

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control
National Institute for Occupational Safety and Health

HEALTH HAZARD EVALUATION DETERMINATION REPORT
Report No. 82-000-004

IDEAL CEMENT COMPANY
FLORENCE, COLORADO

NOVEMBER, 1982

I. SUMMARY

In November, 1980, the United Steelworkers of America Union, Local 14482, asked NIOSH to perform a general health hazard evaluation of the Ideal Cement Company, in Florence, Colorado. At that time, NIOSH was already engaged in the nationwide morbidity study of randomly selected Portland Cement plants. Early in 1981, 36 workers from the Ideal plant served as a control group for a NIOSH medical study of a nearby uranium mill. (HETA 81-055-954 Sept 1981) No environmental evaluations were conducted at the plant in conjunction with the medical testing. Following the results of the medical study there was renewed interest in a general health hazard evaluation. On March 22-23, 1982, industrial hygienists from NIOSH surveyed the facility to determine worker exposure to respirable and total dust, crystalline silica, toxic metals, nitrogen dioxide, and carbon monoxide.

Measurements of employee exposure to crystalline silica and metals were found to be below recommended concentrations. Dusts throughout the plant may be irritating to the nose, throat, and upper airways, but there should be no serious damage to body tissue. No substances were found either in the plant atmosphere or community drinking water in concentrations toxic to kidneys.

KEY WORDS: Sic 3241 (Portland Cement) Nephrotoxins, respirable dust, total dust, toxic metals, crystalline silica, carbon monoxide, nitrogen dioxide.

II. BACKGROUND

The cement plant is located five miles from Florence, Colorado, along the Arkansas River. The original plant was built in 1900, but has since been dismantled. In 1948 a second plant with two kilns was built and remains in use today. In 1973 plant 3, with one kiln, was built. Today, the overall facility is actually two separate plants, with autonomous kilns and mills. Across the river is the limestone quarry which serves as the calcium source for cement production.

The limestone is crushed at the quarry site by a primary roller mill and a secondary hammer mill. Crushed limestone is carried to the plants by conveyor, where it is blended, mixed with water, and ground in ball mills into a fine slurry. Other raw materials, such as sand and iron ore, may be added during the milling process. The slurry is agitated

and blended to the desired chemical and physical compositions and pumped into rotating kilns. The kilns progressively heat the slurry until temperatures of about 2700°F are reached at the fire end of the kiln. At this temperature the raw mix is fused forming "clinker minerals". The four chief clinker minerals are tri-calcium silicate (3CaO-SiO_2), dicalcium silicate (2CaO-SiO_2), tricalcium aluminate ($3\text{CaO-Al}_2\text{O}_3$), and tetra calcium aluminoferrite ($4\text{CaO-Al}_2\text{O}_3\text{-Fe}_2\text{O}_3$). (1,2) Gypsum is added to the clinkers and they are milled to increase the fineness and surface area. This ground powder is Portland cement. The cement is then either bagged or loaded as bulk in trucks or rail cars. Five types of cement are manufactured at this plant.

Coal is used as the fuel source for all three kilns. The coal is brought in by rail from mines in Colorado.

The Mine Safety and Health Administration (MSHA) has surveyed this plant and quarry on several occasions. Although the workers are exposed to crystalline silica, personal exposure levels have generally been below the federal dust standards.

III. METHODS AND MATERIALS

General Comments and Schedule

All respirable and total dust samples except those listed in Table 5, are personal samples and are therefore directly related to worker exposure. Personal and area samples were collected over the full 8-hour shift, and are therefore measurements of the average dust concentrations over the shift. The duties of many cement workers will vary from day to day and station to station. Also, there will be variations in atmospheric conditions such as wind speed and direction, and occurrence of precipitation. Because of this, personal samples collected only over two days may not accurately represent potential worker exposure to various toxicants. We elected, therefore, to primarily sample laborers, repairmen, and workers generally thought to encounter the highest dust exposures. This might indicate the worst case conditions for workers at Ideal Cement.

All sampling equipment was calibrated in Florence the day before the survey began. Temperature and pressure corrections were applied to the volumes of collected air samples. 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. During sampling periods, each personal and area sampler was periodically checked for proper operation. If the sampler was not operating properly, sampler adjustments and appropriate notations were made and, if necessary, the results of such samples were voided.

The sampling schedule was as follows:

Monday, March 22 - 1st shift
Tuesday, March 23 - 1st shift

Average atmospheric conditions for the sampling periods were as follows:

	<u>Monday</u>	<u>Tuesday</u>
Barometric Pressure	633 mmHg	629 mmHg
Temperature	51°F	57°F
Relative Humidity	34%	19%
Precipitation	0	0
Wind Speed	50-100fpm	5-850fpm

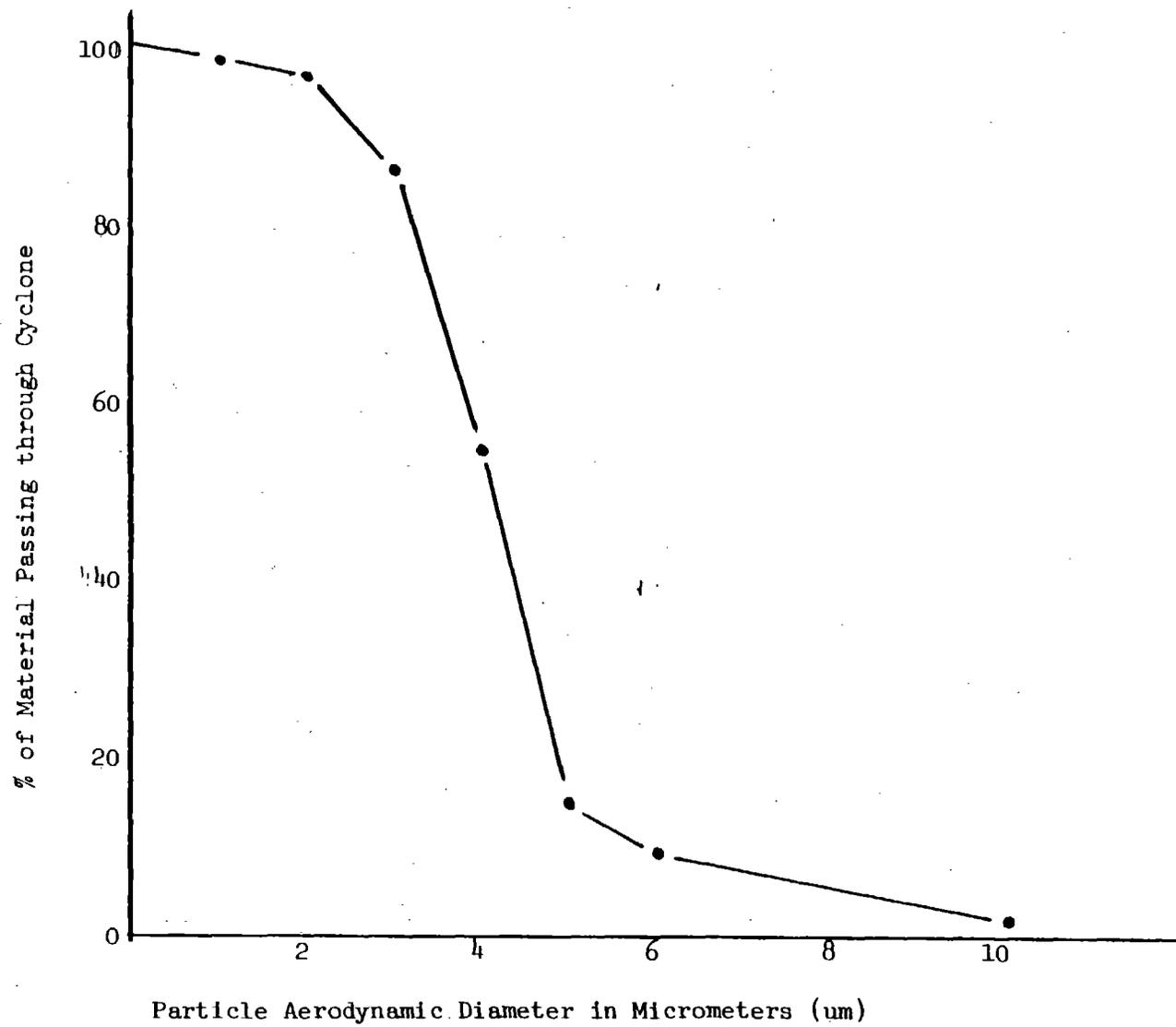
These measurements were taken in the yard of the cement plant.

Personal Respirable and Total Dust Samples

Selected workers were requested to wear respirable or total dust sampling devices. 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 to be non-respirable drop to the bottom of the cyclone and are discarded. The collection efficiency curve for this cyclone is presented in Figure 1. Particles greater than 10 micrometers (μm) in aerodynamic diameter would not pass through the cyclone and be deposited on the filter, whereas almost all particles smaller than 1.5 micrometers in diameter would be collected on the filter. (3) The basic sampling apparatus for respirable dust, minus the cyclone 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 1.7 lpm. Those particles 20 μm and below are collected efficiently on the filter media. Those particles greater than 20 μm generally fall through the air too rapidly to be captured on the filter (4,5). The filters were weighed on a precision balance to the nearest 0.01 milligram (mg), before and after sampling. The weight gain of the filters, the sampling flow rates, and the sampling times were used to calculate time-weighted average airborne dust levels. Personal respirable dust levels are reported in Table 1 as milligrams per cubic meter. Included in the table are the geometric mean (GM) and geometric standard deviation (GSD) of the respirable dust data. Geometric values give a better estimate of the true population mean and standard deviation, because dust concentration data typically follow a log-normal distribution. The geometric mean is the average of the logs of the dust concentrations and the geometric standard deviation is a measure of the variability of the data. The "Range" values are maximum and minimum observed values for the data. After weighing, 13 of the respirable filters were subjected to analysis by x-ray diffraction to determine their content of the crystalline silica polymorphs, quartz and cristobalite. (6) Quartz is also reported in Table 1 as milligram per cubic meter and percent quartz. A value of "N" indicates that the

Figure 1

COLLECTION EFFICIENCY OF THE PERSONAL RESPIRABLE DUST CYCLONE



measured quantity was below the analytical limit of detection. Limit of detection for this method is 0.03 mg per filter. No cristobalite was detected on any of the filters.

Total dust concentrations are listed and summarized in Table 3 as milligrams per cubic meter (mg/m^3).

Eight personal respirable and nineteen personal total dust samples were analyzed for content of 28 elements. These samples were ashed using nitric and perchloric acids and the residues dissolved in diluted nitric acid. The resulting solutions were analyzed for trace metal content by inductively coupled plasma - atomic emission spectroscopy (ICP-AES). (7) The results of the analyses for the respirable and total dust samples are reported in Tables 2 and 4 respectively, as milligrams per cubic meter (mg/m^3). A value of "N" indicates that the measured quantity was below the analytical limit of detection. For this analysis technique, the lower limit of detection is 0.001 mg/filter for all elements.

Area Respirable and Total Dust Samples

Area respirable dust samples were collected in the packhouse and mill room of plant 2. These samples were analyzed for content of quartz and cristobalite. The results of the analyses are reported in Table 5. Samples were collected with a respirable dust cyclone identical to the ones used in personal sampling, and also with high volume respirable dust cyclones. High volume cyclones are designed to collect dust with similar collection efficiency as the personal cyclones when operated at flow rates of 10 liters per minute. At these higher flow rates, they collect more dust on their filters. By increasing the dust load, the sensitivity of quartz and cristobalite detection is increased. The dust concentrations on Table 5, suggest that one high volume sampler tended to underestimate the respirable dust concentrations as measured by the personal cyclone, where the other tended to overestimate dust concentrations. An area total dust sample was collected in the mill room of plant 2 and analyzed for content of crystalline silica. (Table 5)

Cascade Impactor Samples

The Andersen Particle Fractionating Sampler was used to collect samples of airborne particles in the bagging area of the packhouse and the mill room of Plant 2. The Andersen sampler is a multi-stage, multi-orificed, cascade impactor which is used to measure the aerodynamic size distribution of airborne dust particles. After the air enters the impactor it cascades or flows successively through orifices with smaller and smaller diameters. The 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. (8) Glass fiber filters were used as the collection media. No air is actually drawn through the filters; the particles are impacted or come to rest on the filters. These glass fiber filters are weighed to the nearest 0.1 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 are plotted on log-probability graph paper against the corresponding effective cutoff diameters for each stage. From this graph the percentage of the mass of airborne particles below a particular aerodynamic diameter can be estimated.

Graphs of samples collected in the bagging area and mill room are presented in Figures 2 and 3 respectively. On the horizontal coordinate can be seen the percent (by weight) of the sample consisting of particles less than the aerodynamic diameter indicated on the corresponding vertical coordinate. For example, 15% of the dust mass in the bagging area are particles below 4 μm in diameter. Two cascade impactor samples at different flow rates were taken in each location. The effective cutoff diameter is calculated for each impactor stage based on the flow rate. The effective cutoff diameters are the median particle diameter that will be collected on that stage.

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 ground in the general work area. 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 (6); aluminum, chromium, cobalt, magnesium, manganese, and nickel content by atomic absorption (12); and hexavalent chromium by extraction with hot sodium carbonate and sodium hydroxide solution and diphenylcarbazide colorimetry. (13)

The results of these analyses are presented in Table 6. The "AREA" column indicates the work area from which samples were taken or type of dust. The results of analysis are presented as percent by weight of material. For example, if 1% of the raw material is quartz, there is 0.01 gram of quartz in each gram of raw material. The value "N" indicates that the measured quantity was below the analytical limit of detection. The lower limits of detection are listed on Table 6.

One to two liters of five different types of dust were collected and fractionated by a centripetal particle classifier. This classifier suspends the particles in an air stream and then separates them into coarse and fine fractions by centripetal force. The coarse fraction consisted of those particles greater than 20 μm in diameter, and the fine fraction those particles less than 20 μm in diameter. Theoretically, cut points between 20 and 30 μm would divide the particles into those which are inhalable and those which fall through the air too rapidly to be inhaled during normal breathing.

Material collected from the fine portion of the bulk samples was mixed with 15 milliliters of water until a saturated water-particle mixture was produced. This mixture was then tested for hydrogen ion concentration by pH indicator sticks. The results are presented in Table 7.

Nitrogen Dioxide (NO₂)

Nitrogen dioxide sampling was done using passive dosimeters. All samples were personal. Full shift time-weighted average exposures were determined. Dosimeters were constructed by cutting lengths of acrylic tubing to give a length to area ratio of 10 to 1. One end of the tube was fitted with a removable cap-plug and the other end was sealed with a cap containing the collection grids. These grids were coated with triethanolamine which quantitatively absorbs NO₂. During exposure, the cap-plug is removed and the contaminant gas diffuses to the collection grid according to Fick's Law of Diffusion. After collection, a sulfanilamide - phosphoric acid - NEDA solution is added to the dosimeter, where a red color complex with NO₂ is formed. The solution is transferred to a spectrophotometer and the absorbitivity is measured at 540 um. This is compared against a standard curve to give nanomoles NO₂, from which the concentration is calculated as: (9,10)

$$\begin{array}{l} \text{concentration in parts per} \\ \text{million of air} \end{array} = \frac{\text{(nanomoles (NO}_2 \text{))}}{2.3 \times \text{(hours of exposure)}}$$

The results of NO₂ sampling are listed in Table 8. Concentrations are presented in parts per million of air by volume.

Carbon Monoxide

Carbon monoxide was sampled by a portable direct reading analyzer. Air is drawn through an electrochemical voltammetric sensor, passing over a gas diffusion-type-electrocatalytic sensing electrode. Some of the carbon monoxide molecules diffuse into, and are absorbed on the electrode, where they are electrochemically oxidized. This electrochemical reaction generates an electric current, directly proportional to the gas concentrations. The results of sampling are reported in Table 9 and read in parts per million of air (ppm). (11)

Community Water Analysis

Analyses of the drinking water for the city of Florence was obtained from the Colorado Department of Health. The water was analyzed for content of trace elements, pesticides, and herbicides. The concentration of all materials are below the lower limit of detection for that analysis technique, except fluoride. The results are listed in Table 10. Following each material is the detected concentrations, the analytical lower limit of detection (N), and the mandatory guidelines set by the Colorado Dept of Health.

IV. REVIEW OF LITERATURE AND EVALUATION CRITERIA

Nuisance Dusts

Portland Cement is presently considered to be a "nuisance" dust. "Nuisance" particulates, by definition, generally have little adverse effect on lungs and do not produce significant organic disease or toxic effect when exposures are kept under reasonable control. Generally, the

lung-tissue reaction caused by inhalation of nuisance dusts has the following characteristics:

1. The architecture of the air spaces remains intact.
2. Collagen (scar tissue) is not formed to a significant extent.
3. The tissue reaction is potentially reversible. (14)

The MSHA standard for an 8-hour time weighted average exposure to nuisance dusts is 10 milligrams per cubic meter (mg/m^3) of total suspended particulate. The American Conference of Governmental Industrial Hygienists (ACGIH) also recommends a Threshold Limit Value (TLV) for nuisance dusts of $10 \text{ mg}/\text{m}^3$ for total suspended particulate. (TLV's are also based on 8-hour time weighted average exposures.) In addition ACGIH recommends a TLV of $5 \text{ mg}/\text{m}^3$ for respirable samples of nuisance dust.

These limits are for a normal work day and do not apply to brief exposures at higher concentrations, nor to substances which may cause irreversible physiologic impairment. Excessive concentrations of nuisance dusts may seriously reduce visibility, cause unpleasant deposits in the eyes, ears, and airway passages, and cause injury to skin and mucous membranes by chemical and physical irritation. Nuisance dusts may slow down the clearance of non-inert dust particles by increasing the load on the body's dust clearing mechanisms. Nuisance particulates may also act to carry toxic materials adsorbed on their surface further into the lung than would be otherwise possible.

Mineral Dust

If airborne particulates contain greater than 1% by weight crystalline silica, they are no longer considered nuisance particulates; they are mineral dusts. The MSHA standard and ACGIH-TLV for mineral dusts employ the formula:

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

Where the "% respirable quartz" is the percent by weight of quartz on each respirable filter sample, and "PEL" is the permissible exposure level. Therefore, each respirable dust sample for mineral dust has an exposure limit based on its content of quartz.

Some research studies (15,16,17) have suggested that exposures to quartz below a $0.1 \text{ mg}/\text{m}^3$ are safe levels of exposure. The current NIOSH Recommended Standard for crystalline silica is $0.05 \text{ mg}/\text{m}^3$.

Metals

Some metals are essential nutrients, but may also serve as health hazards if they accumulate in the body in sufficient quantity to poison certain physiologic mechanisms. Other metals serve no biologic purpose, but are capable of producing disease. (18)

Trace concentrations of metals may be found in raw materials used in the manufacture of Portland Cement. Exposure to metals may also be introduced during cement production due to the abrasion between rock and metal surfaces in crushing and milling, cutting and welding operations, and shaking and transporting of materials. These metals may be in elemental form, but will almost always be in the oxidized state or bound up as metal silicates.

The following is a list of the MSHA standards, ACGIH-TLV's, and NIOSH recommended standards for 28 metals which were sampled for during this survey. (19) The MSHA standards and ACGIH-TLV's are listed in mg/m^3 as 8-hour time weighted average concentrations and based on samples of the "total" suspended particulate. A dash indicates that either no standard or TLV exists or no standard or TLV exists for the metal in the form it is likely to be encountered in a Portland cement plant. A "ceiling" designation means that exposure to the metal at the noted concentration should not be exceeded even instantaneously. NIOSH recommended standards are based on a 10 hour time weighted average exposure.

<u>Metal</u>	<u>MSHA-PEL</u>	<u>ACGIH-TLV</u>	<u>NIOSH</u>
Aluminum	-	10	-
Arsenic	0.5	0.2	0.002
Beryllium	0.002	0.002	-
Calcium	-	-	-
Cadmium	0.2	0.05	0.04
Chromium -VI	0.1 ceiling	0.05	0.001
Cobalt	0.1	1.0	-
Copper	1.0	1.0	-
Iron	10.0	5.0	-
Lead	0.2	0.15	0.1
Lithium	-	-	-
Magnesium	10.0	10.0	-
Manganese	5.0	5.0	-
Molybdenium	5.0	1.0	1.0
Nickel	1.0	1.0	0.15
Phosphorous	0.1	0.1	-
Platinum	0.002	0.002	-
Selenium	0.02	0.02	-
Sodium	-	-	-
Tellurium	0.1	0.1	-
Thallium	0.1	0.1	-
Tin	2.0	2.0	-
Titanium	10.0	10.0	-
Vanadium	0.5 ceiling	0.05	-
Yttrium	1.0	1.0	0.05
Zinc	5.0	5.0	5.0
Zirconium	5.0	5.0	-

Alkali Dust

Portland Cement and some raw materials used in the manufacture of Portland Cement are alkali dusts. They are materials more basic than the mucous lining of the respiratory airways. (pH = 7.4) These dusts may cause irritation of the eyes and respiratory tract and erosion of the nasal septum. (20)

There are no general guidelines for limiting exposure to alkaline dusts based on their alkalinity or pH. We may compare the pH of dusts collected in the cement plant to the pH of other alkali dusts. (20)

Calcium hydroxide - $\text{Ca}(\text{OH})_2$

pH = 12.8

TLV = 5.0 mg/m³

Moderately irritating to mucous membranes and moist skin.

Calcium oxide - CaO

pH = 12.5

TLV = 2.0 mg/m³

Very irritating to mucous membranes and moist skin.

Potassium hydroxide - KOH

pH = 13 (1% aqueous solution)

TLV = 2.0 mg/m³

Produces strong irritation of the nasal tissue.

Sodium Carbonate - Na_2CO_3

pH = 11.5

TLV = None

Moderately irritating to the nasal membranes.

Sodium hydroxide

pH = 13 (1% aqueous solution)

TLV = 2 mg/m³

Strong irritation of nasal tissue.

Sodium silicates

pH = 11-12

TLV = None

Moderately irritating.

Nitrogen Dioxide

Nitrogen dioxide is a reddish-brown gas which is a common contaminant in the exhaust of internal combustion engines. It is an irritant to the mucous membranes, and inhalation even at low concentrations may cause coughing, sometimes severe, which may be accompanied by mild or transient headache. (21)

Based on animal studies ACGIH recommends a short term exposure limit (STEL-the maximal concentration which workers can be exposed for a period up to 25 minutes) of 5 ppm. (14) This level was considered

sufficiently low to insure against immediate injury or adverse physiologic effects from prolonged daily exposures. The present federal standard (MSHA and OSHA) for nitrogen dioxide is 5 ppm as an 8-hour time weighted average (TWA). (19) This was based upon the ACGIH TLV except that the STEL designation was omitted. (21) A number of human experiments and animal studies suggest that humans with normal respiratory function may be affected by exposure at or below this level and that the conditions of workers with diseases such as bronchitis may be aggravated by such exposures. (22,23,24,25) NIOSH recommends a ceiling of 1 ppm to protect workers with preexisting chronic bronchitis. ACGIH maintains a STEL of 5 ppm and a TWA of 3 ppm.

Carbon Monoxide

Carbon monoxide is a colorless, almost odorless gas, which is encountered as a product of incomplete combustion of almost any carbonaceous material. Carbon monoxide is a chemical asphyxiant, which rapidly diffuses across the alveolar membrane and reversibly binds with hemoglobin resulting in a reduction in the oxygen-carrying capacity of the blood. This reduction in oxygen-carrying capacity has adverse effects, and may lead to tissue injury.(14)

The signs and symptoms of acute exposure to high concentrations of CO are well known and easily recognized. These may include headache, nausea, vomiting, dizziness, drowsiness, and loss of consciousness. There are conflicting reports of effects to exposures at and below 100 ppm. (26,27) ACGIH recommends a TLV of 50 ppm since prolonged exposure to this concentration should not result in blood CO levels above 10 percent, a level above which the development of clinical symptoms such as headache, fatigue, and dizziness occur. (28) The federal standard for carbon monoxide is also 50 ppm for an 8 hour exposure time.

The effect of carbon monoxide is increased by factors such as an increase in physical activity, high environmental temperatures, high altitudes, and simultaneous exposure to narcotic solvents. Also, individual variability in cardiovascular disease status, ability to take up CO, and smoking habits may augment the effects of CO. NIOSH recommends 35 ppm as a TWA and 200 as an excursion limit to provide a margin of safety for the employee with chronic heart disease. (29)

<u>Substance</u>	<u>MSHA-PEL-ppm</u>	<u>ACGIH-TLV-ppm</u>	<u>NIOSH-ppm</u>
Nitrogen dioxide (NO ₂)	5	3 STEL - 5	Ceiling - 1
Carbon monoxide (CO)	50 STEL - 400	50 STEL - 200	35

V. RESULTS

Respirable Dust and Crystalline Silica

The personal respirable dust samples range from 0.32 to 4.18 mg/m³. None of the respirable dust measurements exceed 5 mg/m³. Quartz was detected in two of the samples; one sample was collected from

a painter in the mill room of Plant 3, the other from a driller in the quarry. Neither of these samples exceed the MSHA standard or ACGIH-TLV for mineral dusts, nor are they above the 0.1 mg/m³ level recommended by other researchers. Both samples are above the NIOSH recommended standard of 0.05 mg/m³. The area respirable dust measurements indicate that low levels of quartz are present in the workroom air of the mills and packhouses. Cristobalite was not detected on any of the respirable dust filters.

Eight respirable dust samples were analyzed for content of 28 elements. The respirable dust sample is designed to collect only those particles capable of being deposited in the alveolar regions of the lung where gas exchange takes place. These measurements represent the concentration of elements in dust effecting this region of the lung.

Total Dust and Trace Elements

Six personal total dust measurements exceeded the MSHA standard and ACGIH-TLV of 10 mg/m³ for nuisance total dust. These measurements were collected from a primary crusher operator, a front end loader operator working on the coal pile at Plant 2, and four laborers working in various areas of the plant.

The "total" aerosol should always be sampled when the air contaminant is a material capable of affecting body systems other than the lung. (18) The total dust sample not only collects respirable particles, but larger particles which are captured in the nose, throat, and upper airways. Contaminants may affect these areas, or they may be swallowed, exerting their affects through the digestive system. Particles in the larger size ranges may also irritate the eyes leading to conjunctivitis. Occupational health standards and guidelines for trace elements are based on total dust sampling.

Only one of these samples contained elements in concentrations greater than the standards or recommended guidelines. A welder, constructing handrails in the mill in Plant 3 was exposed to excessive particulate and iron and phosphorus fume. He was using iron-based welding rods.

The lower limit of detection for these elements is 0.001 milligrams per filter. The following elements were below the limit of detection for all filters:

arsenic	lithium	tellurium
beryllium	platinum	thallium
cadmium	selenium	yttrium
cobalt silver	zirconium	

Aerodynamic Particle Sizing

About 30% of the airborne particle mass in the packhouse is below 10 μ m in diameter. About 15% of the dust mass in the mill area is

below 10 μm . More than half of the airborne particle mass is greater than 20 μm in both areas. Particles greater than 20-30 μm in diameter have less probability of being inhaled than smaller particles.

Bulk Material

Quartz was found in bulk material samples of crushed limestone at concentrations of 8.3 and 8.6%. Quartz was also detected in dust collected from a rafter in the millroom of Plant 3, where raw materials are milled, and in waste kiln dust at the back end of kilns in Plant 2 and 3. The only finished cement product found to contain quartz was masonry cement. No cristobalite was found in any of the bulk samples.

Quartz is commonly found in limestone and other raw materials used for the production of cement. Therefore, particulates around the quarry, crushers, raw mills, blending bins, and at the feed end of kilns may contain quartz. There may be variation in quartz concentration depending on the composition of the overburden and ore that employees are working with. Also, the mixing and grinding of the limestone with other materials will result in a range of concentrations. Therefore, the free silica concentrations may vary with area and time.

After materials pass through the high temperatures of the kiln, they become altered morphologically and chemically, so that the quartz content is greatly reduced or nonexistent. This is evident by the fact that no quartz is detected in the clinker samples. Crystalline silica is generally not found in finished cement, but some sand materials containing quartz are added to masonry and mortar type cements. No cristobalite was found in any of the bulk samples.

Roughly, 2% of all bulk samples were aluminum. No chromium, cobalt, or nickel was detected in any of the bulk samples. Magnesium was present in concentrations ranging from 0.46 to 0.71%, and manganese from 0.08 to 0.15%. Because chromium in the +6 valence state is considered more toxic than trivalent chromium or chromium in the +3 valence state, the bulk samples were analyzed for hexavalent chromium. The analytical test for hexavalent chromium is more sensitive than total chromium; therefore, hexavalent chromium was detected in some bulk samples even though no total chromium was. The range of hexavalent chromium was from non-detectable to 0.005%. In order to be exposed to 0.001 mg/m^3 of hexavalent chromium which is the NIOSH recommended standard, a worker would have to be exposed to about 20.0 mg/m^3 of airborne dust.

pH Analysis

The pH of the particulates range from 10.0 to 11.9, indicating that all dusts are alkaline. Raw material dust had the lowest alkalinity and clinker the highest. The pH of these dusts fall within the range of other alkaline dusts known to be mildly irritating to the nose and other airways. The pH of all dusts were below those alkaline materials which are strong irritants or that severely damage nasal tissue.

Nitrogen Dioxide

The highest nitrogen dioxide concentration recorded was 0.18 ppm. None of the nineteen samples for nitrogen dioxide exceeded the federal standard or ACGIH-TLV. Although these are long-term samples and do not give peak or instantaneous concentrations, the levels are so low, it is doubtful that any of the workers were exposed even momentarily to concentrations greater than 1.0 ppm.

Carbon Monoxide

Readings for carbon monoxide were taken in the maintenance shop at the quarry, while a mechanic was working on a gasoline powered forklift. After the engine had run 45 seconds we detected a peak of 40 ppm, holding steady at 30-35 ppm for 6 minutes. After 6 minutes the level of carbon monoxide gradually decreased to below 5 ppm. Readings were also taken in the packhouse while loaded pallets were being moved out by a gasoline powered forklift. Momentary readings as high as 100 ppm were detected in the packhouse. While gasoline or diesel powered machines are being operated, particularly indoors, levels of carbon monoxide may build up to concentrations capable of causing effects on employees.

Water Analysis

No elements, pesticides, or herbicides were found to exceed the analytical lower limit of detection except flouride, and concentrations of this chemical were below mandatory guidelines.

VI. DISCUSSION AND CONCLUSION

Employees at the Ideal Cement Plant who work in raw material or masonry cement contaminated areas, are exposed to low levels of quartz. Quartz is a common contaminant of dust found in Portland Cement Plants, but at generally low levels. Although silicosis is not a common disease of Portland Cement workers, exposure to levels of quartz does present some risks. Efforts should continue to be made to keep exposure to crystalline silica dusts as low as possible.

Samples from six workers exceeded the MSHA standard and ACGIH-TLV for total nuisance dust. Workers exposed to excessive total dust may experience irritation of the eyes, nose, throat, and upper airways. The dusts throughout the plant may be irritating to the nose, throat, and upper airways, but the alkalinity is such that there should be no serious damage to body tissue.

The concentration of metals found in dusts to which workers are exposed are below hazardous concentrations. Of workers at Ideal Cement, it appears that only welders may be exposed to metals in excessive quantities and these metals originate from the welding rods, and not from airborne dusts.

We found no substances either in the plant atmosphere or community drinking water in concentrations toxic to the kidneys. Although a previous NIOSH health hazard evaluation noted a low mean creatinine clearance in uranium millers and Portland Cement workers, other tests were all within published normal limits. An explanation for the low creatinine clearance was offered in the NIOSH report: "It is possible that the low creatinine clearances for both groups, particularly for the cement production workers, may have been due to the effect of physical exertion upon renal blood flow, and thus upon clearance of endogenous creatinine. Population "normals" as reported in the literature, are derived from 24 hour collections of urine, frequently in hospital settings. Since we know that factors such as renal blood flow and the production of creatinine by skeletal muscle use affected by posture and physical exertion, resting creatinine clearances may differ from those during physical exertion." In addition to physical activity, important factors which possibly resulted in low values of creatinine clearance were the short collection period and inherent difficulties in assuring that urine collection was complete. Field measurements of creatinine clearance are imprecise, particularly when collected only over an 8-hour period.

Carbon monoxide from the exhaust of diesel and gasoline powered equipment may build up in enclosed areas such as the packhouse and maintenance garages. Concentrations may reach levels capable of causing effects on workers in these areas.

VII RECOMMENDATIONS

Engineering controls are the most effective means of reducing worker exposure to airborne dust. These controls should be maintained in efficient working order. Ventilation design to remove the dust from the air once it is generated and separation from the dust by enclosing either the worker or the dust are effective means of control. The priority for implementing dust control measures should begin with areas of highest exposure. Workers with the highest dust exposures are generally involved in maintenance and clean-up operations. Since it is difficult to control dust exposures during these operations, personal respirators may need to be provided. Packers, however, are generally stationary. Local exhaust ventilation is provided on the bagging machines. However, there are frequent occurrences i.e., bags rupturing, misconnection of bags on feeder, and dropping of bags onto conveyor which generate large amounts of dust. Ventilation fans may be placed above or behind packers to blow this fugitive dust away from their breathing zone. Helmets attached to ventilation hoses, which supply air to cool the workers and prevent dust from entering the helmet, are an effective control measure for stationary workers who cannot be enclosed from dust sources.

The primary crusher operator station might be enclosed to protect him from noise and excessive dust. Also, the cab of the front end loader might be maintained to provide a tighter seal to outside air. These enclosures would reduce the amount of fugitive emissions to which the workers would be exposed.

Although engineering controls are the recommended course of action, personal protective equipment (respirators and goggles) may be used by workers whenever engineering controls are not available or during maintenance, repair, and clean-up operations. Respirators, such as the disposable paper or cloth respirators do not form an occlusive seal between the respirator and the face. Dust particles would be able to pass through leaks between the respirator and the face. Whenever workers are potentially exposed to excessive quartz concentrations, quarter or half mask dust-fume-mist respirators should be used. The disposable respirators will, however, provide some protection to workers exposed to nuisance particulates. If workers complain of eye irritation, full-face piece respirators may be used instead of half or quarter mask respirators to alleviate the problems. It is suggested that workers be involved in the selection of a comfortable NIOSH/MSHA approved dust-fume-mist respirator and be fit-tested to insure that they are adequately protected. (23)

To reduce the emission of carbon monoxide from engine exhaust in enclosed areas, engines should be shut off or parked outside when not in use. During the loading of bulk material trucks, engines should be shut off to avoid a build-up of gases in the silo control rooms. Increased general room ventilation in the packing building would also reduce exhaust gas concentrations. For operations in low volume buildings, such as the packhouse, gasoline powered forklifts might be replaced by electric or propane powered forklifts. Propane exhaust generally contains less carbon monoxide.

A routine monitoring program is recommended for areas of the cement plant. Workers associated with raw materials and masonry cement may need to be monitored further to make sure respirable quartz concentrations remain below recommended exposure levels. Carbon monoxide levels in the packhouse and maintenance garages may need to be checked during heavy activity.

The corrective actions recommended should be viewed as scientific guidance. There is no legal requirement that any of these recommendations be implemented, and there is no guarantee that if implemented, they 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, and improve the environmental conditions of the workplace.

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TABLE 1

PERSONAL RESPIRABLE DUST AND QUARTZ CONCENTRATIONS
 REPORTED IN MILLIGRAMS PER CUBIC METER - mg/m^3

Ideal Cement - Florence, Colorado

	<u>Sample #</u>	<u>Job</u>	<u>Area</u>	<u>Dust Concentration</u>	<u>Quartz Concentration</u>	<u>% Quartz</u>	<u>TLV</u>
March 22	1	Laborer	Kiln Plant 3	1.25	N	-	-
	2	Maint	Plantwide	0.32	N	-	-
	3	Sack Loader	Packhouse	1.09	N	-	-
	4	Bagger	Packhouse	1.73	N	-	-
	5	Baggeer	Packhouse	2.71	N	-	-
March 23	6	Kiln Laborer	Kiln-Plant 2	2.88	N	-	-
	7	Laborer	Roof-Plant 2	0.50	N	-	-
	8	Crane Oper	Crane-Plant 2	0.66	N	-	-
	9	Painter	Mill Rm Plant 3	2.21	0.07	2.3	2.33
	10	Driller	Quarry	0.84	0.05	4.8	1.47
	11	Laborer	Primary Crusher- Quarry	0.75	N	-	-
	12	Packer	Packhouse	4.18	N	-	-
GM	=	0.96 mg/m^3					
GSD	=	2.25					
Range	=	0.32 - 4.18 mg/m^3					
"N" = below limit of detection (0.03mg per filter)							

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TABLE 2

TRACE ELEMENTS CONCENTRATIONS FROM PERSONAL RESPIRABLE DUST SAMPLES
 REPORTED IN MILLIGRAMS PER CUBIC METER (mg/m³)

Ideal Cement - Florence, Colorado
 March 22, 1982

Elements	1st Shift				
	Laborer Mill Plant #3	Laborer Mill Plant #3	Repairman Plantwide	Driller Quarry	Crusher Oper Quarry
Al	0.095	0.016	0.009	N	0.009
Ca	1.637	0.370	0.180	0.182	0.449
Co	N	N	N	N	N
Cu	N	N	N	N	N
Fe	0.102	0.025	0.103	0.027	0.017
Mg	0.031	0.005	0.002	N	0.004
Mn	0.006	0.001	0.002	N	0.001
Mo	N	N	N	N	N
Na	0.004	0.003	0.003	0.002	N
Ni	N	N	N	N	N
P	0.005	0.002	0.002	N	N
Pb	N	N	N	N	N
Sn	N	N	N	N	N
Ti	0.003	N	N	N	N
V	N	N	N	N	N
Zn	N	N	0.005	N	N

TABLE 2

TRACE METAL CONCENTRATIONS FROM RESPIRABLE DUST SAMPLES
REPORTED IN MILLIGRAMS PER CUBIC METER (mg/m³)Ideal Cement - Florence, Colorado
March 23, 1982

1st Shift

<u>Elements</u>	<u>Repairman Plant 2</u>	<u>Truckdriver Quarry</u>	<u>Bobcat Oper Plant 2</u>
Al	0.024	0.004	0.021
Ca	0.423	0.065	0.389
Cr	N	N	0.003
Cu	N	N	N
Fe	0.075	0.004	0.023
Mg	0.005	N	0.005
Mn	0.002	N	N
Mo	N	N	N
Na	0.001	0.001	0.008
Ni	N	N	N
P	0.002	N	0.002
Pb	N	N	0.002
Sn	N	N	N
Ti	N	N	N
V	N	N	N
Zn	N	0.003	0.006

TABLE 3

PERSONAL TOTAL DUST CONCENTRATIONS
 REPORTED IN MILLIGRAMS PER CUBIC METER - mg/m³

Ideal Cement - Florence, Colorado

	SAMPLE #	JOB	AREA	CONCENTRATION
March 22	1	Laborer	Backend of Kiln-Plant 3	2.41
	2	Sweeper Operator	Plantwide	7.92
	3	Laborer	Raw Silos Plant 3	*12.51
	4	Laborer	Kiln Platform Compressor - Plant 3	*16.40
	5	Maint.	Mill Rm - Plant 3	8.67
	6	Dump Man	Quarry	2.13
	7	Tunnel Man	Finish Tunnel	7.68
March 23	8	Crusher Operator	10 Crusher	*23.19
	9	Laborer	Mill Plant 2	*31.91
	10	Laborer	Clinker Cooler Plant 2	*16.55
	11	Frontend Loader	Coal Pile	*20.68
	12	Electrician	Plantwide Plant 2	3.73

GM = 9.48

GSD = 12.21

Range = 2.41 - 31.91

* = concentrations exceeds MSHA PEL for total nuisance particulate.

TABLE 4

Trace Element Concentrations of Personal Total Dust Samples
Reported in Milligrams per Cubic Meter (mg/m³)

Ideal Cement
Florence, Colorado
March 22, 1982

1st Shift

<u>Elements</u>	<u>Laborer Plant 3</u>	<u>Sweeper Plantwide</u>	<u>Laborer Top-Raw Silos</u>	<u>Laborer Kiln-Plant 3</u>
Al	0.005	0.070	0.069	0.148
Ca	0.120	1.435	1.629	2.825
Cr	N	N	N	N
Cu	N	N	N	N
Fe	0.005	0.109	0.104	0.119
Mg	0.003	0.027	0.049	0.047
Mn	N	0.005	0.007	0.009
Mo	N	N	N	N
Na	0.003	0.011	0.011	0.017
Ni	N	N	N	N
P	N	0.005	0.004	0.013
Pb	N	0.002	N	N
Sn	N	N	N	N
Ti	N	0.003	0.002	.005
V	N	N	N	N
Zn	N	0.001	0.004	.002

Table 4 (Continued)

<u>Elements</u>	Maint	Welder	Dump Man	Tunnel Man	Bulkhead
	<u>Mill Plant #3</u>		<u>Quarry</u>	<u>Packhouse</u>	<u>Finish Silos</u>
Al	0.090	1.715	0.016	0.070	0.030
Ca	1.595	21.355	0.295	1.264	0.523
Co	N	N	N	N	N
Cu	0.002	0.006	N	N	N
Fe	0.146	5.545	0.020	0.075	0.025
Mg	0.008	0.759	0.008	0.021	0.008
Mn	N	0.447	N	0.004	0.002
Mo	N	0.004	N	N	N
Na	0.004	0.461	0.005	0.019	0.001
Ni	N	0.007	N	N	N
P	N	0.101	N	0.003	0.002
Pb	N	0.007	N	N	N
Su	N	N	N	N	0.002
Ti	N	0.063	N	0.003	N
V	N	0.007	N	N	N
Zn	N	N	N	0.001	N

Table 4 (Continued)

Trace Element Concentrations of Personal Total Dust Samples
Reported in Milligrams per Cubic Meter (mg/m³)

Ideal Cement
Florence, Colorado
March 23, 1982

1st Shift

<u>Elements</u>	<u>Laborer Mills Plant #2</u>	<u>Laborer Plant #2 Clinker Cooler</u>	<u>Front Ent Loader Coal Pile Plant #2</u>	<u>Electrician Plant #2</u>
Al	0.114	0.142	0.006	0.726
Ca	2.459	2.571	1.283	0.726
Cr	N	N	N	N
Cu	N	N	N	N
Fe	0.126	0.136	0.067	0.049
Mg	0.042	0.038	0.016	0.012
Mn	0.009	0.008	0.004	0.003
Mo	N	N	N	N
Na	0.027	0.015	0.019	0.009
Ni	N	N	N	N
P	0.006	0.006	0.005	0.002
Pb	0.004	N	N	N
Sn	N	N	N	N
Ti	0.007	0.005	0.002	0.002
V	N	N	N	N
Zn	0.011	N	0.001	0.003

Table 4 (Continued)

<u>Elements</u>	<u>Repairman Plant #2</u>	<u>Miller Plant #2</u>	<u>Crusher Oper Quarry</u>	<u>Shovel Oper Quarry</u>
Al	0.052	0.320	0.065	0.006
Ca	0.993	6.061	1.532	0.100
Cr	N	0.006	N	N
Cu	N	N	N	0.003
Fe	0.070	0.335	0.078	0.009
Mg	0.015	0.092	0.032	0.004
Mn	0.004	0.019	0.006	N
Mo	N	N	N	N
Na	0.002	0.019	0.009	0.012
Ni	N	N	N	N
P	0.003	0.015	0.006	N
Pb	N	N	N	N
Sn	N	N	N	N
Ti	0.002	0.012	0.002	N
V	N	N	N	N
Zn	N	0.011	N	N

Table 4 (Continued)

<u>Elements</u>	<u>Laborer Quarry</u>	<u>Laborer Kiln Plant #2</u>
Al	0.150	0.097
Ca	0.178	1.896
Cr	N	N
Cu	N	0.003
Fe	0.008	0.153
Mg	0.003	0.031
Mn	N	N
Mo	N	0.007
Na	0.015	0.008
Ni	N	N
P	N	0.007
Pb	N	0.008
Su	N	N
Ti	N	0.004
V	N	N
Zn	N	0.

TABLE 5

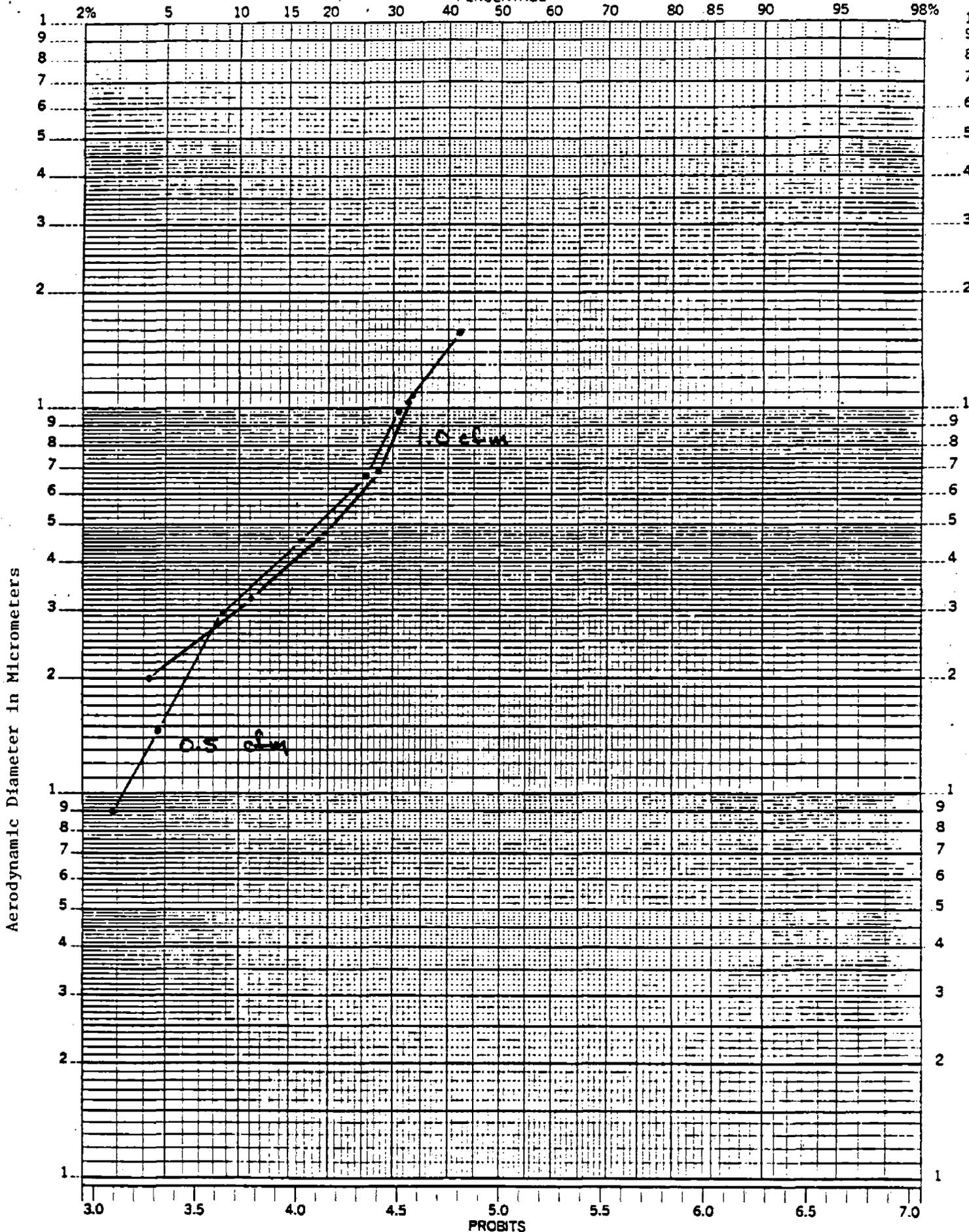
AREA RESPIRABLE DUST AND QUARTZ CONCENTRATIONS
 REPORTED IN MILLIGRAMS PER CUBIC METER (mg/m³)

IDEAL CEMENT - FLORENCE, COLORADO

<u>TYPE SAMPLE</u>	<u>DATE</u>	<u>SHIFT</u>	<u>DUST CONCENTRATION</u>	<u>QUARTZ CONCENTRATION</u>	<u>%</u>
<u>PACKHOUSE</u>					
Respirable	Mar 22	1	0.95	N	-
High Vol Resp			0.85	N	-
High Vol Resp			1.87	0.01	0.8
<u>MILL RM PLANT</u>					
Respirable	Mar 23	1	1.26	N	-
High Vol Resp			0.90	N	-
High Vol Resp			2.45	0.02	0.6
Total			8.32	0.05	0.6

Figure 2

Packhouse - Finished Cement
PERCENTAGE

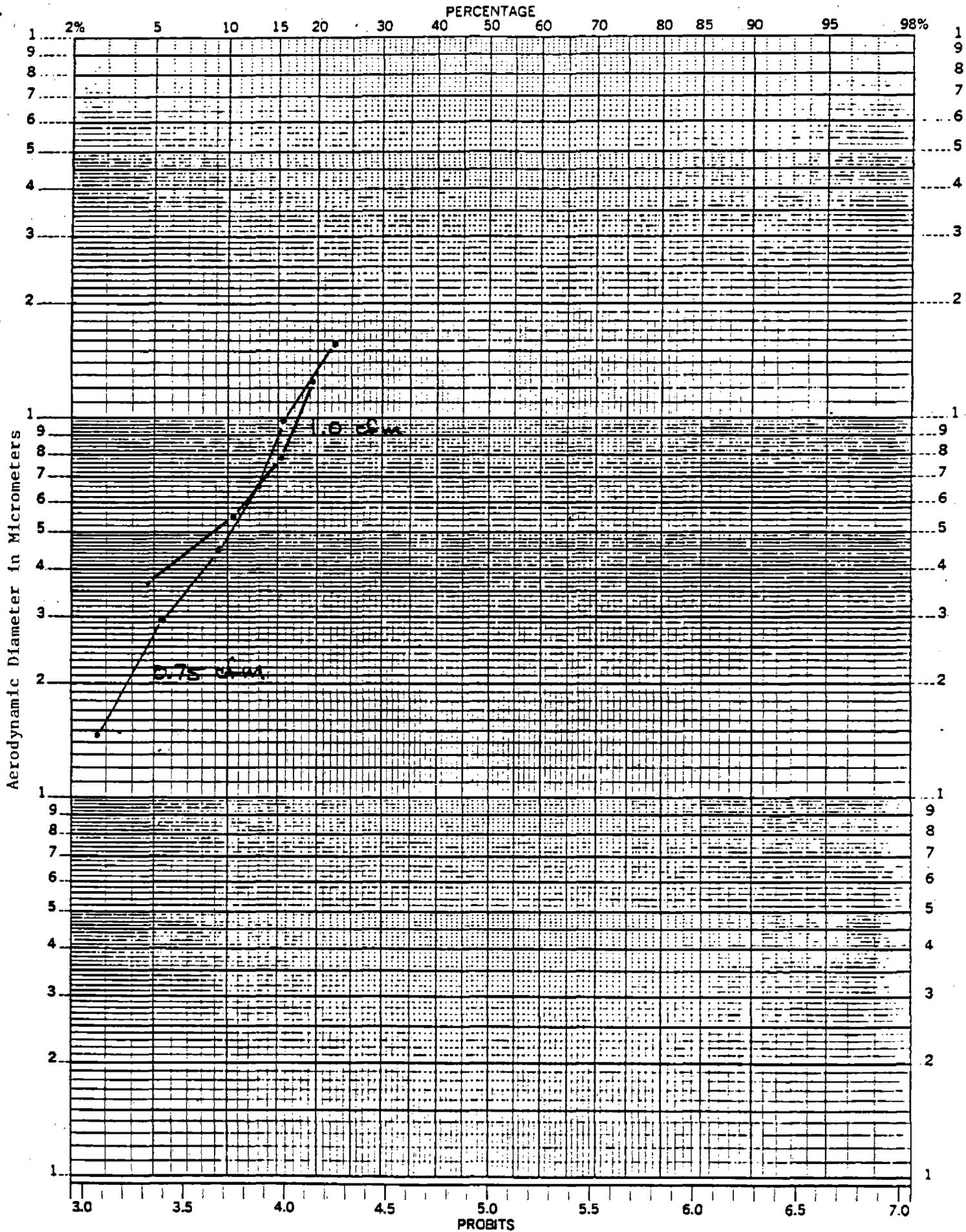


Aerodynamic Diameter in Micrometers

Percentage of Particle Mass Less Than Corresponding Diameter

Figure 3

Mill Area - Plant 2 - Mixed Dust



Percentage of Particulate Mass Less Than Corresponding Diameter

TABLE 6

ANALYSIS OF BULK MATERIAL PRESENTED AS PERCENT BY WEIGHT
IDEAL CEMENT - FLORENCE, COLORADO

<u>AREA</u>	<u>QUARTZ</u>	<u>CRISTB</u>	<u>AL</u>	<u>CR</u>	<u>CO</u>	<u>MG</u>	<u>MN</u>	<u>NI</u>	<u>CR-VI</u>
1 ⁰ Crusher	8.3	N	1.7	N	N	0.60	0.08	N	0.002
2 ⁰ Crusher	8.6	N	2.0	N	N	0.52	0.08	N	0.001
Type 1 Cement	N	N	2.5	N	N	0.71	0.15	N	0.002
Masonry Cement	4.5	N	2.9	N	N	0.58	0.14	N	N
Type 3 Cement	N	N	2.3	N	N	0.63	0.13	N	N
Type 1A Cement	N	N	2.5	N	N	0.68	0.15	N	0.003
Type 2 Cement	N	N	2.0	N	N	0.52	0.13	N	0.003
Clinker Plant 3	N	N	2.0	N	N	0.55	0.12	N	0.005
Mill Rafters Plant 3	4.6	N	2.1	N	N	0.62	0.12	N	0.003
Beneath Precipitation Feed end of Kiln-Plant 3	6.8	N	2.0	N	N	0.52	0.13	N	N
Mill Rm Dust Plant 2	N	N	2.0	N	N	0.52	0.13	N	N
Clinker Cooler Plant 2	Not Analyzed	Not Ana - lyzed	1.8	N	N	0.57	0.13	N	N
Waste Dust Feed End Plant 2	4.4	N	2.0	N	N	0.46	0.12	N	N

Quartz - 1.5%
Cristb - 1.5
AL - 0.2
CR - 0.02
CO - 0.03
MG - 0.02
MN - 0.01
NI - 0.02
CR-VI - 0.001

N = The lower limits of detection =

TABLE 7

HYDROGEN ION CONCENTRATION (pH) of BULK SAMPLES
IDEAL CEMENT - FLORENCE, COLORADO

<u>DUST</u>	<u>PARTICLE SIZE CUTPOINT</u>	<u>pH</u>
Type I Cement	< 20 μm	11.3
Masonry Cement	< 20 μm	11.2
Clinker (Plant 2)	< 30 μm	11.9
Kiln Waste Dust (Plant 2)	< 20 μm	11.5
Raw Material Primary Crusher	< 20 μm	10.0

TABLE 8

PERSONAL DOSIMETER ANALYSIS FOR NITROGEN DIOXIDE
 REPORTED IN PARTS PER MILLION - ppm
 IDEAL CEMENT - FLORENCE, COLORADO

JOB	AREA	DATE	SHIFT	CONCENTRATION-ppm
Laborer	Mill Rm Plant 3	March 22	1	0.09
Laborer	Mill Rm Plant 3			0.04
Laborer	Front End Kiln Plant 3			0.10
Maintenance	Plant Wide Plant 3			0.13
Driller	Quarry			0.12
Crusher	10Crusher			0.18
Operator	Quarry			
Shift	Plant Wide			0.10
Repair	Plant 3			
Sack Loader	Packhouse			0.06
Bagger	Packhouse			0.12
Bagger	Packhouse			0.09
Truck Driver	Quarry	Mar 23	1-	0.07
Driller	Quarry			0.17
Repairman	Mill Rm Plant 2			0.06
Repairman	Plantwide Plant 2			0.06
Kiln Laborer	Front End Kiln Plant 2			0.10
Laborer	Roof - Plant 2			0.07
Crane Oper	Crane - Plant 2			0.02
Bobcat Oper	Plantwide			0.02
Painter	Mill Rm-Plant 2			N

N = below the analytical limit of detection (0.02 ppm)

mean = 0.08 ppm

sd = .05

range = .01 - .18 ppm

TABLE 9

DIRECT READING ANALYSIS FOR CARBON MONOXIDE
 REPORTED IN PARTS PER MILLION - PPM

IDEAL CEMENT - FLORENCE, COLORADO

March 23, 1982

<u>AREA</u>	<u>LOCATION OF FORKLIFT</u>	<u>READING</u>
Aisle of Packhouse Across from office	Bagging Area	45-60
	Backing from bagging area past office	85
	Out on loading dock	6
	Backing past office after placing pallet on truck	100
By workers placing bags on pallet (Door open)	Out on loading dock	0
	Lift idling in area waiting to remove loaded pallet	8

TABLE 10

RESULTS OF COMMUNITY DRINKING WATER ANALYSIS BY
COLORADO DEPARTMENT OF HEALTH

IDEAL CEMENT - FLORENCE, COLORADO

<u>SUBSTANCE</u>	<u>CONCENTRATIONS</u>	<u>LLD</u>	<u>MANDATORY GUIDELINES</u>
<u>Elements</u>			
Arsenic	N	0.01 mg/1	0.05 mg/1
Barium	N	0.5	1.0
Cadmium	N	0.0003	0.01
Chromium	N	0.005	0.05
Fluoride	0.64	0.1	2.4
Lead	N	0.005	0.05
Mercury	N	0.0005	0.002
Nitrates	N	0.5	10.0
Selenium	N	0.002	0.01
Silver	N	0.05	0.05
<u>Pesticides</u>			
Lindane	N	0.000007	0.004
Eudrin	N	0.00006	0.0002
Methoxychlor	N	0.00018	0.1
Toxaphene	N	0.00067	0.005
<u>Herbicides</u>			
2,4-D	N	0.00038	0.1
2,4,5-TP	N	0.00012	0.01

N = below the lower limit of detection of material by chemical analysis.