ENVIRONMENTAL SURVEYS IN THE BARRE, VERMONT AND ELBERTON, GEORGIA GRANITE INDUSTRIES

1973-1974

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Worker exposures to respirable free silica (7631869) were determined at five granite processing facilities in Vermont and twelve similar facilities in Georgia during 1973 and 1974. The surveys were part of a NIOSH study of silica exposures of workers in the granite industry (SIC-1423). There was an average of 13.0 percent free silica in samples collected at the Vermont granite facilities. In the five Vermont facilities, 27, 0, 42, 43, and 50 percent, respectively, of all air samples analyzed exceeded the OSHA standard for respirable free silica of 100 micrograms per cubic meter. For the 12 Georgia facilities, the percentage of air samples exceeding the OSHA standard was 7, 21, 9, 24, 29, 15, 75, 22, 17, 11, 75, and 25 percent, respectively. There was an average of 13.4 percent free silica in the total number of samples collected in Georgia. Of the granite workers in Vermont, 35.9 percent were exposed to free silica in concentrations above the OSHA standard, compared with a comparable figure of 18.3 percent for the Georgia workers. The authors recommend that exposures in two operations, wire sawing and polishing, for both Vermont and Georgia facilities be reduced.

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ABSTRACT

In the Vermont granite industry, pulmonary function tests were published in 1974 on workers who had been studied four years earlier and who had remained in jobs where their exposure to granite dust had not essentially changed. The workers exhibited a decrement in forced vital capacity. This condition was attributed to excess granite dust in the Vermont granite industry, and to prevent these effects, it was recommended that granite dust concentrations be lowered.

This report presents the results of industrial hygiene surveys initiated in 1973 to document worker exposures to respirable free silica in both the Vermont and the Georgia granite industries.

Five plants in Vermont and twelve plants in Georgia, believed to be representative of the industry in each area, were selected for monitoring. Overall, the Vermont granite industry showed a greater percentage of workers exposed above the OSHA standard for free silica (35.9%) than did the Georgia granite industry (18.3%). The difference in worker exposure found in these two granite industries in different geographical locations, may partly be explained by climate conditions, and by the architecture of the plants. For example, in the south, structures with only three sides enclosed are used which permits more dilution ventilation than is obtained in the sturdy, fully enclosed structures used in the north.

In both Vermont and Georgia, exposures in two operations, wire sawing and polishing, were relatively high (arithmetic mean, 98 ug/m^3 for wire sawing, 80-86 ug/m^3 for polishing) compared to the other job categories. It is recommended that wire sawing be run out of doors, or in isolated areas with minimal enclosures. The polishing operation will require engineering study to reduce exposures. This may require isolation, and/or enclosure and ventilation.

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INTRODUCTION

Due to the fact that health effects were reported among workers in the Vermont granite industry which were attributed to an excessive exposure to granite dust[1,2], NIOSH initiated studies in 1973 designed to evaluate the exposure of workers to respirable free silica in both the Barre, Vermont and Elberton, Georgia granite industries. Numerous surveys had been made in both facilities using the impinger method of sampling which is actually suitable only for collecting general area samples. A newer method, the personal respirable sampling method, produces a better estimate of the amount of respirable dust to which the individual worker is exposed. A few surveys had been conducted in Vermont using the new techniques. However, this method apparently had never been employed in the Georgia Granite Industry. The Vermont survey was conducted in November, 1973 and the Georgia survey in April, 1974. The personal respirable sampling method was used in both surveys.[3]

The granite industry in Barre, Vermont had a total population of less than 2000 employees with 1200-1300 working in the fifty fabrication facilities. Most of these facilities were small, employing no more than 10 to 15 workers, but there were two larger companies that had over 100 employees each. Five facilities believed to be a representative cross section of this industry were chosen for this study. There were approximately 300 employees in the five plants monitored.

In the Georgia Granite Industry, the total population was about the same as in Vermont, and though this industry did have a few plants with about 100 employees, the majority of the 65 plants were smaller than most of those in Vermont. Essentially, all the plants in Vermont were represented by the AFL-CIO. In the Georgia industry there were no unions. In Georgia there were 545 employees in the 12 plants involved.

The working population is relatively stable in both locations with most employees having spent most, if not all, of their working careers in the industry.

GRANITE FABRICATION PROCESS

The process of fabricating granite into monuments or shapes was essentially the same in all the facilities in both Vermont and Georgia. A section of granite weighing approximately 30 tons was moved from the quarry and set up in a shed, where several wire saws were used to cut the block of granite into slabs. A wire saw is a device consisting of continuous strands of twisted wire capable of carrying carborundum abrasive. These wires, which are stretched between large wheels that serve as pulleys, may be up to several thousand feet in length to increase wire life by providing sufficient cooling time between cutting contact. The cutting was done wet with the abrasive fed onto the wire at the cutting area. The rate of cutting of a slab of granite was about one foot per hour.

After cutting with the wire saw, the slab was polished on both sides, first with carborundum, then with aluminum oxide, and finally with tin oxide or rouge (iron oxide) applied with a felt buffer. After polishing, the slab was split, usually with a hydraulic cutter, into blocks of a desired size. This machine, known as a hydrosplit, is capable of cutting through about one foot of granite.

Next, the unpolished edges of the blocks were trimmed with a hand chisel, then further shaped with a carborundum wheel or a buffing tool to form the finished surface. Further modiciation of the stone to form designs or to carve intricate figures was accomplished by means of a pneumatic chisel and lettering was done by abrasive blasting. Only non-silica abrasive blasting materials were used for this operation in Vermont but in Georgia silica sand was still being used in a few facilities .

SURVEY METHODS

Sampling

In fabricating granite the respirable dust formed contains free silica, which is a potential health hazard. In this study the worker's exposure to respirable dust was measured by the personal respirable mass sampling techniques[4]. Dust was collected by means of a 2-stage sampling assembly worn on the employee's collar through which air was pulled at a flow rate of 1.7 lpm. The sampling assembly includes a 10 mm nylon cyclone which separates the non-respirable dust fraction from the respirable fraction. The respirable fraction was then collected on a pre-weighed PVC 37 mm 5 um pore size membrane filter. Ideally, sampling was conducted over a worker's full 8-hour shift, though in practice the sampling period was usually nearer to seven hours. A total of 220 personal samples were collected in the five plants in Vermont, while in Georgia a total of 257 personal samples were collected in twelve plants.

Analysis

Personal respirable samples collected in all facilities were analyzed gravimetrically for net respirable weight and for free crystalline silica by the x-ray diffraction method[5]. Since it was not practical to analyze all samples collected by x-ray diffraction, between 25 to 50% of the samples collected in each plant were selected for this analysis. This was done in such a way as to represent various job classifications. The silica content of each sample analyzed was used to calculate the exposure of the worker who was monitored. For those workers whose samples were not analyzed for free silica, an average of the results of all samples from the same job category which were analyzed in each plant was used to calculate the exposure of workers. If no samples for a job category were analyzed then the average percentage free silica for that plant was used.

VERMONT GRANITE INDUSTRY RESULTS

In general in any one facility the free silica content of the individual samples analyzed differed little from the mean value of all the samples found in a par-

ticular facility, even though there are some individual exceptions where the departure from the mean is quite large. For example, of the 115 samples collected in Plant A, the mean free silica content of the 34 samples analyzed was 13.6% while in the saw shed, two individuals samples showed values of 23.6 and 21.6 percent free silica. A sample collected on a polisher showed a value of 30.2% while on a mechanic, 3.7% free silica. Tables 1 and 2 give a summary of results from the sampling surveys.

In addition to the data given in Tables 1 and 2, Tables A-1 to A-10 in Appendix A give results of sampling for respirable dust in each plant. From these data it appears that a greater percent of free silica is generated in the dust associated with large operations than with small operations. The dust samples from the two larger plants indicate the average free silica content of the respirable dust samples analyzed to be approximately 13% while the samples collected in the smaller plants indicate the average of the samples analyzed to be nearer to 10% free silica. Since only a few samples were collected in smaller plants, the lower free silica results may be reflecting only the imprecision of the x-ray diffraction method of analysis for free silica.

Of the samples collected in each plant, only Plant B, with a population of 10-12 people, had all samples below the OSHA standard for respirable dust. In the other plants surveyed, the exposures ranged from 27% of the samples collected above the standard in Plant A to 50% above in Plant E. In Plant A, with a population of 125-150, the majority of the samples above the standard were associated with the wire saw operation and to a lesser extent with polishing. In Plant C, with a population of 10-15, there were values above the standard in many areas primarily due to the fact that the "pick-up" ventilation system was not being operated at the time of the survey. Plant D, with a population of 10-15, had problems also principally with wire sawing and polishing.

Plant E, with a population 125-150, showed one-half of the samples collected to be above the standard for respirable dust. There were dust problems in essentially all the operations, but principally in stone cutting, abrasive blasting, and polishing. Such a situation could indicate either lack of make-up air or possibly the need for more process ventilation, or both.

Table 2 indicates that two job categories, stone cutter and saw operator, had the highest average exposures, 99 ug/m^3 and 98 ug/m^3 respectively. The average exposure for all job categories was above the NIOSH recommended standard of 50 ug/m^3 and all jobs showed at least one individual exposure in the 120 ug/m^3 to 210 ug/m^3 range.

TABLE 1

Summary of Results of Sampling for Respirable Free Silica
at Barre, Vermont - November, 1973

PLANT	PLANT POPULATION	NO. OF AIR SAMPLES COLLECTED	NO. OF AIR SAMPLES ANALYZED	AV. % FREE SILICA IN SAMPLE	SAMPLES >OSHA STANDARD		SAMPLES >100 ug/m^3		SAMPLES BETWEEN 50-100 ug/m^3		SAMPLES < 50 ug/m^3	
					NO.	%	NO.	%	NO.	%	NO.	%
A	125-150	115	34	13.6	31	27	22	19	51	44	42	37
B	10-12	6	5	8.2	0	0	0	0	6	100	0	0
C	10-15	12	8	10.2	5	42	4	33	5	42	3	25
D	10-15	7	5	10.6	3	43	2	29	2	29	3	42
E	125-150	80	41	12.9	40	50	28	35	44	55	8	10
TOTAL	280-342	220	93									

% FREE SILICA - AN AVERAGE OF ALL SAMPLES ANALYZED - 13.0%

TABLE 2
SUMMARY BY JOB CATEGORY OF PERSONAL SAMPLING
FOR RESPIRABLE FREE SILICA IN THE
VERMONT GRANITE INDUSTRY

JOB	NO. OF SAMPLES	RANGE ug/m^3 LOW	HIGH	ARITHMETIC MEAN ug/m^3	STD.ERR	GEOMETRIC MEAN ug/m^3	STANDARD DEVIATION	95% CONFIDENCE LIMITS ug/m^3 LOWER	UPPER
Lumper	20	19	180	79	8.9	71	1.68	55	90
Stone Cutter	42	17	190	99	6.7	88	1.71	75	100
Saw Operator	34	20	210	98	8.4	85	1.73	71	100
Polisher	32	20	170	80	6.8	70	1.75	52	86
Abrasive Blaster	29	19	180	66	7.0	57	1.74	46	70
Crane Operator	12	60	120	66	8.8	55	2.12	34	90
Miscellaneous Worker	51	11	180	66	4.4	59	1.65	51	68

GEORGIA GRANITE INDUSTRY RESULTS

In general in any one facility the free silica content of the individual samples analyzed differed little from the mean value found in the facility, even though there are some individual exceptions where the departure from the mean is quite large. For example, of the 74 samples collected in Plant F, the mean free silica content of the 22 samples analyzed was 14.3%, while individual samples ranged from 6.2% to 32.8% free silica. Tables 3 and 4 give a summary of results from the sampling surveys.

In addition to Tables 3 and 4, Appendix Tables A-11 to A-34 give results of sampling for respirable free silica in each plant. In ten plants, 7% to 29% of the samples collected showed exposure values above the OSHA standard for free silica while Plants L and P showed 75% of the samples above the standard. Plant L is a wire saw plant and this operation generates much dust. To further complicate the problem this facility has no open sides as do most of the other facilities in the area so there is little or no natural ventilation. If it is assumed that operators need only to watch the cutting operation without constantly adjusting the sawing equipment, dust exposure to personnel could be avoided by building a glassed-in enclosure supplied with filtered, cooled or heated air where the operator could be stationed to monitor the equipment.

The problem in Plant P is not as obvious as is that in Plant L. Plant P probably needs an additional air sampling survey to further validate the NIOSH findings since in surveying this plant only four samples were taken. It is possible that conditions at the time of the survey may not have been normal, though nothing was noticed that would suggest the dust levels were high.

Table 4 indicates that in the Georgia surveys, the job catagories that showed the highest average exposure to respirable free silica were the saw operators (98 ug/m^3), followed by the polishers with 86 ug/m^3. The other operations were essentially at or below the NIOSH recommended standard of 50 ug/m^3.

TABLE 3

SUMMARY OF RESULTS OF SAMPLING FOR RESPIRABLE FREE SILICA
AT ELBERTON, GEORGIA - April, 1974

PLANT	APPROXIMATE PLANT POPULATION	NUMBER OF SAMPLES COLLECTED	NO. OF AIR SAMPLES ANALYZED	AVERAGE % FREE SILICA IN SAMPLES	SAMPLES >OSHA STANDARD NO.	%	SAMPLES 100 ug/m^3 NO.	%	SAMPLES between 50-100 ug/m^3 NO.	%	SAMPLES ≤ 50 ug/m^3 NO.	%
F	200	74	22	14.3	5	7	1	1	11	15	62	84
G	100	56	23	12.3	12	21	9	16	18	32	29	52
H	60	32	11	13.7	3	9	3	9	8	25	21	66
I	50	25	14	17.2	6	24	5	20	7	28	13	52
J	30	17	10	12.7	5	29	4	24	4	24	9	53
K	25	13	7	13.2	2	15	2	15	3	23	8	62
L	15	8	6	9.9	6	75	5	63	2	25	1	12
M	15	9	4	15.2	2	22	2	22	4	44	3	34
N	15	6	6	11.1	1	17	1	17	0	0	5	83
O	15	9	5	7.7	1	11	0	0	1	11	8	89
P	10	4	1	10.9	3	75	2	50	1	25	1	25
Q	10	4	4	9.6	1	25	1	25	3	75	0	0
Total	545	257	113									

% Free silica - An average of all samples analyzed - 13.4%

TABLE 4
SUMMARY BY JOB CATEGORY OF PERSONAL SAMPLING
FOR RESPIRABLE FREE SILICA IN THE
GEORGIA GRANITE INDUSTRY

JOB	NO. OF SAMPLES	RANGE ug/m^3 LOW	HIGH	ARITHMETIC MEAN ug/m^3	STD.ERR	GEOMETRIC MEAN ug/m^3	STANDARD DEVIATION	95% CONFIDENCE LIMITS ug/m^3 LOWER	UPPER
Lumper	30	9.0	160	36	6.6	26	2.10	20	35
Stone Cutter	61	7.4	180	55	4.2	47	1.84	40	55
Saw Operator	29	4.3	830	98	29	51	3.16	33	79
Polisher	40	6.1	360	86	11	63	2.29	49	83
Abrasive Blaster	17	4.0	140	37	8.3	27	2.32	18	42
Crane Operator	32	15	92	39	3.5	34	1.61	29	41
Miscellaneous Worker	46	6.7	220	54	8.0	36	2.39	28	47

DUST CONTROL IN THE FABRICATION OF GRANITE

The control of granite dust in facilities in Vermont and Georgia is accomplished by a combination of local exhaust ventilation, dilution ventilation, wet methods, and the architecture of the buildings.

In both locations, local exhaust pick ups which are designed to operate up to 4000 fpm are used in operations such as hand chiseling and grinding of granite. In hand grinding, the exhaust can sometimes be attached to the tool, whereas for hand chiseling, the ventilation pickup is positioned by the operator to collect dust as he chips the granite. In order to have good dust control, he must constantly move the pickup as he works on the granite in order to keep it near enough to the work to effectively pick up the dust.

Other operations encountered in the granite industry are more difficult to control than those described above. For example, wire sawing dust control is not satisfactorily achieved even though the operation is done wet. That is, in wire sawing the abrasive is wet down as it is added to the cutting wire. During the sawing, a granite mud builds up. This mud is carried on the cutting wire and is thrown tangetially off the wire against a steel back-stop as the wire changes direction in traveling around the return wheel. In hitting the back-stop the granite mud disperses a fine dust laden aerosol which ends up as a fine airborne granite dust. This operation is not always isolated, and personnel who tend it usually stay in the vicinity without respiratory protection. NIOSH sampling results indicate that they receive free silica exposures near to or above the present OSHA standard of 100 ug SiO_2/m^3*.

In the polishing of granite, a similar situation is encountered as in wire sawing. In this operation the abrasive (applied wet) dries during the operation and disperses as a very fine aerosol containing granite dust. Workers in the

* OSHA STD: $= \frac{10\ mg/m^3}{\%\ SiO_2+2} = mg/m^3$ respirable dust

Use 100% for free silica which makes the OSHA for free silica 0.1 $mgSiO_2/m^3$ (100 $ugSiO_2/m3$)

vicinity of this operation according to NIOSH sampling results receive exposures near to or above the OSHA standard, as shown in the following table:

TABLE I

SUMMARY OF NIOSH MONITORING DATA FOR FREE SILICA ON WIRE SAWING AND POLISHING OPERATIONS

Wire Saw Operation	No. of Samples	Arithmetic Mean g SiO_2/m^3	Range g SiO_2/m^3
Vermont	34	98	20-210
Georgia	29	98	4.3-830
Polishing Operation			
Vermont	32	80	20-170
Georgia	40	86	6.1-360

Abrasive blasting is also performed in most plants, principally for cutting letters or designs on a finished stone. This is usually accomplished in a chamber where the operator is furnished an air supplied respirator. In Vermont, aluminum oxide is used as the abrasive blasting material, while in Georgia, sand is used. These abrasive blasting chambers are ventilated usually to a bag collector located on the roof or on the side of the building.

The major difference in ventilation and dust control needs in the Vermont and Georgia industries lies in the architecture of the buildings which is mandated by the differences in climate. In Georgia, the buildings are flimsy wood structures and many of them have one and one half sides open to the weather. Since the temperature is moderate for all but about two weeks in the year, the plants shut down during this period (around the first of January), and no heat is required. Because much of the facility is open to the out of doors, there is a great deal of dilution ventilation. Most of the sheds have a low speed 3' diameter fan that pulls air through the back of the building and exhausts it to the out of doors.

The buildings housing the Vermont granite industry are sturdy structures that can be closed up tightly in the winter. Some buildings have high bays and monitor type windows which, even in cold weather, help to reduce airborne dust levels. An examination of silica exposures in Plant A with several high bays shows lower dust levels than does plant E which has only one small high bay, while the rest of the building has low ceilings. This is shown in Appendix C, an attached report which contains floor plans of the Vermont plants, and indicates those with bays.

Plants which are closed tightly like those in Vermont need make up air. The addition of make up air is often accomplished through combination space heaters and make up air units. Since this survey was conducted in November, heated air was being supplied.

In two of the smaller facilities in Vermont (C & D), the ventilation system was shut off when the plant was entered. Local exhaust ventilation should be run whenever the plant is operating. In addition to not operating the ventilation, the sculptors in plant C refused to use ventilation pick ups since they claimed that it interfered with their work. It should be noted that ventilation was turned on before the plants were monitored and sculptors used their pick ups; however, the values for free silica were still high.

Plants C & D had populations of only 10-15 employees each. Of the twelve samples collected in plant C, four (33%) exceeded 100 ug SiO_2/m^3. At plant D seven samples were collected; two samples (29%) exceeded 100 ug SiO_2/m^3. This ranks over exposures at both plants C & D with plant E (population 125-150) where 80 samples were collected which showed 28 samples (35%) to exceed 100 ug SiO_2/m^3. This is shown in Table 1.

Free silica exposure to the workers in the Georgia granite industry in general were found to be lower than exposures to workers in the Vermont granite industry largely because of the fact that warmer climate in Georgia (lending to more open architecture of the buildings) resulted in greater dilution ventilation.

CONCLUSIONS

1. In Vermont, five granite facilities were surveyed in which the total employee population was approximately 300. The surveys involved the collection of 220 personal samples for respirable free silica. In four of the five plants, 27% to 50% of the workers monitored were exposed to respirable silica in excess of the OSHA standard. In Plant B, in which there were only 10-12 employees, none of the workers monitored were exposed to concentrations in excess of the standard. The limited number of samples collected at Plant B, however, would indicate the need for additional sampling to verify this finding.

   Plants C & D had populations of 10-15 employees each. Both plants had the ventilation turned off when they were entered, and the sculptor in Plant C refused to use ventilation pick ups since they claimed that it interfered with their work. The ventilation was turned on and in use before monitoring. Of the twelve samples collected in Plant C, four (33%) exceeded 100 mg SiO_2/m^3. At Plant D seven samples were collected; two samples (29%) exceeded 100 ug SiO_2/m^3. This indicates over exposures at both plants C & D are similar to Plant E (population 125-150)) where 80 samples were collected which showed 28 samples (35%) to exceed 100 ug SiO_2/m^3.

2. In the Georgia granite industry, twelve plants were surveyed in which the total population was approximately 545 employees. During these surveys, personal samples were collected on 257 workers. the results indicated that in the two small plants (L and P) 75% of the samples were above the OSHA standard. In the remaining ten plants, 7% to 29% of the samples indicated exposures in excess of the OSHA standard.

3. Exposures in most job categories were lower in Georgia plants than in Vermont plants. Exposures for polishers, however, were similar for both areas. For lumpers, stone cutters, abrasive blasters, and miscellaneous workers, confidence limits of the average exposures did not overlap with the Georgia plants having lower exposures. The remaining jobs, saw operators, and crane operators, had slightly overlapping confidence intervals but the Georgia plant's exposure means were lower.

4. Work practices and controls appear to be about the same in both industries. In Georgia, however, sand rather than a aluminum oxide was used as an abrasive blasting material.

5. The greatest difference between the two industries is in the climate and in the architecture which houses these industries. In Vermont, the facilities are sturdy structures which are capable of withstanding winter conditions while in Georgia the buildings are mostly flimsy wood buildings with at least one side open to the out of doors. This is possible because the climate is warm enough year around so that heat other than from a few small area heaters (salamanders) is not required. This results in a greater amount of dilution ventilation in the Georgia industry and may account for the lower percent of workers showing exposures in excess of the OSHA standard for free silica.

RECOMMENDATIONS

There are two operations in both Vermont and Georgia, wire sawing and polishing, which are constantly uncontrolled. Exposures to free silica to employees attending wire saws ranged from 20-210 ug SiO_2/m^3 in Vermont, and 4.3 to 830 in Georgia. The arithmetic means of the exposures in both Vermont and Georgia were 98 ug SiO_2/m^3.

The Polishing operation likewise gives high exposures in both locations, ranging from 20-170 ug SiO_2/m^3 in Vermont with a mean of 80 ug SiO_2/m^3. In Georgia values range from 6.1 - 360 ug SiO_2/m^3 with a mean of 86 ug SiO_2/m^3.

Wire sawing could best be controlled by running the operation out-of-doors, or in isolated areas with minimal enclosures.

The polishing operation will require engineering study to reduce exposures. This may require isolation, enclosure and ventilation, and perhaps some of all three of those approaches.

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APPENDIX A

VERMONT

SUMMARY TABLES AND RESULTS OF
SAMPLING FOR RESPIRABLE FREE SILICA

PLANTS A - E

November, 1973

TABLE A-1
SUMMARY OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT A

JOB	NO. OF SAMPLES	RANGE ug/m^3 LOW	RANGE ug/m^3 HIGH	ARITHMETIC MEAN ug/m^3	ARITHMETIC STD.ERR ug/m^3	GEOMETRIC MEAN ug/m^3	GEOMETRIC STANDARD DEVIATION	95% CONFIDENCE LIMITS ug/m^3 LOWER	95% CONFIDENCE LIMITS ug/m^3 UPPER
Lumper	8	38	130	78	13	71	1.61	48	110
Stone Cutter	12	17	150	65	12	54	1.91	36	82
Saw Operator	22	34	210	110	9.9	98	1.54	81	120
Polisher	21	20	120	66	6.9	58	1.74	45	74
Abrasive Blaster	15	19	96	43	5.1	39	1.53	31	49
Crane Operator	11	6.0	120	64	9.4	53	2.22	31	90
Miscellaneous Worker	26	11	120	57	5.7	50	1.71	41	63

TABLE A-2

RESULTS OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT A
November, 1973

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC. (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC. (ug/m^3)
Lumper	430	10.4*	28	0.73	0.37	46	38
	465	10.4*	78	0.79	0.95	120	99
	445	10.4*	96	0.76	1.2	150	130
	526	9.8	73	0.89	0.83	98	82
	482	10.4*	32	0.82	0.38	47	39
	460	10.4*	46	0.78	0.57	70	59
	491	11.0	100	0.84	1.1	140	120
	463	10.4*	46	0.79	0.57	70	58
Crane Operator	475	13.9	42	0.81	0.37	59	52
	426	14.2*	56	0.72	0.54	87	78
	449	14.9	50	0.76	0.44	75	66
	433	14.2*	75	0.74	0.72	120	100
	435	15.6	50	0.74	0.43	75	68
	444	14.2*	59	0.76	0.55	89	78
	450	12.3	40	0.76	0.43	61	53
	490	14.2*	32	0.83	0.27	44	39
	490	14.2*	5	0.83	0.043	6.9	6.0
	481	14.2*	34	0.82	0.29	47	41
	455	14.2*	94	0.77	0.86	140	120

TABLE A-2

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC, (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC, (ug/m^3)
Finisher	515	10.0	36	0.88	0.41	49	41
	515	8.9	37	0.88	0.47	51	42
	515	9.4*	24	0.88	0.29	33	27
	515	9.4*	28	0.88	0.34	39	32
	515	9.4*	35	0.88	0.42	48	40
	515	9.4*	24	0.88	0.29	33	27
	480	9.4*	16	0.82	0.20	23	20
	475	9.4*	23	0.81	0.30	34	28
Polisher	468	15.8	40	0.80	0.32	57	50
	475	17.1*	47	0.81	0.34	65	58
	470	17.1*	84	0.80	0.62	120	100
	495	14.1	90	0.84	0.76	120	110
	460	14.1	70	0.78	0.64	100	90
	480	30.2	80	0.82	0.32	100	98
	326	17.1*	45	0.55	0.48	92	82
	520	17.1*	82	0.88	0.55	110	93
	484	17.0	70	0.82	0.50	94	85
	484	17.1*	70	0.82	0.50	96	85
	495	13.3	80	0.84	0.72	110	95
	493	14.9	100	0.84	0.80	140	120
	497	17.1*	54	0.84	0.38	73	64

TABLE A-2

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC, (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC, (ug/m^3)
Stone Cutter	480	13.6*	59	0.82	0.53	83	72
	480	13.6*	46	0.82	0.41	64	56
	479	13.6*	14	0.81	0.13	20	17
	480	13.6*	47	0.82	0.42	66	57
	480	13.6*	33	0.82	0.30	47	40
	481	13.6*	59	0.82	0.53	83	72
	480	13.6*	103	0.82	0.92	140	130
	470	13.6*	16	0.80	0.14	22	20
	441	13.6*	32	0.75	0.32	50	43
	480	13.6*	64	0.82	0.57	89	78
	474	13.6*	125	0.81	1.1	170	150
Wire Saw Operator	475	12.4*	53	0.81	0.52	75	65
	495	13.6	60	0.84	0.52	81	71
	465	12.4*	27	0.79	0.28	41	34
	456	12.4*	54	0.78	0.56	81	69
	440	11.8	80	0.75	0.91	130	110
	460	11.7	91	0.78	0.99	140	120
Saw Shed Worker	455	15.6*	111	0.77	0.93	160	140
	455	15.6*	134	0.77	1.1	190	170
	455	15.6*	133	0.76	1.1	190	180

TABLE A-2

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC$_3$ (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC$_3$ (ug/m^3)
Saw Shed Worker	445	15.6*	144	0.76	1.2	210	190
	455	12.2	80	0.77	0.85	120	100
	448	15.6*	163	0.76	1.4	250	210
	460	23.6	100	0.78	0.54	140	130
	460	21.6	90	0.78	0.53	130	120
	470	15.6*	68	0.80	0.54	95	85
	470	15.6*	69	0.80	0.55	96	86
	470	11.1	50	0.80	0.56	98	62
	470	15.6*	63	0.80	0.50	88	79
	470	15.6*	62	0.80	0.50	88	78
	468	15.6*	66	0.80	0.53	93	82
	465	15.6*	68	0.79	0.55	96	86
	450	9.6	60	0.76	0.83	97	79
Abrasive Blaster	450	10.2*	25	0.76	0.33	40	33
	480	10.2*	49	0.82	0.59	72	60
	455	10.5	40	0.77	0.50	62	52
	482	12.6	50	0.82	0.48	71	61
	425	10.2*	69	0.72	0.94	110	96
	432	10.2*	39	0.73	0.62	63	53

TABLE A-2

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC$_3$ (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC$_3$ (ug/m^3)
Abrasive Blaster	460	10.2*	22	0.78	0.28	34	28
	478	10.2*	24	0.81	0.29	35	30
	481	10.2*	31	0.82	0.37	45	38
	450	10.2*	34	0.76	0.44	54	45
	480	10.2*	26	0.82	0.30	37	32
	456	10.2*	15	0.77	0.19	23	19
	480	10.2*	23	0.82	1.2	150	28
	455	7.4	30	0.77	0.53	48	39
	495	10.2*	20	0.84	0.24	29	24
Maintenance Worker	460	13.6*	93	0.78	0.87	140	120
	427	30.7	70	0.73	0.31	100	96
Boxer (Wood)	448	13.6**	40	0.76	0.39	61	53
	493	13.6**	45	0.84	0.39	61	54
Dye Washstand Worker	454	13.6**	57	0.77	0.54	84	74
	450	13.6**	35	0.76	0.34	53	46
	440	13.6**	37	0.75	0.37	58	49
	448	13.6**	23	0.76	0.23	36	30

TABLE A-2

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC (ug/m^3)
Wash Tank Worker	482	14.8	80	0.82	0.66	110	98
	495	5.5	22	0.84	0.47	36	26
Wash Stand Worker	495	13.6**	29	0.84	0.25	39	35
Layout Worker	480	16.5	40	0.82	0.30	56	49
Mechanic	480	3.7	30	0.82	0.99	55	37
	470	13.6**	44	0.80	0.40	62	55
Tool Grinder	445	13.6**	26	0.76	0.25	39	34
Grouter	445	9.4*	28	0.76	0.39	44	37
	455	9.4	80	0.77	1.1	120	100
Shipper	490	13.6**	9.0	0.83	0.080	12	11
Lift Truck Operator	480	13.6**	35	0.82	0.32	50	43
Planer	454	13.6**	54	0.77	0.51	80	70
	471	13.6**	49	0.80	0.45	70	61

TABLE A-2

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC (ug/m^3)
Contour Planer	475	9.7*	23	0.81	0.29	34	28
	445	9.7	90	0.76	1.2	140	120
Hydro-Split Operator	455	13.6**	34	0.77	0.32	50	44
Foreman	460	13.6**	53	0.78	0.50	78	68
	445	13.6**	27	0.76	0.26	41	36
	480	11.1	50	0.82	0.55	72	61

* Percent free silica based on mean for that job.

** Percent free silica based on mean for entire plant.

\+ OSHA standard is $\frac{10}{\%SiO_2+2}$

TABLE A-3
SUMMARY OF PERSONAL SAMPLING FOR RESPIRABLE
FREE SILICA AT PLANT B

JOB	NO. OF SAMPLES	RANGE ug/m^3 LOW	RANGE ug/m^3 HIGH	ARITHMETIC MEAN ug/m^3	STD.ERR ug/m^3	GEOMETRIC MEAN ug/m^3	STANDARD DEVIATION	95% CONFIDENCE LIMITS ug/m^3 LOWER	95% CONFIDENCE LIMITS ug/m^3 UPPER
Lumper	1	--	52						
Saw Operator	3	53	66	60	3.8	60	1.12	45	79
Miscellaneous Worker	2	55	79	67	12	66	1.29		

TABLE A-4

RESULTS OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT B
November, 1973

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC. (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC. (ug/m^3)
Lumper	455	8.8	40	0.77	0.59	63	52
Wire Saw Operator	450	8.6	40	0.76	0.77	82	66
	455	7.2	40	0.76	0.73	66	53
	443	7.9*	46	0.75	0.78	78	61
Sculptor	324	7.5	30	0.55	0.73	66	55
Foreman	447	9.1	60	0.76	0.87	97	79

* Percent free silica based on mean for that job.
** Percent free silica based on mean for entire plant.
+ OSHA standard is $\frac{10}{\% SiO_2 + 2}$

TABLE A-5

SUMMARY OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT C

JOB	NO. OF SAMPLES	RANGE ug/m^3 LOW	HIGH	ARITHMETIC MEAN ug/m^3	STD.ERR	GEOMETRIC MEAN ug/m^3	STANDARD DEVIATION	95% CONFIDENCE LIMITS ug/m^3 LOWER	UPPER
Lumper	1		180						
Stone Cutter	2	130	150	140	10	140	1.11		
Saw Operator	2	38	120	79	41	68	2.25		
Polisher	2	78	89	84	5.5	83	1.10		
Abrasive Blaster	1		74						
Miscellaneous Worker	4	35	77	52	10	49	1.44	27	88

TABLE A-6

RESULTS OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT C
November, 1973

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC (ug/m^3)
Lumper	468	10.2**	140	0.80	1.7	210	180
Polisher	460	8.7	61	0.78	0.89	96	78
	465	8.7*	70	0.79	1.0	110	89
Stone Cutter	465	13.6	100	0.79	0.94	140	130
	468	12.6	120	0.80	1.2	180	150
Wire Saw Operator	458	7.7	30	0.78	0.50	50	38
	460	13.4	90	0.78	0.86	130	120
Abrasive Blaster	475	11.0	60	0.81	0.67	87	74
Maintenance Worker	470	7.2	30	0.80	0.52	47	38
Boxer	465	10.2**	45	0.79	0.55	67	57
Sculptor	458	7.8	60	0.78	0.99	99	77
	635	7.8*	38	1.1	0.44	44	35

* Percent free silica based on mean for that job.
** Percent free silica based on mean for entire plant.
\+ OSHA standard is $\frac{10}{\% SiO_2 + 2}$

TABLE A-7

SUMMARY OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT D

JOB	NO. OF SAMPLES	RANGE ug/m^3 LOW	RANGE ug/m^3 HIGH	ARITHMETIC MEAN ug/m^3	STD.ERR ug/m^3	GEOMETRIC MEAN ug/m^3	STANDARD DEVIATION	95% CONFIDENCE LIMITS ug/m^3 LOWER	95% CONFIDENCE LIMITS ug/m^3 UPPER
Saw Operator	4	20	140	60	27	45	2.26	12	170
Polisher	2	80	120	100	20	98	1.33		
Miscellaneous Worker	1		82						

TABLE A-8

RESULTS OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT D
November, 1973

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC (ug/m^3)
Polisher	440	9.1	60	0.75	0.88	98	80
	445	9.1*	90	0.76	1.3	140	120
Wire Saw Operator	448	7.4	30	0.76	0.53	48	39
	450	8.6	30	0.76	0.46	49	39
	445	11.6*	15	0.76	0.17	23	20
	450	18.7	110	0.76	0.77	160	140
Foreman	430	9.3	60	0.73	0.88	100	82

* Percent free silica based on mean for that job.
** Percent free silica based on mean for entire plant.
+ OSHA standard is $\frac{10}{\%SiO_2+2}$

TABLE A-9

SUMMARY OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT E

JOB	NO. OF SAMPLES	RANGE ug/m^3 LOW	RANGE ug/m^3 HIGH	ARITHMETIC MEAN ug/m^3	STD.ERR ug/m^3	GEOMETRIC MEAN ug/m^3	STANDARD DEVIATION	95% CONFIDENCE LIMITS ug/m^3 LOWER	95% CONFIDENCE LIMITS ug/m^3 UPPER
Lumper	10	19	150	73	10	66	1.69	45	96
Stone Cutter	28	57	190	110	7.1	110	1.40	92	120
Saw Operator	3	76	160	130	28	120	1.54	43	360
Polisher	7	47	170	110	16	110	1.56	70	160
Abrasive Blaster	13	54	180	91	11	85	1.45	68	110
Crane Operator	1		88						
Miscellaneous Worker	18	40	180	82	8.2	75	1.49	62	92

TABLE A-10

RESULTS OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT E
November, 1973

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC. (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC. (ug/m^3)
Lumper	455	12.5*	15	0.77	0.16	23	19
	470	11.7	60	0.80	0.64	88	75
	468	12.5*	70	0.80	0.70	100	88
	480	17.5	121	0.82	0.84	160	150
	455	12.5*	54	0.77	0.56	81	70
	485	11.8	60	0.82	0.62	86	73
	498	12.5*	58	0.85	0.54	78	68
	510	12.5*	68	0.87	0.62	90	78
	475	9.1	50	0.81	0.68	76	62
	488	12.5*	41	0.83	0.39	57	49
Crane Operator	400	11.1	60	0.68	0.79	100	88
Polisher	490	13.6*	129	0.83	1.1	170	160
	453	14.2	91	0.77	0.83	130	120
	415	13.6*	54	0.71	0.56	88	76
	417	18.0	120	0.71	0.94	190	170
	420	13.1	80	0.71	0.86	130	110
	480	13.6*	97	0.82	0.87	140	120
	500	9.2	40	0.85	0.51	57	47

TABLE A-10

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC$_3$ (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC$_3$ (ug/m^3)
Stone Cutter	516	13.9*	123	0.88	1.0	160	140
	470	14.7	90	0.80	0.76	130	110
	475	13.1	100	0.81	0.94	140	120
	515	21.9	170	0.88	0.88	210	190
	518	10.1	50	0.88	0.56	67	57
	482	12.0	76	0.82	0.77	110	93
	495	13.9*	68	0.84	0.56	89	81
	506	13.9*	111	0.86	0.93	150	130
	465	13.9*	66	0.79	0.60	95	84
	496	14.0	90	0.84	0.76	120	110
	497	13.9*	81	0.84	0.70	110	96
	499	20.1	80	0.85	0.47	100	94
	500	13.9*	106	0.85	0.90	140	120
	501	12.8	80	0.85	0.74	110	94
	505	13.9*	83	0.86	0.70	110	97
	470	13.9*	142	0.80	1.3	210	180
	510	13.9*	130	0.87	1.1	170	150
	513	14.0	110	0.87	0.90	150	130
	474	13.9*	135	0.81	1.2	190	170
	517	13.0	70	0.88	0.61	91	80
	500	13.9*	68	0.85	0.57	90	80

TABLE A-10

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC, (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC, (ug/m^3)
Stone Cutter	456	13.8	110	0.78	1.0	160	140
	455	13.9*	139	0.77	1.3	210	180
	464	10.8	49	0.79	0.58	74	62
	527	12.4	80	0.90	0.72	100	89
	505	12.2	90	0.86	0.86	120	100
	475	13.9*	49	0.81	0.44	70	60
Wire Saw Operator	450	12.3	120	0.76	1.3	190	160
	450	12.1	121	0.76	1.3	180	160
Carbo Saw Operator	465	9.7	60	0.79	0.78	92	76
Abrasive Blaster	495	10.8	50	0.84	0.55	71	60
	510	13.6*	47	0.87	0.39	61	54
	509	11.5	50	0.86	0.50	68	58
	509	13.6*	63	0.86	0.54	84	73
	504	13.6*	76	0.86	0.65	100	88
	505	11.7	60	0.86	0.60	82	70
	501	13.6*	111	0.85	0.96	150	130

TABLE A-10

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC (ug/m^3)
Abrasive Blaster	509	13.6*	81	0.86	0.69	110	94
	506	13.6*	151	0.86	1.3	200	180
	500	24.2	130	0.85	0.63	170	150
	500	13.6*	66	0.85	0.57	89	78
	495	9.9	60	0.84	0.73	87	71
	495	13.6*	70	0.84	0.62	97	83
Maintenance Worker	490	11.9	70	0.83	0.71	99	84
	484	6.7	50	0.82	0.91	83	85
Boxer	495	9.2*	34	0.84	0.44	49	40
	498	7.9	40	0.85	0.60	60	47
	505	9.2*	38	0.86	0.47	53	44
	500	10.5	60	0.85	0.67	84	71
Grouter	495	13.2	80	0.84	0.72	110	95
	507	13.2*	74	0.86	0.65	98	86
Shipper	498	12.9*	54	0.85	0.49	73	64
	479	12.9*	145	0.81	1.4	210	180

TABLE A-10

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC (ug/m^3)
Planer	480	14.8*	73	0.82	0.60	100	89
	510	14.8*	90	0.87	0.70	120	100
Hydro Split Operator	525	12.9**	64	0.89	0.56	84	72
Washer	489	13.7	70	0.83	0.61	95	84
	482	8.4	40	0.82	0.59	61	49
Inspector	503	16.7*	65	0.86	0.45	85	76
	492	16.7	121	0.84	0.89	170	140
Foreman	525	12.9**	43	0.89	0:38	57	48
	480	12.7	70	0.82	0.67	99	85

* Percent free silica based on mean for that job.
** Percent free silica based on mean for entire plant.
\+ OSHA standard is $\frac{10}{\%SiO_2+2}$

APPENDIX B

GEORGIA

SUMMARY TABLES AND RESULTS OF
SAMPLING FOR RESPIRABLE FREE SILICA

PLANTS F - O

April, 1974

and

JOB DICTIONARY

TABLE A-11

SUMMARY OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT F

JOB	NO. OF SAMPLES	RANGE ug/m^3 LOW	HIGH	ARITHMETIC MEAN ug/m^3	STD.ERR	GEOMETRIC MEAN ug/m^3	STANDARD DEVIATION	95% CONFIDENCE LIMITS ug/m^3 LOWER	UPPER
Lumper	15	9.0	160	34	10	23	2.21	15	36
Stone Cutter	19	13	98	43	5.2	37	1.76	28	49
Wire Saw Operator	6	5.2	52	22	6.7	17	2.20	7.4	39
Polisher	8	6.1	95	40	10	31	2.37	15	63
Abrasive Blaster	3	4.0	91	37	27	18	4.78	0.4	890
Crane Operator	9	16	46	27	3.2	25	1.42	19	33
Miscellaneous Worker	14	9.2	60	24	4.1	21	1.80	15	29

TABLE A-12

RESULTS OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT F
April, 1974

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC. (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC. (ug/m^3)
Bed Setter	495	16.8	75	0.84	0.53	100	89
	495	11.1	35	0.84	0.38	50	42
	495	14.0*	23	0.84	0.19	31	27
	510	14.0*	143	0.87	1.2	190	160
Break Out Man	510	14.3**	39	0.87	0.31	51	45
Crane Operator	495	19.2*	14	0.84	0.086	18	17
	480	19.2*	25	0.82	0.16	34	30
	495	19.2*	22	0.84	0.13	28	26
	510	19.2*	16	0.87	0.094	20	18
	510	30.2	40	0.87	0.15	48	46
	510	19.2*	23	0.87	0.14	30	26
	510	19.2*	14	0.87	0.083	18	16
	510	12.3	25	0.87	0.23	33	29
	510	15.1	30	0.87	0.23	40	34
Diamond Saw Operator	510	14.3**	21	0.87	0.17	28	24
Diamond Saw Set up Man	510	14.3**	19	0.87	0.15	25	22
General Superintendent	505	14.3**	8.6	0.86	0.020	11	10

TABLE A-12

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC. (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC. (ug/m^3)
Grinder Operator	495	14.3**	5.1	0.84	0.043	7.0	6.1
Handy Man	510	14.3**	12	0.87	0.094	15	14
Hydro Split Operator	510	13.3*	14	0.87	0.12	18	16
	510	13.3*	14	0.87	0.12	18	16
	510	13.3	40	0.87	0.34	52	46
Machine Operator	480	14.3**	13	0.82	0.11	18	16
	510	14.3**	12	0.87	0.099	16	14
Pattern Mill Operator	495	15.4	50	0.84	0.39	68	60
Polisher	495	25.6	60	0.84	0.28	78	71
	495	32.8	80	0.84	0.29	100	95
	510	17.9*	29	0.87	0.18	36	33
	510	6.4	20	0.87	0.36	30	23
	510	6.8	40	0.87	0.68	62	46
	510	17.9*	27	0.87	0.17	34	31

TABLE A-12

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	(ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC$_3$ (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC$_3$ (ug/m^3)
Profile Operator	480	14.3**	15	0.82	0.13	21	18
	510	14.3**	30	0.87	0.24	39	34
	510	14.3**	11	0.87	0.087	14	13
Sand Blaster	510	6.2*	79	0.87	1.5	120	91
	510	6.2	15	0.87	0.28	23	17
	510	6.2*	3.5	0.87	0.064	5.3	4.0
Saw Operator	510	14.3**	15	0.87	0.12	20	17
Shipper	510	7.6	35	0.87	0.53	53	40
	510	7.6*	10	0.87	0.15	15	11
	510	7.6*	12	0.87	0.18	18	14
Stencil Cutter	510	14.3**	11	0.87	0.092	15	13
	500	14.3**	21	0.85	0.17	28	25
Stone Banker	510	14.3**	21	0.87	0.17	28	24
	510	14.3**	17	0.87	0.14	23	20
	510	14.3**	13	0.87	0.11	18	15
	510	14.3**	11	0.87	0.092	15	13

TABLE A-12

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC (ug/m^3)
Stone Crater	510	14.3**	15	0.87	0.12	20	17
	495	14.3**	8.3	0.84	0.069	11	9.9
	510	14.3**	22	0.87	0.18	30	25
	510	14.3**	23	0.87	0.19	31	26
	510	14.3**	15	0.87	0.12	20	17
Stone Cutter	510	16.0*	58	0.87	0.41	73	67
	510	21.0	85	0.87	0.46	110	98
	480	14.5	30	0.82	0.25	41	37
	480	24.8	50	0.82	0.25	68	61
	510	16.0*	21	0.87	0.15	27	24
	510	16.0*	33	0.87	0.24	43	38
	510	16.0*	31	0.87	0.22	39	36
	510	11.8	40	0.87	0.39	54	46
	510	12.3	55	0.87	0.51	73	63
	510	16.0*	67	0.87	0.48	86	77
	510	11.9	30	0.87	0.29	40	34
	495	16.0*	38	0.84	0.28	50	45
	480	16.0*	36	0.82	0.27	48	44
Stone Setter	510	3.0*	7.8	0.87	0.30	15	9.0
	510	3.0	9.9	0.87	0.38	19	11

TABLE A-12

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	(ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC (ug/m^3)
Supervisor	500	14.3**	13	0.85	0.11	18	15
	510	14.3**	8.0	0.87	0.064	10	9.2
	495	14.3**	30	0.84	0.25	41	36
Tool Sharpener	510	14.3**	25	0.87	0.20	33	29
Top Polisher	510	4.7	15	0.87	0.37	25	17
Wire Saw Operator	510	10.3	45	0.87	0.50	62	52
	510	10.3*	4.5	0.87	0.051	6.3	5.2

* Percent free silica based on mean for that job.
** Percent free silica based on mean for entire plant.
\+ OSHA standard is $\frac{10}{\%SiO_2+2}$

TABLE A-13

SUMMARY OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT G

JOB	NO. OF SAMPLES	RANGE ug/m^3 LOW	RANGE ug/m^3 HIGH	ARITHMETIC MEAN ug/m^3	ARITHMETIC STD.ERR ug/m^3	GEOMETRIC MEAN ug/m^3	GEOMETRIC STANDARD DEVIATION	95% CONFIDENCE LIMITS ug/m^3 LOWER	95% CONFIDENCE LIMITS ug/m^3 UPPER
Lumper	5	11	56	28	7.6	24	1.81	12	50
Stone Cutter	17	7.4	100	53	5.7	47	1.80	35	64
Saw Operator	5	21	110	44	17	36	1.95	16	83
Polisher	7	60	200	140	20	130	1.57	87	200
Abrasive Blaster	6	14	140	52	19	39	2.24	17	91
Crane Operator	9	15	92	52	9.5	44	1.90	27	72
Miscellaneous Worker	7	28	170	73	18	61	1.89	34	110

TABLE A-14

RESULTS OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT G
April, 1974

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC. (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC. (ug/m^3)
Break Out Man	510	14.3	75	0.87	0.60	98	86
	510	10.9	60	0.87	0.63	81	69
Clean-up Man	510	12.3**	26	0.87	0.25	36	30
	510	12.3**	41	0.87	0.38	54	47
Crane Helper	510	12.3**	20	0.87	0.19	27	23
Crane Operator	510	14.4*	42	0.87	0.34	56	48
	510	14.7	70	0.87	0.54	90	80
	510	14.2	70	0.87	0.57	92	80
	510	14.4	80	0.87	0.64	100	92
	510	14.4*	27	0.87	0.22	36	31
	510	14.4*	57	0.87	0.46	75	66
	510	14.4*	13	0.87	0.10	16	15
	510	14.4*	26	0.87	0.21	34	30
Diamond Saw Operator	510	12.3**	34	0.87	0.32	46	39
Maintenance Man	510	12.3**	24	0.87	0.22	31	28

TABLE A-14

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC$_3$ (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC$_3$ (ug/m^3)
Polisher	510	21.2*	81	0.87	0.44	100	93
	510	21.2*	141	0.87	0.76	180	160
	510	21.7	170	0.87	0.89	210	200
	510	21.2*	98	0.87	0.53	120	110
	510	20.6	160	0.87	0.89	200	180
	510	21.2*	52	0.87	0.28	65	60
	510	21.2*	163	0.87	0.88	200	190
Profile Operator	510	12.5	35	0.87	0.32	46	40
	510	6.9	30	0.87	0.50	45	34
Sand Blaster	510	12.4*	27	0.87	0.25	36	31
	510	12.4*	22	0.87	0.20	29	25
	510	12.4*	124	0.87	1.1	160	140
	510	12.3	59	0.87	0.55	79	68
	510	12.6	30	0.87	0.27	40	34
Sand Blasting Foreman	495	12.3**	12	0.84	0.11	16	14
Stack Man	470	10.1	45	0.80	0.56	67	56

TABLE A-14

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC. (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC. (ug/m^3)
Stock Layout Man	500	14.3	70	0.85	0.57	93	82
Stone Crater	510	9.4*	18	0.87	0.22	25	21
	510	9.4*	10	0.87	0.13	15	11
	510	9.4*	18	0.87	0.22	25	21
	510	9.4*	25	0.87	0.31	35	29
Stone Cutter	510	11.4*	47	0.87	0.47	63	54
	510	14.7	80	0.87	0.63	100	92
	510	6.8	40	0.87	0.68	62	46
	510	7.4	30	0.87	0.46	42	34
	510	11.4*	32	0.87	0.32	43	37
	510	11.4*	49	0.87	0.50	67	56
	510	15.3	90	0.87	0.67	120	100
	510	11.4*	6.4	0.87	0.064	8.5	7.4
	510	11.4*	33	0.87	0.33	44	38
	510	11.4*	58	0.87	0.59	79	67
	510	12.1	65	0.87	0.62	87	75
	510	11.4*	51	0.87	0.51	68	59
	510	11.4*	40	0.87	0.40	53	46
	510	12.3	70	0.87	0.65	93	80
	510	11.4*	35	0.87	0.36	48	40

TABLE A-14

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC (ug/m^3)
Tool Maker	510	12.3**	144	0.87	1.3	190	170
Wire Saw Operator	497	14.4	90	0.84	0.75	120	110
	510	9.4	25	0.87	0.31	35	29
	510	11.9*	18	0.87	0.17	24	21
Wire Saw Shed Foreman	510	5.7	20	0.87	0.40	31	23

* Percent free silica based on mean for that job.
** Percent free silica based on mean for entire plant.
\+ OSHA standard is $\frac{10}{\%SiO_2+2}$

TABLE A-15

SUMMARY OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT H

JOB	NO. OF SAMPLES	RANGE ug/m^3 LOW	RANGE ug/m^3 HIGH	ARITHMETIC MEAN STD.ERR ug/m^3		GEOMETRIC MEAN ug/m^3	GEOMETRIC STANDARD DEVIATION	95% CONFIDENCE LIMITS ug/m^3 LOWER	95% CONFIDENCE LIMITS ug/m^3 UPPER
Lumper	2	35	40	38	2.5	37	1.10		
Stone Cutter	5	34	120	63	15	57	1.60	32	100
Saw Operator	7	4.3	170	68	22	44	3.38	14	130
Polisher	5	29	82	55	8.5	52	1.46	33	83
Abrasive Blaster	3	14	49	28	11	24	1.90	5.0	120
Crane Operator	3	27	29	28	0.6	28	1.04	26	31
Miscellaneous Worker	7	22	80	37	7.7	34	1.58	22	51

TABLE A-16

RESULTS OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT H
April, 1974

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC (ug/m^3)
Bed Setter	503	7.0	30	0.86	0.50	45	35
Chip Crater	510	13.7**	19	0.87	0.16	25	22
	510	13.7**	37	0.87	0.31	48	43
Crane Operator	504	13.7**	25	0.86	0.22	34	29
	506	13.7**	23	0.86	0.20	31	27
	509	13.7**	24	0.86	0.20	31	28
Diamond Saw Operator	490	13.7**	18	0.83	0.16	25	22
Job Foreman	498	13.7**	20	0.85	0.17	27	24
Maintenance Man	510	13.7**	70	0.87	0.59	92	80
Miscellaneous Worker	499	13.7**	28	0.85	0.24	38	33
Polisher	510	14.5*	45	0.87	0.36	59	52
	501	13.7	50	0.85	0.43	67	59
	502	21.0	70	0.85	0.39	91	82
	510	8.9	25	0.87	0.32	35	29
Profile Machine Operator	510	13.7**	56	0.87	0.47	73	64

TABLE A-16

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC$_3$ (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC$_3$ (ug/m^3)
Rack Stacker	510	10.1	35	0.87	0.40	48	40
Sand Blaster	510	13.7**	43	0.87	0.36	56	49
	510	13.7**	12	0.87	0.097	15	14
	505	13.7**	18	0.86	0.16	25	21
Set Up Man	510	13.7**	20	0.87	0.17	27	23
Shipping Clerk	510	13.7**	31	0.87	0.26	41	36
Stone Cutter	510	6.5	40	0.87	0.71	59	46
	510	14.1	45	0.87	0.37	60	52
	510	13.0*	30	0.87	0.27	40	34
	499	18.4	100	0.85	0.64	130	120
Top Polisher	510	18.0	45	0.87	0.29	58	52
Wire Saw Operator	510	17.0	40	0.87	0.27	51	46
	510	16.5	40	0.87	0.28	52	46
	510	16.8*	100	0.87	0.68	130	110
	504	16.8*	143	0.86	0.99	190	170
	506	16.8*	3.7	0.86	0.026	4.9	4.3
	508	16.8*	69	0.86	0.48	91	80

* Percent free silica based on mean for that job.
** Percent free silica based on mean for entire plant.
+ OSHA standard is $\frac{10}{\%SiO_2+2}$

TABLE A-17

SUMMARY OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT I

JOB	NO. OF SAMPLES	RANGE ug/m^3 LOW	HIGH	ARITHMETIC MEAN ug/m^3	STD.ERR	GEOMETRIC MEAN ug/m^3	STANDARD DEVIATION	95% CONFIDENCE LIMITS ug/m^3 LOWER	UPPER
Lumper	1		23						
Stone Cutter	7	27	130	90	15	81	1.75	48	130
Saw Operator	4	44	93	67	11	64	1.40	38	110
Polisher	3	34	49	40	4.5	40	1.21	25	63
Crane Operator	3	27	43	33	4.9	33	1.28	18	60
Miscellaneous Worker	7	6.7	220	78	29	49	3.11	17	140

TABLE A-18

RESULTS OF PERSONAL SAMPLING FOR RESIPRABLE FREE SILICA AT PLANT I
April, 1974

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC$_3$ (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC$_3$ (ug/m^3)
Blacksmith	540	17.2**	200	0.92	1.3	250	220
Crane Operator	540	9.3	28	0.92	0.32	36	30
	540	7.6	25	0.92	0.36	36	27
	540	11.0	40	0.92	0.40	52	43
Foreman	540	17.2**	52	0.92	0.33	63	57
Polisher	540	18.2*	31	0.92	0.18	36	34
	540	18.2*	45	0.92	0.27	54	49
Profile Machine Operator	540	10.2	25	0.92	0.27	33	27
Stencil Cutter	540	17.2**	6.2	0.92	0.039	7.5	6.7
Stone Crater	540	17.2**	21	0.92	0.13	25	23
Stone Cutter	540	26.4	70	0.92	0.29	83	76
	540	24.0	60	0.92	0.27	71	65
	540	24.4*	120	0.92	0.52	100	130
	540	24.4*	110	0.92	0.48	92	82
	540	22.0	110	0.92	0.54	130	120
	540	25.0	121	0.92	0.53	140	130

TABLE A-18

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC, (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC, (ug/m^3)
Top Polisher	540	14.0	35	0.92	0.27	43	38
Truck Driver	540	17.2**	33	0.92	0.21	40	36
Utility Man	540	15.3*	34	0.92	0.24	46	37
	540	8.7	35	0.92	0.44	47	38
	540	21.9	135	0.92	0.67	160	150
Wire Saw Operator	540	17.2*	69	0.92	0.44	84	76
	540	14.9	50	0.92	0.36	61	55
	540	11.8	40	0.92	0.37	51	44
	540	25	85	0.92	0.37	100	93

* Percent free silica based on mean for that job.
** Percent free silica based on mean for entire plant.
+ OSHA standard is $\frac{10}{\%SiO_2+2}$

TABLE A-19

SUMMARY OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT J

JOB	NO. OF SAMPLES	RANGE ug/m^3 LOW	HIGH	ARITHMETIC MEAN ug/m^3	STD.ERR	GEOMETRIC MEAN ug/m^3	STANDARD DEVIATION	95% CONFIDENCE LIMITS ug/m^3 LOWER	UPPER
Lumper	1		20						
Stone Cutter	3	29	180	97	44	75	2.50	7.8	730
Saw Operator	1		100						
Polisher	6	20	360	120	52	79	2.74	28	230
Abrasive Blaster	1		21						
Crane Operator	2	39	52	46	6.5	45	1.23		
Miscellaneous Worker	3	22	28	24	1.9	24	1.14	18	33

TABLE A-20

RESULTS OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT J
April, 1974

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC, (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC, (ug/m^3)
Crane Operator	510	10.9	45	0.87	0.48	62	52
	510	10.9*	34	0.87	0.36	53	39
Crate Stones	510	12.7**	18	0.87	0.16	24	20
Maintenance	510	7.0	20	0.87	0.33	30	23
Polisher	510	32.4	70	0.87	0.25	100	81
	510	19.5	135	0.87	0.80	170	160
	510	16.4	40	0.87	0.28	51	46
	510	20.6	51	0.87	0.28	63	58
	480	22.2*	290	0.82	1.6	240	360
Profile Grinder	480	12.7**	17	0.82	0.17	25	20
Sand Blaster	480	12.7**	18	0.82	0.14	21	21
Shipping Clerk	510	12.7**	19	0.87	0.17	25	22
Stone Cutter	510	5.5	25	0.87	0.52	39	29
	510	11.2	70		0.72	95	81
	510	20.0	160		0.92	200	180

TABLE A-20

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC. (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC. (ug/m^3)
Utility	510	12.7**	24	0.87	0.22	32	28
Wire Saw	510	10.9	90	0.87	0.96	120	100

* Percent free silica based on mean for that job.
** Percent free silica based on mean for entire plant.
\+ OSHA standard is $\frac{10}{\%SiO_2+2}$

TABLE A-21

SUMMARY OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT K

JOB	NO. OF SAMPLES	RANGE ug/m^3 LOW	RANGE ug/m^3 HIGH	ARITHMETIC MEAN ug/m^3	STD.ERR ug/m^3	GEOMETRIC MEAN ug/m^3	STANDARD DEVIATION	95% CONFIDENCE LIMITS ug/m^3 LOWER	95% CONFIDENCE LIMITS ug/m^3 UPPER
Lumper	3	20	76	41	18	34	2.03	5.9	200
Stone Cutter	3	44	66	51	7.3	50	1.26	28	90
Polisher	3	44	140	100	30	93	1.91	19	460
Abrasive Blaster	1		32						
Crane Operator	3	20	55	38	10	35	1.67	9.8	130

TABLE A-22

RESULTS OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT K
April, 1974

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC (ug/m^3)
Bedsetter	540	13.6	70	0.92	0.56	87	76
Crane Operator	540	13.2*	36	0.92	0.30	46	39
	540	13.2*	18	0.92	0.15	23	20
	540	13.2*	50	0.92	0.42	64	55
Crater	540	13.2*	24	0.92	0.20	30	26
	540	13.2*	19	0.92	0.16	24	20
Polisher	540	15.6	120	0.92	0.80	140	130
	540	12.9	130	0.92	1.1	160	140
Profile Operator	540	10.3	40	0.92	0.42	52	44
Sand Blaster	540	13.2**	29	0.92	0.24	36	32
Stone Cutter	540	12.9	60	0.92	0.51	76	66
	540	13.3	40	0.92	0.41	63	44
Top Polisher	540	13.6	40	0.92	0.32	50	44

* Percent free silica based on mean for that job.
** Percent free silica based on mean for entire plant.
+ OSHA standard is $\frac{10}{\%SiO_2+2}$

TABLE A-23

SUMMARY OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT L

JOB	NO. OF SAMPLES	RANGE ug/m^3 LOW	RANGE ug/m^3 HIGH	ARITHMETIC MEAN ug/m^3	STD.ERR	GEOMETRIC MEAN ug/m^3	STANDARD DEVIATION	95% CONFIDENCE LIMITS ug/m^3 LOWER	95% CONFIDENCE LIMITS ug/m^3 UPPER
Saw Operator	3	160	830	380	220	280	2.59	26	2900
Crane Operator	1		47						
Miscellaneous	4	65	200	140	35	130	1.76	51	310

TABLE A-24

RESULTS OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT L
April, 1974

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC, (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC, (ug/m^3)
Crane Operator	500	8.3	40	0.85	0.56	58	47
Mechanic	500	8.3	80	0.85	1.1	110	94
	500	9.2	170	0.85	2.2	250	200
Superintendent Wire Saw	500	9.6	55	0.85	0.67	78	65
Truck Driver	500	11.1	170	0.85	1.8	240	200
Wire Saw Operator	500	12.7*	700	0.85	6.5	770	830
	500	12.7*	140	0.85	1.3	160	160
	500	12.7	140	0.85	1.3	190	160

* Percent free silica based on mean for that job.
** Percent free silica based on mean for entire plant.
+ OSHA standard is $\frac{10}{\%SiO_2+2}$

TABLE A-25

SUMMARY OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT M

JOB	NO. OF SAMPLES	RANGE ug/m^3 LOW	RANGE ug/m^3 HIGH	ARITHMETIC MEAN ug/m^3	ARITHMETIC STD.ERR ug/m^3	GEOMETRIC MEAN ug/m^3	GEOMETRIC STANDARD DEVIATION	95% CONFIDENCE LIMITS ug/m^3 LOWER	95% CONFIDENCE LIMITS ug/m^3 UPPER
Lumper	1		52						
Stone Cutter	2	52	58	55	3.0	55	1.08		
Saw Operator	1		250						
Polisher	1		58						
Miscellaneous Worker	3	28	120	60	30	48	2.22	6.6	350
Crane Operator	1		32						

TABLE A-26

RESULTS OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT M
April, 1974

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC (ug/m^3)
Crane Operator	510	15.2**	28	0.87	0.21	36	32
Foreman (sand blast)	510	15.2**	24	0.87	0.18	31	28
	510	15.2**	29	0.87	0.23	40	33
Machine Operator	360	17.4	75	0.61	0.70	140	120
Polishing Mill	480	14.1	50	0.82	0.43	69	58
Set bed & Brake out	510	15.2**	45	0.87	0.34	59	52
Stone Cutter	510	12.4	50	0.87	0.47	68	58
	510	16.9	45	0.87	0.31	60	52
Wire Saw	510	15.2**	230	0.87	1.7	290	250

* Percent free silica based on mean for that job.
** Percent free silica based on mean for entire plant.
\+ OSHA standard is $\frac{10}{\%SiO_2+2}$

TABLE A-27

SUMMARY OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT N

JOB	NO. OF SAMPLES	RANGE ug/m^3 LOW	RANGE ug/m^3 HIGH	ARITHMETIC MEAN ug/m^3	ARITHMETIC STD.ERR ug/m^3	GEOMETRIC MEAN ug/m^3	GEOMETRIC STANDARD DEVIATION	95% CONFIDENCE LIMITS ug/m^3 LOWER	95% CONFIDENCE LIMITS ug/m^3 UPPER
Lumper	1		140						
Stone Cutter	2	22	40	31	9.0	30	1.53		
Polisher	1		39						
Abrasive Blaster	1		11						
Miscellaneous Worker	1		22						

TABLE A-28

RESULTS OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT N
April, 1974

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC$_3$ (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC$_3$ (ug/m^3)
Bank	520	28.5	125	0.88	0.50	150	140
Foreman	530	5.5	20	0.89	0.40	30	22
Polisher	530	10	35	0.89	0.39	39	39
Profile Operator	530	9.5	20	0.89	0.24	28	22
Sand Blaster	520	2.7	10	0.88	0.42	20	11
Stone Cutter	520	10.2	35	0.88	0.39	48	40

* Percent free silica based on mean for that job.
** Percent free silica based on mean for entire plant.
+ OSHA standard is $\frac{10}{\%SiO_2+2}$

TABLE A-29

SUMMARY OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT O

JOB	NO. OF SAMPLES	RANGE ug/m^3 LOW	HIGH	ARITHMETIC MEAN ug/m^3	STD.ERR	GEOMETRIC MEAN ug/m^3	STANDARD DEVIATION	95% CONFIDENCE LIMITS ug/m^3 LOWER	UPPER
Lumper	1		12						
Stone Cutter	2	12	35	24	12	20	2.13		
Saw Operator	2	17	23	20	3.0	20	1.24		
Polisher	2	17	93	55	38	40	3.33		
Abrasive Blaster	1		40						
Miscellaneous Worker	1		18						

TABLE A-30

RESULTS OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT O
April, 1974

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC. (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC. (ug/m^3)
Foreman	510	7.7*	16	0.87	0.24	23	18
Polisher	510	6.7	15	0.87	0.26	23	17
Profile & Diamond Saw	510	7.7*	15	0.87	0.23	22	17
Sand Blast	510	13.5	35	0.87	0.30	47	40
Set Beds	510	2.8	10	0.87	0.42	20	12
Stone Cutter	510	9.7**	10	0.87	0.12	12	12
	510	9.7	30	0.87	0.36	42	35
Top Polisher	510	7.7*	80	0.87	1.2	120	93
Wire Saw	510	5.7	20	0.87	0.41	32	23

* Percent free silica based on mean for that job.
** Percent free silica based on mean for entire plant.
\+ OSHA standard is $\frac{10}{\%SiO_2+2}$

TABLE A-31

SUMMARY OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT P

JOB	NO. OF SAMPLES	RANGE ug/m^3 LOW	RANGE ug/m^3 HIGH	ARITHMETIC MEAN ug/m^3	ARITHMETIC STD.ERR ug/m^3	GEOMETRIC MEAN ug/m^3	GEOMETRIC STANDARD DEVIATION	95% CONFIDENCE LIMITS ug/m^3 LOWER	95% CONFIDENCE LIMITS ug/m^3 UPPER
Saw Operator	1		220						
Polisher	2	92	200	150	54	140	1.73		
Abrasive Blaster	1		25						

TABLE A-32

RESULTS OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT P
April, 1974

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC (ug/m^3)
Polisher	510	10.9*	170	0.87	1.8	230	200
Sand Blast	510	10.9*	22	0.87	0.23	30	25
Top Polisher	510	10.9	80	0.87	0.85	110	92
Wire Saw Operator	510	10.9*	190	0.87	1.8	230	220

* Percent free silica based on mean for that job.
** Percent free silica based on mean for entire plant.
\+ OSHA standard is $\frac{10}{\%SiO_2+2}$

TABLE A-33

SUMMARY OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA FOR PLANT Q

JOB	NO. OF SAMPLES	RANGE ug/m^3 LOW	RANGE ug/m^3 HIGH	ARITHMETIC MEAN ug/m^3	ARITHMETIC STD.ERR ug/m^3	GEOMETRIC MEAN ug/m^3	GEOMETRIC STANDARD DEVIATION	95% CONFIDENCE LIMITS ug/m^3 LOWER	95% CONFIDENCE LIMITS ug/m^3 UPPER
Stone Cutter	1		52						
Polisher	2	52	140	96	44	85	2.01		
Crane Operator	1		52						

TABLE A-34

RESULTS OF PERSONAL SAMPLING FOR RESPIRABLE FREE SILICA AT PLANT Q
April, 1974

JOB	SAMPLE TIME (min.)	FREE SILICA (%)	FREE SILICA (ug)	SAMPLE VOLUME (m^3)	RESPIRABLE DUST CONC. (mg/m^3)	% OF OSHA STD.	RESPIRABLE FREE SILICA CONC. (ug/m^3)
Crane Operator	510	10.1	50	0.87	0.57	69	58
Polisher	510	9.6	120	0.87	1.5	170	140
	510	9.3	45	0.87	0.56	63	52
Stone Cutter	510	9.3	45	0.87	0.57	64	52

* Percent free silica based on mean for that job.
** Percent free silica based on mean for entire plant.
\+ OSHA standard is $\frac{10}{\%SiO_2+2}$

APPENDIX C

REPORT ON TEST OF ECA
RESPIRABLE DUST MONITOR
KENNETH WALLINGFORD
FEBRUARY, 1974

K. M. Wallingford

GCA RESPIRABLE DUST MONITOR

FIELD TRIAL

Kenneth M. Wallingford

National Institute for Occupational Safety and Health
Division of Field Studies and Clinical Investigations
Environmental Investigations Branch
Cincinnati, Ohio

February 1974

INTRODUCTION

A GCA respirable dust monitor was used in connection with a standard mass respirable sampling program during the silica survey conducted by the Environmental Investigations Branch (EIB), Division of Field Studies and Clinical Investigations from November 5-14, 1973 at five granite sheds in Barre, Vermont. The objective in the use of the GCA respirable dust monitor was to substantiate the feasibility of using this instrument for respirable dust sampling in future EIB surveys.

DESCRIPTION OF SAMPLING PROCEDURES

GCA Respirable Dust Monitor

The Model RDM-101-1 GCA Respirable Dust Monitor was designed for instantaneous measurements of respirable or total dust particulates in milligrams of dust per cubic meter of air (mg/m^3). The device is entirely portable and has an automatic and direct digital readout of the measured dust concentration.

For use in the Vermont granite silica study, only the respirable fraction of airborne dust was measured with the GCA instrument. This required the use of a 10 mm nylon cyclone attached to the inlet part of the instrument. The cyclone is designed to remove all non-respirable particles. All particulates not removed by the cyclone pass through a circular nozzle impactor-beta absorption assembly and are collected on a gel-coated polyester impaction disc. A small geiger detector unit below the disc detects the amount of beta-radiation absorbed by the dust impacted on the disc and through a complex system of solid-state electronic programming and computing circuits translates the input into a direct readout of mass concentration (mg/m^3) on the digital display panel.

GENERAL DESCRIPTION OF PLANT SITES

The Environmental Investigations Branch granite sheds silica survey in Barre, Vermont was conducted at five different sheds, where finished monuments are produced. These were the Rock of Ages, LaCross, Letter, Consolidated and Rouleau sheds. The GCA respirable dust monitor, however, was used in only three of these sheds; Plant A, Plant D, and Plant E. A layout of these three sheds are shown in Figures 1-3. These sheds all deal with the same type of granite and all use similar production operations to produce finished monuments.

SAMPLING PROCEDURES AND EQUIPMENT

Standard Mass Sampling Equipment

The equipment used in collecting normally used general area respirable samples included a MSA Model G personal sampling pump, a hose from the pump inlet to a pre-weighed MSA PVC 37 μm filter and a 10 mm nylon cyclone attached to the filter cassette inlet.

Sampling Procedures

The sampling rate that was used was 1.7 liters per minute (lpm). The MSA respirable dust units were placed in groups of six throughout the three sheds at pre-determined sites with respect to a generalization of activity. One GCA respirable dust monitor was then placed next to one of the MSA group of pumps in each of the three sheds. The MSA pumps were run from seven to eight hours per day. GCA readings were recorded manually from a one to an eight minute sampling interval during a one to two-hour period on the same day. The GCA and MSA sampling sites are shown in Figures 1-3.

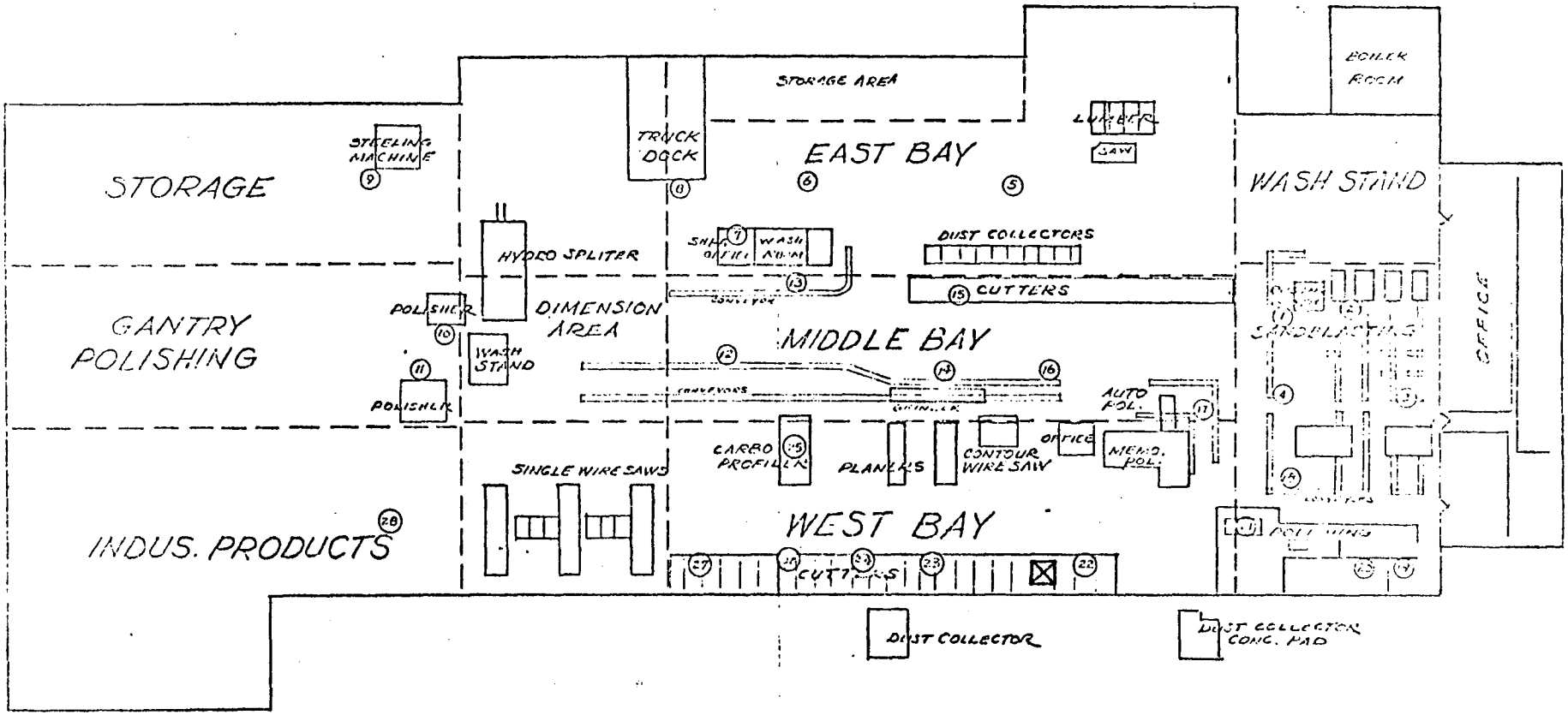

Figure 1. Plant A

○ - SAMPLING STATIONS

⊠ - GCA SAMPLING LOCATIONS

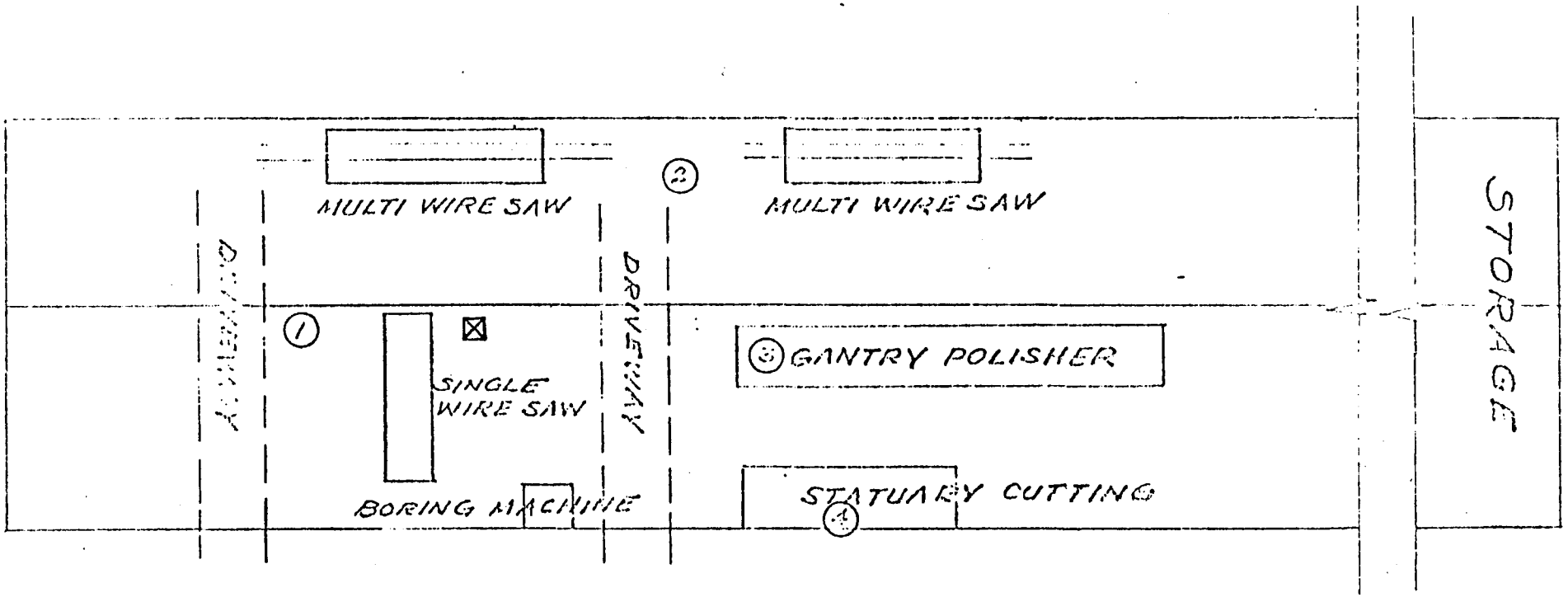

Figure 2. Plant D

○ – SAMPLING LOCATIONS

⊠ – GCA SAMPLING LOCATIONS

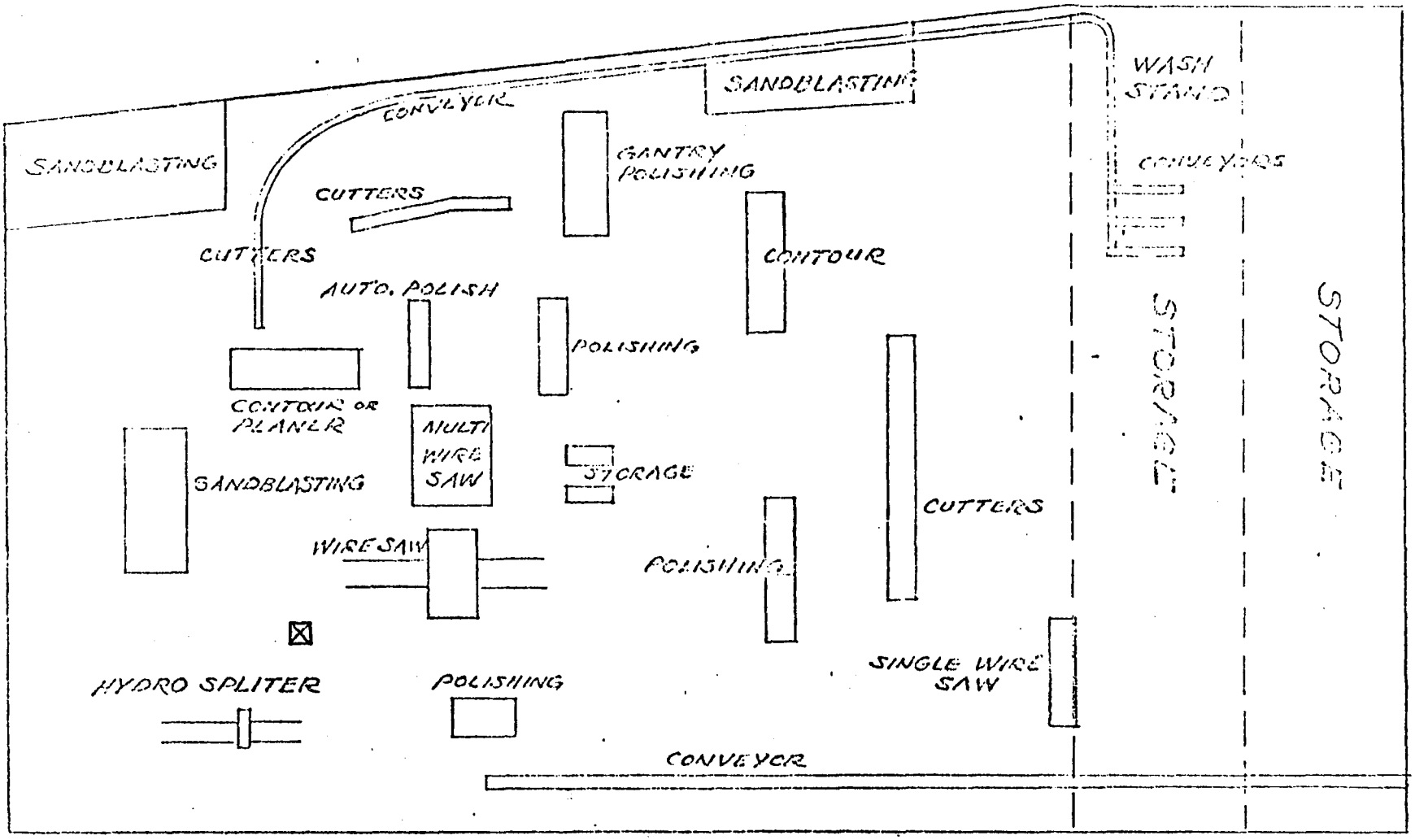

Figure 3. Plant E

☒ – GCA SAMPLING LOCATIONS

Table 1. Correction Factors for GCA
Respirable Dust Monitor

RDM-101-1

Total Sampling time t_t =	Multiply Reading by k =	Concentration Range (mg/m^3)
1 minute	1	1 to 50
1 min 40 sec	0.5	0.5 to 30
2 minutes	0.4	0.4 to 25
3 minutes	0.25	0.25 to 20
3 min 40 sec	0.2	0.2 to 12
4 minutes	0.182	0.18 to 10
5 minutes	0.143	0.14 to 8
6 minutes	0.118	0.12 to 8
7 minutes	0.1	0.1 to 6
8 minutes	0.087	0.09 to 6
10 minutes	0.069	0.07 to 5
13 min 40 sec	0.05	0.05 to 3
$\frac{0.67}{k}$ minutes	$\frac{0.67}{t_t}$	k to $\frac{50}{t_t (min)}$

The GCA readings were recorded at the sheds and the MSA PVC filters were re-weighed in the EIB laboratory for respirable dust concentrations. The GCA readings were then transformed into the actual respirable concentrations by the use of the correction factors supplied with the GCA instruction manual. The K factors are shown in Table 1.

DISCUSSION OF RESULTS

The GCA and MSA results are presented in Tables 2-7. These are self-explanatory for the most part, except for these special notations on the GCA tables. Some zero readings were recorded and marked with an asteric (*) but were not used in determining the mean concentrations. Most of the GCA samples of greater than one minute duration did not give results in accord with the one minute GCA readings. These were marked with a cross (+) and also were not used in determining the mean concentrations.

PROBLEMS ENCOUNTERED WITH THE GCA RESPIRABLE DUST MONITOR

There were three major problems encountered with the GCA respirable dust monitor during this field survey use that hampered its accuracy and efficiency. The first problem concerned the advance mechanism for the polyester disc. The advance mechanism is a spring-loaded, push-button ratchet unit that moves the polyester disc 360° to allow 100 sampling positions per disc. This unit absolutely did not work. Therefore, all advancing of the polyester disc was done manually by removing the top of the sample chamber and turning the disc by hand. Needless to say, this is not a ideal situation because of the minute amounts of airborne particulate that are being measured.

The second problem concerned the start switch when the instrument was being operated on the semi-manual mode. With the GCA respirable dust monitor,

when a longer sampling period than one minute is desired, the start switch must be moved from its intermediate position after the instrument is running to the extend position. While in the extend position, the instrument will run for an indefinite period until the start switch is returned to the intermediate position. When the switch is returned to the intermediate position, the instrument continues to run for one more minute and then displays the dust concentration for the entire extended sampling phase. The problem encountered was the apparent fact that at times, when the switch was returned to the intermediate position, the sampling cycle restarted instead of continuing and the concentration displayed was that of a one minute sample instead of the extended sampling period attempted. This happened approximately 25 percent of the time during the extended sampling period attempts.

The third problem concerned the 10 mm nylon cyclone. At the end of the last sampling date, the cyclone was inspected for the dust that had been collected during the sampling. None was found even through the instrument sampled approximately 0.3 m^3 of air during the three days in use. In contrast, the cyclones used with the MSA personal pumps collected a considerable amount of non-respirable dust after each day in use. (An average of 0.84 m^3 of air was sampled per day.) This may be reflected in the data results by the fact that the GCA results were consistently higher than the MSA results due to the apparent malfunction of the GCA cyclone. A possible explanation of this malfunction could be that the 10 mm nylon cyclone was designed to be operated with a 1.7 lpm flow whereas the GCA respirable dust monitor operates at a recommended flow of 2.0 lpm.

TABLE 2. MSA Respirable Dust Concentrations
Plant A 5-November 8, 1973 - Finishing Area

Sample No.	Total Vol. of Air Sampled, m^3	Weight of Dust Collected, mg	Respirable Dust mg/m^3
647	0.875	0.254	0.290
915	"	0.374	0.427
819	"	0.252	0.288
776	"	0.298	0.340
898	"	0.364	0.416
933	"	0.412	0.470
		mean	0.373

TABLE 3. MSA Respirable Dust Concentrations
Plant D, November 9, 1973 - Sawing Area

Sample No.	Total Vol.of Air Sampled, m^3	Weight of Dust Collected, mg	Respirable Dust mg/m^3
787	.850	.310	.365
764	"	.304	.358
748	"	.354	.416
835	"	.380	.447
692	"	.296	.348
769	"	.264	.310
		mean	.374

TABLE 4. MSA Respirable Dust Concentrations
Plant E, - November 13, 1973 - Splitting Area

Sample No.	Total Vol. of Air Sampled, m^3	Weight of Dust Collected, mg	Respirable Dust mg/m^3
930	.807	.402	.498
659	"	.416	.515
947	"	.502	.622
937	"	.496	.615
323	"	.348	.431
			mean.536

TABLE 5. GCA Respirable Dust Concentrations
Plant A - November 8, 1973 - Finishing Area

Sample No.	Duration of Sample	Digital Reading mg/m^3	K Factor	Respirable Dust mg/m^3
1	1 minute	0.9	1	0.900
2	"	0.3	"	0.300
3	"	1.1	"	1.100
4	"	1.1	"	1.100
5	"	0.8	"	0.800
6	"	0.6	"	0.600
7	"	0.1	"	0.100
8	"	0.6	"	0.600
9	"	1.5	"	1.500
10	"	0.1	"	0.100
11	"	0.8	"	0.800
12	"	1.0	"	1.000
13	"	0.6	"	0.600
14	"	0.3	"	0.300
15	"	0.9	"	0.900
16	"	0.7	"	0.700
17	"	0.2	"	0.200
18	"	0.5	"	0.500
19	"	0.6	"	0.600
20	"	0.7	"	0.700
21	"	0.5	"	0.500
22	2 minute	1.3	0.4	0.520
23	5 minute	1.5	0.143	0.215
24	"	38.4	"	5.491+
25	"	99.9*	"	---
26	"	40.2	"	5.748+
27	"	38.0	"	5.434+
28	"	1.6	"	0.229
29	"	33.6	"	4.805+
30	"	34.3	"	4.905+
			mean	0.619

*Zero Reading
+Not included in mean

Average zero reading - 99.80 based on five readings
Average calibration reading - 9.125 based on five reading 9.20 stnd.

TABLE 6. GCA Respirable Dust Concentrations
Plant D - November 9, 1973 - Sawing Area

Sample No.	Duration of Sample	Digital Reading mg/m^3	K Factor	Respirable Dust mg/m3
31	1 minute	0.3	1	0.300
32	"	1.0	"	1.000
33	"	0.3	"	0.300
34	"	0.2*	"	0.200
35	"	99.3*	"	---
36	"	0.1	"	0.100
37	"	1.1	"	1.100
38	"	1.4	"	1.400
39	"	99.3*	"	---
40	"	99.8*	"	---
41	"	0.4	"	0.400
42	"	0.9	"	0.900
43	"	0.9	"	0.900
44	"	0.9	"	0.900
45	"	0.2	"	0.200
46	"	0.7	"	0.700
47	"	0.1	"	0.100
48	5 minute	31.9	0.143	4.562+
49	"	2.3	"	0.329
50	"	34.7	"	4.962+
51	"	34.9	"	4.991+
			mean	0.589

* Zero Reading
+ Not included in mean

Average zero reading - 8.73 based on five readings
Average calibration reading - 9.125 based on five readings 9.20 stnd.

TABLE 7. GCA Respirable Dust Concentrations
Plant E-- November 13, 1973 - Splitting Area

Sample No.	Duration of Sample	Digital Reading mg/m^3	K Factor	Respirable Dust mg/m^3
52	1 minute	0.4	1	0.400
53	"	1.1	"	1.100
54	"	1.2	"	1.200
55	1 minute	0.8	"	0.800
56	"	1.1	"	1.100
57	"	0.9	"	0.900
58	"	0.2	"	0.200
59	"	0.7	"	0.700
60	"	0.4	"	0.400
61	"	0.8	"	0.800
62	"	0.8	"	0.800
63	"	0.5	"	0.500
64	2 minute	34.1	0.4	13.640+
65	"	32.1	"	12.840+
66	5 minute	37.2	0.143	5.319+
67	"	37.2	"	5.319+
68	"	41.0	"	5.863+
69	"	38.9	"	5.563+
70	"	39.4	"	5.634+
71	8 minute	37.4	0.087	3.254+
			mean	0.741

+ Not included in mean

Average zero reading - based on five readings
Average Calibration reading - based on five readings 9.20 stnd.

CONCLUSIONS AND RECOMMENDATIONS

The GCA and MSA results are not directly comparable since the former were derived from a short form spot sample and the latter from an eight-hour integrated sample. Mechanical problems with the GCA also interfered with attempts to draw any realistic comparison of the values obtained by the two sampling methods.

If some of the mentioned problems with the GCA dust monitor can be corrected, it should be re-evaluated on a future field survey. Also, it is evident that the GCA instrument could be utilized to identify the gradient of dust levels in a given plant which could be utilized to establish the strategy for personal and general area sampling with the procedures now being routinely used.

JOB DICTIONARY

Lumper - One who sets up or moves granite blocks into working positions. Includes stone banker, stone carter, stone setter, bed setter, stack man, rock stacker, and crater.

Stone Cutter - One who cuts stone either with a hand chisel, or by mechanical means. Includes hydrosplit operator, profile operator, and profile machine operator.

Wire Saw Operator - One who tends a sawing operation. Includes wire saw operator, saw shed worker, carbo saw operator, diamond saw operator, diamond saw set-up man, wire saw shed foreman, and profile and diamond saw.

Polisher - One who does rough or fine polishing on granite surfces. This includes wet grinding with a hand held carborundum tool, wet grinding with a stationary spinning abrasive wheel with a moving stone surfce, or may involve operation of a gantry polisher using carborundum, tin oxide or rouge as a polishing agent. Includes finisher, grinder operator, top polisher, profile grinder, and polishing mill.

Abrasive Blaster - One who performs abrasive blasting of granite surfaces using either sand or other abrasives to cut away stone to form a desired surface configuration or effect, also to cut letters or designs into a stone surface. Includes sand blaster, and sand blasting foreman.

Crane Operator - One who operates an overhead crane. Includes crane helper.

Miscellaneous Worker - Those not otherwise classified.