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NIOSH INVESTIGATORS:
Ron Cornwell, I.H.
W. Hanke, M.D.

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 evaluate the respiratory status of highwall drill operators and drill helpers employed at five surface coal mines. This request was precipitated by the fact that one-half of the surface work positions on a reduced dust standard involved highwall drill operations, plus a previous NIOSH report had suggested an increased risk of pneumoconiosis for drill crew members.

NIOSH responded to the request by conducting a respiratory health and environmental survey at the designated mines to assess the prevalence of silicosis in drill crew members and to determine if a more complete epidemiological study was indicated.

Health screening consisted of a chest radiograph, spirometry and a medical questionnaire detailing occupational history. Of the 185 drillers and 166 nondrillers selected for examination, 148 drillers and 108 nondrillers participated in the study. After review of work histories, a substantial portion (41% for drillers, 21% for nondrillers) were excluded from the analysis due to past exposures in underground mining, welding, etc. A total of 88 drillers and 85 nondrillers were included in the analysis of medical data. Analysis of pulmonary function data using multiple regression techniques indicated no significant differences in values of FEV₁ or peak-flow between the groups of drillers and nondrillers. The difference for FVC was borderline significant ($p = 0.058$). Chest radiography indicated six cases of simple pneumoconiosis. Two cases were found in the total analyzed group of workers. One was a former driller helper (1 year tenure) currently employed as an electrician. The other was a mechanic (24 years tenure) with no other work experience. The four additional cases were found in the group excluded from analysis due to past exposures. Three of these had several years (14-19) of underground experience.

Environmental measurements obtained at the selected mines indicated a geometric mean exposure for respirable dust of 0.49 mg/m^3 . Sixty-eight percent of the personal respirable samples had quartz concentrations greater than 5 percent. The overall geometric mean percentage of quartz by weight was 12.9%. Worker exposure to respirable dust containing quartz exceeded the MSHA Threshold Limit Value (TLV) in 36.5% of the measurements. The NIOSH recommended standard (0.05 mg/m^3) for exposure to respirable free silica was exceeded in 68% of all measurements taken. The environmental measurements indicated that the engineering controls employed on the drilling equipment at one mine reduced the dust concentrations by 70% at the operator's station, and that a large percentage (40-45%) of the dust measured at the operator's station in all three mines is in the respirable range (10 microns and less).

No significant excess respiratory disease was found in this survey of currently employed surface coal mine highwall drill crews. However, in light of previous studies, the environmental data collected, and the NIOSH recommended standard for exposure to respirable free silica, it is likely that such risk is present in some situations. Therefore, NIOSH recommends further epidemiological study to effectively evaluate the respiratory status of current and former highwall drill crews throughout the industry.

KEY WORDS: Standard Industrial Classification (SIC): 1111,
Drilling, Silica, Quartz.

INTRODUCTION

In March 1982, the Division of Respiratory Disease Studies, National Institute for Occupational Safety and Health (NIOSH) received a request from the Mine Safety and Health Administration (MSHA) to provide technical assistance in evaluating the respiratory status of highwall drill operators and drill helpers employed at surface coal mines. MSHA had submitted the request because, after their review of work positions which were on a reduced dust standard due to dust quartz content in excess of 5 percent, it was discovered that approximately one-half of the surface reduced dust standards involved highwall drill crew members (drill operators and helpers). The request was also prompted by a previous NIOSH report of surface coal mine operations which suggested an increased risk for pneumoconiosis in drill crew members compared to other workers at surface coal mines. (1,2)

NIOSH responded to the MSHA request by conducting a respiratory health and environmental survey at three MSHA designated surface mines to assess the prevalence of silicosis in drill crew members and to determine if a more complete industry-wide study was indicated.

BACKGROUND

The amount of coal produced by strip mining has steadily increased over the last 30-40 years (128,799,116 tons in 1951 to 484,305,551 in 1981). In 1981 strip coal mining produced more than half of all coal mined in the United States. (3)

The basic objective in strip mining is to remove the surface material, or overburden, from the coal seam so that the coal can be removed for marketing. Usually the first step in the mining process is to remove topsoil which is later used in the reclamation process. Once the topsoil has been removed, overburden materials (generally sandstones, shales, limestones, and unconsolidated soils) can be removed. (4). The preparation required to remove this

The study population included 185 active miners who were current or former highwall drillers and/or driller helpers at mines A, B, and C. (Table 1). These individuals were identified using company personnel rosters, seniority lists, and overtime rosters. Personnel records were reviewed to determine tenure as a driller and/or driller helper and to determine previous work experience. In the same manner, a comparison group of 166 active mechanics, electricians, and oilers was selected. Excluded from the comparison group were workers with a history of working one year or more in underground mines, with asbestos, as welders, as dozer operators, as tippie operators, and/or in drilling operations. Individuals selected for the survey were contacted by letter from NIOSH which encouraged them to participate in the study. At two of the mines, examinations were done on company time.

B. Environmental

The environmental evaluation consisted of collecting: (1) personal respirable dust samples on the drill operators and drill helpers; (2) area respirable dust samples inside and outside the drill cabs; (3) dust samples for particle sizing; and (4) bulk samples for mineral identification and determination of free crystalline silica content.

Respirable dust samples were collected using DuPont Constant Flow Samplers with a nylon cyclone pre-separator at a flow rate of 2 liters per minute (LPM). NIOSH respirable dust measurements were multiplied by a factor of 1.38 to convert the concentration of respirable dust as measured to an equivalent concentration of respirable dust as measured with an MRE (Mining Research Establishment) instrument as is practiced by MSHA.⁽⁵⁾ Tared filters were analyzed per NIOSH Physical and Chemical Analytic Methods 259 to obtain total weight and percent free silica.

Airborne particle size distribution was determined using a DuPont Constant Flow Sampler at a flow rate of 2 LPM with a Sierra Instruments Series 290 Marple Personal Cascade Impactor. Qualitative mineral analysis of the bulk samples was accomplished by both polarized light and analytical transmission electron microscopy. X-Ray diffraction analysis was used to determine the percent free silica in the bulk samples.

C. Medical

A standardized respiratory questionnaire, based upon the British Medical Research Council Questionnaire, was administered by NIOSH personnel to each participant. Questionnaires included job history and smoking history. The prevalence of respiratory

symptoms was investigated only in the Ohio mine. Since, in the two western mines, the crew consisted almost entirely of American Indians who might have problems with understanding English terminology, the respiratory symptoms part of the questionnaire was omitted.

Spirometric tests were conducted according to standard American Thoracic Society techniques.⁽⁶⁾ The test consisted of at least three acceptable maximal expiratory maneuvers into an Ohio 840 waterless spirometer, each generating a flow-volume curve which was electronically recorded. The spirometry data was corrected for body temperature and pressure saturated with water vapor (BTPS) and was stored on tape. At the NIOSH laboratory the tapes were edited; and for each individual the largest forced vital capacity (FVC), the largest forced expiratory volume in the first second (FEV₁), and the largest peak flow rate from acceptable curves were used in the analysis. Analysis of pulmonary function data employed a linear model fit of age, height, race, smoking status, and exposure expressed as total years of drilling. Values of pulmonary indices for the comparison group and the drillers group were compared after allowing for the effects of the other variables mentioned above.

Standard 14 x 17 posteroanterior chest roentgenograms were taken by a registered radiology technician using standard pneumoconiosis techniques.⁽⁷⁾ Chest roentgenograms were independently interpreted by three certified pneumoconiosis readers employing the 1980 ILO classification.⁽⁸⁾ Roentgenograms were read without knowledge of occupational exposures.

V. EVALUATION CRITERIA

A. Environmental

Occupational health exposure limits for individual toxic substances are generally established at levels most workers can be repeatedly exposed during an 8 to 10 hour workday, 40 hour workweek for a working lifetime without significant adverse effects. NIOSH maintains that the worker should be protected by the standard or recommended levels that afford him the greatest degree of protection.

The current MSHA standard for permissible concentrations of respirable dust at surface coal mines requires that the average concentration of respirable dust which each miner is exposed be continuously maintained at or below 2.0 milligrams of respirable dust per cubic meter of air (2.0 mg/m³). However, the standard is adjusted downward for mines where the respirable dust in the atmosphere contains more than 5 percent quartz. Under these conditions, the operator is required to maintain respirable dust

below a concentration computed by dividing the percentage of quartz into the number 10. As the quartz content of respirable dust in the mine increases over 5 percent, the respirable dust standard is correspondingly reduced.⁽⁵⁾

NIOSH recommends that exposure to free silica (SiO_2) be controlled so that no worker is exposed to a time-weighted average (TWA) concentration greater than 0.05 mg/m^3 .⁽⁹⁾

B. Medical

Excess prevalence of respiratory symptoms among drill crew workers was determined when they had statistically significant higher prevalence rates than the comparison group. Spirometry values (FVC, FEV_1 , peak flow) of drillers were considered lower than the comparison group's if such significant differences remained after adjusting for age, height, race and smoking status. Roentgenograms were considered positive for pneumoconiosis if at least two of three readers classified small opacity profusion as category 1/0 or greater.

VI. RESULTS

A. Medical

1. Demographic Characteristics

Of 185 drillers and 166 comparison workers selected for examination, 148 drillers and 108 comparisons participated in the survey (Table 1). Participation rates were 80% and 65% respectively. Of the examined group, a substantial proportion (41% for drillers, 21% for controls) were excluded from the analysis due to other past exposures. A total of 88 drillers and 85 controls were included in the analysis of medical data. No significant differences were seen in the average age of workers in the three mines (Table 2). Average tenure as a driller was 3.8 years. Only 19 drillers (22%) had more than five years tenure as a driller (Table 3). More than half of them were from Mine C.

2. Respiratory Symptoms

In the mine where respiratory symptoms were investigated, no statistically significant differences were observed between the group of drillers and controls in the prevalence of symptoms (Table 4). However, prevalences of chronic cough, phlegm, and breathlessness were all greater in the group of drillers, even though this group had a higher proportion of nonsmokers.

3. Pulmonary Functions

Analysis of pulmonary function results of 85 drillers and 80 control workers using multiple regression techniques are summarized in Table 5. After allowing for effects of age, height, race and smoking, no significant differences were observed in values of FEV₁ or peak-flow between the groups of drillers and control. The difference for FVC was borderline significant (p = 0.058). A similar analysis was performed on the group of drillers using the additional variable - "years of drilling experience". No dose response relationship was observed between the years of exposure and spirometry values (Table 6).

4. Chest Radiography

Two cases of simple pneumoconiosis were found in the total analyzed group of workers. One case (profusion category 2) was a former driller helper (1 yr tenure) currently employed as an electrician. The other one (profusion category 1) was a mechanic (24 yrs tenure) with no other work experience.

Four additional cases of simple pneumoconiosis (one profusion category 2, three profusion category 1) were found in the group excluded from analysis. Three of these had extensive underground mine experience (14-19 yrs), of whom, two were currently members of a drilling crew.

B. Environmental

Listed below are descriptions of the drilling equipment and dust controls employed by each of the facilities at the time of the survey.

Mine A. The Bucyrus Erie 60R and 50R were the two main types of drills being used. The 60Rs have air conditioned, (cooling and heating) enclosed cabs and a local dust collection system which collects the dust at the drill hole and conveys it to a dust collector which discharges the dust onto the ground away from the operator. The 50R drills did not have air conditioned cabs; therefore, doors and windows were kept open. Also, the local dust collection system on the 50R discharges into the air above the cab.

Mine B. The Bucyrus Erie 50R, 60R, 61R, and Ingersoll Rand D-9 were the types of drills used at Mine B. Use of local dust collection systems which collect the dust at the drill hole and conveys it to a dust collector for discharge onto the ground or into the air above the cab were the primary methods for dust control. The cabs had air conditioners which were used only during the hot months. During the survey the air conditioners were not being used. The cab doors and windows were kept closed during drilling operations due to the cold weather.

Mine C. The Bucyrus Erie 45R, M-4, and Gardner Denver 100 were used at Mine C. Operator exposure to the dust was controlled by air conditioning systems which maintained a positive pressure within the cabs.

Samples for which time weighted averages (TWAs) were computed were collected over the length of a normal work period. In instances where this was less than eight hours, a zero value was assigned to the unsampled portion of the work shift in computing the TWAs provided there was no exposure during this unsampled period.

The results of the overburden drill dust silica analyses are contained in Table 7. No cristobalite or tridymite was found in any of the samples. Quartz was the only form of crystalline silica identified in the bulk samples. Table 8 provides results of qualitative mineral analysis of the overburden materials.

Table 9 summarizes the results of personal respirable dust samples collected for the drillers and driller helpers. A total of 74 personal samples were obtained and analyzed both gravimetrically and for free silica content by x-ray diffraction analysis. The lower limit of quantitation for both quartz and cristobalite was 0.03 milligrams. The geometric mean exposure for respirable dust at Mine A was 0.62 mg/m^3 , Mine B 0.33 mg/m^3 and Mine C 0.59 mg/m^3 . The overall geometric mean exposure for all three mines was 0.49 mg/m^3 . Sixty-eight percent of the personal samples had quartz concentrations greater than 5 percent. The geometric mean percentage of quartz by weight on the personal samples was 9.7% at Mine A, 15.8% at Mine B, and 14.9% at Mine C. The geometric mean quartz content for all three mines was 12.9%. These means were calculated by deleting data where the amount of quartz on a filter was less than that needed for analytical quantitation. The limit of quantitation was 0.03 mg per filter. Worker exposure to respirable dust containing quartz exceeded the MSHA adjusted coal mine dust standard in 32% of the measurements at Mine A, in 25% of measurements at Mine B, and in 82% of the measurements at Mine C. When all three mines are considered together, the MSHA standard was exceeded in 36.5% of the measurements. The NIOSH recommendation for respirable free silica was exceeded in 68% of all measurements taken.

Since Mine A uses both open cab drills which have dust collectors that discharge the dust into the air above the cabs and enclosed air conditioned cabs which have dust collection systems that discharge the dust onto the ground away from the cab, a comparison was made of driller exposure. It was found that the operators in the open cabs had less exposure ($\bar{X}_g 0.53 \text{ mg/m}^3$) than the operators of the enclosed cabs ($\bar{X}_g 0.98 \text{ mg/m}^3$). One explanation for this could be that air conditioners without adequate filtration were contributing to the dust build-up by supplying dust laden air into the cabs.

At Mine C a TSI Piezobalance Model 3500 was used to obtain respirable particle measurements inside the cab of the Bucyrus Erie M-4. The measurements were taken while drilling and the air conditioning system turned off and with the air conditioning system turned on. The sampling revealed a 61% reduction (\bar{X} 0.99 mg/m³ with AC off, \bar{X} 0.39 mg/m³ with AC on) in respirable dust concentrations with the air conditioning system turned on. It was observed that the M4 drill was relatively new and the filter used on the air conditioning system was 99.9% efficient using AC fine test dust according to the Society of Automotive Engineers (SAE) J726C code.

Table 10 provides a comparison of the personal respirable dust exposure for the drillers and helpers collected by MSHA in the three mines during the period 1972-1979 with the NIOSH exposure data collected in September 1982 and April 1983. Applying a test for differences between means (two-tailed test, α .05), it was concluded that the geometric mean exposure presented in the MSHA data does not differ from the geometric mean exposure presented by the NIOSH sampling for mines A and C. The geometric means for Mine B did differ.

In addition to the personal respirable dust samples obtained at all three mines, area respirable dust samples were obtained for comparison inside and outside of the drill cabs at Mines B and C. The samples on the outside of the cab were positioned near the air intakes for the cabs at Mine C and on top of the cabs at Mine B and those on the inside were positioned approximately 2 to 3 feet to the rear of the operator and suspended from the ceiling or side of the cab. The sampling revealed that at Mine C, where the method of reducing drill operator exposure to dust was the use of positive pressure within the cabs, the cabs afforded a 70% reduction in concentration of respirable dust (\bar{X} of 2.5 mg/m³ for outside and 0.75 mg/m³ for inside). However, at Mine B, where the method of reducing drill operator exposure was the use of local exhaust, minimal concentrations were measured (\bar{X} of 0.10 mg/m³ for outside and 0.15 mg/m³ for inside) and there was no reduction in the mean respirable dust concentrations inside the cab as compared to the outside.

Personal sampling for particle size distribution was performed on the drillers and helpers at Mine A, and area sampling was performed inside and outside of the drill cabs at Mines B and C. Aerodynamic particle size distribution data is contained in Figures 1,2,3. Approximately 40 percent of particles are shown to be of respirable size (10 microns and less) at Mine A. At Mines B and C a comparison was conducted of the size particles collected inside the cabs with those collected outside the cabs (Figures 2,3). The results indicated that 45-50% of the particles collected inside the cabs were 10 microns and less as compared to 25-30% for those collected outside the cabs.

VII. DISCUSSION

The literature about the health of surface coal mine overburden drillers is limited to only one paper. Banks et al. reported three cases of pneumoconiosis in drillers at a small surface mine in West Virginia.^(1,2) Two of these cases were diagnosed in clinical situations. The third case was found during the examination of eight currently employed and retired drillers from this mine. No pneumoconiosis was found among 60 workers who had never worked as drillers. Banks et al also reviewed the data of drillers employed in eight mines examined by NIOSH in 1972-73 and reported by Fairman, et al.⁽¹⁰⁾ The prevalence of pneumoconiosis was approximately five times greater in the drilling group compared to other surface workers (6% vs 1%). Seven of eight cases among drillers were found in the group with 10 or more years of tenure. Unpublished subsequent analysis by NIOSH⁽¹¹⁾ showed that only one driller had Category 2 pneumoconiosis and was employed in an anthracite mine. All bituminous drillers with pneumoconiosis had Category 1.

Our current negative result contrasts with these previous findings. Several factors might be of importance:

1. Duration or intensity of exposure. The average tenure in the current survey was only 3.8 years. It is well known that, without extremely high exposures, silicosis rarely develops with such relatively short exposures.⁽¹²⁾ All three mines in the current study had slightly more than 5% of free silica in the samples taken by MSHA, which is the only source of our information about past exposure conditions. This study can in no way speculate that the environmental samples were representative of the years of exposure preceding the sampling. However, the study indicated a geometric mean quartz content of 12.9% (range 0-25.6%) and a geometric mean respirable dust exposure of 0.49 mg/m³ (range 0.03 - 4.13 mg/m³). According to the NIOSH recommended standard, a respirable dust concentration of 1 mg or more in which the percent of free silica is greater than 5% might present a significant health hazard.⁽⁹⁾ However, our small study population and its relatively short duration of exposure to respirable silica concentrations only slightly above the standard may have resulted in negative results despite somewhat hazardous environmental conditions.
2. Health selection factors. We did not examine drillers who were no longer employed by the company. Efforts were made to identify and notify former employees. However, no former employees responded to our request for them to participate. Banks et al. also found no silicosis among current workers at a small surface mine operation in West Virginia, though three ex-workers had silicosis.

3. Organizational factors. All three mines had more than 500 employees. Only about 3% of all surface mines have more than 150 workers.⁽¹³⁾ The three mines in this study, by no means, are representative of U.S. surface mines in general. The large operations usually have better industrial hygiene and medical surveillance programs than small mines. When effectively utilized, both medical and industrial hygiene activities can lead to decreased prevalence of disease in exposed workers.

The Federal Mine Safety and Health Act of 1977, Section 204 discusses dust from drilling operations. The Act states: "The dust resulting from drilling in rock shall be controlled by the use of permissible dust collectors, or by water or water with a wetting agent, or by ventilation, or by any other method or device approved by the Secretary which is at least as effective in controlling such dust. Respiratory equipment approved by the Secretary and the Secretary of Health, Education, and Welfare shall be provided persons exposed for short periods to inhalation hazards from gas, dusts, fumes, or mist. When the exposure is for prolonged periods, other measures to protect such persons or to reduce the hazard shall be taken." Controlling dust from drilling operations has never been an easy task because of the extremely small size range of dust particles. As demonstrated in the survey, approximately 38% of the particles collected were 10 microns and below. It is the opinion of several people in the mining industry that wet drilling techniques are very effective in controlling dusts but reduces drill bit life and causes problems during cold weather.⁽¹⁴⁾ As was observed during this survey, the use of positive pressure enclosed cabs at Mine C greatly reduced the concentration of dust for the drill operator while at the controls of the equipment. However, 45% of the of the particles collected inside the cabs were 10 microns and less. It should also be noted that the above statement stresses reduced dust concentrations at the cab controls because the personal respirable dust samples obtained on the drill operators indicated a greater exposure than the area samplers placed inside the cabs. It is felt that one explanation for the greater personal exposure is the fact that the operators were exposed to large concentrations of dust while cleaning the deck of the drills (outside the cab) with air hoses, brooms, and/or shovels. A similar situation existed at Mine B. The limited data collected at Mine B indicated that the dry dust collection systems employed on the drills were effective in reducing the concentrations of respirable dusts in and around the cabs. However, the personal samples indicated a greater exposure than the area samplers inside the cabs.

In addition to the engineering controls present for controlling drill operator exposure to dust, personal respiratory protection was also provided at all three of the mines surveyed. Practically all of the workers at Mine C utilized the respiratory protection provided. However, at Mines A and B very few of the workers utilized the masks provided.

It is recognized that coal mine dust generated during surface mining operations may contain enough quartz (SiO_2) to increase the potential health hazard of environmental dust exposures. However, there is very little data available as to the quantity of quartz in respirable coal dust generated at surface operations and no records available as to a worker's past exposure to silica containing dust. In February 1981, MSHA revised their procedure for quartz analyses allowing analyses of samples that were previously too small. It is felt that this revised MSHA analysis and the reliability of the MSHA data will allow future studies to better estimate the exposure to quartz for workers in the various work positions at surface operations.

VIII. CONCLUSIONS

- A. No statistically significant excess respiratory disease was found in this survey of currently employed surface coal miners with driller experience. However, this study was limited by generally short drilling tenure among the workers studied and by exclusion of workers no longer employed by the drilling company.
- B. Despite the current findings, and in light of previous studies, it is likely that significant risk for silicosis exists in certain coal mine drilling operations. (1,2,11)
- C. Based on the environmental sampling and the NIOSH recommended standard (8) for exposure to respirable free silica, NIOSH feels that the members of the drill crews are subjected to conditions, which over a working lifetime would constitute a significant health hazard.
- D. Efforts have been made and are continually being made to reduce drill crew exposure to dust. However, the engineering controls and the personal protection provided will not suffice without continued proper handling and maintenance of the equipment and strict enforcement of the use of the personal protection.
- E. This study provided informative data as to quantitative respirable quartz exposures for drillers and driller helpers at surface mines.

IX. RECOMMENDATIONS

Based on the Banks et al study there is convincing evidence that drillers might develop both acute pneumoconiosis and chronic silicosis. NIOSH recommends further epidemiological study of surface mine drill crew members to specifically evaluate environmental risk factors. The study design should consider the following:

- A. Characterization of respirable dust concentration, proportion of free silica, tenure as a drill crew member and, characteristics of dust protection equipment used.

- B. Study mines should be selected to allow analysis for the relation between the above factors and the occurrence of pneumoconiosis.
 - 1. MSHA data should be utilized to determine present and past respirable dust concentrations and, if the data is available, the percent of free silica.
 - 2. Supplemental industrial hygiene surveys should provide needed information not available from MSHA.
 - 3. Mines should be contacted and an intensive effort should be made to identify all present and retired drillers, utilizing the information available from the mining companies and unions. The time spent as a driller and the other potentially hazardous jobs of this group should be determined.
- C. After selection of mine sites, proper statistical tests should be applied to assure that the numbers of miners available for study, their tenure, and their exposure characteristics are sufficient to test the hypothesis of the role of the above listed environmental risk factors in the causation of pneumoconiosis.
- D. Maximum effort should be made to assure high participation of current and former drillers selected for the survey.

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XI. AUTHORSHIP AND ACKNOWLEDGEMENTS

Report Prepared By: Ronnie J. Cornwell, CIH
Environmental Investigations Branch
Division of Respiratory Disease
Studies
National Institute for Occupational
Safety and Health
Morgantown, West Virginia

Wojciech Hanke, MD
Clinical Investigations Branch
Division of Respiratory Disease
Studies
National Institute for Occupational
Safety and Health
Morgantown, West Virginia

Originating Office: Mining Hazard Evaluation and
Technical Assistance Program
Environmental Investigations Branch
Division of Respiratory Disease
Studies
National Institute for Occupational
Safety and Health
Morgantown, West Virginia

Report Typed By: Ann Stanley
Secretary
Mining Hazard Evaluation and
Technical Assistance Program

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TABLE 1

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ROSTER OF DRILLERS* AND NON-DRILLERS SELECTED FOR NIOSH SURVEY

N (%)	MINE A		MINE B		MINE C		TOTAL	
	DRILLERS	NON-DRILLERS	DRILLERS	NON-DRILLERS	DRILLERS	NON-DRILLERS	DRILLERS	NON-DRILLERS
Selected From Company Records	79 (100%)	60 (100%)	64 (100%)	65 (100%)	42 (100%)	41 (100%)	185 (100%)	166 (100%)
Examined	57 (72%)	36 (60%)	56 (88%)	45 (69%)	35 (83%)	27 (66%)	148 (80%)	108 (65%)
Excluded**	22 (39%)	8 (22%)	26 (46%)	13 (29%)	12 (34%)	2 (7%)	60 (41%)	23 (21%)
Included in Data Analysis**	35 (61%)	28 (78%)	30 (54%)	32 (71%)	23 (66%)	25 (93%)	88 (59%)	85 (79%)

*All current and former (but still employed) driller or driller helpers.

**Reported as % of examined.

TABLE 2

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CHARACTERISTICS OF EXAMINED DRILLERS* AND NON-DRILLERS

	MINE A		MINE B		MINE C		TOTAL	
	DRILLERS	NON-DRILLERS	DRILLERS	NON-DRILLERS	DRILLERS	NON-DRILLERS	DRILLERS	NON-DRILLERS
N	35	28	30	32	23	25	88	85
Age (Mean \pm SD), Yrs.	37.1 \pm 11.1	40.8 \pm 11.7	32.9 \pm 9.0	33.4 \pm 6.0	36.9 \pm 9.8	36.1 \pm 10.4	34.4 \pm 11.5	36.8 \pm 9.9
Tenure In Mine (Mean \pm SD), Yrs.	8.4 \pm 8.3	11.1 \pm 9.1	5.3 \pm 1.6	5.8 \pm 3.7	6.9 \pm 5.8	8.2 \pm 3.8	7.3 \pm 8.1	8.3 \pm 6.4
Tenure As A Driller (Mean \pm SD), Yrs.	4.3 \pm 4.9	---	3.3 \pm 1.9	---	4.6 \pm 3.9	---	3.8 \pm 3.3	---

*All current and former (but still employed) drillers and driller helpers.

TABLE 3

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CHARACTERISTICS OF EXAMINED DRILLERS* BY TENURE

TENURE AS A DRILLER (OR DRILLER HELPER)

		< 1 YR	2-3 YRS	4-5 YRS	> 5 YRS	TOTAL DRILLERS	TOTAL CONTROL
N		22	28	19	19	88	85
Age (Mean \pm SD), Yrs.		33.1 \pm 8.5	33.2 \pm 7.8	33.6 \pm 9.0	42.6 \pm 12.0	34.4 \pm 11.5	36.8 \pm 9.9
Tenure As Driller (Mean \pm SD), Yrs.		1.0 \pm 0	2.5 \pm 0.5	4.4 \pm 0.5	7.5 \pm 3.9	3.8 \pm 3.3	---
Tenure In Mine (Mean \pm SD), Yrs.		4.3 \pm 4.0	5.4 \pm 3.6	7.1 \pm 3.7	11.2 \pm 7.8	7.3 \pm 8.1	8.3 \pm 6.4
FROM	Mine A	45%	36%	58%	21%	40%	33%
	Mine B	23%	43%	42%	26%	34%	38%
	Mine C	32%	21%	0%	53%	26%	29%

*All current and former (but still employed) drillers or driller helpers.

TABLE 4

REPORT NO. MHEA 82-112-113-114

RESPIRATORY SYMPTOMS IN THE GROUP OF DRILLERS AND NON-DRILLERS
MINE A ONLY

Respiratory Symptoms	Drillers		Non-Drillers	
	N	%	N	%
Number of Workers	35	100	28	100
Chronic Cough	4	11	2	7
Chronic Phlegm	5	14	2	7
Chronic Bronchitis*	2	6	1	4
Breathlessness	2	6	1	4
Shortness of Breath With Wheezing	3	9	1	4
Wheezing	5	14	5	18
Asthma	2	6	0	0
Smoking Status:				
Nonsmokers	15	43	9	32
Exsmokers	6	17	7	25
Smokers	14	40	12	43

*Chronic productive cough for at least three months for the past two years.

TABLE 5

REPORT NO. MHETA 82-112-113-114

COEFFICIENT ESTIMATES FROM REGRESSION ANALYSIS FOR
LUNG FUNCTION OF DRILLERS AND NON-DRILLERS

	FVC(L)	FEV ₁ (L)	Peak-flow (L/S)
Intercept	-2.53	-1.75	2.16
Age (yrs)	-0.03	-0.03*	-0.06*
Height (cm)	0.05*	0.04*	0.06*
Race:			
American Indians	-0.39*	-0.13	1.48*
Caucasian	0.00	0.00	0.00
Smoking Status:			
Nonsmokers	0.00	0.00	0.00
Smokers	-0.05	-0.18	-0.13
Exsmokers	-0.20	-0.21	-0.29
Group:			
Non-Drillers	0.00	0.00	0.00
Drillers	-0.16	-0.11	-0.16

*p < 0.0002

TABLE 6

REPORT NO. MHETA 82-112-113-114

COEFFICIENT ESTIMATES FROM REGRESSION ANALYSIS FOR LUNG FUNCTION
OF DRILLERS IN RELATION TO YEARS OF EXPOSURE

	FVC(L)	FEV ₁ (L)	Peak-Flow (L/S)
Intercept	-1.58	-1.01	10.10
Age (yrs)	-0.03*	-0.03*	- 0.05 ⁺
Height (cm)	0.04*	0.04*	0.01
Race:			
American Indians	-0.51*	-0.26 ⁺	1.27*
Caucasian	0.00	0.00	0.00
Smoking Status:			
Nonsmokers	0.00	0.00	0.00
Smokers	-0.12	-0.24	-0.17
Exsmokers	-0.23	-0.35	-0.46
Tenure as a Driller (Driller Helper)	0.01	0.01	0.01

+p < 0.05

*p < 0.005

TABLE 7

REPORT NO MHEA 82-112-113-114

BULK SAMPLE QUALITATIVE SILICA ANALYSIS BY
X-RAY DIFFRACTION

Mine	Sample Type	Location	Percent Quartz
A	Settled Dust	Pit 1	15-20
	Settled Dust	Pit 3	100
	Settled Dust	Pit 9A	20-30
	Settled Dust	Pit 9B	20-30
B	Settled Dust	J16, Ramp 20	22
	Settled Dust	N14	25
	Settled Dust	N8	22
	Settled Dust	N14	22
	Settled Dust	J16	24
C	Settled Dust	Yazzie	19
	Settled Dust	Yazzie, Ramp 2	17
	Settled Dust	Lowe	20
	Settled Dust	Yazzie, Ramp 2	16
	Settled Dust	Yazzie, Ramp 2	22

TABLE 8

REPORT NO. MMETA 82-112-113-114

BULK SAMPLE QUALITATIVE MINERAL ANALYSIS
BY MICROSCOPY

Mine	Location	Major Phases	Minor Phases
A	Pit 2	Calcite Quartz Clay-Al, Si(tr,Fe,K)	Muscovite
	Pit 9	Calcite Quartz Clays	Muscovite
	Pit 8	Calcite Quartz Muscovite	Feldspars
	Pit 3	Calcite Quartz Muscovite	Feldspars
	Pit 9	Calcite Quartz Clays	Muscovite Biolite-Mg,Al Si,K,Fe
	Pit 6	Calcite Quartz	Hematite Muscovite Clays
	Pit 2	Calcite Quartz Clays	Muscovite
B	N14	Clays Quartz Calcite Feldspars	Magnetite Hematite Pyrite Biotite Coal Dust
	J16	Clays Orthoclase Feldspars Quartz Micas	Dolomite Iron Oxides Coal Fragments

TABLE 8 CONTINUED

	N8	Quartz Clays Orthoclase Feldspars	Pyrite Gypsum Biotite Iron Oxides Ilmonite Coal Dust
C	Yazzie Pit Ramp 2	Clays Quartz Orthoclase Feldspars	Hematite Calcite Biotite Coal Fragments
	Low Pit	Clays Quartz Orthoclase Feldspars	Coal Dust Calcite

TABLE 9

REPORT NO. MHETA 82-112-113-114

SUMMARY OF PERSONAL RESPIRABLE DUST SAMPLES FOR
DRILLERS AND DRILLER HELPERS

	<u>Mine A</u>	<u>Mine B</u>	<u>Mine C</u>
Number of Samples	35	28	11
Geometric Mean Dust TWAs (mg/m ³)	0.62 (0.03-3.36) ¹	0.33 (0.04-4.13)	0.59 (0.13-1.55)
Geometric Mean Quartz Content ² (Percent by Weight)	9.7 (<LLQ ³ -17.95)	15.8 (<LLQ-25.6)	14.9 (<LLQ-18.8)
Percent of Samples > 5% Quartz	71	54	91
Percent of Samples > MSHA TLV	32	25	82
Percent of Samples > NIOSH Recommended Standard for Respirable Silica	80	43	91

¹Range of data is shown in parenthesis.

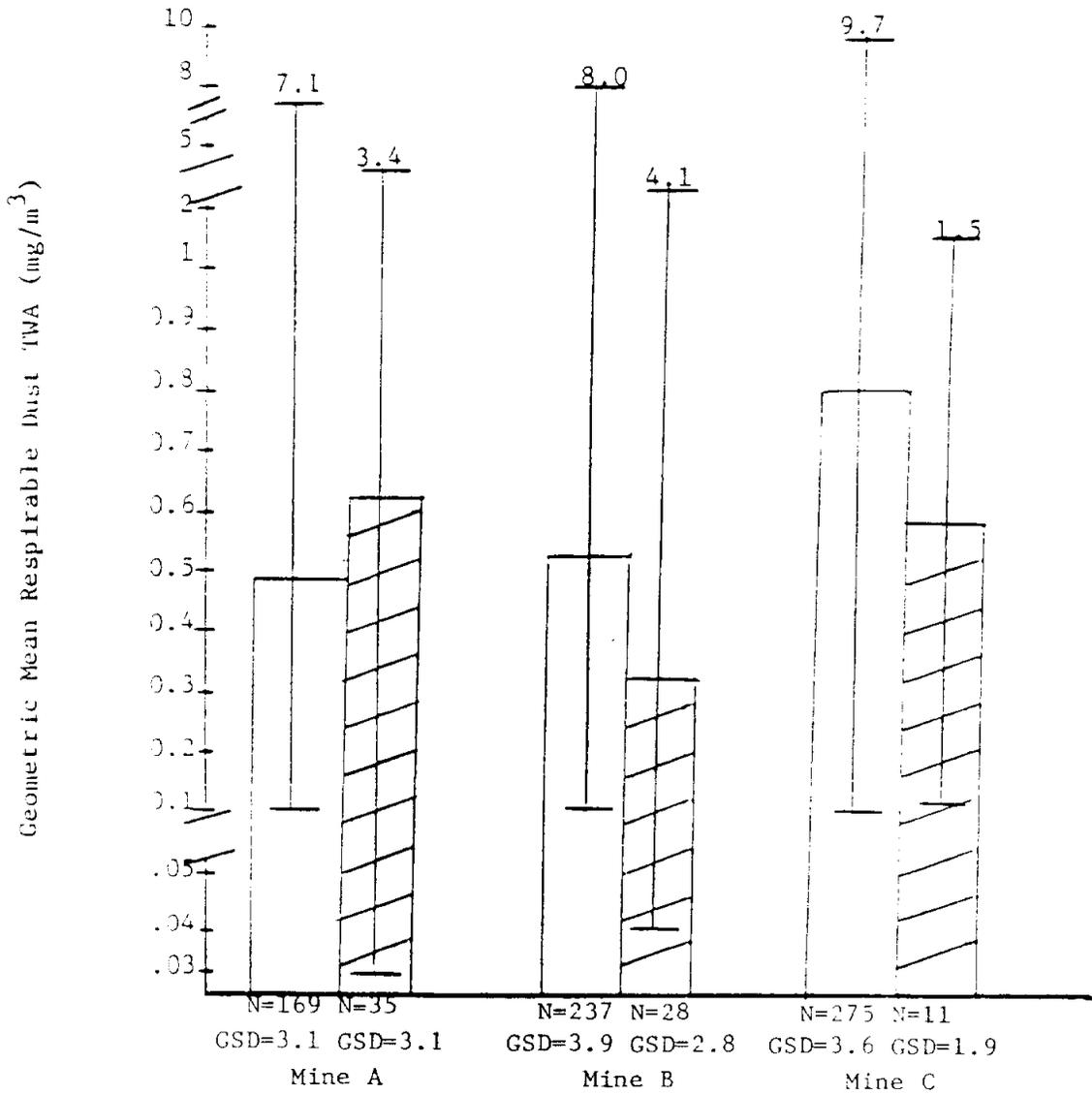
²Mean values were calculated by deleting data where the amount of quartz on a filter was less than needed for analytical quantitation (lower limit of quantitation was 0.03 mg per filter).

³LLQ - Lower Limit of Quantitation (.03 mg).

TABLE 10

Report No. MHEA 82-112/113/114

Personal Respirable Dust (Drillers and Helpers)
MSHA and NIOSH Data



MSHA data for period 1972-1979



NIOSH data September 1982 for Mine A and April 1983 for Mines B and C (adjusted for MRE equivalence, i.e., concentration x 1.38)

FIGURE 1

Report No. MHETA 82-112/113/114
Particle Size Distribution
Mine A

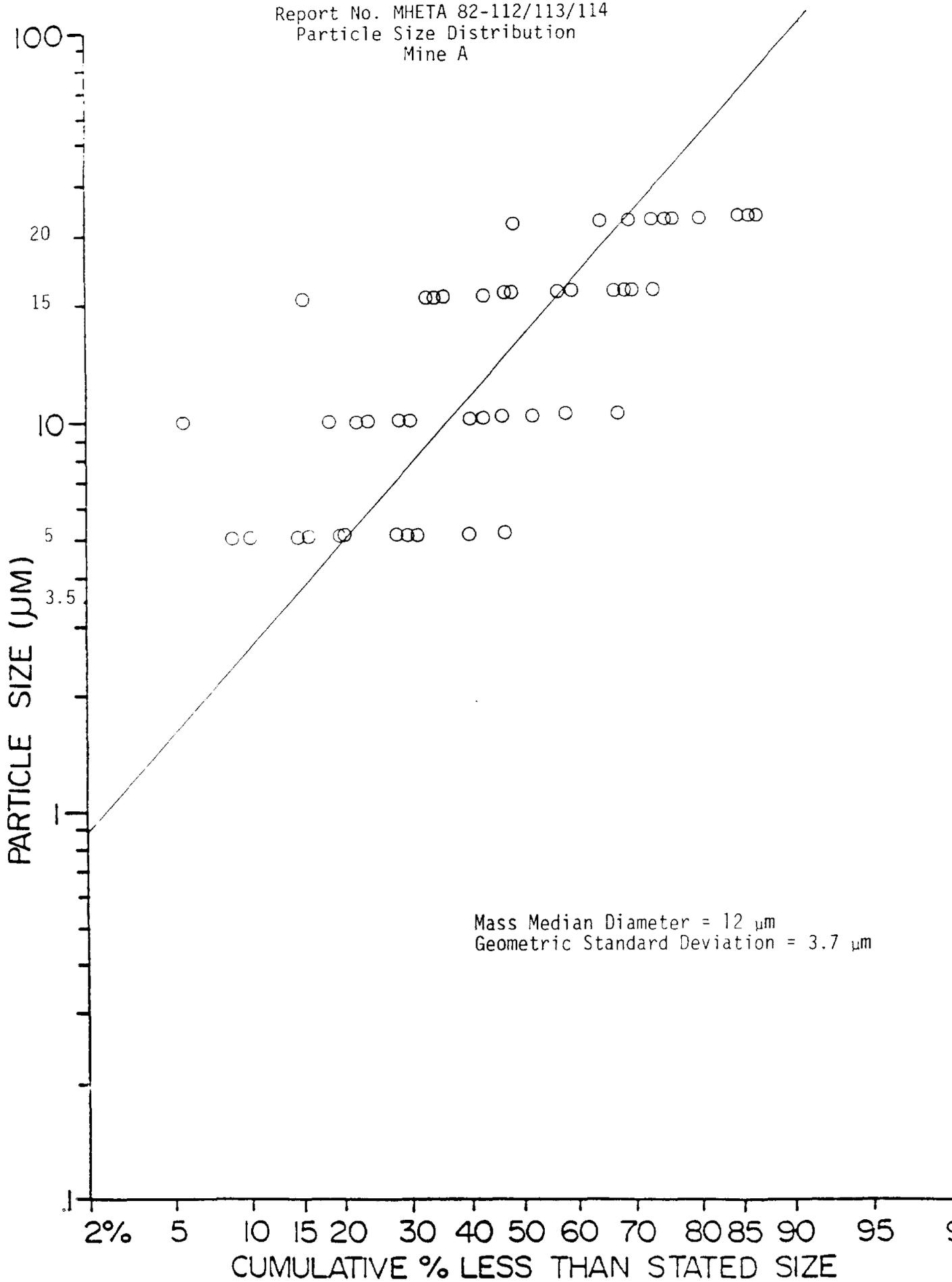


FIGURE 2

Report No. MHETA 82-112/113/114
Particle Size Distribution Inside and
Outside of Drill Cabs - Mine B

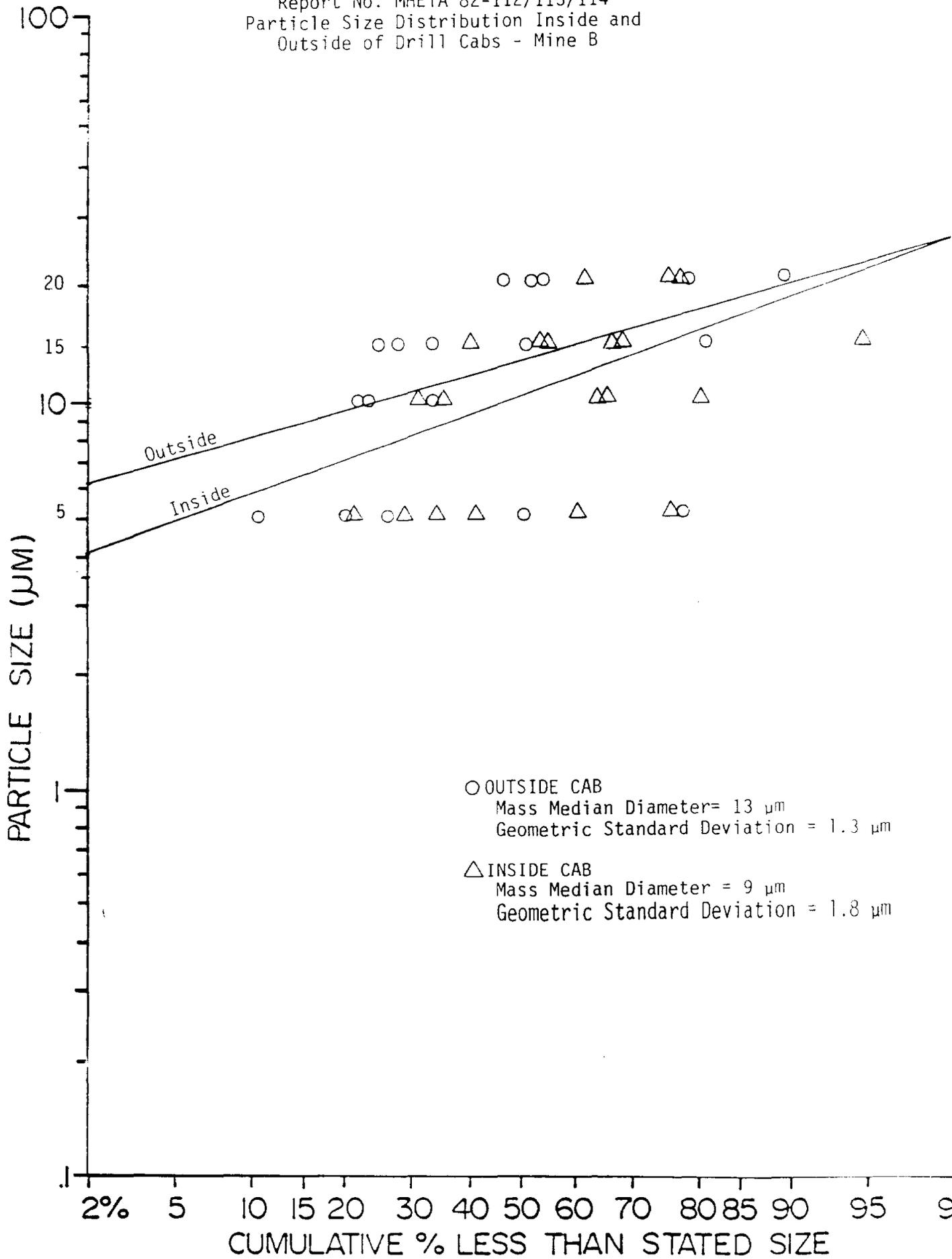


FIGURE 3

Report No. MHETA 82-112/113/114
Particle Size Distribution Inside and
Outside of Drill Cabs - Mine C

