SLAG—IRON AND STEEL

By Rustu S. Kalyoncu

Domestic survey data and tables were prepared by Robin C. Kaiser, statistical assistant.

As early as 350 B.C., the Greek philosopher-physician Aristotle prescribed iron slags for healing wounds. In the ensuing centuries, a number of applications for iron and steel slags were found. However, it was not until the early 20th century, when the modern processes of iron and steel production were developed, that the commercial, large-scale use of iron and steel slags became economical.

The American Society of Testing and Materials (ASTM) (1999) defines blast furnace slag as "the non-metallic product consisting essentially of calcium silicates and other bases that is developed in a molten condition simultaneously with iron in a blast furnace." To the casual observer, one of the most striking features of an iron and steel plant is the site of a mountainous slag pile that presents a continuous display as ladle after ladle pours its incandescent load down the side in the endless accumulation of this "waste product." Almost a century ago, the term waste product aptly described slag. Slag was considered to be essential in the production of iron, but once it served its purpose in refining the metal, it was strictly a nuisance with little or no use. The use of slags became a common practice in Europe at the turn of the 19th century, where the incentive to make all possible use of industrial byproducts was strong and storage space for byproducts was lacking. Shortly after, many markets for slags opened in Europe, the United States, and elsewhere in the world.

In the production of iron, the blast furnace (BF) is charged with iron ore, fluxing agents (usually limestone and/or dolomite), and coke as both fuel and reducing agent. The iron ore is a mixture of iron oxides, silica, and alumina. From this and the added fluxing agents (alkaline earth carbonates), molten slag and iron are formed. Oxygen in the preheated air that is blown into the furnace combines with the carbon of the coke to produce the needed heat and carbon monoxide. At the same time, the iron ore is reduced to iron, mainly through the reaction of the carbon monoxide with the iron oxide to yield carbon dioxide (CO_2) and metallic iron. The fluxing agents dissociate into oxides and CO_2. The oxides combine with silica and alumina to form slag. For air-cooled slag, the slag is transported into a cooling pit either directly or via iron ladles, depending on the distance between the pit and the furnace.

The principal constituents of iron and steel slags are silica, alumina, calcia, and magnesia, which together make up 95% of the composition. Minor elements included are manganese, iron, and sulfur compounds, and trace amounts of several other elements are included. The physical characteristics, such as density, porosity, and particle size, are affected by the cooling rates of the slag and its chemical composition. Depending on the cooling method, three types of BF slag are produced—air-cooled, expanded, and granulated. Fine particle slags also are pelletized.

Allowing the molten slag to cool slowly in air in an open pit produces air-cooled slag. Air-cooled BF slag is defined in ASTM standard C-125 as "the material resulting from solidification of molten blast furnace slag under atmospheric conditions. Subsequent cooling may be accelerated by application of water to the solidified surface" (American Society for Testing and Materials, 1999). The solidified slag has a vesicular structure with closed pores. The rough vesicular texture of slag gives it a greater surface area than smoother aggregates of equal volume and provides an excellent bond with portland cement as well as high stability in asphalt mixtures.

Expanded slag is formed through controlled rapid cooling of molten slag in water or in water combined with steam and compressed air. Steam and other gases enhance the porosity and vesicular nature of the slag, resulting in a lightweight aggregate suitable for use in concrete. Quenching the molten slag into glass granules by using high-pressure water jets produces granulated slag. Quenching prevents the crystallization of minerals constituting the slag composition, thus resulting in a granular, glassy aggregate. This slag is crushed, pulverized, and screened for use in various applications, particularly in cement production, owing to its pozzolanic (hydraulic cementitious) characteristics.

Slags are also coproducts of steelmaking processes. Production of steel calls for the removal of excess silicon by mineralization and excess carbon (by oxidation) from pig or crude iron. Steel slag is a hard, dense material somewhat similar to air-cooled iron slag. It contains significant amounts of free steel or metal, giving it its high density and hardness, which make it particularly suitable as a road construction aggregate and raw material for portland cement manufacture.

Slag is transported to processing plants, where it undergoes crushing, grinding, and screening operations to meet various use specifications. Processed slag is either shipped to its buyer for immediate use or stored to cure or to accumulate adequate stocks for large orders.

Legislation and Government Programs

Classification of slags under several standard waste categories has been the subject of a number of past Government initiatives. The National Slag Association reported no major Government action concerning slag in 2001 (Terry Wagaman, President, National Slag Association, oral commun., 2001). The effect of increased spending on highway construction and repairs as a result of the passage of the Transportation Equity Act for the 21st century (Public Law 105-178) by Congress in 1998, with its $205 billion spending plan, did not show on the consumption and price of slags in 2001 just as it did not in 2000, although steel slag consumption went up slightly.

The Portland Cement Association is promoting slag use in portland cement production. The potential for a carbon tax levy on CO_2 emissions may provide the cement producers with incentives to find ways of reducing unit CO_2 emissions in portland cement production, where the combustion of fuel and decomposition of carbonates in the raw feed contribute to CO_2 emissions.

Texas Industries Inc. has developed a process for cement clinker production involving the use of steel slag. In this process, which is called CemStar, steel slag is fed into the rotary kiln as a part of the raw meal. Replacing a part of the limestone in the raw meal directly with slag results in the lowering of CO_2 emissions as well as increasing cement production directly proportional to the quantity of slag used. Refinements of the process started in 2000 have continued throughout 2001 (Robert D. Rogers, President, Texas Industries Inc., oral commun., 2001).

Production

The iron and steel industry does not routinely measure slag output; therefore, actual annual ferrous slag production data in the United States do not exist. The data collected by the U.S. Geological Survey (USGS) reflect the slag processing industry's sales of slag rather than the output by the furnaces. Slag outputs in iron and steel production are highly variable and depend, mainly, on the composition of the raw materials and the type of furnace. Typically, for ore feed with 60% to 65% iron, BF slag production ranges from about 220 to 370 kilograms per metric ton of pig or crude iron produced. Lower grade ores yield much higher slag fractions, sometimes as high as 1 ton of slag per ton of pig iron. Steel slag outputs are approximately 20% by mass of the crude steel output. Up to about one-half the slag is entrained steel, which is generally recovered and returned to the furnace. After removal of the entrained steel, the marketable slag is equivalent to about 10% to 15% of the original steel output by mass.

According to statistics reported by the American Iron and Steel Institute, U.S. pig iron production was about 42 million metric tons (Mt) in 2001 and 48 Mt in 2000. The iron slag shipments for these years were 10.5 Mt and 11.2 Mt, respectively. Similarly, U.S. steel production was reported to be 90 Mt for 2001 and 102 Mt for 2000. The expected steel slag shipments were 6.5 Mt in 2001 and 5.1 Mt in 2000. As with the United States, no data are available on world slag production. The International Iron and Steel Institute (unpub. data, 2001) reported the world pig iron output to be about 577 Mt and crude steel production to be 845 Mt in 2001. The estimated figures for ferrous slag production from this output would be approximately 200 Mt.

Tables 1 through 8 list data compiled from the USGS survey of domestic slag processors. The data for 2000 and 2001 reflect a response by 85% of the processors queried. Where applicable, estimates have been incorporated for data omitted from the returned questionnaires. Table 8 lists the slag processing facilities that responded to the survey in 2001. As was the case in the 2000 report, Redland Mill Services no longer appears in the table because Lafarge Corp. bought it 2 years ago.

Nucor Corp.'s new 1-million-metric-ton-per-year (Mt/yr) electric arc furnace steel mill in Hertford County, NC, the construction of which was started in 1998, became operational in October 2000 (Kalyoncu, 2000; Giff Daughtridge, plant manager, Nucor Plant, oral commun., 2001). Currently [2001], the mill is operating at 90% capacity and generating approximately 30,000 metric tons of slag, which is processed and reported by Heckett MultiServ Co. GSC Partners is in the process of acquiring Envirosource Inc. (Terry Wagaman, President, National Slag Association, oral commun., 2002).

Bulk Materials International, Inc., imports about 2 Mt granulated slag annually and sells it principally to Lone Star Industries Inc., Essroc Materials, Inc., and Rinker Materials Corporation. Holcim, Ltd., installed state-of-the-art grinding facilities at Fairfield, AL, and Chicago, IL, where slag from Gary, IN, is ground. Holcim also operates a grinding facility at Weirton, WV. Lafarge operates a grinding facility in Tampa, FL. Independent Cement Corporation (St. Lawrence) installed a grinding facility in Camden, NJ, where imported slag from Italy is processed. Lehigh Cement Company processes slag at its Allentown, PA, location. Lone Star operates two grinding facilities in New Orleans and Florida. Most of the slag processed at these facilities are currently reported directly or indirectly by the processors. Measures will be taken to ensure the reporting of the total amounts and to avoid duplication of reported quantities.

Consumption

Uses of iron and steel slag range from building and road construction to waste stabilization and water remediation. Iron slags are predominately air-cooled and used as concrete and masonry aggregate, construction aggregates for road building, mineral wool production, glass manufacture, asphaltic concrete aggregate, and as a mineral supplement and liming agent in soil conditioning. Air-cooled slag is highly prized by owners of Indianapolis and NASCAR racetracks for its stability and frictional properties when used in asphaltic concrete mixes that surface their racetracks. Iron slag is also pelletized or granulated by quickly quenching the molten slag with large volumes of water. Improved production techniques have decreased the density of pelletized slags to 55 pounds per cubic foot. Pelletized slag is used predominately as lightweight aggregate where its high fire resistance and insulation properties make it an excellent aggregate for concrete and masonry units where high fire resistance is required. The other principal use of pelletized slags is in lightweight fill or engineered fill applications. Granulated slag is predominately ground to portland cement fineness and is used as a replacement for portland cement in concrete mixes or is blended with portland cement at the factory. Ground granulated BF slag is valued for its concrete enhancing properties and is becoming widely used in high-performance concrete applications.

Steel furnace slag is currently predominately used as a fill, an asphaltic aggregate, and as road base; however, new uses for this valuable recycled material continue to be found. Increasingly, more emphasis is being placed on using the dense, hard, and durable aggregate in asphaltic concrete. Recent projects point to the benefits provided by the use of steel slag in asphalt mixes. Those benefits include excellent frictional properties and antirutting properties. Pavements that use steel slag provide a skid-resistant, highly stable surfaces. Steel slag also has found use as a barrier material in remediation of waste sites where heavy metals tend to leach into the surrounding environment. Owing to its high oxide mineral content, steel slag forces the heavy metals to drop out of solution in water runoff. Steel slag has been successfully used to treat acidic water discharges from abandoned mines.

Availability of iron and steel slag is dependent on iron and steel production levels and the time of the construction cycle. Slag, especially steel slag, must be allowed to "cure" or age for a period of time, usually 6 months, before it can be used as road base aggregate. The primary reason for the curing process is to allow the free lime or calcium carbonate to hydrate before use to prevent excessive volume expansion.

Heckett MultiServ recently closed its Fontana, CA, operation when the slag bank was depleted. Steel production stopped at that site more than 25 years ago. The Fontana site was one of the few remaining slag banks in the United States. Several other old slag banks in the United States also are nearing depletion.

Increased air-quality and emission standards are impacting the integrated mills and portland cement producers. More integrated steel producers are installing granulators at their blast furnaces. Holcim (US) Inc. recently installed a granulator at the US Steel Corporation Fairfield, AL, facility, and Lafarge recently installed a granulator and two pelletizers at the Ispat facility in East Chicago, IN. There are now five granulators operating in the United States. Increased utilization of granulated slag benefits the portland cement producers by expanding their production capacity without generating additional greenhouse gas CO_2 emissions.

Air-cooled slag accounted for the bulk of slag production (sales) in the United States. The total U.S. sales of about 8 Mt, worth $56 million, of domestically produced air-cooled BF slag recorded a decrease in value (table 1). Expanded and granulated slag sales also decreased in 2001. Total revenues of $137 million (iron plus steel slags) for 2001 were about 3% lower than the $141 million of 2000. The north-central region regained the lead in sales value of BF slag with $69.5 million, accounting for more than 60% of total revenues for the whole country, with the mid-Atlantic region accounting for most of the remaining business (table 3).

In 2001, sales for concrete and asphaltic road construction, including road base, again accounted for almost 70% of the consumption of air-cooled BF slag in the United States; other uses were in soil conditioning, sewage treatment, and mineral wool production (table 4).

Road base was the primary use of steel slag, followed by fill and asphaltic concrete aggregates. The steel slag sales of $25 million in 2001 surged ahead of the 2000 figure of $20.1 million by almost 25% (table 5). Slag prices showed a range of values depending on their use categories (table 6). A significant amount of slag (2.8 Mt) was never shipped but was used at the plants (table 7).

In 2001, the United States imported 2.6 Mt of ferrous slags. Granulated BF slag (GGBFS), which commands the highest price among ferrous slags, led the imports. In 2001, 1.8 Mt of GGBFS was imported. Imports of GGBFS, in descending order, were mainly from Canada, Italy, Brazil, Japan, and France. Principal discharge ports were Tampa, FL, New Orleans, LA, Philadelphia, PA, and Detroit, MI. In 2001, imports accounted for 15% of total ferrous slag shipments in the United States. This significant increase in imports was the result of a decline in the U.S. iron and steel production in 2001.

Transportation

Most ferrous slag sold and not consumed at the plant was transported by truck (11.2 Mt), while rail and barge transportation accounted for 21% of the total (table 7). Most ferrous slag was transported less than 100 kilometers; trucks were the most economical means of transportation for such distances.

Current Research and Technology

No significant developments were made in slag processing technology during 2001. Because slag is a low-unit-value, high-volume commodity and slag processing is an established, conservative industry, all the slag that is processed is readily sold. Therefore, the industry seldom feels the need for innovations and, therefore, invests little, if any, in expensive research efforts. Previously reported advancements in granulating techniques resulted in some improvements in slag granulation systems, especially in reducing the energy costs (Kalyoncu, 1999).

Outlook

Potential classification by the U.S. Environmental Protection Agency of iron and steel slags as hazardous wastes is of continuing concern to the slag industry. Absent such a classification, ferrous slag has a secure future in the construction industry. Some BF operations, however, have been closing owing to an inability to compete in the marketplace. In the case of continuing plant closings, availability of domestic BF slag may decline, which may necessitate an increase in imports. With its more limited uses, the long-term supply of steel slag appears to be more stable. An increase in the use of steel slags may be on the horizon as BF slag production declines.

References Cited

American Society for Testing and Materials, 1999, Standard terminology relating to concrete and concrete materials: West Conshohocken, PA, American Society for Testing and Materials, 4 p.

Kalyoncu, R.S., 1999, Slag—Iron and steel: U.S. Geological Survey Mineral Commodity Summaries 1999, p. 94-95.

GENERAL SOURCES OF INFORMATION

U.S. Geological Survey Publications

Iron and Steel. Ch. in Mineral Commodity Summaries, annual.

Slag—Iron and Steel. Ch. in Mineral Commodity Summaries, annual.

TABLE 1
IRON AND STEEL SLAG SOLD OR USED IN THE UNITED STATES 1/

(Million metric tons and million dollars)

	Blast furnace slag									
	Air-cooled		Expanded 2/		Total		Steel slag		Total slag	
Year	Quantity	Value 3/	Quantity	Value 3/	Quantity	Value 3/	Quantity	Value 3/	Quantity	Value 3/
2000	8.9	59.00 r/	2.3	62.00 r/	11.2	121.00	5.2 r/	20.00 r/	16.3	141.00 r/
2001	8.1	56.00	2.3	56.00	10.5	112.00	6.5	25.00	16.9	137.00

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Includes granulated slag to avoid disclosing company proprietary data.
3/ Value is the selling price at plant and includes, for a few facilities, estimates reported by the plants and/or made by the U.S. Geological Survey

TABLE 2
AVERAGE UNIT VALUE AT THE PLANT FOR IRON AND STEEL SLAG SOLD
OR USED IN THE UNITED STATES, BY TYPE

(Dollars per metric ton)

	Iron blast furnace slag				
Year	Air-cooled	Expanded 1/	Total iron slag	Steel slag	Total slag
2000	6.61	27.21	10.80	3.92	8.65 r/
2001	6.91	24.35	10.77	3.85	8.05

r/ Revised.
1/ Includes granulated slag to avoid disclosing company proprietary data.

TABLE 3
BLAST FURNACE SLAG SOLD OR USED IN THE UNITED STATES, BY REGION AND STATE 1/ 2/

(Million metric tons and million dollars)

	2000				2001			
	Air-cooled		Total, all types		Air-cooled		Total, all types	
Region	Quantity	Value 3/	Quantity	Value 3/	Quantity	Value 3/	Quantity	Value 3/
North-central, Illinois, Indiana, Michigan, and Ohio	4.9	32.00	5.8	50.00	5.1	34.00	6.1	69.50
Mid-Atlantic, Maryland, New York, Pennsylvania, and West Virginia	2.1	15.60	3.2	55.00	2.0	14.00	3.0	29.20
Other 4/	1.9	11.20	2.2	16.00	1.0	8.00	1.4	13.30
Total	8.9	59.00 r/	11.2	121.00	8.1	56.00	10.5	112.00

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Excludes imported slag.
3/ Value is the selling price at plant and includes, for a few facilities, estimates reported by the plants and/or made by the U.S. Geological Survey.
4/ Includes Alabama, California, Kentucky, Mississippi, and Utah.

TABLE 4
AIR-COOLED BLAST FURNACE SLAG SOLD OR USED IN THE UNITED STATES, BY USE 1/ 2

(Million metric tons and million dollars)

	2000		2001	
Use	Quantity	Value 3/	Quantity	Value 3/
Asphaltic concrete aggregate	1.7	11.30	1.9	12.80
Concrete aggregate	1.2	8.70	1.5	12.30
Concrete products	0.3 r/	1.50	0.3	1.60
Fill	0.8	3.90	0.6	2.60
Mineral wool	0.6 r/	5.00	0.6	5.30
Railroad ballast	(4/)	(4/)	(4/)	(4/)
Road bases	3.3	18.40	2.7	14.70
Roofing, built-up and shingles	(4/)	(4/)	(4/)	(4/)
Other 5/	1.0 r/	9.80	0.5	6.60
Total	8.9	59.00 r/	8.1	56.00

See footnotes at end of table.

TABLE 4--Continued
AIR-COOLED BLAST FURNACE SLAG SOLD OR USED IN THE UNITED STATES, BY USE 1/ 2

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Excludes imports.
3/ Value based on selling price at plant.
4/ Less than 1/2 unit.
5/ Includes cement, ice control, glass manufacture, sewage treatment, soil conditioning and miscellaneous.

TABLE 5
STEEL SLAG SOLD OR USED IN THE UNITED STATES, BY USE 1/ 2/ 3/

(Million metric tons and million dollars)

	2000		2001	
Use	Quantity	Value 4/	Quantity	Value 4/
Asphaltic concrete aggregate	1.1 r/	5.00	1.4	6.30
Fill	1.0	3.00	1.4	3.00
Railroad ballast	0.4	1.10	0.4	1.30
Road bases	1.7	6.40 r/	2.4	8.20
Other 5/	1.0 r/	4.80 r/	0.9	5.80
Total	5.2 r/	20.00 r/	6.5	25.00

r/ Revised.
1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Excludes imports.
3/ Excludes tonnage returned to furnace for charge material.
4/ Value based on selling price at plant.
5/ Includes ice control, soil conditioning, and miscellaneous uses.

TABLE 6
AVERAGE AND RANGE OF SELLING PRICES AT THE PLANT FOR IRON AND STEEL SLAG IN THE UNITED STATES IN 2001, BY USE

(Dollars per metric ton)

	Iron blast furnace slag 1/		Steel slag	
Use	Average	Range	Average	Range
Asphaltic concrete aggregate	6.00	4.00-8.00	4.00	0.54-8.00
Concrete products	5.00	3.30-10.00	(2/)	(2/)
Fill	3.00	2.00-10.00	1.00	0.50-14.00
Mineral wool	8.00	4.00-12.00	W	(2/)
Railroad ballast	4.00	4.00-10.00	2.00	1.64-24.00
Road bases	5.00	2.30-10.50	3.00	1.34-5.00
Roofing, built-up and shingles	12.00	8.43-17.48	(2/)	(2/)
Other 3/	60.00	37.38-89.55	7.00	4.26-14.13

W Withheld to avoid disclosing company proprietary data.
1/ Air-cooled slag only. Price range breakouts, by use, for granulated and expanded slag are withheld to avoid disclosing proprietary data; overall, prices ranged from $.50 to $90.00 per metric ton for iron and steel slag.
2/ No use reported.
3/ Includes cement manufacture, glass manufacture, sewage treatment, and soil conditioning.

TABLE 7
SHIPMENTS OF IRON AND STEEL SLAG IN THE UNITED STATES IN 2001, BY METHOD OF TRANSPORTATION 1/ 2/

(Million metric tons)

Method of transportation	Quantity
Truck	11.2
Rail	0.8
Waterway	2.2
Total	14.2
Not transported (used at plant)	2.7

See footnotes at end of table.

TABLE 7--Continued
SHIPMENTS OF IRON AND STEEL SLAG IN THE UNITED STATES
IN 2001, BY METHOD OF TRANSPORTATION 1/ 2/

1/ Data are rounded to no more than three significant digits; may not add to totals shown.
2/ Excludes imported slag.

TABLE 8
PROCESSORS OF IRON AND STEEL SLAG IN THE UNITED STATES IN 2001

		Steel slag			Iron slag	
Company	Plant location	Basic oxygen furnace	Open hearth	Electric arc furnace	Blast furnace	Type of slag
Allega Slag Recovery	Cayouga, OH				X	Air cooled.
ASMI	Holsappie, PA			X		
Beaver Valley Slag	Aliquippa, PA		X		X	Air cooled.
Buffalo Crushed Stone, Inc.	Buffalo, NY	X			X	
C.J. Langenfelder & Son	Baltimore, MD	X				
Do.	Braddock, PA	X				
Edward C. Levy Co.	Detroit, MI	X		X	X	Air cooled and expanded.
Heckett MultiServ Co.	Armorel, AR			X		
Do.	Fontana, CA	X			X	Air cooled.
Do.	Wilton, IA			X		
Do.	Chicago, IL			X		
Do.	Sterling, IL			X		
Do.	East Chicago, IN	X				
Do.	Indiana Harbor, IN	X				
Do.	Ashland, KY	X			X	Air cooled.
Do.	Coalton, KY			X		
Do.	Newport, KY			X		
Do.	Owensboro, KY			X		
Do.	Kansas City, MO			X		
Do.	Canton, OH			X		
Do.	Mansfield, OH	X				
Do.	Massillon, OH			X		
Do. (Warren Plant)	Warren, OH	X				
Do.	do.			X		
Do.	Youngstown, OH			X		
Do.	Butler, PA			X		
Do.	Provo, UT		X		X	Air cooled.
Holcim (US) Inc.	Gary, IN				X	Air cooled, granulated, and expanded.
Do.	Weirton, WV				X	Granulated.
IMS Waylite Corp.	Bethlehem, PA	X	X		X	Air cooled and expanded.
Do.	Cambria, PA		X		X	Air cooled.
International Mill Services	Fort Smith, AR			X		
Do.	Kingman, AZ			X		
Do.	Pueblo, CO	X				
Do.	Claymont, DE			X		
Do.	Cartersville, GA			X		
Do.	Alton, IL			X		
Do.	Chicago, IL			X	X	Air cooled.
Do.	Kankakee, IL			X		
Do.	Gary, IN			X		
Do.	Huntington, IN			X		
Do.	Laplace, LA			X		
Do.	Jackson, MI			X		
Do.	Monroe, MI			X		
Do.	St. Paul, MN			X		
Do.	Jackson, MS			X		
Do.	Charlotte, NC			X		
Do.	Perth Amboy, NJ			X		
Do.	Riverton, NJ			X		
Do.	Sayreville, NJ			X		

TABLE 8--Continued
PROCESSORS OF IRON AND STEEL SLAG IN THE UNITED STATES IN 2001

		Steel slag			Iron slag	
Company	Plant location	Basic oxygen furnace	Open hearth	Electric arc furnace	Blast furnace	Type of slag
International Mill Services--Continued:	Auburn, NY			X		
Do.	Hubbard, OH			X		
Do.	Marion, OH			X		
Do.	Mingo Junction, OH	X		X		
Do.	Warrent, OH			X		
Do.	McMinnville, OR			X		
Do.	Portland, OR			X		
Do.	Brideville, PA			X		
Do.	Coatesville, PA			X		
Do.	Holsopple, PA			X		
Do.	Houston, PA			X		
Do.	New Castle, PA			X		
Do.	Midland, PA			X		
Do.	Pricedale, PA	X		X		
Do.	Reading, PA	X		X		
Do.	Georgetown, SC	X		X		
Do.	Darlington, SC	X		X		
Do.	Beaumont, TX	X		X		
Do.	El Paso, TX	X		X		
Do.	Jewett, TX	X		X		
Do.	Longview, TX	X		X		
Do.	Plymouth, UT	X		X		
Do.	Seattle, WA	X		X		
Do.	Saukville, WI	X		X		
Do.	Weirton, WV	X		X		
Lafarge Corp.	Cuyahoga, OH		X		X	Air cooled.
Do.	Baltimore, MD	X			X	Granulated.
Do.	Lordstown, OH		X		X	do.
Do.	McDonald, OH		X			
Do.	Mingo Junction, OH				X	Air cooled.
Do.	Warren, OH				X	do.
Do.	Youngstown, OH		X			
Do.	West Mifflin, PA				X	Air cooled.
Do.	Weirton, WV				X	do.
Lone Star Inc.	New Orleans, LA				X	Granulated.
The Levy Co. Inc.	Burns Harbor, IN	X			X	Air cooled.
Do.	East Chicago, IN				X	do.
Martin Marietta Aggregates	Raleigh, NC	X			X	do.
Maryland Slag Co.	Baltimore, MD				X	do.
Olympic Mill Services Inc.	Seguin, TX			X		
Stein, Inc.	Decatur, AL	X				
Do.	Cleveland, OH	X			X	Air cooled.
Do.	Lorain, OH				X	do.
Vulcan Materials Co.	Alabama City, AL				X	do.
Do.	Fairfield, AL	X			X	do.