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Industrial Hygiene Survey of Lehigh Cement Co.

Cementon, New York

Cement Workers Morbidity Study

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16. Abstract (Limit: 200 words)
Environmental sampling was conducted at the Lehigh Cement Company in Cementon, New York as part of an investigation of the effects of exposures at Portland cement facilities. Personal respirable dust samples were collected for a subset of workers. Area total dust samples were collected throughout the facility. Bulk material samples were analyzed. Dust levels were relatively low. Only three personal samples out of 65 exceeded the nuisance dust standards. Detectable amounts of quartz (14808607) were found in 17% of respirable dust samples. Quartz exposures apparently occurred only in raw materials handling areas. No asbestos was found in the raw materials. The authors recommend that engineering controls be implemented and maintained at all times. Jobs of particular concern included those using the conveyors for transferring cement and those in the primary and secondary crushing pits and clinker cooler pits. Improved clean up procedures emphasizing the use of personal protective equipment were also suggested.

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Introduction

Environmental investigations were conducted at this facility by a NIOSH field research team consisting of Mr. Steven Lenhart, Steven Minshall, and Wayne Sanderson. This industrial hygiene study was primarily concerned with measuring dust levels in the workplace, and was part of a broader medical/environmental study designed to investigate associations between dust levels and respiratory health in Portland Cement plants. This facility, investigated from Monday, July 23 through Friday, July 27, 1979, was the second of seventeen plants to be studied.

The Lehigh Cement plant is located along the Hudson River near Cementon, New York. The plant began operation in 1910. In 1929 the plant was closed and not reopened until 1940. At its reopening four small kilns were in operation. Two more kilns were built in 1953. When a larger kiln was added in 1960, the four older and smaller kilns were abandoned. The dry process method of cement production is used. Within the last 3-4 years improved particulate collectors have reduced dust levels.

Despite the age of this facility the dust levels are relatively low. Only three personal samples out of sixty-five were found to exceed the nuisance dust standard. This is to be attributed to concern expressed by management and labor for a safe and healthy working environment. There is, however, concern that the quarry workers and those involved in the handling of raw materials may be exposed to harmful levels of crystalline silica.

Methods and Results

Personal Respirable Dust Samples

Since it was not possible to environmentally monitor all individuals at the plant, a subset of workers was randomly chosen to participate in the study. These selected workers were requested to wear a respirable dust sampler. To collect respirable dust, air was pulled through a 10 mm nylon cyclone and a polyvinyl chloride filter (PVC) at a flow rate of 1.7 liters per minute (lpm) by a personal sampling pump. At this flow rate, the cyclone separates the collected airborne dust into two fractions. Those particles considered respirable pass through the cyclone and are collected on the filter; larger particles or those considered to be non-respirable drop into the cyclone "grit pot" and are discarded. The collection efficiency curve for this cyclone is presented in Figure 6. For example, particles greater than 10 micrometers in diameter would not pass through the cyclone and be deposited on the filter. Whereas, all the particles smaller than 1.5 micrometers in diameter would be collected on the filter. The filters were weighed on a precision balance to the nearest .001 milligram (mg), before and after sampling. The weight gain of the filters, the sampling flow rates, and the sampling times were used to calculate airborne respirable dust levels. After weighing, the filters were subjected to analysis by x-ray diffraction to determine their content of free crystalline silica and cristobalite. Respirable dust levels are reported in Table 1 as milligram per cubic meter (DUSTMGM3); and crystalline silica is reported in Table 3 as microgram per cubic meter (QUARTZ) and percent free silica (PCT_SIO2). A value of "N" indicates that the measured quantity was below the analytical limit of detection. Where only a decimal point is listed no detectable weight gain was found. Limits of detection for each method are given in Table 10.

The results from the respirable dust sampling are also summarized in Table 3, with summary statistics computed for each exposure category. The "MEAN" value is a simple arithmetic average of all values obtained in each area; the "STD" values are the standard deviations, which is a measure of the variability of the data. "GM" and "GSD" are the geometric means and geometric standard deviations of the same data respectively. These values sometimes give a better estimate of expected values than do normal arithmetic averages because the effect of an occasional high value is diminished in calculating geometric means. To use the GM and the GSD values, we can be 63% confident that the true exposure value lies between the upper value of the GM x GSD and the lower value of the GM/GSD. The NLOD values are the number of samples which were less than the limit of detection. Note that these samples were not used in calculating the means, standard deviations, geometric means, and geometric standard deviations. Hence those values represent average concentrations for samples with detectable quantities. "MAX" and "MIN" values are maximum and minimum observed values for samples that had detectable amounts of materials.

Mean respirable dust levels are also charted in Figures 1 and 2 by process area and job category respectively. These are presented to provide easy recognition of the highest exposure areas and job categories.

The frequency, or the number, of dust concentrations which occur about certain concentration values are charted in Figure 3. This figure shows that the majority of values are low. This distribution of concentrations is typical of a log-normal population. That is, the values would approximate a normal, bell-shaped curve had the logarithms of the values been charted. This was done in Figure 4. Observe that this distribution is near normal or bell-shaped. It is necessary to know what type of distribution we are dealing with, before our statistical analysis methods are valid. In this case, we will employ statistics for log normal populations.

Area Total Dust Samples

Airborne "total" dust samples were collected at static locations throughout the plant. These areas were selected based on how well they represented the work station of the employees. The basic sampling apparatus for respirable dust, minus the size selector, is used to collect total airborne dust. Air is pulled through a PVC filter mounted in a polystyrene filter holder at a flow rate of 1.5 lpm. Roughly, those particles 30-40 um and below are collected on the filter media. Those particles greater than 40 um generally fall through the air too rapidly to be captured on the filter. This of course depends also on the direction, speed, density, and nearness of the particles to the filter. The filters are then ashed in acid and analyzed by atomic absorption (3) to detect the amount of aluminum (AL), chromium (CR), cobalt (CO), magnesium (MG), manganeese (MN), and nickel (NI) present.

The trace metal concentrations are reported in Table 4 as micrograms per cubic meter of air (___UGM3). The JOB column tells where the sample was collected. The six trace metal concentrations are then given in the next six columns. Once again, a value of "N" indicates that the measured quantity was below the limit of detection.

The results of the trace metal analysis of the area total samples are summarized in Table 5. The MEAN is the arithmetic mean of all the samples with detectable levels of the particular elements. STD DEV is the standard deviation of these samples and is an expression of the variability of the elemental concentrations. The correlation coefficients are also listed in this table. These coefficients give the relationship of the concentrations of each particular element with the other five elements. A value of one means that two elements are very strongly associated with each other. A value of zero means that there is basically no relationship between the presence of the two elements. In other words, if a value close to one occurs, there is a good chance that where you find one element, you will also find the other. Likewise, if a value close to zero occurs, there is little chance that where you find one element the other will be there also.

A value of "N" indicates that the elemental concentration was below the analytical limit of detection. The limits of detection for each element are listed in Table 10. Also listed in Table 10 are the MSHA standards for exposure to these elements.

Airborne Fiber Samples

Samples for airborne fibers and asbestos were collected on cellulose ester filters. These samples are taken with the front of the filters completely open to the environment. Air is drawn through the filters at a flow rate of 1.5 lpm. These filters are then analyzed optically with a phase contrast microscope. If any fibers are detected, identification of fiber type is made using polarized light and disperson staining.(4)

In this survey 15 samples were collected for fibers. These samples were collected in the raw material crushing and milling areas and along transfer belts. No fibers were detected on any of the filters.

Cascade Impactor Samples

The Andersen Particle Fractionating Sampler was used to collect samples of airborne particles in three areas representative of raw materials, clinker, and finished cement of the plant. The Andersen sampler is a multi-stage, multi-orificed, cascade impactor which is used to measure the aerodynamic size distribution of dust particles. After the air enters the impactor it cascades or flows successively through orifices with smaller and smaller diameters. This decrease in orifice size causes the velocity of the air stream to increase. This increase in air stream velocity results in successively smaller particles being inertially impacted on collection media. We use glass fiber filters as our collection media. No air is actually drawn through the filters, the particles simply are impacted or come to rest on the filters. These glass fiber filters are weighed to the nearest .01 milligram. Comparison of initial filter weights with final weights yields the weight of dust particles on each filter. These weights are used to calculate a cumulative weight percentage value for each stage. These cumulative weight percentages for each stage are plotted on log probability paper against the corresponding effective cutoff diameters. From this graph the percentage of airborne particles below a particular aerodynamic diameter can be estimated.

Graphs of samples collected in raw material, clinker, and finished cement exposure areas are presented in Figure 5. The horizontal coordinates are cumulative percent values below the aerodynamic diameter. The vertical coordinates are the aerodynamic diameter in micrometers.

The stages and their corresponding effective cutoff diameters are listed below. These effective cutoff diameters are the mean particle diameters that will be collected on that stage.

pre seperator	10.0 µm
1	9.0
2	5.8
3	4.7
4	3.3
5	2.1
6	1.1
7	.7
8	.4
Final	<.4

Bulk Material Samples

Samples of raw material dust, clinker, finished product, and mixtures of dust were collected for analysis. These samples were generally collected from dust settled on ledges or objects several feet above the floor. For this reason, it is suspected that these particles were at one time suspended in air before coming to rest. These bulk material samples cannot, however, be considered airborne samples. This material was analyzed for content of quartz and cristobalite by x-ray diffraction; aluminum, chromium, cobalt, magnesium, manganese, and nickel content by atomic absorption; and asbestos content by polarized light and dispersion staining microscopy.

The results of these analyses are presented in Table 6. The "AREA" column lists from what exposure category the samples were taken. That is, whether the material was felt to be predominantly raw material, clinker, finished Portland cement, or a mixture of two or more types of dust. The results of analysis are presented as percent by weight of material. For example, 1% of the raw material is quartz or there is .01 gram of quartz in each gram of raw material. The value "N" indicates that the measured quantity was below the analytical limit of detection.

Control filters were collected on site during the survey. These filters received treatment identical to dust laden filters, except no air was drawn through the control filters. These filters were utilized to correct for analytical or handling errors.

During each shift, each personal and area sampler was periodically checked for proper operation. If the sampler was not operating within specifications, sampler adjustments and appropriate notations were made and, if necessary, the results of such samples were voided.

The environmental investigations team began sampling Monday, July 23, 1979. The sampling schedule was as follows:

Monday, July 23	- 2nd shift
Tuesday, July 24	- 2nd shift
Wednesday, July 25	- 1st shift
Thursday, July 26	- 1st shift
Friday, July 27	- 3rd shift

This schedule was utilized in order to adequately measure environmental concentration differences due to day-to-day and shift-to-shift variations.

Plant areas and the work force were separated into four exposure categories based on the type of airborne dust each was subjected to. The categories were:

raw - exposure to raw materials dust
clinker - exposure to clinker dust
finish - exposure to finished Portland cement dust
mix - exposure to a mixture of two or more types of dust

Although these categories are somewhat artificial and arbitrary, they are very important to the design of the study. This is done because the dust particles in these areas are chemically and physically different. The mix category serves to "catch" those jobs such as laborers and repairmen who work throughout the plant or are exposed to more than one type of dust.

Discussion

This study is designed to determine if the normal function of respiratory tissue is impaired because of exposure to gases or particulates found in Portland cement plants. Samples of airborne particulate were collected in conjunction with a medical exam including x-rays, spirometry tests, and questionnaires. Respiratory problems associated with exposure to airborne particulate are influencd by four chemical factors.(5)

1. The type of dust involved
2. The legnth of exposure time
3. The concentration of airborne dusts in the breathing zone
4. The size of the dust particles

The intent of the environmental portion of the study is to determine what materials cement workers are exposed to, and the concentration of those materials. It is also of extreme importance to know the sizes of the dust particles.

All respiratory problems are studied to determine if there is an association between disease and particular airborne materials.

The main function of the lungs is to keep the oxygen and carbon dioxide content of the arterial blood within a certain narrow range. In order to accomplish this, the lungs must bring the blood in contact with the air. The lungs are ventilated by a bellows action, when the chest cavity is expanded by the contraction of the diaphram. This creates a negative pressure in the lungs causing air to rush in.

When a person breathes, air is drawn through the nose into the nasopharynx and trachea. From there it reaches the alveoli or area of gas exchange through a system of ducts: the bronchi, respiratory bronchioles, and the terminal bronchides. It is in the alveoli where the blood is oygenated and carbon dioxide diffuses into the lungs to be excreted. Deposition of airborne particles occurs as a consequence of several different physical processes. Of primary concern are sedimentation, inertial impaction, and diffusion. Sedimentation is simply the settling out of particles onto respiratory tissue under the influence of gravity. Inertial impaction occurs when the momentum of particles being carried along in an air current carries them along their original path when the air current changes direction. The particles may then be deposited on the surface of respiratory tissue. Besides sedimentation and impaction, very small particles are affected by diffusion. Since movement of small particles in air is completely random, those that are in close proximity to the alveolar wall are likely to collide with it and hence be deposited.(5)

In order to remove particles from the resiratory system, two separate mechanisms are present.

Those particles deposited in the upper airways are removed by the mucociliary escalator. In the upper airways there is a series of tiny hairs or cilia which are continually sweeping mucous and particles upward toward the throat. The mucous provides a sticky layer to capture and hold the particulate, while the cilia remove it from the respiratory system. In the terminal bronchioles and the alveoli deposited material is removed by phagocytes; or cells which actually "eat" the particles and digest them.

Problems arise, however, when the respiratory system is overcome Whenever there is a high concentration of dust, the mucociliary escalator and the phagocytes may not be able to remove all of the particles. Also, the particles may possess unique properties which prevent the natural defenses of the lung from eliminating them.

It is the intent of this study to determine what materials may be toxic to the respiratory system, and to what concentration and duration of exposure may be considered safe.

Personal Respirable Dust Samples

These samples measure the dust concentrations that are respirable, or able to enter the lungs. These levels vary however, from job to job. Because of the differences in worker duties and activities, some jobs consistently encounter higher or lower dust levels than other jobs. With some of the jobs, workers experience quite consistent dust levels. Table 7 lists the dust measurements for 3 jobs. The symbol "n" designates the number of observations, "X" the mean dust level, "S" the standard deviation of the dust levels, "S^2" the variance or variability of the dust levels about the mean and CI95 is the 95% confidence interval about the mean. The CI95 is the interval between which we feel the true mean dust levels for these jobs lie, with a 5% chance of errors. The variance is low for all three jobs. This suggests that the dust concentrations are quite constant in the areas where the activities of these jobs take place. There is some variability, however, This is due to changes in environmental conditions, worker activities, and experimental error. For the most part, the dust concentrations for these jobs, is very near their means. We can be confident that kiln burners and kiln helpers are generally exposed to clinker dust levels, and bulk loaders exposed to finished cement dust levels, within their respective confidence intervals. Unfortunately, there are not enough measurements from the other jobs to accurately calculate their variability. Some jobs, such as maintenance workers and laborers may experience quite variable dust levels, because their activities are highly variable from day to day.

Figure 2 charts the means of the dust measurements from each job. Rock drillers, primary crusher operators, conveyor tenders, and general laborers possess the highest dust exposures. These jobs are involved in the manipulation and transfer of materials. These activities generate a considerable amount of dust, from which the workers are not separated Most of the other jobs either do not generate much dust, or are separated from it by enclosures.

There is little variation in concentration of dust levels from shift to shift. Using student's matched paired "t" test ($\alpha = .05$), there was found to be no difference in the mean dust levels of corresponding jobs between the first and second shifts. The personal respirable dust levels of 16 jobs on the first shift were compared to 16 identical jobs on the second shift. The means of each shift sample fall within the other 95% confidence limits. It is proposed that the airborne respirable dust concentrations remain relatively constant throughout the day. See Table 8.

Personal respirable dust data collected at this facility in September, 1978, are presented in Table 9. The plant-wide mean respirable dust value is nearly identical to the plant-wide mean value from July, 1979. The 95% confidence interval limits are also very similar for both 1978 and 1979 data. This suggests that the dust levels remain relatively constant from year to year.

Based on the results of the Cement Workers Pilot Study, there was found to be little variation in concentration of dust levels from shift to shift or among workers in the same job category. There was found to be significant variations in the dust levels from day to day, area to area, and among different job categories. This tells us that environmental dust levels may fluctuate daily, probably depending on process changes or problems, and atmosheric conditions. Also, there are certain jobs and areas of the plant where consistently higher dust levels than other jobs and areas. This survey has pinpointed only a few jobs which may need stronger dust control measures to adequately protect the workers.

The jobs have been separated into four exposure categories. Although these categories are somewhat artificial, they separate the jobs into those exposed to different types of dust. Raw material, clinker, and finished cement dust are all chemically and physically different. The dust concentrations are also significantly different. Using a student's "t" test (α - .05), the mean dust concentrations for each area are found to be statistically different. The dust measurements from the three exposure categories should be considered from separate populations. Not only are the respirable dust levels different, but the physical and chemical makeup of the particles is also different. No where is this more evident than in the crystalline silica analysis.

These samples measure the dust concentrations that are respirable, or able to enter the lungs. Of the 65 personal respirable dust samples collected only two exceed the federal nuisance dust standard. Both of these samples were collected from workers associated with the handling of raw materials. From bulk material analysis, raw materials from this facility generally contain 1% quartz (Table 6). Employing the formula for mineral dust containing quartz

$$\text{TLV for respirable dust} = \frac{10\ \text{mg/m}^3}{\%\ \text{respirable quartz} + 2}$$

with 1% quartz the standard would be changed 3.33 mg/m^3 for those workers exposed to raw material dust. In this case, 3 samples would exceed the federal dust standard. The dust measurement from general laborer is quite close to the federal dust standard.

Crystalline Silica - Only 11 (17%) of the respirable dust samples had any detectable amounts of quartz. All but one of these occurred in the raw material exposure category. This single exception was collected from a crane operator who may have been transferring raw material that day. It is probable that raw material consistently contains 1% quartz. There may, however, be some variance in quartz concentration depending on the compositon of the overburden and the ore that employees are working with. Therefore, the free silica concentration may vary from area to area of the quarry and day to day. At this low concentration of quartz, at least 0.3 mg of respirable dust would need to be collected, since the limit of detection for our analytical method is .003 mg. The calculated percent of quartz on the respirable filters (Table 3) suggests that the airborne dust contains a higher percentage of quartz than does the settled bulk material samples. This would occur if the bulk materials contain a high percentage of particles denser than quartz. These particles may not stay suspended in air long enough to be collected on the filters. Therefore, the particles containing quartz would be more highly represented on the filter than in the bulk materials.

Ten of the fifteen personal respirable dust samples contained detectable levels of crystalline silica. All of these samples exceeded the NIOSH recommended standard of 50 ug/m^3 for crystalline silica. It is possible that with years of exposure to this dust, fibrotic changes may occur in the lungs. Quartz was only detected in raw material dust and a mixture of raw and clinker dust. This suggests that after the material passes through the kiln, the molecular arrangement is transformed such that crystalline silica is no longer present.

Trace Metals - Only one measurement of the six trace metals yielded values which exceeded either NIOSH recommended standards or federally mandated standards. This sample was severely overloaded and should not be considered to represent an exposure that workers might encounter. Raw material, clinker, and finished cement dust all contain aluminum, magnesium, and manganese. There is considerable variation in the concentration of these three trace metals from sample to sample. This was unexpected. Generally the concentration of these metals remains constant. Variation may be caused by differences in milling or processing, or it may suggest inconsistencies in our analytical technique. Chromium, cobalt, and nickel are present in extremely minute quantities. We chose to measure these six metals because nickel and chromium are suspected carcinogens, and aluminum, magnesium, mangese, and cobalt are suspected pneumoconiosis or bronchitis producing agents. There are no past studies to indicate that these elements will cause any disease in the form or concentrations found in a cement plant. This study will look for correlations between respiratory or morbidity studies and exposures to these elements. It is doubtful that at these concentrations any such problems will arise.

Asbestos - In this survey we found no asbestos present in the raw materials. NIOSH has extensively surveyed quarries and raw materials associated with cement plants, as well as other limestone quarries. No asbestos has been found during any of these surveys. It is possible that quarried rock may be contaminated with asbestos fibers due to the occurrence of small deposits of asbestos-bearing rock in the overburden or the quarried strata. If this occurs at all, we expect it to be extremely rare.

Particle Size Distribution - Roughly half of the airborne dust particles in the raw material, clinker, and finished cement areas are in the respirable size range. As material passes through the production process, from quarried rock to finished cement the respirability of the airborne dust particles tends to increase. Figure 5 allows us to estimate the percentage of dust particles below given aerodynamic diameters. About half of the airborne particles in all three exposure categories are too large to be deposited in the respiratory system beyond the nasopharynx, because about all (100%) of the particulates greater than 10um in diameter are captured in the nose or throat. The size of the particles is a factor in determining where in the respiratory system they will be deposited. Those particles between 0.5 and 3.5 are the ones most capable of reaching the lung parenchyma (alveoli and termina bronchides) and being deposited there. We can see from Figure 5 that from 10-15% of the airborne particles fall within this size range.

From Figure 5, we can see that a higher percentage of the finished cement particles would be able to enter the respiratory system, than clinker or crushed stone particles. Limestone and clinker dust seem to have similar particle size distribution curves. For example, about 41% of the airborne finished cement particles are below 6 micrometers in diameter. About 29% of the airborne clinker and limestone particles are below this diameter. These curves also allow us to compare the respirability of particles in this industry with those found in other dusty trades.

Background Samples - Samples placed upwind of the cement plant exhibit very low levels of dust. No trace metals, asbestos, or crystalline silica were detected on the background samples. Since Lehigh is situated among other cement plants and industries, the background respirable and total dust levels are suspected to fluctuate with changes in atmospheric conditions. These dust levels represent the dust exposures people would experience by just being in the community. One approach to data analysis might be to subtract these dust levels from measured plant concentrations. This would give values which represent the additional dust burden attributed to the operation of this plant. Tables 1 and 2 list the background respirable dust levels and their descriptive statistics.

Bulk Samples From Results - The raw materials contain significantly ($\alpha = .05$) less aluminum than clinker or finished cement. This is due to the addition of clay or shale before the material is milled and "burned" in the kiln. All of the other elements also are present slightly more in cliker and finished cement than in raw materials. These elements are introduced during the crushing, milling, and burning processes. All materials tested for are present in very small quantities except for quartz (in raw material), aluminum and magnesium.

Recommendations

To effectively reduce workers' exposure to airborne dust, management should actively seek and implement engineering controls and should maintain these systems in efficient working order at all times.

Jobs of particular concern are those involved with the conveyors for transferring cement and those in the primary and secondary crushing pits and clinker cooler pits. Administrative changes and personal protective equipment (respirators and goggles) may relieve those conditions; however, engineering controls are the recommended courses of action. Ventilation design to remove the dust from the air once it is generated may be an effective means of control. Separation from the dust by enclosing either the worker or the dust is another effective means of control.

During clean-up operations, workers often use compressed air to "blow down" the work areas. This process resuspends a great deal of dust. Substitution with a vacuum system would eliminate this problem.

Personal protective respirators should be provided for the jobs which are subjected to the highest dust exposure. The disposable paper or cloth respirators are generally not efficient enough to protect the workers from respirable particulate. It is suggested that workers be involved in the selection of a comfortable respirator and be fit-tested to ensure that they are adequately protected.

In certain cases, such as quarry driller and crusher operators, where they cannot be enclosed or separated from the aust, wetting agents might be used to reduce fugitive dust emissions. Either enclosure of the workers or enclosure of the dust generating operation is the preferred method of control.

Conclusion

The dust levels at the Lehigh Cement plant in Cementon, New York are relatively low for most jobs. The data collected is considered to be representative of worker exposure to airborne dust at this facility.

Of the contaminants measured, only quartz is considered to be present in hazardous concentrations. Exposure to quartz seems to occur only in the raw material handling areas. Protective measures should be taken.

The corrective actions recommended should be viewed as scientific guidance. There is no legal requirement that you implement any of these recommendations, and no assurance that these actions, if implemented, would be sufficient to prevent future citations for non-compliance. Nevertheless, it is anticipated that implementation of the recommendations listed in this report will reduce airborne dust levels at this facility.

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TABLE 1

ENVIRONMENTAL INVESTIGATIONS BRANCH
INDUSTRIAL HYGIENE STUDY OF CEMENT WORKERS
LEHIGH CEMENT
PERSONAL RESPIRABLE DUST CONCENTRATIONS, MG/M3
MEAN VALUES BY JOB CATEGORY

9:55 TUESDAY, FEBRUARY 3, 1981

AREA=BACKGROUND

JOB	DATE	SHIFT	DUSTMGM3
BACKGROUND	23JUL79	2	0.07
BACKGROUND	24JUL79	2	0.07
BACKGROUND	25JUL79	1	0.11
BACKGROUND	26JUL79	1	.
BACKGROUND	26JUL79	3	0.05

AREA=RAW

JOB	DATE	SHIFT	DUSTMGM3
CONVEYOR OPERATOR	23JUL79	2	2.26
SILO OPERATOR	23JUL79	2	1.43
FRONT END LOADER	23JUL79	2	0.90
CONVEYOR OPERATOR	23JUL79	2	2.01
PRIMARY CRUSHER OPERATOR	23JUL79	2	5.45
QUARRY TRUCK DRIVER	25JUL79	1	0.05
SILO OPERATOR	25JUL79	1	0.42
PRIMARY CRUSHER OPERATOR	25JUL79	1	3.01
CONVEYOR OPERATOR	25JUL79	1	10.77
QUARRY SUPERVISOR	25JUL79	1	.
DRILLER	25JUL79	1	2.81
CONVEYOR OPERATOR	25JUL79	1	4.85
FRONT END LOADER	25JUL79	1	0.41
LABORER (QUARRY)	25JUL79	1	0.20
MECHANIC (QUARRY)	25JUL79	1	0.29
SILO OPERATOR	26JUL79	3	0.37

AREA=CLINKER

JOB	DATE	SHIFT	DUSTMGM3
KILN BURNER	23JUL79	2	0.34
KILN HELPER	23JUL79	2	0.45
KILN HELPER	23JUL79	2	0.86
KILN BURNER	23JUL79	2	0.19
KILN HELPER	23JUL79	2	0.45
KILN BURNER	24JUL79	2	3.30
KILN HELPER	24JUL79	2	0.78
KILN BURNER	24JUL79	2	0.27
KILN HELPER	24JUL79	2	0.80
KILN HELPER	24JUL79	2	0.26
KILN HELPER	25JUL79	1	0.67
KILN HELPER	25JUL79	1	1.09
KILN BURNER	25JUL79	1	0.15
KILN HELPER	25JUL79	1	0.43
KILN BURNER	25JUL79	1	0.25
KILN HELPER	26JUL79	1	0.90
KILN BURNER	26JUL79	1	0.15

Table 1
(continued)

ENVIRONMENTAL INVESTIGATIONS BRANCH — 9:55 TUESDAY, FEBRUARY 3, 1981
INDUSTRIAL HYGIENE STUDY OF CEMENT WORKERS
LEHIGH CEMENT
PERSONAL RESPIRABLE DUST CONCENTRATIONS, MG/M3
MEAN VALUES BY JOB CATEGORY

AREA=CLINKER

JOB	DATE	SHIFT	DUSTMGM3
KILN BURNER	26JUL79	1	0.13
KILN HELPER	26JUL79	1	0.31
KILN HELPER	26JUL79	1	0.83
KILN HELPER	26JUL79	3	0.61
KILN HELPER	26JUL79	3	0.68
KILN BURNER	26JUL79	3	0.44
KILN BURNER	26JUL79	3	0.12
KILN HELPER	26JUL79	3	0.84

AREA=FINISH

JOB	DATE	SHIFT	DUSTMGM3
BULK LOADER	23JUL79	2	1.36
BULK LOADER	23JUL79	2	0.72
BULK LOADER	24JUL79	2	0.82
BULK LOADER	24JUL79	2	1.84
TUNNELMAN (FINISH)	25JUL79	1	0.53
BULK LOADER	25JUL79	1	0.57
BULK LOADER	26JUL79	1	3.12
BULK LOADER	26JUL79	1	0.61
TUNNELMAN (FINISH)	26JUL79	1	1.86

AREA=MIX

JOB	DATE	SHIFT	DUSTMGM3
MILLOPERATOR	24JUL79	2	1.07
CRANE OPERATOR	24JUL79	2	0.96
CRANE OPERATOR	24JUL79	2	0.48
MIX CHEMIST	24JUL79	2	0.18
LOCOMOTIVE OPERATOR	26JUL79	1	0.29
LABORER	26JUL79	1	4.89
REPAIRMAN	26JUL79	1	0.15
LABORATORY WORKER	26JUL79	1	0.34
OFFICE WORKER	26JUL79	1	0.09
PIPEFITTER	26JUL79	1	0.31
MACHINIST	26JUL79	1	0.11
WELDER	26JUL79	1	0.47
ELECTRICIAN	26JUL79	1	0.34
MILLOPERATOR	26JUL79	3	1.11
MILL HELPER (MIX)	26JUL79	3	1.05
CRANE OPERATOR	26JUL79	3	1.49

Table 2

ENVIRONMENTAL INVESTIGATIONS BRANCH 9:55 TUESDAY, FEBRUARY 3, 1981

INDUSTRIAL HYGIENE STUDY OF CEMENT WORKERS

LEHIGH CEMENT

PERSONAL RESPIRABLE DUST CONCENTRATIONS, MG/M3

AREA	SAMPLES	MEAN	STD	GM	GSD	NLOD	MIN	MAX
BACKGROUND	4	0.08	0.03	0.05	2.57	1	0.05	0.11
RAW	15	2.39	2.88	0.79	6.31	1	0.05	10.77
CLINKER	25	0.61	0.63	0.45	2.20	0	0.12	3.30
FINISH	9	1.27	0.87	1.05	1.89	0	0.53	3.12
MIX	16	0.83	1.16	0.47	2.90	0	0.09	4.89
PLANTWIDE	65	1.16	1.69	0.58	3.31	1	0.05	10.77

Figure 1

ENVIRONMENTAL INVESTIGATIONS BRANCH
INDUSTRIAL HYGIENE STUDY OF CEMENT WORKERS
LEHIGH CEMENT
PERSONAL RESPIRABLE DUST CONCENTRATIONS, MG/M3
MEAN VALUES BY AREA

BAR CHART OF MEANS

```
DUSTMGM3 MEAN
           |                   XXXXX
           |                   XXXXX
           |                   XXXXX
       2.1 +                   XXXXX
           |                   XXXXX
           |                   XXXXX
           |                   XXXXX
       1.8 +                   XXXXX
           |                   XXXXX
           |                   XXXXX
           |                   XXXXX
       1.5 +                   XXXXX
           |                   XXXXX
           |                   XXXXX
           |                   XXXXX                   XXXXX
       1.2 +                   XXXXX                   XXXXX
           |                   XXXXX                   XXXXX
           |                   XXXXX                   XXXXX
           |                   XXXXX                   XXXXX
       0.9 +                   XXXXX                   XXXXX
           |                   XXXXX                   XXXXX       XXXXX
           |                   XXXXX                   XXXXX       XXXXX
           |                   XXXXX                   XXXXX       XXXXX
       0.6 +                   XXXXX       XXXXX       XXXXX       XXXXX
           |                   XXXXX       XXXXX       XXXXX       XXXXX
           |                   XXXXX       XXXXX       XXXXX       XXXXX
           |                   XXXXX       XXXXX       XXXXX       XXXXX
       0.3 +                   XXXXX       XXXXX       XXXXX       XXXXX
           |                   XXXXX       XXXXX       XXXXX       XXXXX
           |                   XXXXX       XXXXX       XXXXX       XXXXX
           |       XXXXX       XXXXX       XXXXX       XXXXX       XXXXX
           -------------------------------------------------------------
              BACKGROUND        RAW      CLINKER      FINISH        MIX

                                        AREA
```

Figure 2

ENVIRONMENTAL INVESTIGATIONS BRANCH
INDUSTRIAL HYGIENE STUDY OF CEMENT WORKERS
LEHIGH CEMENT
PERSONAL RESPIRABLE DUST CONCENTRATIONS, MG/M3
MEAN VALUES BY JOB CATEGORY

9:55 TUESDAY, FEBRUARY 3, 1981

BAR CHART OF MEANS

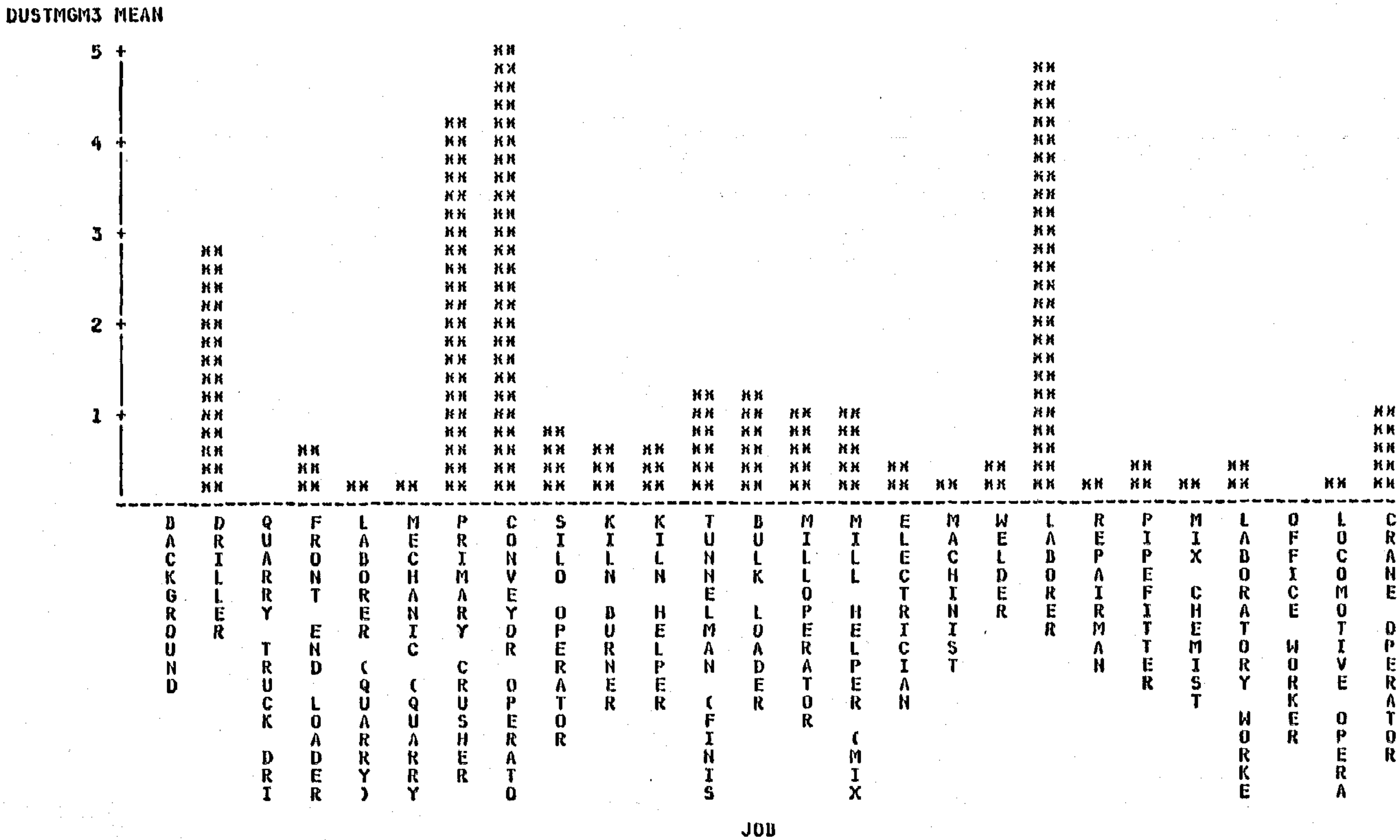

Figure 3

ENVIRONMENTAL INVESTIGATIONS BRANCH 10:05 TUESDAY, FEBRUARY 3, 1981
INDUSTRIAL HYGIENE STUDY OF CEMENT WORKERS
LEHIGH CEMENT ALSEN NY
FREQUENCY DISTRIBUTION OF PERSONAL RESPIRABLE DUST CONCENTRATIONS

FREQUENCY BAR CHART

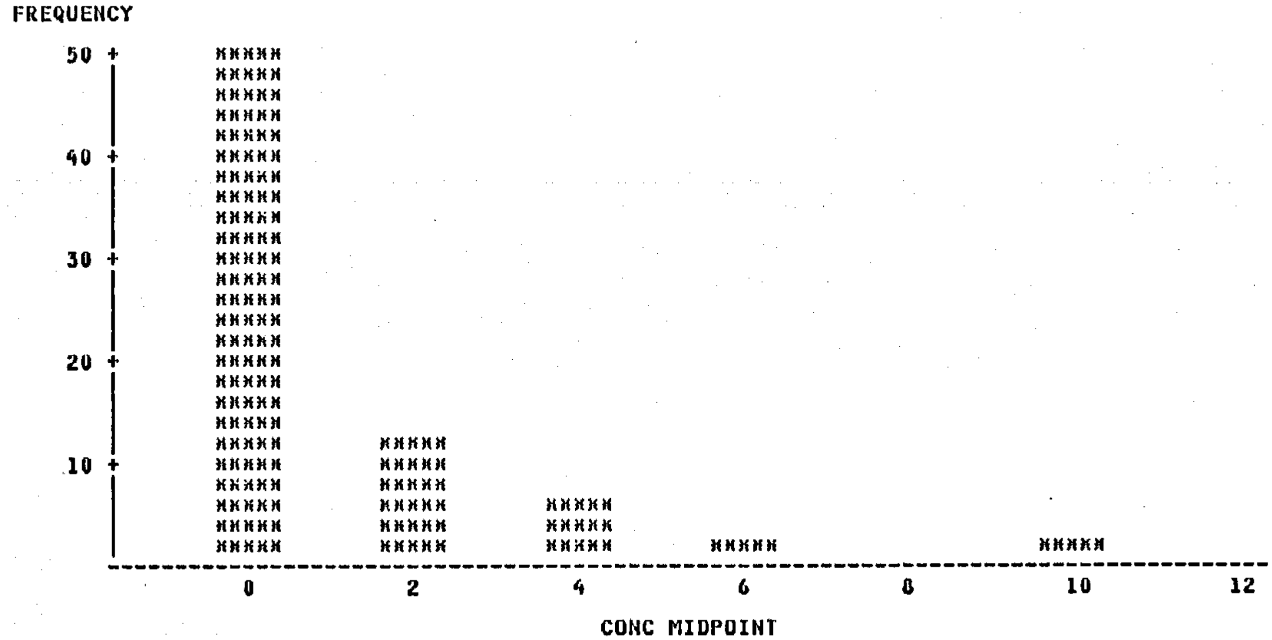

Figure 4

ENVIRONMENTAL INVESTIGATIONS BRANCH 10:05 TUESDAY, FEBRUARY 3, 1981
INDUSTRIAL HYGIENE STUDY OF CEMENT WORKERS
LEHIGH CEMENT ALSEN NY
FREQUENCY DISTRIBUTION OF LOG OF PERSONAL RESPIRABLE DUST CONCENTRATIONS

FREQUENCY BAR CHART

```
FREQUENCY

   |                                           XXXXX
25 +                                           XXXXX       XXXXX
   |                                           XXXXX       XXXXX
   |                                           XXXXX       XXXXX
   |                                           XXXXX       XXXXX
   |                                           XXXXX       XXXXX
20 +                                           XXXXX       XXXXX
   |                   XXXXX                   XXXXX       XXXXX
   |                   XXXXX                   XXXXX       XXXXX
   |                   XXXXX                   XXXXX       XXXXX
   |                   XXXXX                   XXXXX       XXXXX
15 +                   XXXXX                   XXXXX       XXXXX
   |                   XXXXX                   XXXXX       XXXXX
   |                   XXXXX                   XXXXX       XXXXX
   |                   XXXXX                   XXXXX       XXXXX
   |                   XXXXX                   XXXXX       XXXXX
10 +                   XXXXX                   XXXXX       XXXXX
   |                   XXXXX                   XXXXX       XXXXX       XXXXX
   |                   XXXXX       XXXXX       XXXXX       XXXXX       XXXXX
   |                   XXXXX       XXXXX       XXXXX       XXXXX       XXXXX
   |                   XXXXX       XXXXX       XXXXX       XXXXX       XXXXX
 5 +                   XXXXX       XXXXX       XXXXX       XXXXX       XXXXX
   |                   XXXXX       XXXXX       XXXXX       XXXXX       XXXXX
   |                   XXXXX       XXXXX       XXXXX       XXXXX       XXXXX
   |                   XXXXX       XXXXX       XXXXX       XXXXX       XXXXX
   |                   XXXXX       XXXXX       XXXXX       XXXXX       XXXXX       XXXXX
   --------------------------------------------------------------------------------------
            -2.4        -1.8        -1.2        -0.6         0.0         0.6         1.2

                                     LOGC MIDPOINT
```

Table 3

ENVIRONMENTAL INVESTIGATIONS BRANCH 9:55 TUESDAY, FEBRUARY 3, 1981

INDUSTRIAL HYGIENE STUDY OF CEMENT WORKERS

LEHIGH CEMENT

QUARTZ CONCENTRATION OF PRESONAL RESPIRABLE DUST SAMPLES

Quartz Concentration in Micrograms Per Cubic Meter ($\mu g/m^3$)

JOB	DATE	SHIFT	PCT_SIO2	QUARTZ	AREA
BACKGROUND	23JUL79	2	N	N	BACKGROUND
BACKGROUND	24JUL79	2	N	N	BACKGROUND
BACKGROUND	25JUL79	1	N	N	BACKGROUND
BACKGROUND	26JUL79	3	N	N	BACKGROUND
BACKGROUND	26JUL79	1	N	N	BACKGROUND
SILO OPERATOR	23JUL79	2	6.0	86.14	RAW
PRIMARY CRUSHER OPERATOR	23JUL79	2	6.8	372.64	RAW
CONVEYOR OPERATOR	23JUL79	2	7.7	175.22	RAW
FRONT END LOADER	23JUL79	2	8.6	77.06	RAW
CONVEYOR OPERATOR	23JUL79	2	6.5	129.85	RAW
CONVEYOR OPERATOR	25JUL79	1	0.6	63.52	RAW
LABORER (QUARRY)	25JUL79	1	N	N	RAW
FRONT END LOADER	25JUL79	1	18.3	75.09	RAW
QUARRY SUPERVISOR	25JUL79	1	N	N	RAW
PRIMARY CRUSHER OPERATOR	25JUL79	1	5.9	177.43	RAW
SILO OPERATOR	25JUL79	1	N	N	RAW
DRILLER	25JUL79	1	2.6	73.68	RAW
CONVEYOR OPERATOR	25JUL79	1	7.7	370.96	RAW
MECHANIC (QUARRY)	25JUL79	1	N	N	RAW
QUARRY TRUCK DRIVER	25JUL79	1	N	N	RAW
SILO OPERATOR	26JUL79	3	N	N	RAW
KILN HELPER	23JUL79	2	N	N	CLINKER
KILN BURNER	23JUL79	2	N	N	CLINKER
KILN BURNER	23JUL79	2	N	N	CLINKER
KILN HELPER	23JUL79	2	N	N	CLINKER
KILN HELPER	23JUL79	2	N	N	CLINKER
KILN HELPER	24JUL79	2	N	N	CLINKER
KILN HELPER	24JUL79	2	N	N	CLINKER
KILN BURNER	24JUL79	2	N	N	CLINKER
KILN BURNER	24JUL79	2	N	N	CLINKER
KILN HELPER	24JUL79	2	N	N	CLINKER
KILN HELPER	25JUL79	1	N	N	CLINKER
KILN BURNER	25JUL79	1	N	N	CLINKER
KILN HELPER	25JUL79	1	N	N	CLINKER
KILN HELPER	25JUL79	1	N	N	CLINKER
KILN BURNER	25JUL79	1	N	N	CLINKER
KILN BURNER	26JUL79	3	N	N	CLINKER
KILN HELPER	26JUL79	3	N	N	CLINKER
KILN BURNER	26JUL79	3	N	N	CLINKER
KILN BURNER	26JUL79	1	N	N	CLINKER
KILN HELPER	26JUL79	1	N	N	CLINKER
KILN HELPER	26JUL79	3	N	N	CLINKER
KILN HELPER	26JUL79	3	N	N	CLINKER
KILN HELPER	26JUL79	1	N	N	CLINKER
KILN HELPER	26JUL79	1	N	N	CLINKER
KILN BURNER	26JUL79	1	N	N	CLINKER
BULK LOADER	23JUL79	2	N	N	FINISH
BULK LOADER	23JUL79	2	N	N	FINISH
BULK LOADER	24JUL79	2	N	N	FINISH
BULK LOADER	24JUL79	2	N	N	FINISH
TUNNELMAN (FINISH)	25JUL79	1	N	N	FINISH
BULK LOADER	25JUL79	1	N	N	FINISH
BULK LOADER	26JUL79	1	N	N	FINISH

Table 3
(continued)

ENVIRONMENTAL INVESTIGATIONS BRANCH
INDUSTRIAL HYGIENE STUDY OF CEMENT WORKERS
LEHIGH CEMENT
QUARTZ CONCENTRATION OF PRESONAL RESPIRABLE DUST SAMPLES

JOB	DATE	SHIFT	PCT_SIO2	QUARTZ	AREA
TUNNELMAN (FINISH)	26JUL79	1	N	N	FINISH
BULK LOADER	26JUL79	1	N	N	FINISH
CRANE OPERATOR	24JUL79	2	5.1	49.54	MIX
MIX CHEMIST	24JUL79	2	N	N	MIX
CRANE OPERATOR	24JUL79	2	N	N	MIX
MILLOPERATOR	24JUL79	2	N	N	MIX
CRANE OPERATOR	26JUL79	3	N	N	MIX
REPAIRMAN	26JUL79	1	N	N	MIX
LABORATORY WORKER	26JUL79	1	N	N	MIX
LOCOMOTIVE OPERATOR	26JUL79	1	N	N	MIX
WELDER	26JUL79	1	N	N	MIX
OFFICE WORKER	26JUL79	1	N	N	MIX
LABORER	26JUL79	1	N	N	MIX
PIPEFITTER	26JUL79	1	N	N	MIX
ELECTRICIAN	26JUL79	1	N	N	MIX
MILLOPERATOR	26JUL79	3	N	N	MIX
MILL HELPER (MIX)	26JUL79	3	N	N	MIX
MACHINIST	26JUL79	1	N	N	MIX

Table 4

ENVIRONMENTAL INVESTIGATIONS BRANCH

INDUSTRIAL HYGIENE STUDY OF CEMENT WORKERS

LEHIGH CEMENT

TRACE METAL CONCENTRATIONS OF AREA TOTAL DUST SAMPLES

9:55 TUESDAY, FEBRUARY 3, 1981

AREA	DATE	SHIFT	JOB	AL_UGM3	CR_UGM3	CO_UGM3	MG_UGM3	MN_UGM3	NI_UGM3
BACKGROUND	23JUL79	2	BACKGROUND	N	N	N	N	N	N
BACKGROUND	24JUL79	2	BACKGROUND	N	N	N	N	N	N
BACKGROUND	25JUL79	1	BACKGROUND	N	N	N	N	N	N
BACKGROUND	26JUL79	1	BACKGROUND	N	N	N	N	N	N
BACKGROUND	26JUL79	3	BACKGROUND	N	N	N	N	N	N
RAW	23JUL79	2	BACK END OF KILN	N	N	N	N	N	N
RAW	23JUL79	2	PRIMARY CRUSHER	0.865	N	N	0.319	0.016	0.007
RAW	25JUL79	1	RAWMILLS	N	N	N	0.020	N	N
RAW	25JUL79	1	SECONDARY CRUSHER	0.571	N	N	0.390	0.019	N
RAW	25JUL79	1	FEED END RAW MILLS	N	N	N	0.020	N	N
RAW	25JUL79	1	BACK END OF KILN	0.076	N	N	0.033	N	N
RAW	25JUL79	1	SECONDARY CRUSHER	0.862	N	N	0.483	0.023	N
RAW	26JUL79	3	BACK END OF KILN	N	N	N	0.003	N	N
RAW	26JUL79	3	RAWMILLS	0.074	N	N	0.027	N	N
CLINKER	23JUL79	2	CLINKER COOLER	0.174	N	N	0.082	N	N
CLINKER	24JUL79	2	CLINKER CONVEYOR	13.680	0.031	0.021	3.636	0.173	0.031
CLINKER	24JUL79	2	CLINKER COOLER	0.166	N	N	0.059	N	N
CLINKER	25JUL79	1	CLINKER COOLER	0.139	N	N	0.043	N	N
CLINKER	25JUL79	1	CLINKER COOLER	0.112	N	N	0.037	N	N
CLINKER	25JUL79	1	FRONT END OF KILN	0.093	N	N	0.026	N	N
CLINKER	26JUL79	1	CLINKER COOLER	1.075	N	N	0.399	0.018	N
CLINKER	26JUL79	1	FRONT END OF KILN	N	N	N	0.005	N	N
CLINKER	26JUL79	1	CLINKER COOLER	.	.	.	.	.	.
CLINKER	26JUL79	3	KILN CONTROL AREA	N	N	N	0.020	N	N
CLINKER	26JUL79	3	CLINKER COOLER	N	N	N	N	N	N
CLINKER	26JUL79	3	KILN CONTROL AREA	0.136	N	N	0.042	N	N
FINISH	23JUL79	2	BULK LOADING SILOS	0.367	N	N	0.124	0.006	N
FINISH	24JUL79	2	BULK LOADING SILOS	0.394	N	N	0.137	0.007	N
FINISH	24JUL79	2	FINISH BALL MILLS	0.085	N	N	0.034	N	N
FINISH	25JUL79	1	BULK LOADING SILOS	N	N	N	0.015	N	N
FINISH	25JUL79	1	BULK LOADING SILOS	0.150	N	N	0.054	N	N
FINISH	25JUL79	1	BULK LOADING SILOS	0.104	N	N	0.036	N	N
MIX	23JUL79	2	OVERHEAD CRANE	0.730	N	N	0.269	0.013	N
MIX	24JUL79	2	OVERHEAD CRANE	0.166	N	N	0.068	N	N
MIX	26JUL79	1	RAW AND FINISH BALL MILLS	0.100	N	N	0.048	N	N
MIX	26JUL79	1	OVERHEAD CRANE	0.161	N	N	0.053	N	N
MIX	26JUL79	3	MILL CONTROL AREA	0.025	N	N	0.009	N	N
MIX	26JUL79	3	STORAGE	0.029	N	N	0.011	N	N

Table 5

ENVIRONMENTAL INVESTIGATIONS BRANCH
INDUSTRIAL HYGIENE STUDY OF CEMENT WORKERS
LEHIGH CEMENT
CORRELATION MATRIX FOR TRACE METAL EXPOSURES

9:55 TUESDAY, FEBRUARY 3, 1981

VARIABLE	N	MEAN	STD DEV	SUM	MINIMUM	MAXIMUM
AL_UGM3	24	0.84726858	2.74997510	20.33444584	0.02518519	13.67965368
CR_UGM3	1	0.03116883	0	0.03116883	0.03116883	0.03116883
CO_UGM3	1	0.02077922	0	0.02077922	0.02077922	0.02077922
MG_UGM3	30	0.21683175	0.65916531	6.50495253	0.00307220	3.63636364
MN_UGM3	8	0.03449708	0.05633327	0.27597667	0.00611621	0.17316017
NI_UGM3	2	0.01899738	0.01721302	0.03799477	0.00682594	0.03116883

CORRELATION COEFFICIENTS / PROB > |R| UNDER H0:RHO=0 / NUMBER OF OBSERVATIONS

	AL_UGM3	CR_UGM3	CO_UGM3	MG_UGM3	MN_UGM3	NI_UGM3
AL_UGM3	1.00000	0.00000	0.00000	0.99553	0.99738	1.00000
	0.0000			0.0001	0.0001	
	24	1	1	24	8	2
CR_UGM3	0.00000	1.00000	0.00000	0.00000	0.00000	0.00000
	1	1	1	1	1	1
CO_UGM3	0.00000	0.00000	1.00000	0.00000	0.00000	0.00000
	1	1	1	1	1	1
MG_UGM3	0.99553	0.00000	0.00000	1.00000	0.99997	1.00000
	0.0001			0.0000	0.0001	
	24	1	1	30	8	2
MN_UGM3	0.99738	0.00000	0.00000	0.99997	1.00000	1.00000
	0.0001			0.0001	0.0000	
	8	1	1	8	8	2
NI_UGM3	1.00000	0.00000	0.00000	1.00000	1.00000	1.00000
	2	1	1	2	2	2

Table 6

ENVIRONMENTAL INVESTIGATIONS BRANCH
INDUSTRIAL HYGIENE STUDY OF CEMENT WORKERS
LEHIGH CEMENT ALSEN, NY
ANALYSIS OF BULK MATERIAL PRESENTED AS PERCENT BY WEIGHT

AREA	QUARTZ	CRISTB	AL	CR	CO	MG	MN	NI	ASBEST
RAW	1.0	0.0	0.49	N	0.003	0.290	0.018	0.003	0.0
RAW	1.0	0.0	0.55	N	0.003	0.300	0.018	0.003	0.0
RAW	1.0	0.0	0.78	0.003	0.001	0.340	0.018	0.003	0.0
RAW	1.0	0.0	1.10	0.003	0.002	0.380	0.019	0.004	0.0
RAW	1.0	0.0	0.61	N	0.003	0.340	0.018	0.003	0.0
RAW	1.0	0.0	0.78	0.002	0.002	0.360	0.019	0.003	0.0
RAW	1.0	0.0	0.90	0.002	0.003	0.400	0.021	0.003	0.0
RAW	1.0	0.0	1.20	0.003	0.003	0.470	0.020	0.003	0.0
CLINKER	0.0	0.0	2.70	0.004	0.004	0.700	0.029	0.005	0.0
CLINKER	0.0	0.0	2.70	0.004	0.004	0.640	0.026	0.005	0.0
CLINKER	0.0	0.0	2.20	0.004	0.004	0.600	0.026	0.005	0.0
CLINKER	0.0	0.0	2.30	0.005	0.004	0.690	0.025	0.004	0.0
CLINKER	0.0	0.0	2.30	0.004	0.004	0.640	0.027	0.005	0.0
CLINKER	0.0	0.0	2.10	0.005	0.004	0.460	0.022	0.005	0.0
FINISH	0.0	0.0	2.50	0.004	0.004	0.720	0.026	0.005	0.0
FINISH	0.0	0.0	2.20	0.004	0.004	0.700	0.025	0.005	0.0
FINISH	0.0	0.0	2.20	0.004	0.004	0.640	0.025	0.005	0.0
FINISH	0.0	0.0	2.70	0.004	0.004	0.680	0.025	0.005	0.0
MIXED	0.0	0.0	2.70	0.006	0.004	0.650	0.026	0.005	0.0
MIXED	1.0	0.0	0.88	0.002	N	0.027	0.004	0.002	0.0
MIXED	0.0	0.0	2.10	0.004	0.004	0.500	0.024	0.005	0.0

Table 7

Respirable Dust Measurements Collected from Kiln Burners, Kiln Helpers, and Bulk Loaders

Kiln Burner	Kiln Helper	Bulk Loader
0.34 mg/m^3	0.84 mg/m^3	1.36 mg/m^3
0.19	0.68	0.72
3.30	0.61	0.82
0.27	0.83	1.84
0.15	0.31	0.57
0.25	0.90	3.12
0.15	0.43	0.61
0.13	1.09	
0.44	0.67	
0.12	0.26	
	0.80	
	0.78	
	0.45	
	0.86	
	0.45	
n = 10	n = 15	n = 7
X = .53 mg/m^3	X = .66	X = 1.29
S = .98	S = .24	S = .93
S^2 = .86	S^2 = .05	S^2 = .74
C.I.-95 = 0.0-1.09 mg/m^3	C.I.-95 = .55-.77mg/^{3}	C.I.-95 = .62-1.96mg/m^3

Table 8
Comparison of Sixteen Corresponding Jobs of
First Versus Second Shift

Shift	N	GM	GSD	95% C.I.
1	16	.639	3.346	.336 U 1.216 mg/m^3
2	16	.762	2.618	.456 U 1.272

Table 9
Personal Respirable Dust Concentrations
Collected at Lehigh Cement
September, 1978

	N	Mean mg/m^3	SDS	GM mg/m^3	GSD	MAX mg/m^3	MIN mg/m^3
Plant wide	48	1.03	1.20	.64	2.72	6.47	0.0
Raw	16	.81	.68	.62	2.14	2.77	.21
Clinker	8	.53	.40	.36	2.98	1.07	0.0
Finished Product	8	1.91	2.23	.96	3.68	6.47	.15
Mix	16	1.07	1.04	.71	2.63	3.78	.10

Table 10

Contaminant	# Samples Collected	# Samples With Detectable Conc.	# Samples Above Recommended Level	Limit of Detect.	NIOSH Criteria	MSHA Standard
Respirable Dust	65	65	2	.001 mg/m^3	--	5 mg/m^3
Quartz	65	6	10	30 ug/m^3	50 ug/m^3	--
Cristobalite	65	0	0	30 ug/m^3	50 ug/m^3	--
Aluminum	33	24	0	25 ug/m^3	--	10,000 ug/m^3
Chromium	33	1	0	3 ug/m^3	1 ug/m^{3*}	1,000 ug/m^3
Cobalt	33	1	0	3 ug/m^3	--	100 ug/m^3
Magnesium	33	25	0	1 ug/m^3	--	10,000 ug/m^3
Manganese	33	8	0	2 ug/m^3	--	5,000 ug/m^3
Nickel	33	2	0	3 ug/m^3	15 ug/m^3	1,000 ug/m^3

* = standard for carcionogenic hexavalent chromium

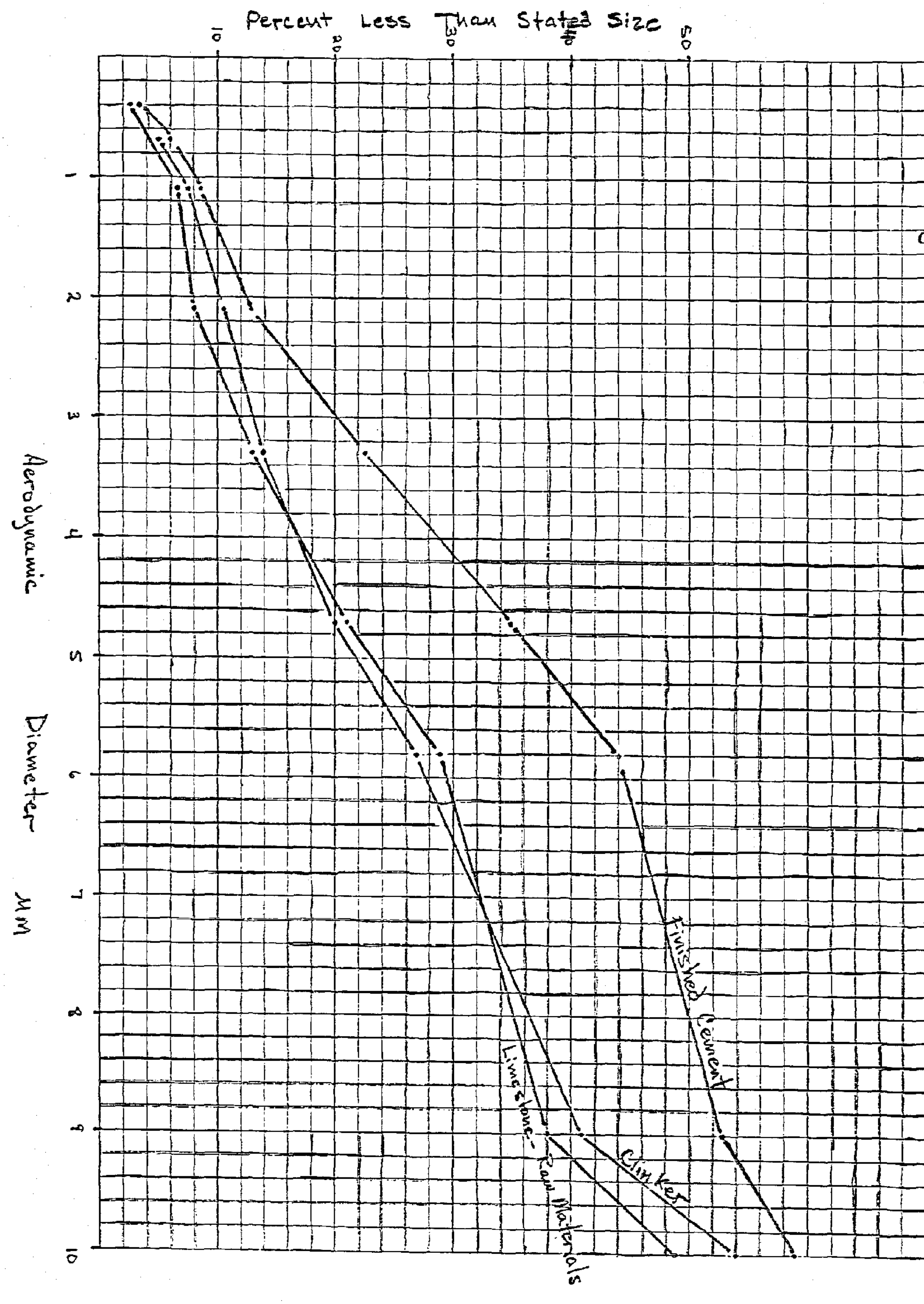
Percent Less Than Stated Size
10
20
30
40
50
Aerodynamic Diameter μm
1
2
3
4
5
6
7
8
9
10
Finished Cement
Clinker
Limestone - Raw Materials

Figure 5

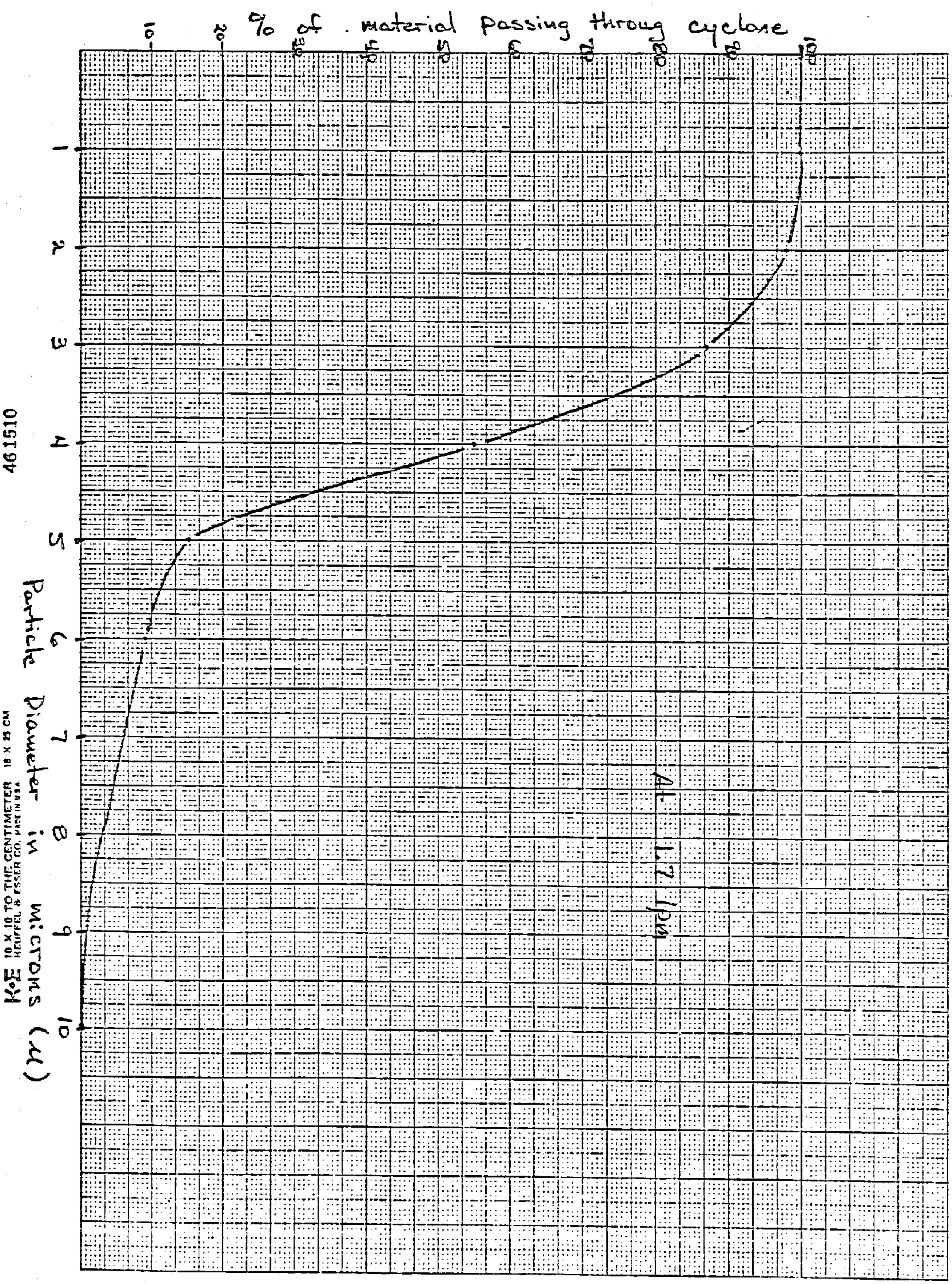
% of material passing throug cyclone
10
20
30
40
50
60
70
80
90
100
1
2
3
4
5
6
7
8
9
10
Particle Diameter in microns (μ)
At 1.7 lpm
461510
K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM
KEUFFEL & ESSER CO. MADE IN U.S.A.

Figure 6