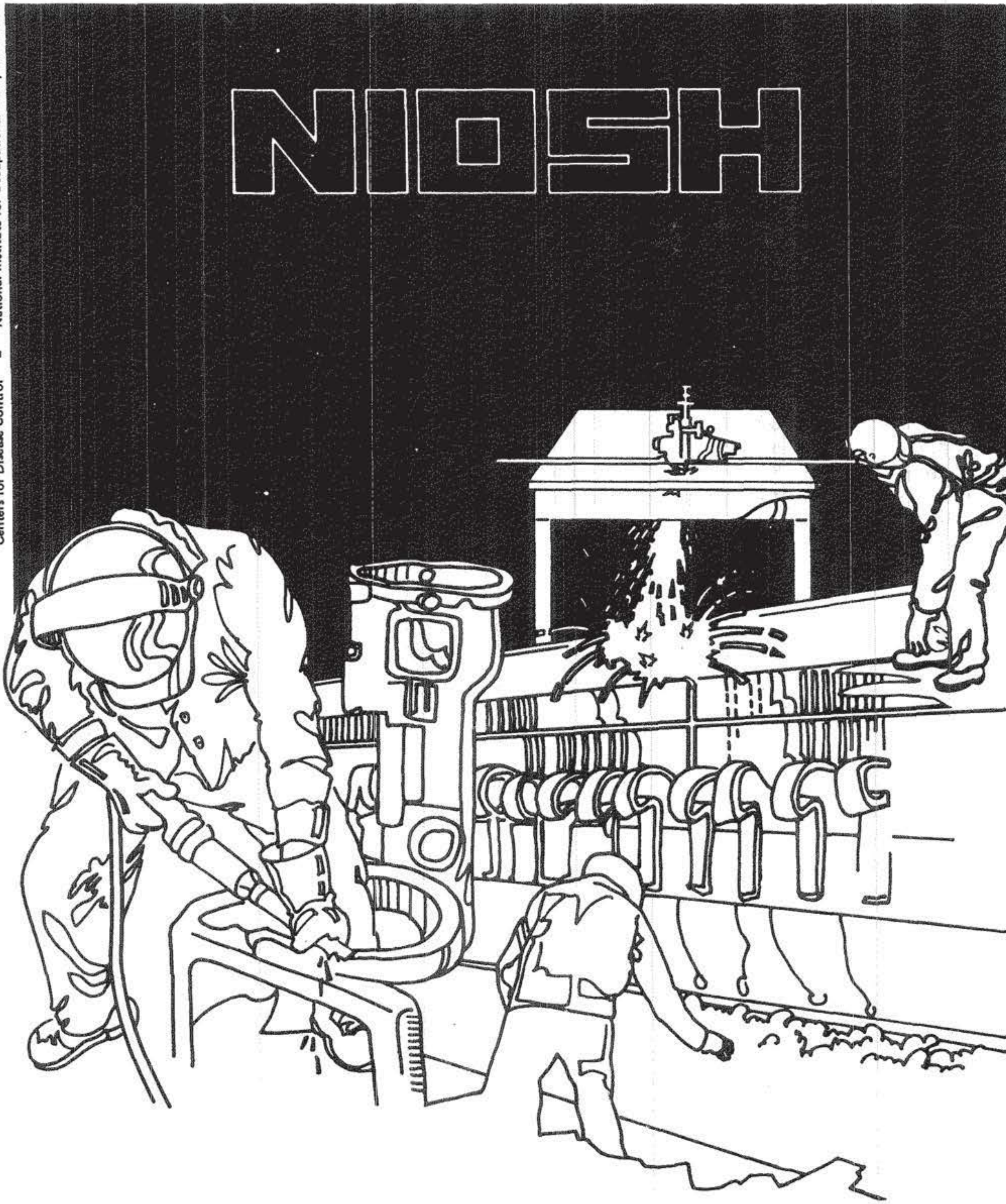

Health Hazard Evaluation Report

HETA 82-174-1298
PACER CORPORATION
CUSTER, SOUTH DAKOTA

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.

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PACER CORPORATION
CUSTER, SOUTH DAKOTA

NIOSH INVESTIGATOR
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I. SUMMARY

The National Institute for Occupational Safety and Health (NIOSH) received a technical assistance (TA) request from the Mine Safety and Health Administration (MSHA) to investigate the health of employees exposed to silica-containing dust at Pacer Corporation, Custer, South Dakota. This request was precipitated by the diagnosis of silicosis in two former employees of the Pacer Corporation. Before NIOSH could complete its investigation, the inspection authority for facilities such as Pacer's was removed from MSHA and given to the Occupational Safety and Health Administration (OSHA). Subsequently NIOSH received a technical assistance request from OSHA to complete the investigation.

An environmental and medical survey of current and former workers was conducted during the week of May 3, 1982, at the Pacer Corporation. The purposes of the study were to determine if workers were currently being exposed to hazardous levels of silica dust and to determine the prevalence of silicosis among current and former workers.

Environmental measurements were obtained during an industrial hygiene survey conducted at the Brite-X and Mica Plant, Feldspar Plant, and the Dakota Quartz Plant. Worker exposures to respirable dust containing quartz exceeded the TLV of the American Conference of Governmental Industrial Hygienists (ACGIH)[1] in seventeen out of twenty-six measurements (65%) at the Brite-X and Mica Plant; three out of twenty-three (13%) at the Feldspar Plant; and five out of seventeen (29%) at the Dakota Quartz Plant. The NIOSH recommended standard[2] for exposure to respirable free silica (0.05 mg/m^3) was exceeded in 53% of the 66 measurements taken in all plants. Job categories associated with higher levels of respirable free silica concentrations were baggers and mill operators (Brite-X and Mica), maintenance and baggers/loaders (Feldspar), and sorters (Dakota Quartz). Analysis of bulk samples by X-ray diffraction revealed that quartz was the only form of crystalline silica present.

Health screening consisted of a chest radiograph, spirometry and a medical questionnaire detailing occupational history, smoking habits and pulmonary symptomatology.

All current production workers (N = 50) and 45% (28) of former workers who ever worked for Pacer Corporation participated. Current employees of an electronic component manufacturing company located at a nearby city were chosen as a control group. No radiographic evidence of silicosis was found in Pacer workers with less than one year of dust exposure. Five of the 47 current workers (11%) and four of the 20 former workers (20%) with one or more years of dust exposure had radiographic evidence of silicosis. Of these nine workers with silicosis six had simple pneumoconiosis and three had progressive massive fibrosis. Four of these workers had less than five years of silica dust exposure, indicating accelerated disease. This form of silicosis is associated with exposure to high levels of respirable free silica and enhanced morbidity and mortality. Lung function and symptoms of Pacer employees were not significantly different from those of control plant workers.

Based on the findings of this study NIOSH concludes that the high prevalence of silicosis is due to the high free silica content of the dust and excessive respirable dust levels. The presence of accelerated forms of silicosis in some workers underscores the very hazardous nature of this exposure. Recommendations are made for engineering controls to reduce and maintain free silica dust levels below current recommended exposure limits.

Key Words: SIC 1493, milling, mica, feldspar, silicosis.

II INTRODUCTION

Under Public Law 91-173, as amended by Public Law 95-164 (Federal Mine Safety and Health Act of 1977), the National Institute for Occupational Safety and Health has been delegated responsibility for evaluating, upon written request, the potential hazard of any substance in the concentrations normally used or found in the workplace or to determine whether any physical agents or equipment found or used in the workplace has potentially hazardous effects.

NIOSH received such a request on October 7, 1981, from the Mine Safety and Health Administration to investigate the health of employees exposed to silica-containing dust at Pacer Corporation, Custer, South Dakota. This request was precipitated by the diagnosis of silicosis in two former employees of the Pacer Corporation.

NIOSH conducted a walk-through survey of the Pacer Corporation facilities during the week of January 25, 1982. Before the investigation could be completed, the responsibility of MSHA in regard to facilities such as Pacer Corporation was transferred to the Occupational Safety and Health Administration. NIOSH subsequently received a request for assistance from OSHA on March 30, 1982. The investigation was completed under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6).

NIOSH conducted an environmental and medical survey of current and former workers during the week of May 3, 1982, at the Pacer Corporation.

III. BACKGROUND

The Pacer Corporation has two divisions. One is at Custer, South Dakota, and the other is at Keystone, South Dakota. The location of each worksite is as follows:

Custer, South Dakota	Keystone, South Dakota
Super Quartz Plant	Dakota Quartz Plant
Feldspar Plant	Metals Plant
Brite-X and Mica Plant	
Brite-X Mine	

The United Steel Workers of America (USWA) union represents workers at the Feldspar Plant. No other worksite is unionized. The detailed operations of each of these plants have been presented in an earlier NIOSH report. [3] During the week of May 3, 1982, the Super Quartz and Metal plants were not operating.

IV. EVALUATION DESIGN AND METHODS

1. Environmental

During the walkthrough survey of January 26 and 27, 1982, bulk samples of raw materials, final products, and settled dust were collected to obtain mineral characterizations and to assist in the eventual laboratory analysis for respirable crystalline silica. Bulk samples were analyzed for trace metals by Inductively Coupled Plasma-Atomic Emission Spectroscopy,[4] for silica content by X-ray Diffraction,[5] and for mineral and fiber identification by Transmission Electron Microscopy and Polarized Light Microscopy.[6]

During the industrial hygiene survey of May 3 to May 7, 1982, employees at the Brite-X and Mica Plant, Feldspar Plant, and the Dakota Quartz Plant wore respirable dust samplers in accordance with NIOSH physical and chemical analytical method #259 (P&CAM #259). To collect respirable dust, air in the breathing zone of the worker was pulled through a 10mm nylon cyclone and a polyvinyl chloride filter at a flow rate of 1.7 liters per minute by a personal sampling pump. The filters were weighed before and after sampling. After weighing, the filters were analyzed for quartz content by x-ray diffraction.[5] The Andersen 1 ACFM Particle Fractionating Sampler was used to collect samples of airborne particles in bagging and mill areas. This sampler is a multi-stage, multi-orifice, cascade impactor which measures the aerodynamic size distribution of airborne dust.

2. Medical

Medical testing done on May 4 and 6, 1982, consisted of a chest x-ray, breathing test, a smoking history, and a questionnaire detailing pulmonary symptomatology and occupational history. Because of the high turnover rate of workers and the usual period between the beginning of exposure and the development of radiographically detectable silicosis, we also studied the health of former production workers. All former production workers who ever worked for Pacer Corporation were requested to participate in the study. A list of current and former workers was supplied by the company. Both current and former workers were notified via two letters mailed three weeks and one week before the study.

Standard 14 x 17 inch posteroanterior chest x-rays were obtained. Radiographs were independently interpreted by three certified pneumoconiosis readers.

A modified British Medical Research Council (BMRC) respiratory questionnaire with additional information on occupational and smoking history was administered by trained interviewers.

Pulmonary function tests were performed on an Ohio 840 waterless spirometer. At least three acceptable forced expiratory maneuvers were recorded on each participant and the largest forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) were chosen as the values best describing a participant's lung function. The weight and height of all participants were recorded.

The current employees of an electronic component manufacturing company located at a nearby city were chosen as a control group. This control group was available from a NIOSH study done in 1981. Medical testing was identical to that performed at the Pacer Corporation. Chest x-rays, however, were not performed on control group workers.

V. EVALUATION CRITERIA

1. Environmental

The American Conference of Governmental Industrial Hygienists (ACGIH) recommends the following threshold limit value (TLV) for exposure to respirable mineral dust containing greater than 1% quartz:[1]

$$TLV\ (mg/m^3) = \frac{10\ mg/m^3}{\%\ \text{Respirable quartz} + 2}$$

This same TLV has been adopted by MSHA.[7] NIOSH recommends that exposure to respirable quartz be limited to 50 micrograms (ug) per cubic meter of air averaged over a workshift of up to 10 hours per day, 40 hours per week.[2]

2. Medical

Pulmonary function testing conformed to criteria for spirometry recommended by the American Thoracic Society (ATS).[8] Predicted values employed were those of Knudson et al[9]. Obstructive lung disease was defined as an FEV_1/FVC ratio of less than 0.70, and restrictive lung disease was defined as an FVC less than 0.80 of the predicted FVC.[10]

Chest x-rays were interpreted by three certified pneumoconioses readers according to the 1971 ILO/UC International Classification of Radiographs of the Pneumoconioses.[11] Chest x-rays interpreted as category 1/0 or greater by at least two of the three readers were considered positive for pneumoconiosis.

VI. RESULTS

1. Environmental

The results of bulk sample qualitative silica analysis are contained in Table 1. The most notable result of this analysis was that no cristobalite or tridymite was found in any sample. Quartz was the only form of crystalline silica identified. Therefore, the airborne dust samples were analyzed only for quartz content. Interferences were encountered in the use of analytical method #259 due to the presence of feldspar and mica type minerals.

Table 2 summarizes the results of personal and area respirable dust sampling by plant. Worker exposures to respirable dust containing quartz exceeded the MSHA TLV in 65% of measurements at the Brite-X and Mica Plant, in 13% of measurements at the Feldspar Plant and in 29% of measurements at the Dakota Quartz Plant. When all plants are considered together, the MSHA TLV was exceeded in 38% of the measurements. The NIOSH recommendation for respirable quartz was exceeded in 53% of measurements taken in all plants. The average percentage of quartz by weight on each filter was 8.5% at the Brite-X and Mica Plant, 5.9% at the Feldspar Plant, and 38.3% at the Dakota Quartz Plant. These averages were calculated by deleting data where the amount of quartz on a filter was less than that needed for analytical quantitation. A few area and respirable samples were not analyzed (i.e., where they did not approximate a full shift sample).

Figure 1 shows the mean values of personal respirable dust concentrations divided by the TLV for each job category and plant. Data has been deleted where the amount of quartz on a filter was less than that needed for analytical quantitation. Those job categories where average personal respirable dust concentrations divided by the TLV exceeded one were the bagger and mill operator (Brite-X and Mica Plant), maintenance and bagger/loader (Feldspar Plant), and sorter (Dakota Quartz Plant). This data is corroborated by the results of area sampling in that those areas where workers could be exposed to relatively high levels of respirable dust containing quartz are the bagging area (Brite-X and Mica Plant), the milling area (Feldspar Plant), and the AC mill area (Dakota Quartz Plant).

It should be noted that the above personal and area respirable dust measurement results might well have been higher if it were not for the reduced operations of Pacer Corporation facilities during the industrial hygiene survey of May 3-7, 1982. These reduced operations, according to management, were due to depressed economic conditions and included the closing of the Metals Plant which normally received incoming raw material from the Dakota Quartz Plant. The Super Quartz Plant was not operating since it was being moved to Keystone, South Dakota.

Aerodynamic particle size distribution data is contained in Figures 2, 3, and 4. The size of particles of concern as a silicosis health hazard is generally considered to be below 10 micrometers (um) in diameter. The mass of airborne dust particles that are 10 um in aerodynamic diameter and below by work area/job are:

Brite-X bagging	-	23%	
Mica bagging	-	46%	
Feldspar bagging	-	36%	(average of 2 readings)
Dakota Quartz AC mill	-	41%	(average of 2 readings)
Dakota Quartz bagging	-	45%	

The results of bulk sample trace metal analysis are contained in Table 3. The most prevalent metal for which ACGIH has provided a TLV recommendation is aluminum. However, since no trace metal analyses were conducted on airborne samples, the potential health hazard of trace metals is unknown.

The results of bulk sample mineral and fiber analysis are contained in Table 4. Only one sample from the Dakota Quartz Plant contained any evidence of a fibrous mineral (wollastonite). No asbestos was found in any sample.

2. Medical

As reported in Table 5, all fifty current production workers participated in the study. The company provided us with a list of 87 former production workers. All former workers who ever worked for Pacer were asked to participate. Two of these 87 former workers were reported as deceased and 22 moved out of the town and were not available for participation. We examined 28 of the 63 workers available for participation, including one former production female employee (45% participation). There were no data available on 35 former workers who did not participate except their length of employment with Pacer. The mean tenure for non-participant former workers was 2.5 years compared to 5.4 years for participating former workers. A total of 78 production workers were tested. All current and former employees were white males except one. The single female employee examined has been excluded from all our analysis. Of the 78 control plant workers from a NIOSH study done in 1981, only 46 production workers who are white males are included in the analyses.

Demographic data for the participants are reported in Table 5. The control plant workers (mean age 29 years) were slightly younger than the Pacer workers (mean age 35). The average duration of exposure (tenure) for Pacer workers was 6 years. Total number of eversmokers (current and ex-smokers) were identical in Pacer and control sites (80%). However, Pacer workers smoked approximately twice as much as the control group (23 mean pack years) and had a greater percentage of current smokers.

The prevalence of pneumoconiosis is reported in Table 6. No worker with less than one year of exposure to free silica containing dust had radiographic evidence of silicosis. Of the 47 current workers with more than one year of exposure, two had simple pneumoconiosis (5%), and three had progressive massive fibrosis (6%). The highest prevalence was recorded in workers with more than 5 years of dust exposure. One case of simple pneumoconioses and two cases of progressive massive fibrosis were recorded among workers with 1 to 5 years of dust exposure. The majority of the x-rays showed predominantly rounded opacities extending over all three zones of both lungs.

Among participating former employees four had simple pneumoconiosis. Of these 4 workers with pneumoconiosis, one had less than 5 years of dust exposure. None of the former workers had progressive massive fibrosis. Of the nine workers with pneumoconiosis, two workers worked at the Feldspar plant (free silica 6%), three at Dakota quartz plant (free silica 38%), and four at more than one plant (Table 6).

Table 7 shows % predicted lung function by exposure group and smoking category. No significant differences were observed in these data between Pacer and control plant workers. Multiple regression analyses were also done in order to isolate any effect associated with dust exposure from that due to smoking. The following variables were considered in regression models of lung function: height, age, pack years of smoking and Pacer tenure. After allowing for the effect of height, age and smoking, no significant association was found between the reduction in FEV_1 and FVC and tenure at Pacer Corporation.

Data on the nine Pacer employees with pneumoconiosis are shown in Table 8. Five were 45 years of age or younger and four of them had less than 5 years of exposure to silica dust. Three mill operators and one mill helper developed pneumoconiosis. All three mill operators had less than five years of exposure to silica dust. Our industrial hygiene survey also indicated baggers, mill operators, sorters and baggers/loaders as job categories associated with high levels of respirable free silica concentrations.

Table 9 summarizes the prevalence of symptoms by smoking status among the Pacer employees and among the control group. Pacer employees did not report more symptoms than the control group.

VII. DISCUSSION

1. Environmental

Of the three facilities studied, workers at the Dakota Quartz Plant are potentially exposed to the highest concentrations of respirable quartz dust. This is shown by the mean quartz content by weight of each personal filter (38.3%) and the percent of personal samples exceeding the NIOSH recommendation of .050 mg/m^3 respirable free silica (71%). The potential of overexposure to respirable quartz is present at all plants, however, even though the mean quartz content by weight of personal filters might be less than at the Dakota Quartz Plant (8.5% at the Brite-X and Mica Plant and 5.9% at the Feldspar Plant).

In analyzing the survey results with a view towards control of respirable dust hazards, two categorizations are helpful. The first is a ranking of those job categories by mean value of personal respirable dust concentration divided by the TLV:

Brite-X Bagger
Brite-X and Mica Mill Operator
Feldspar Bagger/Loader
Dakota Quartz Sorter
Feldspar Maintenance
Mica Bagger

While all of these job categories are associated with mean values of personal respirable dust concentration which exceed the TLV, the Brite-X Bagger category has the highest potential of overexposure. Another useful categorization is that of highest respirable dust level work area for each plant:

Brite-X and Mica Bagging Areas
Feldspar Milling Area
Dakota Quartz AC Mill Area

These job categories and work areas should receive primary attention in efforts to control exposures to respirable dust containing quartz.

2. Medical

Silicosis is a debilitating respiratory disease caused by inhalation of fine crystalline silica dust that is retained in the lungs.[12] The amount of dust inhaled, the percentage of free or uncombined silica in the dust, the size of the dust particles, and the length of exposure all affect the onset of silicosis. The inhaled dust deposited in the bronchioles and alveoli reacts within the lung tissue to form silicotic nodules. The nodules appear on chest radiogram as discrete, rounded opacities or shadows. The presence of silicotic nodules and a history of occupational exposure to silica dust are necessary for a positive diagnosis of silicosis.

Silicosis manifests several forms depending on exposure conditions and individual susceptibility. Three forms of the disease have been described. They differ primarily in the length of exposure before the onset of the disease and the rate at which the disease then progresses.

The most common form of silicosis is chronic silicosis which has been recognized as an occupational disease since antiquity. It may take 15 or more years of exposure before a chest radiogram shows silicosis. Usually there is little or no respiratory impairment associated with the early stages of chronic simple silicosis. The radiographic changes in simple silicosis are primarily nodular. These are commonly 1.5 to 3.0 mm in diameter, located in the lung interstitium and scattered throughout the lung fields.

If the simple disease progresses, the silicotic nodules may coalesce and form a continuous mass of fibrotic tissue, called progressive massive fibrosis. On the chest radiograph, the result of this nodular coalescence is a greater than 1 cm lesion which may be surrounded by residual air spaces, and associated with loss of functional lung volume, and retraction of the hilum toward the apex with compensatory bullous spaces located at the lung bases. Physiologically, these changes correlate with restrictive lung disease due to the loss of functional lung tissue and obstructive lung disease due to distortion of airways and loss of normal airway support.

A less common form of silicosis is accelerated silicosis. The changes that have been described in chronic silicosis are also seen in accelerated silicosis, but the rate of progression is more rapid and the lesions usually become visible on chest x-ray after 4-8 years of exposure. The disease leads more frequently to massive fibrosis.

A rare form of silicosis is "acute" silicosis. It is related to exposure to high concentrations of respirable free silica in enclosed spaces with minimal protection. The disease develops rapidly and clinical features appear after an exposure of approximately 1-3 years. There is rapid loss of pulmonary function, invariably followed by death.

No effective medical treatment is available for silicosis. All forms of silicosis may progress, even after the worker is no longer exposed to silica dust.[13]

In this study the occurrence of silicosis in four workers with less than 5 years of exposure indicates accelerated silicosis. This form of silicosis has a worse prognosis than chronic silicosis since respiratory morbidity and mortality are more likely. Two of these four workers with accelerated silicosis also developed progressive massive fibrosis. One worker with chronic silicosis had progressive massive fibrosis after 10 years exposure to silica dust. The young ages of workers who developed progressive massive fibrosis (a 25 year old, a 41 year old, and a 58 year old) means a lifetime of respiratory impairment, as this disease is unresponsive to treatment. One case of accelerated silicosis with progressive massive fibrosis is described below.

This worker developed progressive massive fibrosis with only four years and ten months of dust exposure. He had moderate restriction of lung volumes by lung function testing, and symptoms of chronic bronchitis and breathlessness on minimal exertion. He denied any previous occupational respiratory exposures, and had smoked a pack of cigarettes daily for six years.

The prevalence both of respiratory symptoms and pulmonary function abnormalities were not significantly different in Pacer employees compared to the control group. However, some studies have shown that those with early radiographic changes of silicosis have an increased prevalence of bronchitis and a greater decrement in ventilatory capacity with increasing age as compared to control groups.[14]

The overall prevalence rate of pneumoconiosis in the Pacer employees studied was 12%. More than 60% of the current workers studied had less than five years of exposure to silica dust. In this group silicosis was noted on chest radiograph in 9%. The high prevalence of pneumoconiosis and the occurrence of complicated disease in workers with brief tenures suggests a highly respirable crystalline silica exposure.

VIII. CONCLUSION

1. The high prevalence of silicosis and the finding of accelerated silicosis are due to the respirable size of the particles, the high free silica content of the dust, and the excessive respirable dust concentrations.

2. NIOSH considers the situation found at Pacer Corporation to be hazardous. Continued exposure to workers at current dust levels poses a serious risk to the health of these workers.

IX. RECOMMENDATIONS

Worker exposure to free silica containing dust should be controlled to within NIOSH's recommended standard for respirable crystalline silica of 0.05 mg/m^3, averaged over a workshift of up to 10 hours a day, 40 hours a week. Employers and workers should take appropriate actions to reduce crystalline silica dust exposure to this limit. To accomplish this, the following is recommended:

1. Engineering controls should be instituted in order to reduce respirable quartz dust levels.

   a. Modify bagging operations at all plants to reduce operator exposure. A local exhaust ventilation hood should be added to the Mica bagging machine which would remove dust from the operator's breathing zone from the time of bag filling through being sewn closed. The local exhaust ventilation hood at the Brite-X bagging machine, should enclose the top of the filling bags. A great deal of dust was generated at the Brite-X bagging operation when filled bags fell onto a hard surface. Less dust would be produced if the drop distance was reduced and the impact surface made more resilient. A local exhaust ventilation hood should be istalled at the bagging operation of the Dakota Quartz plant. Broken bags containing product should be disposed of in containers or ventilated hoppers to avoid reintrainment of dust.

b. Engineering controls should be added to reduce dust emmissions from material transfer points during milling operations. Dust emissions were noted where material was added to or removed from milling machines.

c. Improve housekeeping and work practices to reduce reintrainment of settled dust. Vacumming or wet methods should replace dry sweeping operations.

d. Several references are available to assist in adopting engineering controls to reduce respirable dust exposure in the non-metal milling industry (15-21).

2. Periodic monitoring of workers' respirable quartz dust exposure should be instituted to insure that engineering controls are continually effective.

3. Until engineering controls are effective in reducing dust exposures a comprehensive personal respiratory protection program should be instituted to insure proper selection, training, use, and maintenance of respirators. Table 10 provides a list of respirator recommendations for exposure to varying amounts of crystalline silica dust. Respirator use should not be a substitute for engineering controls. Although respirator use in dusty areas is a company policy, actual usage was observed to be an individual choice of the worker.

4. Preplacement and periodic medical examinations should be made available to all workers who are exposed to high free silica containing dust. These examinations should include at least:

a. Comprehensive work and medical histories to evaluate exposure, signs and symptoms of respiratory disease;

b. a 14 x 17 inch posteroanterior chest radiogram interpreted using the 1980 ILO Classification by a NIOSH certified pneumoconiosis reader;

c. Pulmonary function tests including forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV_1), with calculation of the FEV_1/FVC ratio.

5. Enforcement of regulations is mandatory to assure compliance with the MSHA standard and protection of the worker's health.

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XI. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report are currently available upon request from NIOSH, Division of Technical Services, Publications Dissemination, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National Technical Information Service (NTIS), Springfield, Virginia 22161.

Copies of this report have been sent to:

1. Pacer Corporation
2. MSHA - Rocky Mountain District Office
3. OSHA - Region VIII
4. NIOSH - Region VIII
5. USWA - Local 7547

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Table 1

BULK SAMPLE QUALITATIVE SILICA ANALYSIS BY X-RAY DIFFRACTION

Sample Type	Location	Percent Quartz
	Brite-X and Mica Plant	
settled dust	dryer	interference
settled dust	hammermill	<10
settled dust	Brite-X bagger	interference
settled dust	Mica bagger	interference
	Feldspar Plant	
settled dust	mill	interference
settled dust	bagger	interference
	Dakota Quartz Plant	
settled dust	1st crusher	55-70
settled dust	2nd crusher	70-95
settled dust	bagger	80-95
settled dust	magnetics	< 95
settled dust	AC mill	< 95
	Super Quartz Plant	
bulk	plant input	80-100
bulk	plant output	80-100
	Metals Plant	
settled dust	dryer	interference

Table 2

SUMMARY OF SAMPLES OF RESPIRABLE DUST CONTAINING QUARTZ

	Plants		
	Brite-X and Mica	Feldspar	Dakota Quartz
Personal Respirable Dust Samples			
Number of Samples	26	23	17
Mean Dust Concentration (mg/m^3)	2.12 (0.63 - 8.24)[2]	0.93 (0.20 - 4.06)	0.30 (0.17 - 0.66)
Mean Quartz Content [1] (Percent by Weight)	8.5 (<1.0 - 13.8)	5.9 (3.4 - 7.9)	38.3 (21.7 - 57.1)
Percent of Samples> MSHA TLV	65	13	29
Percent of Samples> NIOSH Recommendation	69	22	71
Area Respirable Dust Samples			
Number of Samples	6	7	4
Mean Dust Concentration (mg/m^3)	2.11 (0.86 - 4.69)	0.92 (0.06 - 4.95)	0.54 (0.08 - 1.54)
Mean Quartz Content [1] (Percent by Weight)	6.6 (4.7 - 8.6)	4.8 (single value)	59.2 (33.3 - 100)

1 Mean values were calculated by deleting data where the amount of quartz on a filter was less than needed for analytical quantitation or where the quartz represented less than 1% of the dust on the filter.

2 Range of data is shown in parentheses.

Table 3

BULK SAMPLE TRACE METAL ANALYSIS BY INDUCTIVELY COUPLED PLASMA - ATOMIC EMISSION SPECTROSCOPY

Percent Metal by Weight	Metal
Brite-X and Mica Plant	
Input from Mine	
< 0.003	Ag, As, Be, Cd, Co, Pt, Se, Sn, Te, Y
0.003 - 0.05	Cr, Cu, Li, Mo, Ni, Pb, Tl, V, Zn, Zr
0.05 - 0.10	Ca, P, Ta
0.10 - 0.50	Al, Mg, Mn, Ti
0.50 - 1.0	Na
> 1.0	Fe
Brite-X Plant Output	
< 0.003	Ag, As, Be, Cd, Co, Pt, Se, Sn, Te, Y
0.003 - 0.05	Cr, Cu, Li, Mo, Ni, P, Pb, Tl, V, Zn, Zr
0.05 - 0.10	Ca, Ta
0.10 - 0.50	Al, Mg, Mn, Ti
0.50 - 1.0	Na
> 1.0	Fe
Mica Chip Input	
< 0.003	Ag, Be, Cd, Co, Cr, Cu, Ni, Pb, Pt, Se, Te, V, Y, Zr
0.003 - 0.050	As, Cd, Mn, Mo, P, Sn, Tl, Zn, Ta
0.05 - 0.10	Mg, Ti
0.10 - 0.50	Li
0.50 - 1.0	Na
> 1.0	Al, Fe
Crushed Mica Chip Input	
< 0.003	Ag, As, Be, Cd, Co, Cr, Cu, Pb, Pt, Se, Te, Tl, V, Y, Zr
0.003 - 0.050	Mg, Mn, Mo, P, Zn
0.05 - 0.10	Li, Sn, Ti
0.5 - 1.0	Na
> 1.0	Al, Fe

Table 3 (con't)

BULK SAMPLE TRACE METAL ANALYSIS BY INDUSTIVELY COUPLED PLASMA - ATOMIC EMISSION SPECTROSCOPY

Percent Metal by Weight	Metal
	Mica Plant Output
< 0.003	Ag, As, Be, Cd, Co, Pt, Se, Sn, Te, Y
0.003 - 0.050	Cr, Cu, Li, Mo, Ni, P, Pb, Tl, V, Zn, Zr
0.05 - 0.10	Ca, Ta
0.10 - 0.50	Mg, Mn, Na, Ti
0.50 - 1.0	Fe
> 1.0	Al
	Feldspar Plant
	Plant Output
< 0.003	Ag, As, Be, Cd, Co, Cr, Cu, Ni, Pb, Pt, Se, Sn, Te, Ti, Tl, V, Zn, Zr, Y, Ta
0.003 - 0.050	Li, Mg, Mn, Mo, Ca
0.10 - 0.50	Fe, P
> 1.0	Al, Na
	Dakota Quartz Plant
	Plant Output
< 0.003	Ag, As, Be, Cd, Co, Cr, Cu, Mg, Mo, Ni, Pb, Pt, Se, Sn, Te, Ti, Tl, V, Y, Zn, Zr, Ta
0.003 - 0.050	Ca, Li, Mn, P
0.05 - 0.10	Fe
> 0.10 - 0.50	Al, Na
	Plant Input (after 2nd crusher)
< 0.003	Ag, As, Be, Cd, Co, Cr, Cu, Li, Fe, Mg, Mn, Mo, Ni, P, Pb, Pt, Se, Sn, Te, Ti, Tl, V, Y, Zn, Zr, Ta
0.003 - 0.050	Ca
0.10 - 0.50	Al, Na

Table 3 (con't)

BULK SAMPLE TRACE METAL ANALYSIS BY INDUCTIVELY COUPLED PLASMA - ATOMIC EMISSION SPECTROSCOPY

Percent Metal by Weight	Metal
Super Quartz Plant	
Plant Input and Output	
< 0.003	Ag, As, Be, Ca, Cd, Co, Cr, Cu, Mg, Mn, Mo Ni, P, Pb, Pt, Se, Sn, Te, Ti, Tl, V, Y, Zn, Zr, Ta
0.003 - 0.050	Li, Na, Fe
0.05 - 0.10	Al
Metals Plant	
Plant Input	
< 0.003	Ag, Cd, Co, Cr, Cu, Ni, Pt, Se, Te, Tl, V, Y, Zn
0.003 - 0.050	As, Be, Mg, Mn, Mo, Sn, Ti, Ta, Zr
0.05 - 0.10	Ca, P, Pb
0.10 - 0.50	Fe, Li, Na
> 1.0	Al
Settled Dust Above Dryer	
< 0.003	Ag, Cd, Co, Pt, Se, Te, V, Y
0.003 - 0.050	Be, Li, Mo, Ni, Sn, Tl, Zr
0.05 - 0.10	As, Cr, Cu
0.10 - 0.50	Mg, Mn, P, Pb, Ti, Zn, Ta
0.50 - 1.0	Ca
> 1.0	Al, Fe, Na

Table 4

BULK SAMPLE MINERAL AND FIBER ANALYSIS BY TRANSMISSION ELECTRON MICROSCOPY AND POLARIZED LIGHT MICROSCOPY

Sample Description	Constituents Major (>20%)	 Minor (5–20%)	 Trace (< 5%)
	Brite-X and Mica Plant		
Input from Mine	Muscovite	Quartz(SiO_2) Feldspars(Sodic Plagioclase) Biotite	Iron Oxides Ilmenite Mn-Fe Oxides
Brite-X Plant Output	Muscovite Biotite	Quartz Feldspars(Sodic Plagioclase)	Iron Oxides
Mica Chip Input	Muscovite Feldspar(Sodic Plagioclase)	Quartz	Apatite
Crushed Mica Chip Input	Muscovite	Feldspar	Iron Oxides
Mica Plant Output	Muscovite Biotite	Quartz Al, Silicates	Feldspar Mn & Fe Oxides
	Feldspar Plant		
Plant Output	Microcline/ Orthoclase	Al, Silicates	Quartz Plagioclase Feldspar
	Dakota Quartz Plant		
Plant Output	Quartz	Muscovite	Feldspars (Undifferentiated) Iron Oxides
Plant Input (after 2nd crusher)	Quartz	Muscovite	Biotite Wollastonite Vesuvianite Feldspars (undif.)

Table 4 (con't)

BULK SAMPLE MINERAL AND FIBER ANALYSIS BY TRANSMISSION ELECTRON MICROSCOPY AND POLARIZED LIGHT MICROSCOPY

Sample Description	Constituents Major (<20%)	Minor (5–20%)	Trace (>5%)
Super Quartz Plant			
Plant Input	Quartz(SiO_2)	--	Iron Oxides Micas Feldspars
Plant Output	Quartz(SiO_2) (Some contained fibrous inclusions)	--	Micas Iron Oxides Clays/ Feldspars
Metals Plant			
Plant Input	Muscovite Feldspar(Sodic Plagioclase)	Quartz Al, Fe Silicate	Apatite

Table 5

SUMMARY OF WORKFORCE STUDIED

Current production workers	50
Current workers studied	50
Percent participation	100%
Former production workers available for participation	63
Former workers studied	28
Percent participation	45%

DEMOGRAPHIC CHARACTERISTICS OF PARTICIPANTS

	Number	Mean Age (year)	Mean Years Exposed to Silica Dust	Smokers (%)	Ex-Smokers (%)	Never Smokers (%)	Mean Pack/yr for Smokers
Control Plant Workers	46	29	0.00	13 (28%)	24 (52%)	9 (20%)	10.8
Pacer							
Current Workers	50	32	6.2	24 (48%)	15 (30%)	11 (22%)	22.7
Former Workers	27	39	5.4	14 (52%)	9 (33%)	4 (15%)	23.0
All Pacer Current and Former Workers	77	35	5.9	38 (49%)	24 (31%)	15 (20%)	22.8

Table 6

PREVALENCE OF PNEUMOCONIOSIS* BY TENURE

	Number	Simple	PMF**	Total
Current Workers (<1 year exposure)	3	0	0	0
Current Workers (>1 <5 years exposure)	31	1	2	3
Current Workers (>5 years exposure)	16	1	1	2
TOTAL	50	2	3	5
Ex-Workers (<1 year exposure)	7	0	0	0
Ex-Workers (>1 <5 years exposure)	14	1	0	1
Ex-Workers (>5 years exposure)	6	3	0	3
TOTAL	27***	4	0	4

PREVALENCE OF PNEUMOCONIOSIS BY DIVISION

Division	Number	Simple	PMF*	Total
Feldspar	29	2	0	2
Dakota Quartz	18	1	2	3
Brite-X	18	0	0	0
Mixed (more than one division)	12	3	1	4
TOTAL	77	6	3	9

* Pneumoconioses is considered present if two of the three "B" readers described the x-ray as category 1/0 or greater using the ILO U/C 1971 classification.

** Progressive Massive Fibrosis

*** One former female worker is excluded from the analysis.

Table 7

% PREDICTED LUNG FUNCTION BY EXPOSURE GROUP AND SMOKING CATEGORY

	PACER WORKERS			CONTROL GROUP		
	Smokers	Ex-Smokers	Never Smokers	Smokers	Ex-Smokers	Never Smokers
Subjects Nos.	38	23*	15	13	8*	24
Mean Silica Tenure (Yrs)	5.0 (4.65)	6.89 (7.6)	3.2 (2.1)	-- --	-- --	-- --
Mean Pack Years	21.3 (20.9)	23.0 (28.6)	-- --	11.7 (10.0)	10.4 (6.7)	-- --
Lung Function % Predicted** FVC	107 (12)	111 (19)	110 (14)	109 (11)	117 (13)	109 (14)
% Predicted** FEV_1	100 (16)	105 (22)	108 (17)	103 (11)	111 (13)	107 (14)

* One participant from each group is excluded in analysis due to technically unsatisfactory pulmonary function tests.

Numbers in parentheses indicate standard deviation.

FVC = Forced vital capacity

FEV_1 = Forced expiratory volume in one second

** Knudson et al [9]

Table 8

LUNG FUNCTION AND RELATED DATA IN PACER EMPLOYEES WITH SILICOSIS

Patient No.	Age (yr)	Tenure (yr)	Job Title	Pack/yr	FVC* (% pred)	FEV_1* (% pred)	FEV_1/FVC%
1**	41	5	Driller	28 (ex-smoker)	88	70	64
2**	25	4.8	Mill Oper.	6	54	51	78
3**	58	10.0	Sorter	55 (ex-smoker)	92	83	72
4	46	16.9	Driller	32	103	88	68
5	49	3.2	Mill Oper.	32 (ex-smoker)	91	85	74
6	70	37.6	Foreman	78 (ex-smoker)	Technically	Unsatisfactory	
7	67	19.5	Mill Helper	46 (ex-smoker)	125	109	68
8	42	10.1	Bagger & Loader	24	102	86	68
9	25	3.6	Mill Oper.	12.25 (ex-smoker)	121	107	72

*See reference 9

** Progressive Massive Fibrosis

Obstructed: FEV_1/FVC 70%

Restricted: FVC 80% predicted

Table 9

PREVALENCE OF SYMPTOMS BY SMOKING STATUS

	Never-Smokers		Ex-Smokers		Smokers		Total	
	Pacer	Control	Pacer	Control	Pacer	Control	Pacer	Control
Subjects No.	15	24	25	9	37	13	77	46
Mean Age	26	26	41	34	34	32	35	29
Mean Pack Years	--	--	23	10.4	21.3	11.7	22.8	10.8
Mean Tenure	3.2	--	6.9	--	4.9	--	5.9	--
Chronic cough	3	0	5	0	14	5	22	5
Chronic phlegm	3	0	6	0	14	6	23	6
Chronic bronchitis*	0	0	5	0	6	1	11	1
Breathlessness	0	0	3	0	2	1	5	1

*Chronic Bronchitis - productive cough on most days for three months or more per year for two consecutive years.

TABLE 10

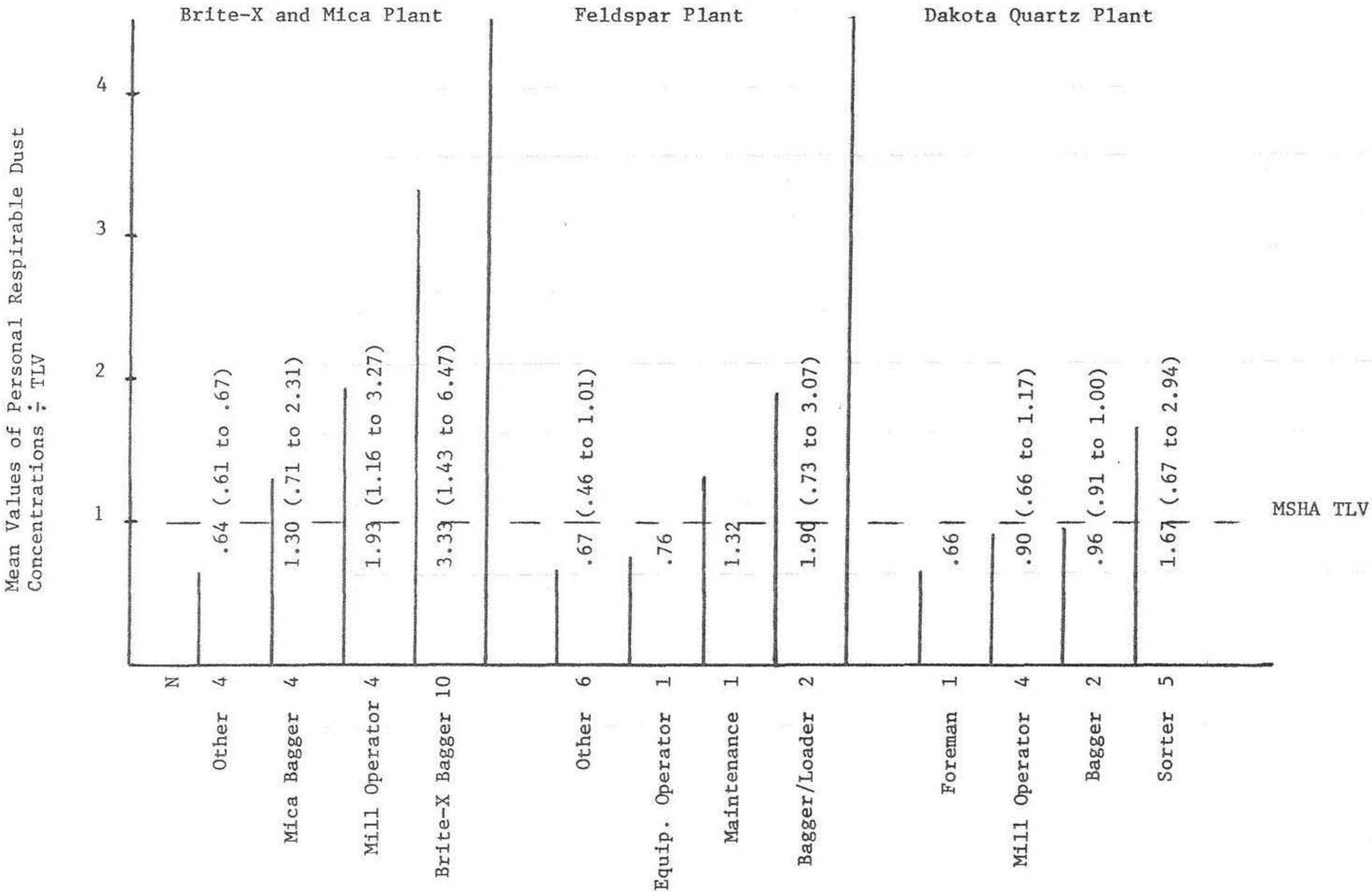
RESPIRATORY PROTECTION FOR CRYSTALLINE SILICA

Condition	Minimum Respiratory Protection* Required Above X** mg/m³
Particulate Concentration	
5X** mg/m³ or less	Any dust respirator.
10X** mg/m³ or less	Any dust respirator, except single-use or quarter-mask respirator. Any fume respirator or high efficiency particulate filter respirator. Any supplied-air respirator. Any self-contained breathing apparatus.
50X** mg/m³ or less	A high efficiency particulate filter respirator with a full facepiece. Any supplied-air respirator with a full facepiece, helmet, or hood. Any self-contained breathing apparatus with a full facepiece.
500X** mg/m³ or less	A powered air-purifying respirator with a high efficiency particulate filter. A Type C supplied-air respirator operated in pressure-demand or other positive pressure or continuous-flow mode.
Greater than 500X** mg/m³ or entry and escape from unknown concentrations	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode. A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous-flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive pressure mode.
Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode.

*Only NIOSH-approved or MSHA-approved equipment should be used.

**X indicates the permissible exposure as defined above.

FIGURE 1
MEAN VALUES OF PERSONAL RESPIRABLE DUST CONCENTRATIONS ÷ TLV BY JOB CATEGORY



Note: Range of data associated with mean concentration is contained in parentheses. N is the number of samples. Data has been deleted where the amount of quartz on a filter was less than that needed for analytical quantitation.

FIGURE 2

ANDERSON SAMPLER DATA FROM BRITE-X AND MICA PLANT

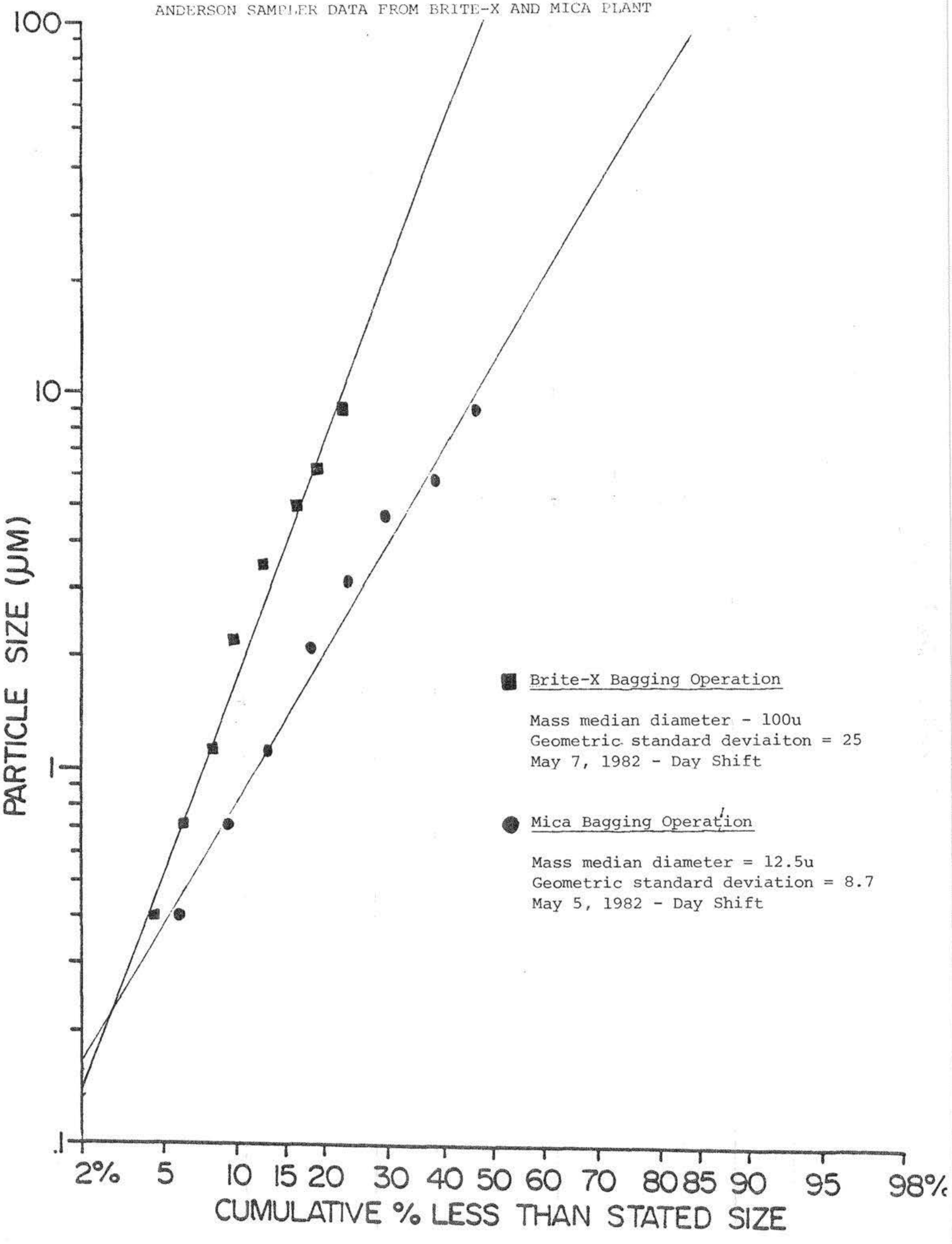
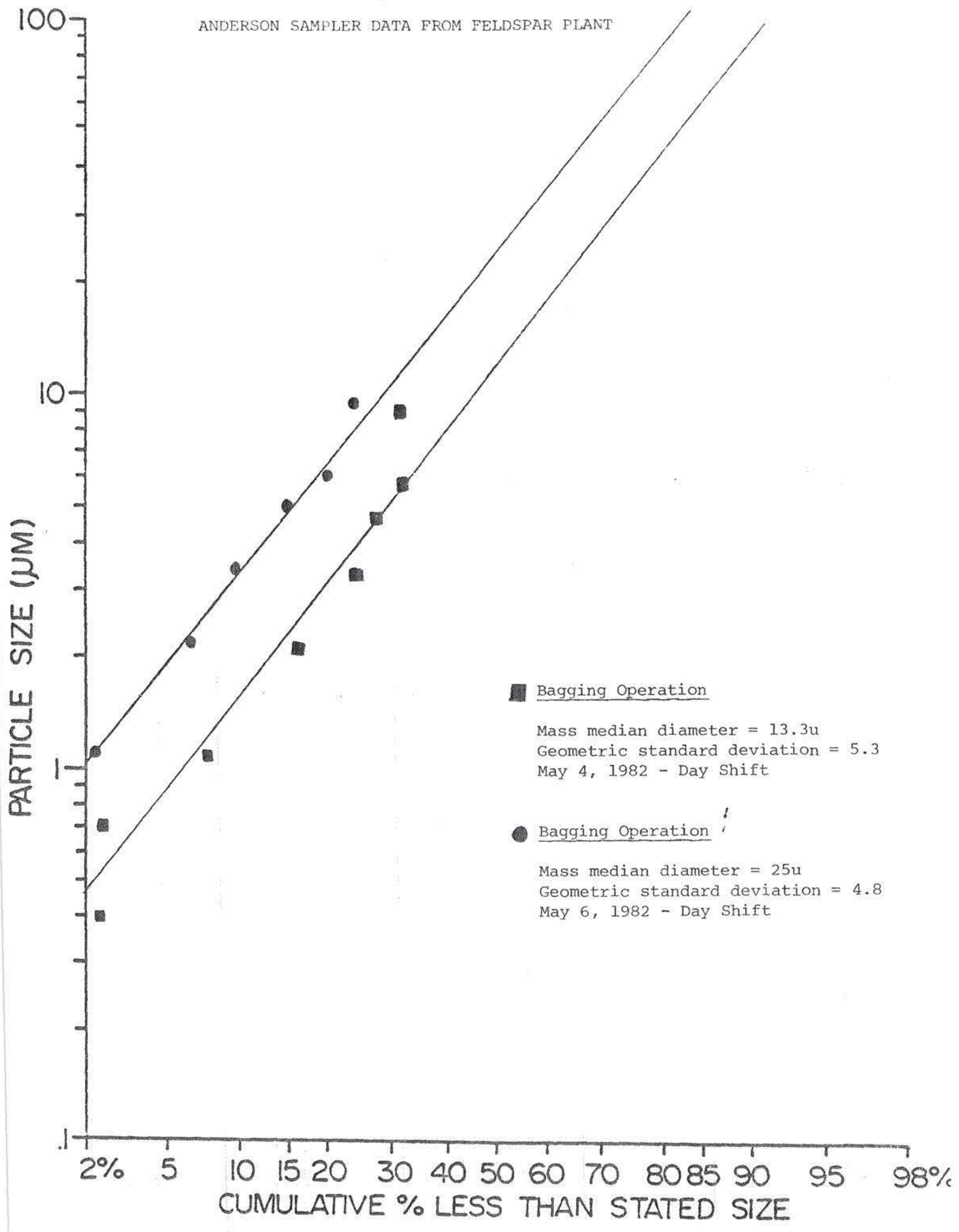


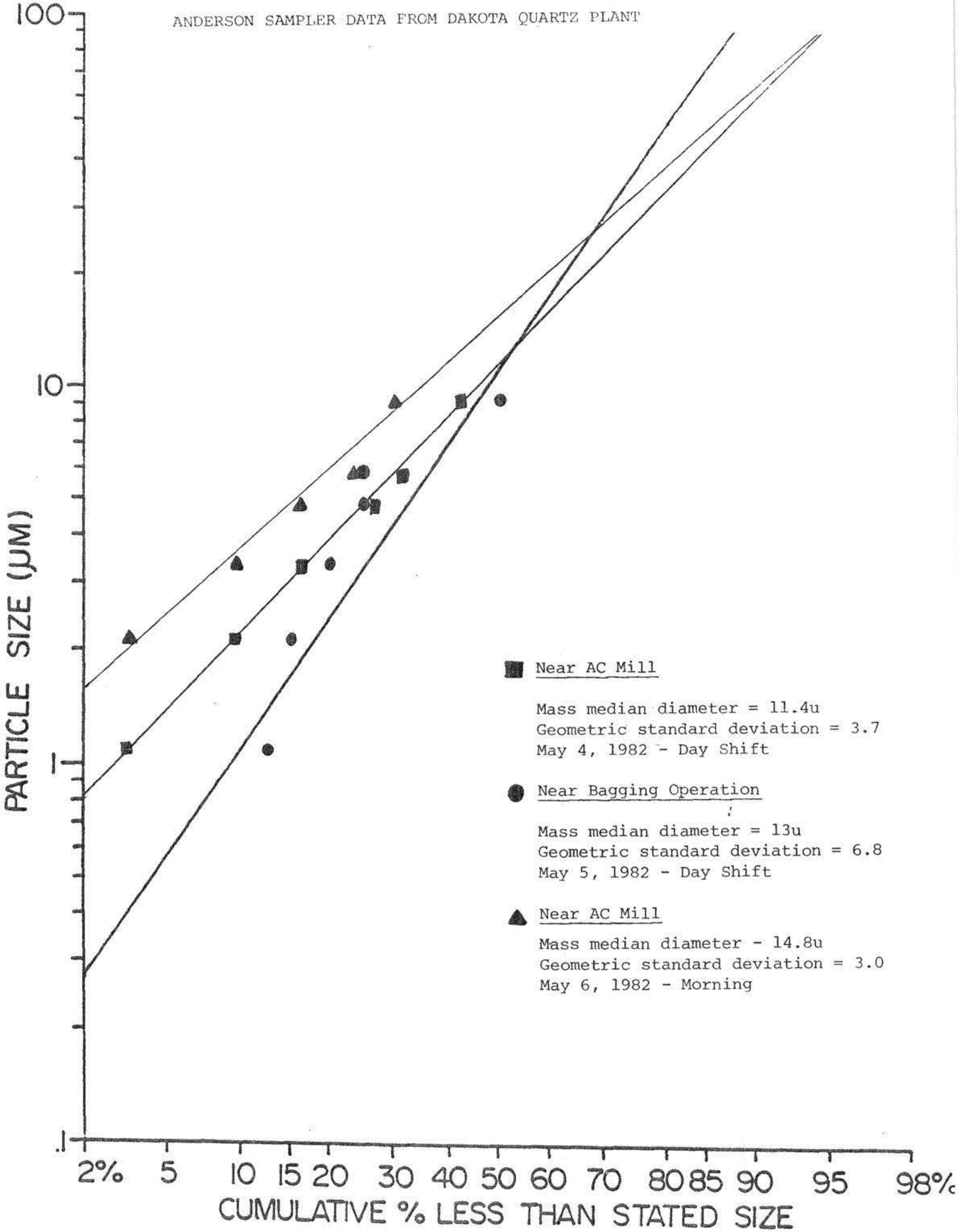
FIGURE 3



ANDERSON SAMPLER DATA FROM FELDSPAR PLANT
100
10
1
.1
PARTICLE SIZE (μM)
2%
5
10
15
20
30
40
50
60
70
80
85
90
95
98%
CUMULATIVE % LESS THAN STATED SIZE
Bagging Operation
Mass median diameter = 13.3u
Geometric standard deviation = 5.3
May 4, 1982 - Day Shift
Bagging Operation
Mass median diameter = 25u
Geometric standard deviation = 4.8
May 6, 1982 - Day Shift

FIGURE 4

ANDERSON SAMPLER DATA FROM DAKOTA QUARTZ PLANT



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