U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public Health Service
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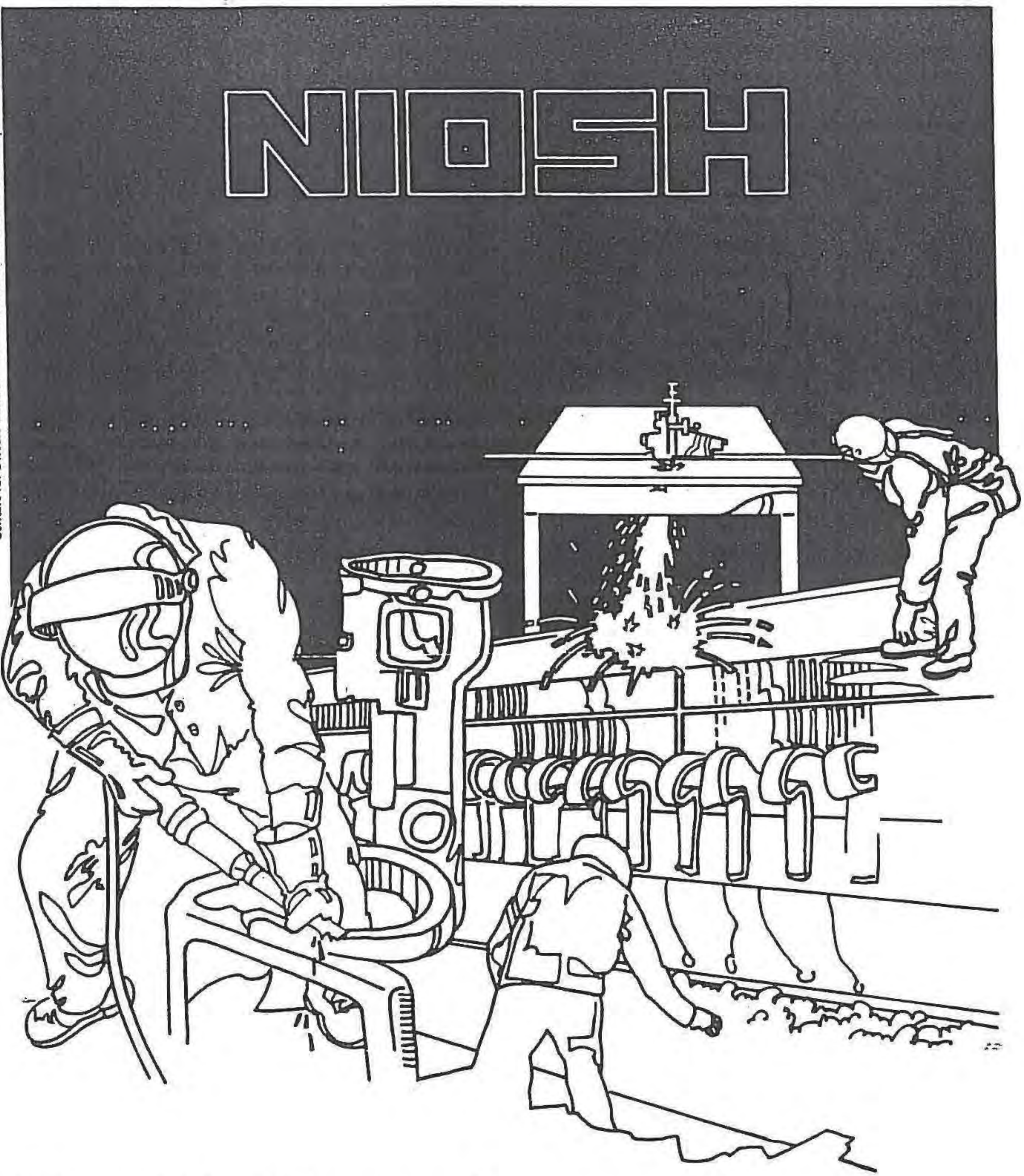

Health Hazard Evaluation Report

HETA 84-066-1883
ARTESIAN INDUSTRIES
MANSFIELD, OHIO

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

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I. SUMMARY

On November 30, 1983, the National Institute for Occupational Safety and Health (NIOSH) received a request for a Health Hazard Evaluation from a group of workers at the Artesian Industries vitreous china plant in Mansfield, Ohio. A second request was received on January 4, 1984, from Local 719, International Union of Electricians, which represents the workers at this plant. Light headedness, shortness of breath, fainting, lung problems, and skin rash were reported, as were exposures to talc and several dusty compounds containing silica. Environmental and medical evaluations were conducted in October 1984. A follow-up investigation to further evaluate engineering controls was conducted in August 1985.

The environmental evaluation included collecting personal air samples for respirable dusts, silica, and fibers. Respirable crystalline silica personal exposures averaged 0.12 mg/m^3 for 86 air samples collected. Thirty-eight (44%) exceeded the NIOSH REL for respirable crystalline silica of 0.05 mg/m^3 as a time-weighted average (TWA) for up to a 10-hour workday, 40-hour workweek, and 37 (43%) exceeded the OSHA PEL for an 8-hour TWA. The highest exposures to respirable silica were in the slip house where 15 samples averaged 0.33 mg/m^3. All exceeded the NIOSH REL, and 13 (87%) exceeded the OSHA PEL. In the casting areas, 18 samples contributed to an average exposure of 0.06 mg/m^3. Eight of these exceeded the NIOSH REL and 11 exceeded the OSHA PEL. Eighteen samples contributed to an average respirable silica exposure of 0.11 mg/m^3 in the dry finish area. Ten exposures exceeded the OSHA PEL and 12 were greater than the NIOSH REL. In the glaze spray area three personal exposure samples for respirable silica averaged 0.24 mg/m^3, all exceeding both criteria.

Exposures to other respirable dusts, predominantly nonfibrous talc dust, averaged 2.7 mg/m^3 in the casting areas for 38 samples. Nineteen (50%) of these were greater than the ACGIH TWA-TLV for respirable nonfibrous talc dust of 2.0 mg/m^3. Fibrous talc was in use for a period of time in the past.

The medical survey included a medical and occupational history questionnaire, pulmonary function tests, and a chest x-ray. The 196 participants worked at the plant from 2 months to 28 years, with a mean of 12 years; 48 (24%) worked there at least 20 years. Nineteen (10%) of the participants reported symptoms of chronic cough, 10 (5%) symptoms suggestive of chronic bronchitis, and 60 (31%) shortness of

breath. These were all statistically associated with smoking, and chronic bronchitis and shortness of breath were associated with time in the cast shop (as determined by job history), an indicator of talc exposure. Percent predicted forced vital capacity (FVC) was marginally inversely associated with total time at the plant ($p = 0.06$) and cigarette smoking ($p = 0.07$). Percent predicted one-second forced expiratory volume (FEV_1) was inversely associated with cigarette smoking ($p < 0.001$) and time in the cast shop ($p = 0.04$); the FEV_1/FVC ratio was inversely associated with smoking ($p < 0.001$), and, marginally, time in the cast shop ($p = 0.08$). Eighteen (9.2%) of the 196 chest X rays had findings suggestive of asbestos or talc exposure; 5 of them also had findings suggestive of silicosis. The presence of irregular opacities, pleural plaque, or bilateral costophrenic angle pleural thickening (findings suggestive of asbestos or talc exposure) was associated with age ($p = 0.003$); but rounded opacities (suggestive of silicosis) were not associated with any exposure variable.

A serious and extensive problem with respect to respirable silica and respirable dust exposures was documented. Overexposures to respirable silica were prevalent in the slip house, spray department, and dry finish department. Overexposures to respirable talc dust predominated in the cast shop. Respiratory symptoms and pulmonary function impairment were all associated with some indicator of dust exposure at Artesian. This was more often an indicator of talc (alone or in combination with other exposures in the cast shop), rather than silica, exposure. More X rays had abnormalities suggestive of exposure to talc or asbestos than to silica. Whether this reflects an effect of talc itself, or of previous asbestos contamination of the talc, cannot be determined from the data from this study. Recommendations regarding engineering controls and medical monitoring are contained in Section VIII of this report.

KEYWORDS: SIC 3621 (Vitreous china plumbing fixtures and china and earthenware fittings and bathroon accessories), silica, talc, respirable dust, vitreous china, pneumoconiosis

II. INTRODUCTION

On November 30, 1983, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation from a group of workers at Artesian Industries' Vitreous China Plant in Mansfield, Ohio. The request described health effects of workers at the plant including light headedness, shortness of breath, fainting, non-specific lung problems, and skin rash. The hazard described was exposure to Nytal 100, 1736 talc, Frit 39A, and A200 talc (actually Nepheline Syenite), which the requestors thought may contain asbestos.

On January 4, 1984, a second request was received from Local 719 of the International Union of Electricians, which represents the workers at the plant. The second request did not describe a health problem, but listed 24 substances used in vitreous china production that were thought to be hazardous. The list included the substances from the first request.

Due to a work stoppage, an initial investigation was not conducted until August 29, 1984. A follow-up investigation, conducted October 1-5, 1984, included extensive medical and environmental assessments. Interim report no. 1, issued in April 1985, described the manufacturing process and exposure controls and presented the environmental sampling results. Interim report no. 2, issued in June 1986, discussed the findings of a more intensive follow-up survey (conducted August 26, 1985) of exposure control systems. Interim report #3, issued in September 1987, presented the findings from the medical survey. Individual workers were notified of their own medical results.

III. BACKGROUND

Information provided to NIOSH after the initial investigation revealed that a number of the raw materials used in vitreous china production contain silica. Material Safety Data Sheets for at least 10 ingredients of slips (clay slurry) and glazes used at Artesian indicated free silica content from 2 to 100 percent. None was reported to contain asbestos.

A. Process Description

Vitreous china bathroom products are manufactured at the Artesian plant in Mansfield, Ohio. These products include toilets, water tanks and their lids, and lavatories (sinks). About 17,000 pieces are manufactured per week; a piece being a tank with a lid, a lavatory, or a toilet. Seven different materials are used in preparation of the casting slip (slurry) containing up to 100 percent free silica. On a dry weight basis, about 13,500 tons of casting slip materials are used annually with 4000 tons arriving at the plant in water slurry form. Other clay materials containing silica are used in the preparation of glazes. A plan view of the manufacturing process appears in Figure 1.

The casting slip (or slurry) is prepared in the sliphouse. Adjacent to the sliphouse are dry storage areas holding baged and bulk ingredients. The various slip ingredients are transported to a preweigh hopper by front-end loader. A skip hoist transports the weighed material to a feeder which in turn feeds a belt conveyor. Material from the belt conveyor drops into a hopper which empties into one of two slurry tanks through a chute. Slurry from holding tanks is pumped to the production lines in the cast shop. These include one lid line, one tank line, three bowl lines, and the lavatory bench casting area.

The glazes, which impart color to the finished ware, are also prepared in the sliphouse and then transported as a slurry to the glaze spray area. The variety of clays, silica and pigments used in batching the glazes arrive at the plant in paper bags. These ingredients are preweighed in a ventilated hopper, transferred to a ball mill, and then to a slurry tank.

In each of the production lines, slip is poured into molds which are dusted with talc. At the time of this survey, the reusable mold was cleaned of residual clay and talc from a previous casting by using jets of compressed air. Dusting with talc is necessary to prevent the slip from sticking to the mold. On the line, the molds are filled with slip as they pass under a spigot. After the casting sets up, the mold is disassembled and the casting (greenware) retrieved. The greenware is dried in tunnel dryers and transported on trolleys to the dry finish area.

In the dry finish area the dried pieces are individually mounted on a platform anchored to a grating through which air is exhausted. Rough surfaces are smoothed using sandpaper, and wet sponges. Scrapers are also used to remove flashing from the pieces.

B. Potential Sources of Exposure

1. General

There are two potential sources of airborne silica and dust which are common to all production areas of the plant. These are the baghouses used to filter air from local exhaust systems and dust settled on various surfaces within the production areas. In the case of the baghouses, dust may penetrate as a result of a mechanical failure of the bags. This is significant since all but one were found to recirculate aiir into production areas.

In many areas of the plant dust has accumulated as a result of spills. It may be regarded as a potential source of exposure since it may be resuspended into the air by vehicles used in material handling and other means.

2. Sliphouse Operations

Activities in the sliphouse are the major source of silica exposure to workers. Transfer of clay and silica by front-end loader from the clay bins to the clay weigh-up hopper was observed to be a source of spilled and suspended dust in the area. Material handling equipment (skip hoist and belt conveyor) which transfers powder from the weigh hopper to the slurry tanks was also perceived as a potential source because of a lack of enclosures. Dust from these two sources may be dispersed directly into the air. Spilled material may be resuspended in the air by activities in the area.

The glazes are made from bagged materials which are manually dumped into a weigh hopper. The materials are transferred to a ball mill, then to a slurry tank. The glaze slurry is transferred to the glaze spray area in portable vessels filled from holding tanks.

Finally, there are two overhead doors that lead from the sliphouse to the cast shop. At the time of the August 1985 visit one of the doors was open. Measurements made at that time, using a velometer and smoke tubes, indicated that a net airflow of about 20,000 cfm takes place from the sliphouse to the cast shop. The strength of this dust source for the casting areas was estimated at about one pound of respirable dust per 8 hour shift based on the geometric means of air samples taken in the sliphouse during the October 1984 evaluation.

3. Cast Shop

In the cast shop there are two potential sources of exposure to silica and/or talc. The first of these is cleaning the previously used molds of residual material (talc and clay) using a compressed air jet. The other potential source is the dusting of the molds with talc-filled cloth bags. This occurs at each one of the cast lines; namely the three "bowl" lines, the "tank" line, the "lid" line and the "lavatory" bench cast area. The talc dusting operations at the lid line (where no control exists) caused a visible "fog" to be formed in the bench casting area.

4. Dry Finish

It was observed that some of the material that is removed during dry finishing escapes capture by the down draft hoods because of the intensity of the sanding and scraping. This was substantiated by environmental measurements collected during the earlier NIOSH evaluation.

5. Glaze Spray Area

Glaze spray operations (both manual and automatic) seem to be a source of exposure even though the silica containing glazes are suspended in water. Silica exposure from this source may occur if the slurry aerosol is not captured by the ventilation in the booths. The particulate may also be suspended in the air after the moisture evaporates.

C. Engineering Controls in Use (1985)

1. Local Exhaust Systems - Slip House

Dust emissions from loading the preweigh hopper using the front-end loader (as shown in Figure 2) are controlled by a ventilated enclosure which in turn is vented to a baghouse. A face velocity traverse of the enclosure indicated an average of 155 fpm. While this would normally be adequate to capture dust from less intense operations, such as using scoopfuls of material to fill the preweigh hopper, the quantity of material dumped and the amount of dust generated here are such that the capture capability of the hood is frequently overwhelmed. Material also spills over the side. The dust-laden air from the weigh hopper enclosure is filtered in a Pangborn baghouse with 16 oz polyester felt bags. It is rated at 5000 cfm. The flow into the face of the enclosure was measured at 3200 cfm. The point at which material is picked up by the belt conveyor (Figure 3) from the feeder is ventilated. The exhausted air is filtered through a 1500 cfm baghouse with paper cartridges before being returned to the work area.

The belt conveyor transfers material into a hopper which in turn empties into a mixing tank through a chute. The freeboard space in the mixing tank is ventilated as shown in Figure 4. The exhausted air is filtered in two Griffin baghouses (one for each tank) rated at 1120 cfm. The bag material is 16 oz polyester felt. The dust control at this point appears to be adequate as no material was seen to escape. The filtered air is recirculated back to the workplace.

Other controls in the sliphouse include a ventilated enclosure for the preweigh hopper for the glaze batching (Figure 5) and a device to ventilate the process of dumping material from the hopper into the ball mill. The two baghouses which filter the air from these sources are vented to the sliphouse. These were not in operation at the time of the August 1985 visit.

2. Cast Shop

The primary exposure problems here are the mold cleaning and talc dusting operations. A number of local exhaust systems to control dust emissions from talc dusting are planned. One such local control has been installed at the talc dusting station at the tank line (Figure 6). The back draft hood has two open areas. At the front end an average velocity of 140 fpm was achieved. The velocity at the side where the tanks enter the hood is about 200 fpm. Good capture of the talc dust was observed.

Compressed air is currently used to remove residual talc and silica from the molds before reuse in the cast shop. Two techniques are being investigated to replace compressed air. One is the use of vacuum while the other involves the use of brushes.

3. Dry Finish

Dust emissions from the scraping of dry ware are controlled by the use of downdraft hoods at each of the 12 work stations. One of these work stations is shown in Figure 7. To improve the performance of these hoods air is supplied from a 5 inch duct at about 3 ft behind the worker and about 7 ft. above floor level. This was intended to be a push/pull system.

In evaluating the performance of these hoods air velocity measurements were made in the vicinity of the midpoint between the worker's breathing zone and the piece. The justification for these measurements was that in scraping excess material from the work some of the particulate may travel in the direction of the worker's breathing zone. Measurements of capture velocities at the aforementioned critical points are as shown in Figure 7.

In view of the number of overexposures measured, the capture velocities were inadequate to capture dust generated in dry finishing.

4. Glaze Spray

The slurry containing the glaze is sprayed on the pieces either manually (Figure 8) or automatically (Figure 9). Air distribution across the face of the booth is achieved by the use of baffles. In some of the booths, where the spray is applied manually, suction across the face of the booth is obtained by liquid spray nozzles which entrain air as in a jet ejector. Airflows generated in this manner are low. The company is in the process of replacing these booths because of insufficient capture (face) velocities.

In some of the booths a buildup of glaze on the baffles was observed. Over a period of time this build up would compromise the performance of these booths where face velocities of 100 fpm or better should always be maintained. Booths in the glaze area are vented to a wet collector which is exhausted outside the plant.

Exposure measurements for workers in the glaze spray area indicated that, at least in some cases, the booths where manual spraying is performed are not efficiently capturing all overspray aerosol generated.

Also, the production line which carries the pieces to the automatic spray booth is not adequately enclosed when the pieces pass in front of the nozzles. It is very likely that some of the aerosol is escaping to the general work area.

5. General Ventilation

Air is supplied through ceiling grilles to the sliphouse. The quantity of the air was not measured. Exposure measurements conducted in October 1984 indicated that the air supplied is not sufficient for the dilution of silica and total respirable dust levels to acceptable values. During the August 1985 visit, sliding doors which provide access to the outdoors were left open. Tests with smoke tubes indicated an inflow of outdoor air into the sliphouse. Air is exhausted from the sliphouse in a number of ways. In one, 5000 cfm from the clay weigh-up hopper is exhausted to the roof. Also, between 17,000 and 20,000 cfm flow toward the cast shop through the two openings with overhead doors. The lower figure is the flow when only one door is open. An inflow of outside air was noted to occur through doors open to the outside.

In warm weather, air is exhausted from the kiln area by roof ventilators (fans). In cold weather warm air from the kiln area is exhausted through insulated duct work and used to heat the cast shop and the dry finish area.

Finally air is exhausted from the bench casting area by several duct/fan combinations. Air is withdrawn at floor level through a louver at one end of a duct and a fan exhausts the air outside the building at the other end of the duct.

IV. EVALUATION DESIGN AND METHODS

A. Environmental Evaluation

NIOSH investigators conducted environmental and medical evaluations on October 1-5, 1984. The environmental aspect consisted of collecting personal breathing-zone air samples for respirable dust, and fibers, and general area air samples for total and respirable dusts. Bulk samples of certain raw materials were collected to aid in some of the analyses. Each area of the plant was sampled over the course of two work shifts.

Respirable dust samples were collected on tared 37mm, 5um PVC membrane filters mounted in 10mm Dorr-Oliver cyclones. Air was drawn through the filter at a flow rate of 1.7 liters per minute (lpm) using a battery powered sampling pump (NIOSH method 0600[1]). Total dust samples were collected using tared 37mm, 5um PVC filters mounted in two-piece cassettes, at a flow rate of 2.0 lpm (NIOSH method 0500[1]). The instrumental precision for the gravimetric analyses was 0.01 milligrams (mg) per sample. All of the total and respirable samples were analyzed for silica (NIOSH method 7500[1]) after weighing. The filters were dissolved in tetrahydrofuran and then analyzed for quartz and cristobalite using X-ray diffraction. The analytical limit of detection (LOD) for both polymorphs was 0.015 mg/sample and the limit of quantitation (LOQ) was 0.03 mg/sample.

Total dust sampling was used for general area monitoring only. Worker monitoring consisted of respirable dust sample collection in all areas. In the cast shop, we also collected personal samples for fibers, since large amounts of talc were used there.

Samples for fibers were collected according to NIOSH Method P&CAM 239[2], using a 37mm, 0.8um cellulose ester membrane filter in the open-faced configuration. The filters were mounted in 3 piece cassettes, and the samples were collected at a flow rate of 2.0 lpm.

Bulk samples of two types of talc used, settled rafter dust, and high-volume respirable dust samples, were collected to aid in the analysis of other samples. The talc samples were used to determine the fiber content before the personal sample analysis. If no fibers were present in the bulk, the other samples collected where that talc was used were not analyzed for fibers. The rafter dust and hi-vol respirable samples were used to confirm the silica polymorphs present and determine any interferences.

B. Medical Evaluation

All hourly and salaried employees, current and retired, were invited to participate in the medical survey, which consisted of a questionnaire, spirometry (pulmonary function tests), and a chest X-ray.

NIOSH personnel administered a questionnaire that included (a) those portions of the American Thoracic Society respiratory questionnaire that address cough, phlegm, wheezing, breathlessness, and past respiratory and heart conditions,[3] and (b) additional questions regarding cigarette smoking history and occupational history at Artesian and elsewhere. For epidemiologic purposes of this study, we defined chronic bronchitis as cough with phlegm on most days, at least three consecutive months a year, for at least two years.[4] By analogy, we defined chronic cough as cough on most days, at least three consecutive months a year, for at least two years. We categorized the degree of breathlessness (dyspnea) according to the responses to the five pertinent questions on the questionnaire.

Grade 1 -- troubled by shortness of breath when hurrying on the level or walking up a slight hill.

Grade 2 -- having to walk more slowly (on the level) than people of the same age because of shortness of breath.

Grade 3 -- having to stop for breath when walking at one's own pace on the level.

Grade 4 -- having to stop for breath after walking about 100 yards (or after a few minutes) on the level.

Grade 5 -- too breathless to leave the house or breathless on dressing or undressing.

One-second forced expiratory volume (FEV_1) and forced vital capacity (FVC) were measured with an Ohio Medical Model 822 dry rolling seal spirometer attached to a Spirotech 200B dedicated computer. Equipment and test procedures conformed to the American Thoracic Society's criteria for screening spirometry.[5] Predicted values for FEV_1 and FVC were calculated using the equations of Knudson;[6] these values were multiplied by 0.85 to obtain the predicted values for Blacks.[7]

Chest X rays were read using the International Labour Organisation (ILO) 1980 classification system.[8] Each X ray was read independently by two "B readers", radiologists specially trained and certified in the use of this system. If their interpretations differed substantially, the X rays were returned to them for a concensus reading. Because of apparent discrepancies between the readings of the NIOSH X rays and the reports of X-rays taken during a company-sponsored survey in 1982, the NIOSH X-rays were sent to a second pair of B readers to be read again. They initially read each X ray independently, and then together to resolve any substantial differences. For this analysis, we considered a finding consistent with pneumoconiosis to be present if <u>either</u> pair of radiologists reported it. (In such cases, the affected individuals were informed of both interpretations.)

For each participant, using job history information from the questionnaire, we calculated length of employment, duration of talc exposure, and an index of cumulative silica exposure. We considered the total time assigned to jobs in the cast shop (the area with the highest potential talc exposures) to be the best available indicator of talc exposure. As an index of cumulative silica exposure, we defined "silica-year equivalents" as the sum of each job-specific exposure, each such exposure being the time in a given job multiplied by the exposure level assigned to that job. We used the median of all concentrations of respirable silica measured for a job as the exposure level for that job, with undetectable amounts assigned a value of half the limit of detection (LOD), and trace (detectable but not quantifiable) amounts assigned a value midway between the LOD and limit of quantitation. For jobs in silica-exposure areas (cast shop, slip house, dry finish, spray finish) that were not sampled, we assigned values estimated on the basis of (a) measured exposures, if available, for jobs involving similar potential exposure, or (b) the median of values used for other, comparable jobs in the area. Since jobs in the kiln, glossware, refire, receiving, warehouse, mold shop, quality assurance, and management areas were judged to involve no substantial silica exposure, we took no air samples for respirable silica in these areas and considered exposure levels to be 0 for the purpose of calculating the silica exposure index. Maintenance and general plant workers' silica exposures depend on their specific job assignments, but we had neither this historical information nor exposure measurements for these groups. Therefore, for purposes of calculating the index, we somewhat arbitrarily assigned maintenance workers an exposure level of "non-detectable" and general plant workers a level of "trace".

The exposure variables described above, and the confounding variables age and pack-years of cigarette smoking, were analyzed to determine their contribution to health outcomes (chronic cough and bronchitis, shortness of breath, pulmonary function parameters, and X ray abnormalities). Stepwise logistic regression, generating the chi-square (X^2) statistic, was used in the case of dichotomous outcome variables, and stepwise regression, generating the F statistic, was used in the case of continuous outcome variables. Age and pack-years were forced into all models. We considered an association with a "p-value" (the probability of the result occurring by chance in the absence of a true association) of 0.05 or less to be statistically "significant".

V. EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy).In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the evaluation criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: 1) NIOSH Criteria Documents and Recommended Exposure Limits (RELs), 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs), and 3) the U.S. Department of Labor (OSHA) Permissible Exposure Limits (PELs). Often, the NIOSH RELs and ACGIH TLVs are lower than the corresponding OSHA PEL. Both NIOSH RELs and ACGIH TLVs usually are based on more recent information than are the OSHA standards. The OSHA standards also may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH RELs, by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is legally required to meet those levels specified by an OSHA standard.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limits or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

A. <u>Toxicological</u>

1. Crystalline Silica

The crystalline form of silica, silicon dioxide, is widely distributed in nature and constitutes a major portion of most rocks, soils, and sand. Much of the silica of naturally occurring rocks (i.e. bauxite, clay) is in the combined form, bound chemically with other mineral oxides. Free crystalline silica, such as quartz, cristobalite, and tridymite, is silica which is not combined with any other element or compound.[9] The crystalline forms of silica can cause severe lung damage when inhaled. Silicosis is a form a pulmonary fibrosis caused by the deposition of fine particles of crystalline silica in the lungs. Symptoms usually develop insidiously, with cough, shortness of breath, chest pain, weakness, wheezing, and non-specific chest illnesses. Silicosis usually occurs after years of exposure, but may appear in a shorter time if exposures are very high. This latter form is referred to as rapidly-developing silicosis. Silicosis is usually diagnosed through chest X-rays, occupational exposure histories, and pulmonary function tests. The manner in which silica affects pulmonary tissue is not fully understood, and theories have been proposed based on the physical shape of the crystals, their solubility, toxicity to macrophages in the lungs, or their crystalline structure. There is evidence that cristobalite and tridymite, which have a different crystalline form from that of quartz, have a greater capacity than quartz to produce silicosis.[10]

2. Talc

Talc is a mineral product, the composition of which varies widely from one geological deposit to another and even within the same deposit. The main component is a crystaline hydrated silicate of magnesium that is usually in the form of plates but may also be in the form of fibers. In many talc deposits other silicates such as tremolite and anthophyllite (both of which are amphiboles) and serpentines in the form of antigorite, lizardite, and even chrysotile may be present. According to the Bureau of Mines, [11] fibrous minerals include those with a crystallization habit ranging from prismatic, acicular, and fibrous to asbestos. However, difficulties arise in attempting to differentiate between these fibrous minerals. There are deposits that consist almost entirely of platiform talc crystals without significant admixture by other types of crystals or materials.

The dust of nonfibrous talc, consisting almost entirely of platiform talc crystals and containing no asbestos, carries a relatively small respiratory hazard.[12] Exposures to high concentrations of fibrous talc dusts among talc miners and millers were reported to lead to increased mortality due to both nonmalignant and malignant respiratory diseases.[12,13] Morbidity studies among these workers indicated increased symptoms (cough, phlegm, and dyspnea), and X-ray and lung function changes consistent with pneumoconiosis.[13]

B. Environmental Criteria

1. Silica

NIOSH recommends that occupational exposure be controlled so that no worker is exposed to a TWA concentration of free silica greater than 50 micrograms per cubic meter of air (0.05 mg/m^3) as determined by a full shift respirable dust sample for up to a 10-hour work day, 40-hour work week.[10] OSHA requires that the PEL for respirable silica be dependent upon the percent silica in the sample, and that the respirable dust exposure for an 8-hour TWA not exceed the value obtained from the formula:[14]

$$\frac{10\ mg/m3}{\%SiO_2 + 2}$$

2. Talc

The current OSHA PEL for nonfibrous talc is 20 million particles of talc per cubic foot of air (mppcf) or 2.7 mg/m.[14] This is a total dust exposure criterion. The ACGIH has a respirable dust exposure criterion for nonfibrous talc of 2 mg/m.[15] For fibrous talc the OSHA PEL is the same as for asbestos, 0.2 fibers per cubic centimeter (f/cc) of air as an 8-hr TWA. The ACGIH TLV for fibrous talc depends on the fiber type; amosite, 0.5 f/cc, chrysotile, 2 f/cc, crocidolite, 0.2 f/cc, and other forms, 2 f/cc.

VI. RESULTS AND DISCUSSION

A. Environmental Evaluation

Respirable silica exposures averaged 0.12 mg/m^3 for 86 personal samples collected (Table 1). Forty-four percent (38 samples) of these were greater than the NIOSH REL for respirable silica of 0.05 mg/m^3 for up to a 10-hour work shift. Forty-three percent (37 samples) of these exceeded the OSHA PEL. Personal respirable exposures to other dusts averaged 2.80 mg/m^3. Averages by plant area of general area dust concentrations are presented in Table 2. The total dust concentration averaged 3.28 mg/m^3 for all 27 area samples.

Among the five areas of the plant where personal respirable dust sampling was conducted, the slip house averaged the highest respirable silica exposure, 0.33 mg/m^3 (Table 1). The 15 personal samples collected in the slip house ranged from 0.06 to 1.80 mg/m^3 for respirable silica (Table 3). Thirteen of these exceeded the OSHA PEL and all 15 exceeded the NIOSH

REL. On both sampling dates the clay makeup man received the greatest respirable silica exposure (0.70 mg/m^3 on 10/2/84 and 0.53 mg/m^3 on 10/3/84). The personal exposure to respirable dusts, other than silica, of the utility operator on 10/2/84 exceeded the OSHA PEL for respirable nuisance dusts of 5 mg/m^3.

Respirable silica concentrations for 6 area samples collected in the slip house averaged 0.28 mg/m^3 (Table 2). Total silica dust concentrations for 6 samples averaged 0.77 mg/m^3. All 12 of these samples were greater than the respective OSHA PELs for personal exposure ($\frac{30\ mg/m3}{\%SiO_2 + 2}$ for total silica dust).

Exposures in the sliphouse are to all of the dry raw materials used in the slips and glazes. Flint, a material used in both, is essentially pure silicon dioxide, with a substantial portion (34%) of the particles having a diameter less than 10 microns. Other slip raw materials containing free silica are KTS-2 ball caly (29%), and NC-4 Feldspar (5-12%). Glaze materials containing free silica include Kona F-4 Feldspar (5%), No. 1 Glaze Ball Clay (28%), Superpax (7% respirable quartz), and Nytal 100 (2%). The reason for the higher exposure to the clay makeup man compared to the glaze makeup man is most likely due to the batch size and batching method. The slip batches are made up from front-end loader scoops of material. The glaze is batched from bagged materials, in smaller batches. Exposure to the other slip house workers results from the dust created during the almost constant batching operations. The front-end-loader stirs up dust by running back and forth for scoop loads and during the dumping into the weigh-hopper, although the weigh-hopper is hooded. A more modern method of materials handling is needed in the slip house. Methods using automated, enclosed, and ventilated systems from the point of raw material storage to the weigh station would reduce exposures here. The slip house is a designated respirator area. Single use, disposable respirators are required here. The clay makeup man wears a powered, air purifying respirator (PAPR) helmet.

One breathing-zone respirable dust sample was collected while a worker was transferring bulk raw material (Cyprucast) from a railcar to a storage bin. This transfer operation was accomplished using a front-end loader to scoop the material in the railcar, then moving it about ten yards and dumping it into the bin. The unloading lasted about 2 1/2 hours and resulted in an exposure of 8.89 mg/m^3 of respirable dust. This exposure was greater than the OSHA PEL for respirable fractions of nuisance dusts of 5 mg/m^3. There was a trace amount of silica in the sample. The dust created during this operation was a safety hazard, as well as a health hazard, due to reduced vision. For example, at the point of dumping, there was a drop-off of about 15 feet, with no barrier to stop the loader from driving off the edge. The operator was wearing a PAPR helmet, similar to that worn by the clay makeup man, with a single-use respirator underneath. This combination drastically reduces the effectiveness of the PAPR. Automated material handling systems should also be considered for these transfer operations.

The dust exposure in the cast shop was predominantly to the talc used to dust the molds. Transmission electron microscopic (TEM) analysis of a bulk sample of the talc being used at the time of the survey (Montana Treasure Talc) showed it to be free of fibers. However, TEM analysis of a talc used for a period of time in the past (NYTAL 100) confirmed its fibrous nature. Figure 10 is a photomicrograph of the bulk sample of NYTAL 100. Respirator use in the casting areas was up to the discretion of the worker. Single-use disposable respirators were avalilable.

Respirable silica exposures were not as pervasive in the cast shop as in the slip house. Of 32 samples from casting line workers (Table 4), silica was not detected in 4 samples, and only trace quantities were found in 15 samples (trace values are those between the analytical limit of detection and limit of quantitation, LOD = 0.015 mg/sample, LOQ = 0.030 mg/sample). The quantitated respirable silica results ranged from 0.04 to 0.13 mg/m^3 for the casting line workers. These exposures averaged 0.07 mg/m^3. For the bench casting workers, 5 of 6 samples ranged from 0.03 to 0.08 mg/m^3, and averaged 0.06 mg/m^3. One sample had a trace value.

The average respirable talc dust exposure in the casting areas was 2.69 mg/m (Table 1). Individual values ranged from 1.05 to 15.1 mg/m. The OSHA PEL for nonfibrous talc is 20 mppcf, or 2.7 mg/m, total dust. The ACGIH respirable dust exposure criterion for nonfibrous talc is 2 mg/m. Fifteen of the respirable dust exposure samples exceeded 2.0 mg/m, and seven exceeded the OSHA talc total dust PEL. Four of the six samples collected on the bench cast workers exceeded the ACGIH criterion. In the line casting areas, those whose job involved dusting the molds with talc, such as the turn out job, had the higher exposures.

As in the slip house, the general area sample results reflect those found in the personal samples. Only one of 11 area samples contained respirable silica above the LOD (Table 2). The primary respirable air contaminant was talc, at concentrations averaging 1.04 mg/m^3. Total dust concentrations in the cast shop averaged 3.48 mg/m^3.

A bulk sample of the talc used in the casting areas for dusting molds was analyzed for silica content. It contained none. Other possible sources of silica would be infiltration of dust from other areas of the plant and resuspension of the silica-containing clay dust in the area. The slip house and the spray department are in areas adjacent to the casting shop. Both areas have dusts with high silica content. The small particle sizes of these dusts would allow them to remain airborne for extended periods and possibly migrate to other areas of the plant along airflow patterns.

Keeping the cast shop positively pressured, with respect to these other areas, would reduce this infiltration. Improved housekeeping would decrease potential exposure to resuspended particulates.

Respirable silica exposures averaged 0.11 mg/m^3 in the dry finish area (Table 1). Finisher exposures to silica ranged from 0.03 to 0.25 mg/m^3, with only two sample values below the limit of quantitation (Table 5). Ten of the 20 samples were in excess of the OSHA PEL, and 12 of them exceeded the NIOSH REL. The exposures were not highly variable. The dust in this area was generated mostly from scraping and sanding dry ware. A part of the exposure here may be talc dust from the cast shop.

Significant area results from the finishing area were those for total silica exposure (Table 2). Results from three samples averaged 0.25 mg/m^3. Two of the three exceeded the OSHA PEL for total silica dust.

Spray area exposures result from overspray not captured by the spray booth ventilation system. The spray velocity is such that the glaze particles have sufficient momentum to escape the exhaust hood and enter the worker's breathing zone. Three respirable silica exposures were above the LOQ. They ranged from 0.13 to 0.38 mg/m^3 (Table 6) and averaged 0.24 mg/m^3 (Table 1). These exposures were experienced by the manual spray booth operators. The automatic sprayer operator's highest respirable silica exposure was a trace value. Redesigning the manual spray booth ventilation systems, and perhaps additional training in spraying work practices would reduce exposures for these jobs. An alternative would be to automate all spraying operations.

The mold shop was the one area in the plant where there was essentially no silica exposure. Respirable dust exposures averaged 0.68 mg/m^3 (Table 1), and the range was 0.34 to 1.01 mg/m^3 (Table 7). Their chief exposure is to plaster dust.

B. Medical Evaluation

One hundred ninety-five (87%) of 225 (179 of 205 hourly and 16 of 20 salaried) current employees and 1 retiree participated in the medical survey. There were 194 men and 2 women; 181 (92%) were white and 15 were black. They ranged in age from 18 to 66 years, with a mean of 40. They worked at Artesian from 2 months to 28 years, with a mean of 12 years; 48 (25%) of the 195 who provided the information worked there 20 or more years. Ninety-eight (50%) were current cigarette smokers, 37% (19%) were former smokers, and 61 (31%) were lifelong non-smokers (a lifetime total of less than 20 packs). Seventy-one (36%) of the 196 participants had 20 or more pack-years.

Age was significantly associated with pack-years of cigarette smoking and the three occupational variables (length of employment, duration of talc exposure, and cumulative silica exposure index). Smoking was associated with time at Artesian (but not with time in the cast shop or the index of silica exposure). There was some correlation among the three exposure variables. Time at Artesian was associated with the other two occupational variables (Table 8). Time in the cast shop was not associated with the index of silica exposure.

Nineteen (10%) of the participants reported symptoms that met the criteria for chronic cough, which was associated with cigarette smoking ($X^2 = 14.2$, $p < 0.001$). Ten of the 19, 5% of the particpiants, reported symptoms that met the criteria for chronic bronchitis, which was associated with both cigarette smoking ($X^2 = 8.17$, $p = 0.004$) and time in the cast shop ($X^2 = 9.08$, $p = 0.003$). Sixty (31%) of the participants reported some degree of shortness of breath; 26 (43% of the 60, or 14% of the 196) were of at least grade 2 severity. Eleven were of grade 3, 4 were of grade 6, and 3 were of grade 5 severity. Shortness of breath (any amount) was associated with cigarette smoking ($X^2 = 10.55$, $p = 0.001$) and time in the cast shop ($X^2 = 7.65$, $p = 0.006$).

Percent predicted FVC was inversely associated with both age ($F = 9.87$, $p = 0.002$) and smoking ($F = 4.39$, $p = 0.04$) [variation explained by model (r^2) = 0.095] when these were the only variables in the model. When time at Artesian was added, the model "improved" ($r^2 = 0.11$); the association with age disappeared ($F = 1.71$, $p = 0.19$), but the associations with smoking ($F = 3.21$, $p = 0.07$) and time at Artesian ($F = 3.52$, $p = 0.06$) were only marginal. Percent predicted FEV_1 was inversely associated with smoking ($F = 23.7$, $p < 0.001$) and time in the cast shop ($F = 4.23$, $p = 0.04$) ($r^2 = 0.182$). FEV_1/FVC was inversely associated with smoking ($F = 28.2$, $p < 0.001$), and marginally with age ($F = 3.23$, $p = 0.07$) and time in the cast shop ($F = 3.12$, $p = 0.08$) ($r^2 = 0.20$). When time at Artesian was added, the model "improved" statistically ($r^2 = 0.22$); the inverse associations with smoking ($F = 31.9$, $p = 0.001$), age ($F = 7.13$, $p = 0.0008$), and time in the cast shop ($F = 6.11$, $p = 0.01$) were stronger, but the association with time at Artesian was, illogically, positive ($F = 4.21$, $p = 0.04$) rather than inverse.

Eighteen (9.2%) of the 196 chest X rays had changes suggestive of silicosis or of asbestosis or talc exposure. One X ray had only irregular opacities, 5 had both rounded and irregular opacities, 11 had pleural plaque, and 1 had bilateral costophrenic angle thickening (Table 9). There were thus 18 X rays with findings (irregular opacities, pleural plaque, or bilateral costophrenic angle thickening) suggestive of asbestos[16] or talc[17] exposure, and 5 suggestive of silicosis (rounded opacities).[18] Asbestos/talc-suggestive findings were associated with age ($X^2 = 9.13$, $p = 0.003$), but not smoking or any of the occupational exposure variables. Rounded opacities were not associated with age, smoking, or any of the occupational exposure variables.

Six of the 18 persons with X ray signs of exposure to fibrogenic dust had a history of potential exposures other than at Artesian (Table 9). One worked a total of 8 years at jobs involving potential exposure to silica and talc. Another had a job for 4 months that might have involved asbestos exposure. Of the 6 persons who had previous jobs with potential exposure to silica or coal dust, only one had rounded opacities. Thus, identified potential exposures other than at Artesian could not have accounted for most of the X ray findings.

Medical Summary

The association of smoking with chronic cough, bronchitis, shortness of breath, and obstructive pulmonary function, and the association of age with decreased FEV_1/FVC, are not surprising. Even after controlling for age, smoking, and total time at Artesian, however, time in the cast shop was associated with chronic bronchitis, shortness of breath, and obstructive pulmonary function. This suggests an exposure (possibly talc), or combination of exposures, in the cast shop that adversely affects the respiratory system. Exposures to silica have been present at Artesian, but the indicator of silica exposure was, not an independent, statistically significant predictor of the pulmonary outcomes. The X ray abnormalities tended to be more characteristic of exposure to talc or asbestos than to silica. Whether this reflects an effect of talc itself, or of previous asbestos contamination of the talc, cannot be determined from the data from this study.

VII. RECOMMENDATIONS

A. Environmental

1. Respirator Policy

A respiratory protection program should be in place which meets the requirements of Section 1910.134 of the OSHA Standard.[14] Because of measured exposures, it is recommended that all workers in the slip house wear a powered air-purifying respirator with a loose-fitting hood or helmet and any type of particulate filter. All workers in the casting areas, the dry finish area, and the spray area should be required to wear single-use respirators at all times.[19]

2. Material Handling Systems

Material handling operations in use at the time of the evaluations in the sliphouse were the major source of dust exposure there. They were also a potential source of exposure for workers in other areas of the plant. It is recommended that engineering controls in the form of enclosed and ventilated material storage and weighing systems be implemented. Respiratory protection should be used by all workers in the slip house while engineering controls are being installed.

Preweighing of batches with multiple ingredients may be carried out in three different ways as shown in Figure 11 (Ref. 20). In the cumulative method all the ingredients are introduced to one weigh hopper from their respective storage bins via individual feeders as shown. The weight of each ingredient is the difference between the total weight before it was added to the weigh hopper and the total weight after its addition is complete. The main drawback to this method is that it required that the scales be accurate over the entire range. For ingredients which are present in relatively small amounts, these may present an accuracy problem. Another method which circumvents this drawback in the cumulative method is weighing the materials simultaneously where each ingredient has its own weigh hopper. A combination of these two methods would probably be optimal.

A schematic of a modern batching system which operates by the cumulative method appears in Figure 12. It is presented here as an example of what is available currently and is not specifically recommended as a replacement for the clay handling systems at Artesian. The system shown consists of material storage bins, individual feeders for each ingredient and a common weigh hopper. For proper operation of the system all bins and weigh hoppers should be vented to outside air through dust collection devices. Recommended ventilation rates for the bins and hopper may be at a rate of 100 cfm per $ft.^2$ of cross section of vessel (pp 5-36 through 5-39 Ref. 21). Lower ventilation flowrates are reported in the literature for similar processes. For example, a total of 15,000 cfm of ventilation air is used to control dust emissions from storage silos, bucket elevators, conveyor transfer points, etc. at a process where tonnage quantities of a mineral containing silica are prepared (p 14, Ref. 22).

It can be seen from Figure 5 that the method used for preweighing the glazes may present exposure and spillage problems. Use of more advanced bag opening stations such as the one described in Reference 23 would alleviate potential problems associated with the currently used method.

2. Air Cleaning Devices

Dust-laden air from local exhaust systems is filtered by passing through baghouses. Except in two cases this air is recirculated back to the workplace. The stated purpose of this recirculation is the savings realized by eliminating the need to replace the recirculated air with fresh outside air. From a worker health point of view this practice poses some risks because individual bags in a baghouse are prone to failure. When this happens uncontrolled concentrations of dust will be introduced to the workplace. Continuous monitors for respirable aerosols with alarms would have to be installed to monitor dust concentrations in the air exiting the baghouse. In case of a bag failure the work activity being controlled by the baghouse would have to cease until the baghouse is repaired. Over a period of time this practice may prove more costly than venting the air outside the building.

In a 1981 NIOSH study , the performance of an electrostatic precipitator fitted with 14 oz polyester felt bags was evaluated.[24] Welding fume with an aerodynamic particle size range of 0.22 to 7.20 microns was used . Average inlet and outlet concentrations of 12.6 and 0.11 mg/m^3 respectively were obtained during the study. The average penetration was 0.96 percent. An area sample taken on top of one of the baghouses at Artesian had a silica concentration of 0.03 mg/m^3. But since the sampling was anisokinetic the actual concentration is estimated at between two to three times the measured value (p 190, Ref 25).

Two types of baghouse failure were reported in the NIOSH study cited above. These were blinding of the bags and dust breakthrough. Blinding was attributed to either small particle penetration into the bag material or bag cleaning mechanism failure with the latter more likely to occur. Blinding causes an increase in the pressure drop with a corresponding decrease in flowrate through the baghouse. Breakthrough was observed to occur as a result of bag tear or gasket leak (between filtered and unfiltered air). Both of these events were likely to occur "unexpectedly".

A more recent study by NIOSH evaluated the performance of a baghouse installed to control dust in the air from a ventilated bag opening work station.[23] The bags being opened contained crushed limestones. The respirable dust concentration in the effluent from the baghouse averaged 0.12 mg/m^3. The bag material was 14 oz polyester felt. The station operator's exposure amounted to 0.11 mg/m^3 and the background" concentration, at a point 15 ft. away from the worker, was 0.10 mg/m^3. By performing an unsteady state mass balance on the air and dust within the room and assuming a perfectly stirred atmosphere there, the following differential equation is obtained.

$$C_B F_B = A_C C_R/60 + dC_R/dt (V_R)$$

where:

C_R = dust concentration in the room, mg/m^3

C_B = dust concentration in baghouse effluent, mg/m^3

F_B = air flow from baghouse, m^3/min

V_R = volume of room, m^3

A_c = air change per hour (typically 1 to 4)

t = time, min

The solution to the differential equation assuming that at t=0, C_R=0 is as follows:

$C_R = C_B F_B 60/(V_R A_c) (1 - EXP(A_c t/60))$

Using the above formula it was found that for the case study of Ref. 23 the dust concentration in the room approached the baghouse effluent concentration within 20 minutes. Therefore, it may be concluded that the baghouses at Artesian where the air is recycled to the workplace contribute at least 0.1 mg/m^3 to ambient levels. If the silica content is 50 percent, this concentration would exceed the NIOSH recommended standard of 0.05 mg/m^3. If the silica content is 100 percent, the OSHA standard is likely to be exceeded. Much higher concentrations would result in case of bag failure. Therefore we recommend that Artesian vent all baghouse effluents outside the plant.

3. Local Exhaust Systems

The backdraft hood installed at the tank line to control the talc emission while dusting (Figure 6) appears to be adequate. It is recommended that such hoods be installed at production lines for other pieces as well. The operation of cleaning the molds should be similarly controlled.

Based on measurements of capture velocities and actual worker exposures, it is recommended that the effectiveness of the downdraft hoods in the dry finish area be increased. This may be achieved by placing a 4 in. circular jet of supply air 9 ft. above floor level directly above the workpiece. A jet flow between 20 and 50 cfm should achieve capture velocities of 100 fpm at the level of the workpiece being finished (Ref. 26, p. 335). The usefulness of the push/pull system should be validated through capture velocity and exposure measurements.

The booths in the glaze spray area were not evaluated during the August 1985 visit. However, worker exposures in this area indicate a need for improving the effectiveness of the local exhaust systems. Face velocities of at least 100 fpm should be maintained in these booths. Baffles used to equalize the airflow into the booths should be maintained free of caked material. Some of these booths showed a buildup of material there. This has the effect of obstructing the air flow thus decreasing the face velocities.

Further enclosure of the automatic glaze spray line is needed. To maintain adequate face (capture) velocities higher airflow rates through the booths may be required.

4. General Ventilation

Once the potential sources of exposure have been effectively controlled there is a need to provide fresh outside air to areas of the plant where workers are likely to be found. In such areas a supply rate of 2 cfm per sq. ft. of floor area is recommended (Ref. 27, p. 19.3).

For maximum comfort the air should be supplied at a height of about 10 ft. above floor level. Oncethrough local exhaust systems will serve as an aid in exhausting the air supplied.

5. Housekeeping

Removal of accumulated clay and silica from all surfaces is necessary for maintaining dust levels at acceptable values. This cleanup may be achieved in two stages. In the first stage the caked material and dirt accumulated over the years should be removed by an outside contractor which specializes in the decontamination of industrial work sites. Vacuum techniques are usually employed in such cleanups. When respirable silica is a contaminant the vacuum device would be exhausted through a high efficiency particulate air (HEPA) filter. High pressure water jets may be used to remove caked material. Decontamination is achieved when high volume area samples (at 9 liters per min) indicate non-detectable levels. Wipe samples may also be taken at random. When the plant is in normal operation daily cleanup of potentially contaminated areas should be practiced. A central vacuum system would have to be installed for that purpose (Ref. 22, p. 14).

B. <u>Medical</u>

Employees exposed to silica or talc should have pre-placement and periodic medical evaluations. These should include a medical and occupational history, physical examination, pulmonary function tests, and a chest x ray. The X rays can be taken infrequently at first (at 5-year intervals, for example), unless other medical findings suggest a need for a diagnostic x-ray sooner. The other components of the medical examination should be done annually. After 10 or 15 years of exposure, more frequent X rays are appropriate. X rays should be read according to the ILO 1980 system.[8] Pulmonary function testing should be performed using equipment and procedures conforming to the American Thoracic Society's revised criteria for screening spirometry.[28] An employee with significant respiratory symptoms, physical findings, pulmonary function test abnormalities, or X-ray signs of pneumoconiosis should be evaluated by a physician (preferably a pulmonary or occupational medicine specialist) to determine whether it is advisable for the employee to be removed from further exposure to silica or talc.

OSHA regulations (29 CFR 1910.10) give employees the right of access to their own medical and exposure records. The regulations also give employees and employee representatives the right of access to other pertinent exposure records and, in a form that does not identify specific individuals, to statistical or other compilations of data from medical or exposure records.

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1. Artesian Industries, Mansfield, Ohio
2. International Union of Electricians, Local 719
3. OSHA, Region V

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

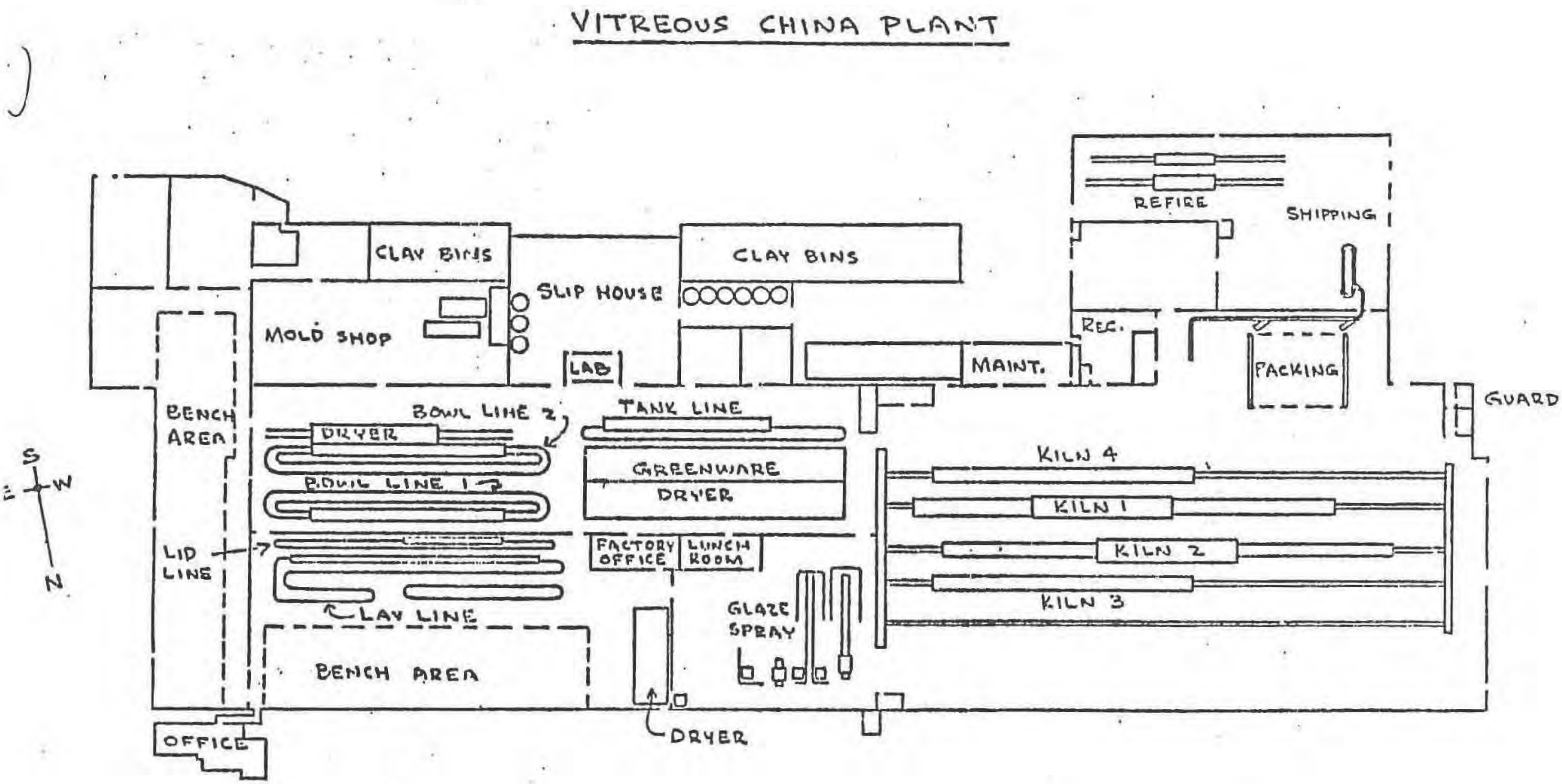


Figure 1: Plan View of Vitreous China Operation

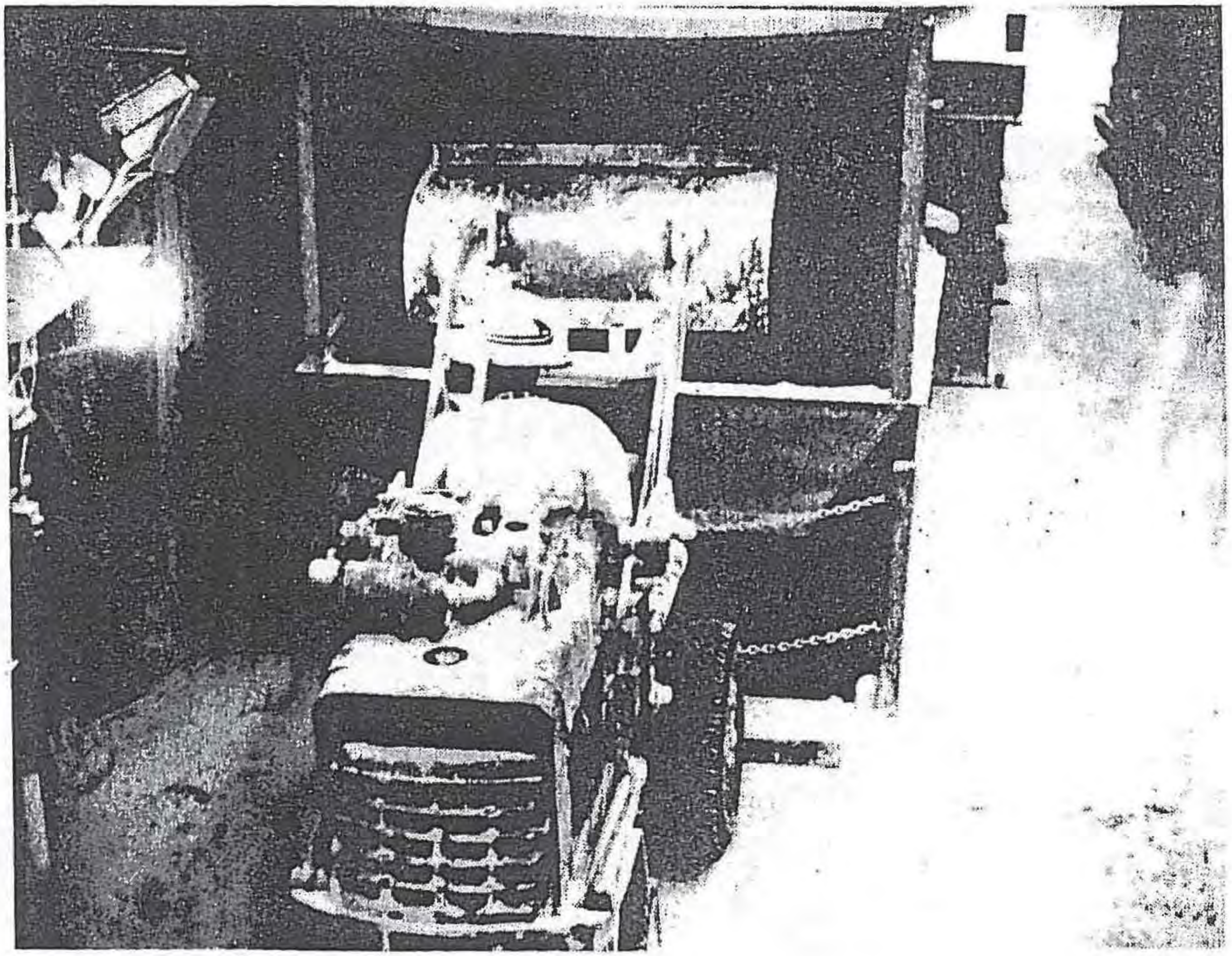


Figure 2. Front End Loader Dumping Clay into Preweigh Hopper

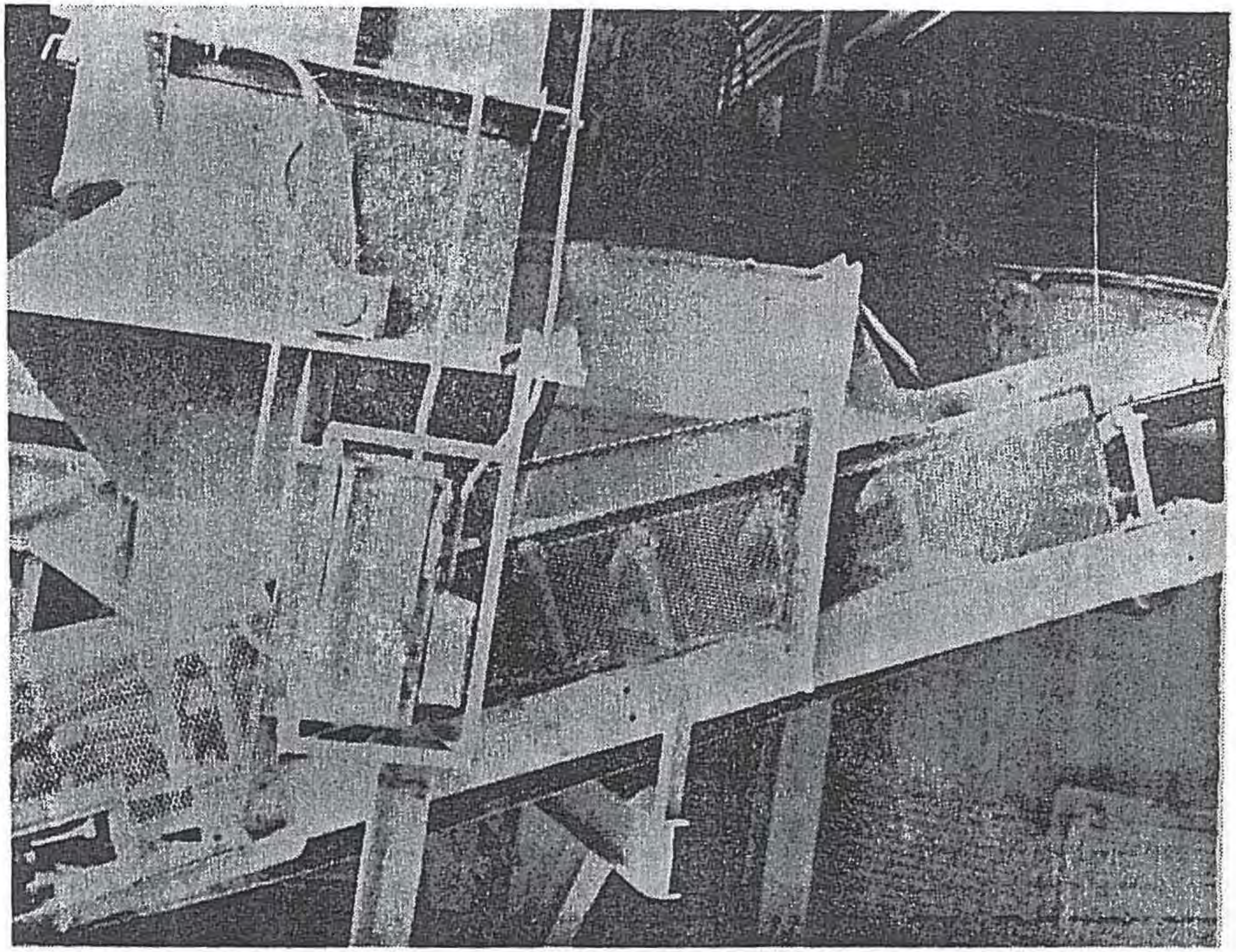


Figure 3. Material Transfer from Feeder to Belt Conveyor

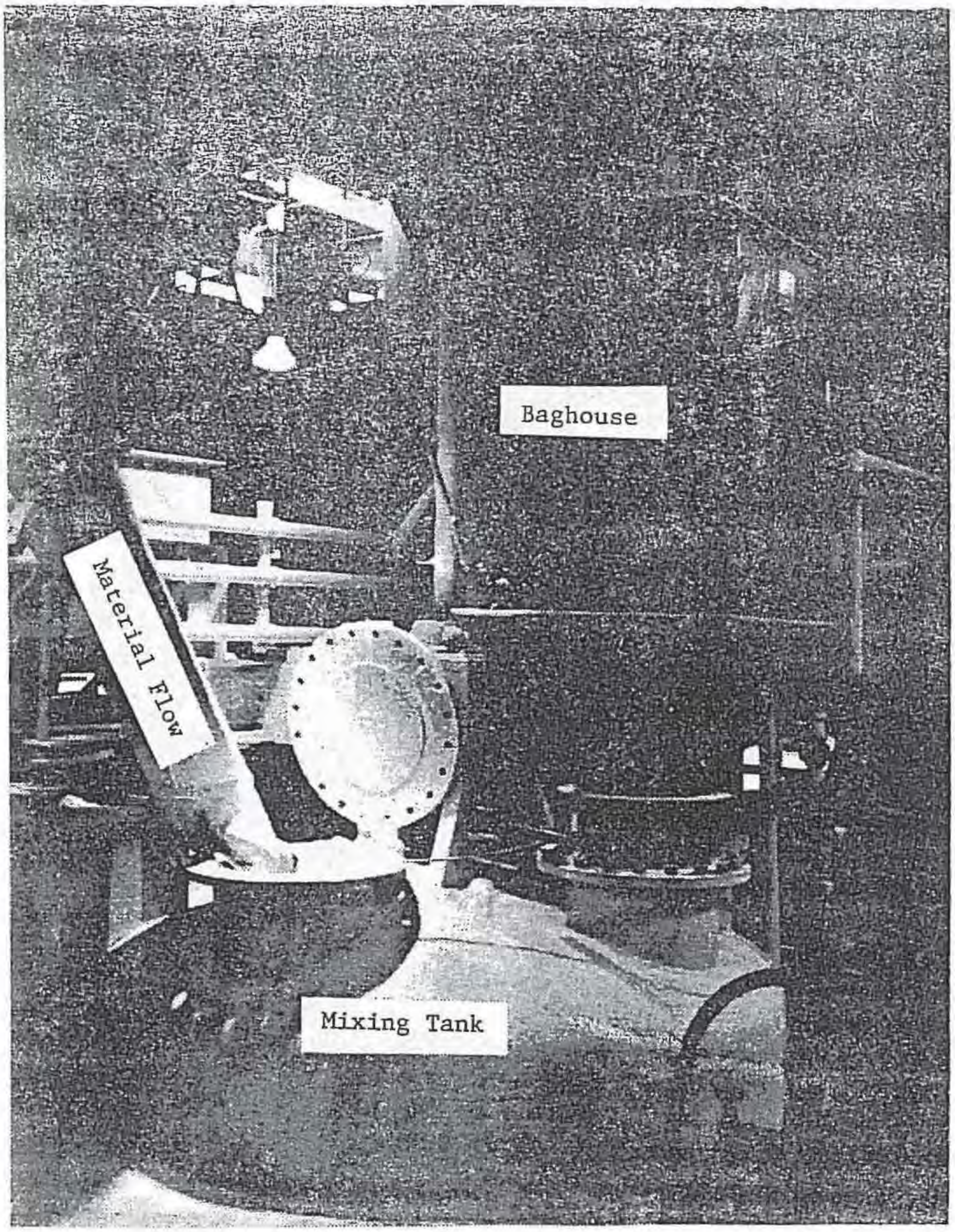


Figure 4. Material Flow into Slurry Mixing Tank

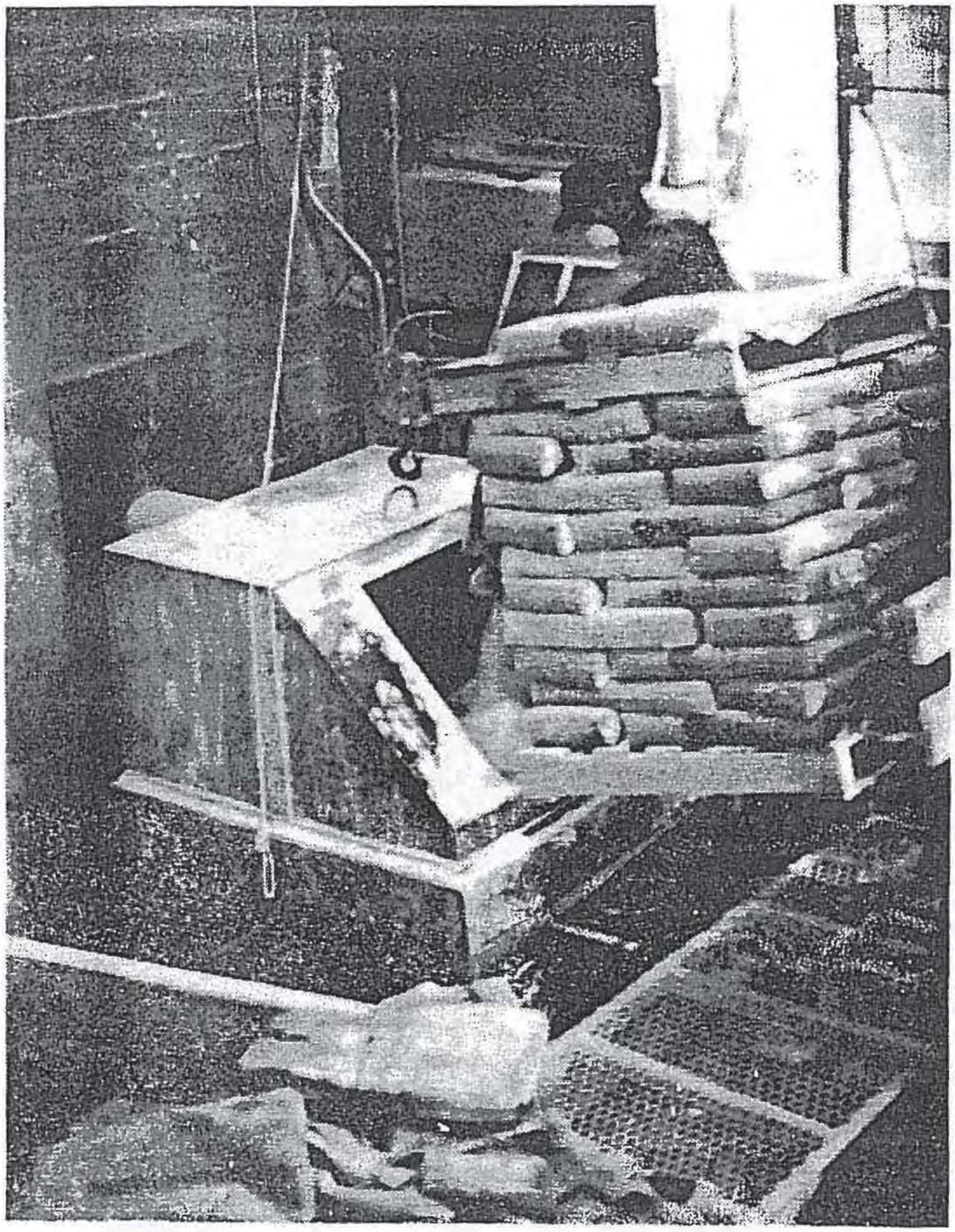


Figure 5. Ventilated Preweigh Hopper for Glazes

Figure 6. Backdraft Hood for Control of Talc Dusting of Molds at Tank Line

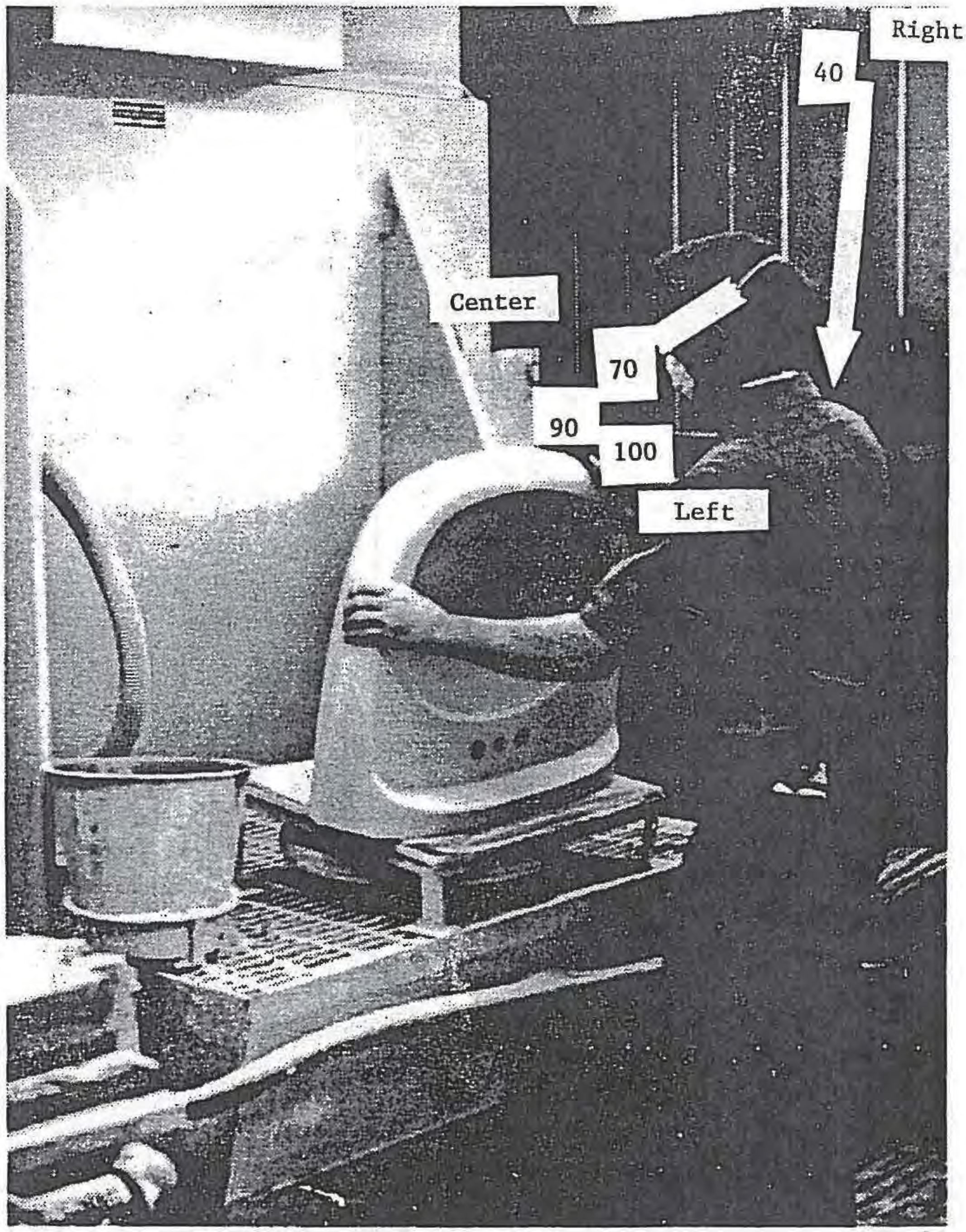


Figure 7. Capture Velocities (fpm) in Worker's Breathing Zone at a Dry Finishing Work Station

Figure 8. Booth Where Glaze is Sprayed Manually

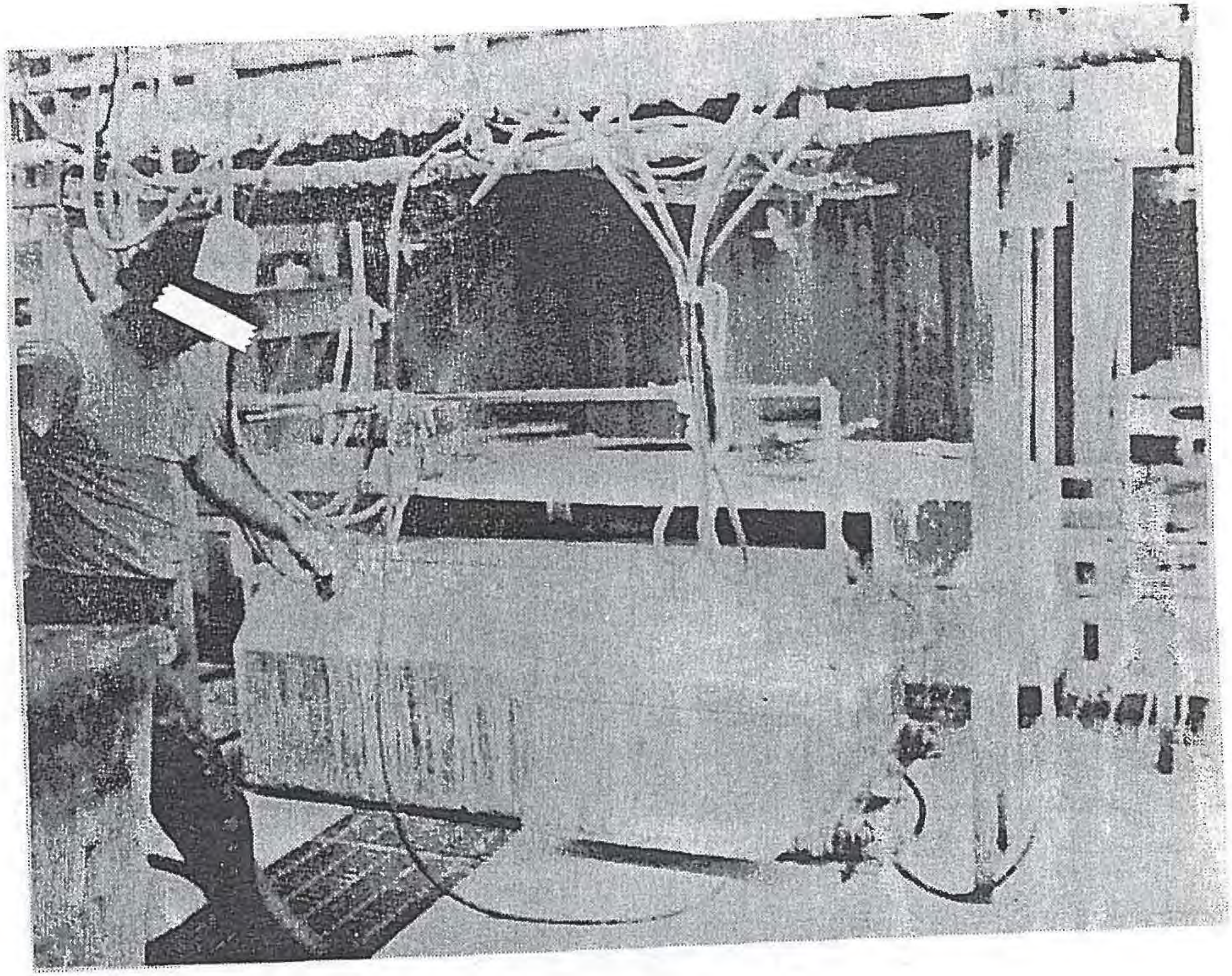


Figure 9. Booth Where Glaze is Sprayed Automatically

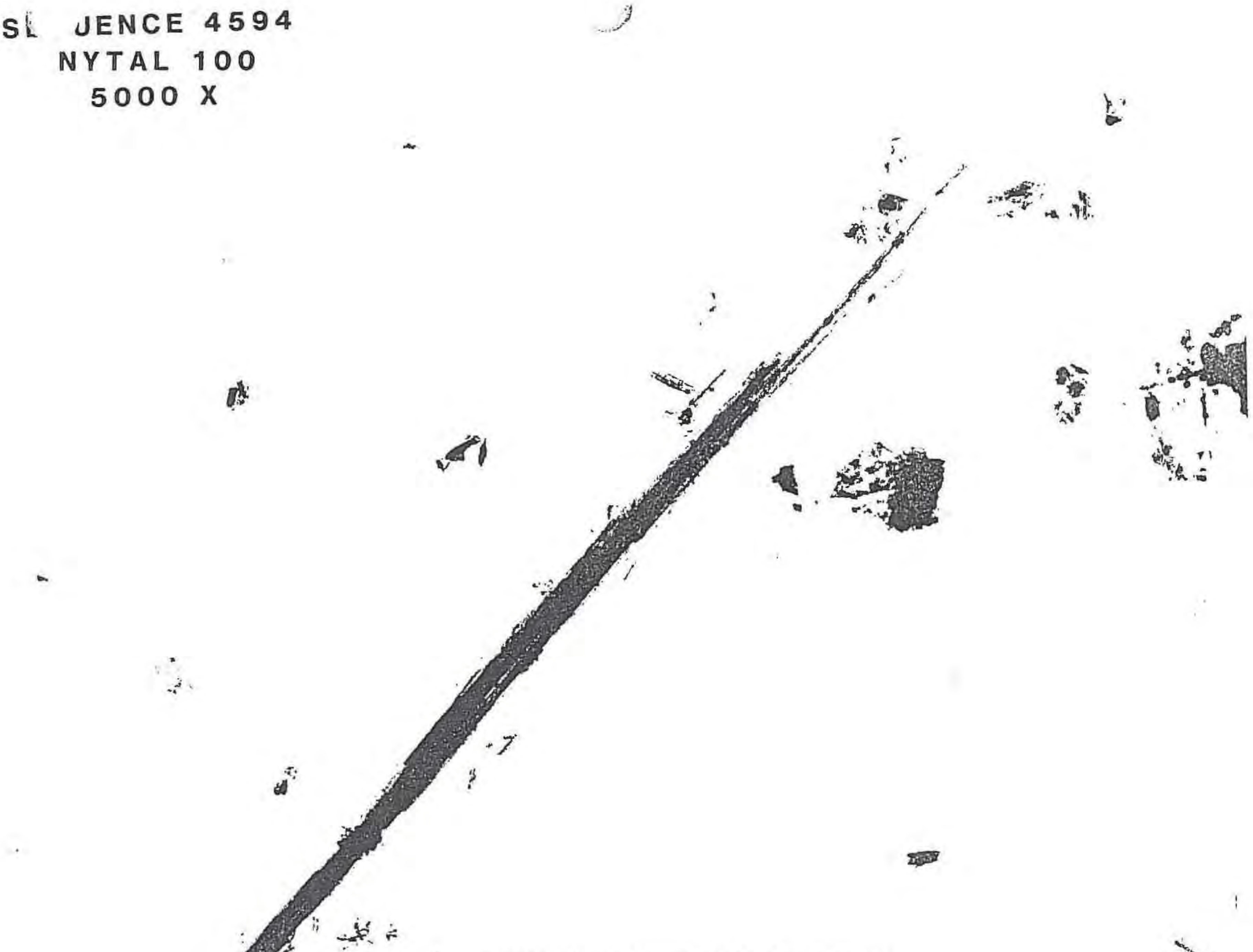
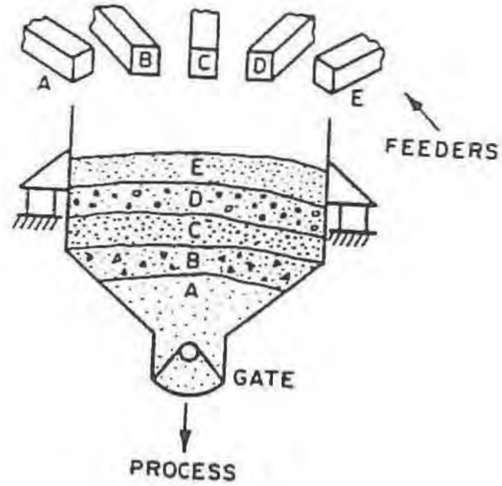
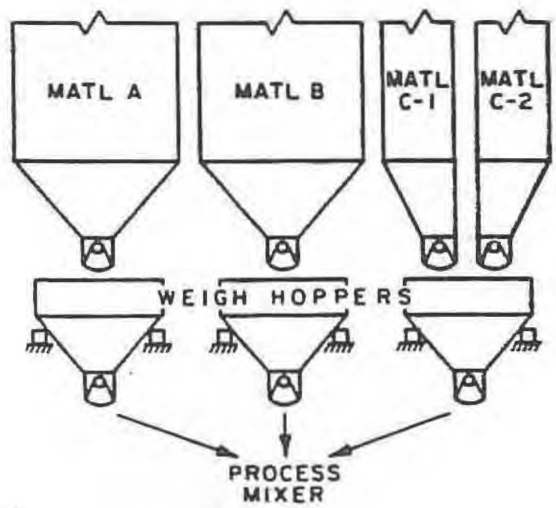


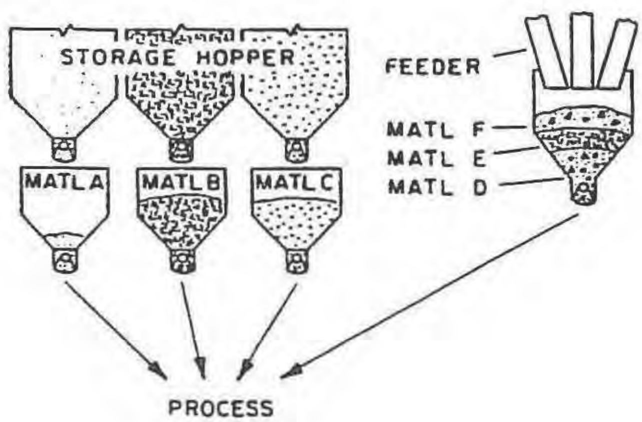
FIGURE 10 - Fibrous Habit of Nytal 100



Cumulative



Simultaneous



Combination

Figure 11 - Three Methods for Preweighing of Batch Ingredients

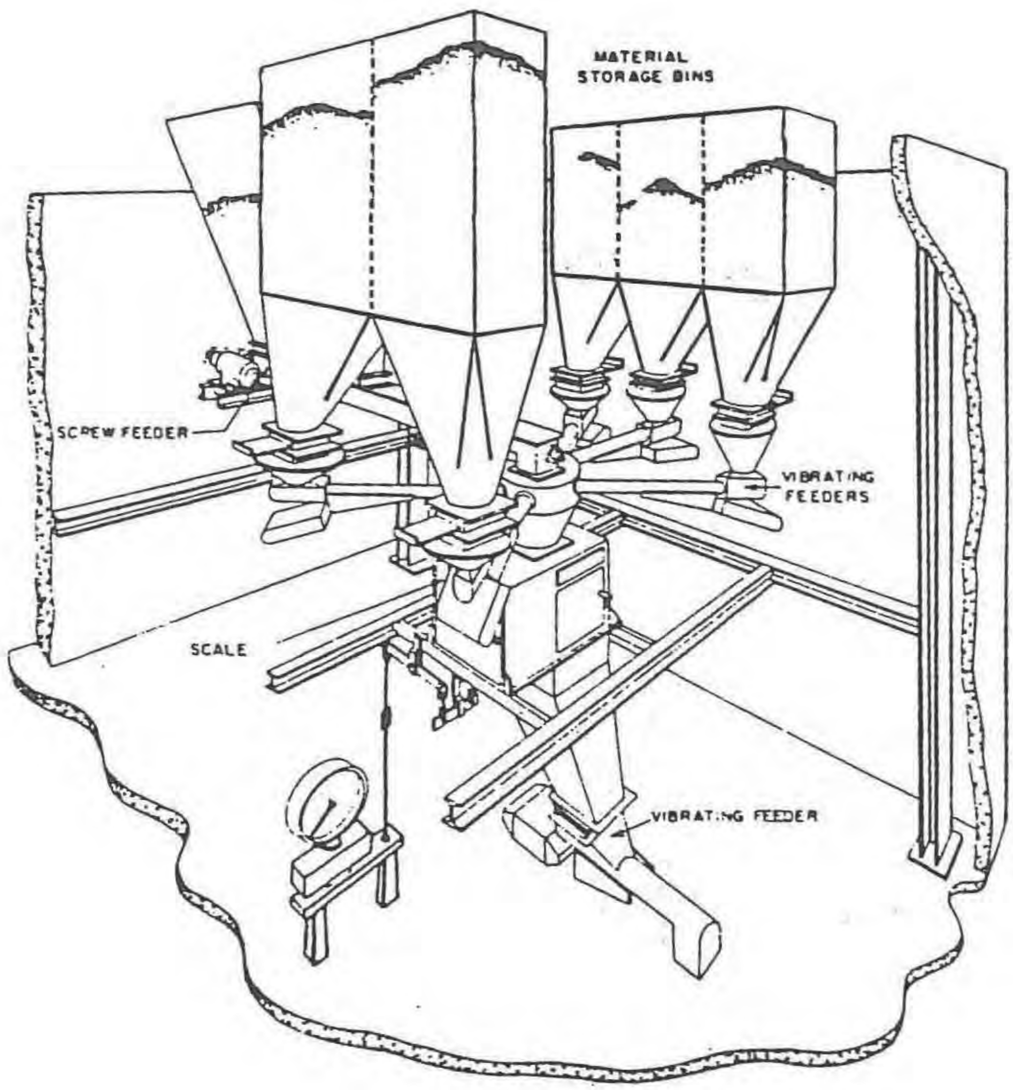


Figure 12. Schematic of an Enclosed Batching System (Ref. 1)

Table 1

Worker Respirable Dust Exposure Summary

Artesian Industries
Mansfield, Ohio
October 2-5, 1984
HETA 84-066

Area	Number Samples	Average Respirable Silica, mg/m³	Average Respirable Dust, mg/m³	Percent (Number) Over OSHA Silica PEL	Percent (Number) Over NIOSH Silica Criteria +
Slip House	15	0.33 (SD±0.44)	1.87 (SD±1.78)	87 (13)	100 (15)
Cast Shop	38	0.06* (SD±0.03)	2.69 (SD±2.73)	29 (11)	21 (8)
Dry Finish	20	0.11* (SD±0.06)	1.54 (SD±1.16)	50 (10)	60 (12)
Spray	6	0.24* (SD±0.13)	2.54 (SD±3.24)	50 (3)	50 (3)
Mold Shop	7	-	0.68 (SD±0.24)	-	-
Plant Totals	86	0.12	2.80	43 (37)	44 (38)

* This is an average of those values above the Limit of Quantitation. Does not include trace or none detected values.

+ NIOSH Respirable Silica Recommended Standard - 0.05 mg/m³

Table 2

General Area Dust Exposure Concentrations

Artesian Industries
Mansfield, Ohio
October 2-5, 1984
HETA 84-066

Area	n	Average Dust Concentration, mg/m³ Respirable Silica	Respirable Dust	n	Total Silica	Total Dust
Slip House	6	0.28 (SD±0.28)	1.40 (SD±1.14)	6	0.77 (SD±0.55)	4.32 (SD±3.04)
Cast Shop	11	0.10*	1.04 (SD±0.49)	8	0.13 (SD±0.05)	3.48 (SD±1.55)
Dry Finish	3	0.04*	0.83 (SD±0.15)	3	0.25 (SD±0.02)	2.72 (SD±0.42)
Spray	2	-----	0.77 (SD±0.17)	2	0.21 (SD±0.08)	3.25 (SD±1.72)
Mold Shop	5	-----	0.42 (SD±0.22)	5	0.04 (SD±0.02)*	1.96 (SD±0.95)

* This is an average of those values above the Limit of Quantitation. Does not include trace or none detected values.

Table 3

Slip House
Worker Respirable Dust Sampling Results

Artesian Industries
Mansfield, Ohio
HETA 84-066

Job	Date	Duration	Volume (liters)	Concentration, mg/m³ Respirable Silica	OSHA PEL	Respirable Dust
Supervisor	10/2/84	0707-1457	799	0.06	0.78	0.58
	10/3/84	0655-1457	819	0.07	0.69	0.59
Group Leader	10/2/84	0616-1455	882	0.18	0.54	1.10
		0626-1458	870	0.11	0.89	1.25
Clay Makeup	10/2/84	0410-1216	826	0.70 +	0.36	2.93
	10/3/84	0402-1217	842	0.53 +	0.42	2.67
Glaze Makeup	10/2/84	0506-1355	899	0.20 +	0.62	1.41
	10/3/84	0458-1355	913	0.13 +	0.92	1.48
Pumper/Screener	10/3/84	0404-0910	520	0.15	0.78	1.42
Utility #1	10/2/84	0451-1313	853	0.30 +	0.46	1.54
	10/3/84	0625-1459	874	0.15	0.59	1.41
Utility #2	10/2/84	0504-1324	850	1.80 +	0.36	7.81
	10/3/84	0526-1329	821	0.28	0.66	2.13
Utility #3	10/2/84	0632-1455	855	0.13	0.59	0.85
	10/3/84	0634-1457	855	0.11	0.75	0.94
			Criteria: NIOSH	0.05		
			OSHA		$\frac{10}{\%SiO_2+2}$	

+ = These samples contained quartz and cristobalite. Cristobalite valves ranged from trace to 0.20 mg/m³. OSHA PEL's for these samples were calculated using: $PEL = \frac{10\ mg/m^3}{\%\ quartz + (2)\%\ cristobalite + 2}$

Other samples contained only quartz.

Table 4

Cast Shop
Worker Respirable Dust Sampling Results

Artesian Industries
Mansfield, Ohio
HETA 84-066

Job	Line	Date	Duration	Volume (liters)	Concentration, mg/m³ Respirable Silica	OSHA PEL	Respirable Dust
Bowl Pour, C	4305-30	10/4/84	0507-1255	796	0.05	1.92	1.57
Rim Pour, C	4305-30	10/4/84	0512-1257	790	0.04	3.14	3.20
Core Pull, B	4305-30	10/4/84	0637-1342	722	ND*	-	8.01
Rim Drain, B	4305-30	10/4/84	0640-1343	719	Trace**	-	1.67
Turn Out	4305-30	10/4/84	0719-1501	785	0.04	2.91	2.66
Turn Out	4305-30	10/5/84	0719-1437	745	Trace	-	2.00
Top Off	4305-30	10/5/84	0649-1434	790	ND	-	1.32
Rim Punch	4305-30	10/5/85	0644-1433	797	ND	-	1.44
Peg In	4505-30	10/5/84	0822-1500	677	Trace	-	1.05
Peg In	4305-30	10/5/84	0825-1500	672	Trace	-	1.77
Group Leader	4305-30	10/5/84	0736-1455	746	Trace	-	1.30
Bowl Pour, C	4350	10/4/84	0515-1258	787	0.13	0.93	1.46
Strip & Condition	4350	10/4/84	0708-1459	801	Trace	-	1.57
Strip & Trim	4350	10/4/84	0712-1459	794	0.06	1.94	2.00
Turn Out	4350	10/5/84	0721-1453	768	Trace	-	5.36
Turn Out	4350	10/5/84	0731-1454	750	Trace	-	15.1
Bowl Pour	4360	10/4/84	0500-1252	802	Trace	-	1.17
Strip & Condition	4360	10/4/84	0645-1438	804	Trace	-	1.97

(Continued)

Table 4 (Cont.)

Job	Line	Date	Duration	Volume (liters)	Concentration, mg/m^3 Respirable Silica	OSHA PEL	Respirable Dust
Strip & Trim	4360	10/4/84	0648-1438	799	0.05	2.03	1.71
Turn Out	4360	10/5/84	0705-1443	779	ND	-	3.80
Turn Out	4360	10/5/84	0706-1443	777	Trace	-	2.33
Supervisor	4360-Bench	10/5/84	0709-1445	775	Trace	-	1.21
Lid Pour	LID	10/4/84	0558-1321	753	0.11	1.61	2.52
Lid Strip	LID	10/4/84	0650-1416	758	0.04	4.14	9.59
Lid Finish	LID	10/4/84	0724-1503	780	Trace	-	1.32
Group Leader	Tank	10/5/84	0712-1451	780	0.06	1.98	2.10
Tank Pour & Dust, C	Tank	10/4/84	0517-1300	787	0.05	3.07	4.05
Core Pull, C	Tank	10/4/84	0604-1323	746	Trace	-	1.41
Punch & Patch	Tank	10/4/84	0657-1420	753	0.07	1.48	1.39
Tank Pull	Tank	10/5/84	0716-1442	758	0.12	0.89	1.29
Green Finish	Tank	10/5/84	0758-1458	714	0.04	1.84	1.22
Green Finish	Tank	10/5/84	0759-1458	712	Trace	-	1.31
Bench Cast, B		10/4/84	0549-1325	775	0.05	2.07	1.82
		10/4/84	0552-1250	711	0.08	1.64	2.05
		10/4/84	0612-1442	867	0.03	2.83	2.25
		10/4/84	0615-1444	865	0.08	1.73	2.14
		10/4/84	0617-1444	862	Trace	-	1.58
		10/5/84	0646-1404	745	0.05	2.37	2.42
				Criteria: NIOSH	0.05		
				OSHA		$\frac{10}{\%SiO_2+2}$	2.7 Talc, Total
				ACGIH			2.0 Talc, Resp.

*ND - None Detected

**Trace - These values were between the Limit of Detection (LOD) and the Limit of Quantitation (LOQ)
LOD = 0.015 mg/sample
LOQ = 0.030 mg/sample

Table 5

Dry Finish
Worker Respirable Dust Sampling Results

Artesian Industries
Mansfield, Ohio
HETA 84-066

Job	Date	Duration	Volume (liters)	Concentration, mg/m^3 Respirable Silica	OSHA PEL	Respirable Dust
Bowl Finisher, Booth 2	10/2/84	0542-1417	876	0.05	1.23	0.74
	10/3/84	0646-1456	833	0.05	1.58	1.10
Bowl Finisher, Booth 3	10/2/84	0605-1414	831	0.13	1.14	1.96
	10/3/84	0649-1459	833	0.18	1.12	2.61
Bowl Finisher, Booth 4	10/2/84	0554-1419	858	Trace*	-	0.83
	10/3/84	0703-1459	809	0.05	1.34	0.90
Bowl Finisher, Booth 5	10/2/84	0556-1421	858	0.03	1.50	0.75
	10/3/84	0701-1501	816	0.06	1.37	1.15
Bowl Finisher, Booth 6	10/2/84	0550-1423	872	0.05	1.42	0.91
	10/3/84	0659-1459	816	0.11	1.00	1.38
Bowl Finisher, Booth 7	10/2/84	0547-1425	881	0.08	0.95	0.93
	10/3/84	0652-1501	831	0.13	0.78	1.23
Bowl Finisher, Booth 8	10/2/84	0547-1426	882	0.15	2.20	5.79
	10/3/84	0653-1503	833	0.18	0.78	1.66
Bowl Finisher, Booth 9	10/3/84	0656-1504	833	0.17	0.81	1.62
Bowl Finisher, Booth 11	10/3/84	0715-1315	612	0.08	1.21	1.31
Bowl Finisher, Booth 12	10/3/84	0711-1453	785	0.13	0.99	1.57

(Continued)

Table 5 (Cont.)

Job	Date	Duration	Volume (liters)	Concentration, mg/m³ Respirable Silica	OSHA PEL	Respirable Dust
Bowl Inspector	10/2/84	0711-1426	756	0.04	1.17	0.61
Sink Inspector	10/2/84	0702-1406	721	0.25	0.89	2.72
Tank Inspector	10/3/84	0706-1250	585	Trace	-	1.04
		Criteria:	NIOSH	0.05		
			OSHA		$\frac{10}{\%SiO_2+2}$	5

Trace - These values were between the Limit of Detection (LOD) and the Limit of Quantitation (LOQ)
LOD = 0.015 mg/sample
LOQ = 0.030 mg/sample

Table 6

Spray
Worker Respirable Dust Sampling Results

Artesian Industries
Mansfield, Ohio
HETA 84-066

Job	Date	Duration	Volume (liters)	Concentration, mg/m³ Respirable Silica	OSHA PEL	Respirable Dust
Sprayer, Booth 3	10/2/84	0559-1430	869	ND*	-	0.69
	10/3/84	0728-1457	770	0.13	1.12	1.87
Sprayer, Booths 5 & 6	10/2/84	0707-1410	719	0.38	1.61	8.96
	10/3/84	0708-1455	794	0.20	0.99	2.48
Automatic Sprayer Operator	10/2/84	0603-1414	835	ND	-	0.81
	10/3/84	0644-1459	842	Trace**	-	0.44
			Criteria: NIOSH	0.05		
			OSHA		$\frac{10}{\%SiO_2+2}$	5

*ND - None Detected

**Trace - These values were between the Limit of Detection (LOD) and the Limit of Quantitation (LOQ)
LOD = 0.015 mg/sample
LOQ = 0.030 mg/sample

Table 7

Mold Shop
Worker Respirable Dust Sampling Results

Artesian Industries
Mansfield, Ohio
HETA 84-066

Job	Date	Duration	Volume (liters)	Concentration, mg/m³ Respirable Dust
Mold Maker	10/3/84	0530-1334	823	1.01
Mold Maker	10/4/84	0546-1343	811	0.49
Material Handler	10/3/84	0546-1337	801	0.81
Material Handler	10/4/84	0536-1348	836	0.61
Utility	10/3/84	0534-0722	184	0.92
Chief Modeler	10/3/84	0538-1337	814	0.34
Apprentice Modeler	10/3/84	0540-1337	811	0.59

Criteria: OSHA 5

TABLE 8
CORRELATIONS BETWEEN EXPOSURE VARIABLES
ARTESIAN INDUSTRIES
MANSFIELD, OHIO
HETA 84-006
OCTOBER 1-5, 1984

	Cigarette smoking (pack-years)	Years at Artesian	Years in cast shop	Index of silica exposure*
Age (years)	0.257** <0.001	0.636 <0.001	0.272 <0.001	0.271 <0.001
Cigarette smoking (pack-years)		0.294 0.001	0.019 0.8	0.111 0.12
Years at Artesian			0.469 <0.001	0.443 <0.001
Years in cast shop				0.075 0.3

*Silica-year equivalents; see text for explanation
**Upper number is Pearson's correlation coefficient; lower number is p-value.

TABLE 9
X RAY READINGS SUGGESTIVE OF ASBESTOS/TALC OR SILICA EXPOSURE[1]
ARTESIAN INDUSTRIES
MANSFIELD, OHIO
HETA 84-066
OCTOBER 1-5, 1984

	Pair A			Pair B				Years of potential exposures at jobs other than at Artesian	
	Reader #1	Reader #2	Consensus	Reader #1	Reader #2	Consensus	Category used for data analysis	Silica/coal	Asbestos/talc
1.	-	P	-	-	IO,P	P	P	8	8
2.	P	P		P	-	-	P	1	0
3.	P	P	P[2]	P	IO,RO,P	P	P	0	0
4.	-	P	-	-	IO,P	P	P	12	<1
5.	P	P	P[2]	P	P		P	18	0
6.	-	-		P	IO	P	P	0	0
7.	-	IO,RO	-	IO,RO	IO	NR	IO,RO	2	0
8.	-	-	-[3]	RO	IO	NR	IO,RO	0	0
9.	-	-		RO,P	IO	IO,RO	IO,RO	0	0
10.	P	-	P	P	P		P	0	0
11.	P	P		-	IO,P	-	P	0	0
12.	-	-		-	IO,RO	CP	P	0	0
13.	IO	-	-	-	RO	IO,RO	IO,RO	0	0
14.	-	IO,P	IO,P	-	IO,P	IO	IO	0	0
15.	-	-		-	RO	P	P	0	0
16.	-	-		P	-	P	P	7	0
17.	-	-		P	RO	P	P	0	0
18.	-	-		RO	IO	NR	IO,RO	0	0

1. - = no findings of asbestos/talc or silica exposure, P = pleural plaque, IO = irregular parenchymal opacities, RO = rounded opacities, CP = bilateral costophrenic angle pleural thickening, NR = no consensus reading obtained despite differences in the initial readings. A blank in the consensus column indicates that no reading was necessary.

2. Consensus reading obtained because readers #1 and #2 reported different pleural findings.

3. Conser[illegible] reading obtained because of incidental finding b[illegible] reader.