A FEASIBILITY STUDY OF THE ADEQUACY OF COMPANY RECORDS FOR A PROPOSED NIOSH STUDY OF SILICOSIS IN INDUSTRIAL SAND WORKERS

BY

HARLAN AMANDUS, PhD

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EPIDEMIOLOGICAL INVESTIGATIONS BRANCH
DIVISION OF RESPIRATORY DISEASE STUDIES
NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

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SUMMARY

In 1987, the Division of Respiratory Disease Studies (DRDS) proposed a prospective study of the relationship between individual cumulative quartz exposure and radiographic evidence of silicosis in industrial sand workers. Data for this study were to be obtained from company Occupational Health Program (OHP) records.

In order to determine whether company OHP data were suitable for the proposed study, data from 4 of the largest plants in the industry were reviewed. This report summarizes the results of this effort, paying particular attention to (1) the precision of job category quartz exposure estimates, (2) the completeness of work histories, medical examination, cigarette smoking, and demographic information, (3) the prevalence of silicosis, (4) respirator usage, and (5) analytical measurement of quartz content.

These findings were indicative of the data quality that would be available to the proposed study:

- The precision of quartz exposure estimates for most jobs in 3 of the 4 plants was marginal and was high in one plant which has followed the NISA OHP guidelines for sampling frequency.
- Work histories were incomplete in 1 plant and possibly inaccurate in another.
- Radiographs were available for only 56% of the 949 workers who met the study inclusion criteria and for 81% of those who had been employed 6 or more years.
- Only 317 workers had 2 radiographs taken 5-9 years apart and only 1 worker had 2 films over 10 years apart.

- Based on Company 'B' reader reports, the prevalence of small radiographic opacities was 27% in workers who had been employed over 20 years. Because these data were not collected as part of an appropriately designed radiographic reading trial, accuracy of the prevalence estimates could not be determined. These data indicate a sufficient number of cases for the proposed study.

These results indicate that company data are not complete and of sufficient quality at this time, and improvement of the data will be necessary before proceeding with the proposed DRDS exposure-response study of silicosis.

I. INTRODUCTION

In 1987, the Division of Respiratory Disease Studies (DRDS) proposed a 2-part investigation of the health of industrial sand workers. One Part consisted of a prospective study of the relationship between individual cumulative quartz exposure and radiographic evidence of silicosis and the second part a study of the relationship between quartz exposure and lung cancer mortality risk. This report addresses only Part I.

As part of the proposed silicosis study, radiographs taken annually by sand companies in their Occupational Health Program (OHP)[1] were to be re-read by 3 NIOSH 'B' readers. Individual cumulative quartz exposures were to be estimated from company and government dust sample data. All workers employed since 1976 were eligible for study and silicosis incidence was to be evaluated in 1987, 1992, and 1997.

In an open review meeting (March 3, 1987) of the DRDS protocol by industry, labor, and affected parties, reviewers recommended that a feasibility study be conducted to establish the quality of the OHP environmental and medical data prior to proceeding with the industry-wide silicosis study. This recommendation was included in the July 20, 1987 protocol.

The purpose of this report was to address the feasibility of going forward with DRDS' proposed epidemiological study of silicosis paying special attention to (1) the precision of exposure estimates during 1976-87, (2) the completeness of work histories, (3) the completeness of medical, smoking status, and demographic data, (4) the prevalence of silicosis, (5) respirator usage, and (6) analytical measurement of the quartz content in air samples.

II. METHODS

During 1987-1988 DRDS obtained all OHP dust sample data, work histories, and medical examination information which had been collected by companies after 1976 on approximately 1,000 employees of 4 industrial sand facilities (referred to herein as Plants A, B, C, D). The facilities were owned by 4 of the largest companies in the industry and were selected because they were expected to have more complete environmental and medical data than other facilities. Information abstracted from company records is described in Appendix IV.

DRDS assembled work histories from personnel records for plants A and C, from self-reported questionnaires for plant B, and from personnel records and company administered questionnaires for plant D. Jobs were coded according to a scheme developed by NIOSH (Appendix I).

Each company had employed a 'B' reader who had interpreted all radiographs according to the ILO classification for the pneumoconioses. Three different readers had interpreted the films from the 4 plants. DRDS did not re-read any radiographs or conduct any direct examinations of workers in this feasibility study. The prevalence of silicosis from company collected data was estimated in order to determine whether there was a sufficient number of silicotics for the proposed DRDS study. Because the radiographic data were not collected as part of a controlled reading trial, the accuracy of the estimates of prevalence could not be determined.

Company dust sample work sheets were reviewed to verify the calculations of the quartz concentration. MSHA dust data was obtained from the agency's computer files and from MSHA's written survey reports.

III. PRECISION OF EXPOSURE ESTIMATES

The primary areas of activity in the study plants were quarrying, wet processing, draining, drying, screening, bulk loading, and bagging, maintenance shops, and administrative offices. Additionally, some facilities had or have had a grinding mill where silica flour was made (eg. plants A, C, and D). Different quarrying methods were used. Sand was slurried and pumped to the wet processing area in plant A, dredged from a pond and pumped in plant C, and drilled, blasted, hauled to a crusher, and transported by beltline to a wet mill in plants B and D.

Precision of exposure estimates was evaluated in accordance with the method which was to be employed for estimating individual cumulative quartz exposure. In our study protocol, we proposed that individual cumulative exposure was to be calculated as an arithmetic average (AM) of job quartz exposures weighted by tenure in each job. Job estimates were to be calculated from personal dust sample data on all workers who had performed the job. (This is referred to as a 'group' approach in contrast to estimating cumulative exposure from each individual's personal samples.)

A detailed description of the method of estimating job exposure estimates is given below. Measures of precision of AM estimates were the 95% confidence interval (CI) and coefficient of variation (CV).

The purpose of this analysis was to determine whether precision (i.e. CI length and CV%) of job estimates were acceptable for DRDS' proposed study. There are no published standards for acceptable precision levels and thus, such a decision required selecting a cutpoint for CI length and CV% below which precision would be considered low by any standard.

Two sets of cutpoints were chosen. A first set of cutpoints was chosen as a CI length of 100ug/m^3 and a CV% of 100%. CI lengths above 100ug/m^3

would be poor precesion for low exposures (eg less than 100 ug/m^3). A second cutpoint was chosen as a CI length of 500 ug/m^3. CI lengths above 500 ug/m^3 would be poor precision at even high exposures (eg 500 ug/m^3).

As a first step toward deriving the job estimates, each plant was divided into job categories (Appendix I) of similar activity and exposure. Annual average job quartz exposures were estimated for the period 1976-1987 during which 3,130 personal samples had been collected by the companies and MSHA. Area samples were excluded from the analysis.

Several questions had to be answered in order to determine the method for estimating job quartz exposures:

(1) What was the distribution of the quartz exposure data? (normal, log-normal, other?)

(2) Did engineering process and dust control changes effect average quartz exposure?

(3) Were there serial trends in the average exposure?

Quartz concentrations (ug/m^3) appeared to be log-normally distributed in each plant (Appendix II). Thus, the geometric mean (GM) was employed to make inferences concerning serial trends in dust exposure due to engineering changes and dust control,[2] and the arithmetic mean (AM) was employed for average job estimates because it is the appropriate statistic for estimating individual cumulative exposure.[2,3,4]

A log-linear model was employed to determine the years in which the GM quartz exposure (ug/m^3) differed due to changes in process and dust control:

$$Y_{ij} = \mu + \text{PERIOD}_i + \text{YEAR}_{ij}$$

Where

Y_{ij} = Natural log of the 8-hour TWA quartz concentration μg/m^3).

$PERIOD_i$ = Time period when process changes and dust controls were similar (categorical variable).

$YEAR_{ij}$ = Year in the with time period (categorical variable).

u = overall mean to which serial and process effects are added.

By employing the model statistically significant differences in GM quartz exposures over time were determined. The AM quartz exposure was then calculated by pooling samples during periods in which differences in the GM quartz exposure were not found. This method required running models on a large number of job categories, but this is not without precedent.[2-5]

Tables AIII-1 to AIII-4 (Appendix III) present AM (ug/m^3) job exposure estimates during selected time periods (herein referred to as job-year estimates, see footnotes in tables AIII-1 to AIII-4), the number of samples, and 95% confidence intervals (CI) and coefficient of variation (CV) by job year category for 1976-1987. The proportion of job-year exposure estimates which had a 95% confidence interval (CI) length less than 100 ug/m^3 was 14% (16/42) in plant A, 26% (15/19) in plant B, 44% (9/22) in plant C, and 65% (52/80) in plant D. Similarly, the proportion of job-year estimates with a coefficient of variation (CV%) less than 100% was 57% (24/42), 42% (8/19), 59% (13/22), and 78% (62/80) in plants A-D, respectively.

Additionally, the proportion of job-year estimates which had a CI length greater than 500 μg/m^3 was 52% (22/42) in plant A, 37% (7/19) in plant B, 23% (5/22) in plant C, and 5% (4/80) in plant D.

Maintenance jobs (700 series codes) and administrative jobs (800 series codes) had very few samples and an alternative scheme is required in order to estimate their average exposure. Because employees in these jobs have worked in different areas, exposure estimates for these jobs should be calculated as an average of area estimates weighted by the time worked in the areas. This was beyond the scope of the feasibility study and was not done.

In any event, even when excluding maintenance and administrative jobs, the proportion of remaining jobs-year estimates with a CI length less than 100 $\mu g/m^3$ was similar to the figures presented above for all jobs.
The greater precision of estimates in Plant D was the result of a higher sampling frequency. In Plant D, 2409 samples were collected from 1973-1987 and the average sampling rate was 5.1 samples per job category per year (Table 1). Similar figures were 342 and .9 for Plant A, 189 and 1.1 for Plant B, and 190 and .9 for Plant C, respectively. In Plants A-C, fewer than 3 samples per year were taken in high exposed areas (milling and bagging). Additionally, plants A-C had less than 5 years of samples for most job categories during the 1976 to 1987 time span.

IV. WORK HISTORIES

Workers were eligible for the silicosis study if they had been employed at least 1 year after 1976 and 949 met the inclusion criteria. Eligibility could not be determined for 119 men who had missing work history data (Table 2). Thus, 1068 were potentially eligible (949 with work history data and 119 with uncertain data). The percentage of workers who had uncertain histories was high in plant A (106/209=51%).

Work histories with complete information on job dates and titles were available (Table 2) for 87% (830/949) of all eligible workers, for 39% (40/103) in plant A, 69% (75/108) in plant B, 99% (403/407) in Plant C, and 94% (312/331) in plant D. Work histories were either complete or had less than 5 years missing for 58% (60/103), 72% (78/108), 99% (406/407), and 95% (315/331) of the eligible workers in plants A-D, respectively. Corresponding figures for workers who were employed during 1986-1987 were 54%, 61%, 99%, and 98%.

V. MEDICAL DATA

Of 949 workers who had met the study criteria, 919 (97%) had date of birth recorded, 947 (99%) had information on sex, 519 (55%) had at least one radiographic examination, 530 (56%) had information on smoking status, and 529 (47%) had at least one spirometry tracing.

The proportion who had one radiographic examination after 1976 (Table 3) was 85% (88/103) in Plant A, 77% (83/108) in Plant B, 40% (163/407) in Plant C, and 56% (185/331) in Plant D. The proportion increased with tenure and was 26% (114/443) and 81% (390/484) in workers who had achieved less than 6 years and 6 or more years tenure, respectively. Similar figures for those who were employed in 1986-87 were 56% and 97%, respectively.

The proportion of workers who had 2 or more radiographic examinations during 1976-87 was 51% (484/949). Of the 484 with 2 or more examinations, the number of years between the first and most recent examination after 1976 was less than 5 years for 166 workers, 5-9 years for 317 workers, and over 10 years for 1 worker. If these figures are projected to the 1500-2000 workers in the sample for the proposed industry-wide silicosis study, then less than 2 workers who had been employed 10 or more years would likely have had 2 or more examinations over a 10 year period.

Less than 0.2% of the films were reported to be unreadable and film quality appeared to be sufficient for the study.

VI. RADIOGRAPHIC FINDINGS

The prevalence of category 1/0 or greater small opacities on the most recent radiograph after 1976 ranged among plants from 13.0% to 33.0% in workers who had achieved 20 or more years tenure (Table 4). A significant trend with tenure was also observed (p value <.05 from a chi-square test).

Cases were distributed (Table 5) with greater frequency in jobs associated with high exposure (drying, screening, milling, loading, and bagging).

The time interval between the first and most recent examination after 1976 was short for most workers which accounted for a low net progression (progressors minus regressors). Of 318 workers who had 5 or more years tenure and who had 2 examinations 5 or more years apart, there were 22 progressors and 25 regressors (a change of one or more major ILO radiographic categories).

VII. RESPIRATOR USAGE

Respirator usage was observed during visits in all but one plant in areas of high exposure. Three plants have had a respirator usage policy in effect since the 70's.

VIII. PERCENT SILICA

Each company reported that their finished products contained over 99% quartz. However, reports on respirable dust samples indicated that the percent quartz rarely exceeded 60% and the average percent quartz from personal samples ranged by plant from 31% to 41% (Figures 1-4). The low percent quartz was not likely explained by fugitive dust contamination. For example, in the screen room of plant C in which the finished product was transported to storage bins, results from 14 area samples in 1984-85 indicated that quartz concentrations ranged from 7 to 34 mg/m^3 and the percent quartz only ranged from 18% to 38%.

Results do not suggest that company data are in error. Companies in this study have employed AIHA accredited laboratories. The issue is in the analytic procedure. A microscopic analysis of air samples taken in plant D was performed and the size of these particles was compared to the size of two commonly used silica reference materials (MIN-U-SIL 5 and NBS standard reference material 1878). Both of these reference dusts were found to contain some large (>10um) particles. These large particles are not typically found in a respirable dust sample. Since x-ray powder diffraction is known to give biased results when the size of the calibration dust does not match the size of the sample, this may in part account for the low quartz content. Separate work is underway to examine the effect of these large particles on x-ray diffraction analysis of respirable dust samples.

IX. DISCUSSION

Prior to conducting this study, NISA had indicated that since 1976 industrial sand companies had collected 8 to 10 years of medical examination and environmental exposure data which were possibly suitable for epidemiological analyses. Companies were to have recorded these data on NISA OHP forms according to NISA guidelines.[1] We found that these data were not available or of adequate quality (not collected according to OHP guidelines) for all 4 study plants.

Because other plants in the industry possibly have data quality similar to or perhaps less than the 4 study plants, then it is likely that industry-wide OHP data are not yet ready for the epidemiological analyses proposed in the DRDS silicosis study plan. The specific areas of data collection that contributed significantly to the problem were (1) the completeness of work histories, (2) the proportion participating in OHP medical examinations, and (3) length of time between examinations. Improvements are needed in these areas for an epidemiological prospective evaluation of the exposure-response relationship for silica and silicosis.

According to the 1987 protocol, DRDS and NISA proposed to work together to improve the quality of company collected OHP data in order to establish an epidemiological data base suitable for analyses. Based on results of this feasibility study, steps to generate such information, particularly the time necessary to build a sufficient data base would extend the projected length of the proposed silicosis study by more than 5 years. At least 5 more years of follow-up is also necessary for a greater number of employees to have been examined twice over a 10-15 year period which is a minimal follow-up period for a prospective study of silicosis.

The proportion of jobs with a CI length greater than 500 ug/m^3, was 23-52% in plants A-C and only 5% in plant D. Moreover, the CI length was less than 100 ug/m^3 in 65% of the jobs in plant D. Thus, acceptable precision was only found in exposure estimates for Plant D which appeared to have followed the NISA guidelines[1] more closely than the other study plants. Although our estimates of precision for Plants A-C could have been improved for low exposed areas by combining jobs into broader areas of activity (eg. pit non-drilling, drain bin and wet mill), few jobs in areas of high exposure could have been combined because of significantly different exposures, locations, and activities.

In any event, even though the OHP environmental sample data for plants A-C did not provide a high level of precision, the number of samples per job category in each plant is as high or higher than that employed in previous epidemiological studies of the exposure-response relationship for silicosis.[4,10,11] Thus, in the future industrial sand plants are advised to follow the NISA guidelines which will effectively provide a sufficient number of samples for a future prospective study of silicosis.

Collection of work history data needs to be standardized industry-wide for epidemiological purposes. Questionnaires need to be administered to all workers examined by a trained interviewer. They should not be self-reported. In order to minimize under-reporting of jobs and misclassification of individual exposure estimates, companies should employ the OHP work history form which is suitable for epidemiological purposes.

Clearly, the participation rate in examinations needs to be increased. The participation rate was 25% in workers with less than 5 years tenure which indicates that this group would have to be excluded from a study of silicosis. The participation rate for greater than 5 or more years tenure was 81% and is acceptable if the proportion of silicotics is similar between participants and non-participants. Because this is not easily evaluated results from an epidemiological study will be more convincing if radiographs were available on all workers.

There appears to be a sufficient number of cases of radiographic opacities to estimate the dose-response relationship in a cross-sectional prevalence study as proposed in the DRDS protocol. This is supported by the relationship found between prevalence of radiographic opacities and tenure. However, the length of time between exams for most individuals was less than 10 years and coupled with a low net progression (progressors minus regressors), the DRDS proposal for a prospective progression study does not appear feasible at this time.

The radiographic findings warrant concern because all company 'B' readers have had long experience in pneumoconiosis film reading. On the other hand, prevalence estimates have questionable accuracy and should be interpreted cautiously for many reasons. First, companies had employed different readers and each film received only one reading, while at least 3 readers are generally employed in epidemiological studies in order to minimize reader variability. Second, 81% of the workers with over 5 years tenure were examined and the prevalence of radiographic small opacities may have possibly been over-estimated if proportionately more unhealthy than healthy workers tended to participate in company examination programs. Third, work histories were incomplete in 2 plants and prevalence estimates by tenure may not be accurate. Fourth, adjustment for age, cigarette smoking, and exposure in other dusty jobs were not made. Fifth, 7% of 318 workers evidenced radiographic progression over 5-9 years and 8% regressed, and thus, the net radiographic progression is unclear from these data.

Respirator usage is a formidable problem in estimating individual cumulative exposure. Respirator usage policy varied from plant to plant and between employees. Respirator usage has not been required in all production areas in every plant. However, workers in Plants A, B, and D who were employed in areas where dust exposure has been a potential problem (generally all production areas except in the pit and wet process) have been recommended or required to use respirators.

In the 1987 protocol it was proposed that companies would administer respirator usage pattern questionnaires to workers and this information would be employed to weight individual exposure estimates by published respirator efficiency factors. Additionally, DRDS would conduct field testing of exposures inside and outside the mask as necessary to establish a weighting factor. Previous studies of respirator efficiency under normal use[7,8,9] have indicated that individual variability is high, and thus, some field testing may possibly be required.

The possible excessive number of cases of small radiographic opacities in the workforce clearly warrants further investigations, and if prevalence estimates prove to be accurate, warrants continued exposure and medical surveillance. Due to the caveats in the radiographic findings, an appropriately designed epidemiological investigation is needed to verify these results. NIOSH realizes that companies in the industrial sand industry have continued to pursue and invest resources in their OHP program, and these data could become available in the future. Unfortunately limitations in the industry-collected data make it unlikely that the proposed DRDS 10-year prospective study could be done at this time.

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Table 1

Total Number of Samples and the Average Number of Samples Taken Per Job Category Per Year During 1977-87 by Plant and Area*

	Plant							
	A		B		C		D	
Area	Average No./Job /Year	Total No. Samples	Average No./Job /Year	Total No. Samples	Average No./Job /Year	Total No. Samples	Average No./Job /Year	Total No. Samples
Pit	.1	12	.7	40	.2	2	2.4	129
Crushing	--	--	5.8	64	--	--	4.0	88
Wet Process.	.1	3	2.6	28	1.3	14	3.3	109
Dry./Screen.	.4	39	--	--	2.8	62	4.3	421
Milling	1.6	71	.4	9	--	--	8.4	369
Loading	.3	6	2.8	31	1.0	56	10.0	220
Bagging-Sand	3.0	33	--	--	2.0	22	22.8	251
Bagging-Flour	6.8	150	--	--	--	--	8.0	618
Total	.9	342	1.1	189	.9	190	5.1	2409

* Derived from Tables AIII-1 to AIII-4 in Appendix III.

Table 2

Work History Completeness by Plant

Plant		All Job Dates and Titles Present	Missing Less than 5 Years+	Missing Greater than 5 Years|	Missing Beginning and Ending Dates‖	Sub-Total*	Uncertain work history** Dates	Total
A	Number	40	20	37	6	103	106	209
	% Subtotal	39	19	36	6	100		
B	Number	75	3	1	29	108	11	119
	% Subtotal	69	3	1	27			
C	Number	403	3	0	1	407	1	408
	% Subtotal	99	1	0	0	99		
D	Number	312	3	14	2	331	1	332
	% Subtotal	94	1	4	1	100		
Total	Number	830	29	52	38	949	119	1068
	% Subtotal	87	3	5	4	100	100	
	% Total	78	3	5	4	89	11	100

+ Date of hire and last date worked were recorded; less than 5 years was missing from history.

| Date of hire and last date worked were recorded; greater than 5 years was missing from history.

‖ Date of hire or last date worked were not recorded.

* Sub-total of all workers employed at least 1 year during 1976-1987.

** Uncertain history data: date of hire and last date worked was not recorded and work history was too incomplete to determine whether the workers' length of service exceeded one year.

Table 3

Number and Proportion of Workers Who Met The Study Inclusion Criteria Who had at Least One Radiographic Examination After 1976 by Tenure and Plant

		Tenure (years)*					
Plant		Missing	0-1	2-5	6-9	≥10	Total
A	Number X-rayed	3	1	4	9	71	88
	Total number	3	6	11	12	71	103
	% X-rayed	100	17	37	75	100	85
B	Number X-rayed	12	16	13	9	33	83
	Total number	19	21	21	11	36	108
	% X-rayed	63	76	62	82	92	77
C	Number X-rayed	0	31	39	24	69	163
	Total number	0	206	82	33	86	407
	% X-rayed	0	15	47	73	80	40
D	Number X-rayed	0	2	8	19	156	185
	Total number	0	60	36	26	209	331
	% X-rayed	0	3	22	73	75	56
Total	Number X-rayed	15	50	64	61	329	519
	Total number	22	293	150	82	402	949
	% X-rayed	68	17	43	74	82	55

* Gross tenure (time from date of hire to date of termination or 1987-88 for active workers).

Table 4

Proportion of Cases* by Tenure and Plant

Plant		Tenure <1	 1-9	 10-19	 ≥20	 Unknown	 Total #
A	# cases/total	0/1	0/13	4/46	4/25	1/3	9/88
	%	0.0	0.0	8.7	16.0	33.3	10.2
B	# cases/total	0/2	0/36	1/16	4/17	0/12	5/83
	%	0.0	0.0	6.3	23.5	0.0	6.0
C	# cases/total	0/1	0/93	0/46	3/23	0/0	3/163
	%	0.0	0.0	0.0	13.0	0.0	1.9
D	# cases/total	0/1	2/28	2/50	35/106	0/0	39/185
	%	0.0	7.1	4.0	33.0	0.0	21.1
Total	# cases/total	0/5	2/170	7/158	46/171	1/15	56/519
	%	0.0	1.2	4.4	26.9	6.7	10.8

* Evidence of ILO radiographic category 1/0 or greater small opacities or large opacities.

Table 5

Number of Cases of Radiographic Small or Large Opacities

Exposure Category*	All Cases	Small Opacities Only	Large Opacities
Low	1	1	0
Mixed	18	17	1
High	34	27	7
Missing History	3	2	1
Total	56	47	9

*Low:	All jobs in areas of low exposure (pit, wet process, adm.)
Mixed:	At least 1 job in maintenance, utility, or general labor.
High:	At least 1 job in high exposed areas (drying, screening, milling, loading, or bagging).

Figure 1

Distribution of Percent Quartz
from Samples Collected in
Plant A

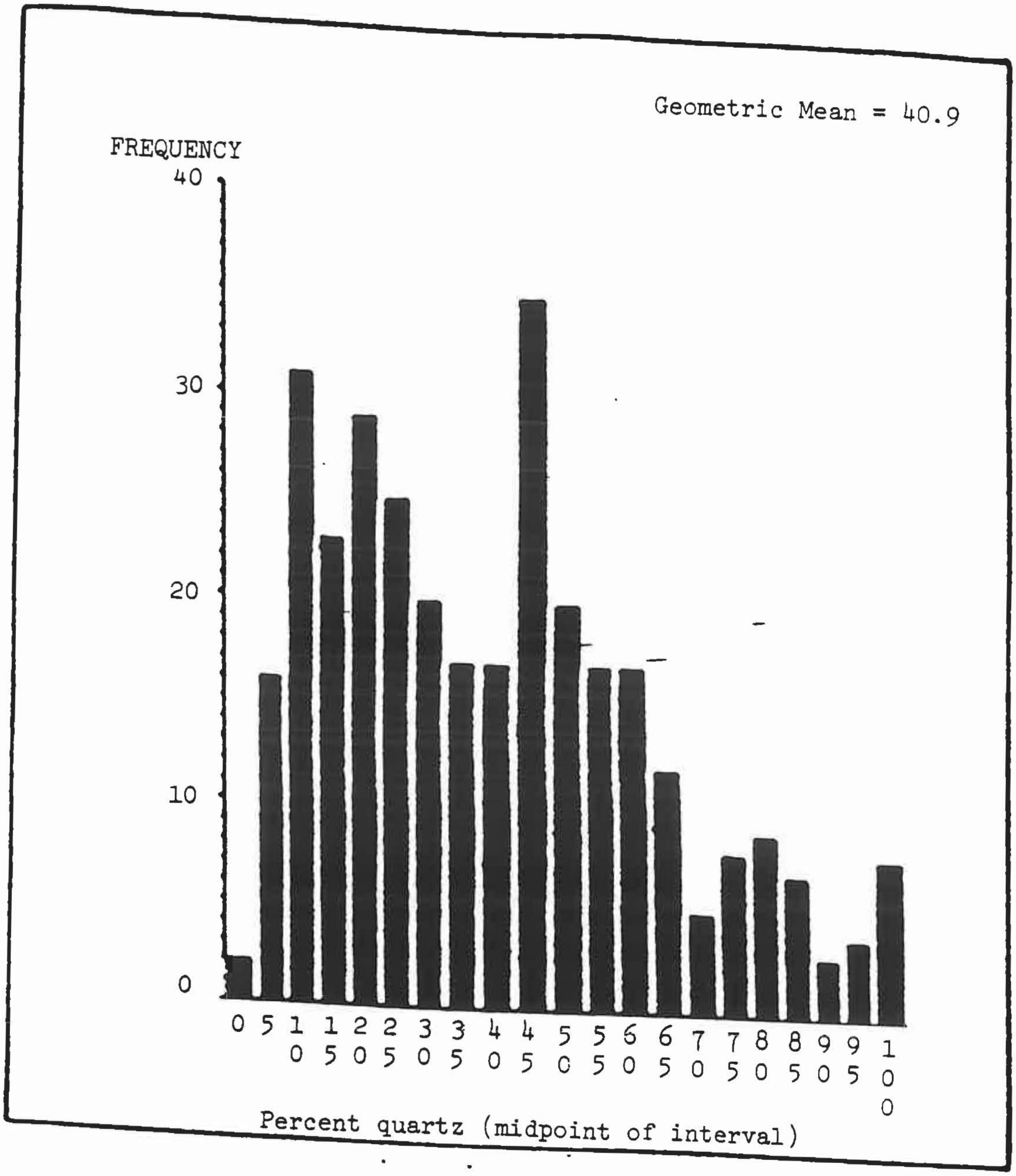


Figure 2

Distribution of Percent Quartz
from Samples Collected in
Plant B

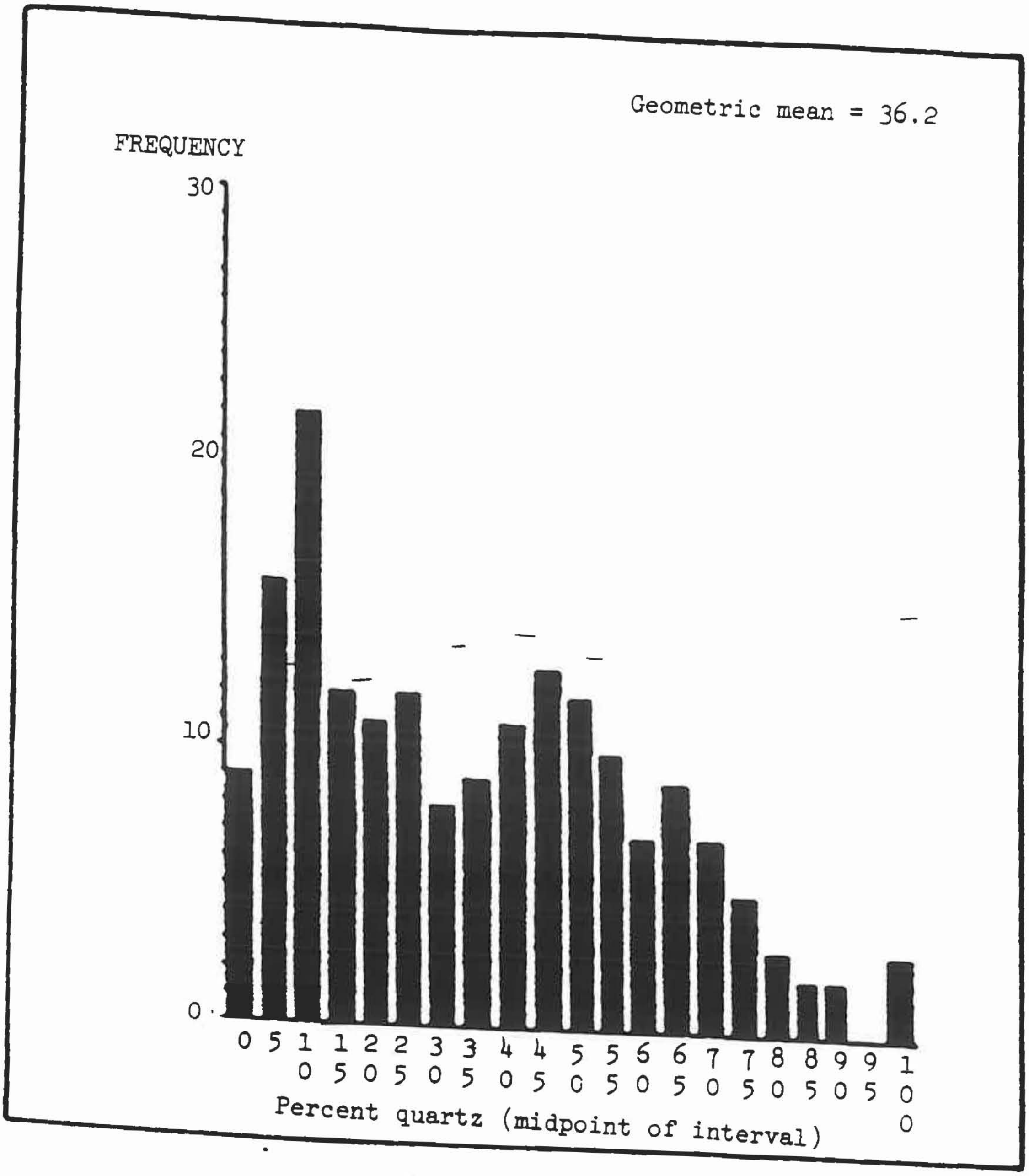


Figure 3

Distribution of Percent Quartz
from Samples Collected in
Plant C

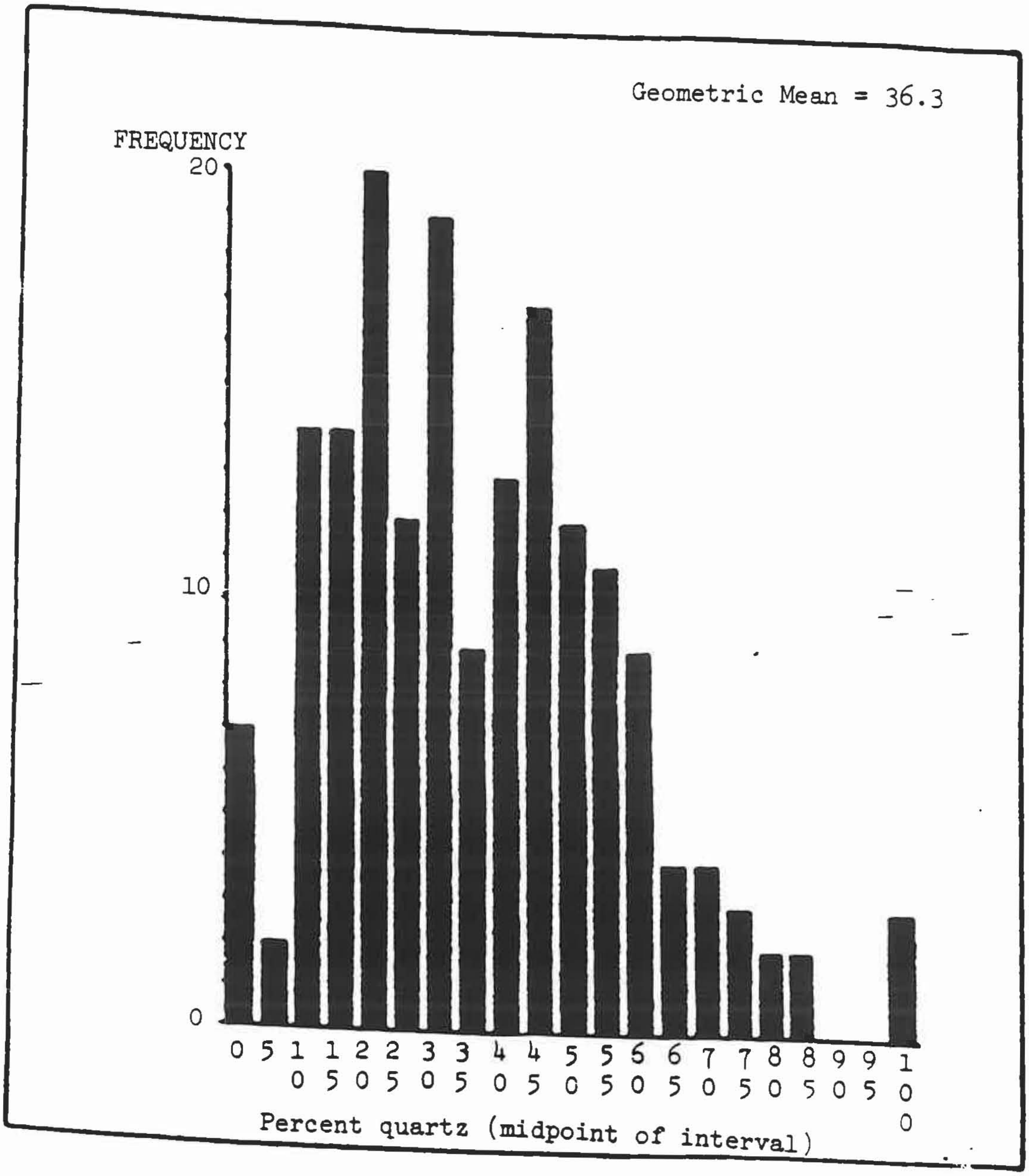
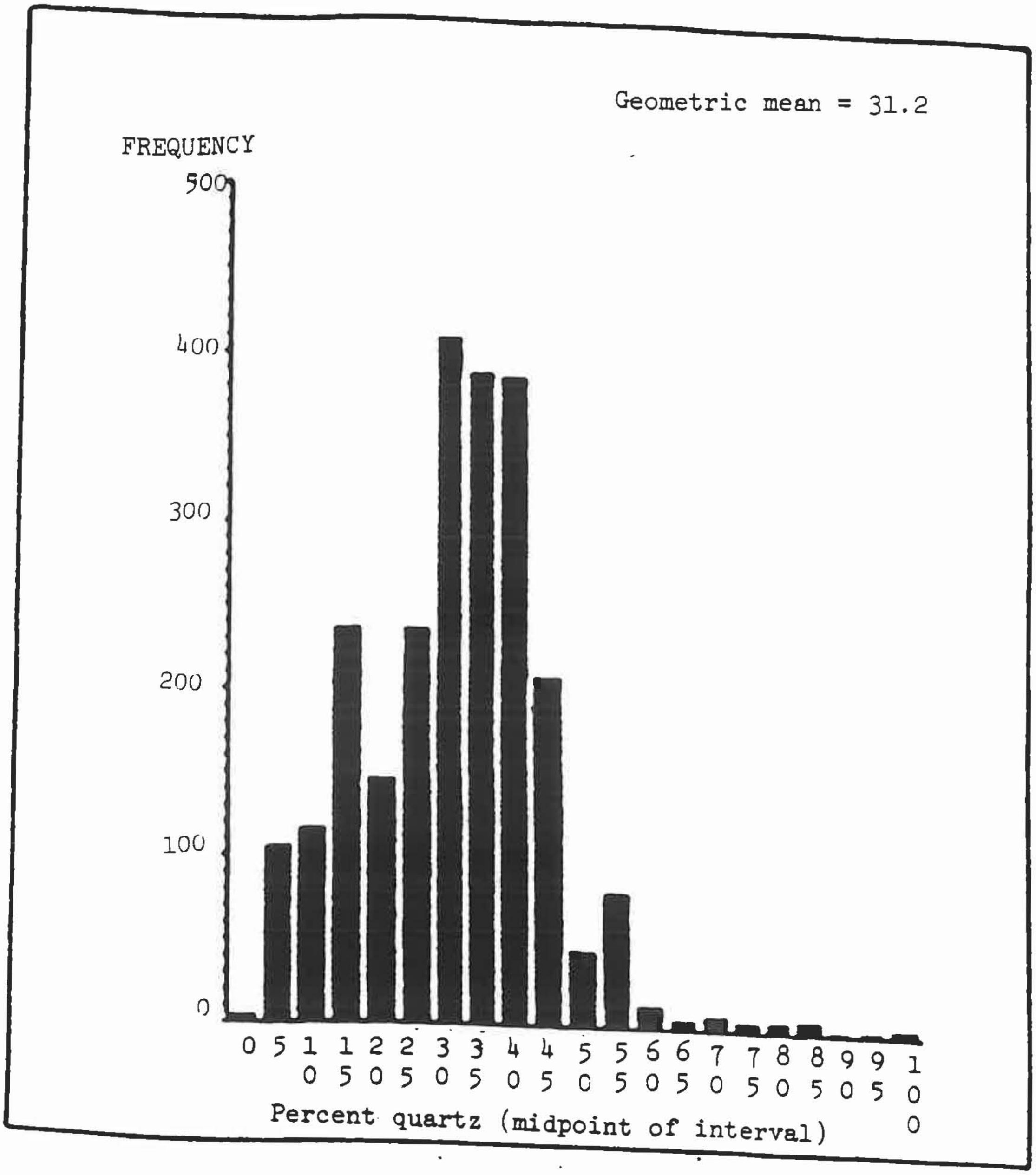


Figure 4

Distribution of Percent Quartz
from Samples Collected in
Plant D



Appendix I

Job Code List for Industrial Sand Study**

Quarry

100	Driller/blaster
101	Tunneling (Coyote)
102	Bulldozer, tractor, front end loader operator (clean-up at face or crusher)
103	Stripping crew (over-burden removal, bulldozing, scraping, trucking, brush clearing)
104	Truck hauling (face to crusher or plant)
105	Dredge operator
106	Monitor operator
107	Pump attendant, checker, operator
108	Pit relief, utility, foreman, misc. equipment, water truck driver, labor quarry, misc. quarry, quarry helper, quarry pitman
109	Front end loader loading trucks, shovel opr.
110	Drop ball operator
111	Surveyor, land prospector
112	Scraper operator
113	Scalp screen operator

Crushing

200	Primary crusher operator
202	Transfer line, reclaim tunnel, belt attendant (between primary and secondary crusher) operator
203	Secondary crusher operator
204	Transfer line maintenance

Wet Washing Process

300 #1 Wash plant operator, flotation operator, washman, wet process operator*

301 Drain bin operator, wet sand storage

302 Vacuum table operator

303 #2 Wash plant operator

304 Operator for wash plant, dryer, screens, and grinding mill from control room in wet proc. plant

Drying

399 #1 Crane operator*

400 #2 Crane operator

401 #1 Dryer operator*

402 #2 Dryer operator

403 #1 Dryer building clean-up*

404 #2 Dryer building clean-up

405 Dry surge tunnel, transfer line from dryer to screen plant

(See 711, 712)

Screening

425 #1 Screen plant operator*

426 #2 Screen plant operator

427 #1 Screen plant clean-up*

428 #2 Screen plant clean-up

429 #1 Screen plant utility, brushing, & testing*

430	#2 Screen plant utility, brushing, & testing
431	#1 Screen plant tester or sampler*
432	#2 Screen plant tester or sampler
433	Lunch room in screen plant
434	Office in screen plant
435	Screen and dryer operator

(See 709,710)

Sizing Plant

440	Sizing operator

Storage-blending

445	Blending Operator

Ground Silica (flour) Milling

450	#1 Mill operator*
451	#2 Mill operator
452	#1 Clean-up in mill*
453	#2 Clean-up in mill
454	#1 Mill Tester or samplers
455	#2 Mill Tester or samplers
456	Mill lunch room
457	Dust collector maintenance
458	Mill foreman/mechanic
459	Mill opr. - operates whole grain sand and flour mill operation

(see 713, 714)

Loading

500	Whole-grain sand loading to rail cars
501	Whole-grain sand loading to trucks
502	Specialty sand loading to trucks
503	#1 Ground silica loading to railcars*
504	#2 Ground silica loading to railcars
505	#1 Ground silica loading to truck*
506	#2 Ground silica loading to truck
507	Car cleaner
508	Hauling from truck loading area to rail loading area
509	Equipment opr., front end loader loading trucks and moving sand in yard.
510	Combination truck and rail loading, and bagging of flour and whole grain sand
511	Combination whole grain sand loading and bagging of rail and trucks

Bagging

549	Sand bagger of speciality sands
550	Sand bagger of whole grain sand, (sewing machine opr.)
551	#1 Ground flour silica bagger*
552	#2 Ground flour silica bagger
553	#1 Clean-up in bagging area*
554	#2 Clean-up in bagging area
555	Bagger - gravel

Use following codes when reference is made to specialty flour bagging operations in Plant D:

556 Supersil bagger and AGP opr. (Automated ground packaging)

557 MIN-U-SIL bagger; 10-30 micron

558 5-micron bagger

559 utility man in bagging area

560 Palletizer in bagging area

561 Forklift operator in bagging area

562 Shipping office when in mill

563 Bagging of flour and whole grain sand

564 Spotter truck - moving cars or trailers for bag loading

Quality Control Lab

600 Testers, lab workers, and lab supervisors-do not take samples

601 Dust monitoring technician

(See 431, 432, 454, 455)

Boilerhouse

620 Fireman

621 Engineer

622 Coal feeder - Front end loader feeding coal hopper, coal passer

Maintenance

700	Mechanic
701	Electrician
702	Quarry equipment maintenance
703	Millwright
704	Welder
705	Greaser/oiler in plant
706	Storekeeper
708	Maintenance - general
709	#1 Maintenance - screen plant*
710	#2 Maintenance - screen plant
711	#1 Maintenance - dryer*
712	#2 Maintenance - dryer
713	#1 Maintenance - ground silica (flour) mill*
714	#2 Maintenance - ground silica (flour) mill*
715	Construction, carpenters, painters
716	Dust collector repair

Miscellaneous

800	Laborer (Common, yard, general laborer moving throughout facility))
801	Utility
802	Clean-up
803	Weighmaster
804	Janitor
805	Service truckdriver (non-hauling of ore), equipment operator in yard

806	Watchman guard
807	Administration, clerical, office, and non-production managers, engineers, designers, geologist
808	Production managers and foreman (roving)
809	Storehouse, warehouse (not in process building)
810	Grounds Maintenance

Gravel Plant (Mauricetown)

900	Screen operator
902	Loader to rail
903	Loader to truck
904	Clean-up

998	Mill operator (Mauricetown plant-error in job title)
999	No code or job listed

* Use for plants with only one operation. #1 and #2 designations are for plants with more than one operation. When there are 2 or more operations (e.g. dryer, mill, or screenhouse buildings) and job title recorded does not specify which one, then record code for #1 operation (*) and put a '1' in department code.

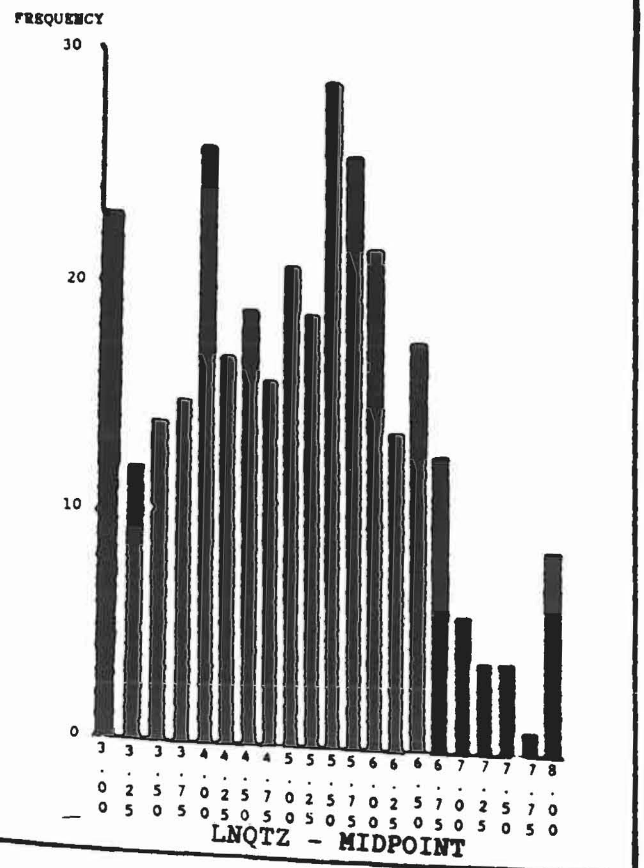
** All foreman are included in job title

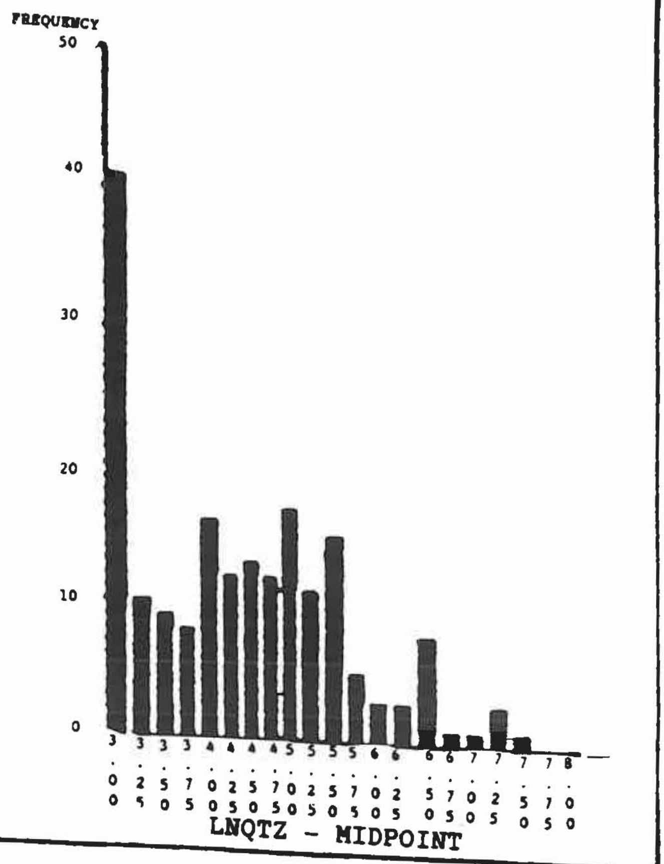
APPENDIX II

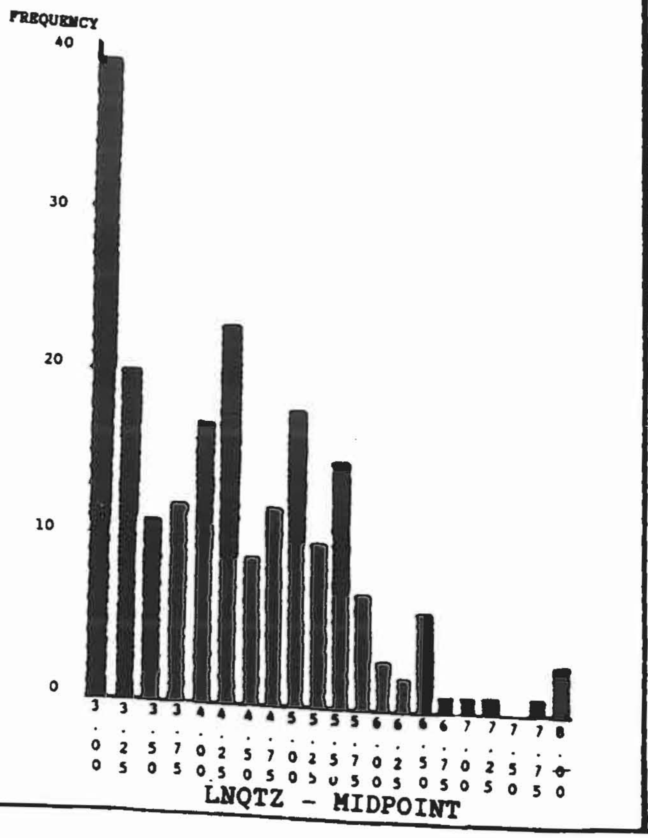
Distribution of Log-quartz Concentrations ($\mu g/m^3$) From All Samples in Plants A-D and for Selected Job Categories

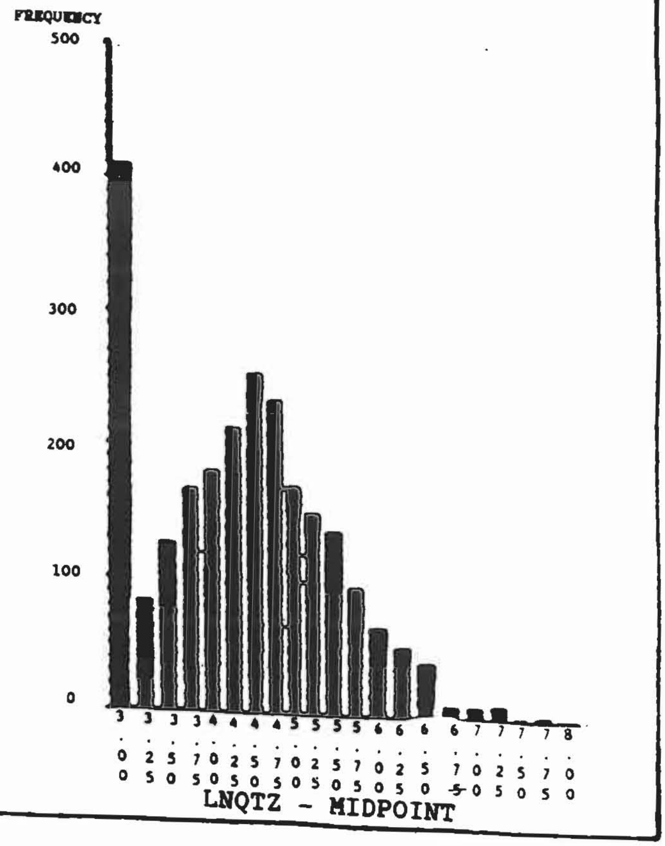
Legend:

LNQTZ = log of quartz concentration ($\mu g/m^3$)
MIDPOINT = midpoint of intervals in increment of .20 $\mu g/m^3$.
JOBCODE = see Appendix I


PLANT A


PLANT B


PLANT C


PLANT D

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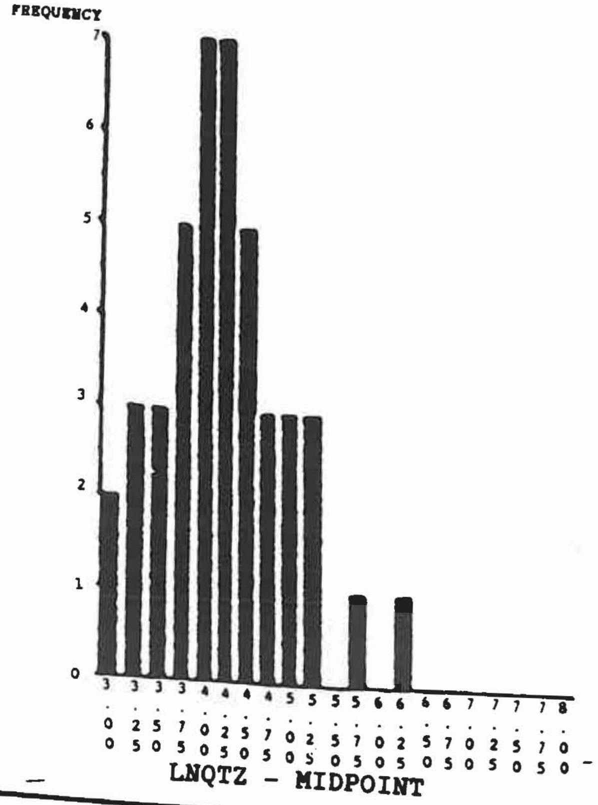

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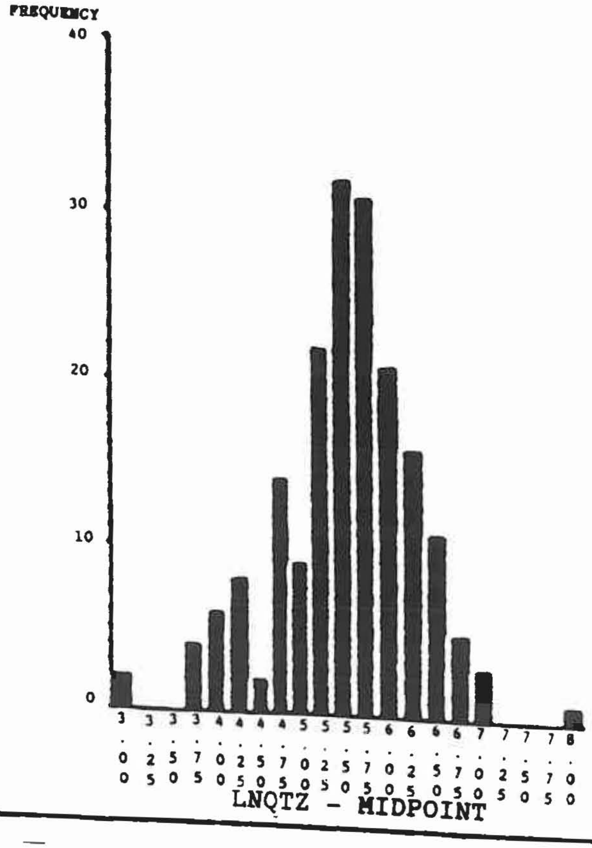
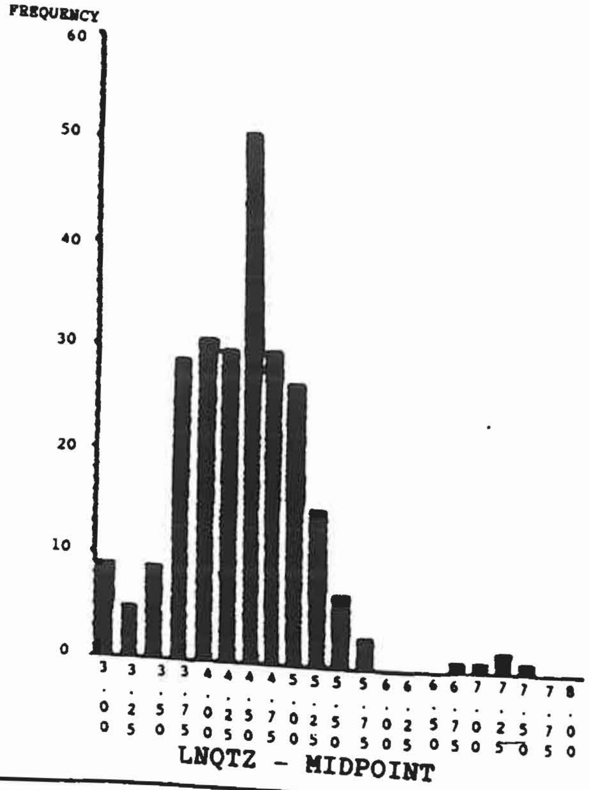
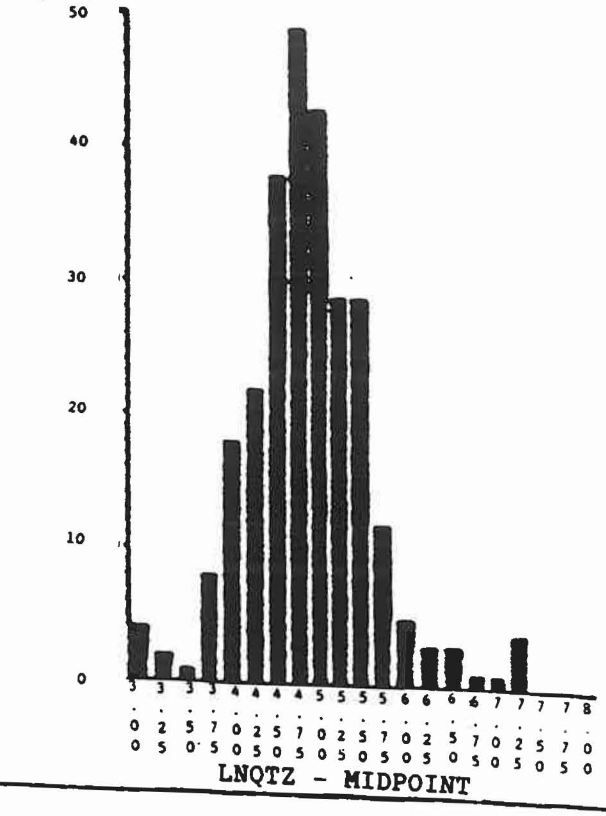


PLANT C Job Code = 550



PLANT D Job Code = 550



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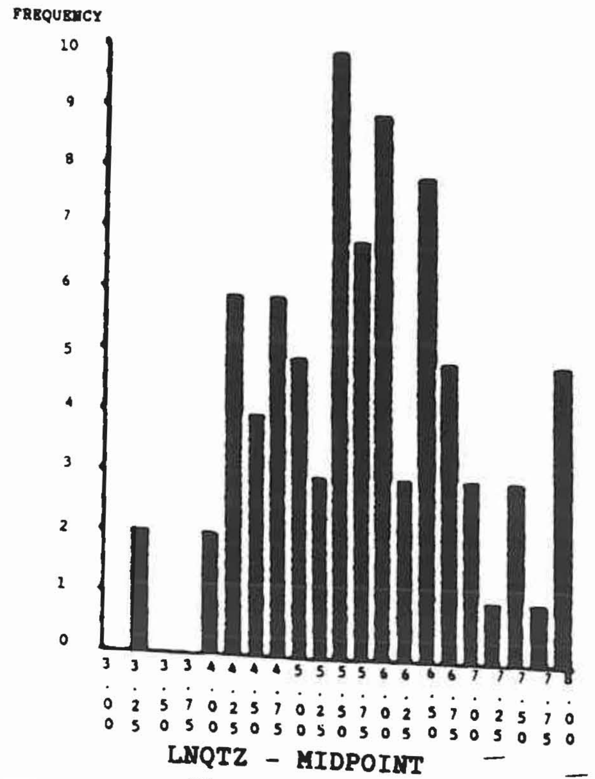

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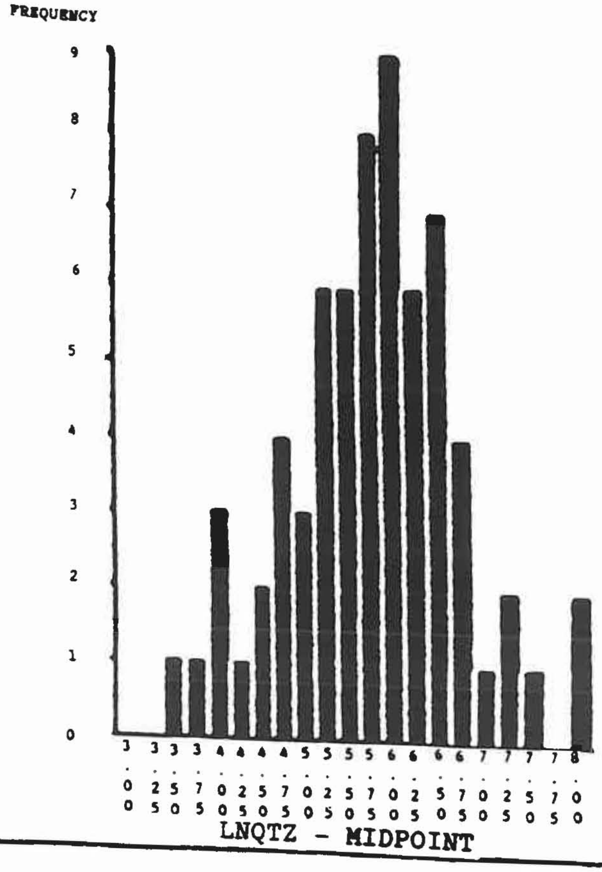

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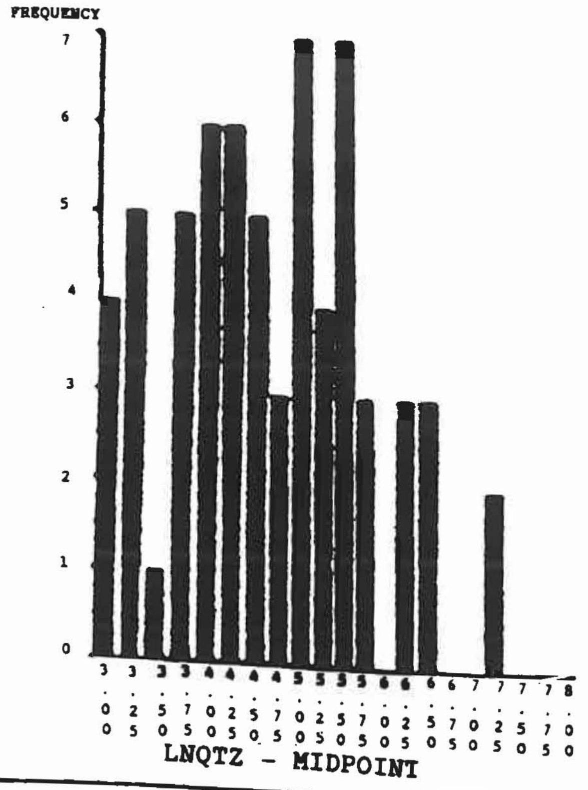

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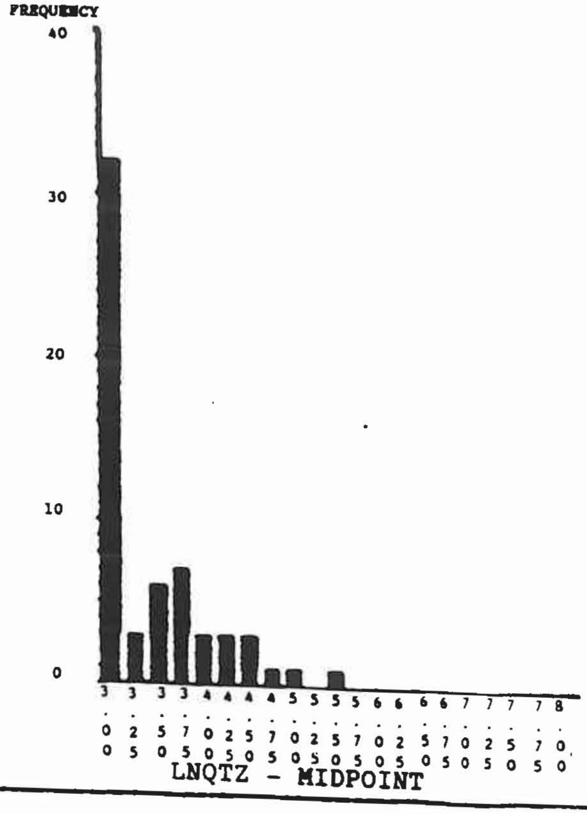

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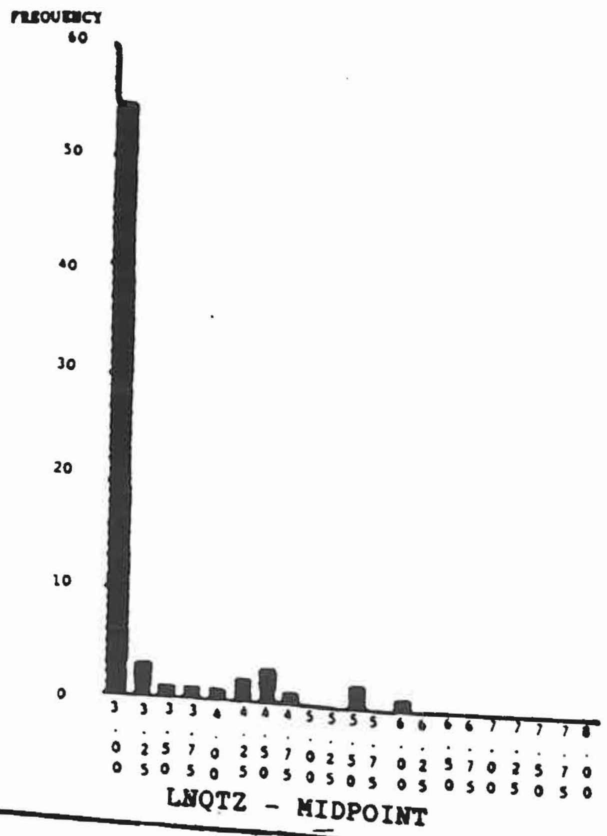
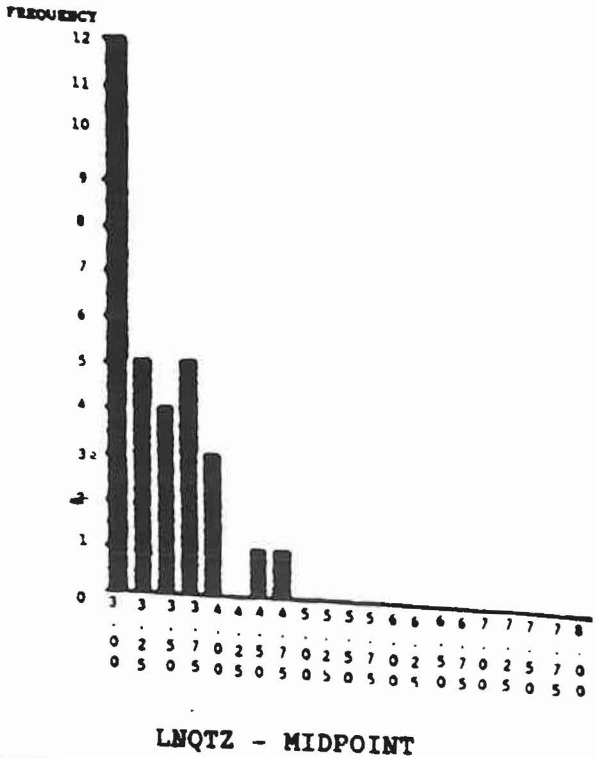


PLANT D Job Code = 402



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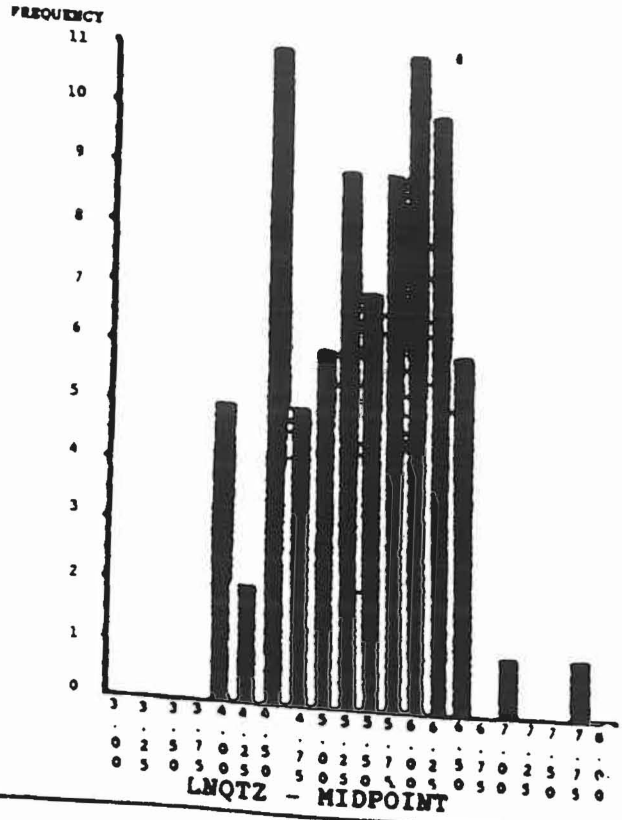

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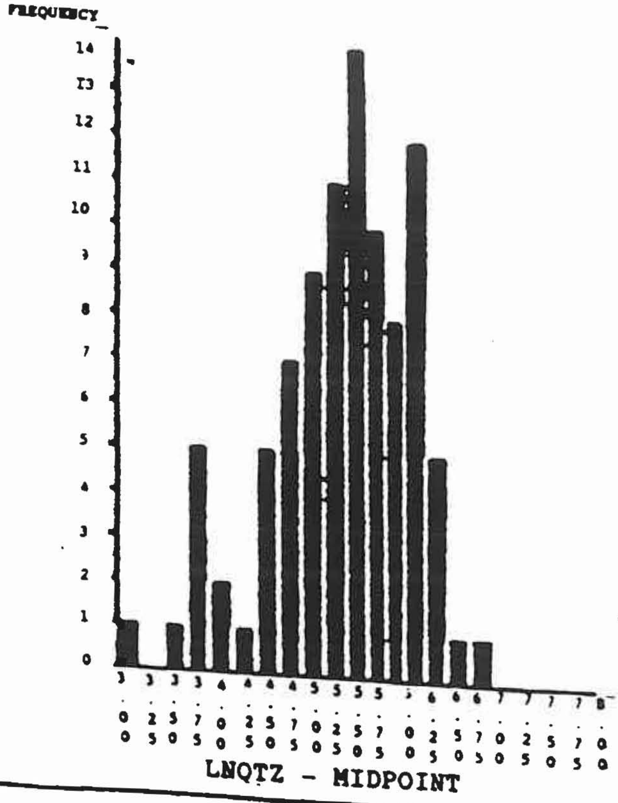

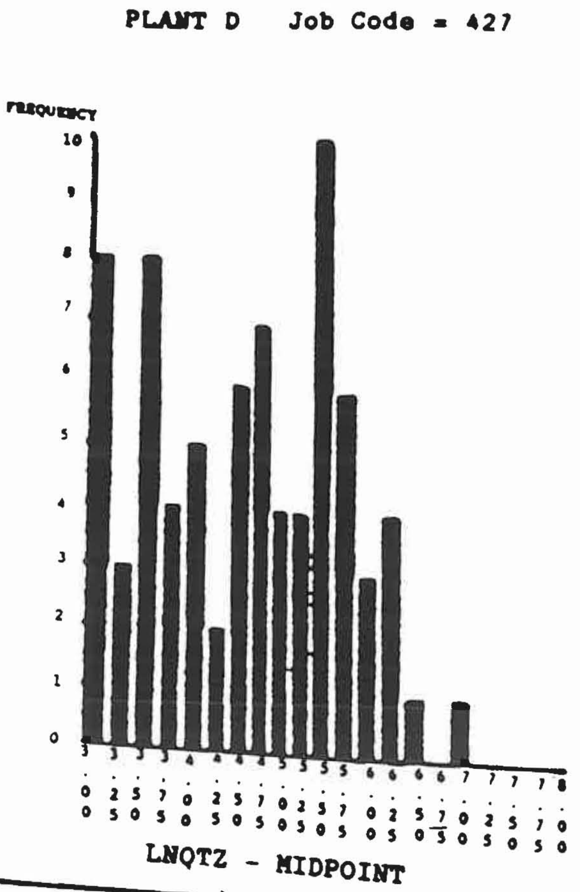

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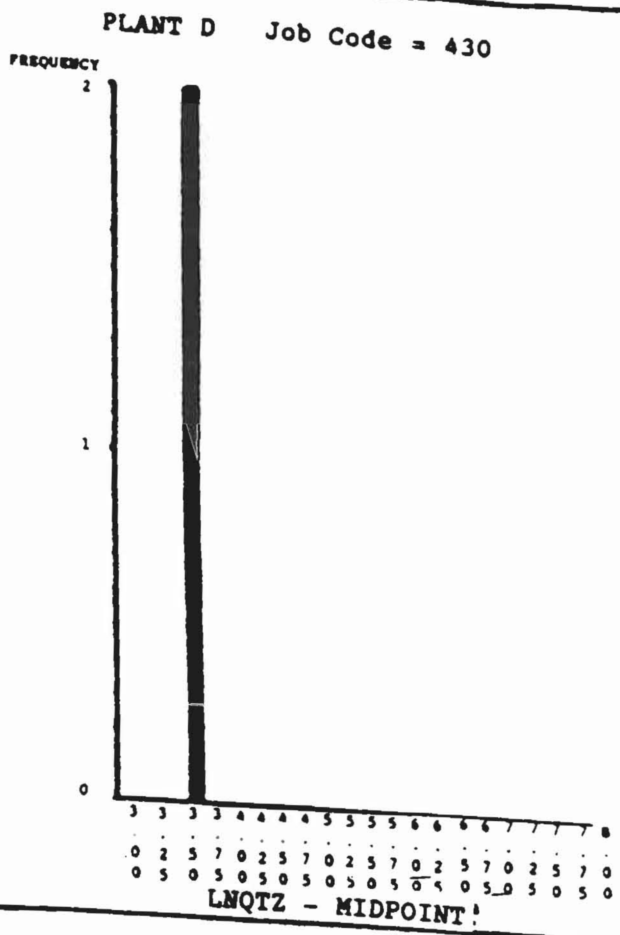

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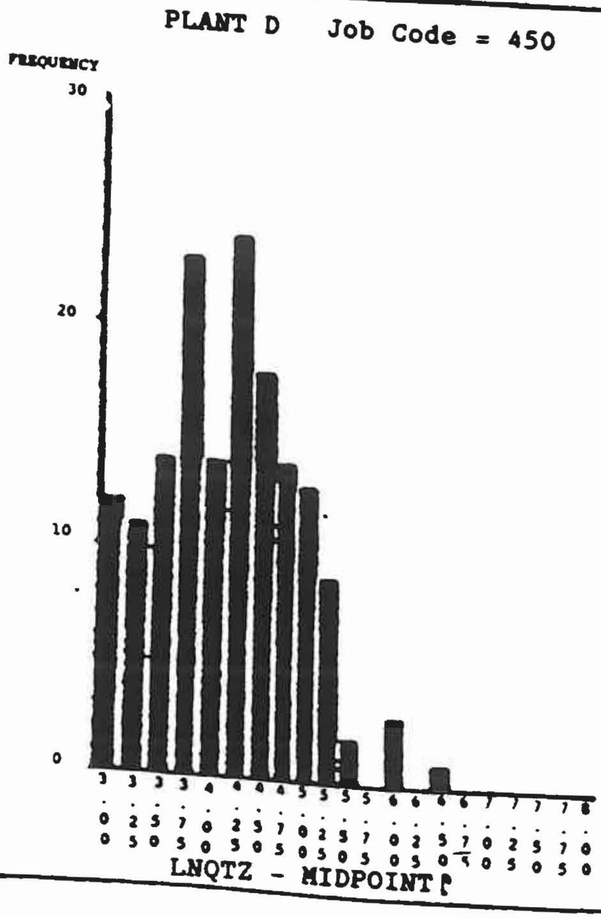
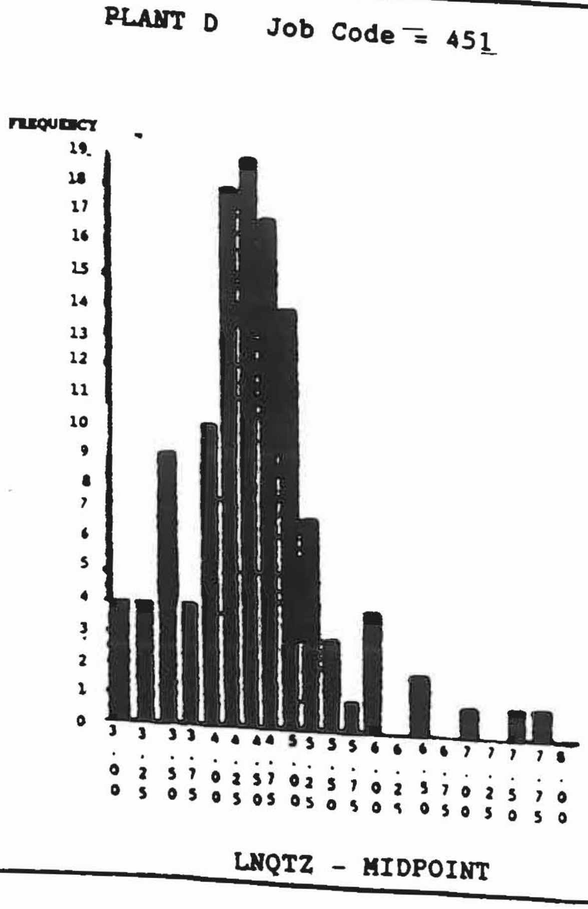
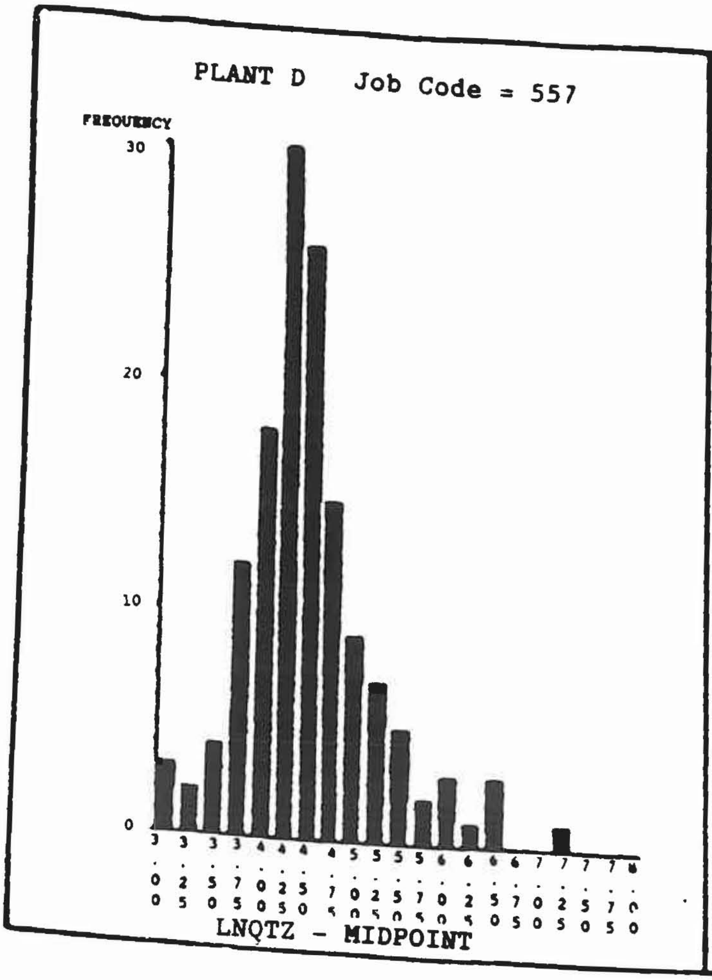
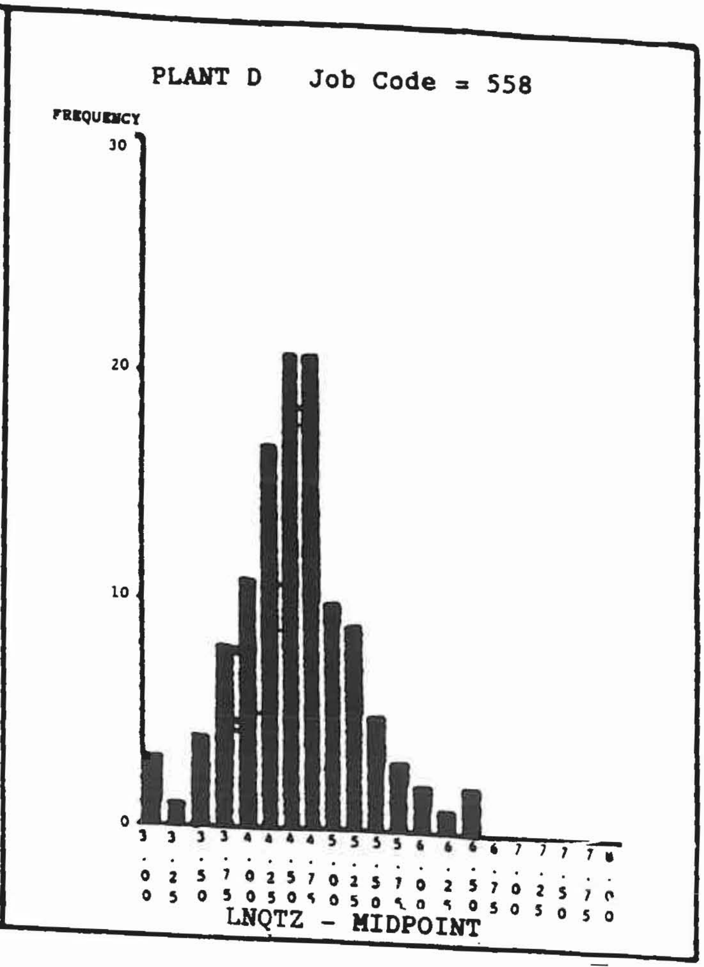


PLANT D Job Code = 450



PLANT D Job Code = 451


PLANT D Job Code = 557


PLANT D Job Code = 558

Appendix III

Geometric mean (GM) quartz exposure was estimated from personal dust samples for every job category (see coding scheme in Appendix I) in each plant during 1976 to 1987 according to the following procedure:

1) A log-linear model (see text) was employed to determine differences in the GM during time periods when dust controls and production processes had differed, and during years within these time periods.
2) The arithmetic mean (AM) and 95% confidence interval (CI) were calculated from samples pooled over consecutive years in which serial differences in the GM was not found. Results of the AM analysis are summarized in Tables AIII-1 to AIII-4.

Table AIII-1

Arithmetic mean (AM) quartz concentrations ($\mu g/m^3$) and statistics by job code for Plant A

Job Code+	Year of Samples+	Number of Samples	Number of Years++	AM	95% Confidence Interval Lower	Upper	Length	CV**
100	77	1	1	8	--	--	--	--
103	77	5	1	24	13	37	24	39
106	77	2	1	9	7	10	3	2
107	77	2	1	8	0	53	90	66
108	77	2	1	16	0	90	148	52
300	77	1	1	13	--	--	--	--
301	77-84	2	2	31	0	93	125	23
399	77-82	2	2	96	0	954	*	100
400	77-83	3	2	158	0	515	715	91
401	80-86	6	4	62	0	128	131	100
402	80-83	3	2	50	0	117	134	54
425	83-86	7	4	140	67	214	147	56
427	77-80	3	2	138	0	412	546	79
429	77-80	7	3	77	5	148	142	100
	82	2	1	489	0	*	*	51
431	77	2	1	232	0	976	*	36
	78-80	4	2	42	17	66	48	37
450	77-83	21	7	446	112	780	668	164
451	77-81	23	4	253	152	356	204	93
452	77-78	3	2	515	0	*	*	68
	80	6	1	68	14	122	108	76
	81-83	4	3	780	0	*	*	71
453	80-81	14	2	464	0	*	*	269
500	80-85	4	3	137	0	370	466	107
501	80-84	2	2	77	0	901	*	120
550	77	12	1	124	65	185	120	76
	80	13	1	62	18	106	88	117
	81-82	3	1	485	0	*	*	76
	83-85	5	3	79	0	182	206	105
551	77-78	9	2	614	381	848	466	49
	79-83	74	5	794	434	*	722	196
552	79-80	46	2	740	278	*	925	210
	81	21	1	339	210	467	257	83
620	77-82	2	2	53	0	495	884	93
621	77-82	2	2	47	0	328	561	66
622	77	1	1	48	--	--	--	--
701	80	1	1	16	--	--	--	--
704	80	1	1	25	--	--	--	--
708	80	2	1	47	0	241	388	46
801	80	1	1	51	0	--	--	--
803	80-82	3	2	22	0	69	95	87
805	77	1	1	60	0	--	--	--

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*Greater than 1000.

+There are 42 job-year categories (lines in the table).

**CV = (Standard deviation/arithmetic mean)*100.

++Number of years in which samples were collected.

Table A III-2

Arithmetic mean (AM) quartz concentrations ($\mu g/m^3$) and statistics by job code for Plant B

Job Code+	Year of Samples+	Number of Samples	Number of Years++	AM	95% Confidence Interval Lower	Upper	Length	CV**
100	77-82	4	3	31	0	76	91	93
	85-86	6	2	486	0	*	*	132
102	82	1	1	95	--	--	--	--
104	79-86	14	6	22	2	41	39	158
108	82-83	2	2	31	0	264	466	85
109	77-85	13	7	34	5	63	58	143
200	77-87	64	11	200	131	269	138	138
300	78-86	28	9	91	53	128	75	106
450	77-81	8	5	453	88	819	731	96
452	80	1	1	74	--	--	--	--
713	79-81	3	2	188	0	404	433	47
500	79-82	12	4	343	161	525	363	83
	83-85	13	3	137	93	181	88	53
	86-87	6	2	73	21	126	105	68
708	81-87	8	3	113	0	308	359	205
801	80	1	1	13	--	--	--	--
802	79-82	3	2	52	0	146	187	72
808	81	1	1	69	--	--	--	--
809	80	1	1	182	--	--	--	--

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*Greater than 1000.

+There are 19 job-year categories (lines in the table).

**CV = (Standard deviation/arithmetic mean)*100.

++Number of years in which samples were collected.

Table AIII-3

Arithmetic mean (AM) quartz concentrations ($\mu g/m^3$) and statistics by job code for Plant C

Job Code+	Year of Samples+	Number of Samples	Number of Years++	AM	95% Confidence Interval			CV**
					Lower	Upper	Length	
105	80-82	2	2	12	10	14	4	2
300	77-85	14	7	35	13	58	41	110
401	79-83	20	5	297	182	412	230	83
	84-87	11	4	*	0	*	*	188
402	78-84	26	7	56	40	72	32	71
	86-87	5	2	170	18	322	304	72
500	78-84	7	5	42	4	81	77	97
501	84-87	6	4	169	46	291	245	69
502	78-87	21	7	168	120	217	97	63
508	79-81	13	3	38	15	61	45	99
509	77-82	9	5	55	33	78	44	52
550	77-86	19	10	85	45	125	80	97
	87	3	1	182	94	270	177	20
555	77-87	21	7	133	62	204	141	116
600	79-86	3	2	352	0	*	*	141
700	77	2	1	47	0	324	554	66
708	78-85	8	5	106	4	208	204	115
800	79-83	6	4	67	0	144	153	108
802	77	1	1	67	--	--	--	--
807	87	1	1	186	--	--	--	--
808	79-80	4	2	50	18	83	65	40
809	79-82	9	4	62	12	113	101	105

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*Greater than 1000.

+There are 22 job-year categories (lines in the table).

**CV = (Standard deviation/arithmetic mean)*100.

++Number of years in which samples were collected.

Table AIII-4

Arithmetic mean (AM) quartz concentrations (μg/m^3) and statistics by job code for Plant D

Job Code+	Year of Samples+	Number of Samples	Number of Years++	AM	95% Confidence Interval			CV**
					Lower	Upper	Length	
100	84-87	21	4	40	29	50	21	57
101	74-83	27	8	62	42	83	41	83
104	73-87	34	13	22	17	27	10	65
109	73-87	31	13	28	19	38	19	92
110	79-87	16	9	18	12	23	12	63
200	74-87	60	14	34	24	44	20	114
202	74-87	28	13	93	55	131	76	106
300	76,79-87	65	10	21	9	34	26	243
	78	5	1	155	39	271	232	60
301	76,81-87	17	8	27	21	34	13	47
	79-80	4	2	151	0	301	301	63
303	76-87	18	10	7	3	11	7	104
399	78-87	21	9	51	32	69	38	82
400	74-84	20	9	37	23	51	28	81
401	74-87	47	11	18	6	29	23	224
402	73-87	31	13	32	22	42	20	85
425	74-80	37	6	477	355	599	243	76
	81-83	23	3	222	154	290	136	71
	84-87	23	4	147	104	189	86	68
426	73-80	34	4	434	374	493	119	39
	81-83	24	3	278	177	379	202	86
	84-87	35	4	143	117	169	52	53
427	78-80	34	3	296	227	365	138	67
	81	12	1	100	45	155	109	86
	82-84	21	3	39	28	50	22	61
	85-86	9	2	112	31	193	162	94
428	78-80	14	3	818	484	*	668	71
	82-87	34	6	90	76	105	28	45
430	86	2	1	44	29	59	30	4
710	79-80	10	2	278	215	341	126	32
	81-83	17	3	133	76	190	114	83
	84-85	22	4	62	45	79	34	63
450	73-77	12	4	100	60	142	82	64
	78-84	112	7	80	64	97	33	111
	85-87	34	3	107	80	134	54	72
451	73-78	2	2	166	125	207	81	3
	79-81	47	3	80	60	100	39	84
	82-84	38	3	213	55	370	315	225
	85-86	24	2	249	155	343	189	90
	87	8	1	75	52	98	46	37
454	74-77	3	2	49	0	202	305	125
	78-84	25	7	91	61	120	60	80
	85-87	21	3	75	55	96	41	60
458	76-87	43	11	92	66	117	51	91

Table AIII-4 continued

Arithmetic mean (AM) quartz concentrations (μg/m^3) and statistics by job code for Plant D

					95% Confidence Interval			
Job Code+	Year of Samples+	Number of Samples	Number of Years++	AM	Lower	Upper	Length	CV**
500	74-77	7	3	*	0	*	*	221
	78-79	43	2	492	413	571	159	52
	80-81	56	2	341	296	387	91	50
	82-85	58	4	231	198	265	67	55
	86-87	23	2	132	94	170	76	67
507	74-87	33	11	59	39	80	42	99
550	73-76	11	2	471	12	930	919	145
	77-79	78	3	148	111	186	74	111
	80-84	125	5	83	74	93	19	64
	85-87	37	3	68	56	79	23	50
551	73-84	4	2	219	0	464	490	70
556	75-77	12	3	146	75	218	143	77
	78	10	1	233	145	321	176	53
	79-82	147	4	157	134	180	46	90
	83	14	1	83	61	104	42	44
556	84	13	1	117	84	149	65	46
	85-86	56	2	285	189	380	191	125
	87	20	1	132	84	180	96	78
557	74-84	141	11	123	98	148	50	123
558	76-84	86	9	124	99	150	51	96
	85-87	32	3	128	102	153	51	56
559	85-86	11	2	344	194	494	300	65
	87	9	1	136	48	225	177	84
560	86	21	1	146	107	185	78	59
	87	10	1	86	50	122	72	58
561	85	7	1	215	161	269	108	27
	86	16	1	171	125	216	91	50
	87	9	1	133	15	251	235	115
600	84	2	1	82	0	274	383	26
620	74-80	5	3	32	2	62	61	77
700	76-87	46	11	26	15	37	22	146
701	79-87	33	9	39	8	60	42	153
702	78-87	33	10	27	5	38	23	122
800	74-81	5	3	72	29	115	86	48
805	79-87	30	9	15	11	20	9	76
809	86	1	1	12	-	-	-	-

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*Greater than 1000.

+There are 80 job-year categories (lines in the table).

**CV = (Standard deviation/arithmetic mean)*100.

++Number of years in which samples were collected.

APPENDIX IV

Recording Forms for Abstracted OHP Data

MORTALITY STUDY DATA

RECORD CODE 1 ☐ (0 = ORIGINAL: D = DELETE, U = UPDATE, C = CHANGE)
STUDY CASE 2 ☐
PLANT ID. 4 ☐
NAME (L, S, F, M) 10 ☐
STREET 45 ☐
CITY 70 ☐
STATE 85 ☐
ZIP 87 ☐
DATE OF DET. OF STATUS 92 ☐
SOURCE OF ADDRESS 96 ☐
DATE OF BIRTH 98 ☐
SOCIAL SECURITY NO. 105 ☐
SEX 114 ☐ (M = MALE, F = FEMALE)
RACE 115 ☐ (0 = UNKNOWN, 1 = WHITE, 2 = BLACK, 3 = HISPANIC, 4 = A
5 = ASIAN & PACIFIC, 6 = OTHER)
TELEPHONE NO. 116 ☐
DECEASED (Y) (N) 1 ☐
DATE OF DEATH 2 ☐
PLACE: CITY 8 ☐ STATE ☐

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JOB HISTORY AT PLANT	JOB TITLE	DATES BEGIN MTH	DAY	YR	END MTH	DAY	YR	JOB CODES DEPT.	JOB.
25									
39									
53									
67									
81									
95									
09									
1									
15									
29									
43									
57									
71									
85									
99									

COMPANY PRE-EMPLOYMENT WORK HISTORY*

	Ever worked (Y,N)	Years Worked
1. Rock, coal, uranium mine	____	____
2. Quarry including sand	____	____
3. Milling quarried materials	____	____
4. Foundry	____	____
5. Sand blasting	____	____
6. Pottery	____	____
7. Construction, insulation, shipyard	____	____
8. Drilling	____	____
9. Asbestos manufacturing	____	____
10. Talc	____	____
11. Diatomaceous earth	____	____
12. Grinding or sanding	____	____
13. Welding	____	____
14. Other dusty jobs	____	____
Any dust job (total)	____	____

*Any dusty job ever held other than at sand plant presently employed.

COMPANY EXAMINATION DATA ON EVERY EXAM AFTER JANUARY 1, 1976

	Year of exam											
	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Month of exam(MM)												
Day of exam (DD)												
Age at exam (YY)												
Height (in)(xx)												
(cm)(xxx)												
Weight (lb)(xxx)												
(kg)(xx)												
Spirometry test: Tracing (Y,N)												
FEV$_1$ (x.xxx)												
FVC (x.xxx)												
Smoking history: Cigarettes Status(C,X,N)												
Yrs. smoked												
Pks./day												
Pack-years												
Year quit												
Pipe (Y,N)												
Cigar(Y,N)												
Radiograph: Quality (1,2,U)												
Comb. profusion (0,1,2,3)												
Type (0,R,I,B)												
Large (0,A,B,C)												

COMPANY EXAMINATION DATA ON FIRST EXAM AFTER JANUARY 1, 1976 AND MOST RECENT EXAM

	First exam after Jan. 1, 1976	Most recent exam
Date of exam (MM DD YY)	__ __ /__ __ / __ __	__ __ /__ __ / __ __
Medical history Ever had (Y,N):		
Heart trouble	___	___
High blood pres.	___	___
Asthma	___	___
Hayfever	___	___
Bronchitis	___	___
Pleurisy	___	___
Pneumonia	___	___
Tuberculosis	___	___
Cough blood	___	___
Emphysema	___	___
Severe sinus	___	___
Kidney disease	___	___
Cancer	___	___
Allergies	___	___
Chest operation	___	___
Chest accident		
Respiratory Symptoms (Y,N):		
Cough most days and nights for ≥3 months/yr	___	___
Phlegm most days and nights for ≥3 months/yr	___	___
Dyspnea when walking up slight hill or hurrying on level ground	___	___
Dyspnea when walking with others of own age	___	___
Ever have attacks of wheezing		

ENVIRONMENTAL SAMPLES

1. Type of sample (A:area; P:personal) ____

2. Date of sample (MM DD YY) _ _ / _ _ / _ _

3. If personal sample:
Name of person sampled:
_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _
(Last, first, Initial)

Social security number of person sampled _ _ _ _ _ _ _ _ _

Job title of person sampled ________________ Code: _ _ _

4. Source of sample (N:NIOSH; U:USPHS;
C:Company; M:MSHA; S:State; I:Insurance) ___

5. Sampling duration (hours) _ . _

6. Analytical method of quartz determination (I:IR; X:XRD): _

7. 8-hour TWA respirable dust concentration (mg/m^3) _ _ . _

8. 8-hour TWA respirable quartz concentration (ug/m^3) _ _ _ _ . _