APPENDIX A

PLANT MODELS

APPENDIX A

TABLE OF CONTENTS

	Page
PLANT MODELS	A-2
FIGURES:	
Small Bulk Plant - Figure A-1	A-4
Small Shape Plant - Figure A-2	A-11
Medium Bulk Plant - Figure A-3	A-22
Medium Shape Plant - Figure A-4	A-31
Large Bulk Plant - Figure A-5	A-42
Large Shape Plant - Figure A-6	A-55
Silica Brick Plant - Figure A-7	A-64
PLANT DESCRIPTIONS:	
Small Bulk Plant	A-5
Small Shape Plant	A-12
Medium Bulk Plant	A-23
Medium Shape Plant	A-32
Large Bulk Plant	A-43
Large Shape Plant	A-56
Silica Brick Plant	A-65
COST OF COMPLIANCE:	
Small Bulk Plant	A-8
Summary Cost of Compliance	A-10
Small Shape Plant	A-17
Summary Cost of Compliance	A-20
Medium Bulk Plant	A-27
Summary Cost of Compliance	A-29
Medium Shape Plant	A-37
Summary Cost of Compliance	A-40
Large Bulk Plant	A-48
Summary Cost of Compliance	A-53
Large Shape Plant	A-60
Summary Cost of Compliance	A-62
Silica Brick Plant	A-69
Summary Cost of Compliance	A-71

specification for alternative remedial procedures and evaluation of the associated costs.

Seven plant models have been developed to represent typical operations within the refractories industry. Each model is different with respect to individual production operations, procedures for materials handling, production quantity and product-mix. Where more than one type of product (shape versus bulk) is made at a facility, the plant is classified based upon the product having the larger annual production in 1976.

The following abbreviations are used to identify certain operations within these facilities:

FEL -- Front End Loader

FL -- Forklift Truck

WSB -- Weigh Scale Bucket

SC -- Shuttle Conveyors

PLANT DESCRIPTION

SMALL BULK PLANT

Raw Materials

Tabular alumina, calcined flint, clay, mullite, silica.

Range of Products

Castables, mortars and ramming mixes.

Production Flow

- Raw Material Receipt and Storage

Raw materials in bulk and bagged form are received by truck and rail. Bulk materials are transferred by front-end loader to open top storage bins within the main plant. Bagged materials are also stored on pallets within the same building. Some grog is also used as a raw material.

- Crushing

All raw materials with the exception of grog are purchased in a classified sized form. The grog is transferred by a front-end loader from the open stockpiles to the crusher building where it is fed to an uncovered, unventilated crusher.

- Batching, Mixing and Packaging

Materials for batching are drawn from storage and fed into a front-end loader which transfers these to an open top weigh bucket. The weigh bucket is then transferred by forklift truck and discharged into a ventilated skiphoist which feeds the mixers. Sacked materials are added directly to the skiphoist and the discarded sacks are

The process description information plus an assessment of dust exposure problems were utilized to identify and evaluate the individual controls required to reduce employee exposures to crystalline silica. The various activities required to control these exposures to the minimum feasible level include:

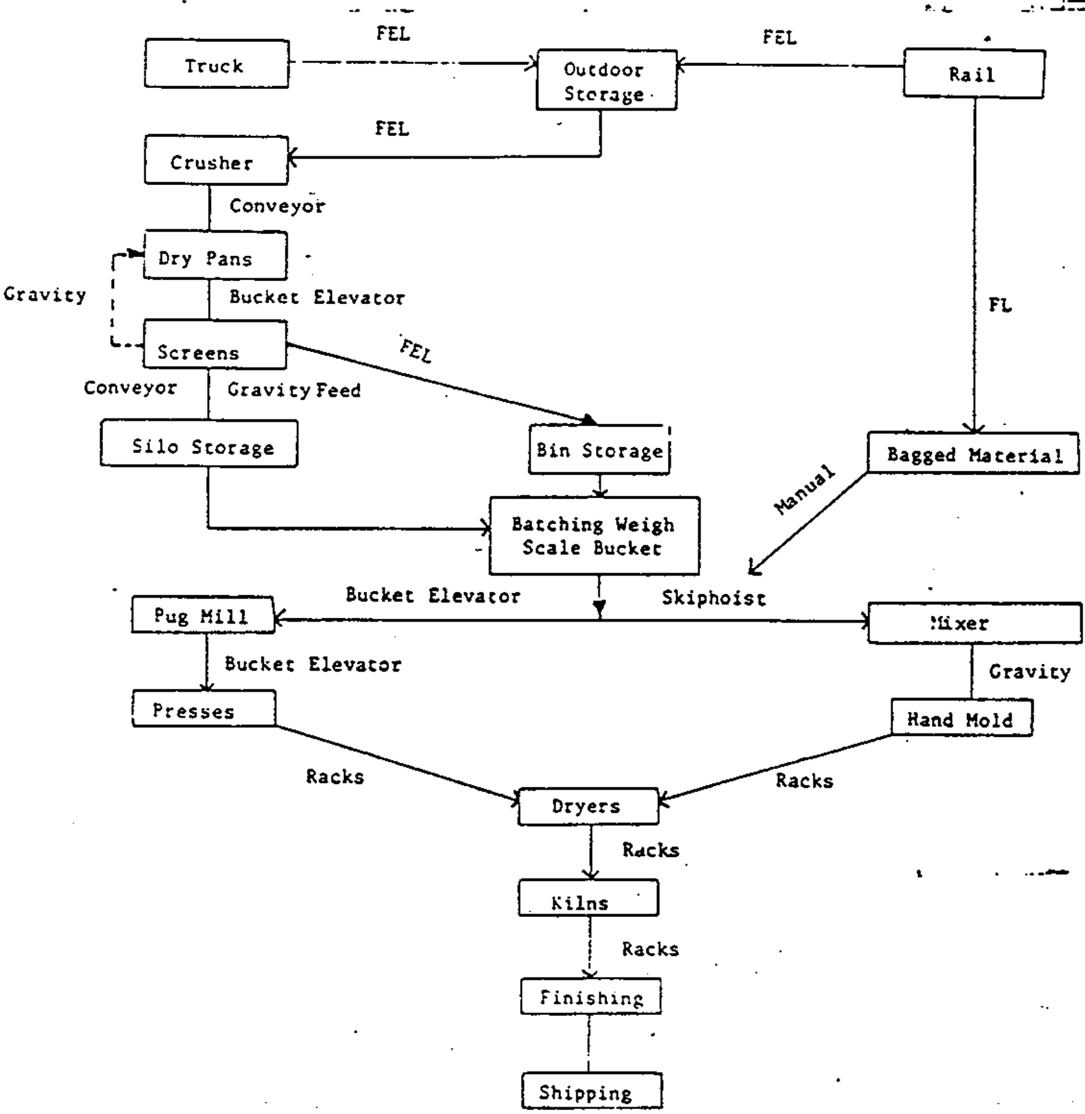
- Installation and operation of engineering controls;
- initial plant clean-up and subsequent maintenance programs;
- other OSHA related compliance activities including medical surveillance, employee monitoring, etc.;
- employing either a substitute for the silica setting sand or replenishing the sand more frequently.

The capital and annual operating costs for these compliance activities are presented in the following table.

	Capital	Annual Operating Cost $
Mixing		
1. Rework the enclosures and the exhausts on the wet pan, dry pan and small pan mixer.	$117,090	$12,489
Packaging		
1. Replace or rework the sacking machine.	37,600	4,080
General Maintenance		
1. Purchase 1 heavy-duty vacuum system.	33,000	12,500
2. Initial clean-up.		18,000
Demolition	68,321	

Figure A-2

SMALL SHAPE PLANT



- Batching and Mixing

Batching occurs at grade level where classified raw materials are selectively added to an overhead rail weigh hopper. The batched materials are selectively drawn from silo storage, open bin storage, or from sacks. Silo materials are fed directly into the weigh hopper, while open bin materials and sacked materials are added manually. Flexible ventilation ducts are provided at each open bin station for attachment to the weigh hopper. When the batch is complete, the weigh hopper is emptied into an enclosed bucket elevator which raises the material to the second floor pug mill or by skiphoist to a mixer. Milled material is transferred by a set of bucket elevators to holding boxes over each of six mechanical presses. Material from the mixing is drawn by gravity and transferred to the hand mold area.

- Forming and Firing

Six brick presses are gravity-fed from overhead holding boxes. The pressed shapes are removed by hand, stacked on drying cars, and transferred to drying tunnels. The dried bricks are transferred to the periodic kilns where they are hand set prior to firing. Some materials are diverted to a hand molding process where the mix is drawn off, kneaded and hand-packed into molds. Following a setting and air-drying period, racks are used to transfer the cast shapes to the dryers and the periodic kilns.

The batching operation involves the manual handling of raw materials including those stored in open bins as well as sacks. For example, materials within bins are hand-shoveled into weigh hoppers while sacks are cut open and their contents dropped directly into either weigh hoppers or mixers. The storage of classified materials in open bins results in dust generation during the initial gravity feed following grinding and subsequently in the process of emptying the bin by shovel or front-end loader.

The press area has large accumulations of spilled excess materials resulting from forming operations. Mixed material dries and becomes entrained in the air as a result of both foot and vehicular traffic in the press area. The brick finishing area also has inadequate controls to properly contain the dust generated during precision grinding and cutting operation. Finally, there are excessive dust levels within the periodic kiln which may be attributed to the reuse of setting sand which although initially sized and washed will degrade with continued reuse and pose a potential silica exposure problem.

COST OF COMPLIANCE

SMALL SHAPE PLANT

I. Engineering Controls	Capital	Annual Operating Cost
Raw Material Receipt and Storage		
1. Enclose cab on front-end loaders	$ 4,000	
Crushing		
1. Enclose and exhaust crusher.	58,810	6,144
2. Install 100 feet of covered and exhausted conveyor to feed dry pan mixers.	40,000	1,200
3. Exhaust 6 open drop points	69,300	10,080
Grinding		
1. Enclose and exhaust 2 dry pan mixers.	78,060	8,226
2. Rework the bucket elevators feeding the screens.	31,400	3,200
Screening		
1. Enclose and exhaust the 2 vibratory screens.	76,000	7,800
2. Install 70 feet of covered conveyor to feed the storage bins.	28,000	2,100

<u>Finishing</u>		
1. Rework the grinding machine to provide more adequate control.	31,250	3,350
<u>General Maintenance</u>		
1. Purchase heavy-duty vacuum to provide daily cleaning.	33,000	12,500
2. Initial clean-up.		18,000
<u>Demolition</u>	66,000	

SUMMARY COST OF COMPLIANCE (cont.)

II. RECURRING COSTS	Capital	Annual Operating Costs
A. Annual Operating & Maintenance		151,303
B. OSHA Activities		29,400
C. Material Substitution		37,500
Total Recurring Cost		$218,203

PLANT DESCRIPTION

MEDIUM BULK PLANT

Raw Materials

Fireclay (several types), flint, Portland cement, graphite, alumina, iron oxide, titania, lime magnesia, alkalies.

Range of Products

Castables, plastics, mortars, gunning mixes.

Production Flow

- Raw Materials Receipt and Storage

Bulk clays and sacked materials are delivered by truck and rail with bulk storage in open stockpiles. Sacked materials are transferred via forklift to pallet storage adjacent to the sack breaking station. Classified materials are fed directly to silo storage.

- Crushing, Grinding and Screening

Bulk materials are transferred to the crusher by front-end loader. The operator dumps material in a feed hopper and manually starts the crushing operation. During the shift the operator alternates between feeding the crusher, monitoring the process and operating the bucket elevator. A bucket elevator transfers crushed material to the shuttle conveyor floor where it can be directed either to a rotary dryer (for drying and/or calcining) or to the grinding operation for bulk product line #1. Dried material is conveyed to a separate grinding operation for bulk product line #2. Oversized material from the screens is

The batching of silo stored classified material results in the release of dust through poorly fitting connections between the silo and the portable weigh hopper. There is also a tendency for the silo discharge valves to leak and spill material onto the bin floor area.

Sacked materials are currently opened at a sack breaking station and discharged into an open portable weigh hopper. The sack breaking operation is not properly controlled and results in considerable dust generation. Also, the charging, elevation to the mixer floor, and discharging of the skiphoists results in dust generation which contributes to overall plant contamination. The covers on the mixer pans are badly damaged and should be repaired to reduce dust generation at this location.

The automatic sacking machines are poorly maintained and contribute to dust release because of excessive nozzle discharge, overfilling of sacks, sack breakage during filling, leaking seals and seams on sacks and poor maintenance and housekeeping adjacent to the filling station. The drum filling station suffers from similar problems and is also a major contributor to dust exposures within the packaging area of the plant.

The process description information plus an assessment of dust exposure problems was utilized to identify and evaluate the individual controls required to reduce employee exposures to crystalline silica. The various activities required to control these exposures to the minimum feasible level include:

COST OF COMPLIANCE

MEDIUM BULK PLANT

I. Engineering Controls	Capital	Annual Operating Cost
Raw Material Receipt and Storage		
1. Provide covered storage.	$216,000	
2. Enclose front-end loaders	4,000	
Crushing		
1. Enclose and exhaust jaw crusher	58,810	6,104
Drying - None		
Grinding		
1. Enclose and exhaust dry grinding	39,030	4,163
2. Install covers on 800 feet of conveyor.	42,400	
Screening		
1. Rework and exhaust 2 screens.	76,060	7,790
2. Rework two bucket recycle systems.	31,388	3,200
Storage		
1. Enclose and exhaust 14 silo storage bins.	254,388	36,260
2. Install 500 feet of covered conveyor.	200,000	15,000

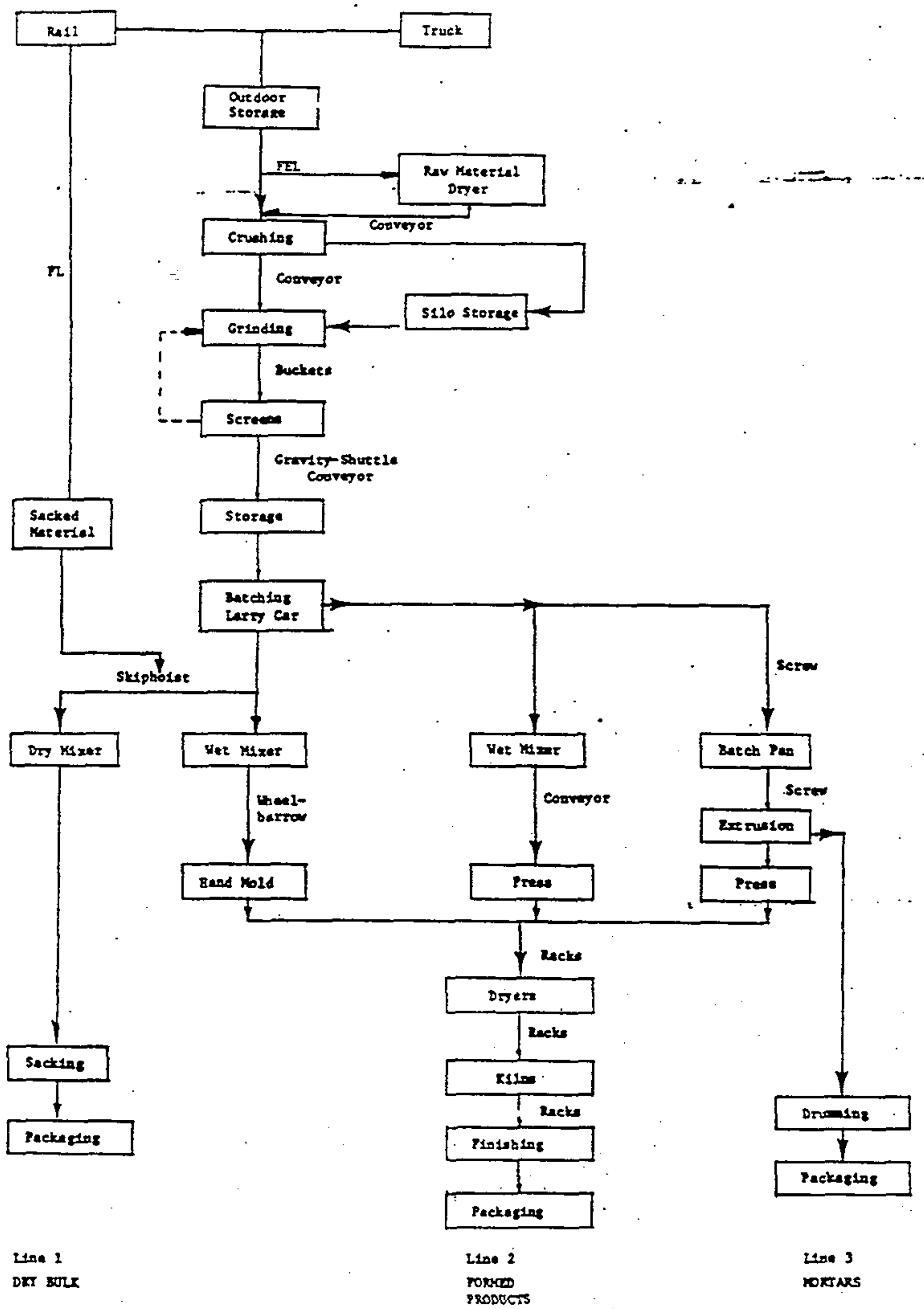
SUMMARY COST OF COMPLIANCE

MEDIUM BULK PLANT

I. FIRST YEAR COST	Capital	Annual Operating Costs
A. Engineering Controls		
1. Raw Materials Receipt	$ 220,000	-
2. Crushing, Grinding Screening	247,688	21,257
3. Storage	454,388	51,260
4. Batching and Mixing	399,870	36,126
5. Forming, Firing, Finishing	-	-
6. Packaging	75,200	8,160
7. General Maintenance	66,000	25,000
8. Demolition	92,000	-
Total Engineering Controls	1,555,146	141,803
B. Plant Clean-Up		
1. Initial		27,000
2. Annual		40,000
C. OSHA Activities	-	29,400
D. Material Substitution	-	-
Total First Year Cost	$1,555,146	$238,203

Figure A-4

MEDIUM SHAPE PLANT



• Batching and Mixing

A larry car is utilized to collect sized materials which are measured into a weigh hopper and discharged at the covered wet pan. Raw materials for the specialty line are collected in the larry car and fed via screw conveyor to the batch pan. The mixer in the hand mold department is fed via a skiphoist which receives materials from both bin storage and the sack breaking station. The specialty mixer is fed in a similar fashion and the finished mix is discharged directly into sacks.

• Forming and Firing

The stiff mud material is screw conveyed from the batch pan into the mud extruder and then pressed to shape. Materials used for hand molding are transferred to the molding floor via wheelbarrow. Here the wooden molds are sprinkled with silica sand to prevent adhesion and the mix is then hand transferred and pressed into the mold. Each of the brick presses is automatically fed from above through a wet pan conveyor. The pressed brick is then set with silica sand prior to drying and firing in tunnel kilns.

• Finishing

Individual shapes may require specific finishing including grinding and sawing to achieve desired product dimensions. These operations are conducted in the brick finishing department where each selected shape is individually processed on either a brick saw, circular sander or both.

storage bins. Both operations result in dust generation which is further compounded by the presence of uncontrolled open drop points at the bin floor level.

The batching operations generate dust during charging of the weigh hopper and discharge of the hopper to the dry pan mixer via gravity flow. The wet pan and stiff mud mixer also require preventative maintenance to reduce the level of dust generation during loading and mixing operations.

The skiphoist operations for both the specialty and hand-mold departments generate excessive levels of dust during charging, elevation, and discharge into the mixer. These mixers are also poorly maintained and the inadequate levels of exhaust ventilation contribute to the release of silica dust.

The present procedures for filling sacks in the specialty department result in considerable exposure to dust. This situation is directly related to overfilling of sacks, leakage through broken seams, and lack of good housekeeping in the area adjacent to the sacking machine. Current procedures for sack breaking and disposal of empty sacks contribute to dust generation and exposure to silica flour and related materials.

Finally, the application of silica sand as a setting material during firing of shapes results in exposure to silica.

I. PURPOSE OF THE QUESTIONNAIRE

The purpose of the attached questionnaire is to obtain sufficient information about plants making refractory products to enable a determination of the impact of a proposed OSHA standard for silica dust. The information sought falls into three general categories:

- plant process
- economics of operation
- current worker health records and procedures.

To the extent possible, Arthur D. Little, Inc., has tried to minimize the number of questions and amount of proprietary information requested. As described in the cover letter, all data wll be kept confidential for an individual plant and used in aggregate form only in Arthur D. Little's final report. All individual responses and data will be destroyed by Arthur D. Little at the conclusion of this study.

To assist you in understanding the purpose of the questionnaire, a brief description of the purpose and objectives of each section follow:

I. Identification (Corporate Information):

This section identifies the corporation and the individual who completes the questionnaire. Item B identifies the refractories plants for which questionnaires are to be completed. Companies with more than three plants should complete questionnaires for their representative plants.

II. Plant Information

A. *Identification*: This section identifies the plant.

B. *Product Mix and Production Process*: This section seeks information on the product mix, raw materials used, and production process at the plant. This information is useful and necessary to understand the potential for worker exposure to silica as well as to provide product characterization and data on the economics of operation for the plant.

C. *Revenues and Expenses*: Pro-forma expense figures (expenses as a percentage of sales) are requested in order to construct aggregate plant operating profiles. This information will be used to assess the impact of the cost of OSHA compliance activities upon plant costs and product prices. For example, one measure of the impact of an OSHA regulation is the increase in

5. All questions should be answered by checking the appropriate box or boxes. Those questions requiring a written response should be answered by printing or typing in the appropriate space.

6. Attempt to answer all questions. Where appropriate, answers should be provided for the most recent fiscal year. If you cannot provide a full response to a question, answer as much of it as you can. If a question is not relevant to your plant operation or the information requested is not obtainable, please provide an explanation. If clarification or supplementation of any response is necessary, please attach a separate sheet. If you do not know the answer to a question, write "don't know" or "DK". If a value is zero, write in zero (0).

7. If you have difficulty understanding or answering any question, please call Stuart Young or Scott Stricoff at 617-864-5770.

8. Please retain a copy of your completed survey, since it may be necessary to contact you in the future to verify your responses.

III. DEFINITIONS

A. Economic

Accumulated Depreciation – Total depreciation to date or the difference between original book value and current book value.

Annual Cost of Pollution Control and Other Environmental Regulations – Depreciation charges for pollution control equipment or for plant and equipment modifications required by regulations. Operating costs include the cost of maintenance and operating labor, supplies, fuel, and electricity required to operate the equipment related to the regulation.

Depreciation – Annual book depreciation of assets at this plant.

Direct Wages, Salaries and Related – Payroll costs (salaries, wages, unemployment insurance, FICA and other related costs) of direct labor (production employees) engaged in the manufacture of refractories products.

Fixed Assets – Capital assets, plant site land, and equipment are all categories of fixed assets. The book values or values net to depreciation or depletion should be shown.

Gross Fixed Assets – Original book value of Fixed Assets.

Materials Cost – Chemicals and other supplies used in the production of refractories products.

Operating Margin – Earnings before interest, taxes, general and administrative expense.

OSHA – The Occupational Safety and Health Administration.

Other Income (Expense) – Income (expense) not directly or indirectly associated with refractories product manufacture.

Production Workers – Direct and indirect labor engaged in and attributable to the production of refractories products at this point.

Profit After Tax – If this is a single-plant company, the net profit remaining after Federal Income taxes. If a multi-plant company, calculate an approximate profit after tax by using the company's aggregate tax rate.

Profit Before Tax – Sales less all costs, except Federal Income Taxes.

Codes 1013, 1015, 1017, 1019–Insulating fire brick and shapes – The subdivision of codes 1013, 1015, 1017, and 1019 should be made in accordance with the ASTM Classification C-155, the respective groups being 16, 20, 23 combined with 26 and 28 and higher.

Code 1025–Refractory bonding mortars, wet and dry types – *Include* both air-setting and heat-setting bonding mortars which contain up to 60% Al_2O_3, dry basis, by analysis. Report bonding mortars which contain more than 60% Al_2O_3, dry basis in code 2020, "High alumina mortars."

Code 1026–Plastic refractories and ramming mixes, up to 50% Al_2O_3 – *Include* products referred to as plastic fire brick and the less plastic materials intended for ramming into place after the addition of water (when shipped in dry form) containing up to 50% Al_2O_3. Report products containing over 50% to 87.5% Al_2O_3 in code 1028.

Code 1028–High alumina plastic refractories and ramming mixes, containing over 50% to 87.5% Al_2O_3 – *Exclude* plastic refractories and ramming mixes of mullite or extra high alumina. Report products made of these materials in code 2028. "Other nonclay plastic refractories and ramming mixes, wet and dry types."

Code 1030–Clay castable refractories (hydraulic setting), up to 50% Al_2O_3 – *Include* hydraulic setting castables made from calcined fireclay, diaspore or bauxite base, and Portland or calcium aluminate cements containing up to 50% Al_2O_3.

Exclude high alumina castable refractories over 50% Al_2O_3. Report these in code 1032. Also exclude castables based on mullite, fused or tabular alumina, or other nonclay materials. Report castables made from these materials as nonclay refractories in code 2023.

Code 1032–High alumina castable refractories (hydraulic setting), over 50% Al_2O_3 – *Exclude* mullite and extra high alumina castables. Report these products as nonclay refractories in code 2023.

Code 1036–Fireclay gunning mixes, up to 50% Al_2O_3 – *Include* alumino-silicate compositions up to 50% Al_2O_3 specifically engineered for gunning applications; may include hydraulic setting or other chemical bonding agents. Report compositions over 50% Al_2O_3 in code 1038.

Code 1038–High alumina gunning mixes, over 50% to 87.5% Al_2O_3 – *Include* alumino-silicate compositions over 50% to 87.5% Al_2O_3 specifically engineered for gunning applications.

Exclude mullite and extra high alumina materials which should be reported in code 2032.

Codes 1040 and 1042–Other clay refractory materials – *Include* in code 1040 domestic shipments of materials for direct use as finished refractory products, and all exports.

Exclude from code 1040 all domestic shipments or transfers to plants of your company or to other companies for reprocessing in the manufacture of brick or other refractories. Report these domestic shipments in code 1042.

2. *Definitions of Nonclay Refractories*

NOTE: Molten cast refractories are made by fusing refractory oxides, as in an electric furnace, and pouring the molten material into molds to form finished shapes.

Codes 2004, 2006, 2008–Magnesite and magnesite-chrome brick and shapes (magnesite predominating; products analyzing greater than 55% MgO) – *Include* in code 2004 all pitch-bonded magnesite and magnesite-dolomite brick (magnesite predominating), even though baked or tempered, but do not include burned impregnated brick, which are to be reported under code 2006. Report dolomite-magnesite brick (dolomite predominating) in code 2016.

Exclude molten cast magnesite and magnesite-chrome brick and shapes as well as those made of fused magnesia. Report products made by these methods in code 2017, "Other nonclay brick and shapes."

Code 2010–Chrome and chrome-magnesite brick and shapes (chrome predominating; products analyzing no more than 55% MgO). – *Exclude* molten cast chrome and shapes. Report products made by this method in code 2017. "Other nonclay brick and shapes."

CONFIDENTIAL

REFRACTORIES INDUSTRY SURVEY

I. CORPORATE INFORMATION

A. IDENTIFICATION

1. Company Name: ______________________________

2. Corporate Headquarters: ______________________________
Street
____
City State Zip

3. Person Completing Questionnaire:

   a. Name: ______________________________

   b. Title: ______________________________

4. Attach a copy of the company's most recent annual report or available financial statement.

B. REFRACTORY PLANTS

Please list the refractories plants that your company operates:

Complete Part II for each refractory *plant* up to three plants. Companies with more than three plants should complete the questionnaire for three representative plants. It is desirable that the plants selected represent the *size* distribution of your refractory plants or other characteristics which give rise to differences in worker *exposure* to free silica.

b. Type of Grinding Equipment

	Total Tons passing through each type of mill in 1976
Dry Pan	______
Gyratory Crusher	______
Jaw Crusher	______
Roll Mill	______
Ring Roll	______
Hammer Mill	______
Rod or Ball Mill	______
Other Type (Specify)	______

c. Size Classification Equipment

	Tons Passing in 1976
All Screening Units	______
All Air Classifiers	______

5. If shapes are produced at this plant, what portion of the total units are produced by the extruded versus pressed process?

	Percent Total Production (Short Tons)					
	0	Under 25%	26-50%	51-75%	Over 75%	100%
Extruded	☐	☐	☐	☐	☐	☐
Power Pressed	☐	☐	☐	☐	☐	☐

6. At what capacity utilization rate was this plant operation in 1976?

	1976 Production as Percent of Capacity			
	Under 50%	51-75%	76-90%	Over 90%
Bulk Refractories	☐	☐	☐	☐
Brick and Shapes	☐	☐	☐	☐

10. Average number of employees during 1976:

	Under 10	11-30	31-50	51-75	76-100	101-500	Over 150
a. Production Workers	☐	☐	☐	☐	☐	☐	☐
b. Other Employees	☐	☐	☐	☐	☐	☐	☐

C. REVENUES AND EXPENSES

1. Income Statement

Please check the box which most closely approximates your costs as a percentage of sales.

(1976 or most recent fiscal year)

This Plant's Cost as an Approximate Percent of Sales

	< 10	10-19	20-29	30-39	40-49	> 50
a. Direct Wages, Salaries and Related	☐	☐	☐	☐	☐	☐
	< 20	21-29	30-39	40-49	50-59	> 60
b. Materials and Supplies	☐	☐	☐	☐	☐	☐
	< 1	2-3	3-4	4-5	5-6	> 6
c. Depreciation	☐	☐	☐	☐	☐	☐
d. Workers Compensation Insurance	☐	☐	☐	☐	☐	☐
e. Other Plant Expenses (Including rent, fuel energy, other insurance and property taxes)	☐	☐	☐	☐	☐	☐
	< 10	11-15	16-20	21-25	26-30	> 30
f. Operating Margin	☐	☐	☐	☐	☐	☐
	< 7	8-10	11-13	14-16	17-19	> 19
g. Selling, General and Admin. (Including allocation from Parent)	☐	☐	☐	☐	☐	☐

2. What are the Annual Depreciation Charges on this equipment? $ ____________________

3. What are the Annual Operating Costs associated with this equipment? $ ____________________

F. OCCUPATIONAL HEALTH RECORDS AND PROCEDURES

1. Evaluation of Refractory Plant Personnel Data

   a. How many years after a worker terminates employment are his personnel records kept on file?
   ________ years

   b. Do these records include the following information for each employee? (Check if Yes)

   ________ Date and age of employment
   ________ Durations and descriptions of jobs held
   ________ Durations and levels of free silica exposure
   ________ Date and age at termination of employment
   ________ Reason for termination of employment (e.g., job change, retirement, injury)
   ________ Home address

   c. Do most production employees terminate employment before reaching retirement?

   Yes ☐ No ☐

   d. Do most production employees terminate employment for health reasons?

   Yes ☐ No ☐

   If not, why do they quit? ____

   ____

   ____

   e. What is the average length of employment for production employees? ____________ years

   f. How many workers have received worker's compensation for silicosis in the past five years?

   ____

   g. How does this compare with previous years?

   Higher ☐ Same ☐ Lower ☐

   h. If there have been changes in the number of worker's compensation awards for silicosis, what factors are responsible? ____

   ____

d. Section 4 – Personal Protective Equipment

i. Are employees provided with respiratory protective equipment?

Yes ☐ No ☐

ii. If yes, what percent of your employees use them? ________ %

iii. Where exposure to free silica is above the recommended limit, is work clothing vacuumed before removal?

Yes ☐ No ☐

e. Section 5 – Hazard Information

i. Are employees informed about the hazards of silica and the appropriate precautions for its safe use?

Yes ☐ No ☐

f. Section 6 – Work Practices and Controls

i. Please specify if local exhaust ventilation (e.g., with a dust collector) is used in the following plant areas:

	Used	Not Used
Grinding and Crushing Operations	☐	☐
Screening	☐	☐
Storage Areas	☐	☐
Mixing Operation	☐	☐
Bagging Operation	☐	☐
Forming Operation	☐	☐
Firing Operation	☐	☐

Other Operations (specify) ________________________________

____

ii. Do you process silica to eliminate the respirable particles?

Yes ☐ No ☐

iii. Have you changed from dry to wet processes?

Yes ☐ No ☐

iv. Do you use process enclosures?

Yes ☐ No ☐

ATTACHMENT A

Product Code	Item Description	Item Code	Produced at Plant
	CLAY REFRACTORIES		
	Brick and shapes		
3255011	Fireclay (including semi-silica) brick and shapes, except as listed below	1001	☐
3255015	Superduty fireclay brick and shapes	1003	☐
3255021	High alumina brick and shapes (50% Al_2O_3 and over) made substantially of calcined diaspore or bauxite (*Exclude mullite and extra high alumina refractories, which should be reported in codes 2009 and 2011.*)[1]	1005	☐
3255031	Ladle brick (containing less than 50% Al_2O_3)[1]	1006	☐
3255035	High alumina ladle brick (containing 50% or more Al_2O_3), previously reported in code 1005[1]	1008	☐
3255041	Sleeves, nozzles, runner brick, tuyeres, and slide gate brick (externally applied)[1]	1009	☐
3255045	Glass-house pots, tank blocks, feeder parts, and upper structure shapes used only for glass tanks (*Exclude mullite and extra high alumina refractories, which should be reported in codes 2009 and 2011.*)[1]	1011	☐
	Insulating fire brick and shapes[1]		
3255026	1600°F to 2000°F (but not including 2000°F)	1013	☐
3255027	2000°F to 2300°F (but not including 2300°F)	1015	☐
3255023	2300°F to 2800°F (but not including 2800°F)	1017	☐
3255024	2800°F and higher	1019	☐
3255047	Hot top refractories	1021	☐
3255049	Clay kiln furniture, radiant heater elements, potters' supplies, and other miscellaneous shaped refractory items	1023	☐
3255053	Refractory bonding mortars (up to 60% Al_2O_3, dry basis by analysis), wet and dry types[1]	1025	☐

Product Code	Item Description	Item Code	Produced at Plant
	NONCLAY REFRACTORIES (Continued)		
	Magnesite and magnesite-chrome brick and shapes (magnesite predominating; products analyzing greater than 55% MgO.) (*Exclude molten cast and those made of fused magnesia, which should be reported in code 2017.*)[1]		
3297016	Pitch-bonded	2004	☐
3297017	Pitch-impregnated	2006	☐
3297018	Others	2008	☐
3297021	Chrome and chrome-magnesite brick and shapes (chrome predominating; products analyzing no more than 55% MgO.) (*Exclude molten cast, which should be reported in code 2017.*)[1]	2010	☐
3297033	Graphite crucibles, retorts, stopper heads, and other shaped refractories containing natural graphite	2013	☐
3297035	Carbon refractories; brick, blocks, and shapes, excluding those containing natural graphite	2029	☐
3297052	Mullite brick and shapes made predominantly of kyanite, sillimanite, andalusite, or synthetic mullite (*Exclude molten cast, which should be reported in code 2017.*)[1]	2009	☐
3297053	Extra high alumina brick and shapes made predominantly of fused bauxite, fused or dense-sintered alumina (*Exclude molten cast, report in code 2017.*)[1]	2011	☐
3297048	Silicon carbide kiln furniture (made predominantly of silicon carbide)	2012	☐
3297049	Silicon carbide brick and shapes (made predominantly of silicon carbide), except kiln furniture	2014	☐
3297055	Zircon and zirconia brick and shapes (made predominantly of either of these materials)	2015	☐
3297057	Dolomite and dolomite-magnesite brick and shapes and other brick containing a substantial amount of dolomite grains[1]	2016	☐
3297058	Other nonclay brick and shapes not included above (e.g., molten cast, forsterite, pyrophillite, etc.)[1]	2017	☐

APPENDIX F

MISCELLANEOUS TABLES

APPENDIX F

TABLE OF CONTENTS

	Page
MISCELLANEOUS TABLES	F-2
TABLES:	
Dust Sampling Results - Table F-1	F-3
Dust Sampling Results - Table F-2	F-4
Dust Sampling - Table F-3	F-5
Respirable Free Silica Sampling - Table F-4	F-6
Respirable Free Silica Sampling - Table F-5	F-7
Respirable Free Silica Sampling - Table F-6	F-8
Weight of Refractories - Table F-7	F-9

TABLE F-1

DUST SAMPLING RESULTS

Operation	Sample[1]	Duration (min)	Total Dust (mg/m^3)	Free Silica (ug/m^3)	% Free Silica	TLV (mg/m^3)
Cement Mill Crush & Bag	R	120	2.647	3667*	∿ 100	< 0.1
Periodic Kiln Unloading		285	0.343	22	6.4	1.2
Dry Pan Operator	R	270	0.603	121	20	0.46
Grinder-Screener	R	235	1.471	1030	70	0.14
Dry Pan Area	AR	265	0.181	< 11	< 6.1	> 1.2
Shuttle Conveyor	BG	-	1.6	-	-	-
Batching Department	BG	-	4	-	-	-
Pan Area	BG	-	0.9	-	-	-
Press Feed Hopper	BG	-	2.5	-	-	-
Impact Press	BG	-	0.4	-	-	-
Ganister Bagging	BG	-	0.9	-	-	-
2nd-floor Elevator	BG	-	9.8	-	-	-
Screen Room	BG	-	5.1	-	-	-
Upper Floor	BG	-	10.4	-	-	-

*Concentration of free silica exceeds recommended analytical range

(1) R - respirable; AR - area respirable; BG - β gauge respirable

TABLE F-3

DUST SAMPLING

Operation	Sample[1]	Duration (min)	Total Dust (mg/m^3)	Free Silica ($\mu g/m^3$)	Free Silica %	TLV (mg/m^3)
Claymaker	R[2]	415	3.335	675	20	0.46
Jaw Crusher	R[2]	415	4.062	548	13	0.67
3rd Floor Cleaner	R[2]	400	2.813	635	23	0.40
Cart Floor Area	AR	400	0.848	52	6	1.25
Wet Grinder	R[2]	390	0.488	7	1	3.33
Grinding Department	BG	-	0.9	-	-	-
Skip Hoist	BG	-	3.8	-	-	-
Room 9-Bucket Loading	BG	-	2.1	-	-	-
Tennant Sweeping	BG	-	3.2	-	-	-
Wet Grind	BG	-	0.9	-	-	-
Hand Dressing	BG	-	0.6	-	-	-
Primary Crusher	BG	-	1.8/10.0	-	-	-
Grog Breaker	BG	-	2.2	-	-	-

(1) R-Respirable, AR-Area Respirable, BG-Beta Gauge

(2) Samples observed to contain some large particles which should have been excluded by the cyclone. Concentrations are overstated for these samples by as much as 10-20 percent.

TABLE F-5

RESPIRABLE FREE SILICA SAMPLING

Percent Samples > 25 g/m^3 - 50 ug/m^3 by Plant Operation and Production Size[1]

Operation	Small	Medium	Large	Silica	Total
Grinding-Crushing Screening	8	27	0	17	18
Batching-Mixing	11	13	16	25	15
Press-Form	0	25	0	18	18
Fire-Finish	50	13	100	33	30
Sacking	0	17	0	0	10
Miscellaneous Operations	25	0	0	0	8
TOTAL	12	19	14	22	17

(1) Arthur D. Little, Inc., samples (4) with no free silica detected and a minimum detectable concentration > 25 $\mu g/m^3$ are excluded from the denominator.

TABLE F-7

WEIGHT OF REFRACTORIES

Type	(1) Lbs. Cubic Foot[1]	(2) Lbs. per Brick[2]	(3) Average lbs. Brick[3]	(4) Bricks/ Ton Refractories
Fireclay	120-140	7.05-8.20	7.6	263
Superduty	130-150	7.62-8.79	8.2	244
High Alumina	125-150	7.32-8.79	7.9	250
Insulating Firebrick	19-60	1.11-3.52	2.4	833
Silica Brick	100-110	5.86-6.44	6.2	204
Magnesite Brick				
Burned	160-165	9.37-10.25	9.8	187
Bonded	180-185	10.55-10.84	10.7	
Chrome Brick				
Burned	180-190	10.55-11.13	10.8	183
Bonded	180-195	10.55-11.43	11.0	
Silicon Carbide	136-158	7.99-9.26	8.6	233
Fosterite	150-160	8.79-9.37	9.1	219
Zircon			13.0	154
Ladle Brick			8.0	250
Mullite			8.0	250

[1] *Brickwork Construction*, p. 397.

[2] Col. 1 ÷ 17 9" equivalents.

[3] Based upon distribution of production (e.g., insulating firebrick) or ADL estimate.

COST OF COMPLIANCE

LARGE SHAPE PLANT

I. Engineering Controls	Equipment	Annual Operati Cost
Raw Material Receipt and Storage		
1. Provide covered storage for up to 2 months supply of selected raw material.	$900,000	
2. Enclose cab or front-end loaders	20,000	
Crushing		
1. Cover and exhaust both the jaw and roll crushers.	117,620	12,200
2. Cover 200 ft of conveyor feeding crushed material to grinders.	10,600	
Grinding		
1. Enclose and exhaust grinders.	234,000	25,000
2. Rework 5 bucket elevators feeding screens.	78,470	8,000
Screening		
1. Enclose and exhaust 8 screens.	304,210	30,900
2. Install solid floor in screen room.	108,000	-
3. Rework recycle system	15,600	-
Storage		
1. Enclose and exhaust 42 storage bins and silos.	936,000	80,000
2. Install 250' of covered exhausted conveyor.	166,[illegible]20	12,500

Classified materials are fed to open top storage bins which result in dust generation during feeding and discharge of the bins. Batched materials are fed to the individual mixers via open conveyors with a series of open drop transfer points which produce excessive levels of dust. The mixer is improperly exhausted and the rates of local exhaust are insufficient to properly control this operation. Also, the mixer covers are often left open to assist in visual observation of this process, a practice which enables dust to escape into the mixing-batching area. Mixed materials are fed to press feed bins where spillage from both the feeder system and bins result in dust generation. There are also considerable accumulations of excess feed materials at the front and rear of the press which upon drying can become suspended due to vehicular or foot traffic. Additional exposure to silica include those associated with the use of this material as a parting sand during setting operations prior to firing the green brick.

The process description information plus an assessment of dust exposure problems was utilized to identify and evaluate the individual controls required to reduce employee exposures to crystalline silica. The various activities required to control these exposures to the minimum feasible level include:

- Installation and operation of engineering controls;
- initial plant clean-up and subsequent maintenance programs;
- other OSHA related compliance activities including medical surveillance, employee monitoring, etc.;

PLANT DESCRIPTION

LARGE SHAPE PLANT

Raw Materials

Fire clays, bauxite (raw and calcined), kyanite, iron oxide, alumina, additives and bonding agents.

Range of Products

Standard brick and shapes, nozzle blocks, formed sleeves.

Production Flow

- Raw Materials Receipt and Storage

Raw materials are received by truck and rail. The majority of the materials arrive as raw bulk with a smaller percentage of classified materials. Some of the raw materials are sent to classified storage while the remainder are open stockpiled. Sacked materials are transferred by forklift to storage on pallets.

- Crushing, Grinding, and Screening

Raw clays are crushed with a portion of the material being passed through a rotary kiln. Crushed raw materials are then further classified through grinding and screening with this product passed to intermediate storage. Oversized materials are recycled from the screens to grinding to maintain uniformly sized raw materials.

- Batching and Mixing

Classified materials are batched via a conveyor and weigh hopper system and transferred to the mixer. The materials discharged from the mixers are conveyed to the press feeder bins via a surge hopper.

II. RECURRING COSTS	Equipment	Annual Operating Costs
A. Annual Operating & Maintenance		365,341
B. OSHA Activities		10,100
C. Material Substitution		-
Total Recurring Cost		$375,441

	Capital	Annual Operating Cost
Packaging		
1. Automate drumming operation on line 1 to remove manual shoveling of wet material	$ 20,000	$ --
2. Rework screw conveyor on line 2 feeding extruder	3,000	
3. Modify screw conveyor feeding sacking machine on line 3	2,000	--
4. Install automatic system for truck loading on line 4 with 100 feet conveyor, screw feed from silo and 2000 CFM	40,000 7,604 22,000	1,200 572 3,200
5. Upgrade the screw conveyor on line 5 feeding the bagging machine	2,000	--
6. Rework screw conveyor feeding extruder	2,000	--
7. Rework the sacking machine on line 3	37,600	4,080
8. Rework the sacking machine on line 5	37,600	4,080
General Plant Maintenance		
1. Initial cleanup	--	54,000
2. 3 vacuum systems	99,000	37,500
Demolition	244,000	--
Electrical		
1. Initial construction of electrical transformers.	20,000	

	Capital	Annual Operating Cost
Storage		
1. Modify 5 open bins on line 3 to enclose and exhaust.	$ 145,000	$ 11,000
2. Modify 6 open bins on line 4 to enclose and exhuast.	174,000	13,200
3. Rework 12 silos on line 3 to enclose and exhaust.	218,000	31,000
4. Install two 30-ton capacity silos on line 4 to replace open bulk	40,000	--
storage. Add dust collection system.	29,260	3,200
5. Upgrade the exhaust ventilation	4,600	--
and discharge valves on hopper storage for line 5.	29,260	3,200
6. Upgrade the existing silo storage to improve exhaust on line 6.	144,000	20,000
Batching		
1. Replace existing manual handling of materials on lines 1 and 2 with a tote bin system.*	109,850	46,000
2. Replace existing sacking station on lines 1 and 2 with new exhaust design	53,515	4,720
3. Modify the skiphoists feeding the	55,152	5,800
wet pans on lines 1 and 2	55,152	5,800
4. Replace the batching system on line 3 with a tote bin station	59,850	4,600
5. Upgrade skiphoist feeding dry pan on line 4	55,152	5,800
6. Eliminate FEL on line 4 and install 100 feet of exhausted conveyor to	40,000	1,200
discharge feed from dry pan to bulk storage	61,448	5,000

*Includes 50 tote bins.

COST OF COMPLIANCE

LARGE BULK PLANT

I. Engineering Controls	Capital	Annual Operating Cost
Raw Material Receipt and Storage		
1. Install covered and enclosed storage for raw materials fed to lines 3, 4, 5, and 6.	$ 720,000	
2. Install 250 feet of covered conveyor from raw storage to grinder on line 3.	80,000	6,000
3. Cover conveyor on line 3 from crusher to kiln 100 feet.	5,300	
4. Install 100 feet conveyor to feed covered raw material to crusher on line 6.	40,000	3,000
5. Enclose 5 front-end loaders	20,000	
Crushing		
1. Cover and enclose the jaw crusher on line 3 and the roll crusher on line 6.	117,620	12,208
2. Upgrade conveyor on line 5 from crusher to dryer. Cover and exhaust at 3000 CFM.	37,000	4,800
3. Install conveyor on line 6 to feed crushed material to grinder.	33,000	4,800
Kiln and Dryer		
1. Add 200 feet of conveyor to transfer calcined material to bin storage on line 3.	80,000	6,000
2. Upgrade conveyor on line 5 from dryer to hopper storage cover and exhaust at 3000 CFM.	4,000 33,000	4,800

SUMMARY COST OF COMPLIANCE

MEDIUM SHAPE PLANT

I. FIRST YEAR COST	Capital	Annual Operating Costs
A. Engineering Controls		
1. Raw Materials Receipt	364,000	
2. Crushing, Grinding Screening	412,870	33,604
3. Storage	572,660	43,700
4. Batching and Mixing	376,274	32,852
5. Forming, Firing, Finishing	31,250	3,370
6. Packaging	37,600	4,080
7. General Maintenance	99,000	37,500
8. Demolition	132,000	
Total Engineering Controls	2,025,654	158,906
B. Plant Clean-Up		
1. Initial		27,000
2. Annual		40,000
C. OSHA Activities		79,074
D. Material Substitution		105,000
Total First Year Cost	$2,025,654	$409,980

Storage

1.	Exhaust and enclose 8 silos.	$125,040	12,800
2.	Enclose and elevate 6 open storage bins.	174,000	13,200
3.	Install 300 feet of conveyor to feed bin.	120,000	9,000
4.	Cover and exhaust 10 open shuttle drop points on bin floor.	153,620	12,500
5.	Enclose and exhaust 8 open bins.		

Batching

1.	Install tote bin system to replace current design.	109,850	4,600
2.	Rework 2 skiphoists feeding specialties mixer and hand mold mixer.	110,304	11,600

Mixing

1.	Cover stiff mud batch pan fed by Larry Car.	39,030	4,163
2.	Cover wet pan fed by Larry car.	39,030	4,163
3.	Rework specialties mixer.	39,030	4,163
4.	Rework wet mixer in hand mold department.	39,030	4,163

Forming - None

Firing

1.	Material substitution or more frequent replacement of setting sand.		105,000

APPENDIX E

QUESTIONNAIRE

The following questionnaire was employed to collect input information regarding current financial statuses and operating conditions of individual plants within the refractores industry.

Table D-2

MODEL INCOME STATEMENT

SMALL BULK PLANT

Production: 15,000 TPY

Sales:	$2,000,000	$1,750,000
Plant Book Value:	$1,000,000	$750,000

		Marginal Plant
Sales	100	100
Cost Goods Sold		
Direct Wages	27	33
Materials/Supplies	40	45
Depreciation	2	1
Workers Comp.	1	2
Other Plant Expenses	10	14
Total Cost Goods Sold	80	95
Gross Margin	20	5
Selling, G&A	12	10
Interest	0	0
Profit Before Tax	8	(5)
Profit After Tax	4	(3)

APPENDIX D

FINANCIAL STATEMENTS

The individual pro-forma financial statements developed from the questionnaire survey data, and other sources including ~~annual reports~~ are presented in the following tables. Both balance sheets and income statements were developed to evaluate the current financial health of the industry at a point in time and its ability to finance compliance activities based upon current cost position.

employer must inform these employees of the hazards of the silica exposure, of the information contained in the OSHA standard, of emergency procedures, of the purpose, proper use, and the limitations of any personal protective equipment,and the operations which could result in a substance exposure in, at, or above the action level. A copy of the regulation and the appendices must be made available to all exposed employees.

The cost of training can be summarized as follows:

Preparation cost: 4 hours per facility at $20 per hour to gather and prepare the information necessary for the training program	$80 per facility
Cost of materials: Copy of the regulation and appendices at $0.10 per page, 5 pages	.50 per employee
Training costs: To train 20 employees at each facility requires 1 hour of trainer's time at $20	20 per class
Plus 1 hour of each employee's time at $14 per hour	14 per employee

Total Training Cost Per Facility = 80 + 20 x # classes + 14.50 x Total Employees
where number of classes = Total Employees/20

6. Recordkeeping

The contemplated regulation requires that the employer keep records concerning exposure determinations and measurements, mechanical ventilation measurements, training, and medical surveillance.

The first three of these four record systems will be maintained for each facility. Recordkeeping will require intermittent one-line up-dates and can be maintained by a clerk expanding two hours each year at $8 per hour. The total cost each year for the facility-specific

The labor costs associated with conducting the measurements can be summarized as follows:

Measurement at L points, 4 times per year 15 minutes per measurement @ $10 per hour plus 100% overhead	$ 20 L

3. Signs and Labels

The proposed regulation requires that certain signs be placed at entrances and access ways to areas where employees may be exposed to silica in excess of the action level, and other signs must be placed in any work area where employees may be exposed in excess of the action level. The cost of a metal sign containing three lines and ten words is needed per facility, the total cost is $67.50 per facility for the required signs (first year only).

The new regulation also requires that precautionary labels be applied to all containers, packages, or equipment containing free silica. As a minimum, these labels must contain the word "warning" or "caution", and a warning against being exposed to silica through inhalation.

4. Medical Surveillance

Where employees are exposed to free silica above the action level, medical surveillance is required prior to employee placement and at least once every three years thereafter. A medical history will be required and a physical examination will be called for including specified tests or organ system examinations.

Monitoring equipment	450
Calibration	10
Initial determination	112 E + 56
Total Exposure Measurement	450 + 112 E + 66

(b) Recurring costs

Facilities are not required to monitor employee exposures below the action level. Recurring monitoring costs for employees below the action level is zero.

(2) Initially Above the Action Level

(a) First-year costs

The employer purchases monitoring equipment, calibrates the monitoring equipment, makes an initial measurement and then follow-up measurements during the first year. The costs for these activities are as follows:

Monitoring equipment	450
Calibration (4 times)	40
Initial measurement	112 E + 56
Follow-up measurements	3 [112 E above + 56]
Total Cost Exposure =	450 + 4 [112 E + 66]

(b) Recurring costs

The employer is required to monitor employee exposures above the action level on a monthly basis until such time as the employee exposure is reduced below the recommended standard. The costs for this where

E = (Number of workers x .5) ÷ Number of shifts

1.4 Follow-up Measurement

Follow-up measurements must be performed if the first measurements reveal that employees are exposed to concentrations at or above the action level. If an employee's exposure is determined to be at or above the action level but below the permissible exposure limit, follow-up measurements must be performed at least biannually. The cost per facility for each follow-up is the same as above except that the follow-up measurements are required only for that portion of the sample above the action level:

Sample labor		40 E above + 20
Sample collector		2 E above + 1
Sample analysis		70 E above + 35
Cost of Follow-Up Measurement	=	112 E above + 56

1.5 Calibration

In order to carry out the initial exposure measurements and the follow-up measurements, sampling pumps must be calibrated periodically. This typically is done by the person engaged in sampling, and each calibration takes 30 minutes at $20 per hour. At each facility, the pump will be calibrated once at the time of initial exposure measurements and once at the time of each of the N follow-up measurements. The total cost for calibration is $10 (N + 1) per facility.

Calibration Labor Cost Per Facility $10 (N + 1) measure the exposure level of that employee most likely to have the greatest exposure at each operation for which a positive determination has been made.

Measurements must be performed so that the sampled employee's actual exposure averaged over an 8-hour shift can be determined. This is best done using personal sampling devices which collect samples from the employee's breathing zone. Such devices normally consist of a sample collection device (filter cassette) worn at the lapel and connected by flexible tubing to a calibrated sampling pump normally worn on the belt.

While there are a variety of pumps available, they generally are priced between $300 and $400. The following pump and calibration kit are representative of those available.

Pump, Bendix, Model BDX-44 ($310) and charger ($40)	$350.00	
Calibration kit ($98), including bubble meter, tubing, stopwatch	100.00	
Total Equipment Cost Per Facility	$450.00	(2)

These relatively small costs will be "expensed" in the year of their purchase, thus yielding a cost of $450 per facility in the first year.

- Filter Sampling for Particulates

The procedure most commonly employed in NIOSH methods for collection and analysis of particulates involves sample collection in a 37-mm filter cassette using a membrane filter supported by a cellulose

APPENDIX C

OTHER OSHA COMPLIANCE COSTS

This Appendix presents a generalized methodology developed by ADL to assess the OSHA compliance costs for any occupational health regulation. In this instance it was applied for crystallize silica to estimate the costs of compliance for the proposed regulation. These formulations reflect a computational procedure developed to evaluate compliance costs for situations where more than one contaminant is found in the occupational environment. However, the methodology is directly applicable to the assessment of the complaince costs associated with the silica regulation.

Operating and Maintenance Costs

General	$ 1,000
Ventilation	4,800
Total Operating and Maintenance Costs	$ 5,800

12d. SKIPHOIST OPERATIONS

Dust generation during skiphoist operation is difficult to control particularly at the loading and dumping stations. Many of the dust collection systems presently installed do not have adequate capture velocities and often during charging the frontend loader interferes with the dust capture mechanism. Compared with enclosed bucket elevators or pneumatic systems, skiphoists present a more difficult problem in terms of dust control but they do provide greater control during the formulation of the batch.

If it is determined that a skiphoist operation is essential from a production standpoint then the path of travel of the hoist should be completely enclosed with braced and supported sheet metal with removeable panels for maintenance. The charge point should be exhaust ventilated using the existing dust collection system with replacement or reworking of the exhaust ducting.

Capital Costs

Skiphoist Enclosure	\$ 6,468
Angle Iron Framing	2,000
Dust Collection (3000 cfm)	24,000
Ducting	9,000
Materials and Equipment Cost	\$41,468
Engineering Cost	13,684
Total Capital Cost	\$55,152

12c. BUCKET ELEVATOR

Although bucket elevators are not generally considered to be sources of dust generation many have leaking seals and missing panels. Dust can also be a problem during material feed and discharge. With proper maintenance bucket elevators provide an efficient mechanism for the vertical transfer of materials. In some cases skiphoists will be replaced by bucket elevators which will also be installed as a loading mechanism for new storage facilities. For bucket elevators currently in place a typical reworking operation will include 40 hours of welding of broken seams and holes and installation of 1000 cfm of dust collection at the discharge.

- Rework Elevator

Capital Costs	
Contractor welding	$ 800
Dust Collection (1000 cfm)	8,000
Ducting	3,000
Materials and Equipment	$11,800
Engineering	3,894
Total Capital Cost	$15,694
Operating and Maintenance Costs	
General	$ 0
Dust Collection System	1,600
Total Operating and Maintenance Costs	$1,600

12b. PNEUMATIC CONVEYOR SYSTEMS

Pneumatic conveyor systems provide the most effective engineering control of dust generation during material handling. This system is most useful over distances greater than 50 feet and for material of 100-mesh or smaller particle size. Although pneumatic systems are clean they are also expensive. Elbows, in particular, are subject to the abrasive action of the raw material. The pneumatic systems proposed in this section are for illustrative purposes only. The exact specifications will vary widely depending upon the specific plant layout.

- <u>Pneumatic Transfer System 125 hp/30 tph</u>

<u>Capital Cost</u>

Pneumatic Unloader	$ 80,000
Airconveyor with Piping	30,000
Equipment and Materials	$110,000
Engineering Cost	36,300
Total Capital Cost	$146,300
<u>Operating and Maintenance Cost</u>	14,630

Capital Costs

Disconnect and remove press	$ 6,000
Press Foundation	25,000
Collection Hopper	1,000
Inclined Belt Conveyor	5,400
30' Bucket Elevator 8" x 12"	18,000
Reposition and Reinstall Press	10,000
Recrusher System	6,000
Press Dust Collection	56,000
Materials and Equipment	$127,400
Engineering	42,042
Total Capital Costs	$169,442/press

Operating and Maintenance Costs

General	$ 3,000
Dust Collection	12,800
Total Operating and Maintenance Costs	$ 15,800

Capital Costs	
Crossley Press	$300,000*
Dust Collection (7000 cfm)	56,000
Ducting	21,000
Equipment and Material	$377,000
Engineering	124,000
Total Capital Costs	$501,000
Operating and Maintenance Costs	
General	$ 30,000
Ventilation	11,200
Total Operating and Ventilation Costs	$ 41,200

*This cost represents a completely outfitted press and lower priced models may be available. Also, other presses may be appropriate and individual designs should be selected based upon the needs of each specific operation.

36" Covered Belt Conveyor (suspended)

Capital Cost

Materials and Equipment	$500/ft
Engineering Cost	$167/ft
Total Capital Cost	$667/ft

Operating and Maintenance Cost	$ 50/ft

36" Covered Belt Conveyor (gallery)

Capital Cost

Materials and Equipment	$1000/ft
Engineering Cost	333/ft
Total Capital Cost	$1333/ft

Operating and Maintenance Cost	$ 100/ft

36" Belt Conveyor Covers

Capital Cost

Materials and Equipment	$ 40/ft
Engineering Cost	$ 13/ft
Total Capital Cost	$ 53/ft

11. SACKING MACHINES

Sacking of refractory materials is a dusty operation which is difficult to control with local exhaust ventilation. The typical machine ~~leaks~~ dust from cracked seams and shaft seals. During the filling operation dust leaks from the fill nozzle and excess material spills on the floor. On occasion sacks break during the filling process and spill their contents on the floor. Local exhaust at the nozzle can control some of the dust at the nozzle but inadequate capture velocity limits its effectiveness. A large part of the control problem is the necessity for frequent maintenance and adjustment of the loading mechanism. This should be accompanied by frequent clean-up of spilled material.

Capital Costs

Rework Sacker	$ 800
Dust Collection (2500 cfm*)	20,000
Ducting	7,500
Materials and Equipment	$28,300
Engineering	9,300
Total Capital Costs	$37,600

Operating and Maintenance Costs

General	$ 80
Ventilation	4,000
Total Operating and Maintenance Costs	$ 4,080

*2500 cfm/2 tube sacker

a) Communal System

In this recycling system excess material pushed from the front of the press platen is manually loaded through a grated opening onto a trenched conveyor. This conveyor collects material along the line of presses and discharges to a communal trenched conveyor which runs to a central bucket elevator. The excess material is elevated and recycled back to the mixer. For analytical purposes system costs such as trenching, lining and conveyors have been allocated on a per press basis. This procedure assumes that such a system would not be applicable to plants with limited pressing capacities and that with larger operations the communal equipment might be expanded.

Capital Cost per Press

Manual trenching and dressing	$ 500	
Gunnite lining of trench sides and bottom	1,000	
Belt conveyor installations	7,500	
30-foot 8" x 12" Bucket Elevator	2,000	550 x 30 =
1/4" Trench Cover Plates	750	
Press Enclosure	16,250	
Dust Collection	56,000	
Engineering	27,720	
Total Capital Cost	$111,720/press	

Batching		
1. Modify current use of weigh scale buckets and conveyors to include provision for Larry Car System using 2 cars with one held in reserve.	$168,600	$ 5,500
Mixing		
1. Enclose and exhaust 5 mixers feeding the press lines.	185,150	20,815
Forming		
1. Rework 10 presses to install recycle system to collect spilled materials.	1,744,420	158,000
Firing		
1. Material substitute or more frequent replacement of setting sand.		312,500
Finishing		
1. Rework 2 grinding machines to reduce dust release during finishing.	63,000	6,800
General Maintenance		
1. Initial plant clean-up.		54,000
Demolition	340,000	
Electrical		
1. Initial construction of electrical transformers.	20,000	753,923

II. RECURRING COSTS	Capital	Annual Operating Costs
A. Annual Operating & Maintenance		439,715
B. OSHA Activities		137,100
C. Material Substitution		312,100
Total Recurring Cost		$889,315

PLANT DESCRIPTION

SILICA BRICK PLANT

Raw Materials

Iron oxide, calcium nitrate, lime, alumina, magnesia, bats, calcium oxide, titanium dioxide, gannister.

Range of Products

Silica brick and custom shapes.

Production Flow

- Raw Materials Receipt and Storage

Raw materials are received by truck and rail with unclassified materials stored in open stockpiles and purchased classified materials conveyed directly to storage.

- Crushing, Grinding and Screening

Raw materials are fed to the crusher via a dump truck and the product is conveyed to intermediate storage facilities. Portions of the material from open stockpiles may be passed through a rotary kiln for drying purposes prior to crushing. Crushed materials are fed to grinding and screening operations to achieve further size reduction and are discharged into classified material storage bins. Oversized material is recycled to the grinder to maintain uniformity of product characteristics.

The discharge from the crusher is transferred via open conveyor to the primary storage areas where dust is generated during the filling of open storage bins. Additional sources of dust generation relate to the secondary grinding and vibratory screening to further ~~classify~~ the raw materials. The screens are also operated with their covers removed which produces significant levels of dust. All intermediate material transfers are conducted via open conveyor including those shuttle conveyors employed to load individual storage bins. Storage bins have poor fitting covers and dust escapes from the bins during the filling operation.

Dry materials are drawn from storage and batched on a conveyor. Dust is generated at each of the conveyor drop points and problems are complicated because mixer access doors are left open during the feeding operation. The uncontrolled mixing operations are a continual source of dust generation until the mix achieves a water content of approximately 7% by weight.

The mixed materials are transferred via conveyor to the press storage bins. Dust is generated when the wet materials drop from the conveyor, dry and become entrained. The press feeder bins discharge via gravity flow measured quantities of raw material to the press. Dust is generated both from the uncovered feeder bins and from the accumulations of excess feed material in the front and rear of the press. This material dries and becomes suspended as a result of drafts and physical disturbances associated with pedestrian and vehicular traffic.

COST OF COMPLIANCE

SILICA BRICK

I. Engineering	Capital	Annual Operating Cost
Raw Materials Receipt and Storage		
1. Install covered storage and enclose FEL	$360,000	$ --
2. Install 135 feet of covered and exhausted conveyor	54,000	4,050
3. Exhaust 6 internal points	92,172	7,500
4. Enclose front-end loader	4,000	
Crushing		
1. Rework crusher	58,810	6,104
2. Install 120 ft of suspended conveyor with 4 exhaust points	80,040 61,448	6,000 5,000
Dryer		
None		
Grinding		
1. Cover and exhaust 7 grinders	273,210	29,141
Storage		
1. Cover and exhaust 7 bins	202,524	15,400
2. Cover and exhaust batching conveyor 120 feet of 36 inch belt	61,448	5,000
Screening		
1. Rework 6 units	228,180	23,154
2. Install solid screen floor	72,000	--
Batching /Mixing		
1. Cover and exhaust 420 feet of conveyor and 14 exhaust points	215,068	17,500
2. Cover and exhaust 9 wet pan mixers.	273,210	29,141

SUMMARY COST OF COMPLIANCE

SILICA BRICK PLANT

I. FIRST YEAR COST	Equipment	Annual Operating Costs
A. Engineering Controls		
1. Raw Materials Receipt	$510,172	11,550
2. Crushing, Grinding Screening	773,688	69,399
3. Storage	263,972	20,400
4. Batching and Mixing	488,278	46,641
5. Forming, Firing, Finishing	97,750	28,370
6. Packaging		
7. General Maintenance		
8. Demolition	143,570	
Total Engineering Controls	$2,280,430	$176,360
B. Plant Clean-Up		
1. Initial		27,000
2. Annual		40,000
C. OSHA Activities		79,040
D. Material Substitution		
Total First Year Cost	$2,280,430	$427,400

VOLUME II

IMPACT OF AN OSHA REGULATION FOR CRYSTALLINE SILICA UPON THE REFRACTORIES INDUSTRY

To

THE REFRACTORIES INSTITUTE
Pittsburgh, Pennsylvania 15222

Submitted by

ARTHUR D. LITTLE, INC.
Cambridge, Massachusetts 02140

C-80884

August 1, 1978

APPENDIX B

COMPLIANCE COSTS

APPENDIX B

TABLE OF CONTENTS

		Page
COMPLIANCE COSTS		B-2
UNIT COSTS		B-3
COMPOSITE COSTS		B-7
1.	Raw Material Storage	B-7
2.	Primary Crushing	B-8
3.	Grinding and Mixing Pans	B-11
4.	Screening	B-12
5.	Storage of Sized Materials	B-16
	a. Bin Enclosures	B-16
	b. Silo Storage	B-19
6.	Tote Bins	B-23
7.	Larry Cars	B-25
8.	Automatic Sack Breaker	B-27
9.	Press Modifications	B-30
10.	Finish Grinding	B-39
11.	Sacking Machines	B-40
12.	Conveying	B-41
	a. Belt Conveyors	B-41
	b. Pneumatic Systems	B-44
	c. Bucket Elevators	B-46
	d. Skiphoist	B-48
	e. Screw Conveyors	B-50
	f. Drop Point Enclosures	B-51

UNIT COSTS

APPLICATION	COST
36" BELT CONVEYORS	
Floor mounted	$ 300/ft
Suspended	500/ft
Suspended with gallery	1000/ft
9" SCREW CONVEYORS	
First 10' with motor and drives	$2500 } + 25%
Additional	100/ft } + 25%
Use	250/ft
PNEUMATIC SYSTEMS - 10-30 TON/HR	
Equipment (pumps, compressor, piping controls)	$10,000-$15,000/Tons/hr
Maintenance	$ .20/Ton/hr
Power	$ .15/Ton/hr
BUCKET ELEVATORS (8" x 12")	
Equipment: Head, Boot, Terminal ends, Drive	$550/ft
SCREENS	
Double deck 4 x 12, 20 tons/hr	$2500/ton
Scalper 150 ton/hr	51,000
Exhaust	27,000

LARRY CAR

Dust tight car with local exhaust, bottom discharge	$50,000/car

PRESS MODIFICATIONS

Vacuum system	$ 33,250
Recycle system	$170,000
New press	$365,000

DUST COLLECTION SYSTEM

Collectors	$8/cfm
Ducts	$3/cfm
Operating	$.10/1000 cfm/hr
Maintenance	$1/cfm/yr

VACUUM SYSTEMS FOR MAINTENANCE*

50 hp, 5 ton/hr	$25,000
Piping	$ 5,000

CONVEYOR COVERS

Duct replacement

8"	$30/ft
4"	$12/ft

MATERIAL HANDLING VALUES

Butterfly	$ 800/valve
Rotary	$2300/valve

---

*Good for 150' diameter coverage

COMPOSITE COSTS

1. RAW MATERIAL STORAGE

In most medium and large refractory plants raw material is delivered directly from mines and stored in open stockpiles prior to crushing. Because of the coarseness of the material and the costs of material handling it is impractical to use a totally enclosed storage system. However, dust generation from the stockpiles does contribute to ambient dust concentrations and some control is warranted. In order to reduce dust levels, raw materials should be stored under cover on a 9-inch concrete pad 80' x 400'. Movable partitions within the storage building should be provided to prevent cross-contamination of materials.

Capital Costs

Reinforced Concrete Floor	$300,000
Structural Steel	100,000
Corrugated Roofing	120,000
Portable Dividers	10,000
Materials and Equipment	$530,000
Engineering Cost	53,000
Total Capital Cost	$583,000

1) Control Booth

The crusher operator should be provided with a dust-tight booth from which he can observe and control the crushing operation.

Capital Costs

Concrete Foundation	$2,340
Control Booth: Acoustical	5,000
Materials and Equipment	7,340
Engineering	1,650
Total Capital Cost	$7,990

Operating and Maintenance Costs

General	$ 772

2) Hopper Vibrator

For those cases where the flow of material in the crusher hopper becomes restricted, hopper vibrators should be installed. Manual operations are not only unsafe but also lead to excessive exposures to silica dust. The feeder hopper should be modified to increase the angle of repose of the hopper sides.

Capital Costs

Modifications to Feeder Hopper	$ 1,000
Installation of Hopper Vibrators	1,700
Acoustical Control Booth	5,000
Concrete Foundation	2,340
Materials and Equipment	$10,040
Engineering	1,650
Total Capital Cost	$11,690

3. GRINDING AND MIXING PANS

Grinding and mixing pans are found in several sizes with various combinations and conditions of enclosures, seals, access doors and ventilation systems. In general, they are in poor repair and even enclosed systems have numerous holes and broken seams from which dust escapes. Costs for dust control will vary depending upon the availability of pre-existing dust collection capacity and the degree of effort required to make the pan dust-tight. Production interruptions will occur when the mixing pans are reworked.

Capital Costs	
Full Pan Enclosure	$ 1,500
Dust Collection System (2500 cfm*)	27,500
Door Gasket and Interlock	130
Materials and Equipment	29,130
Engineering	9,900
Total Capital Cost	$39,030
Operating and Maintenance Costs	
General	$ 163
Dust Collection	4,000
Total Operating and Maintenance Costs	$ 4,163

*Assumes no exhaust provided. If exhaust is provided it should be incremented to 2500 cfm.

The most effective control involves fully covered and exhausted screens with individual screens separated from the general plant and each other through a dust-proof enclosure. The enclosure must, however, be of ample size to permit full service of the screening unit, including adequate room to change the screens.

Capital Costs (Per Screen)

Screen Enclosure	$ 6,344
Dust Collection (2000 cfm)	16,000
Ducting	6,000
Screen Cover	250
Equipment and Materials	$28,594
Engineering Costs	9,436
Total Capital Costs	$38,030

Operating and Maintenance Costs

General	$ 659
Ventilation System	3,200
Total Operating and Maintaining Costs	$ 3,859

B. Flat Deck Screen - 20 Tons/Hr

Capital Costs

Double Deck Screen	$50,000
Dust Collect (2000 cfm)	22,000
Equipment and Materials	$72,000
Engineering	24,000
Total Capital Costs	$96,000

Operating and Maintenance Costs

General	$ 5,000
Ventilation System	3,200
Total Operating and Maintenance Costs	$ 8,200

Covered Screw Conveyor	2,000
Covered Belt Conveyor	4,080
Weigh Plate	500
Materials and Equipment	$21,754
Engineering Cost	7,178
Total Capital Cost	$28,932

Operating and Maintenance Cost

General	$ 600
Dust Collection	1,600
Total Operating and Maintenance Cost	$ 2,200

- Steel Bin Enclosures (conveyor transfer)

Capital Cost

Dust Collection (1000 cfm)	$ 8,000
Ducting	3,000
Bin Enclosure	1,000
Covered Screw Conveyor	2,000
Covered Belt Conveyor	4,080
Materials and Equipment	$18,080
Engineering Cost	4,151
Total Capital Cost	$22,231

5b. SILO STORAGE

The storage of classified materials in open bins and stockpiles leads to dust generation and exposures during material handling operations. This is also a source of contamination for other plant areas because of the tendency for airborne dust to circulate. The preferred system includes an enclosed silo with a covered conveyor or bucket elevator feed and an enclosed discharge to the grinding and screening areas. Steel silos are supported by structural steel members mounted on individually reinforced concrete footings. Additional bracing steel trusses may be necessary to ensure adequate latitudinal support. The dimensions and capacity of the silos will vary depending upon the amounts and varieties of materials to be stored. As a general rule a storage silo for classified material should not exceed 6 feet in diameter. In situations where raw material is wet provisions should be made for rotary drying before storage

- Silo Costs

Bulk storage of unclassified material is to be maintained in ~~12~~ feet diameter silos with capital costs of $175/ton for capacities of 350-500 tons. For silos of 50-350 tons capacity, the cost is $250/ton. Classified materials will be stored in silos of up to 50 ton capacity but restricted to 6 feet diameter. Capital costs are $400 per ton of capacity. In all cases, foundation costs are 25% of silo costs.

- Silo Loading

Depending upon the plant layout and the material being handled, a silo may be loaded by a covered inclined conveyor, by an enclosed bucket elevator, by a combination of conveyors and bucket elevators or by a pneumatic system.

36" Covered Conveyor-floor mounted	$300/ft
Engineering Cost	100/ft
	$400/ft
Operating and Maintenance Cost	$ 30/ft
36" Covered Conveyor - suspended	$500/ft
Engineering Cost	167/ft
	$667/ft
Operating and Maintenance Cost	$ 50/ft
36" Gallery Covered Conveyor	$1000/ft
Engineering Cost	333/ft
	$1,333/ft
Operating and Maintenance Cost	$ 100/ft
8" x 12" Enclosed Bucket Elevator	$ 550/ft
Engineering Cost	180/ft
	$ 730/ft
Operating and Maintenance Cost	$ 55/ft

6. TOTE BINS

Many batching systems utilize portable tote bins to collect materials from several sources including silos, bins and bag breaking stations. Tote bins can have open tops or narrow mouths and may discharge from the bottom or tip into the receptacle (e.g., skiphoist or mixer). In some cases the entire tote bin is loaded into the skiphoist and elevated to the mixing location. Although considerable variety exists in tote bin material handling systems, most generate excessive amounts of dust. Enclosed and ventilated systems are recommended for all material handling operations. The composite cost presented below are for a ventilated station where four tote bins (mounted on a weigh station) discharge material via covered screw conveyors to a weigh hopper which in turn is used to feed known amounts of material to a mixer.

Capital Cost

Tote Bins	$ 4,000
Weigh Station	30,000
Dust Collection (1000 cfm)	8,000
Ducting	3,000
Equipment and Materials	$45,000
Engineering Cost	14,850
Total Capital Cost	$59,850

7. LARRY CARS

Batch handling of sized raw materials from storage bins often requires use of a ventilated larry car which is manually propelled or powered on rails below the bin feeders. Batches are drawn by weight or volume and transferred to mixers. Although the cars are usually ventilated, the drop point from the bin feeder to the car is open and the exhaust capacity is not sufficient to control all of the dust emissions.

In some cases it may be possible to retrofit the present larry cars to provide for a dust-tight connection between the valve in the hopper discharge and the inlet to the larry car. There is some concern regarding the efficacy of this retrofit operation and in many situations the only alternative is to purchase new larry cars which are designed specifically to insure that dust-tight and ventilated connections are maintained during the batching operation.

Capital Costs	
Retrofit of Existing Car	$ 3,000
Ventilation (1000 cfm)	8,000
Ducting	3,000
Equipment and Material	$14,000
Engineering	4,620
Total Capital Costs	$18,620
Operating and Maintenance Costs	
General	$ 300
Ventilation	$ 1,600
Total Operating and Maintenance Costs	$ 1,900

8. AUTOMATIC SACK BREAKING STATIONS

Whenever sack breaking occurs there is considerable material spillage and dust generation. Ventilated sack breaking stations can limit the amount of dust generation, however, the capture velocities are insufficient to adequately control the dust. Even the most modern manual stations can cause silica exposures in excess of the present standard. An alternative method for handling sacked material would include the installation of ventilated sack breaking machines with enclosed feed to a conveying system or tote bin. These devices have not been employed within the refractories industry because of problems associated with product contamination. An additional advantage of the automatic system is that the optional bag compactor will eliminate dust generated from handling empty bags.

Sack breaking stations should be utilized for those situations where there is a limited amount of variation in the product-mix. For those operations where there would be a continuous run of a single sacked material (equivalent to 15-25 tons) it may be practical to install a sack breaking machine. The large number of single product bags which would be continuously broken can justify the intallation of the automatic sack breaking machine.

It should be mentioned that costs are comparable for the automatic sack breaking machine and the traditional sack breaking station. However, when there are a large number of different sacked products being batched, Capital Costs

Bag Breaking Station Fabrication	$ 5,000
Compactor	9,000
Ventilation (1500 cfm)	12,000
Ducting	4,500
Hopper Discharge	1,000
Conveyor Loader	3,000
Equipment and Material	$34,500
Engineering	11,385
Total Capital Costs	$45,885

Operating and Maintenance Costs

General	$ 1,400
Ventilation	2,100
Total Operating and Maintenance Costs	$ 3,500

Portable Vacuum System (50 hp)

Capital Cost	$25,000
Engineering	8,250
Total Capital Cost	$33,250
Operating and Maintenance Cost	12,500

2) Press Enclosure

In some cases a system currently is in place to collect and dispose/recycle material spillage, but there may still be a dust problem. Where spilled material becomes rapidly airborne it will be preferable to enclose the press except for the working mouth and platen. Because of the necessity to clean and maintain the press, the enclosure must be designed with easily removeable panels. The structure is constructed of medium gauge sheet metal attached to framing with all seams gasketed in a dust-tight manner.

Capital Cost Per Press

Top 338 ft^2 @ $10	$ 3,380
Sides (2) 676 ft^2 @ $10	6,760
Rear Panel 338 ft^2 @ $10	3,380
Partial Front Panel 273 ft^2 @ $10	2,730
Capital Cost	$16,250
Engineering	5,363
Total Capital Cost	$21,613/press
Operating and Maintenance	2,163/press