Refractories Manufacturing NESHAP: Industry Profile, Methodology, and Economic Impact Analysis

Draft Report

Prepared for

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U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Innovative Strategies and Economics Group (MD-15)
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SECTION 1

INTRODUCTION

The U.S. Environmental Protection Agency's (EPA's) Office of Air Quality Planning and Standards (OAQPS) is compiling information on refractory manufacturing plants as part of its responsibility to develop National Emission Standards for Hazardous Air Pollutants (NESHAP) under Section 112 of the 1990 Clean Air Act. The NESHAP is scheduled to be proposed in 2001. This industry profile of the refractory manufacturing industry provides information to support the regulation.

A refractory is a material that retains its shape and chemical identity when subjected to high temperatures and is used in applications that require extreme resistance to heat. Specifically, refractories must be able to withstand temperatures above 538°C (1,000°F). Refractories are mechanically strong and heat resistant to withstand rapid temperature change and corrosion and erosion by molten metal, glass, slag, and hot gas. Refractories are used in kilns, furnaces, boilers, incinerators, and other applications.

Refractory manufacturing falls under the North American Industry Code System (NAICS) 327124 for clay refractories and NAICS 327125 for nonclay refractories. According to the *1997 Census of Manufactures*, 149 establishments owned by 115 companies manufactured clay refractories, and 124 establishments owned by 90 companies manufactured nonclay refractories in 1997 (U.S. Department of Commerce, 1999b, 1999c). In 1998, the refractory industry employed 13,709 people and shipped products valued at over $2.6 billion (U.S. Department of Commerce, 2000).

The primary pollutants in the refractory industry are particulate matter (PM). These emissions occur during the crushing, grinding, screening, calcining, and drying phases of refractory manufacture. Other pollutants include sulfur dioxide (SO_2), nitrogen oxide (NO_x), carbon monoxide (CO), carbon dioxide (CO_2), hydrogen fluoride (HF) and volatile organic compounds (VOCs). The NESHAP will most directly affect facilities that produce organic-bonded products that include resins, pitch, and other organics in addition to refractory materials. The pitch-impregnated refractory manufacturing process is expected to be regulated for polycyclic organic matter (POM) during a thermal processing step.

This industry profile report is organized as follows. Section 2 provides a detailed description of the production process for refractories, with discussion of individual refractory products, inputs, and costs of production. Section 3 describes the characteristics, uses and consumers of refractories, and substitution possibilities. Section 4 discusses the organization of the industry and provides facility- and company-level data. In addition, small businesses are reported separately for use in evaluating the impact on small business to meet the requirements of the Small Business Regulatory Enforcement and Fairness Act (SBREFA). Section 5 contains market-level data on prices and quantities and discusses trends and projections for the industry.

SECTION 2

THE SUPPLY SIDE

Estimating the economic impacts associated with the options to regulate the refractory manufacturing industry requires characterizing the industry. This section describes the production process, inputs, and outputs of this process. In addition, characterizing the supply side of the industry involves describing various types of refractory products, by-products, and input substitution possibilities. This section describes costs of production and economies of scale.

2.1 Production Process, Inputs, and Outputs

The manufacturing process for refractories depends on the particular combination of chemical compounds and minerals used to produce a specified level of thermal stability, corrosion resistance, thermal expansion, and other qualities. Refractory manufacturing involves four processes: raw material processing, forming, firing, and final processing. Figure 2-1a illustrates the basic refractory manufacturing process and Figure 2-1b depicts specific product production processes for various refractory products. The production of refractories begins with processing raw material. Raw material processing involves crushing and grinding raw materials, classifying by size, calcining, and drying. The processed raw materials may then be dry-mixed with other minerals and chemical compounds, packaged, and shipped as product.

Following the mixing process, the raw materials are formed into desired shapes. This process typically occurs under moist or wet conditions. After the refractory is formed, the material is fired. Firing involves heating the refractory material to high temperatures in a periodic batch or continuous tunnel kiln to form a ceramic bond. This process gives the raw materials their refractory properties. The final processing stage includes milling, grinding, and sandblasting the finished product. For some products, final processing may also include impregnation with tar and pitch and product packaging (The Technical Association of Refractories, Japan, 1998).

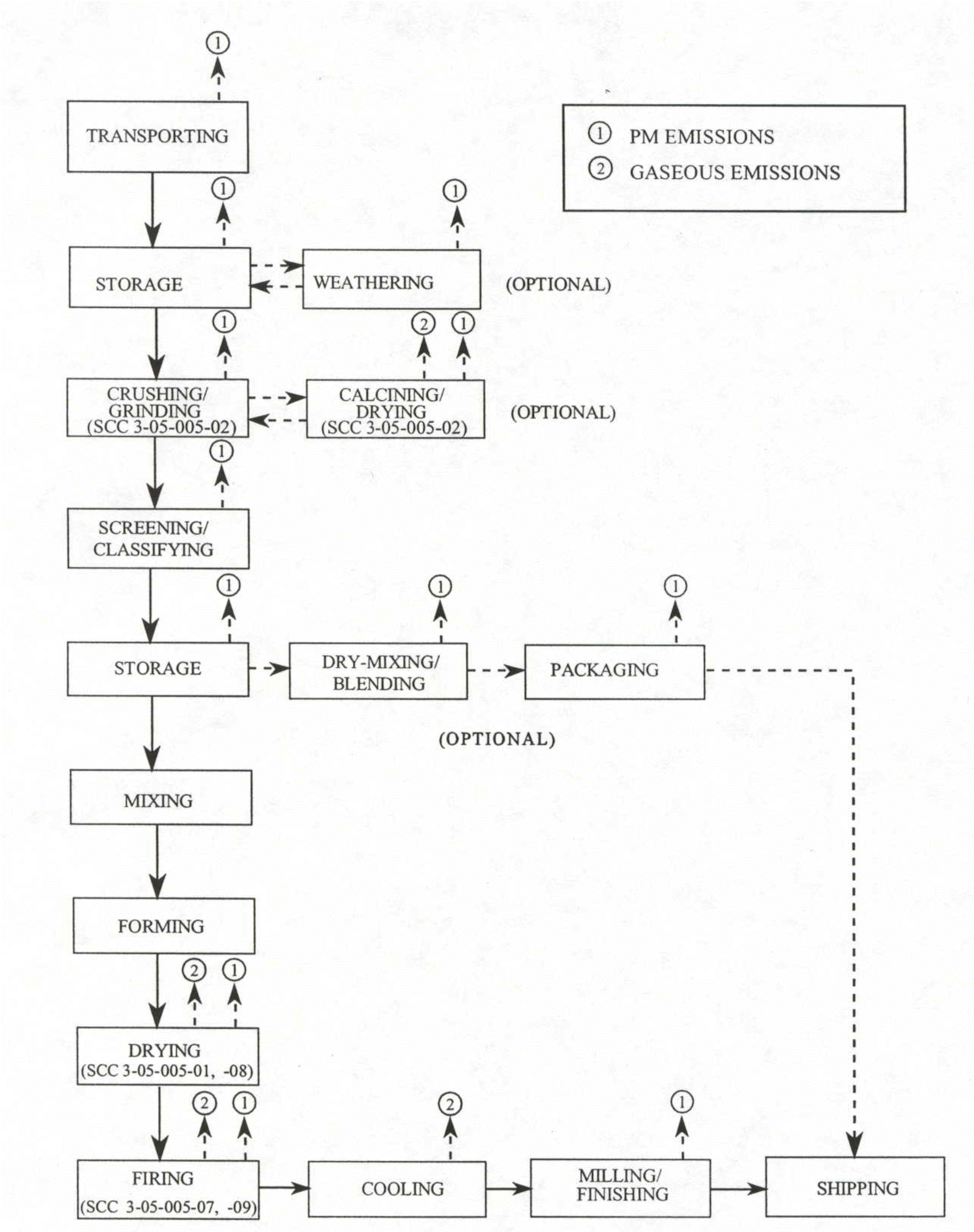


Figure 2-1a. Refractory Manufacturing Process Flow Diagram

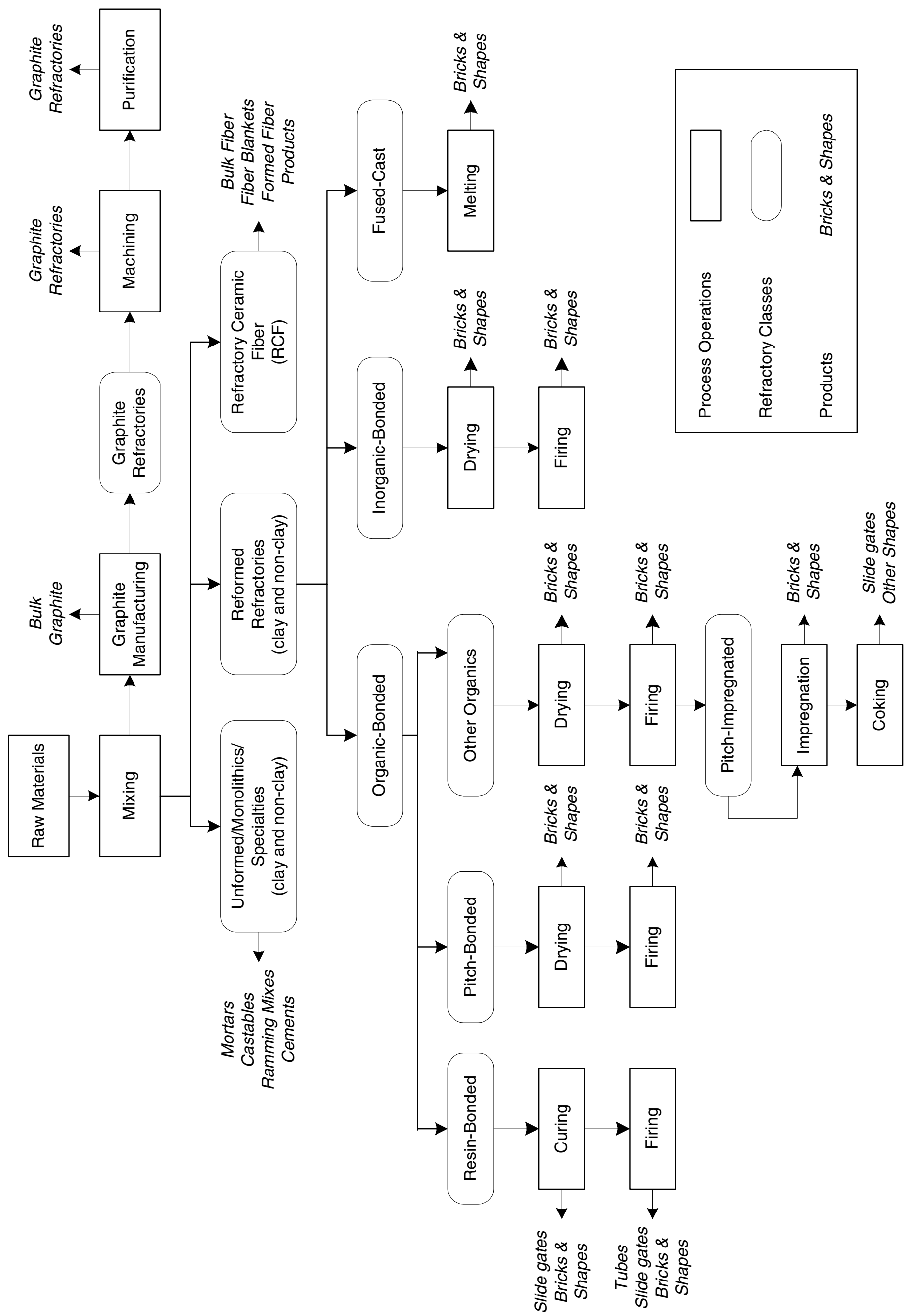


Figure 2-1b. Specific Production Processes

2.1.1 Machines Used in the Production Process

Several types of machines are used to produce refractories: mixing/kneading machines, presses, and kilns.

2.1.1.1 Mixing/Kneading Machines

Figure 2-2 illustrates different machines used to mix or knead refractory products. There are two types of mixing and kneading machines: fixed vessel and driven vessel. Mixing homogenizes more than two types of bulk materials, and kneading machines make a uniform coating layer. Mixing and kneading machines are equipped with mixing blades or muller wheels. Heating, cooling, or de-airing equipment may also be applied to the vessel. Mixing and kneading machines are used for manufacturing shaped and unshaped refractories. Unshaped refractories, however, are not processed any further (The Technical Association of Refractories, Japan, 1998).

2.1.1.2 Presses

Refractory pressing machines are broadly categorized into three groups: impact and static, vibrating, and cold isostatic press. Choosing between the three groups of presses largely depends on the type of raw materials used.

- Impact and Static Presses: Figure 2-3 illustrates a friction and a hydraulic screw press, two types of impact presses. Figure 2-4 is a diagram of a hydraulic screw press, a type of static press. Impact and static presses are typically equipped with a vacuum deaerator. Impact presses have a higher allowable maximum compacting force than static presses. However, static presses are finding increasing application in the production of sophisticated refractories such as submerged nozzles and shrouds and in the production of industrial ceramics. Bricks formed with static presses are flat, uniform and, compact. (The Technical Association of Refractories, Japan, 1998).

- Vibrating Press: Vibrating presses, shown in Figure 2-5, are classified into two types: air cylinder type and hydraulic cylinder. The vibrator in the air cylinder type is attached to the table, and the air cylinder compacts the material. The hydraulic vibrating press is constructed with the hydraulic pulse generator attached to the pressure block, and the hydraulic cylinder compacts the material. Vibrating presses are typically used for the compaction of complexly shaped refractories (The Technical Association of Refractories, Japan, 1998).

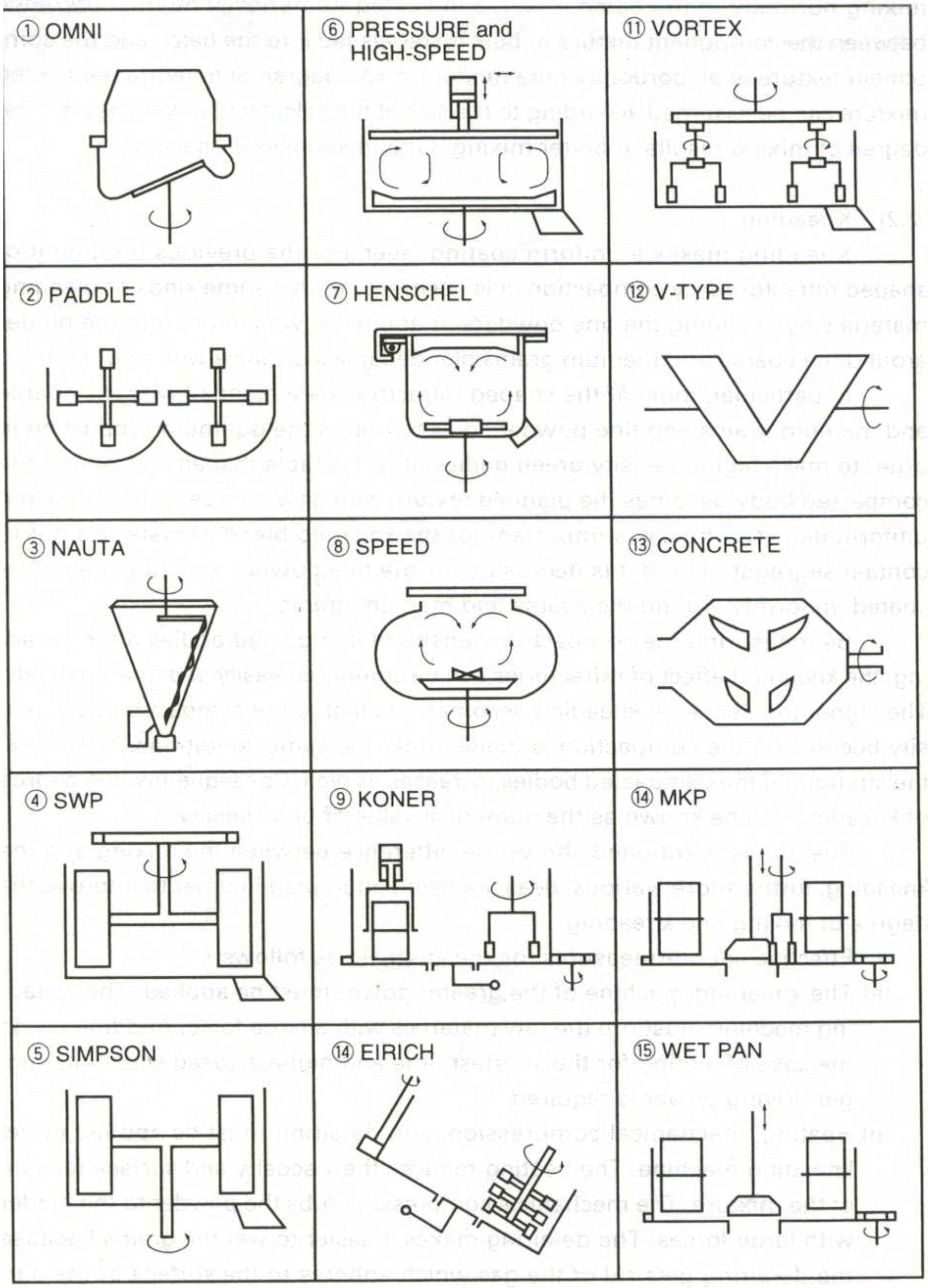


Figure 2-2. Mixing and Kneading Machines

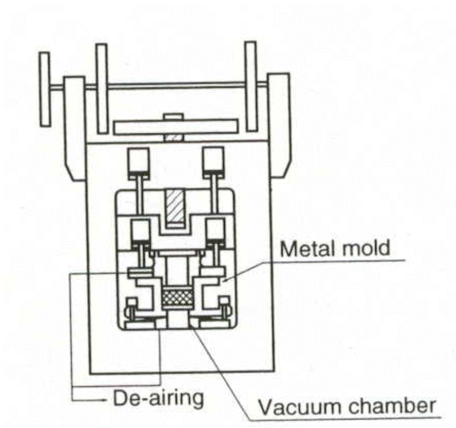


Figure 2-3. Vacuum Press (Friction, Hydraulic Press)

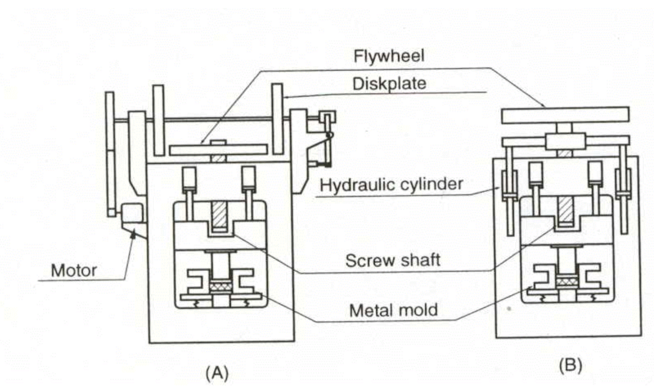


Figure 2-4. Friction Press (A), and Hydraulic Screw Press (B)

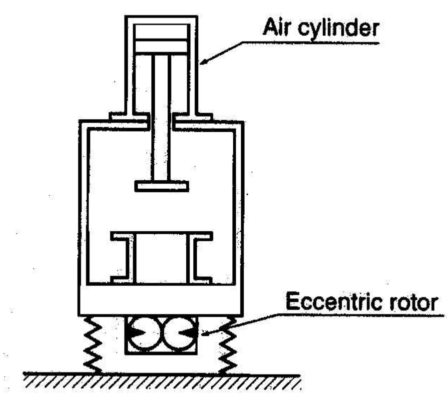


Figure 2-5. Vibrating Press

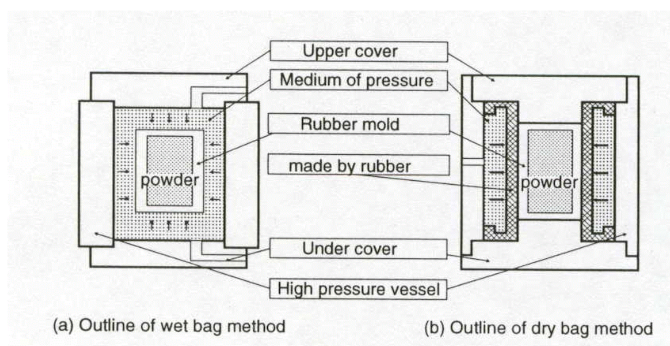


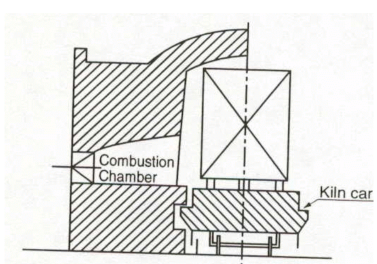
Figure 2-6. Cross Section of CIP

- Cold Isostatic Press (CIP): A CIP, illustrated in Figure 2-6, is a molding device that provides homogeneous hydrostatic pressure over the entire surface of a rubber mold filled with powder. This method, also referred to as a hydrostatic press or a rubber press method, is a materials processing technique in which processing in which high fluid pressure is applied to a powder part at ambinet temperature to compact it into a predetermined shape. The power part is consolidated into a dense compacted shape. Water or oil is usually used as the presser medium. CIPs are based on either the wet bag method, where the mold is placed in pressurized liquid, or the dry bag method, in which the mold does not touch the pressurized liquid. High pressurized molding provides uniform density, which leads to a reduction of internal stresses, eliminating cracks, strains and laminations, the ability to make complex shapes, and to press more than one shape at the same time (The Technical Association of Refractories, Japan, 1998).

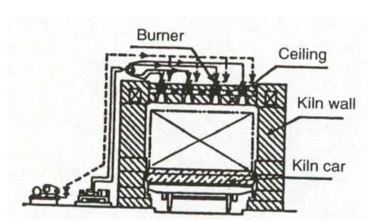
2.1.1.3 Kilns

Refractories are fired to develop the materials' refractory properties. The unfired ("green") refractories pass through a heat treatment, which results in a thermally stable refractory and or crystallization. The industry uses three types of kilns:

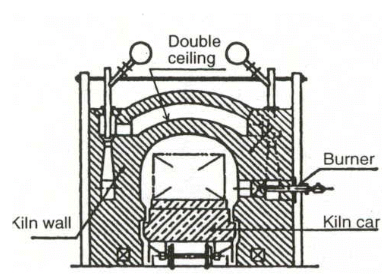
- Tunnel Kiln: In a tunnel kiln, refractory products consecutively pass through preheating, firing, and cooling zones (see Figure 2-7). The combustion gas from the firing zone is typically used to preheat the refractories. Heat can be recovered from cooling fired refractories and reused as combustion air. Approximately 80 percent of shaped refractories are fired in tunnel kilns (The Technical Association of Refractories, Japan, 1998).



Indirect Flame System



Top Combustion System



Side Combustion System

Figure 2-7. Tunnel Kiln

- Round Periodic Kilns: Round periodic kilns are typically used to fire silica bricks. Figure 2-8 is a diagram of a round periodic kiln. These kilns can be used to fire large refractory products that cannot be fired in a tunnel kiln and can easily accommodate changes in production (The Technical Association of Refractories, Japan, 1998).

- Shuttle Kilns: As illustrated in Figure 2-9, the design of a shuttle kiln resembles the firing zone of a tunnel kiln. Shuttle kilns effectively store heat and are used to fire fireclay and specialty bricks (The Technical Association of Refractories, Japan, 1998).

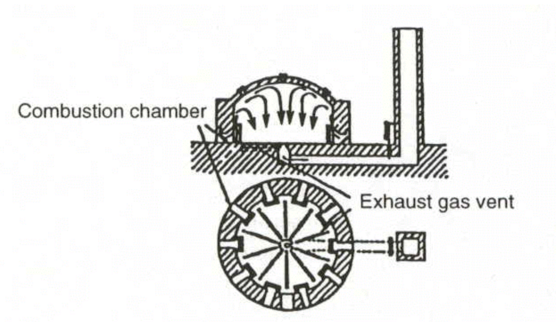


Figure 2-8. Round Kiln with Downdraft System

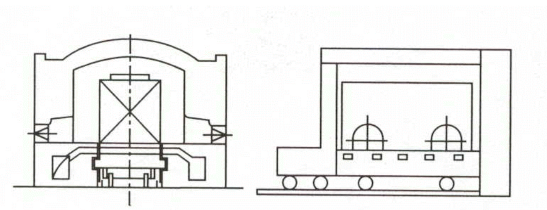


Figure 2-9. Shuttle Kiln

2.1.2 Final Commodities

Refractories are manufactured in two forms—shaped objects and unshaped, and unshaped refractories come in granulated or plastic compositions. Briefly described here, shaped and unshaped refractories are the two broad categories of refractories. Section 2.2 contains more information on the types of refractory products.

2.1.2.1 Shaped Refractories

Preshaped refractories include bricks, shapes, crucibles, and monolithics. Shaped refractories are pre-fired to exhibit their ceramic characteristics. Table 2-1 lists each type of shaped refractory and a description of its use.

Table 2-1. Types and Descriptions of Refractories Produced

Kind	Definition
Shaped Refractories	
Bricks	Refractories that have shapes and are used to line furnaces, kilns, glass tanks, incinerators, etc.
Insulating firebrick	Low thermal conductivity firebrick.
Unshaped Refractories (Monolithic)	
Mortar	Materials for bonding bricks in a lining. The three types of mortar—heat-setting, air-setting, and hydraulic-setting—have different setting mechanisms.
Castables	Refractories for which raw materials and hydraulic-setting cement are mixed. They are formed by casting and used to line furnaces, kilns, etc.
Plastics	Refractories in which raw materials and plastic materials are mixed with water. Plastic refractories are roughly formed, sometimes with chemical additives.
Gunning mixes	Refractories that are sprayed on the surface by a gun.
Ramming mixes	Granular refractories that are strengthened by gunning formulation of a ceramic bond after heating. Ramming mixes have less plasticity and are installed by an air rammer.
Slinger mixes	Refractories installed by a slinger machine.
Patching materials/ coating materials	Refractories with properties similar to refractory mortar. However, patching materials have controlled grain size for easy patching or coating.
Lightweight castables	Refractories in which porous lightweight materials and hydraulic cement are mixed. They are mixed with water and formed by casting. Lightweight castables are used to line furnaces, kilns, etc.
Fibrous Materials	
Ceramic fiber	Man-made fibous refractory materials. There are several different types of ceramic fiber, including blanket, felt, module, vacuum form, rope, loose fiber, etc.

Source: The Technical Association of Refractories, Japan. 1998. *Refractories Handbook*. Tokyo: The Technical Association of Refractories, Japan.

2.1.2.2 Unshaped Refractories

The unshaped products include mortars, gunning mixes, castables (refractory concrete), ramming mixes, and plastics. The manufacture of unshaped refractories differs slightly from shaped refractories. Unshaped refractories typically do not go through a firing process until they reach the final consumer. These unshaped refractories can be installed by spraying, casting, molding, or ramming. Table 2-1 lists each type of refractory and a description of its use.

2.1.3 Emissions and Controls in Refractory Manufacturing

Refractory production leads to emissions of organic particulate matter (PM); metals; and gaseous pollutants, including sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), carbon dioxide (CO_2), fluorides, and volatile organic compounds (VOCs) (EPA, 1994). Emission points are indicated by type of emission in Figure 2-1a.

2.1.3.1 PM and Metals Emissions

PM and metal emissions occur during the crushing, grinding, calcining, and drying of the raw materials; the drying and firing of unfired refractory bricks and tar and pitch operations; and finishing of the refractories. Emissions from crushing and grinding are readily controlled with fabric filters. Product recovery cyclones and wet scrubbers are used on calciners and dryers to reduce PM emissions. Electric arc furnaces are generally controlled by a baghouse.

2.1.3.2 Gaseous and VOC Emissions

As previously mentioned, SO_2, NO_x, CO, CO_2 are produced along with refractory products. The source of most of the SO_2 emissions is the fuel used to fire the kiln and dryers. The composition of the clays and plaster added to refractories and the amount of refractories produced affect the amount of SO_2 produced. VOCs emitted from tar and pitch operations are controlled by incineration.

2.1.4 Inputs

The inputs in the production process for refractories include general inputs, such as labor, capital, and water. The inputs specific to this industry are the type of fuel and the clay or other alumina and nonclay material used. These two specific inputs are discussed below.

Table 2-2. Types and Characteristics of Raw Materials used in Refractory Manufacture Type

Type	Characteristics
Clay Refractories	
Fireclay	Consists of kaolinite ($Al_2O_32SiO_22H_2O$) and minor amount of other clay materials. Fireclay refractories can be low, medium, high, or super-duty based on their resistance to high temperature or refractoriness. Fireclay refractories are used to produce bricks, insulating refractories, and two types of ladle brick.
High-alumina	Composed of bauxite or other raw materials that contain 50 to 87.5 percent alumina. High-alumina refractories are generally multipurpose, offering resistance to chipping and higher volume stability. High-alumina refractories are used to produce brick and insulating refractories.
Nonclay Refractories	
Basic	Produced from a composition of dead-burned magnesite, dolomite, chrome ore, and small amount of other minerals. Basic refractories can be further subdivided into magnesia, dolomite, chrome, and combination bricks. Basic refractories are typically used to make bricks.
Extra-high alumina	Made predominately from bauxite or alumina (Al_2O_3), extra-high alumina refractories contain from 87.5 to 100 percent alumina and offer good volume stability. They are typically poured into special shapes using a fused casting process.
Mullite	Made from kyanite, sillimanite, andalusite, bauxite, or mixtures of alumina silicate materials; mullite refractories are about 70% alumina. They maintain a low level of impurities and high resistance to loading in high temperatures.
Silica	Containing silica, silica refractories are characterized by a high coefficient of thermal expansion between room temperature and 500°C (930°F). Silica brick is available in three grades: super-duty (low alumina and alkali), regular, and coke oven quality. Silica compositions can be used for hot patching, shrouds, and bricks.
Silicon carbide	Produced by the reaction of sand and coke in an electric furnace, silicon carbide refractories are used to make special shapes, such as kiln furniture, to support ceramicware as it is fired in kilns. It has high thermal conductivity, good load bearing characteristics at high temperatures, and good resistance to changes in temperatures.
Zircon	Containing siconium silicate (ZrO_2SiO_2), zircon refractories maintain good volume stability for extended periods or exposure to high temperatures. Zircon refractories are widely used for glass tank construction.

2.1.4.1 Clays

Clay is composed mainly of fine particles of hydrous aluminum silicates and other minerals that is plastic when moist but hard when fired. In 1998, approximately 3.09 Mt of clays were used in the manufacture of refractories. Table 2-2 lists different clays used in refractory products and their characteristics. Fireclay is the predominate clay used infirebrick; bentonite, in foundry sand; common clay, in refractory mortar and cement; and kaolin, in calcine, grog, high alumina brick, kiln furniture, and plug, tap, and wad (Virta, 1998).

2.1.4.2 Nonclays

Nonclay refractories are composed for alumina, mullite, chromite, magnesite, silica, silicon carbide, zircon, and other nonclays. Table 2-2 lists various minerals used in the production of nonclay refractories, the type of refractory produced, and characteristics of the refractory.

2.2 Types of Products

Table 2-1 lists the different forms of refractories and describes them briefly. Refractories are generally categorized as either clay or nonclay products. To further classify the products, refractories are labeled as acidic or basic. Refractories are typically produced as shaped refractories, unshaped refractories, and fibrous materials. Shaped refractories include bricks, shapes, and crucibles. Bricks and shapes are formed by mixing raw materials with water and/or other binders and pressing or molding the mixture into a desired shape.[1] Crucibles are ceramic containers used for melting metal. Unshaped refractories, also called monolithic, are unformed products that are dried to form a unified structure after application. These refractories can be used as mortars, plastics, ramming mixes, castables, and gunning mixes. Monolithic refractories are applied by either pouring, pumping, troweling, or gunning (spraying).

[1]Bricks and shapes can be formed by a variety of methods, including hand molding, air ramming, pressing, extruding, or casting.

2.3 Costs of Production

The costs incurred by refractory manufacturers are labor, materials, and capital. This section provides data on these costs and discusses economies of scale.

2.3.1 Cost Data

Between 1994 and 1998, clay refractory manufactures spent an average of more than 70 percent and nonclay refractory producers almost 64 percent of expenditures on input materials. Figure 2-10 illustrates the percentage breakdown of refractory manufacturing expenditures by refractory type. Tables 2-3 and 2-4 also provide expenditures in dollars for wages, materials, and new capital from 1977 to 1998 in both current and 1997 dollars. Costs of materials include all raw materials, containers, scrap, and supplies used in production, repair, or maintenance during the year, as well as the cost of all electricity and fuel consumed. Costs are included for materials whether they are purchased from outside the company or transferred from within the company. New capital expenditures include permanent additions and alterations to facilities and machinery and equipment used for expanding plant capacity or replacing existing machinery.

These tables show that the cost of materials is by far the greatest cost to refractory producers. Refractory producers spend as much as two and a half times more on materials than they do on labor. For 1998, the Annual Survey of Manufacturers reported that the clay refractory industry spent $31.6 million and the nonclay refractory industry spent $52.7 million on energy, almost 6 and 8 percent, respectively, of the total materials cost for that year. Energy costs for manufacturers of refractory bricks and shapes are generally greater than energy costs for manufacturers of monolithic refractories because of the energy-intensive nature of operations that require using forming equipment, dryers, and kilns. Table 2-5 contains a more detailed breakdown of the costs of materials used in producing and manufacturing refractory materials.

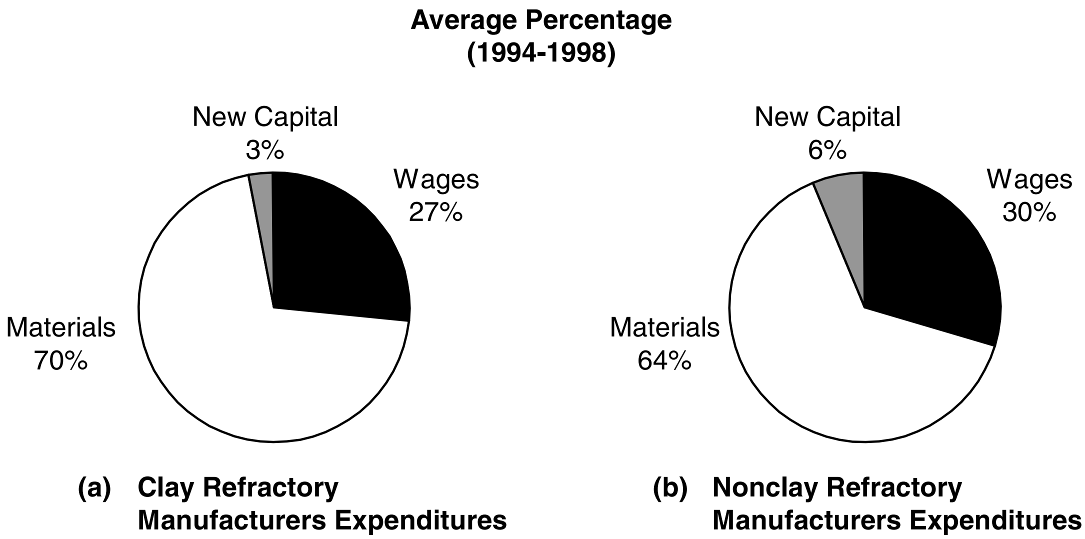


Figure 2-10. Clay and Nonclay Refractory Manufacturers Expenditures

Table 2-3. Labor, Material, and New Capital Expenditures for Clay Refractory Manufacturers (NAICS 327124)[a] ($$10^6$)

	Wages		Materials		New Capital	
Year	Current	1997$	Current	1997	Current	1997
1977	146.8	224.30	296.8	453.48	20.0	30.56
1978	171.8	254.08	364.6	539.21	23.1	34.16
1979	191.5	273.16	384.7	548.74	29.4	41.94
1980	183.6	253.02	363.1	500.39	31.5	43.41
1981	199.6	266.09	410.6	547.37	36.1	48.12
1982	155.2	204.68	339.0	447.07	21.2	27.96
1983	147.1	191.19	358.5	465.94	12.0	15.60
1984	176.6	226.17	438.2	561.20	22.0	28.18
1985	166.8	211.69	397.5	504.47	22.1	28.05
1986	160.4	202.68	412.6	521.36	15.8	19.96
1987	150.2	188.05	387.5	485.15	11.7	14.65
1988	160.0	193.46	401.7	485.70	14.0	16.93
1989	176.7	207.39	451.3	529.69	11.9	13.97
1990	168.8	196.28	475.3	552.68	15.2	17.67
1991	166.0	191.22	464.8	535.40	18.5	21.31
1992	183.8	196.57	452.8	484.27	24.6	26.31
1993	163.9	180.42	377.0	415.00	7.2	7.93
1994	179.0	191.44	494.0	528.33	16.5	17.65
1995	199.0	205.37	510.3	526.63	16.6	17.13
1996	196.4	200.88	510.7	522.34	18.6	19.02
1997	210.0	210.42	566.0	567.13	30.1	30.16
1998	201.8	201.80	536.5	536.50	25.6	25.60

[a] Prices were deflated using the producer price index (PPI) from the Bureau of Labor Statistics. 2001. <http://146.142.4.24/cgi-bin/surveymost>.

Sources: U.S. Department of Commerce, Bureau of the Census. 1994b. *1992 Census of Manufactures, Industry Series—Cement and Structural Clay Products*. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1995. *1993 Annual Survey of Manufactures*. M93(AS)-1. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1996a. *1994 Annual Survey of Manufactures*. M94(AS)-1. Washington, DC: Government Printing Office.
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U.S. Department of Commerce, Bureau of the Census. 1999b. *1997 Census of Manufactures, Industry Series—Manufacturing: Clay Refractory Manufacturing*. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 2000. *1998 Annual Survey of Manufactures*. M98(AS)-1. Washington, DC: Government Printing Office.

Table 2-4. Labor, Material, and New Capital Expenditures for Nonclay Refractory Manufacturers (NAICS 327125)[a] ($$10^6$)

	Wages		Materials		New Capital	
Year	**Current**	**1997**	**Current**	**1997**	**Current**	**1997**
1977	134.3	205.20	336.4	513.99	37.1	56.69
1978	162.7	240.62	434.9	643.17	43.1	63.74
1979	172.5	246.05	434.6	619.91	24.4	34.80
1980	177.4	244.47	482.3	664.66	47.2	65.05
1981	196.5	261.95	484.7	646.15	69.7	92.92
1982	148.4	195.71	343.3	452.74	48.5	63.96
1983	129.5	168.31	312.8	406.55	20.8	27.03
1984	147.5	188.90	347.1	444.53	24.7	31.63
1985	152.0	192.90	369.2	468.55	32.5	41.25
1986	162.7	205.59	372.1	470.19	13.7	17.31
1987	202.5	253.53	443.5	555.26	16.3	20.41
1988	209.6	253.43	470.7	569.12	18.0	21.76
1989	232.6	273.00	480.4	563.85	36.3	42.61
1990	239.9	278.96	499.0	580.24	30.3	35.23
1991	241.3	277.95	500.6	576.64	26.5	30.53
1992	249.2	266.52	541.4	579.03	44.9	48.02
1993	279.3	307.45	578.8	637.14	62.5	68.80
1994	247.6	264.81	562.5	601.59	41.1	43.96
1995	274.9	283.70	588.3	607.13	35.9	37.05
1996	278.6	284.95	574.0	587.09	42.7	43.67
1997	288.4	288.98	621.3	622.54	88.8	88.98
1998	307.1	307.10	650.9	650.90	96.8	96.80

[a] Prices were deflated using the producer price index (PPI) from the Bureau of Labor Statistics. 2001. <http://146.142.4.24/cgi-bin/surveymost>.

Sources: U.S. Department of Commerce, Bureau of the Census. 1994a. *1992 Census of Manufactures, Industry Series—Abrasive, Asbestos, and Miscellaneous Mineral Products*. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1995. *1993 Annual Survey of Manufactures*. M93(AS)-1. Washington, DC: Government Printing Office.
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U.S. Department of Commerce, Bureau of the Census. 1998. *1996 Annual Survey of Manufactures*. M96(AS)-1. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1999c. *1997 Census of Manufactures, Industry Series—Manufacturing: Nonclay Refractory Manufacturing*. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 2000. *1998 Annual Survey of Manufactures*.

Table 2-5. Costs of Materials Used in Refractory Production and Manufacture[a]

Material	1997 Delivered Cost ($\$10^6$)	1997 Percentage of Material Costs	1992 Delivered Cost ($\$10^6$)	1992 Percentage of Material Costs
Clay NAICS 327124				
Materials, ingredients, containers, and supplies	35.2	6.22	26.7	6.55
Clay, ceramic, and refractory minerals	284	50.18	209	51.26
Dead-burned magnesia or magnesite	6.9	1.22	8.4	2.05
Refractories, clay or nonclay	90.8	16.04	79.6	19.52
Other stone, clay, glass, and concrete products	4.4	0.78	5.2	1.28
Industrial chemicals	6.5	1.15	2.2	0.53
All other materials and components, parts, containers, and supplies	65.1	11.50	76.8	18.83
Nonclay NAICS 327125				
Materials, ingredients, containers, and supplies	50.4	8.11	65.4	11.12
Clay, ceramic, and refractory minerals	224.2	36.09	156.2	26.58
Dead-burned magnesia or magnesite	38.7	6.23	59.1	10.05
Refractories, clay or nonclay	NA	NA	65.6	11.16
Other stone, clay, glass, and concrete products	NA	NA	NA	NA
Industrial chemicals	21.4	3.44	21.1	3.58
All other materials and components, parts, containers, and supplies	73.9	11.89	75.3	12.82

NA = Not available.

[a] Prices were deflated using the producer price index (PPI) from the Bureau of Labor Statistics. 2001. <http://146.142.4.24/cgi-bin/srgate>.

Source: U.S. Department of Commerce, Bureau of the Census. 1999b. *1997 Census of Manufactures, Industry Series—Manufacturing: Clay Refractory Manufacturing*. Washington, DC: Government Printing Office.

SECTION 3

THE DEMAND SIDE

Estimating the economic impacts of the regulation on the refractory manufacturing industry requires characterizing various aspects of the demand for refractory products. This section describes the product characteristics decided by end users; the uses for refractories, including use in the glass, metal, and electronics industries; and possible substitutes for refractories.

3.1 Product Characteristics

Because the quality and characteristics of refractories vary considerably, consumers often employ chemical and physical tests to ensure that the refractories purchased meet their requirements. The American Society for Testing and Materials (ASTM) provides specifications and tests for various kinds and uses of refractory products. Depending on the intended end use, consumers may test refractories for thermal conductivity, resistance to abrasion and corrosion, permeability, oxidation resistance, and other characteristics (ASM International, 1987).

Most refractory products are sold as preformed shapes. However, they are also available in special purpose clays; bonding mortars; and monolithic, plastic refractories; ramming mixes; and gunning mixes. A variety of processed refractory grains and powders are also produced (DHAN, 1999). From the physical form, refractory products can be further classified into oxide bricks, nonoxide bricks, and composites. Table 3-1 lists types of oxide, nonoxide, and composite refractories; their characteristics; and their applications.

3.2 Uses and Consumers

Principle end-use markets for refractory products include iron and steel, cement, and nonferrous metal industries. The steel industry consumes the largest percentage of refractories, estimated between 50 and 80 percent of the refractory production (Semler,

Table 3-1. Characteristics and Types of Refractories

Refractory Type	General Characteristics	Application
Oxide Bricks		
Silica	High strength at high temperatures, residual expansion, low specific gravity, high expansion coefficient at low temperatures, low expansion coefficient at high temperatures	Glass tank crown, copper refining furnace, electric arc furnace roof
Fused silica	Low thermal expansion coefficient, high thermal shock resistance, low thermal conductivity, low specific gravity, low specific heat	Coke oven, hot stove, soaking pit, glass tank crown
Chamotte (fireclay)	Low thermal expansion coefficient, low thermal conductivity, low specific gravity, low specific heat, low strength at high temperatures, less slag penetration	Ladle, runner, sleeve, coke oven, annealing furnace, blast furnace hot stove, reheating furnace, soaking pit
Alumina	High refractoriness, high mechanical strength, high slag resistance, high specific gravity, relatively high thermal conductivity	Hot stove, stopper head, sleeve, soaking pit cover, reheating furnace, glass tank, high-temperature kiln
High alumina	High refractoriness, high mechanical strength, high slag resistance, high specific gravity, relatively high thermal conductivity	Slide gate, aluminum melting furnace, skid rail, ladle, incinerator, reheating furnace hearth, skid rail, ladle, incinerator
Roseki	Low thermal expansion coefficient, high thermal shock resistance, low thermal conductivity, low specific gravity, low specific heat	Ladle, runner, sleeve, coke oven, annealing furnace, blast furnace hot stove, reheating furnace, soaking pit
Zircon	High thermal shock resistance, high slag resistance, high specific gravity	Ladle, nozzle, stopper head, sleeve
Zirconia	High melting point, low wettability against molten metal, low thermal conductivity, high corrosion resistance, high specific gravity	Nozzle for continuous casting, glass tank, high-temperature furnace, crucible
Alumina zirconia silica	High slag resistance, high corrosion resistance against molten glass	Glass tank, incinerator, ladle, nozzle for continuous casting
Lime	High slag resistance, low hydration resistance	Special refining surface
Magnesia	High refractoriness, relatively low strength at high temperature, high basic slag resistance, low thermal shock resistance, low durability at high humidity	Hot-metal mixer, secondary refining vessel, rotary kiln, checker chamber of glass tank, electric arc furnace
Magnesia-chrome	High refractoriness, high refractoriness under load, high basic slag resistance, relatively good thermal shock resistance (low MgO bricks), high strength at high temperature (direct bonded and fusion cast)	Hot-metal mixer, electric arc furnace, secondary refining vessel, nonferrous refining furnace, rotary cement kiln, lime and dolomite kiln, copper furnace, ladle, checker chamber for glass tank, slag line of electric arc furnace, degasser for copper, nonferrous smelter

(continued)

Table 3-1. Characteristics and Types of Refractories (continued)

Refractory Type	General Characteristics	Application
Oxide Bricks (continued)		
Chrome	High refractoriness, low strength at high temperature, low thermal resistance	Buffer brick between acid and basic brick
Dolomite	High refractoriness, high refractoriness under load, high basic slag resistance, low durability in high humidity, high thermal expansion coefficient	Basic oxygen furnace, electric arc furnace, secondary refining vessel, rotary cement kiln
Spinel	High thermal shock resistance, high strength at high temperatures, high slag resistance	Rotary cement kiln, ladle
Nonoxide Bricks		
Carbon	High refractoriness, high slag resistance, low oxidation resistance	Blast furnace hearth, electric arc furnace
Silicon carbide	High refractoriness, high strength at high temperature, high thermal conductivity, high thermal shock resistance, reduced oxidation resistance at high temperature, high slag resistance	Kiln furniture, incinerator, blast furnace
Silicon carbide-graphite	High refractoriness, high strength at high temperature, high thermal conductivity, high thermal shock resistance	Incinerator
Silicon nitride	High strength, high thermal shock resistance, relatively high oxidation resistance	Kiln furniture, blast furnace
Composite		
Silicon carbide Containing	High corrosion resistance against low iron oxide, high strength at high temperatures, high thermal shock resistance	Ladle, blast furnace, electric arc, torpedo ladle, iron ladle
Magnesia-carbon	High slag resistance, high thermal shock resistance	Basic oxygen furnace, electric arc furnace, ladle
Alumina-carbon	High refractoriness, high thermal shock resistance, high corrosion resistance	Submerged entry nozzle, slide gate

Source: The Technical Association of Refractories, Japan. 1998. *Refractories Handbook*. Tokyo: The Technical Association of Refractories, Japan.

2000).[1] Table 3-2 presents metric ton production of raw steel and nonferrous metals for the period 1994 to 1999. Refractory products are used in the steel industry to line coke ovens,

[1]The U.S. International Trade Commission (USITC) estimated consumption of the steel industry at over 50 percent, and DHAN estimated it at 75 percent.

Table 3-2. Steel and Nonferrous Production (10^3 Metric Tons)

Year	Raw Steel Production	Nonferrous
1994	91,300	11,216
1995	95,200	13,606
1996	94,700	11,608
1997	98,500	14,501
1998	98,700	14,811
1999	95,300	15,215

Source: U.S. Department of Commerce, and International Trade Administration. 1999. *U.S. Industry & Trade Outlook 2000*. New York: The McGraw-Hill Companies and U.S. Department of Commerce.

blast furnaces, blast furnace stoves, basic oxygen vessels, electric furnaces, open-hearth furnaces, and other heat-related manufacturing equipment (ASM International, 1987).

Because of improved quality of refractory products, the steel industry has decreased consumption of refractories from 25 to 30 kg per ton of steel to 10 kg in Japan and the United States (Semler, 2000). This is the result of increased life-span of refractory products. Other consumers of refractory products, including the petroleum industry and concrete industry are following the steel industry's pattern of reducing consumption of refractories.

3.3 Substitution Possibilities in Consumption

Although there is no direct substitute for refractories, industries that use refractory products have reduced the amount of the product consumed. Since the 1980s, the steel industry has restructured closing inefficient facilities and modernizing remaining plants. The industry developed and implemented technologies, such as the basic oxygen furnace (BOF), that significantly reduced the amount of refractories used per ton of steel (USITC, 1994; DHAN, 1999). Also, the refractory industry has made significant strides in developing more durable refractories. These two factors have reduced the overall consumption of refractory materials.

SECTION 4

INDUSTRY ORGANIZATION

This section examines the organization of the U.S. refractory industry, including plant location and production characteristics, commercial and captive producers, firm characteristics, market structure, and degree of integration. Understanding the industry's organization helps determine how it will be affected by complying with the refractory production NESHAP.

4.1 Refractory Manufacturing Plants

A facility is a site of land with a plant and equipment that combine inputs (clay, fuel and labor) to produce an output (refratory products). Companies that own these facilities are legal business entities that conduct transactions and make decisions that affect the facility. The terms "facility," "establishment," and "plant" are synonymous in this study and refer to the physical location where products are manufactured. Likewise, the terms "company" and "firm" are used interghangeably to refer to the legal business entity that owns one or more facilities. This section presents information on the companies that own refractory plants.

4.1.1 Refractories Database Facilities

Table 4-1 presents detailed information on refractory companies, including the location of the facility, its estimated sales volume in millions of dollars, and its employment.

4.1.2 Facility Location

Approximately 280 refractory manufacturing plants operate in the United States. Refractory materials are produced in 37 states. Table 4-2 lists the number of refractory facilities in the 50 states and Puerto Rico. The leading refractory-producing states are Pennsylvania and Ohio. Figure 4-1 illustrates the distribution of the refractory producing facilities in the United States.

Table 4-1. Selected Refractory Manufacturers, by Type

Company	Location	Sales ($\$10^6$)	Employment	Company Type	Owning Company	Sales ($\$10^6$)	Employment
Clay							
Able Supply Co.	Houston, TX	NA	NA	NA	NA	NA	NA
Alsey Refractories Co.	Alsey, IL	10 to 20	20 to 49	Private			
B&B Refractories, Inc.	Santa Fe Springs, CA	2.5 to 5	10 to 19	Private			
Bay State Crucible Co.	Tauton, MA	5 to 10	20 to 49	Private			
Bloom Engineering Co., Inc.	Pittsburgh, PA	38	187	Subsidiary	Sterling Industries PLC, England	NA	NA
BNZ Materials, Inc.	Littleton, CO	25	150	Private			
Carpenter EPG Certech, Inc.	Wilkes Barre, PA	14	150	Subsidiary	Carpenter Technology Corp.	1,000	5,324
Carpenter Technology Corp.	Reading, PA	1,000	5,324	Public			
Ceradyne, Inc.	Costa Mesa, CA	26	300	Private			
Certech, Inc.	Wood Ridge, NJ	62	758	Subsidiary	Carpenter Technology Corp.	1,000	5,324
CFB Industries, Inc.	Chicago, IL	23	176	Private			
Christy Refractories Co. LLC	St. Louis, MO	14	80	Private			
Clay City Pipe	Uhrichsville, OH	14	200	Private			
Cooperheat-MQS, Inc.	Houston, TX	120	1,200	Private			
ER Advanced Ceramics, Inc.	East Palestine, OH	NA	NA	NA	NA	NA	NA
Ermhart Glass Manufacturing, Inc.	Owensville, NJ	NA	NA	NA	NA	NA	NA
Fels Refractories, Inc.	Edison, NJ	1 to 2.5	NA	Private			
Ferro Corp.	Cleveland, OH	331	6,693	Public			
Freeport Area Enterprises, Inc.	Freeport, PA	10	150	Private			
Freeport Brick Co.	Creighton, PA	NA	NA	NA	NA	NA	NA

(continued)

Table 4-1. Selected Refractory Manufacturers, by Type (continued)

Company	Location	Sales ($\$10^6$)	Employment	Company Type	Owning Company	Sales ($\$10^6$)	Employment
Clay (continued)							
Global Industrial Technologies, Inc.	Dallas, TX	142	4,262	Public			
Green AP Refractories, Inc.	Mexico, MO	25	300	Subsidiary	RHI AG	1,580	14,500
Harbison-Walker Refractories Co.	Pittsburgh, PA	263	1,615	Subsidiary	RHI AG	1,580	14,500
Heater Specialists, Inc.	Tulsa, OK	17	160	Private			
Holland Manufacturing Corp.	Dolton, IL	2.5 to 5	20 to 49	NA	NA	NA	NA
Howmet Corp.	Whitehall, MI	1,300	10,350	Subsidiary	Cordant Technologies, Inc.	2,513	17,200
Industrial Ceramic Products, Inc.	Columbus, OH	NA	NA	NA	NA	NA	NA
Industrial Product International	Englewood, CO	1 to 2.5	5 to 9	Private			
Inland Enterprise, Inc.	Avon, OH	14	100	Private			
Insul Co., Inc.	East Palestine, OH	15	77	Private			
International Chimney Corp.	Williamsville, NY	18	140	Private			
Lousiville Firebrick Works	Grahm, KY	NA	NA	NA	NA	NA	NA
Martin Marietta Magnesia Specialties, Inc.	Raleigh, NC			Subsidiary	Martin Marietta Materials, Inc.	1,057	570
Maryland Refractories Co.	Irondale, OH	1 to 2.5	NA	Private			
Mono Ceramics, Inc.	Benton Harbor, MI	11	45	Subsidiary	Monocon International Refractories, England	NA	NA
Morganite Crucible, Inc.	North Haven, CT	15	75	Subsidiary	Morgan Crucible Co. PLC, England	1,394	16,885
Mt. Savage Firebrick Co.	Frostburg, MD	NA	NA	NA	NA	NA	NA
National Refractories & Minerals Corp.	Livermore, CA	115	600	Subsidiary	National Refractory Holding Co., Inc.	NA	810
New Castle Refractories	Massillon, OH	14	122	Subsidiary	Dixon Ticonderoga	115	1,354

Table 4-1. Selected Refractory Manufacturers, by Type (continued)

Company	Location	Sales ($\$10^6$)	Employment	Company Type	Owning Company	Sales ($\$10^6$)	Employment
Clay (continued)							
North America Refractories Co.	Cleveland, OH	331	1,500	Subsidiary	Didier-Werke AG, Germany	448.5	NA
P-G Industries, Inc.	Pueblo, CO	12	160	Private			
Plibrico Co.	Oak Hill, OH	10 to 20	20 to 40	Private			
Porvair Corp.	Hendersonville, NC	18	200	Private			
Premier Refractories, Inc.	King of Prussia, PA	64	778	Private			
Premier Refractories International, Inc.	King of Prussia, PA	90	900	Subsidiary	Alpine Group, Inc.	1,370	6,600
Pryotech, Inc.	Spokane, WA	45	650	Private			
Refco, Inc.	Boylston, MA	34	88	Subsidiary	Industrial Distribution Group, Inc.	273	1,200
Refractories Sales and Service Co., Inc.	Bessemer, AL	NA	NA	NA	NA	NA	NA
Reno Refractories, Inc.	Morris, AL	16	85	Private			
Resco Products, Inc.	Norristown, PA	50	500	Private			
RHI Refractories America		NA	NA	NA	NA	NA	NA
Riverside Clay Co., Inc.	Pell City, AL	15	100				
Riverside Refractories, Inc.	Pell City, AL	14	100	Subsidiary	Riverside Clay Co., Inc.	15	100
Rutland Products	Jacksonville, FL	NA	NA	NA	NA	NA	NA
Servsteel, Inc.	Morgan, PA						
SGL Carbon Corp.	Charlotte, NC	255	1,891	Subsidiary	SGL Aktiengesellschaft, Germany		
Shenango Refractories, Inc.	New Castle, PA	5 to 10	20 to 49	Private			
Sterling Industries of Delaware, Inc.	Pittsburgh, PA	57	312	Subsidiary	Sterling Industries PLC, England		
The Nock and Son Co.	Oak Hill, OH	2.5 to 5	10 to 19	Private			

(continued)

Table 4-1. Selected Refractory Manufacturers, by Type (continued)

Company	Location	Sales ($$10^6$)	Employment	Company Type	Owning Company	Sales ($$10^6$)	Employment
Clay (continued)							
The Whitacre-Greer Fire Proofing Co.	Alliance, OH	5 to 10	NA	Private			
Thermal Ceramics, Inc.	Augusta, GA	138	1,200	Subsidiary	Morgan Crucible Co. PLC, England	1,394	16,885
Thorley Refractories, Inc.	Southgate, CA	5 to 10	20 to 49	Private			
Transit Mix Concrete Co., Inc.	Colorado Springs, CO	25	210	Subsidiary	Contenental Materials Corp., Delaware	NA	NA
TYK America, Inc.	Clairton, PA	37	122	Subsidiary	TYK Corp., Japan	133.5	NA
Unifrax Corp.	Niagara Falls, NY	85	285	Subsidiary	Kirkland Capital Partners LP	90	808
Universal Refractories, Inc.	Wampum, PA	24	130	Private			
Utah Refractories Co.	Lehi, UT	NA	NA	NA	NA	NA	NA
Wahl Refractories, Inc.	Fremont, OH	17	68	Subsidiary	Thermatex Corp.	10	148
Zero Refractories, Inc.	Taylor MI	0.5	1 to 4	Private			
Nonclay							
Advanced Ceramics Corp.	Cleveland, OH	25 to 50	NA	Private			
Advanced Ceramics International, Inc.	Cleveland, OH	21	175	Private			
Allied Mineral Products, Inc.	Columbus, OH	56	240	Private			
Alpine Group, Inc.	New York, NY	1,370	6,600	Public			
Aluminum Company of America (ALCOA)	Pittsburgh, PA	15,300	103,500	Public			
AMPAC	Amsterdam, NY	13	100	Private			
B S C Holding, Inc.	Shawnee Mission, KS	23	15	Private			
Baker Holding Co., Inc.	York, PA	190	1,300	Public			
Baker JE Co.	York, PA	190	1,050	Subsidiary	Baker Holding Co., Inc.	190	1,300
Bartley Crucible &	Trenton, NJ	NA	NA	NA	NA	NA	NA

Table 4-1. Selected Refractory Manufacturers, by Type (continued)

Company	Location	Sales (10^6)	Employment	Company Type	Owning Company	Sales (10^6)	Employment
Nonclay (continued)							
Bethlehem Advanced Materials Corp.	Knoxville, TN	14	110	Subsidiary	The Bethlehem Corp.	14	117
Blash Precision Ceramics, Inc. (Texas United)	Houston, TX	63	515	Private			
BNZ Materials, Inc.	Zelienople, PA	1 to 2.5	5 to 9	private			
CCPI, Inc.	Blanchester, OH	25 to 50	NA	private			
Cercom, Inc.	Vista, CA	11	76	Private			
Certech, Inc.	Streetsboro, OH	62	758	Subsidiary	Carpenter Technology Corp.	1,000	5,324
CFB Industries, Inc.	Chicago, IL	23	176	Private			
Chicago Firebrick Co., Inc.	Chicago, IL	18	58	Private			
Coors Porcelain Co., Inc.		304	2,900	Subsidiary	ACX Technologies, Inc.	988	5,600
Dixon Ticonderoga Co., Inc.	Lake Mary, FL	85	1,562	Public			
ETS Schaefer Corp.	Macedonia, OH	13	195	Subsidiary	Alumitech, Inc.	21	210
Foseco, Inc.	Cleveland, OH	71	500	Subsidiary	Foseco Holding BV, Netherlands		
Global Industrial Technologies, Inc.	Dallas, TX	142	4,262	Public			
Harbison-Walker Refractories Co.	Pittsburgh, PA	263	1,615	Subsidiary	RHI AG	1,580	14,500
Insul Co., Inc.	East Palestine, OH	15	77	Private			
JW Hicks, Inc.	Merrellville, IN	5 to 10	20 to 49	NA	NA	NA	NA
Magneco, Inc.	Addison, IL	19	150	Subsidiary	Magneco/Metrel, Inc.	34	
Martin Marietta Magnesia Specialties, Inc.	Raleigh, NC			Subsidiary	Martin Marietta Materials, Inc.	1,057	570
Minco Acquistion Corp.	Midway, TN	21	170	Private			
Minco, Inc.	Midway, TN	15	135	Subsidiary	Minco Acquisition Corp.	21	170
Minerals Technologies, Inc.	New York, NY	609	2,260	Public			
Minteq International, Inc.	New York, NY	205	1,800	Subsidiary	Minerals Technologies, Inc.	609	2,260

(continued)

Table 4-1. Selected Refractory Manufacturers, by Type (continued)

Company	Location	Sales ($\$10^6$)	Employment	Company Type	Owning Company	Sales ($\$10^6$)	Employment
Nonclay (continued)							
Mitsubishi Cement Corp.	Ontario, CA	74	619	Subsidiary	Mitsubishi Materials Corp., Japan	9,354	6,556
Mixed Mineral Products, Inc.	Columbus, OH	NA	NA	NA	NA	NA	NA
Monofrax, Inc.	Falconer, NY	50 to 100	250 to 499	Private			
Morganite Crucible, Inc.	North Haven, CT	15	75	Subsidiary	Morgan Crucible Co. PLC, England	1,394	16,885
National Refractories & Minerals Corp.	Livermore, CA	115	600	Subsidiary	National Refractory Holding Co., Inc.		
New Castle Refractories	Massillon, OH	14	122	Subsidiary	Dixon Ticonderoga	115	1,354
Newport Sand & Gravel Co., Inc.	Newport, NH	13	100	Private			
North American Refractories Co.	Cleveland, OH	331	1,500	Subsidiary	Didier-Werke AG, Germany	NA	NA
Norton Co., Inc.	Worcester, MA	1,500	9,000	Subsidiary	Saint-Gobain, France	23,113	165,000
Osram Sylvania, Inc.	Danvers, MA	5,200	13,000	Subsidiary	Siemans Corp.		
Osram Sylvania Products, Inc.	Danvers, MA	1,800	1,100	Subsidiary	Siemans Corp.		
Pell Industries	Grove City, PA	5 to 10	20 to 49	Private			
Prefromix Technologies LTD	Warren, OH	10	75	Private			
Premier Refractories International, Inc.	King of Prussia, PA	90	900	Subsidiary	Alpine Group, Inc.	1,370	6,600
Premier Services, Inc.	Bettsville, OH	NA	NA	NA	NA	NA	NA
Pyrotek Inc.	Spokane, WA	50 to 100	NA	Private			
Rex Roto Corp.	Fowlerville, MI	14	80	Private			

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Table 4-1. Selected Refractory Manufacturers, by Type (continued)

Company	Location	Sales ($\$10^6$)	Employment	Company Type	Owning Company	Sales ($\$10^6$)	Employment
Nonclay (continued)							
Saint-Gobain Advanced Materials Corp.	Louisville, KY	533	3,300	Subsidiary	Norton Co., Inc.		
Selee Corp.	Hendersonville, NC	5	190	Subsidiary	Porvair PLC, England		
Silicon Carbide Products, Inc.	Elmira, NY	1 to 2.5	5 to 9	Private			
Spar, Inc.	Jacksonville, FL	NA	NA	NA	NA	NA	NA
Thermatex Corp. (Thermalite)	Fremont, OH	10	148	Private			
TYK America, Inc.	Clairton, PA	37	122	Subsidiary	TYK Corp., Japan	133.5	NA
UCAR Carbon Co.	Danbury, CT	105	1,506	Subsidiary	UCAR International, Inc.	947	4,952
Universal Refractories, Inc.	Wampum, PA	24	130	Private			
Varsal Instruments, Inc.	Warminster, PA	15	224	Private			
Vesuvius Crucible Co.	Champaign, IL	400	2,500	Subsidiary	Cookson Group PLC, England	3,011	17,101
Vesuvius USA Corp.	Champaign, IL	400	1,600	Subsidiary	Cookson Group PLC, England	3,011	17,101
Wulfrath Refractories, Inc.	Tarentum, PA	22	115	Private			
Zircar Products, Inc.	Florida, NY	12	85	Private			
Zircoa, Inc.	Solon, OH	20	140	Subsidiary	Didier-Werke AG, Germany	448.5	4,717

NA = Not available.

Source: Dun & Bradstreet. 2000. *D&B Million Dollar Directory*. Series 2000. Bethlehem, PA: Dun & Bradstreet, Inc.

Table 4-2. Number of Refractory Manufacturing Facilities by State

State	Number of Refractory Plants	
	Clay (NAICS 327124)	Nonclay (NAICS 327125)
Alabama	8	
California	10	6
Georgia	5	4
Illinois	7	7
Indiana		7
Kentucky		6
Maryland	4	
Michigan		7
Missouri	9	3
New York		3
New Jersey		7
North Carolina		2
Ohio	27	24
Pennsylvania	30	22
Texas	7	
West Virginia		3
Totals	107	101

Source: U.S. Department of Commerce, Bureau of the Census. 1999a. *1997 Census of Manufactures.* Washington, DC: Government Printing Office.

4.2 Capacity Utilization

Capacity utilization indicates how well the current facilities meet demand. One measure of capacity utilization is capacity utilization rates. A capacity utilization rate is the ratio of actual production volumes to full-capacity production volumes. For example, if an industry is producing as much output as possible without adding new floor space for equipment, the capacity utilization rate would be 100 percent. On the other hand, if under the same constraints the industry were only producing 75 percent of its maximum possible output, the capacity utilization rate would be 75 percent. On an industry-basis, capacity utilization is highly variable from year to year depending on economic conditions. It is also variable on a company-by-company basis depending not only on economic conditions, but

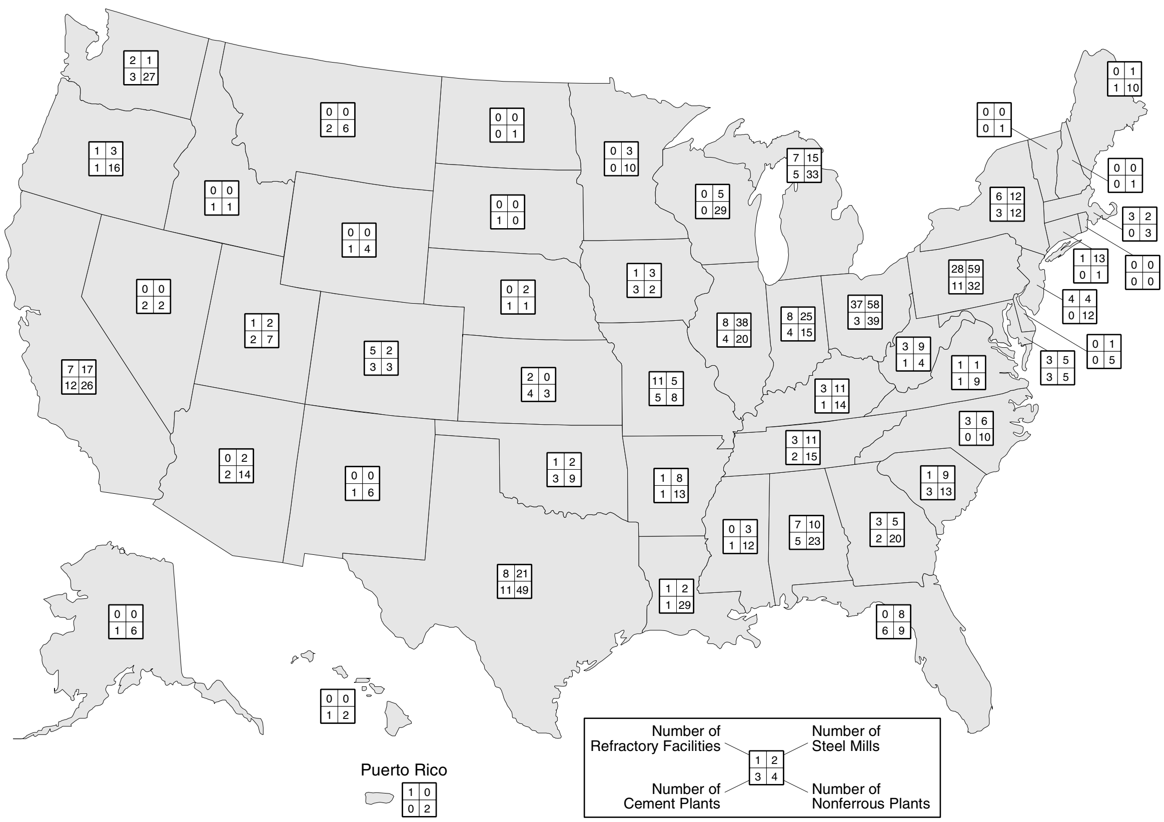

Figure 1

Figure 4-1. Location of Refractory Manufacturing Facilities

also on company's strategic position in its particular industry. While some plants may have idle production lines or empty floor space, others need additional space or capacity.

Table 4-3 lists the capacity utilization rates for clay and nonclay refractory manufacturers refractories for 1993 though 1998. Reduction in the demand for refractory replacements parts led to lower capacity utilization rates throughout this time period. Nonclay refractories, which includes specialty refractory products, has seen increased demand, allowing that part of the industry to maintain an approximately 70 percent capacity utilization rate.

Table 4-3. Full Production Capacity Utilization Rates for Clay and Nonclay Refractories: Fourth Quarters 1993 through 1998

	Clay (NAICS 327125)	Nonclay (NAICS 327125)
1993	75	71
1994	80	75
1995	63	81
1996	61	82
1997	49	78
1998	54	72

Source: U.S. Department of Commerce, Bureau of the Census. 1999d. *1998 Survey of Plant Capacity*. Washington, DC: Government Printing Office.

4.3 Industry Concentration and Market Structure

Market structure, which characterizes the level and type of competition among refractory producers, determines the behavior of producers and consumers in the industry, including their power to influence market price. If an industry is perfectly competitive, then the individual producers have little market power; they are not able to influence the price of the outputs they sell or the inputs they purchase. Perfectly competitive industries have large numbers of firms, the products sold are undifferentiated, and the entry and exit of firms are unrestricted.

Conversely, imperfectly competitive industries or markets are characterized by a smaller number of firms, differentiated products, and restricted entry or exit. Product differentiation can occur both from differences in product attributes and quality and from brand name recognition of products. Entry and exit of firms are restricted in industries when government regulates entry (e.g., through licenses or permits), when one firm owns the entire stock of critical input, or when a single firm is able to supply the entire market.

When compared across industries, firms in industries with fewer firms, more product differentiation, and restricted entry are more likely to have the power to influence the price they receive for a product by reducing output below perfectly competitive levels. At the extreme, a single monopolistic firm may supply the entire market and hence set the price of the output. On the input market side, firms may be able to influence the price they pay for an input if few firms, both from within and outside the industry, use that input.

4.3.1 Measures of Industry Concentration

To assess the competitiveness of an industry, economists often estimate four-firm concentration ratios (CR4), eight-firm concentration ratios (CR8), and Herfindahl-Hirschmann indexes (HHI) for the subject market or industry. The CR4s and CR8s measure the percentage of sales accounted for by the top four and eight firms in the industry. The HHIs are the sums of the squared market shares of firms in the industry. Table 4-4 provides concentration ratios for the refractory industry.

Table 4-4. Market Concentration Measures for SIC 3255 Clay Refractory Manufacturing and SIC 3297 Nonclay Refractory Manufacturing

	Value	
Measure	**Clay**	**Nonclay**
Herfindahl-Hirschmann Index (HHI)	578	527
Four-firm concentration ratio (CR4)	40	36
Eight-firm concentration ratio (CR8)	62	58
Number of companies	95	102
Number of facilities	145	142
Value of shipments	886.8	1,203.8

Source: U.S. Department of Commerce, Bureau of the Census. 1996b. *Concentration Ratios in Manufacturing*. MC92-S-2. Washington, DC: Government Printing Office. Available at <http://www.census.gov/mcd/mancen/download/mc92cr.sum>.

Unfortunately, there is no objective criterion for determining market structure based on the values of these concentration ratios. However, there are criteria for determining market structure based on the HHIs for use in merger analyses, which are provided in the 1992 Department of Justice's Horizontal Merger Guidelines (U.S. Department of Justice and the Federal Trade Commission, 1992). According to these criteria, industries with HHIs below 1,000 are considered unconcentrated (i.e., more competitive), those with HHIs between 1,000 and 1,800 are considered moderately concentrated (i.e, moderately competitive). Firms in less-concentrated industries are more likely to be price takers, while firms in more-concentrated industries are more likely to be able to influence market prices. These measures of market concentration can be computed using four-digit SIC codes based on U.S. Bureau of the Census data (U.S. Department of Commerce, 1993). Based on the HHI criteria, the refractory industry is not concentrated, and, therefore, competitive in structure. These indices are measures of concentration of the industry at the national level. There is no reason to believe, however, that the markets for refractories may be regional rather than national.

4.3.2 Market Structure

The refractories industry is characterized by having the majority of its products used as inputs for the steel industry. Small numbers of buyers can result in the buyers maintaining some measure of control over the input price (monopsony or oligopsony).

A monopsony occurs when a firm is the sole purchaser of an input. The monopsonist has the market power in the input market and can reduce the price paid without losing all input. An oligopsony is characterized by the presence of a few large buyers (even though there may also be many small buyers of insignificant size). In oligopsony, large firms are aware of their competitors for purchasing inputs and determine their purchasing price and quantity based on their expectations of their competitors' behavior. Because of multiple steel manufacturers, refractory inputs are purchased by multiple buyers resulting in oligopsonisonistic market.

4.3.3 Small Businesses that Own Lime Facilities

To determine the possible impacts on small businesses, both clay and nonclay refractory manufacturers are categorized as small or large using the Small Business Administration (SBA) general size definitions (SBA, 1998). For clay refractory manufacturers, a small company has 500 or fewer employees. For nonclay refractory manufacturers, small is defined as having 750 or fewer employees.

Table 4-5 lists the employment and sales data for the small companies that are owners of refractory producing facilities. Data on employment and sales for many of these companies is difficult to acquire, because they are privately held. Thirty-five companies owning clay refractory plants and 26 nonclay refractory owning businesses are small, while 7

Table 4-5. Characteristics of Small Businesses in the Refractory Industry

Company	Location	Sales ($\$10^6$)	Employment	Organization Type
Able Supply Co.	Houston, TX	NA	NA	NA
Alsey Refractories Co.	Alsey, IL	10 to 20	20 to 49	Private
B&B Refractories Inc.	Santa Fe Springs, CA	2.5 to 5	10 to 19	NA
Bay State Crucible Co.	Taunton, MA	5 to 10	20 to 49	NA
Ceradyne Inc.	Costa Mesa, CA	26	300	Private
Christy Refractories Co. LLC	St. Louis, MO	14	80	Private
Clay City Pipe	Uhrichsville, OH	14	200	Private
ER Advanced Ceramics Inc.	East Palestine, OH	NA	NA	NA
Ermhart Glass Manufacturing Inc.	Owensville, NJ	NA	NA	NA
Fels Refractories Inc.	Edison, NJ	1 to 2.5	NA	Private
Freeport Area Enterprises Inc.	Freeport, PA	10	150	Private
Freeport Brick Co.	Creighton, PA	NA	NA	NA
Heater Specialists, Inc.	Tulsa, OK	17	160	Private
Holland Manufacturing Corp.	Dolton, IL	25 to 5	20 to 49	Private
Industrial Ceramic Products Inc.	Columbus, OH	NA	NA	NA
Industrial Product International	Englewood, CO	1 to 2.5	5 to 9	Private
Inland Enterprise Inc.	Avon, OH	14	100	Private
International Chimney Corp.	Williamsville, NY	18	140	Private
Lousiville Firebrick Works	Grahm, KY	NA	NA	NA
Maryland Refractories Co.	Irondale, OH	1 to 2.5	NA	Private
Mt. Savage Firebrick Co.	Frostburg, MD	NA	NA	NA
P-G Industries Inc.	Pueblo, CO	12	160	Private
Plibrico Co.	Oak Hill, OH	10 to 20	20 to 49	NA
Porvair Corp.	Hendersonville, NC	18	200	Private
Refractories Sales and Service Co. Inc.	Bessemer, AL	NA	NA	NA
Reno Refractories Inc	Morris, AL	16	85	Private
Resco Refractories, Inc.	Norristown, PA	50	500	Private
RHI Refractories America		NA	NA	NA
Riverside Clay Co. Inc.	Pell City, AL	15	100	
Rutland Products	Jacksonville, FL	NA	NA	NA

(continued)

Table 4-5. Characteristics of Small Businesses in the Refractory Industry (continued)

Company	Location	Sales ($\$10^6$)	Employment	Organization Type
Servsteel Inc.	Morgan, PA			
Shenango Refractories, Inc.	New Castle, PA	5 to 10	20 to 49	Private
Nock and Son Co., The	Oak Hill, OH	2.5 to 5	10 to 19	Private
Whitacre-Greer Fire Proofing Co., The	Alliance OH	5 to 10	NA	Private
Thorley Refractories Inc.	Southgate, CA	5 to 10	20 to 49	Private
Utah Refractories Co.	Lehi, UT	NA	NA	NA
Zero Refractories, Inc.	Taylor MI	0.5 to 1	1 to 4	Private
BNZ Materials Inc.	Littleton, CO	25	150	Private
CFB Industries Inc.	Chicago, IL	23	176	Private
Insul Co. Inc.	East Palestine, OH	15	77	Private
Pyrotek Inc.	Spokane, WA	50 to 100	NA	Private
Thermatex Corp. (Thermalite)	Fremont, OH	10	148	Private
Universal Refractories Inc.	Wampum, PA	24	130	Private
Advanced Ceramics Internaitonal Inc.	Cleveland, OH	21	175	Private
Allied Mineral Products Inc.	Columbus, OH	56	240	Private
Alumitech Inc.	Canada	77	447	Public
AMPAC	Amsterdam, NY	13	100	Private
B S C Holding Inc.	Shawnee Mission, KS	23	15	Private
Bartley Crucible & Refractories, Inc.	Trenton, NJ	NA	NA	NA
Blash Precision Ceramics, Inc. (Texas United)	Houston, TX	63	515	Private
CCPI Inc.	Blanchester, OH	25 to 50	NA	Private
Cercom Inc.	Vista, CA	11	76	Private
Chicago Firebrick Co. Inc.	Chicago, IL	18	58	Private
JW Hicks Inc.	Merrellville, IN	5 to 10	20 to 49	Private
Magneco/Metrel Inc.	Addison, IL	34	150	Private
Minco Acquistion Corp.	Midway, TN	21	170	Private

(continued)

Table 4-5. Characteristics of Small Businesses in the Refractory Industry (continued)

Company	Location	Sales ($\$10^6$)	Employment	Organization Type
Mixed Mineral Products Inc.	Columbus, OH	NA	NA	NA
Monofrax Inc.	Falconer, NY	50 to 100	250 to 499Private	NA
Newport Sand & Gravel Co. Inc.	Newport, NH	13	100	Private
Pell Industries	Grove City, PA	5 to 10	20 to 49	Private
Prefromix Technologies LTD	Warren, OH	10	75	Private
Premier Services, Inc.	Bettsville, OH	NA	NA	NA
Rex Roto Corp.	Fowlerville, MI	14	80	Private
Silicon Carbide Products Inc.	Elmira, NY	1 to 2.5	5 to 9	NA
Spar, Inc.	Jacksonville, FL	NA	NA	NA
Bethlehem Corporation, The	Easton, PA	14	117	Private
Varsal Instruments Inc.	Warminster, PA	15	224	Private
Wulfrath Refractories Inc.	Tarentum, PA	22	115	Private
Zircar Products Inc.	Florida, NY	12	85	Private

companies that produce both clay and nonclay refractories are small. These are shown in Table 4-5.

4.4 Current Trends in the Refractory Industry

To remain competitive, refractory manufacturers have continued to improve raw materials and manufacturing and testing processes. The trend toward increased lining life in most applications has reduced the costs of repair and replacement to refractory consumers. Improvements in the production process of steel, glass, and petrochemicals in combination with improvements in refractory products and linings have culminated to reduce the amount of refractory consumption. Recently, the basic oxygen steelmaking furnace linings have exceeded 20,000 heats. The glass industry has experienced increased time between repairs in glass furnaces from every 4 years to 13 years, with little or no preventative maintenance (Sheppard, 2000; Anonymous, 2000). From 1998 to 1999, the refractory industry reported a 6 percent decline in production and a 12 percent decline in turnover (DHAN, 2001).

SECTION 5

MARKETS

This section provides data on domestic production, domestic consumption, imports, and exports of refractories. It also includes data on gross margin growth in prices. Finally, this section discusses trends and projections for the refractory industry.

5.1 Market Data

This section provides data on volumes of refractory products produced and consumed in the U.S., the quantities imported and exported, and prices. Figure 5-1 illustrates refractory production trends from 1977 to 1998.

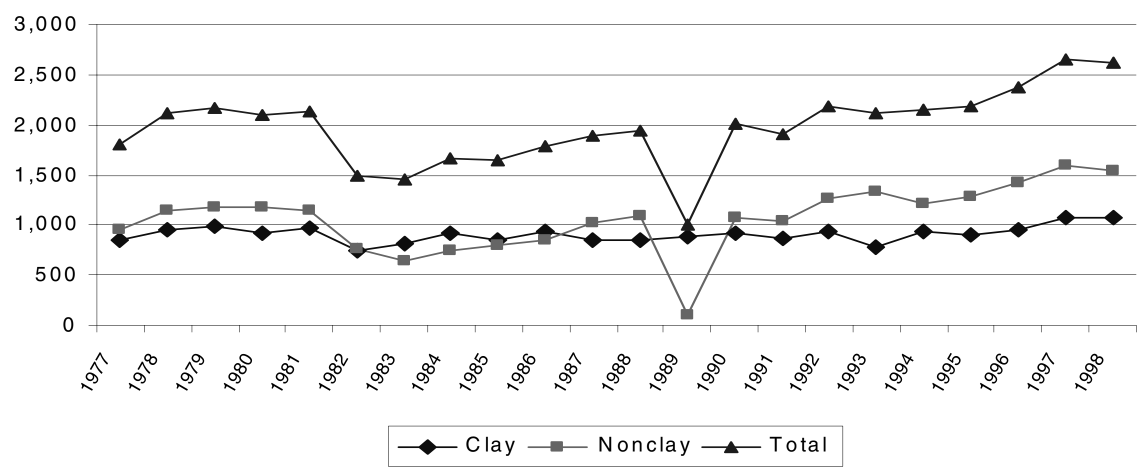

Figure 5-1. Historical Refractory Production Trends

Note: All financial figures are adjusted for inflation using the Producer Price Index available from the U.S. Bureau of Labor.

5.1.1 Domestic Production

During the last two decades, the refractory industry has been affected by declining demand for traditional refractory products, such as bricks and shapes, and customer requirements for higher quality special refractories. Accounting for nearly 40 percent of all shipments, bricks and shapes are the principal forms of refractory products produced in the United States (USITC, 1993). Table 5-1 illustrates the values of domestically produced clay and nonclay refractories from 1977 to 1998 in both current and 1998 dollars.

5.1.2 International Trade

As indicated in Table 5-2, international trade is not a major component of the U.S. market for refractory products. In 1999, refractory exports accounted for a little over 16 percent of shipped refractory products. Nations with significant iron, steel, cement, and nonferrous metal industries, including the United States, Europe, and Japan, are the major world markets for refractory products. From 1988 to 1992, Canada was the leading importer of U.S. refractory products, with over 38 percent of all exports, followed by Mexico. Emerging foreign markets for the United States include India, China, and other countries in Central and South America. Japan and Canada are the top suppliers of imports to the United States (USITC, 1994).

5.2 Market Prices

Table 5-3 lists some average prices for refractory products for 1989, 1993 and 1998. Most refractory products are typically used in kilns and ovens and are refractories engineered for a particular use. Price is typically based on the consumer’s requirements.

5.3 Industry Trends

In the last decade, the refractory industry has experienced significant restructuring. Two large conglomerates, RHI and Vesuvius, dominate refractories markets (Sheppard, 2000). In 1999, Alpine Group sold its Premier Refractories unit to Cookson Group of the U.K., and Global Industrial Technologies (parent of Harbison-Walker Refractories) was acquired by RHI AG (formerly Radex Heraklith Industriebeteiligungs) of Austria. Other leading refractory producers are Allied Mineral Products, Baker Refractories, Minerals Technologies (via MINTEQ), Morgan Crucible, National Refractories Holding Co., Resco Products, and Compagnie de Saint-Gobain.

Table 5-1. Production of Refractories: 1977–1998 ($\$10^6$)

Year	Clay		Nonclay		Total	
	Current	1998	Current	1998	Current	1998
1977	607.2	848.9	680.2	950.9	1,287.4	1,799.8
1978	717.3	956.4	864.2	1,152.3	1,581.5	2,108.7
1979	776.9	983.5	934.9	1,183.5	1,711.8	2,167.0
1980	761.6	922.4	975.9	1,182.0	1,737.5	2,104.4
1981	864.2	976.0	1020.9	1,153.0	1,885.1	2,129.0
1982	670.3	738.4	691.0	761.2	1,361.3	1,499.5
1983	745.5	813.8	588.9	642.9	1,334.4	1,456.7
1984	868.6	920.1	701.4	743.0	1,570.0	1,663.1
1985	803.0	849.2	755.3	798.7	1,558.3	1,647.9
1986	843.5	931.4	768.5	848.6	1,612.0	1,780.0
1987	788.2	851.2	954.5	1,030.8	1,742.7	1,882.1
1988	836.7	851.0	1,078.1	1,096.5	1,914.8	1,947.5
1989	906.3	892.5	113.3	111.6	1,019.6	1,004.0
1990	922.9	927.0	1,077.6	1,082.4	2,000.5	2,009.5
1991	850.4	872.6	1,009.2	1,035.5	1,859.6	1,908.1
1992	886.8	930.6	1,203.5	1,263.0	2,090.3	2,193.6
1993	758.0	784.6	1,282.2	1,327.1	2,040.2	2,111.7
1994	938.8	929.5	1,232.2	1,220.0	2,171.0	2,149.5
1995	958.2	896.2	1,370.4	1,281.7	2,328.6	2,178.0
1996	977.3	953.6	1,459.4	1,424.0	2,436.7	2,377.6
1997	1,101.6	1,072.9	1,631.2	1,588.7	2,732.8	2,661.6
1998	1,082.8	1,082.8	1,535.8	1,535.8	2,618.6	2,618.6

Sources: U.S. Department of Commerce, Bureau of the Census. 1994b. *1992 Census of Manufactures, Industry Series—Cement and Structural Clay Products*. Washington, DC: Government Printing Office.
U.S. Department of Commerce, Bureau of the Census. 1995. *1993 Annual Survey of Manufactures*. M93(AS)-1. Washington, DC: Government Printing Office.
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U.S. Department of Commerce, Bureau of the Census. 2000. *1998 Annual Survey of Manufactures*. M98(AS)-1. Washington, DC: Government Printing Office.

Table 5-2. Exports and Imports of Refractories: 1993–1999 ($$10^6$ 1998)

Year	Exports			Imports			Apparent Consumption		
	Clay	Nonclay	Total	Clay	Nonclay	Total	Clay	Nonclay	Total
1993	72.8	251.9	324.7	28.8	177.7	206.5	740.3	1,065.2	1,805.5
1994	62.1	262.9	325.5	26.4	183.7	210.1	843.3	992.8	1,836.1
1995	76.8	298.0	374.8	33.2	198.6	231.8	873.8	1,045.6	1,919.3
1996	71.7	314.7	386.4	27.0	211.1	238.2	856.9	1,077.4	1,934.3
1997	81.8	290.1	372.0	27.8	248.3	275.9	863.5	1,197.5	2,061.0
1998	59.6	278.9	338.6	30.9	225.1	256.0	942.0	1,113.3	2,055.3
1999	53.2	287.4	340.6	104.0	218.7	323.2	934.5	989.0	1,923.6

Source: U.S. Department of Commerce, Bureau of the Census. 1993–1999. *Current Industrial Reports: Refractories.* MA 32C. Available at <http://www.census.gov/industry/ma32c97>.

Table 5-3. Average Price for Refractory Products[a] ($/ton)

Form	1989		1993		1998
	Current	1998	Current	1998	Current
Monolithics	451	526	491	544	533
Bricks and Shapes	709	826	782	866	910
Other [1]	394	459	442	490	497

1 Other refractory forms consists of ceramic fibers and refractory raw materials that are supplied in lump or ground form used to manufacture refractories "inhouse."

Source: Freedonia Group. September 1999. "Refractories in the United States to 2003." Profound WorldSearch <http://www.profound.com>

[a] Prices were deflated useing the producer price indes (PPI) from the Bureau of Labor Statistics. 2001. <http://146.142.4.24/cgi-bin/surveymost>.

A recent study projects that shipments of U.S. refractory products will increase 2.5 percent annually to $2.9 billion in 2003 (Anonymous, 2000). In 1997, refractory products shipments increased 10.7 percent. The refractory industry typically parallels the steel industry, which is expected to maintain steady growth in the next few years (Bagsarian, 2001).

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