IN-DEPTH SURVEY REPORT

CONTROL TECHNOLOGY FOR THE CERAMICS INDUSTRY

AT

DIDIER TAYLOR REFRACTORIES CORPORATION
NEWTOWN, OHIO

REPORT WRITTEN BY

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National Institute for Occupational Safety and Health
Division of Physical Sciences and Engineering
Engineering Control Technology Branch
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PLANT SURVEYED:	Didier Taylor Refractories Corporation, Newtown, Ohio
SIC CODE:	3255
SURVEY DATE:	July 13 - 15, 1982
SURVEY CONDUCTED BY:	Robert Mahon, Frank Godbey, Thomas Cooper, Paul Caplan, Stan Shulman
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DISCLAIMER

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ABSTRACT

An in-depth control technology survey was conducted at the Didier Taylor Refractories Corporation bulk refractories manufacturing plant in Newtown, Ohio July 13-15, 1982. Although clays, alumina, zircon, chrome oxide, mullite, kyanite, liquid silicates and phosphate binders, constitute 90% of the raw materials used, sampling results indicate no employees are exposed, under normal operating procedures, to concentrations of free silica, respirable or total dust, hexavalent or elemental chromium in excess of OSHA's permissible exposure limit (PEL). The engineering, work practice, and personal protective equipment health hazard controls were assessed and documented.

ACKNOWLEDGEMENTS

We gratefully acknowledge the cooperation and assistance of the Didier Taylor Refractories Corporation and their employees who participated in this study. Their cooperation and coordination efforts helped make this control technology assessment successful. In particular, we wish to thank Gayle R. Howard, Plant Manager, Harry Wheeler, Plant Superintendent, and Robert Crawford, President, Brick and Clay Workers of America, Local 911. We are also indebted to Richard Carlson for the illustrations and Myra D. Brooks for the typing.

CONTENTS

CONTENTS (cont'd)

CONTENTS (cont'd)

TABLES

FIGURES

Figure		Page

I. INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) is charged with the responsibilty of conducting research and developing criteria for the advancement of health and safety in the workplace. In order to expand the knowledge of available options for the solution of occupational health problems and the constraints that influence the selection of these options, NIOSH has sponsored a series of health hazard control technology evaluations. The goals of these evaluations or assessments are to stimulate private industry to control hazardous exposure of workers, and to establish a catalog of solutions by documenting successful application of control measures. These studies seek to identify the best control techniques practiced by different companies, encourage the dissemination of this knowledge across industries, and outline control technology research needs; this is all done to aid in the voluntary application of demonstrated control technologies.

This report presents the findings of a state-of-the-art study of available technology associated with the batching (involving much bag breaking of dry raw materials), mixing (both wet and dry), and packaging (involving bagging, containerization, and wrapping of individual products) activities associated with the production of a variety of refractory industry products. This plant was chosen as it has the potential for relatively high worker exposure.

The following materials make up approximately 90% of the raw materials used: clays, alumina, zircon, chrome oxide, mullite, kyanite, liquid silicates and phosphate binders. (See Appendix B).

A. BACKGROUND

The refractory industry is a billion-dollar plus, subpart of the multi-billion dollar, ceramics industry universe. Refractories are heat-resistant materials that provide the structure or linings for high-temperature furnaces, reactors, and other objects. A few specific applications would be to line the water walls of boilers and furnaces of all types, reactors, ladles, stills, kilns, and space vehicle surfaces.

In addition to being resistant to thermal stress and other physical phenomena induced by temperature extremes, refractories are usually required to withstand physical wear and corrosion from chemical agents.

According to OSHA data, the principal identified health hazards appear to be silica, noise, and heat. In a review of unpublished[1] OSHA data on silica samples, collected from 7-74 through 6-79 in the ceramic industry, 83%, (225 of 270) were reported to be in excess of the OSHA standard of 100 ug/m^3. In addition, Health Hazard Evaluations[2,3,4] (HHE's conducted by NIOSH) in this industry reported some excessive employee exposures. The National Safety Council reports the overall illness and injury incidence rates for the ceramics industry to be well in excess of the "all-industry" average.

In this study, the effectiveness of the control technology associated with exposure to total dust, respirable dust, crystalline silica (SiO_2), as well as elemental and hexavalent chromium, was evaluated and documented.

B. PURPOSE OF STUDY

The overall purpose of this study was to evaluate, document, and discuss the effectiveness of the health hazard control procedures being used by this plant during the handling, formulating, mixing, and packaging of a variety of refractory products. The specific objectives were:

1. To evaluate and document the effectiveness of the individual health hazard control technology methods in use.

2. To evaluate and document the operating parameters of the exhaust ventilation system(s) in use.

3. To make general observations, draw conclusions, and discuss the results of the above evaluations and their documentation.

C. CONTROL TECHNOLOGY ELEMENTS

Health hazard control technology consists of four elements. Two of these are equipment, process, and facilities oriented: engineering controls and environmental monitoring; and two are worker oriented: good work practices and the use of personal protective equipment.

II. STUDY PROTOCOL

A. EVALUATION CRITERIA

The OSHA standard, or Permissible Exposure Limit (PEL), for respirable crystalline silica (quartz), which is applicable in the refractories industry, is contained in 29CFR (Code of Federal Regulations) Part 1910.1000. (The NIOSH recommended standard for all forms of respirable, crystalline silica, including quartz is 0.05 mg/m^3 or 50 ug/m^3.) Although the PEL pertains specifically to an 8-hour time weighted average (TWA) exposure to employees, in this study, it was also used as an environmental criterion to evaluate the effectiveness of the control technology studied. For respirable dust, containing silica, the PEL is determined by the equation:

$$PEL = \frac{10}{\%\ silica + 2} \text{ milligrams per cubic meter of air } (mg/m^3)$$

For 100% silica dust (respirable), this calculated PEL is approximately equivalent to 0.1 mg/m^3 or 100 ug/m^3.

For total dust the PEL is determined by the equation:

$$PEL = \frac{30}{\%\ silica + 2}$$

The OSHA Standard (PEL) for metallic chromium and insoluble salts (1 mg/m^3) which is applicable to the refractories industry, is also called out in 1910.1000. (The NIOSH recommended standard for non-carcinogenic chromium compounds is 0.025 mg/m^3). Although the PEL pertains specifically to an 8-hour TWA exposure to employees, in this study, it was also used as an environmental criterion to evaluate the effectiveness of the relevant control technology in use.

B. INDUSTRY DESCRIPTION

1. Process Description

The following descriptions are limited to the production and dust control systems observed in this study. There are other processes and procedures common to the refractories industry which were not present so were not evaluated.

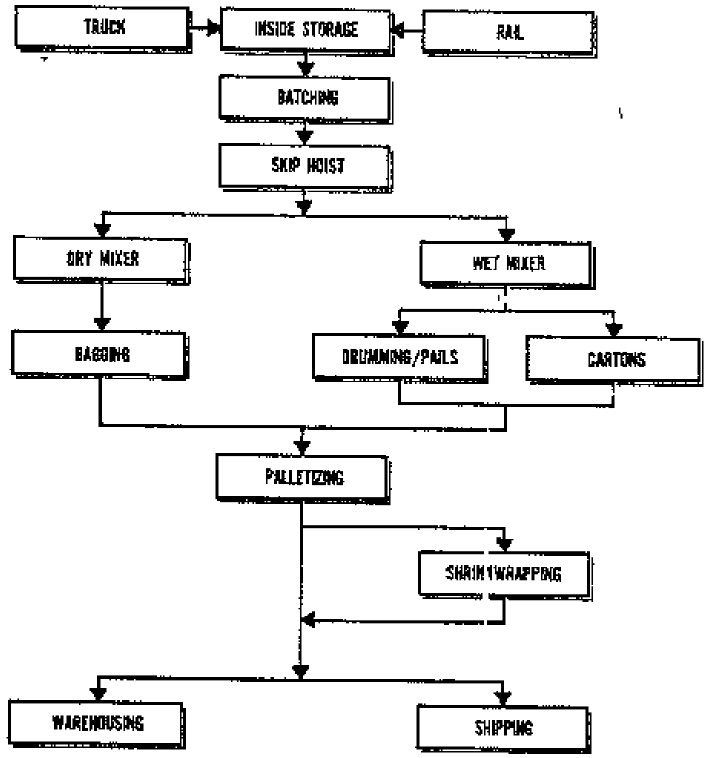


Figure 1. Process Flow Diagram

a. Raw Materials Receipt and Storage--

Raw materials are received by truck and rail. Those in a solid state are generally in sacks or cardboard containers. Those in a liquid state are pumped into large storage tanks. All raw materials are placed into inside storage. Forklift trucks are used to transfer raw materials to batching stations.

b. Batching--

Batching occurs where raw materials are selectively placed into a skip hoist bucket. Sacks are manually cut open and shaken either directly into the skip hoist bucket or indirectly through a vibrating screen. There are exhaust ventilation cross draft hoods at both ends of the skip hoist bucket. When the batch is complete the skip hoist bucket is elevated and it dumps into a mixer. The empty sacks are hand carried by the operator to the incinerator, which is located outside of the building. (See Figure 2).

c. Mixing--

The mixing operations may be either wet or dry and are programmed to achieve a uniform mixture of the raw materials formulated during the batching process. The nature of the mixing operation is dependent upon the characteristics of the final product being produced. Its consistency varies from a dry powdery mix, which is bagged, to a plastic mix, which is extruded and packaged, or to a slurry which is poured into pails and other types of containers. Exhaust ventilation is used to control airborne contaminants generated during the mixing operation.

d. Packaging--

Packaging operations involve the filling of bags, drums, pails, and cartons.

1) Single spout bagging machines, with an integral exhaust ventilation system, are used to fill pasted valve bags with the dry granular finished products.

2) Finished products that are highly plastic, such as; cements, ramming mixes, and patching mixes, are fed by gravity into drums and/or pails. One station used to package this product line is also equipped with an integral exhaust ventilation system.

3) Cartons and/or individual wraps may be used to package brick and other pressure formed (extruded) finished products.

e. Storage and Shipping--

The transport to storage and/or shipping operations associated with handling the packaged finished products may or may not involve shrinkwrapping. Shrinkwrapping reduces leakage, waste, environmental contamination, and increases storage stacking stability and weatherability. All warehousing is inside and transport is with forklift trucks. Rail and trucks are the most frequently used forms of shipping transport.

2. Dust Control

Extensive exhaust ventilation is required to control airborne contamination inherent to the batching, mixing, and some of the packaging operations. This ventilation system discharges into a baghouse type dust collector and air cleaner. The cleaned air may be exhausted to the outside atmosphere or returned in whole or in part to the plant. Worker comfort ventilation is provided by natural air circulation through a variety of wall openings. There are five axial flow fans in the west end of the building, near the roof line, that exhaust air from the plant and also provide dilution ventilation. Only one pedestal fan for localized person comfort ventilation was noted.

Another very effective dust control method involves an excellent housekeeping program. For example, the end-of-shift washdown of all work stations greatly reduces the potential for reentrainment of the dust generated during the daily production schedule. An ample supply of sweeping compound is also readily available for use as needed.

C. SCOPE OF STUDY

The potential for hazardous exposures to mineral dusts, nuisance particulates, and chemical agents may exist in many of the refractories industry processing operations. The major emphasis in this study, however, was limited to exposure control during the batching, mixing, and packaging operations. The four elements of health hazard control technology - engineering, environmental monitoring, work practices/administrative, and the use of personal protective equipment, were each evaluated and documented either quantitatively or qualitatively. In this study, the major emphasis was directed toward the evaluation and documentation of the effectiveness (capability of the control system to achieve a given environmental standard) of the in-place and operating engineering controls.

1. Study Plan

Preliminary (walk-thru type) surveys were made of several refractory industry plants. In this plant it appeared to the surveyors that good health hazard control technology was in place and operating. So it was chosen for an in-depth evaluation. The effectiveness of the aforementioned operations health hazard controls were quantitatively evaluated over a three-day period.

2. Investigation Procedures

Air samples were collected and air flows were measured in order to determine the effectiveness of controls based on the environmental levels present during the aforementioned operations.

a. Environmental Dust Measurements--

Samples of workplace airborne dust concentrations were collected to evaluate the effectiveness of dust control procedures. These samples were taken at potential sources of dust contamination inside the plant; at various general work areas; as well as in the breathing zone of several of the workers. Additional atmospheric samples were collected outside of the plant in the vicinity of the incinerator and dust collector. Bulk samples, in the form of rafter and raw material, (as opposed to bulk air samples) were collected to estimate the chemical composition of airborne dust. Basically the following four types of dust samples were collected and analyzed:

1) Integrated personal air samples (several hours in duration) were collected with DuPont Gravimetric Dust Samplers with attached cyclones (respirable dust) and without cyclones (total dust).

2) Short-term, direct reading atmospheric measurements of "respirable dust" (several minutes in duration) were made with the TSI Respirable Aerosol Mass Monitor, Model 3500, to help identify potential dust emission sources.

3) General area air samples were collected with MSA Gravimetric Dust Samplers.

4) Bulk rafter and product samples were collected and analyzed for silica and chromium content.

All samples were analyzed by the Utah Biological Testing Laboratory (UBTL). Descriptions of sampling and analytical procedures and methods are presented in Appendix A.[5]

b. Ventilation Control Measurements--

Ventilation and air flow pattern measurements were made and evaluated to determine the effectiveness of the local and general/dilution ventilation systems. Velocity measurements were made with either a pitot tube and manometer or with a Kurz Air Velocity meter (Model 441). Air flow patterns were identified by using Gastec Smoke tester tubes.

III. PHYSICAL PLANT AND PRODUCTS

In this section the building, equipment, and refractory product characteristics (Figure 2) that are relevant to this in-depth survey are discussed.

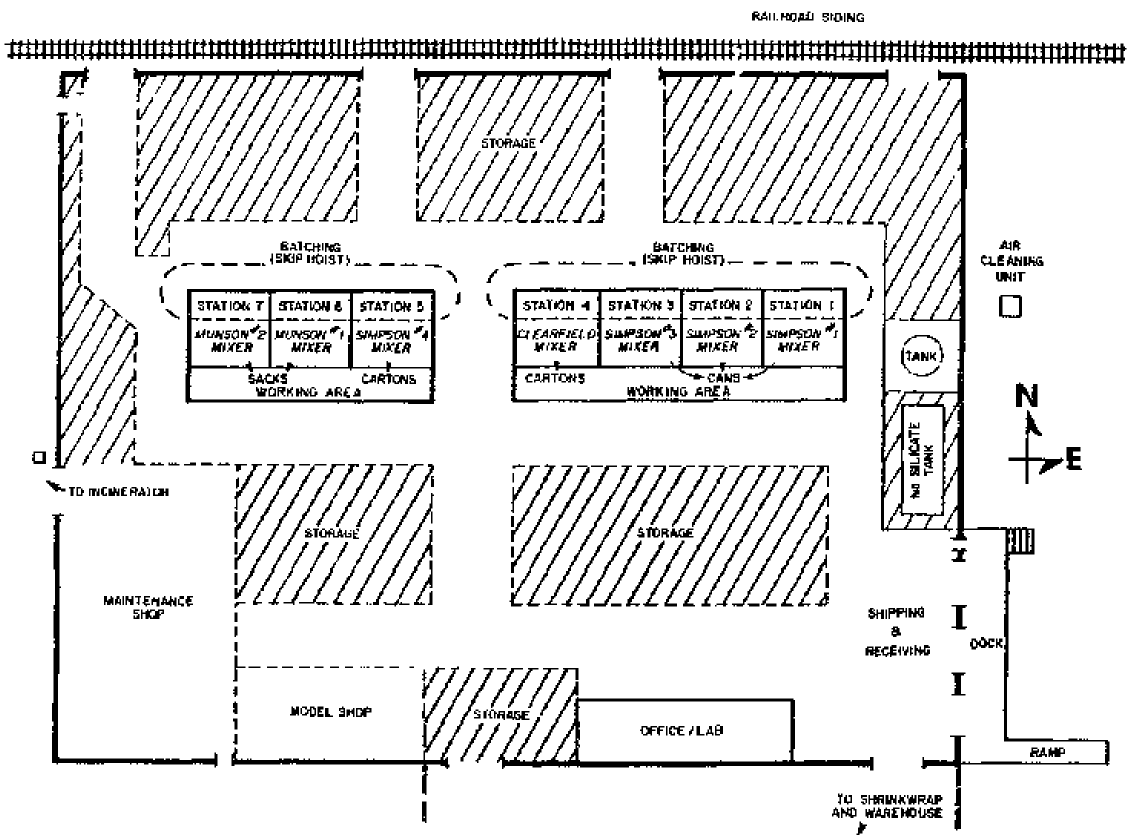


Figure 2. Plant layout

A. BUILDING

This medium-sized refractories bulk plant is housed in a dedicated single story 242.7 ft. by 180 ft. (43,686 sq. ft.) building (Figure 3). The all metal structure, built in 1969, has a concrete floor, metal walls, metal trussed roof (36 ft. average height) and approximately 1,572,696 cu.ft. volume.

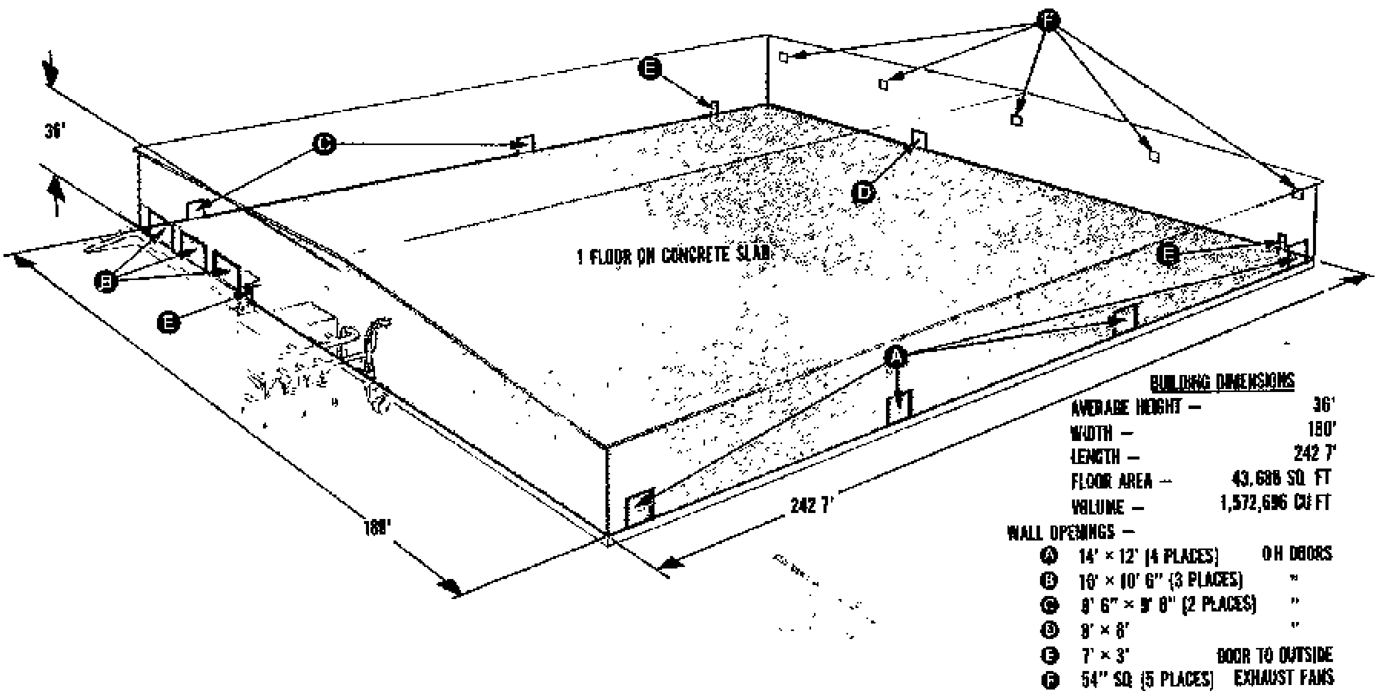


Figure 3. Plant specifications

The plant is located in a partially developed industrial area with corn fields on two sides. At the time of this survey the owners were in the process of constructing a new building of similar construction adjacent to part of the South side of the building. The new building will be dedicated to refractories warehousing and Research and Development.

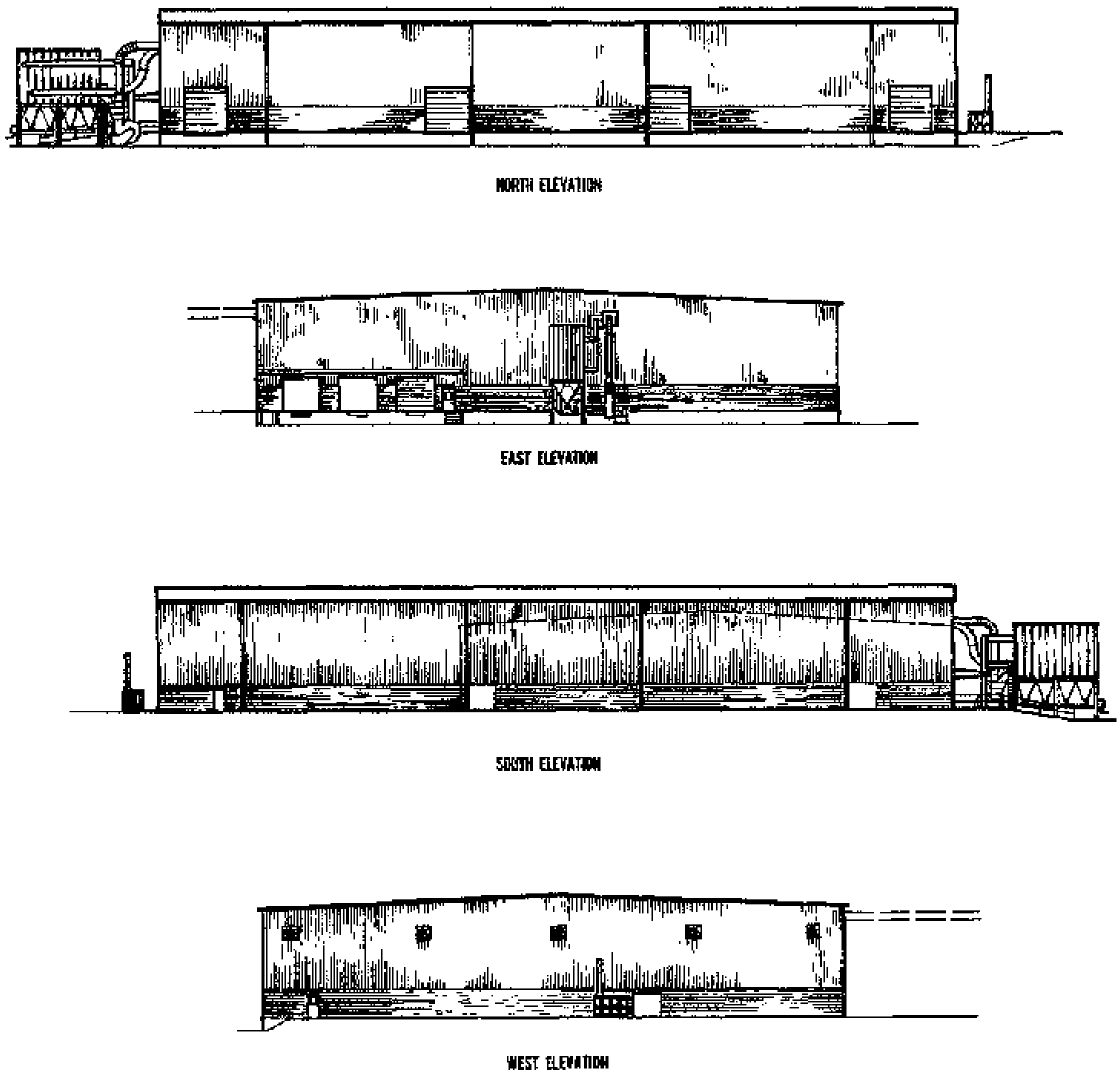


Figure 4. Plant elevations

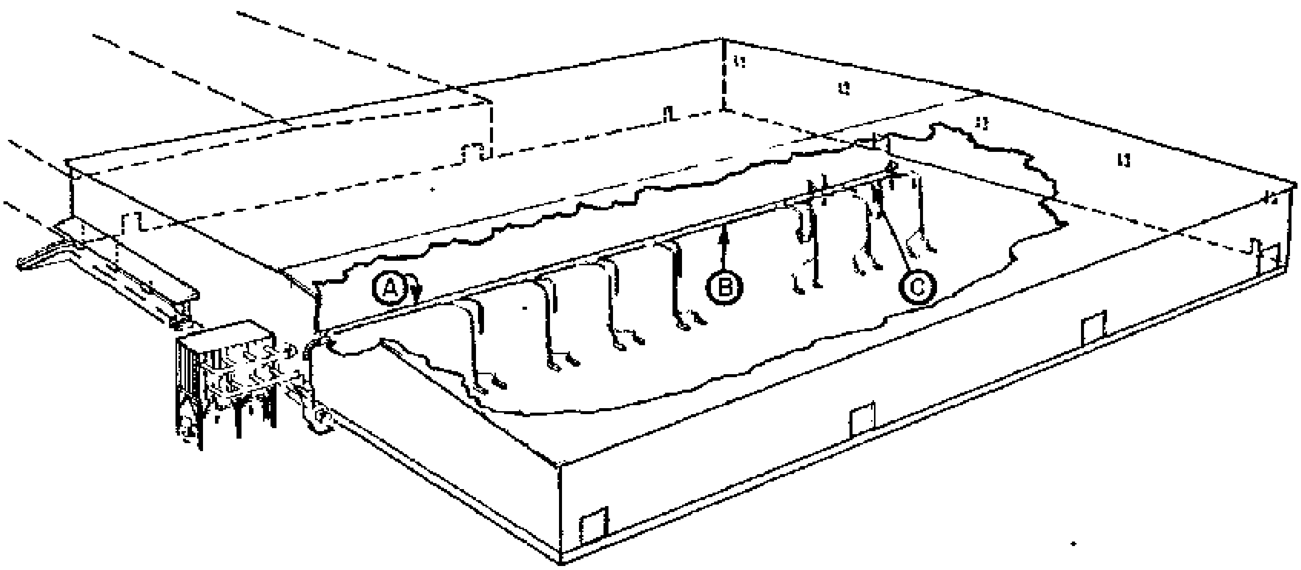
The average annual precipitation in the area is 40" (including 24" snowfall) and the temperatures range from 20 - 90°F.[6] The prevailing winds are from the NW.

B. EQUIPMENT

The major pieces of equipment evaluated in this survey are associated with the dust collector system, batching stations, wet and dry mixers, bagging stations, drum and pail filling stations, carton filling stations, and general ventilation fans. Following is a brief description and discussion of each.

1. Dust Collector System

The dust collector system ductwork (Figure 5) consists of numerous sizes of branch ducts from each work station which exhaust into a central duct trunk. The branch ducts are equipped with blast gates. The central duct trunk is progressively sized from 16" OD to 33" OD. All trunk duct work is made of galvanized sheet metal and is circular shaped. The branch duct-work is also made of galvanized sheet metal but the shapes vary to fit the need. The gauges of sheet metal used are also varied.



NOTE:

POSITION A	- DUCTWORK	DIAMETER	33"	AVERAGE	AIR	FLOW	3782 FPM
B	- "	"	23"	"	"	"	3075 "
C	- "	"	16"	"	"	"	2792 "

Figure 5. Exhaust system ductwork

The 33" central duct trunk passes through the building's East wall and discharges into a fabric bag filter dust collector. Figures 6, 7. The specifications for the collector are as follows:

a. No. 23/168 Wheelabrator Corporation unit

b. 10,640 sq. ft. cotton sateen cloth surface

c. C.F.M./cloth ratio:2.25/1 for 24,000 C.F.M.

d. 572 bags 5 1/4" dia., 168" long.

The collector is equipped with four (9 in.) rotary valves and knockers (Figure 8). A 9" screw conveyor driven by a 3 H.P. Motor discharges the collected dust into a collection container.

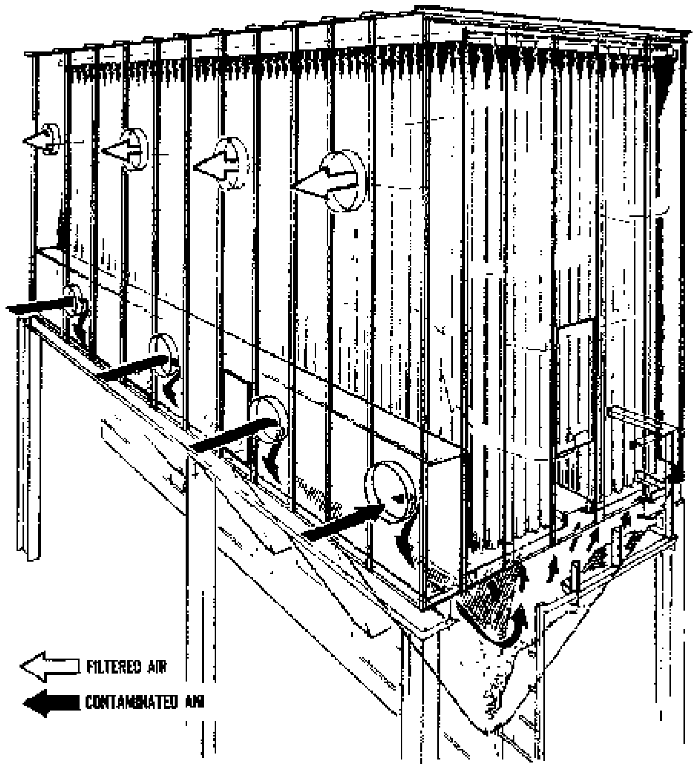


Figure 6. Dust collector air flow

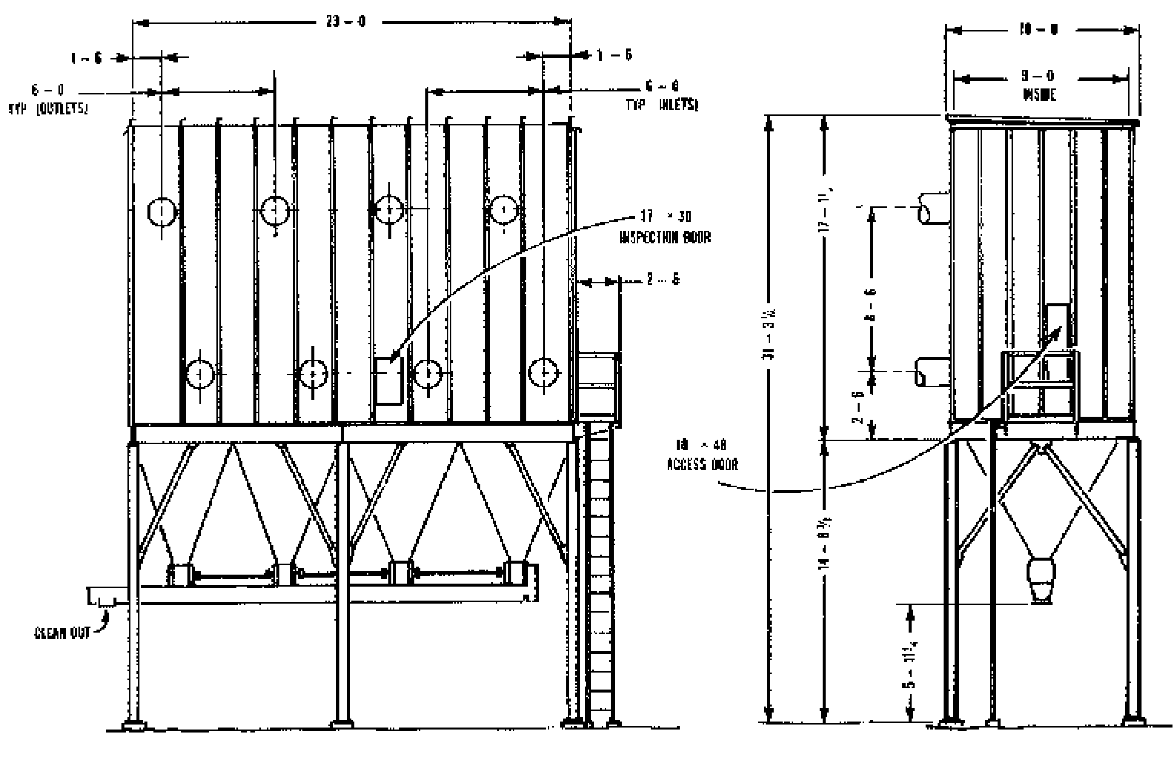


Figure 7. Dust collector details

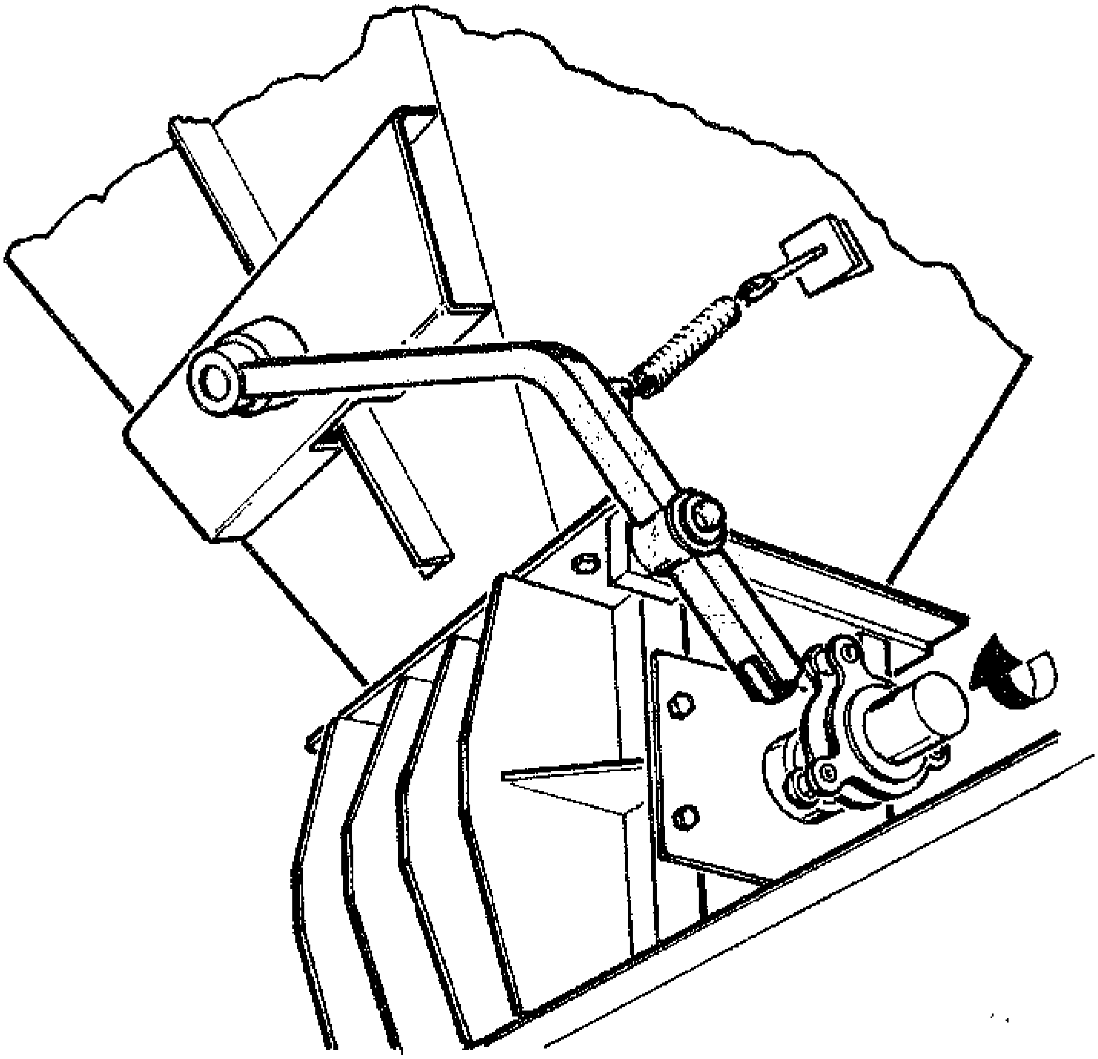


Figure 8. Dust collector knocker

The blower (Figure 9) is a No. 133, Clarage X L/KBC, with extended shaft for v-belt mounting. Service specifications are as follows:

a. 24000 CFM/12 in. H_2O at 820 R.P.M./73 S.H.P.

The blower motor is 75 HP/1800 R.P.M./480 V 3-phase, 60 cycle, ball bearing, open type with base.

The blower discharge ductwork is equipped with a gate, so the cleaned air can be either discharged to the outside or returned, in whole or in part, to the building.

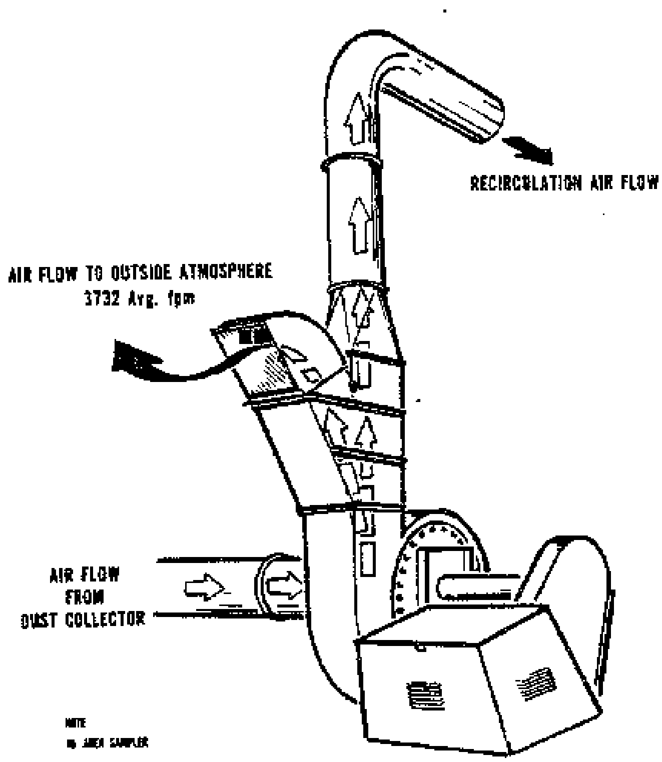


Figure 9. Dust collector blower air flow

2. Batching Stations

All batching (Figure 10) is done in the bucket of a skip hoist. The operator slits open the side of bags of raw materials and either dumps them directly into the bucket or through a vibrating screen into the bucket. In some mixtures, he weighs out predetermined amounts of the raw materials, in less than whole bag lots, and dumps them into the bucket.

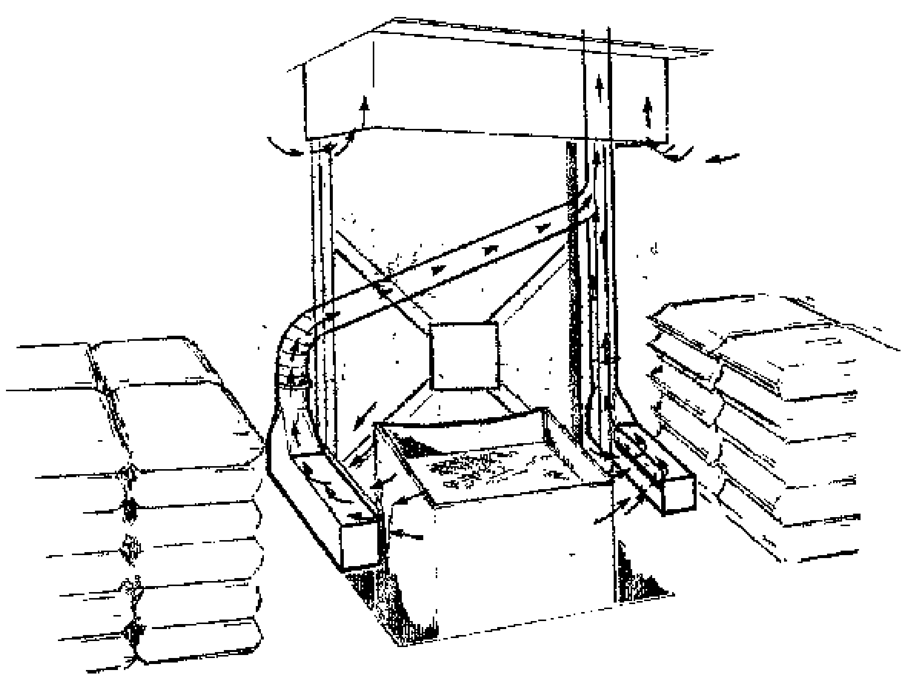
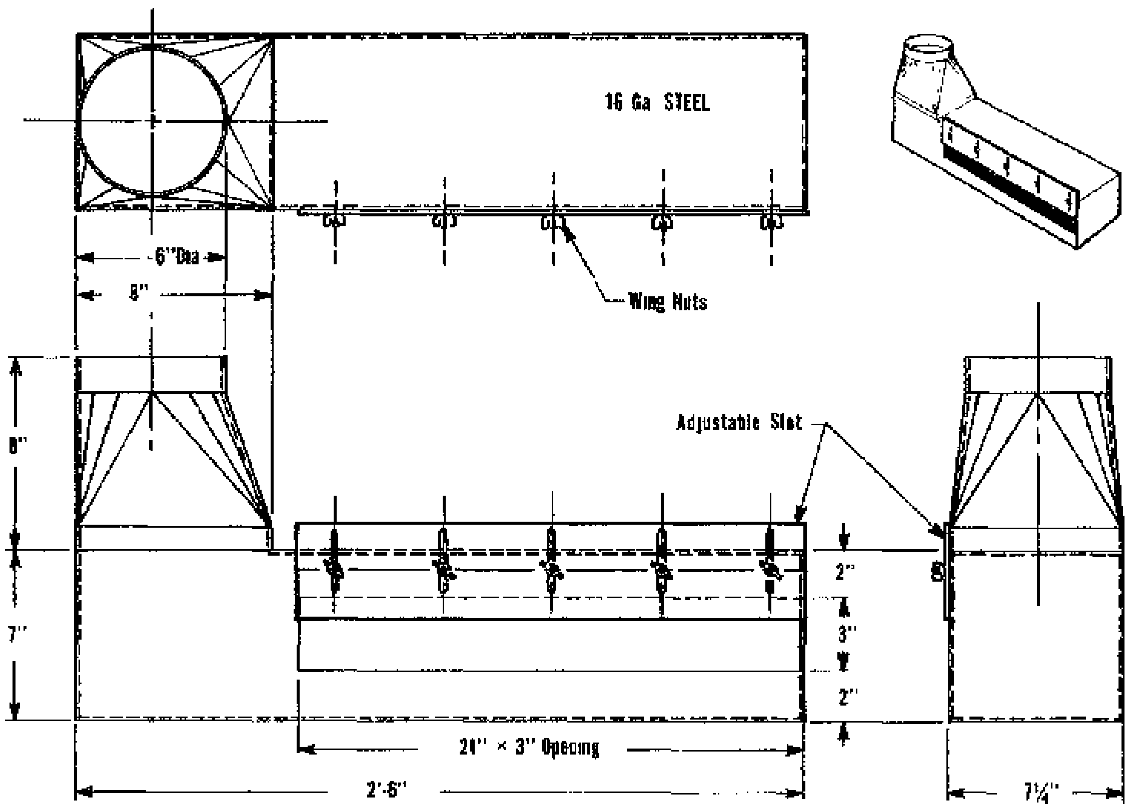


Figure 10. Typical batching station air flow

There is an exhaust hood at each end of the bucket to capture the airborne dust. (Figure 11). Each hood has an adjustable slot door. There are also blast gates in the duct work leading from the hoods to the central dust collector system trunk duct. The smoke tube traverse indicated that there was an updraft in each of the skip hoist bucket runways.



NOTE:
OPENINGS OF EACH PAIR OF HOODS ARE FABRICATED ON OPPOSITE SIDES SO THEY CAN FACE EACH OTHER WITH BATCHING STATION CENTERED BETWEEN THEM.

Figure 11. Typical batching station dual ventilation hoods

3. Wet and Dry Mixers

The skip hoist bucket automatically dumps the batched raw materials into a variety of locally exhausted enclosed mixers. The mixers (Figures 12, 13) may involve dry pans, and/or pug mills. If the raw materials are pugged, water may be either manually and/or automatically added. In some cases, the operator opens the mill enclosure door and adds water. The exhaust ventilation may discharge directly into the central exhaust trunk or into a plenum above the skip hoist tipple.

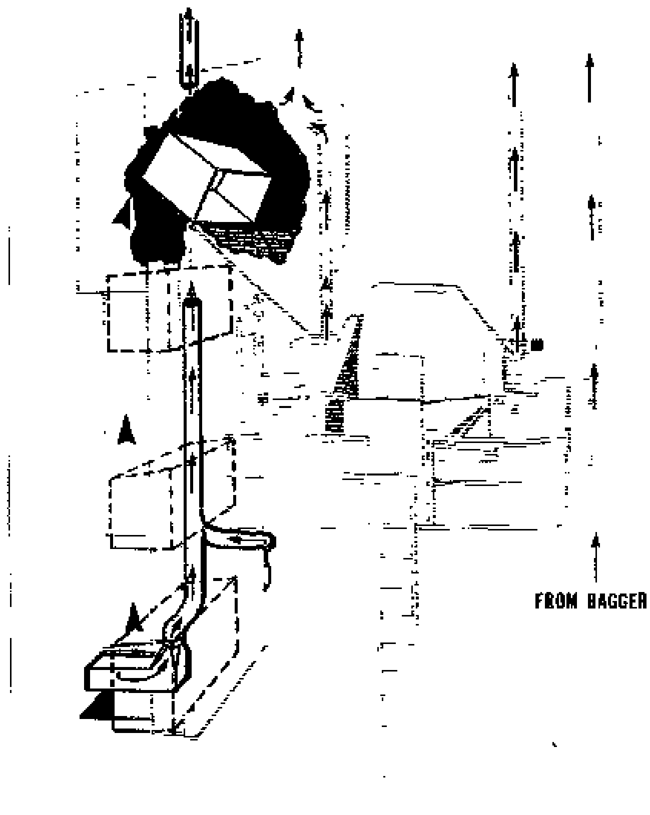


Figure 12. Typical dry mixer exhaust ventilation air flow

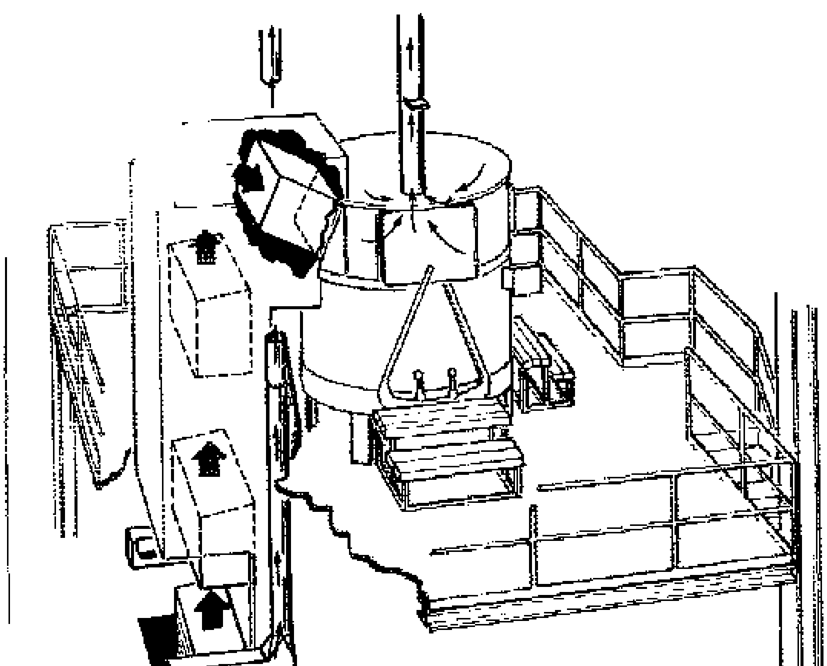


Figure 13. Typical wet mixer exhaust ventilation air flow

4. Bagging Stations

The bag packer machines are of single spout, force flow design and will accommodate a variety of valved bags (Figure 14). There is a dust collection hood around the spout. The hood exhausts into a duct leading to the central dust collection system.

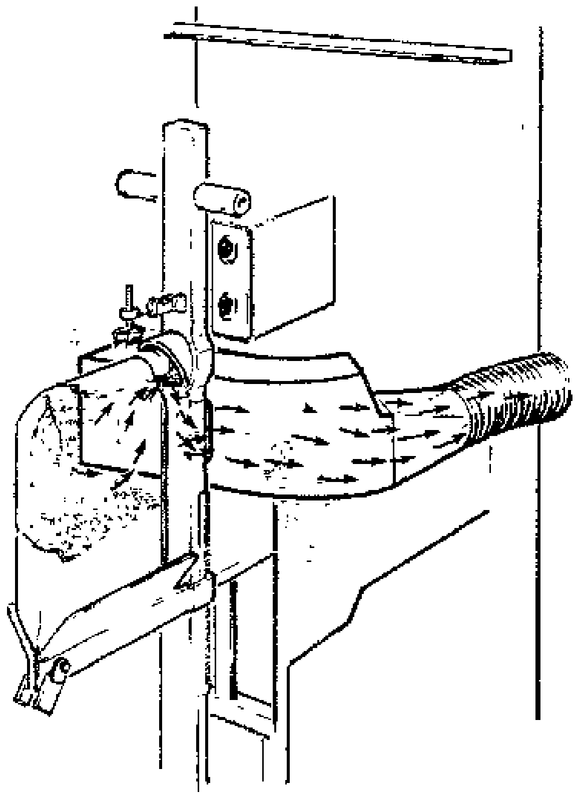


Figure 14. Typical bagging station exhaust ventilation air flow

5. Drum and Pail Filling Stations

Manual and semi-automatic equipment systems are used to fill different sized drums and pails with a wide range of viscous refractory products (Figure 15). Because the product is a wet slurry and dust free, local exhaust ventilation was only provided at one station.

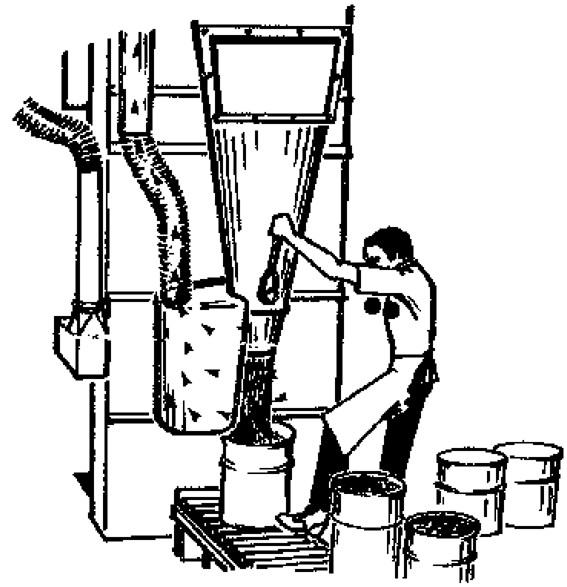


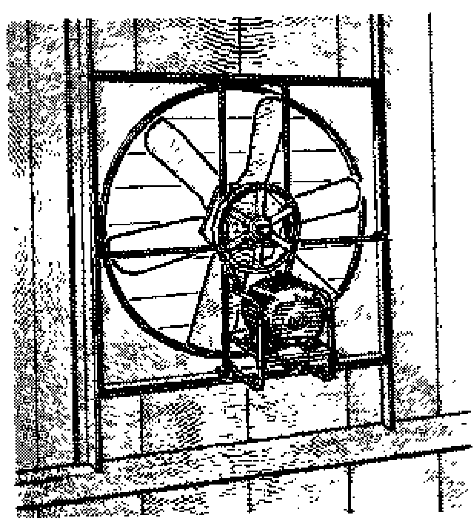
Figure 15. Typical pail filling station exhaust ventilation air flow

6. Carton Filling Station

The carton filling station equipment involves pressing and extrusion, followed by wrapping, as each refractory product produced at this station is packed separately. Because the product is plastic and dust free, no local exhaust ventilation is required.

7. General Ventilation Fans

There are five (5), 3 HP, 535 R.P.M., 48" diameter blade, belt-driven, axial flow exhaust fans installed in the West end of the building near the roof line (Figure 16). Each is designed to move 25,400 CFM at 1/8" S.P. Each fan is manually controlled and exhausts directly to the outside atmosphere. They are primarily used to remove the superheated air that accumulates beneath the roof line especially on warm days.



NOTE
FAN SPECIFICATIONS 3HP, 535 RPM,
48" DIA BLADE, 25400 CFM. ½ IN.SP.

Figure 16. Typical general ventilation exhaust fan

C. PRODUCTS

Refractory products in the following categories are produced at this plant:[7] Bricks, patches, ramming mixes, cements, castables, plastics, and miscellaneous. The raw materials used in these products may contain varying percentages of such compounds as: Al_2O_3, SiO_2, Fe_2O_3, TiO_2, CaO, MgO, P_2O_5, Na_2O, K_2O, ZrO_2, B_2O_3, Cr_2O_3, and sulphates. The generic names for the most common raw materials are: clay, zircon, alumina, chrome oxide, mullite, kyanite, liquid silicates and phosphate binders. Appendix B[8].

IV. RESULTS AND DISCUSSION

In this section the atmospheric concentrations of total and respirable dusts in the general work areas, as well as in the breathing zones of the workers, are reported. The composition of the airborne dusts, as well as that accumulated on rafters and elevated duct work, is also reported. The effectiveness of the engineering, work practices, and personal protective equipment controls is discussed.

A. WORKPLACE ENVIRONMENTAL CONDITIONS

Table 1 presents the area air concentrations of total dust at the sites identified in Figure 17.

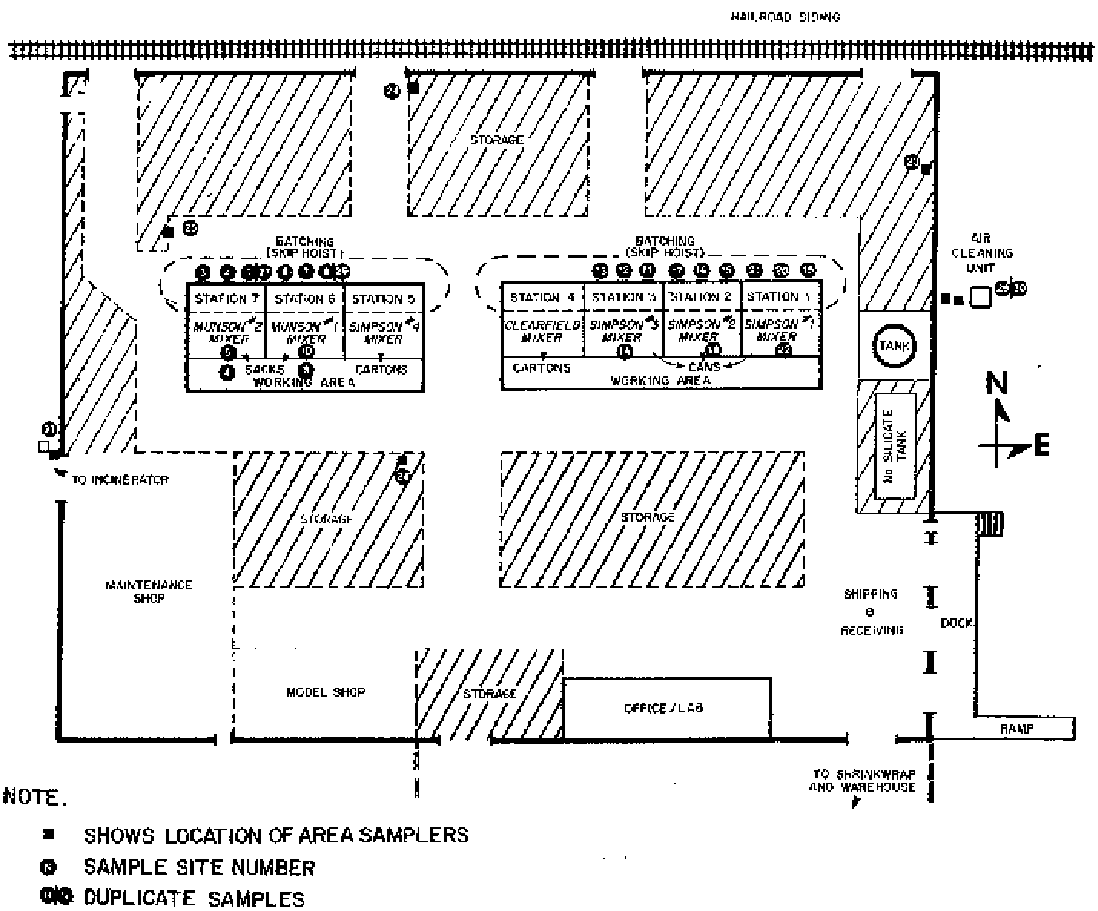


Figure 17. Plant layout showing area sampling sites

Area samples are shown in Table 1 for total dust collected at various locations around Work Stations 1-7, in the general production area, and outside the building at the air cleaner discharge grill and near the incinerator. Concentrations of samples collected for all three days were within the calculated OSHA PEL of 3.45 mg/m^3 with the exception of Sample Site Nos. 1, 3, 6, 8, 15, 26, and 27 (see Table 1 footnote).

The area samples taken at Site No.1, Work Station No. 7, ranged in concentration from 4.43 mg/m^3 to 7.50 mg/m^3 with a three-day mean concentration of 5.62 mg/m^3 or 163% of the PEL. The area samples taken at Site No. 27, Work Station No. 7, ranged in concentration from 3.05 mg/m^3 to 9.73 mg/m^3 with a three-day mean concentration of 5.72 mg/m^3 or 166% of the PEL. Although the area sample taken on Day 1 at Site No. 3, Work Station No. 7, was 5.61 mg/m^3 or 163% of the PEL, the three-day mean was 3.06 mg/m^3 or 89% of the PEL. The area samples taken at all sites at Work Station No. 7 ranged in concentration from 0.02 mg/m^3 to 9.73 mg/m^3 with a three-day mean concentration of 2.80 mg/m^3 or 81% of the PEL.

The area samples taken at Site No. 6, Work Station No. 6, ranged in concentration from 13.56 mg/m^3 to 14.74 mg/m^3 with a three-day mean concentration of 14.06 mg/m^3 or 408% of the PEL. The area samples taken at Site No. 26, Work Station No. 6, ranged in concentration from 15.63 mg/m^3 to 26.68 mg/m^3 with a three-day mean concentration of 21.63 mg/m^3 or 627% of the PEL. Although the area sample taken on Day 2 at Site No. 8, Work Station No. 6, was 4.41 mg/m^3 or 128% of the PEL, the three-day mean was 3.22 mg/m^3 or 93% of the PEL. The area samples taken at all sites at Work Station No. 6 ranged in concentration from 0.22 mg/m^3 to 26.68 mg/m^3 with a three-day mean concentration of 7.06 mg/m^3 or 205% of the PEL.

The area samples taken at Site No. 15, Work Station No. 2, ranged in concentration from 2.89 mg/m^3 to 17.07 mg/m^3 with a three-day mean concentration of 8.54 mg/m^3 or 248% of the PEL. The area samples taken at all sites at Work Station No. 2 ranged in concentration from 0.24 mg/m^3 to 17.07 mg/m^3 with a three-day mean concentrating of 2.52 mg/m^3 or 73% of the PEL.

Area samples were not analyzed for chromium because of negative results on the bulk sample analysis.

Table 1. Area Samples - Air Concentration - Total Dust

Sample Site No.	Location/Description (See Figure 17)	Concentration mg/m3/day Day 1	Day 2	Day 3	Mean mg/m3	Per Cen* of PEL
1	Work Station No. 7 - Batching - Left side	7.50	4.43	4.92	5.62	163
27	Work Station No. 7 - Batching - Left side - Duplicate	9.73	3.05	4.39	5.72	166
2	Work Station No. 7 - Batching - Eye level	0.38	0.02	0.30	0.23	7
3	Work Station No. 7 - Batching - Right side	5.61	2.67	0.90	3.06	89
4	Work Station No. 7 - Bagger - Eye level	0.79	1.14	-	0.97	28
5	Work Station No. 7 - Munson Mixer level	0.88	0.68	0.26	0.61	18
	Work Station No. 7 - Mean	4.15	2.00	2.15	2.80	81
6	Work Station No. 6 - Batching - left side	13.56	14.74	13.87	14.06	408
26	Work Station No. 6 - Batching - Left side - Duplicate	22.59	26.68	15.63	21.63	627
7	Work Station No. 6 - Batching - Eye level	0.22	1.00	0.67	0.63	18
8	Work Station No. 6 - Batching - Right side	3.09	4.41	2.15	3.22	93
9	Work Station No. 6 - Bagger - Eye level	1.13	2.80	1.19	1.71	50
10	Work Station No. 6 - Munson Mixer level	0.42	2.23	0.70	1.12	32
	Work Station No. 6 - Mean	6.83	8.64	5.70	7.06	205
11	Work Station No. 3 - Batching - Left side	0.75	1.80	2.60	1.72	50
12	Work Station No. 3 - Batching - Eye level	0.38	0.20	0.38	0.32	9
13	Work Station No. 3 - Batching - Right side	0.25	0.42	0.80	0.49	14
14	Work Station No. 3 - Mixer level	0.14	0.25	0.28	0.22	6
	Work Station No. 3 - Mean	0.38	0.67	1.02	0.69	20
15	Work Station No. 2 - Batching - Left side	17.07	5.66	2.89	8.54	248
16	Work Station No. 2 - Batching - Eye level	0.31	0.26	0.63	0.40	12
17	Work Station No. 2 - Batching - Right side	0.50	0.80	1.15	0.82	24
18	Work Station No. 2 - Mixer level	0.24	0.27	0.42	0.31	9

Table 1. Area Samples - Air Concentration - Total Dust (Cont'd)

Sample Site No.	Location/Description (See Figure 17)	Concentration mg/m³/day Day 1	Day 2	Day 3	Mean mg/m³	Per Cent of PEL*
	Work Station No. 2 - Mean	4.53	1.75	1.27	2.52	73
19	Work Station No. 1 - Batching - Left side	1.88	0.57	1.62	1.36	39
20	Work Station No. 1 - Batching - Eye level	0.49	0.41	0.37	0.42	12
21	Work Station No. 1 - Batching - Right side	0.58	0.31	0.35	0.41	12
22	Work Station No. 1 - Mixer Level	0.23	0.27	0.42	0.31	9
	Work Station No. 1 - Mean	0.80	0.39	0.69	0.63	18
23	NE Storage Area - Approx. 5 ft above floor	0.27	0.40	0.43	0.37	11
24	North Center Storage Area - Approx. 5 ft above floor	0.14	0.46	0.39	0.33	10
25	NW Storage Area - Approx. 5 ft above floor	0.24	0.19	0.13	0.19	6
28	South Center Storage Area - Approx. 5 ft above floor	0.45	0.35	0.27	0.36	10
	Inplant General Background - Mean	0.28	0.35	0.31	0.31	9
29	Air Cleaner Discharge - At grill	0.04	0.11	0.00	0.05	1
30	Air Cleaner Discharge - At grill (Resirable)	0.02	0.11	0.00	0.01	--
31	Incinerator - Approx. 5 ft above ground	0.31	0.45	0.23	0.33	10
	Outside General Background - Mean	0.12	0.22	0.08	0.14	4

*PEL = 3.45 mg/m³ (calculated from bulk sample analysis average results of 6.7% crystalline silica - Table 3)

Table 2 presents the concentration of airborne dust in the breathing zone of the workers identified in Figures 18, 19, 20, 21, 22, 23, 24, 25, and 26.

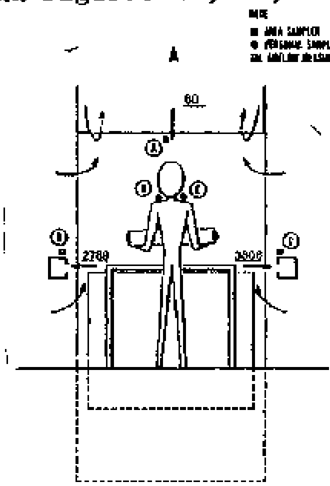


Figure 18. No. 1 batching station and worker

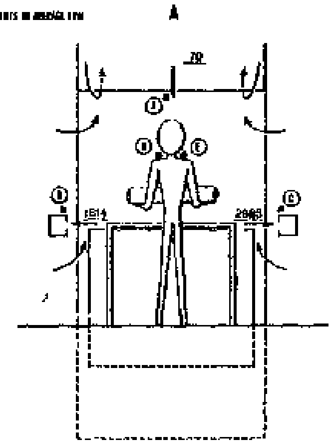


Figure 19. No. 2 batching station and worker

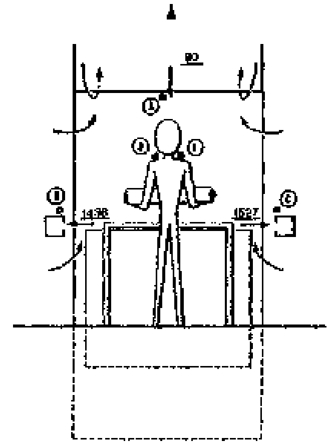


Figure 20. No. 3 batching station and worker

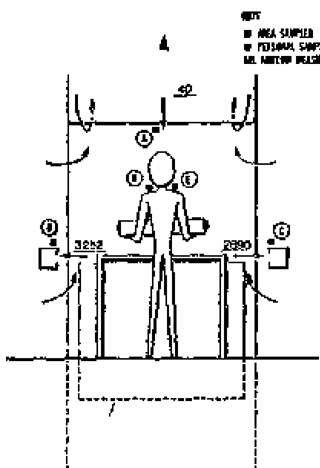


Figure 21. No. 4 batching station and worker

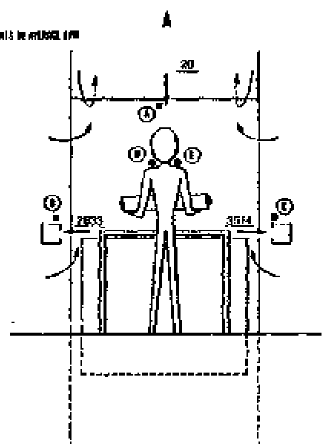


Figure 22. No. 5 batching station and worker

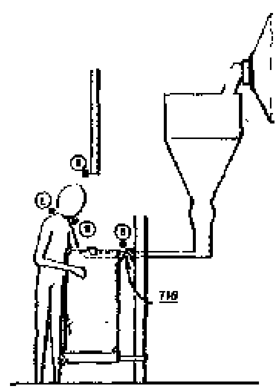


Figure 23. No. 6 bagging station and worker

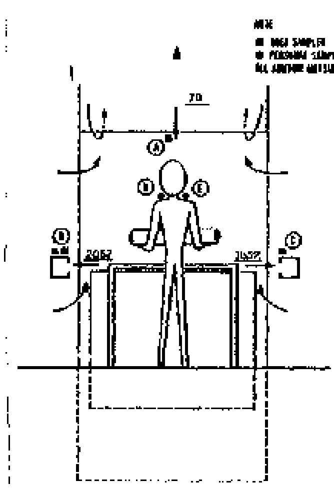


Figure 24. No. 6 batching station and worker

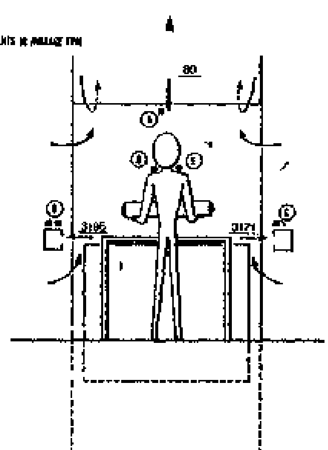


Figure 25. No. 7 batching station and worker

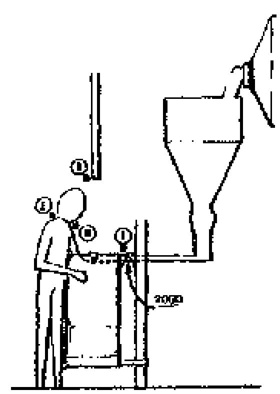


Figure 26. No. 7 bagging station and worker

Personal sampling results are shown in Table 2 for respirable and total dust collected for Operators of Work Stations 1-7, the Gel Caster employee, and the Plant Clean-up employee. Concentrations of personal samples collected for all three days were within the calculated OSHA PEL (See Table 2 notes) with the exception of those for Operators of Work Stations, 1, 2, and 6.

The Work Station No. 1 Operator third day sample results of 5.49 mg/m^3 respirable and 4.12 mg/m^3 total dust represents 477 and 119 per cent respectively of the calculated PEL's. These sample results are not believed to be representative of this operator's normal exposure levels but may be attributable to unusual sampling cassette positions and work practices observed. Sample results from days 1 and 2 support this conclusion.

The Work Station No. 2 Operator third day total dust sample result was 4.99 mg/m^3 or 145% of the calculated PEL. This sample result is not believed to be representative of this operator's normal exposure levels but may be attributable to unusual sampling cassette positions and work practices observed. Sample results from days 1 and 2 support this conclusion. The three-day total dust results ranged in concentration from 0.89 mg/m^3 to 4.99 mg/m^3 with a mean concentration of 2.37 mg/m^3 or 69% of the PEL. The three-day respirable dust sample results ranged in concentration from 0.13 mg/m^3 to 0.61 mg/m^3 with a mean concentration of 0.30 mg/m^3 or 26% of the PEL.

The Work Station No. 6 Operator second day sample results of 1.14 mg/m^3 respirable and 6.78 mg/m^3 total dust represents 197 and 392 per cent, respectfully, of the calculated PEL's. This sample result is not believed to be representative of this operator's normal exposure levels but may be attributable to unusual sampling cassette positions and work practices observed. Sample results from days 1 and 3 support this conclusion. The three-day respirable dust sample results ranged in concentration from 0.28 mg/m^3 to 1.14 mg/m^3 with a mean concentration of 0.62 mg/m^3 or 72% of the PEL. The three-day total dust sample results ranged in concentration from 2.03 mg/m^3 to 6.78 mg/m^3 with a mean concentration of 3.70 mg/m^3 or 143% of the PEL.

Table 2. Personal Samples - Breathing Zone Concentration

Location/Description (See Figures 18 - 26)	Day	Total Dust (Breathing Zone D) TWA mg/m³	Total Dust (Breathing Zone D) Per cent of PEL(1)	Respirable Dust (Breathing Zone E) TWA mg/m³	Respirable Dust (Breathing Zone E) Per cent of PEL(1)
Work Station No. 1, Operator Simpson No. 1, Mixer	1	0.68	20	0.19	17
	2	1.66	48	0.13	11
	3	4.12*	119	5.49*	477
Mean		2.15	62	1.94	168
Work Station No. 2, Operator Simpson No. 2, Mixer	1	1.23	36	0.16	14
	2	0.89	26	0.13	11
	3	4.99*	145	0.61	53
Mean		2.37	69	0.30	26
Work Station No. 3, Operator Simpson No. 3, Mixer	1	0.67	19	0.10	9
	2	0.87	25	0.19	16
	3	0.80	23	0.14	12
Mean		0.78	23	0.14	12
Work Station No. 5, Operator Simpson No. 4, Mixer	1	1.01	29	0.17	15
	2	1.58	46	0.17	15
Mean		1.30	38	0.17	15
Work Station No. 6, Operator Munson No. 1, Mixer St. Regis Bagger	1	2.03	59	0.44	38
	2	6.78*	392(2)	1.14*	197(2)*
	3	2.28	88(3)	0.28	33(3)
Mean		3.70	143	0.62	72
Work Station No. 7, Operator Munson No. 2, Mixer St. Regis Bagger	1	2.98	86	0.53	46
	2	3.38	98	0.56	49
	3	3.19	92	0.50	43
Mean		3.18	92	0.53	46
Gel Caster Model Shop	1	0.38	11	0.19	17
	2	0.72	21	0.09	8
	3	0.92	27	0.23	20
Mean		0.67	20	0.17	15
Plant Clean Up	2	2.56	74	1.00	87

*Unusual cassette position and work practice observed.

(1)PEL = 3.45 mg/m³ Total Dust and 1.15 mg/m³ Respirable Dust (Calculated from bulk sample analysis average results of 6.7% SiO_2 - Table 3).

(2)PEL = 1.73 mg/m³ Total Dust and 0.58 mg/m³ Respirable Dust (Calculated from personal sample analysis results of 15.3% SiO_2).

(3)PEL = 2.59 mg/m³ Total Dust and 0.86 mg/m³ Respirable Dust (Calculated from personal sample analysis results of 9.6% SiO_2).

Table 3 presents the percentages of Crystaline Quartz, Cristobalite, Hexavalent and Total Chromium present in bulk dust samples collected at locations identified in Figures 5, 7, 17.

Table 3. Bulk Dust Sample Percentages

Location	Crystalline Quartz	Cristobalite	Hexavalent Chromium	Total Chromium
Dust Collector Clean out 7/14/82	9.1	*ND	ND	0.02
Top of 33" Ventilation Exhaust Duct	6.7	ND	ND	0.04
Top of 23" Ventiation Exhaust Duct	5.7	ND	ND	0.06
Top of 16" Ventilation Exhaust Duct	5.3	ND	ND	0.05
Dust Collector Clean Out 7/15/82	6.6	ND	ND	0.02
Silica Flour Raw Material	100.0	< 1.5	ND	< 0.007
Lower Limit of Detection			< 0.0002	0.007
Lower Limit of Quantitation	5.0	1.5		

*ND = None detected, i.e., below limit of detection

B. EFFECTIVENESS OF ENGINEERING CONTROLS

Tables 4, 5 and 6 present the results of the evaluation of the plants' ventilation control systems. Table 7 shows the exhaust and/or recirculation capability of the dust collector discharge.

1. Local Exhaust Ventilation System (Figure 5)

Remarks in right-hand column of Table 4 call attention to factors that may influence and quantitate the effectiveness of their engineering control.

Table 4. Local Exhaust Ventilation

Location/Operation	Description of System	Velocity Measurement fpm (avg.)	Remarks
No. 1 Work Station a) Skip Hoist Runway	(Figures 17, 18) 28" x 17" opening 6' 6" above floor line	60	Mean Total dust concentration at sampling pt. # 20 = 0.42 mg/m^3
b) left side of batching operator	(Figures 11, 17, 18) 21" x 1 5/8" slot	2789	Mean Total dust concentration at sampling pt. # 19 = 1.36 mg/m^3
c) Right side of batching operator	(Figures 11, 17, 18) 21" x 1 5/8" slot	3806	Mean Total dust concentration at sampling pt. # 21 = 0.41 mg/m^3
d) Mixer - No. 1 Simpson	(Figures 13, 17) At entrance to 7" dia. exhaust duct with blast gate	3600	1/2" x 1/2" Grill in place & duct blast gate wide open. Both mixer doors open
No. 2 Work Station a) Skip Hoist Runway	(Figures 17, 19) 58" x 30" opening 6' 1" above floor line	70	Mean Total dust concentration at sampling pt. # 16 = 0.40 mg/m^3
b) Left side of Batching operator	(Figures 11, 17, 19) 21" x 2" slot	1814	Mean Total dust concentration at sample at pt. 15 = 8.40 mg/m^3
c) Right side of batching operator	(Figures 11, 17, 19) 21" x 2 11/16" slot	2985	Mean Total dust concentration at sampling pt. # 17 = 0.82 mg/m^3
d) Mixer - No. 2 Simpson	(Figures 13, 17) At entrance to 7" dia. exhaust duct with blast gate	5467	No grill over duct opening. Blast gate open, some build-up on duct inner surfaces. Both mixer doors open.
No. 3 Work Station a) Skip Hoist Runway	(Figures 17, 20) 38" x 20" opening, 6' 1/2" above floor line	90	Mean Total dust concentration at sampling pt. # 12 = 0.32 mg/m^3

Table 4. Local Exhaust Ventilation (Cont'd)

Location/Operation	Description of System	Velocity Measurement fpm (avg.)	Remarks
b) Left side of Batch operator	(Figures 11, 17, 20) 21" x 3 1/8" slot	1436	Slot partially obstructed. Mean Total dust concentration at sampling pt. # 11 = 1.72 mg/m3
c) Right side of batching operator	(Figures 11, 17, 20) 23 1/2" x 3 3/4" slot	1527	Slot adjustable gate removed. Mean Total dust concentration at sampling pt. # 13 = 0.49 mg/m^3
d) Mixer - No. 3 Simpson	(Figures 13, 17) At entrance to 7" dia. exhaust duct with blast gate	5350	No grill over duct opening. Blast gage wide open. Both mixer doors open.
No. 4 Work Station a) Skip Hoist Runway	(Figures 17, 21) 59" x 30" opening is 6' 6" above floor line	40	Station not in operation
b) Left side of batching operator	(Figures 11, 17, 21) 21" x 1 1/2" slot	3252	Slot partially obstructed.
c) Right side of batching operator	(Figures 11, 17, 21) 21" x 2 1/2" slot	2890	
d) Mixer - Clear field	(Figures 13, 17) At entrance to 9" dia. exhaust duct with blast gate	4333	Grill over exhaust duct opening. Opening is in center of mixer. Blast gate in duct was wide open.
No 5 Work Station a) Skip Hoist Runway	(Figures 5, 17, 22) 58 x 30" opening 6' 8" above floor line	20	Station not in operation. Skip hoist bucket was elevated when air flow measurements were taken.
b) Left side of batching operator	(Figures 11, 22) 21 x 2 7/8 slot	2633	Slot partially obstructed

Table 4. Local Exhaust Ventilation (Cont'd)

Location/Operation	Description of System	Velocity Measurement fpm (avg.)	Remarks
c) Right side of batching operator	(Figures 11, 22) 21" x 2" slot	3514	
d) Mixer No. 4 Simpson	(Figures 13, 17) At entrance to 7" dia. circular exhaust duct with blast gate	4367	Grill in place 2 doors to mixer open
e) Pail filling operator	(Figure 15) 12" dia annulus around 6" dia. spout. Exhaust duct collects airborne contaminants around pail filling spout	533	Moisture content of products being placed in pails reduces airborne contaminants.
No. 6 Work Station a) Skip Hoist Runway	(Figures 17, 24) 57" x 29" opening 6' 8" above floor line	70	Mean Total dust concentration at sampling pt # 7 = 0.63 mg/m^3
b) Left side of batching operator	(Figures 11, 24) 28" x 1 1/2" slot	2057	Slot partially obstructed. Heavy deposits on plenum surfaces. Mean Total dust concentration at sampling pt # 6 = 14.06 mg/m^3
c) Right side of batching operator	(Figures 11, 24) 27" x 2 1/2" slot	1852	Mean Total dust concentration at sampling pt # 8 = 3.22 mg/m^3
d) Bag filling operator	(Figures 14, 17, 23) 4" dia. annulus exhaust duct around 3" dia. bag filling spout	716	Wide fluctuation in air flow in annulus ring and duct. Mean Total dust concentration at sampling pt # 9 = 1.71 mg/m^3

Table 4. Local Exhaust Ventilation (Cont'd)

Location/Operation	Description of System	Velocity Measurement fpm (avg.)	Remarks
e) Mixer - No. 1 Munson	(Figures 12, 17)		Mixer is totally enclosed. Duct work discharges into exhaust system.
<u>No. 7 Work Station</u> a) Skip Hoist Runway	(Figures 17, 25) 57" x 29 1/2" opening 6' 6" above floor line	80	Mean Total dust concentration at sampling pt # 2 = 0.23 mg/m^3
b) Left side of batching operator	(Figures 11, 17, 25) 21" x 1 5/8" slot	3195	Slot partially obstructed. Mean Total dust concentration at sampling pt # 1 = 5.62 mg/m^3
c) Right side of batching operator	(Figures 11, 17, 25) 21" x 1 1/2" slot	3171	Mean Total dust concentration at sampling pt # 3 = 3.06 mg/m^3
d) Bag filling operator	(Figures 14, 17,. 26) 4" dia. annulus exhaust duct around 3" dia. bag filling spout	2000	Opening between annulus and plenum needs to be sealed. A pedestal fan was delivering 800 fpm of general ventilation in face of operator. This fan should be either mounted above or behind operator. Mean Total dust concentration at sampling pt # 4 = 0.97 mg/m^3
e) Mixer No. 1 Munson	(Figures 12, 17)		Mixer is totally enclosed. Duct work discharges into exhaust system.

In most cases, the local exhaust ventilation system was able to maintain dust concentrations (total and respirable) below the OSHA standard (PEL). However, a review of the "remarks" column identifies several location/operation conditions which, if improved, would result in a more effective engineering control.

2. General Ventilation System (Figures 3, 17, 27)

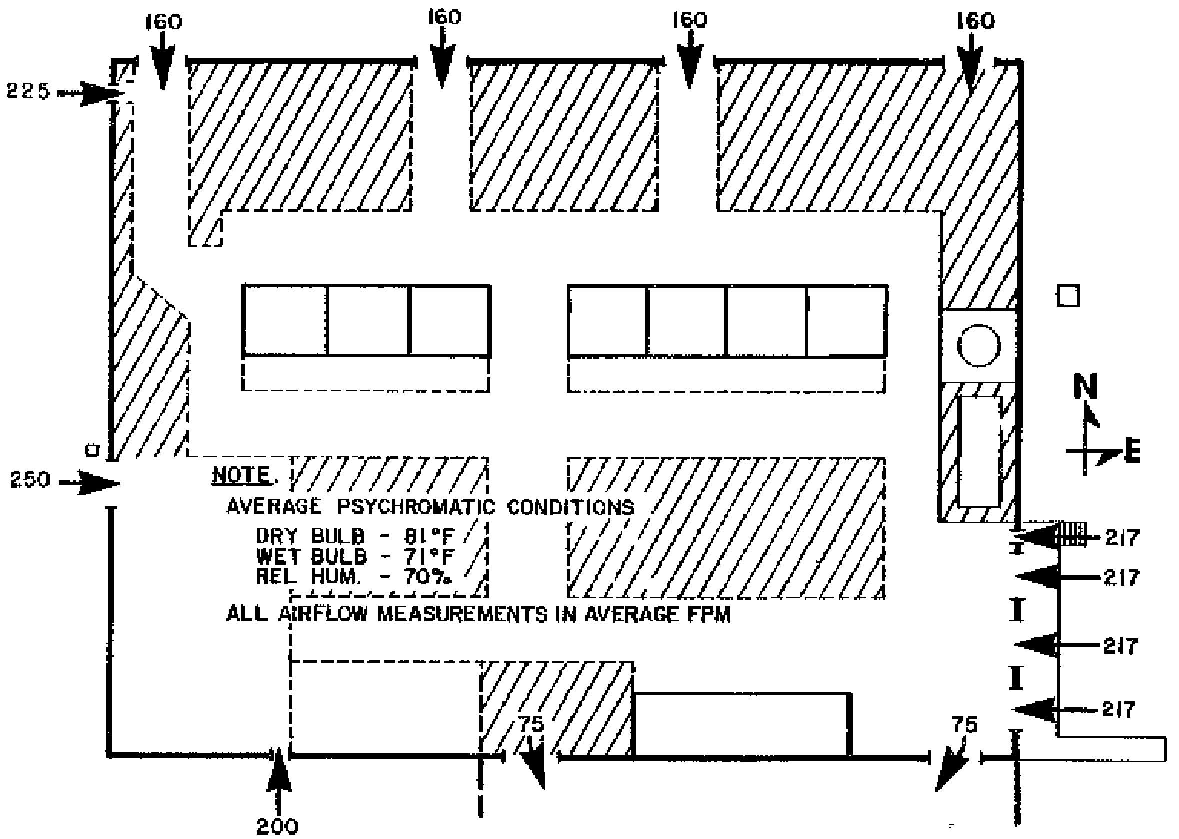


Figure 27. General ventilation through wall openings

The remarks in the right-hand column of Table 5, as well as the psychromatic conditions noted at the time of this survey, call attention to factors that may influence the air flows reported.

Table 5. General Ventilation*

Location/Operation by wall openings	Description of System	Velocity Measurement fpm (avg.)	Volume cfm (avg.)	Remarks
1) Five(5) exhaust fans mounted in West end of building, just below roof line	(Figure 16) Individual fans can be manually controlled from floor level. Each discharge through a 48" dia. wall opening.	Variable**	Variable**	Fans discharge through louvered openings to outside. Since prevailing winds are from N.W. fans might be more efficient if mounted in East end of building
2) Four(4) overhead doors on North side of building	(Figure 27) 14' x 12' openings	160	107520	Air flow is into building
3) Three(3) overhead doors and one(1) pedestrian door on East end of building	(Figure 27) O.H. Doors = 10 1/2' x 10' Pedestrian = 6' 8" x 3'	217	72691	Doors open onto loading dock. Air flow is into building.
4) Two(2) overhead doors on South of building	(Figure 27) 9' 8" x 8' 6" openings	75	12317	Doors open into adjacent building. Air flow is into adjacent building.
5) One(1) pedestrian door on South side of building	(Figure 27) 7' 7" x 3' opening	200	4500	Door opens from maintenance area to outside. Air flow is into building.
6) One(1) overhead door on West end of building	(Figure 27) 8' x 8' opening	250	16000	Door opens to outside in area adjacent to incinerator. Air flow is into building.
7) One(1) pedestrian door on West end of building	(Figure 27) 6' 8" x 3' opening	225	4496	Door opens to outside. Air flow is into building.

*Readings taken when psychromatic conditions in plant areas averaged:
Dry Bulb = 81°F
Wet Bulb = 71°F
Rel. Hum. = 70%

**Not all (5) fans were ever operating simultaneously during survey

One aspect of the design of this plant building, that is especially conducive to effective general ventilation, is the wall openings to the outside on each side. The addition of ventilation fans near the roof line to exhaust superheated air during warm weather was well advised. Albeit, their effectiveness may have been increased if they were located in the end of the building opposite the prevailing winds. The operations in this building are somewhat unique for the ceramics industry, in that thermal risers common to kilns, ovens, and shrinkwrapping are not present. The effects on the general ventilation of recirculating the exhaust from the dust collector was not evaluated, since it was not being done during this survey.

3. Local Exhaust System Ductwork

The design method[9] used to obtain the desired distribution of air flow involves the use of blast gates and adjustable slots (Figure 11). This method is normally selected where less toxic materials are being controlled but care must be used in choosing the "branch of greatest resistance" when balancing the system. The fact that the blast gates and adjustable slots are easily accessible to the operator can allow unauthorized adjustments. Table 6 shows the air flow velocity and volume at three points in the exhaust system duct work. (Figure 5)

Table 6. Local Exhaust System Ductwork Air Flow*

Location/Description	Velocity Measurement fpm (avg.)	Volume cfm (avg)	Remarks
1) Main exhaust duct, 25' from East wall and 10' down stream from nearest branch duct entrance. duct entrance. Figure 5 position A	3782	22465	Duct diameter 33" (Area 5.94 ft^2)
2) Main exhaust duct, 25' upstream and downstream from nearest branch duct entrance. Figure 5 position B	3075	8888	Duct diameter 23" (Area 2.89 ft^2)
3) Main exhaust duct, 9.5' upstream and 8' downstream from nearest branch duct entrance. Figure 5 position C	2792	3041	Duct diameter 16" (Area 1.40 ft^2). Duct was clogged at 12 1/2" depth (78% effective)

*All measurements made by pitot traverse (20 points). Ten readings taken across duct diameter at right angles to each other (except for 16" diameter duct) see remarks.

4. Dust Collector and Blower Airflow

A fabric (sateen bag) filter dust collector (Figures 6 and 7) removes the dust (particulates) from the exhaust system airstream. It operates only during the period of time products are being manufactured. It is equipped with a knocker (Figure 8) type cleaner that may be actuated manually or automatically by means of a timed sequencer. The former mode was in use during this survey. The collected particulates are removed by an auger which discharges into a collection container.

The cleaned air discharge from the blower may be exhausted outside or returned, in part or in whole, to the plant (Figure 9). During the winter the latter practice is in effect. During this study, all filtered air was being exhausted outside to the down wind side of the building. Table 7.

Table 7. Airflow from Dust Collector and Blower

Location/Description	Velocity Measurement fpm (avg.)	Volume cfm (avg.)	Remarks
Measurements were taken across outside surface of 1/2" x 1/2" mesh grill, made of 1/32" wire, covering 42" x 28" discharge duct See Figure 9.	3732	Approximately 26000	Effective area (8.16 ft^2) of discharge duct is reduced by grill work.

5. Other Engineering Controls

The single spout, St. Regis baggers are equipped with a dedicated, integral exhaust hood in the principal dust source area. The pail filling operations are also similarily equipped. All skip hoist runways are enclosed and exhausted.

A large mobile industrial sweeper/vacuum is used to clean the aisle and warehouse area floors. The primary gas fired area heater has been enclosed, so its operation is not adversely affected by the air movement within the plant. The value of this enclosure is most significant when exhaust ventilation is being recirculated. The incineration of empty bags is done outside of the plant.

Leakage from bags during filling operations is reduced by the use of a valved opening bag design.

Dust dispersion from bagged materials is reduced by shrink wrapping the loaded pallets.

C. WORK PRACTICES

Good work practices are achieved by a multi-faceted program, that involves housekeeping, incentive awards, and a labor/management committee.

1. Housekeeping

Each employee is responsible for maintaining good housekeeping in a specific area of the plant. While this procedure was effective in this plant it may not have the same degree of success in all plants. The large sweeper/vacuum mentioned above supplements the broom and shovel approach in large open areas. The aisleways are marked, as are designated storage areas, so bag breakage is minimized. A generous supply of sweeping compound is always readily available to all employees. At the end of the shift each batch station operator washes down his/her equipment and area.

2. Incentive Awards

Employees can accumulate points as a result of good safety, health, and housekeeping in their areas. Gifts can be selected from four different catalogues, depending upon the number of points accumulated. Supervisors also accumulate points and qualify for awards.

3. Labor/Management Committee

The plant manager, plant superintendent, and local union president make monthly safety/health surveys of the premises and operations. Supervisors hold tailgate-type safety and health meetings with employees as needed. The company sponsors sports teams and makes an outside exercise area available.

The local union's master agreement with management, contains a safety and health article. Routine chest x-rays are not required. However, pre-employment physicals are given at a nearby clinic.

The plant manager has recently been assigned division-wide safety and health responsibility. He has taken steps in the safety and health areas that should make this plant's work areas even more safe and healthful.

D. PERSONAL PROTECTIVE EQUIPMENT PROGRAM

NIOSH/MSHA approved quarter-mask dust, fume, and mist disposable type respirators are available and worn on selected jobs. Bump type hard hats are available to all employees. All workers may have laundered shirt and pants work uniforms at no cost. Safety shoes and safety glasses are also available.

V. GENERAL OBSERVATIONS, CONCLUSIONS, AND RECOMMENDATIONS

A. GENERAL OBSERVATIONS

1. The control of dust in the plant makes use of the following major engineering controls: A local exhaust system, a general ventilation system, a mobile vacuum/brush sweeper, dedicated exhaust system ductwork directed at major dust emission sources, enclosure of major dust emitters, and product containers that are conducive to efficient and effective dust control.

2. A firm commitment by the plants' management and the exclusive labor bargaining unit to health, safety, and good housekeeping is essential and exists.

3. The implementation and perpetuation of good work practices are essential if the engineering controls are to continue to be effective and efficient.

4. The efficiency and effectiveness of the local ventilation system need to be periodically checked, as blast gate adjustments, slot openings, duct surfaces and/or operations may periodically change.

5. Partial enclosure of the sides of the batching stations would offset some of the present "short circuiting" of air flow at the batching stations.

6. On some jobs it is now mandatory that respirators be worn. The respirator program must be periodically reviewed.

7. The arrangement of the local ventilation system blower discharge, so the cleaned air can be either exhausted outside or recirculated, has the potential for heating cost savings, but could introduce health hazards. There presently is no monitoring device in the recirculation air stream to detect and/or guard against returning contaminated air to the plant. However, at the time of this survey the concentration of total and respirable dust in the air cleaner discharge was well below the OSHA PEL's so there is no apparent health problems associated with recirculation. (At time of study no filtered air was being recirculated into the building).

B. CONCLUSIONS

1. The major engineering controls presently in use in this plant are, in most cases, maintaining total and respirable dust concentrations in the breathing zone of workers below the calculated OSHA PEL's.

2. An effective safety, health, and good housekeeping program is in place in the plant which is supported by both labor and management.

3. The housekeeping procedures, bag handling methods (both manual and mechanical), and preventive maintenance schedules, in conjunction with an incentive awards plan, all contribute to good work practices.

4. There is no established respirator program covering the selection, fitting, maintenance, and use of same.

5. If all of the cleaned and conditioned air from the local ventilation system blower (24000 cfm or approximately 53 tons of air/hr.) is exhausted outside, when the make-up air temperature is 32°F or below, a large heating cost is involved. If 32°F air is conditioned to 68°F, approximately 950,000 BTU's/hr. are required.[10] Relating heat load to gas supply at 1000 BTU's/ft^3, about 900 ft^3 gas/hr should be required. (Engineering-wise a 25% savings might be possible). The local utility is presently charging approximately \$0.555/ft^3 for natural gas.

6. At the time of this survey the airborne concentrations of elemental and/or hexavalent chromium was below the limit of detection.

C. RECOMMENDATIONS

1. The feasibility of using a self-contained empty bag compactor in conjunction with the disposal of empty bags should be investigated.

2. A check-out procedure, in accordance with good engineering practices, should be developed and implemented, for testing and maintaining the local exhaust ventilation system. Once the system is balanced it may be advisable to secure the blast gates and slot opening covers in a fixed position.

3. The use of a pedestal fan, for personal cooling during extremely warm weather, should neither direct contaminated air into the workers breathing zone, nor should it counteract the effectiveness of the local exhaust system.

4. The feasibility of partially enclosing the sides of the batching operations should be investigated.

5. When employees are required to wear respirators, there should be an effective program to ensure proper selection, fit, maintenance, and use of same.

6. The feasibility of relocating the five general ventilation fans from the West end of the building to the East end to take advantage of the prevailing N.W. winds may warrant consideration.

7. When the local ventilation system exhaust is being recirculated the air flow should be monitored for contamination. A warning device should be installed to warn employees in the event a predetermined level of contamination is reached.

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VII. APPENDICES

APPENDIX A

Description of Air Sampling and Analytical Equipment

1. MSA and DuPont Gravimetric Dust Samplers are manufactured by Mine Safety Appliance, Inc., and the DuPont Corporation respectively. These sampling systems consist of a two-piece plastic filter holder cassette, containing a 37 mm PVC Filter No. M5, manufactured by Millipore Corporation, a portable, battery powered pump, and if collecting respirable dust fraction a 10 mm plastic cyclone to remove "non-respirable" dust. The respirable samplers operated at 1.7 liters per minute (lpm) and the nonrespirable at 2.0 lpm.

2. TSI Respirable Aerosol Mass Monitor, Model 3500, Manufactured by Thermo Systems, Inc. This instrument permits direct measurement of dust concentrations, at either two-minute or 24-second intervals. It collects particles from 0.01 to 10 um in diameter. In a one-minute sampling time it will measure mass concentration in the range of 100 $ug/m^3 \pm 10$ accuracy.

3. UBTL analyzed the samples collected for quartz and cristobalite. They used a Phillips Automated powder diffractometer Model ADP-3501, with a "limit of detection" of 15 ug per sample. Total dust weights were measured on a Perkins-Elmer Electro-balance, Model AD-2, with a "lower limit of quantitation" of 0.15 mg. All samples were desiccated for 48 hours to obtain constant weight.

   The samples were sieved to pass through a ten micron precision sieve. A preliminary scan of the screened material indicated that all but one of the samples had interferences present in the primary quartz region. There were also indications of possible interferences in the secondary quartz regions. Due to the interferences the samples were taken through a phosphoric acid (Talvitie) clean-up procedure.

   A three-milligram portion of the samples was weighed onto FWSB filters. The samples were pretreated by the Talvitie procedure and NIOSH Method P&CAM 259 was used to analyze the samples, after Talvitie treatment, with the following modification: Standards and samples were run concurrently and an external calibration curve was prepared from the integrated intensities rather than using the suggested normalization procedure.

   A two-milligram portion of the one sample mentioned above was weighed onto a FWSB filter in duplicate and analyzed as described above with the exception that it was not taken through the pretreatment procedures.

   Results of the analysis showed that the interference in the primary quartz region had not been removed by the Talvitie procedure. Subsequent analysis of the secondary peak was possible. Results of the analysis of the tertiary peak confirmed the values calculated using the secondary quartz peak.

4. UBTL analyzed a select number of the samples collected for chromium. The samples were wet ashed with nitric acid to insure complete oxidation. They were then diluted to a final volume of 25 ml and aspirated into the atomic absorption spectrophotometer as described in NIOSH Method P & CAM 323.

APPENDIX B

Types and Classifications of Refractories

1. Clay Refractories (SIC-3255): The primary types are; fire clay, semi-silica, high alumina, insulating, and ladle.

   a. Fireclay

   Fireclay is an earth or stony mineral aggregate which has as its essential constituent hydrous silicates of aluminum, with or without free silica; plastic or formable when sufficiently pulverized and wetted; rigid when subsequently dried; and of suitable refractoriness for use in commercial refractory products.

   Fireclay desposits seldom are pure hydrous aluminum silicates; the nature and percentage of impurities found in the fireclay help determine the properties of refractories made from them. Fireclays from various deposits are mixed in varying amounts to produce products with differing refractory characteristics. Fireclay refractories are classified as low-duty, medium-duty, high-duty, or super-duty depending on their resistance to high temperatures or refractoriness.

   Fireclay brick are characterized by moderately high resistance to heat, small thermal expansion, and fair thermal insulation. They are reasonable impervious to attack by highly acidic materials but fail rapidly when exposed to chemically basic materials at high temperatures.

   b. Semi-Silica

   Fireclay with a relatively high percentage of free silica is called semi-silica and is used to make products with good rigidity under load at high temperature. Semi-silica refractories exhibit high reistance to fracture or spalling caused by rapid temperature changes, and good volume stability at moderately high temperatures.

   c. High-Alumina

   High-alumina refractories were originally based on diaspore but are now made of bauxite. They include materials, except mullite, containing between 50 and 85% aluminum oxide (Al_2O_3). Compositions containing up to approximately 85% aluminum oxide are classified for statistical purposes by the Bureau of Census as clay refractories; those with a higher percent are classified as non-clay, extra-high alumina refractories.

   In its naturally occurring form, bauxite contains a number of impurities; primarily silica, titania, and iron oxides. The properties of high-alumina compositions change with an increasing percentage of aluminum oxide. Compositions are available from 50% to 85% aluminum oxide. These are multipurpose refractories, some suitable for temperatures up to 1650°C (3002°F), and highly resistant to chemical and slag attack. Depending on composition and impurities, they have fair-to-excellent resistance to spalling and somewhat higher volume stability than other clay refractories.

d. Insulating

Insulating refractories can be made of high alumina or fireclay materials. They are made by two general processes. In one, a combustible material added to the composition mix burns out during manufacture leaving spaces which result in low density. In the other, a lightweight ingredient such as expanded clay or perlite is added to the composition to lower the density of the finished product.

In fireclay and high-alumina insulating firebrick, a range of compositions is available commercially with temperature tolerances to 1815°C (3299°F).

Depending on their use, insulating refractories may be the primary refractory, or may be a backup layer for a denser, more heat-resistant refractory. This scheme conserves energy and protects the shell of the container from the high temperature inside the refractory lining while the denser refractory resists high temperatures, slags, acidity, and the like.

e. Ladle

Ladle brick are considered a unique fireclay refractory. They are of two general types: A bloating brick made from fireclay of moderate refractoriness but which expands (or bloats) significantly when heated at 1280°C (2335°F) or above, and a volume-stable brick made from fireclay with good refractoriness which shows little or no volume change when heated to 1280°C (2336°F) or above. High density and low porosity are important characteristics of both types.

2. Non-Clay Refractories (SIC-3297); the primary types are silica, basic, silicon carbide, extra-high alumina, mullite, zircon, and fused cast, ceramic fibres, and other non-clay.

a. Silica

Silica is a naturally occurring mineral found abundantly in the earth's crust. Fine-grained deposits with low contents of alumina and alkali make excellent refractories with high temperature load bearing ability. Principal uses for silica refractories today are in coke ovens, glass melting furnace crowns, and in Europe, as checker brick in blast furnace stoves.

b. Basic

Basic refractories are produced from a composition of dead-burned dolomite, dead-burned magnesite, chrome ore, or compatible mixtures of magnesite-dolomite or magnesite-chrome. Early magnesite brick were produced from natural minerals that contained a number of impurities that limited their refractoriness. Magnesium oxide (MgO), the primary metallic oxide in magnesite, is highly refractory in its pure form; its mineral name is periclase. Impurities in both natural magnesite and chrome ores lead to the formation of low-melting compositions which greatly diminish refractoriness. However, as a class, the magnesia-chrome combinations have good mechanical strength and volume stability at high temperatures. In addition, they have high resistance to corrosion by chemically basic slags, especially those found in the steel and copper industries.

Chrome-magnesite combinations -- a larger proportion of chrome than of magnesite -- exhibit less thermal expansion than high magnesia compositions. Chrome-free compositions of high purity sea-water or brine-well magnesia or high purity natural magnesite, often referred to as periclase, provide maximum refractorieness and resistance to iron oxides. With coal tar binders, these compositions are particularly suited for steel furnaces using the basic oxygen process (BOP). Tar bonded dolomite and magnesite-dolomite compositions are also well suited for lining sections of BOP vessels.

c. Silicon Carbide

Silicon carbide, (SiC) is produced by reaction of sand and coke in an electric furnace. It is used to make special shapes, such as kiln furniture, which are used to support and separate pieces of ceramic ware as they are fired in kilns. Silicon carbide has exceptionally high thermal conductivity (it transmits heat readily), has good load-bearing characteristics at high temperatures, and good resistance to rapid changes in temperature.

d. Extra-High Alumina

Extra-high alumina refractories are made predominantly from bauxite or alumina (Al_2O_3) which has been fused or densely sintered. Extra-high alumina refractories contain from 85% to slightly less than 100% alumina. Extra-high alumina refractories have good volume stability at temperatures up to 1815°C (3299°F).

e. Mullite

Mullite, ($3Al_2O_3$, $2SiO_2$) refractories are made of kyanite, sillimanite, andalusite, bauxite, or mixtures of aluminum silica materials to give about 70% alumina. Any of these materials must be sintered at high temperatures or melted in electric furnaces to bring about the formation of the mineral mullite. This is the most stable of any alumina-silica combination. These refractories are noted for their low level of impurities and their excellent resistance to load at high temperatures.

f. Zircon

Zircon is a naturally occurring zirconium silicate (ZrO_2,SiO_2) mineral. It has good volume stability for extended periods of exposure to high temperature. Zircon is frequently used for nozzles to control the flow of molten metals. Zircon refractories are widely used for glass tank construction where resistance to certain molten glasses is required.

g. Fused Cast

Some of the materials mentioned as non-clay refractories are formed into special shapes by fusing in electric furnaces and pouring, while still molten, into molds. Fused casting is applied to magnesite-chrome, alumina, and compositions of alumina-zirconia-silica. Their chief characteristics are resistance to glass and slag corrosion, abrasion resistance, and high refractoriness with volume stability under extended high-temperature conditions.

h. Ceramic Fibers

Ceramic fibers possess outstanding insulating characteristics at very low density as compared to other refractory materials. Typical fiber properties include melting points in excess of 1760°C (3200°F), average diameters of 3 microns, and lengths up to 10'. Most ceramic fibers have temperature use limits of 1260°C (2300°F); however, fibers are now available for temperatures up to 1650°C (3002°F) in alumina and zirconia compositions.

Ceramic fibers have been used commonly as expansion joint fillers, but today are a significant refractory material. The bulk fibers are converted into blankets used for hot face furnace linings, into vacuum formed shapes, and into paper, strip, and wet felt.

i. Other Non-Clay

This group includes graphite, chrome-alumina, magnesia-alumina, forsterite, alumina-zirconia-silica, zirconia, and pyrophyilite-andalusite -- each having special properties for specific industrial uses.