BRICK INSTALLATION GUIDE

TECHNICAL INFORMATION

Harbison-Walker Refractories Company

Harbison-Walker Brick Installation Guide

Please contact your Harbison-Walker Representative at any time for more specific information on the use of refractory products in your applications.

NOTE: Technical data within this brochure are subject to reasonable variations and should not be used for specification purposes. ASTM procedures, where applicable, are used for determination of data.

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DISCLAIMER: The information presented in this book is for general educational use only. It does not contain recommendations for any particular refractory for any particular use. It is not intended as, and should not be taken as, a warranty of any kind, including but not limited to a warranty of fitness.

WARNING: Some materials which are present in refractory products are harmful. One such group is classified as substances known to cause cancer to humans. Other substances may be classified as probably or possibly carcinogenic. These materials include minerals used in or formed during the manufacture of these products. The primary threat presented by many of these materials comes from inhaling respirable dust. The use of proper respiratory equipment, as well as other personal protective equipment is mandatory where required by applicable law. Please refer to the applicable Material Safety Data Sheet for such product.

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INTRODUCTION

Out of the Fire

The history of high heat manufacturing and refractory technology began with the discovery of fire. Nature provided the first refractories, crucibles of rock where metals were softened and shaped into primitive tools. Modern refractories are customized, high-temperature ceramics designed to withstand the destructive and extreme service conditions needed to manufacture metals, glass, cement, chemicals, petroleum and other essentials of contemporary life.

The History of Harbison-Walker

The refractories company known as Harbison-Walker opened on March 7, 1865, as the Star Fire Brick Company. The firm was founded by J.K. Lemon, a Pittsburgh entrepreneur who hoped to build a fortune on America's growing demand for refractory brick following the Civil War.

In 1866, Lemon hired Samuel Pollock Harbison as a part-time bookkeeper. Within four years, the ambitious accountant had acquired enough stock and refractory expertise to be named General Manager of Star Fire Brick. In 1875, Harbison teamed with another stockholder, Hay Walker, to purchase the underachieving company, and renamed it Harbison-Walker.

Almost immediately, Harbison and Walker realized a major opportunity to grow their business and its reputation. Through an ongoing relationship with Thomas Carnegie, the fledging company landed a contract from Kloman, Carnegie, and Company to build the Lucy Furnace, the largest blast furnace ever designed.

The company garnered accolades for the superior performance of the Lucy Furnace and began to expand rapidly, pushed in large measure by the explosive growth of the steel industry. In 1910, a 10-company merger created Harbison-Walker
Refractories Company, a 33-plant operation that was the largest of its kind in the world. Harbison-Walker also thrived on its vertical structure, exerting control over every stage of its production process, through mining and raw materials
management to manufacturing, transportation and distribution.

In the decades that followed, Harbison-Walker established and fortified its position of industry leadership by building new facilities and acquiring related organizations.

- In 1916, Harbison-Walker organized the Northwest Magnesite Company near Chewelah, WA. This gave the company a secure domestic source of magnesite, a material of choice for industrial furnaces in short supply during World War I.

- In 1927, Harbison-Walker acquired majority ownership of Northwest Magnesite, and following World War II, commissioned the company to build and operate a sea-water magnesite facility at Cape May, NJ.

- In 1945, the company purchased Canadian Refractories Limited, makers of MAGNECON, an outstanding refractory for rotary cement kilns.

- In the 1950's, Harbison-Walker built a high-quality magnesite facility at Ludington, Michigan. This keyed the development of several industry standard products, including direct-bonded magnesite-chrome brick, pitch-bonded and pitch-impregnated magnesite products, and magnesite-carbon refractories.

- In 1954, Harbison-Walker became the first U.S. company to produce refractories for the basic oxygen furnace.

- In 1962, the company discovered massive deposits of high purity bauxitic kaolins at

Eufaula, AL. This permitted the company's Bessemer and Fairfield, Alabama, plants to manufacture significantly improved high-alumina brick that became a refractory of choice for much of the refractory consuming industries.

- In 1967, Harbison-Walker was purchased by Dresser Industries, prompting an accelerated diversification into non-steel related industries.

- In 1994, the company became a part of Global Industrial Technologies, a major manufacturer of technologically advanced industrial products. This development enabled Harbison-Walker to strengthen its presence in several key markets through alliances with other Global Industrial Technologies companies. They included Refractories Mexicanos (REFMEX) and Refractorios Chileanos (RESCA), two of Latin America's leading refractory producers; and Magnesitwerk Aken, a German refractory maker.

- In 1998, Harbison-Walker acquired A.P. Green Industries, Inc. With 22 plants in six countries, A.P. Green, a major refractory producer in its own right, expanded considerably the global resources at Harbison-Walker's disposal.

- In 2000, RHI AG, an Austrian company with many holdings in the global refractories industry, completed its acquisition of Global Industrial Technologies, Inc., the parent company of Harbison-Walker. RHI AG subsequently combined North American Refractories Company (NARCO) and Harbison-Walker, at the time naming the resulting organization RHI Refractories America.

Today, the U.S. and export operations have been reorganized and operate independently under the name ANH Refractories. Because of the strong reputations that Harbison-Walker and NARCO established over their long histories, the companies have retained their names and are continuing to be the refractory suppliers of choice in their respective market places. Harbison-Walker continues to provide outstanding refractory materials to meet the needs of the industrial markets, while NARCO serves the needs of the steel industry.

Harbison-Walker Today

Following World War II and the subsequent proliferation of technological advances, Harbison-Walker recognized the need for additional research capacity. In 1958, the company opened Garber Research Center, now known as the Technical Center West Mifflin. The new facility vastly enhanced Harbison-Walker's ability to test products under simulated service conditions and to conduct "post-mortem" analyses of used refractory samples.

Today, the Technical Center West Mifflin, ranks among the world's largest and most well-equipped refractory research facilities. A staff of outstanding physicists, chemists, metallurgists and engineers work closely with Harbison-Walker customers to develop new products and to solve process or production problems.

In the mid-1990s, Harbison-Walker completed a multi-million-dollar investment in the Technical Center West Mifflin aimed at providing the company's engineers and scientists with the very latest testing and analytical equipment. This commitment, made at a time when many refractory companies were diminishing their internal research capability, aggressively positioned Harbison-Walker for the new century of refractory industry leadership.

The capabilities and equipment at the Technical Center West Mifflin have been further enhanced by its additional staff and equipment acquired through its acquisition of A.P. Green and merger with NARCO.

Application Focused Technical Marketing and Sales Support

Harbison-Walker has adopted a marketing structure that enables it to function more like a network of smaller, industry-focused companies. Throughout each of its markets, Harbison-Walker employs application focused technical marketing support, each with specific training in a particular industry or series of related industries. Individual market segments include glass, industrial metals, minerals processing and environmental, energy and chemicals markets.

Over the long term, this structure is specifically designed to promote innovation through a continuous dialogue between Harbison-Walker and the individual industries the company serves. On a daily basis, this structure allows Harbison-Walker to respond more quickly to customer requests and to serve as a reliable and ever present problem-solving partner.

Over the years, this studied, individualized approach to customer service has yielded an unending stream of innovative refractory products and application strategies for the entire range of heat-processing industries.

Broad Based Expertise

Harbison-Walker's sales and technical support staff consists of chemical, ceramic, metallurgical, industrial and mechanical engineers. With strong technical educations and practical knowledge of the industries they serve, these individuals are highly skilled at working with customers to identify and select refractories that can extend service life and improve process efficiencies.

Typical consultations explore specific operating conditions in a customer's furnace and why those conditions suggest the implementation of one refractory type over another in a particular furnace zone. This process can be further aided through interactive CAD systems that allows customers to select and preview refractory linings and configurations.

Another valuable service Harbison-Walker offers is performance assessments. This process is usually aimed at identifying causes for deteriorating refractory performance resulting from changing operating conditions within a customer's plant. Most often, diagnoses are based on post-mortem analyses of used refractories to determine the modes of refractory wear.

Test results may point to the adaptation of existing refractories, applying refractories in new combinations, the selection of different refractory brands or the custom design of new refractories to better meet the altered service conditions.

Helping customers understand and implement a proper refractory management strategy is the first step in an on-going relationship between Harbison-Walker and the refractory user. Sales and technical representatives are often on-site for refractory installation and furnace start-up. Follow-up technical support can include orientation and training programs, troubleshooting, and service and performance assessments.

Quality Control

Harbison-Walker's quality control programs encompass every facet of the organization, from the acquisition of raw materials to the packaging and shipment of the finished material.

The company operates an aggressive program of mineral land acquisition, permitting it to control a significant percentage of the raw materials it consumes. This program also helps ensure the uniform quality of raw materials while insulating the company from fluctuating supplies of key refractory minerals. Imported minerals, such as chrome ore, also are examined and tested for quality by Harbison-Walker engineers.

At the processing stage, manufacturing sites are dedicated to a single product or single class of products. This enables Harbison-Walker to maintain a high degree of chemical purity, resulting in uniform products, free of contaminants and capable of tight dimensional tolerances. In addition, each plant maintains a laboratory and a staff of quality control engineers to measure product characteristics against stated specifications.

The company also operates a centralized Quality Control Department in West Mifflin, PA., which is responsible for monitoring quality standards for all Harbison-Walker brands.

Industry Dialogue

Harbison-Walker encourages a continuous dialogue among its industry "partners" by communicating continuously with contractor/installers and soliciting regular customer input and feedback about all aspects of refractory performance.

Every year, the company brings together its engineers and select installers to disseminate technical information in an educational forum. This presents opportunities for installers to discuss their goals and expectations of refractory performance, as well as plant safety requirements.

In turn, Harbison-Walker engineers offer refractory product updates, and a comprehensive review of installation and construction techniques. This mutual information exchange leaves participants more prepared to work cooperatively throughout the year

As the refractory industry continues to evolve and expand, Harbison-Walker pledges to maintain this dialogue, seeking ways to better ways to contain the heat of industrial progress.

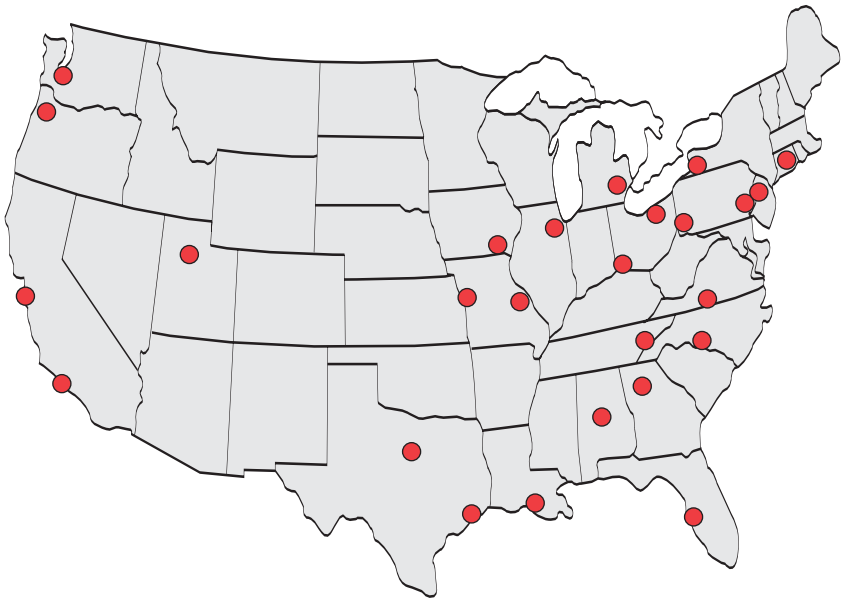
HARBISON-WALKER DISTRIBUTION CENTERS

Harbison-Walker Distribution Centers

Harbison-Walker offers the only nation-wide refractories and insulation distribution system. Our 26 locations continue to stock the best refractories in the industry, including fireclay and high alumina brick, mortars, plastics, and castables as well as a full line of ceramic fiber and mineral wool products. Kiln liners, anchoring systems and special shapes are also available.

Harbison-Walker Distribution Centers

Atlanta, (Doraville) GA	(770) 448-6266	Knoxville, TN	(865) 546-4930
Baton Rouge, (Gonzales) LA	(225) 644-2111	Lakeland, FL	(863) 669-1040
Birmingham, AL	(205) 788-1685	Los Angeles, (Pico Rivera) CA	(562) 942-2151
Buffalo, (Tonawanda) NY	(716) 692-1761	New York, (Rahway) NY	(732) 388-8686
Charlotte, NC	(704) 599-6540	Philadelphia, (Trevose) PA	(215) 364-5555
Chicago, (Calumet City) IL	(708) 474-5350	Pittsburgh, (Leetsdale) PA	(412) 741-3200
Cincinnati, (Milford) OH	(513) 576-6240	Portland, (Clackamas) OR	(503) 656-2854
Cleveland, OH	(216) 398-1790	Roanoke, (Salem) VA	(540) 375-2107
Dallas, TX	(214) 330-9243	Salt Lake City, UT	(801) 886-0545
Davenport, IA	(563) 445-1244	San Francisco, (Richmond) CA	(510) 236-7415
Detroit, (Romulus) MI	(734) 955-6025	Seattle, (Kent) WA	(253)872-2552
Houston, TX	(713) 635-3200	St Louis, MO	(314) 521-3314
Kansas City, (Lenexa) MO	(913) 888-0425	West Haven, CT	(203) 934-7960

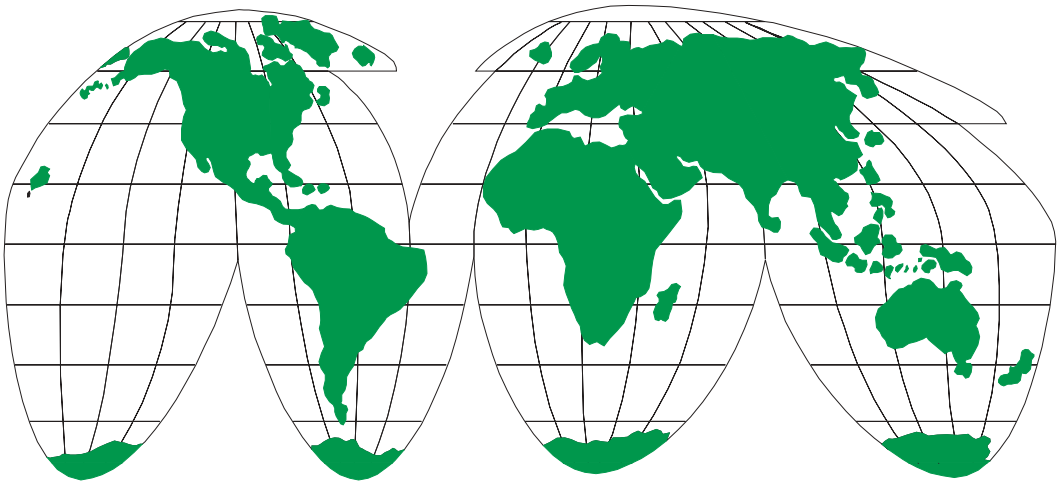


Visit our website at www.hwr.com or
Call (800) 887-5555 to reach the location nearest you.
For your convenience we accept,
American Express, MasterCard and VISA.

Harbison-Walker Manufacturing Facilities

As part of the ANH Refractories Family of Companies, Harbison-Walker maintains a number of manufacturing facilities. 20 ANH Refractories plants, spread across 9 U.S. states, 1 Canadian province and 4 foreign countries, manufacture Harbison-Walker brand refractory materials. Below is a list of ANH Refractories manufacturing locations:

- Acton, Ontario
- Bromborough, England
- Calle, Colombia
- Cilegon, Indonesia
- Fairfield, AL
- Fulton, MO
- Gary, IN
- Minerva, OH
- Monterrey, Mexico
- Oak Hill, OH
- Pryor, OK
- Smithville, Ontario
- Solon, OH
- South Shore, KY
- Sproul, PA
- Thomasville, GA
- Vandalia, MO
- West Mifflin, PA
- White Cloud, MI
- Windham, OH



Harbison-Walker on the Web

Since the rise of the internet as a viable business tool, Harbison-Walker has realized the importance of providing relevant information to its customers via the World Wide Web. By accessing www.hwr.com users can view all of the most up-to-date Material Data Sheets, MSDS and Mixing & Using Instructions. Users may also request literature materials detailing refractory use in many of the industry's most relevant applications.

SELECTION OF REFRACTORIES

Optimum use of refractories is achieved by careful study of furnace design and evaluation of operating conditions prior to selection of refractory products which meet the design and operating requirements.

From the multiple factors listed below, it may appear that the choice of most suitable material would be exceedingly difficult. Sometimes this is true. However, there are usually data on hand from previous experience under similar conditions. Moreover, the best refractory selection often depends on a few requirements so important that other factors play a minor role. In some cases, just refractoriness alone, i.e., maximum service temperature, will be the deciding factor. In others cases high refractoriness will have to be coupled with resistance to thermal shock. Under other circumstances, resistance to metals, slags, or disintegration by reducing gases may be the governing factors. Sometimes high insulating value is desirable, but in other situations high thermal conductivity may be needed. When selecting refractories, the following major factors must be identified.

OPERATING FACTORS

- Function of the furnace
- Nature of material being processed
- Rate and continuity of operation
- Range and rapidity of temperature changes
- Chemical attack by metals, slags, ash, etc.
- Fluidity of molten metal or slag
- Velocity of furnace gases
- Abrasion from contained solids or gases
- Impact from charging
- Erosion by molten furnace contents
- Impinging flames or hot spots

FURNACE DESIGN AND CONSTRUCTION

- Type of furnace
- Design and dimensions of walls and arches
- Loads imposed on the lining
- Conditions of heating (one or more sides)
- Amount of insulation
- Air- or water-cooling
- Type of refractory construction (brick or monoliths)
- Methods of bonding or support
- Provision for thermal expansion
- Mechanics of any moving furnace parts

REFRACTORY-RELATED FACTORS

Properties at room temperature –

- Workmanship and physical strength
- Density, porosity, permeability
- Chemical and mineral composition
- Uniformity
- Size and design

Properties at high temperatures –

- Refractoriness or maximum service temperature
- Reversible thermal expansion
- Resistance to thermal shock
- Resistance to chemical attack
- Resistance to mechanical impact or stress
- Resistance to abrasion or erosion
- Permeability to gases or liquids
- Volume stability (bloating or shrinkage)
- Resistance to gases and fumes
- Thermal conductivity
- Heat capacity
- Electrical resistance

Economic factors –

- Delivered cost
- Cost of installation (brick vs. monoliths)
- Special shapes or forming required
- Service life

ORDERING REFRACTORIES

Refractory technology is becoming increasingly specialized, year after year, so that it is often necessary to thoroughly understand an application area before making refractory selections. Harbison-Walker Marketing Representatives have been trained to do this work and are ready as an accommodation to discuss your application with you. Acess our website www.hwr.com for contact information.

In most cases, careful specification of your requirements and operation will help Harbison-Walker fill your order correctly and without delay. When you order various shapes and sizes, provide a complete description and correct dimensions for the shapes that you need. If you order circle brick or other shapes designed to fit a circular lining, provide both the inside and outside diameter of the lining.

Orders for brick should include enough mortar material of the right kind to lay the brick. Information required to specify the number, shape and size of brick as well as the quantity of mortar appears in the following tables and in the Brick Sizes and Shapes Section of the Handbook.

Special Shapes

On initial orders for special shapes, send a drawing of the shape and the assembly into which it fits. The assembly drawing will help Harbison-Walker engineers evaluate the design and verify that the combination of refractories and design produces the best results. On subsequent orders the Harbison-Walker drawing number or your drawing and shape number will ensure that the order is properly filled. Refer to the previous order by number and date.

When filling orders for special shapes, Harbison-Walker makes a slightly larger number of shapes than specified to cover possible breakage in firing. In some cases, all of the extra pieces will come from the kilns in perfect condition.

Then, Harbison-Walker will ship a limited quantity of extra pieces in accordance with the following table, unless special instructions are entered on the order. This standard procedure also helps avoid shortages resulting from breakage during transit and handling.

Standard Packaging

Standard packaging for monolithic refractories are 55 lb. sacks, pails, and cartons, and 2,000 lb., 3,000 lb., and 4,000 lb. bulk bags. Non standard palletizing for brick or monoliths and non standard packaging options including export palletizing are available for additional charges.

Number of Refractory Straights Required Per Square Foot of Wall or Floor	
Wall or Floor Thickness, Inches	9 X 4½ X 3 Inch Brick
3	3.6
4½	5.3
6	7.2
7½	8.9
9	10.7
12	14.2
13½	21.4
18	21.4
27	32.1

Approximate Pounds of Mortar per 1000 9-Inch Brick (9 X 4½ X 2½ Inch)*

Mortar Materials	Brick Laid Dry and Grouted	Brick Laid with Dipped or Thinly Trowelled Joints
Heat-Setting Mortars		
SATANITE®	250 - 300	350 - 450
Air-Setting Mortars		
HARWACO BOND®	250 - 300	350 - 450
'SAIRSET®	250 - 300	350 - 450
H-W® PERIBOND™	300 - 400	500 - 600
'SAIRBOND®	250 - 300	350 - 450

* This is for 9-inch straights. Normally, for larger sizes the quantities required are reduced in porportion to the decrease in surface area covered by the mortar per 1000 9-inch equivalent.

NOTE: Minimum figures are used ordinarily for estimating.

TYPICAL BRICK GROSSING CHARTS

Quantity Specified	Overage	Quantity Specified	Overage
1-100	10%	5,001 - 10,000	2%
101-1,000	7%	Over 10,000	1%
1,001-5,000	3%		

Note: Not less than one shape. If in sets, one complete set.

Overview

Sound furnace refractory lining and construction — whether carried out by experienced masonry specialists working on a high production furnace or a contractor building a municipal incinerator — begins with a few fundamental ideas required to produce satisfactory performance.

FOUNDATION

The foundation must function at the temperature produced by the furnace. For many industrial furnaces, contractors build foundations of concrete, consisting of a crushed stone aggregate, sand and binder of hydrated Portland cement. Under normal conditions, Portland cement concrete has been safely used for furnace foundations up to 700°F (371°C). When the temperature reaches 900°F (483°C), dehydration of the cement reaches a point where the concrete retains little mechanical strength.

Ordinary aggregates include quartz pebbles, silica gravel, crushed silica rock and/or crushed limestone. An aggregate of silica rock in any form will expand sufficiently at temperatures up to 1,000°F (538°C) to set up stresses in the concrete and weaken the foundation. Limestone or dolomite rock in an aggregate will calcine at somewhat higher temperatures and weaken considerably. For temperatures above 700°F (371°C), good practice points to the choice of a castable refractory for the foundation. Calcined fireclay, in sizes up to 1 inch, can be substituted for conventional aggregate. Its thermal expansion is low, and it will not shrink at the highest temperature to which concrete can be subjected.

High temperature furnace operation also calls for ventilation in the lower courses of brickwork or the upper part of the foundation. Good furnace design often requires placement of the furnace on plates, girders or low brick piers, so that air circulates under the vessel. Sometimes, cross flues are formed in the top of the concrete foundation. At others, pipes, 3 inches in diameter or larger, are embedded in the foundation.

Building furnaces is a specialized branch of masonry, best placed in the hands of bricklayers experienced in furnace construction. Walls, arches and other furnace details should be designed and constructed to assure structural stability. Otherwise, a return on your refractory investment may not be realized.

WALL CONSTRUCTION

Courses of brick laid in a wall so that the lengths parallel the face of the wall are called stretchers. Brick with lengths running at right angles to the face are headers. In soldier courses, the brick stand on end, and in row-lock courses, they lie on one edge (See illustration, p. 11).

Header courses tend to spall less than stretchers at the hot face of a furnace wall because they expose a smaller area to high temperature. However, stretcher courses expose fewer joints than headers, and this provides an advantage in applications where joints tend to wear more rapidly than brick.

Bonding, or tightening construction through combinations of headers and stretchers and off-setting vertical joints, strengthens and stabilizes furnace walls. The type of bond selected for any particular furnace will depend upon the design of the furnace, thickness of the walls, the need for gas-tight construction, severity of operating conditions and the need for easy maintenance.

In any case, the wall should be bonded so that loads will be transferred to the cooler part of the wall when the inner, hotter portion loses its ability to carry them. Walls must be designed to carry structural loads at high temperatures.

Stretcher walls — one brick thick — usually have the least structural stability, but they are sometimes used in smaller furnaces and in furnaces where heat must pass through the walls. Double tongue and groove brick provide stability for thin walls.

Alternate header and stretcher courses probably provide the most common arrangement for standard industrial furnaces. Large 9-inch brick break joints, start ends of walls and turn corners.

Courses consisting mostly of headers are often used advantageously in 9 and 13½-inch walls subject to high temperatures, heavy loads and slag attack. This construction is usually preferred for basic brick walls. The bond provides stability and easy replacement, but most expansion joints pass entirely through 9-inch walls.

Courses consisting mainly or entirely of headers on the inner face and mainly stretchers on the cold face are sometimes considered desirable when spalling conditions are severe. Three or four stretcher courses to one header provide a wall to which a 4½-inch skin wall can be tied for repairs. However, it should not be used where stretcher courses may fall into the furnace.

In composite wall construction consisting of two or more kinds of brick in inner and outer courses, the courses are sometimes tied together. Usually, the more refractory brick go into the interlocking courses.

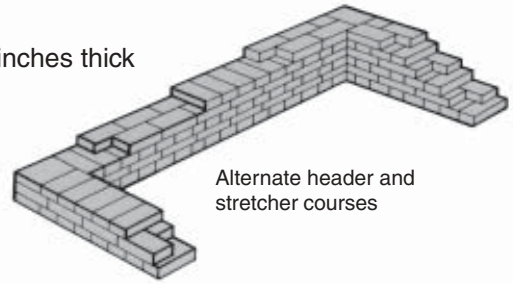
However, when brick have marked differences in rates of thermal expansion, the backup courses should not be tied to the inner courses. This is especially true when the temperature gradient through the wall makes a significant difference in total expansion.

The number of refractory straights required to build a simple wall can be determined from the chart on p.12. Multiply brick per square foot from the appropriate row, depending on wall thickness, by the area of the wall to provide the brick count. For walls not of simple rectangular shapes, determine the volume in cubic feet from the appropriate formula on this page and multiply by the number of brick per cubic foot.

Wall thickness must bear some relation to height and unsupported

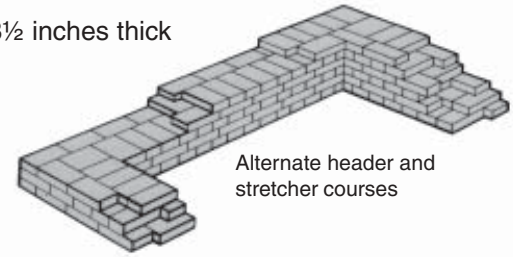
BONDING OF WALLS BUILT WITH RECTANGULAR BRICK

Wall 9 inches thick



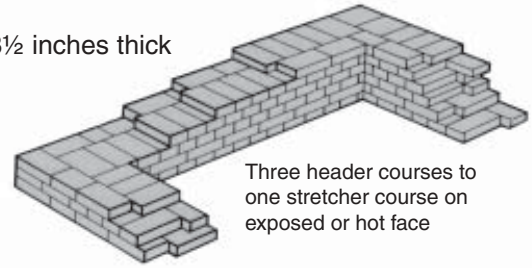
Alternate header and stretcher courses

Wall 13½ inches thick



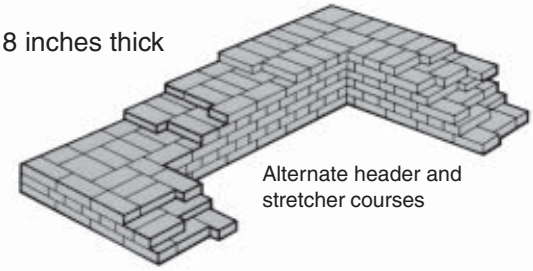
Alternate header and stretcher courses

Wall 13½ inches thick



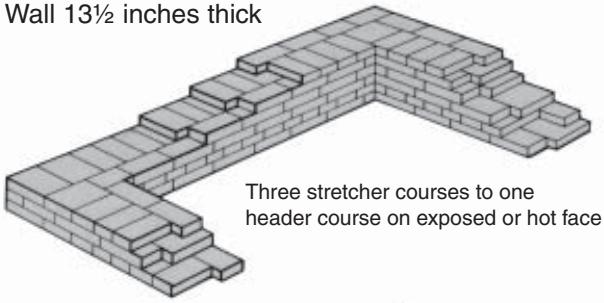
Three header courses to one stretcher course on exposed or hot face

Wall 18 inches thick



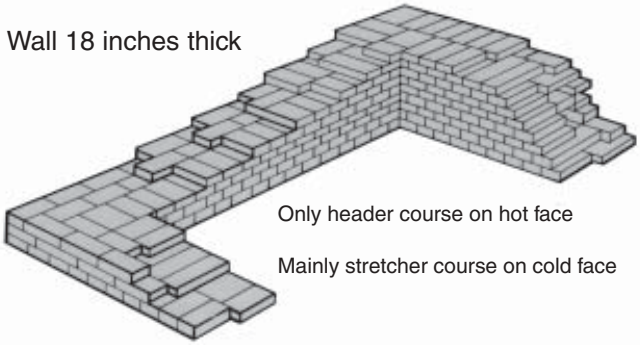
Alternate header and stretcher courses

Wall 13½ inches thick



Three stretcher courses to one header course on exposed or hot face

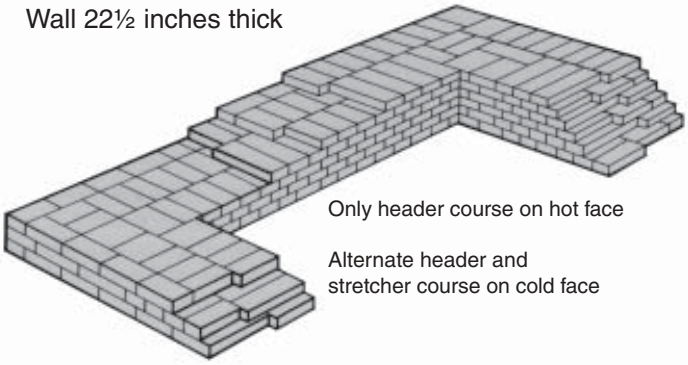
Wall 18 inches thick



Only header course on hot face

Mainly stretcher course on cold face

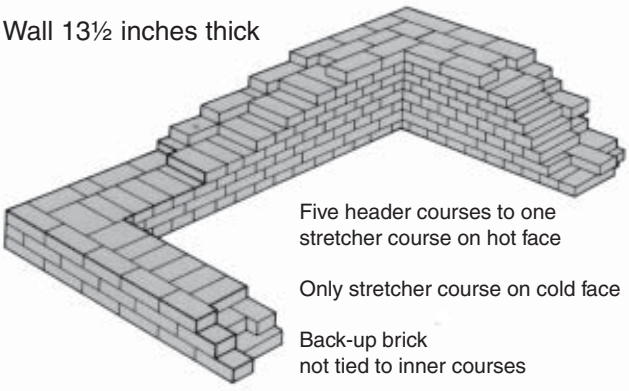
Wall 22½ inches thick



Only header course on hot face

Alternate header and stretcher course on cold face

Wall 13½ inches thick



Five header courses to one stretcher course on hot face

Only stretcher course on cold face

Back-up brick not tied to inner courses

length. In unsupported straight walls, a 4½-inch thickness will carry heights up to 3 feet; 9 inches will carry heights of 3 to 8 feet; 13½ inches, 8 to 12 feet; and 18 inches, walls higher than 12 feet.

Walls with unsupported length more than one and one half times their heights should be somewhat thicker, and thermal spalling conditions may indicate additional thickness. Walls of cylindrical furnaces and stacks, with adequate backing, may be somewhat thinner for a given height than straight walls.

Cylindrical walls, arches and domes are built with brick tapered to turn circles. Arch brick slope from edge to edge so that the length of the brick parallels the furnace wall like a stretcher, while the wedge tapers from end to end so that it faces into the furnace like a header. A 9 x 4½ x 2½-inch arch brick makes a 4½-inch lining, while the same wedge shape makes a 9-inch lining. In basic brick, key brick shapes may also taper along the edges. Combinations of these shapes taper in two dimensions to turn domes.

JOINT CONSIDERATIONS

In many cases, brick sizes and shapes or the type of bond will be chosen to minimize the number of joints in the lining. Monoliths — not without construction or thermal expansion joints – present the fewest joints and opportunities for penetration by metal, slag or furnace gases.

Ramming mixes or castable refractory materials are often used to fill places where brick would be cut to fit. For example, ramming mixes or dry refractory materials can be used to protect the toe of the skewback (See discussion of Arch Construction, UR - 22). On many installations, the irregular space between electric furnace roof brick and electrode ports is filled with ramming mix or castable refractories.

The thickness of joints between refractory brick depends on the brick, the mortar, the need for preventing gas leakage or slag penetration, and the requirements for thermal expansion. When there is no need for an especially strong bond, the brick are laid without mortar. In some cases, the fusion that takes place on the hot face will provide the bond required. Generally, however, the use of mortar is desirable to level courses and to provide smooth bedding for the brick.

Brickwork laid with heat-setting mortars should have thin joints, either dipped or poured. The brick should be rubbed or tapped into place to produce as much brick-to-brick contact as possible. Joints made with an air-setting mortar generally can be somewhat thicker, but such joints should be completely filled.

In furnace construction, proper allowance must be made for thermal expansion. Usually, vertical expansion allowances permit walls to move freely upward and horizontal expansion allowances appear at joints in the brick.

HEARTHS

The construction of furnace hearths presents special problems. Some furnace bottoms must withstand impact and abrasion from a charge of scrap metal. Liquid pressure may tend to float brick. Many hearths must resist penetration by metal or slag accompanied by corrosion or erosion.

Furnace hearths, in many cases, are built of refractory brick, usually seated on a monolithic refractory bed. Others have sub-bottoms built of brick with working hearths composed of monolithic refractories, such as dead-burned magnesite or a ramming mix.

Construction details, as well as the refractories themselves, depend on applications. Even different furnaces within the same application area may perform more efficiently with a different refractory design.

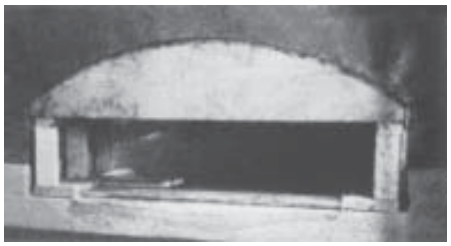
Sophisticated applications for refractories call for specialists in refractories design. A number of engineering firms specialize in high temperature process design, and many contractor/installer organizations concentrate on refractory construction.

Harbison-Walker maintains close contact with these organizations, lending its engineering skills and applications know-how to the search for solutions to any problem involving the use of refractories.

Number of Refractory Straights Required Per Square Foot of Wall or Floor

Thickness, Inches	9 x 4½ x 3” Brick
3	3.6
4½	5.3
6	7.2
7½	8.9
9	10.7
12	14.2
13½	16.0
18	21.4
27	32.1

Rammed plastic refractories used for arch construction minimize the number of joints.



Arch Construction

Overview

Arches form the roofs of most furnaces, combustion chambers and flues. Providing the standard solution to the problem of spanning the high temperature process with refractories. In some application, arches span wall openings, and sometimes they carry the weight of walls or checkerwork. Most arches are built of brick, but monolithic materials are gaining popularity throughout the industry.

TYPES OF ARCHES

Sprung Arches

In a true arch, the design of the whole determines the shape of each block or structural unit. Theoretically, each joint is a small piece of the radius of the circle of which the arch is a segment. Each end of the arch rests on a skewback. The arch becomes self-supporting after all of the pieces go into place, but it must be supported until the final, center shapes the keys go into place. When it is complete, the arch springs from the sloping faces of the skewback shapes. The skewbacks cut off the arc of the circle on the outside radii of the arc.

The sprung arch exerts a downward vertical force and an outward horizontal force on the skewbacks, essentially a distribution of its weight. The vertical force may be carried by steel beams or by the furnace walls or a combination of walls and steel buttresses. The horizontal thrust of a roof arch travels through the skewbacks to a steel supporting system known as the binding which is composed of beams and tie rods. The tie rods, usually above the furnace, link one side of the furnace to the other, and balance opposing forces, one against the other.

In traditional furnace design, the binding consists of:

1. *Horizontal buttress beams running lengthwise to the furnace in contact with the skewbacks where possible;*
2. *Vertical beams, or backstays, spaced at intervals along the concrete; and*
3. *Horizontal tie rods, I-beams, or channels extending across the furnace above the roof to connect the upper ends of opposite buckstays.*

Ring Arches

In ring arches, each course of brick forms a separate ring running across the roof and the joints are continuous across the roof. Ring arches require somewhat less labor for initial construction. Cold repairs are easier to make and they offer better resistance to spalling. However, ring arches require support at the end of the furnace to forestall outward displacement.

In bonded construction, all joints are broken and the rings help bond one another in a stronger construction. Bonded roofs are better adapted for hot repairs but they demand more skill of the brick masons and more uniformity in the brick.

Sometimes, furnace designers strengthen ring arch roofs by using a longer brick in every third or fourth ring. This construction creates ribs across the roof, which remain strong when the thinner parts of the roof wear away. The strength of the ribs also helps when roofs must be patched.

Suspended Arches

In suspended arches, a steel superstructure helps carry the weight of the roof, otherwise distributed through the arch to the walls and binding. Suspended arches are often used with dense, heavy basic brick. Harbison-Walker has basic brick brands to provide a method for attaching the brick to an overhead steel superstructure.

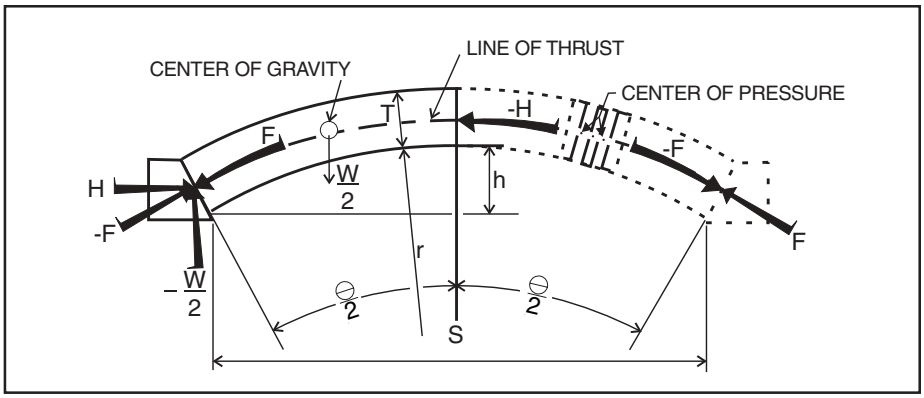
In suspended construction, refractories carry smaller loads and therefore, suffer less deformation at high temperatures than they otherwise might. Using suspended construction, it is also easier to make allowance for thermal expansion to avoid thermal stresses and pinch spalling.

Monolithic Arches

Monolithic arches–cast over forms much like those required for brick arches–have replaced brick in some applications. Skews may be eliminated in monolithic arches, but design considerations remain the same as those for brick arches. A monolithic arch provides all of the advantages monolithic construction, including reduced cost and downtime.

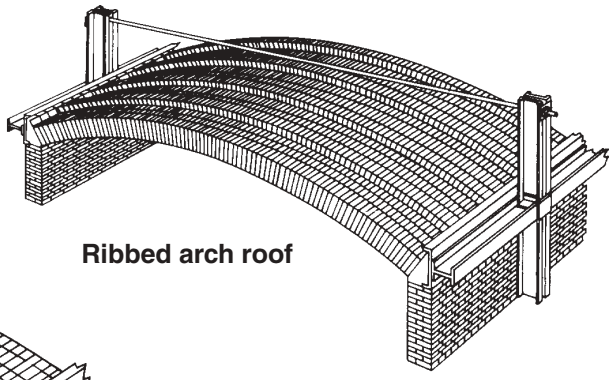
ARCH GEOMETRY

Arch geometry determines all design characteristics. From the viewpoint of arch design, the outside and inside arcs, or surfaces of the roof, are segments of concentric circles separated by the thickness of the roof. The skewback slope cuts the arc, and its angular value equals half the included central angle of the arch. The rise of the arch measures the distance from the inner chord - equal to the span and cutting the inside arc to the center of the roof at midspan.

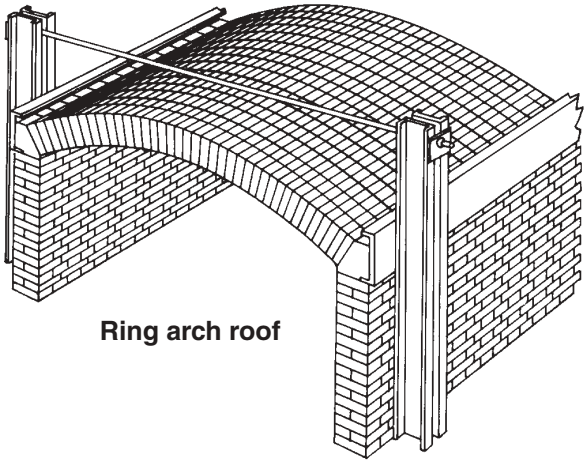


Hypothetical position of thurst in a simple sprung arch, when the bricks are in full contact at joints.

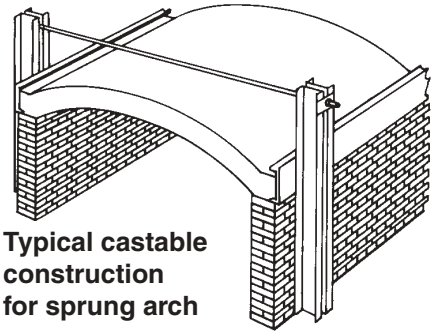
Arch Construction



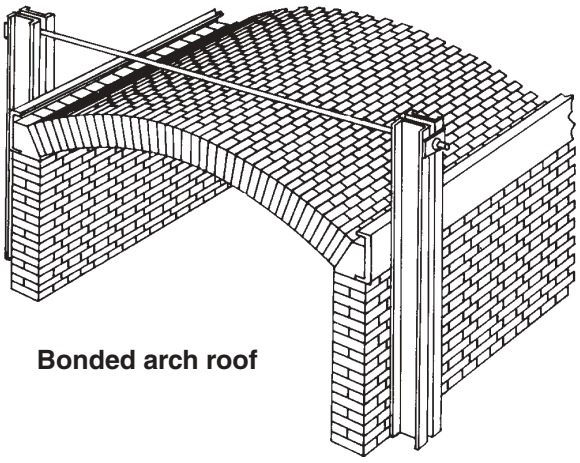
Ribbed arch roof



Ring arch roof



Typical castable construction for sprung arch



Bonded arch roof

Arch Construction

When span, thickness and rise are established, all other dimensions can be calculated using the formulas in this section.

The stability of any arch will depend on its rise, thickness and weight, as well as the thermal properties of the refractories. Hot strength and thermal expansion are particularly important. Good arch design must take these factors into consideration.

Rise is normally expressed in inches per foot of span, or in terms of the central angle. They are directly related. It should be easy to visualize a larger angle including a higher rise and a shorter radius. On the other hand, the flatter roof with a smaller rise indicates a smaller included central angle and a longer radius.

Experiences suggests that a simple roof arch should rise not less than one nor more than three inches per foot of span. For any particular furnace, the rise selected should depend on operating conditions, chiefly temperature, thermal cycling and the refractories used.

Typically, stable fireclay arches rise from $1^1/_2$ to three inches per foot of span. High temperatures and soaking heat call for higher values. Silica roofs made with brick that maintain dimensional stability and hot strength almost to their melting point, normally rise from one to two inches per foot.

High-alumina refractories used in arch construction call for at least 1.608 inch per rise per foot of span. Basic refractories need $2^1/_4$ to three inches of rise in sprung arches. Insulating firebrick, which give up hot strength in exchange for low thermal conductivity, call for two to three inches of rise per foot of span.

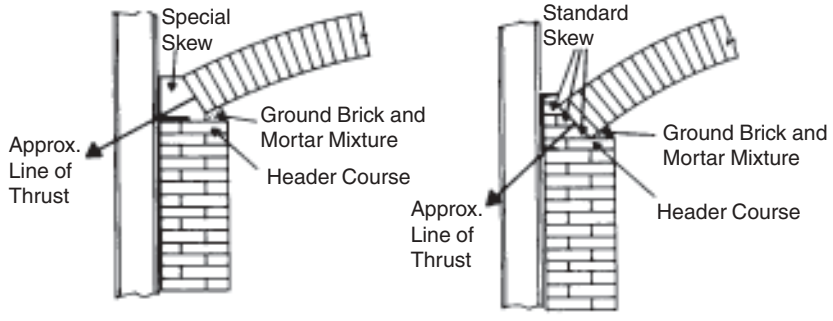
For many applications, a 1.608 inch rise, about $1^5/_8$-inch, is a logical standard in that it meets normal requirements for strength and stability. The 60° central angle equals one sixth of a circle and the span equals the inside radius, so the number of brick required to build the roof is easy to calculate.

The reaction of refractory brick to furnace operation, i.e., heat-up, establishes the practical limit for roof rise. Operation and thermal expansion tend to push the brick upward, opening joints at the top and pinching brick at the bottom. Brick that soften at operating temperatures may become permanently deformed, shortening the radius of the arc and increasing the rise.

As the arch rises on heat-up, the line of thrust, the line of force along which the arch distributes the vertical and horizontal elements of its weight, shifts downward. As the line of thrust approaches a horizontal position in the arch, the horizontal force approaches its maximum value.

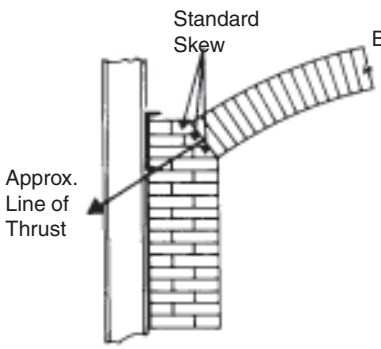
In some furnaces allowance for thermal expansion of the brick will limit upward movement of the arch. Steel casings can provide an allowance for expansion. Paperboard placed between brick will burn out and make room for expansion. In some cases, horizontal tie rods arc spring loaded or manually adjusted to permit thermal expansion of the refractories.

Without adequate provision for thermal expansion, the relationship between arch thickness and rise* of the cold arch must be such that the line of thrust does not drop out of the arch

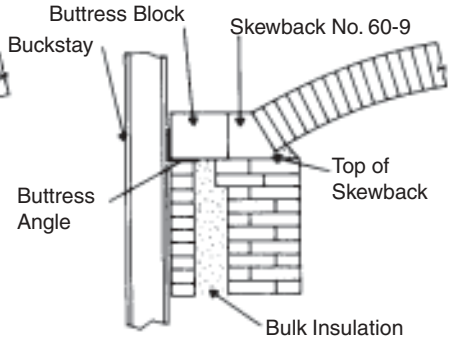


Special skewback
A recommened construction

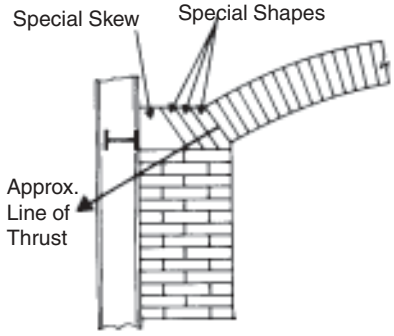
Built-up skewback
A recommened construction



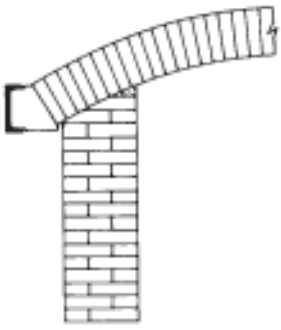
Built-up skewback
A construction to be avoided.



A 60° skewback with
buttress block.



Special skewback
A construction occasionaly used



Arch with skewbacks
supported outside of walls

Note: A stretcher course should never be used immediately below the skewback.

when it is heated. If it does, the arch will not be stable.

The line of thrust in a cold arch should lie within the middle third of the brick. Generally, selecting the proper combination of brick shapes and doing a professional job to assure face-to-face contact between brick will keep the thrust where it belongs.

In practical construction problems, the vertical and horizontal components are more important than the resultant force. The walls, with or without steel supports, must carry the vertical force, and the horizontal binding, including buckstays and tie rods, must contain the horizontal force.

---

* Assuming that the absolute lower limit for the rise of the line of thrust is $^1/_4$ inch ($^1/_{48}$) per foot of span, the rise (h) must exceed thickness (T) times the of the cosine of the central angle (θ)plus $^1/_{48}$ span (S). This implies that T should not exceed:

$$\frac{h - {}^1/_{48}S}{\text{Cosine}\,\theta/2}$$

For a more complete discussion of arch stresses see: J. Spotts Mcdowell, "Sprung-Arch Roots for High Temperature furnaces," Blast Furnace and Steel Plant, September 1939.

ARCH CONSTRUCTION CALCULATIONS

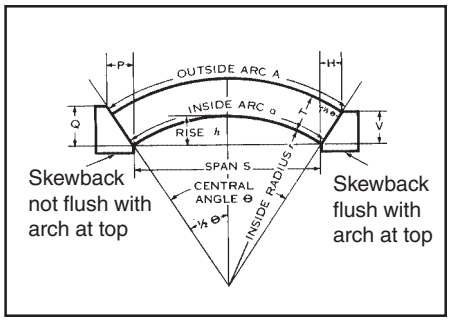
The brick count for many sizes can be calculated from the tables of brick combinations for rings, since simple sprung arches are segments of circles.

Calculation of arch parameters, the arch numbers, is sometimes lengthy, but not difficult, especially when carried out with a pocket calculator. Equations required to produce the necessary values are included in this section.

Suppose that a furnace design calls for an arch with a 12 foot span, 13½ inches thick built of NARMAG® 60DB brand brick, on a furnace 20 feet long. NARMAG® 60DB basic brick, requires a minimum rise of 2¼ inches per foot of span.

The table of Arch Constants below provides data to develop the required design values. For a 2¼ inch rise, multiply the span by 0.76042 to determine the inside radius, in this case, 9.125 or 9 feet, 1½ inches. That means the arch is a segment of a circle with an 18 foot, three inch inside diameter, twice the inside radius.

The table also indicates that the central angle for this arch will be 82° 13.4', equal to 2,284 ten thousandths of a circle.



On page IR - 45 the tables of brick combinations for rings for 13½ inch linings show that an 18 foot, 3 inch ring can be built with:

82 pieces, No. 2 Wedge and
176 pieces, No. 1 Wedge

If this design calls for 2,284 ten thousandths of a ring, then:

0.2284 x 82 = 18.73 or 19 pieces, No. 2 Wedge
0.2284 x 176 = 40.2 or 41 pieces, No. 1 Wedge

If the design specifies 13½ x 6 x 3 inch shapes, then two rings will cover a running foot on the 20 foot roof, and 40 rings will roof the furnace. Thus, the design calls for 40 times 19, a total of 760 pieces, No. 2 Wedge, and 40 times 41, a total of 1,640 pieces, No. 1 Wedge.

Arch Constants for Given Rises per Foot of Span

Rise Inches Per Foot of Span (d)	Inside Radius (r)	Central Angle θ		Inside Arc (a_a)	Difference Between Outside & Inside Arc ($A_a - a_a$)	Skewback		
		Degress	Part of Circle			H	V	F
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	1.54167S	37° 50.9'	0.10514	1.01840S	0.66059T	0.32432T	0.94595T	0.34286Q
1¼	1.25208S	47° 4.4'	0.13076	1.02868S	0.82157T	0.39933T	0.91681T	0.43557Q
1½	1.06250S	56° 8.7'	0.15596	1.04117S	0.97992T	0.47059T	0.88235T	0.53333Q
1.608	1.00000S	60° 0.0'	0.16667	1.04720S	1.04720T	0.50000T	0.86603T	0.57735Q
1¾	0.93006S	65° 2.5'	0.18067	1.05579S	1.13519T	0.53760T	0.84320T	0.63757Q
2	0.83333S	73° 44.4'	0.20483	1.07251S	1.28701T	0.60000T	0.80000T	0.75000Q
2¼	0.76042S	82° 13.4'	0.22840	1.09125S	1.43507T	0.65753T	0.75342T	0.87273Q
2.302	0.74742S	83° 58.5'	0.23326	1.09544S	1.46563T	0.66896T	0.74329T	0.90000Q
2½	0.70417S	90° 28.8'	0.25133	1.11200S	1.57918T	0.71006T	0.70414T	1.00840Q
2¾	0.66004S	98° 29.7'	0.27360	1.13464S	1.71906T	0.75753T	0.65280T	1.160444Q
3	0.62500S	106° 15.6'	0.29517	1.15912S	1.85459T	0.80000T	0.60000T	1.333334Q

NOTE: The factors in the above tables are the following functions of θ: Column 2, ½ cosecant ½θ; column 4, Ø divided by 360°; column 5; ½ cosecant ½θ

SKEWBACK DESIGN

Skewbacks may be built-up combinations of rectangular brick sizes, as previously illustrated, or one-piece special skews designed to fit the arch. Built-up skews satisfy the requirements of narrow spans, four feet or less, but the one-piece skewback generally provides greater strength and better support at the buttress.

The slope of the skewback must be designed to match the central angle of the arch, determined by the rise and span. When the skewback is carried on a channel or angle, the line of thrust should pass through, or slightly above, the corner of the supporting steel.

Skewback dimensions can be determined from the table of Arch Constants below. From the example above, a 2¼ inch rise produces a central angle of 82° 13.4'. The slope equals half the central angle, amounting to 41° 6.6' in this example. Other dimensions can be calculated from constants in the same table.

The V dimension is 0.75342 times the thickness of an arch with a 2¼ inch rise. In this example above, 0.75342 times 13.5 equals approximately 10.17 inches. Other skewback dimensions can be determined in the same way.

The amount of stress in a furnace can be only approximated because of the following variables: (1) the exact position of the line of thrust, even when the arch is cold, is not known, (2) workmanship in construction of the arch may be less than perfect, (3) the position of the line of thrust will change when the furnace is heated, (4) tie rods can stretch and the furnace can settle, changing arch parameters, and (5) arch stresses can be increased by the weight of material adhering to, or absorbed by the bricks. The force acting against the skewbacks depends primarily on the span, rise and thickness of the arch, the weight of the brick, and conditions in the furnace. Vertical force equals one half the weight of the arch per running foot.

The horizontal force depends on the weight of the arch and on the span and rise.

The resultant thrust (F) acting at the skewback equals the square root of the sum of the squares of horizontal (H) and vertical (W) forces, that is:

$$F=\sqrt{H^2+(W/2)^2}$$

However, the stresses of a cold arch, in which all adjoining brick are in full contact, can be approximately determined from the table below. The limiting value which the horizontal thrust approaches in a heated arch, H_{max}, can be calculated approximately from the constants in the table of Maximum Values on the following page.

Consider the NARMAG® 60DB brick arch design described earlier in this chapter. Its design parameters are:

Span (S) = 12 ft

Thickness (T)= 1.125 ft

Inside Radius (r) = 9.125 ft

Density of NARMAG® 60DB (D) = 192 lb/ft^3

Rise (h) = 2.25 inches per foot of span=12 x 2.25 = 27 inches=2.25 ft

Outside radius (R+T) = 10.25 ft

Central Angle (θ) = 82°13.4'

The following calculations are based on the assumption that the line of thrust passes from the center of arch thickness at midspan to the center of arch thickness at the skewbacks.

As shown in the table below, the weight of the arch equals 1.17 DST. That is, for this arch, 1.17 times 192 times 12 times 1.125 equals 3032.64 pounds per foot of arch length. Since W/2 equals 1516.32, the vertical force that the walls and buttresses must carry amounts to 1516.32 pounds per foot of arch length.

From the same table, the horizontal thrust of cold arch with a 2¼ inch rise per foot of span equals 0.64 time its weight (W). For the arch under consideration, 0.64 times 3032.64 equals 1940.89 pounds per foot of arch length.

Constants for Calculation of Stresses in Unheated Arches

Rise in Inches Per Foot of Span	Central Angle (θ)	Forces Per Foot of Arch Length		
		W Weight	H Horizonal Thrust	F Resultant Thrust at Skewback
1	37° 50.9'	1.05 DST	1.49 W	1.57 W
1¼	47° 4.4'	1.07 DST	1.18 W	1.28 W
1½	56° 8.7'	1.09 DST	0.98 W	1.10 W
1.608	60° 0.0'	1.10 DST	0.91 W	1.04 W
1¾	65° 2.5'	1.11 DST	0.83 W	0.97 W
2	73° 44.4'	1.14 DST	0.72 W	0.88 W
2¼	82° 13.4'	1.17 DST	0.64 W	0.81 W
2.302	83° 58.5'	1.17 DST	0.62 W	0.80 W
2½	90° 28.8'	1.19 DST	0.57 W	0.76 W
2¾	98° 29.7'	1.22 DST	0.51 W	0.71 W
3	106° 15.6'	1.25 DST	0.46 W	0.68 W

D= Density of brick in pounds per cubic foot. S=Span in feet. T=Thickness of arch in feet. W=Weight of brick per foot of arch length. The constants given in this table are based on the assumption that the line of thrust passes from the center of the arch thickness at the point of midspan, to the center of arch thickness at the skewbacks.

The resultant force, also determined from the table above, is 0.81 times 3032.64 equals 2546.44 pounds per foot of arch length.

Maximum values approached by horizontal thrust can be determined from the factors listed in the table. These data indicate that the maximum value approached by horizontal thrust for a heated arch free to rise can be determined by multiplying the cold arch horizontal thrust by a factor dependent on the ratio of thickness to span. In the example considered earlier, thickness equals 9% of span, that is, 1.125/12 equals 0.09. For a 2¼ inch rise, maximum thrust approaches 1.84H, or 1.84 times 1940.89 equals 3571.24 pounds per foot of arch length. This value is an approximation, but it lies well within the requirements of practical furnace design.

The safety factor used in furnace binding design is ordinarily higher than that used in conventional steel structural design because the furnace binding may become overheated. For ordinary structural steel bindings, many furnace designers limit tensile stress to 12,000 pounds per square inch.

COMPLEX REFRACTORY DESIGN PROBLEMS

Customers who design or build refractory structures often tap Harbison-Walker resources, e.g., engineering skills and advanced refractories technology, for solutions to complex problems involving refractory applications. Harbison- Walker engineers have developed computer programs, which are used with customers, that can produce complex arch or dome design parameters in a few minutes, often saving many man-hours of calculation. For assistance with your difficult design problems, please call your Harbison-Walker representative.

Initial Heat-Up Considerations

In most cases, a new furnace should be heated slowly with enough air circulating over the walls to remove moisture. Steam trapped in the pores of brick or mortar may damage the brickwork. Good practice permits a furnace to dry out thoroughly at a temperature not over 250°F(121°C) for 24 hours or longer, depending on the size of the vessel and the refractories in use. Temperatures above 400°F to 600°F (205°C to 316°C) should be avoided until all steaming ceases.

Furnace builders and refractory consumers should understand the requirements of the brands that line their furnaces. Careful drying of linings built of magnesia and some of its compounds is especially important. Water vapor or steam under pressure can cause hydration of the magnesia.

Flame impingement on brickwork during heat-up can cause rapid, localized expansion with consequent spalling. Silica and basic brick, especially, tend to spall when subjected to excessively rapid changes in temperature.

In low temperature furnaces, it is often good practice to heat the refractories to a higher temperature than that required for operation for a short period of time. This preliminary heat-up develops the ceramic bond in mortared joints and increases their mechanical strength.

Maximum Value Approached by Horizonal Thrust in Heated Arch Free to Rise

Inches Per Foot of Span	Central Angle (Θ)	H_{max} Per Foot of Arch Length Thickness of Arch in Precent of Span						
		4%	5%	6%	7%	8%	9%	10%
1	37° 50.9’	1.88 H*	2.41 H	3.29 H	5.0 H	**	**	**
1¼	47° 4.4’	1.61 H	1.86 H	2.29 H	2.80 H	3.73 H	5.34 H	**
1½	56° 8.7’	1.47 H	1.63 H	1.94 H	2.14 H	2.55 H	3.06 H	3.88 H
1.608	60° 0.0’	1.43 H	1.59 H	1.79 H	1.98 H	2.31 H	2.75 H	3.30 H
1¾	65° 2.5’	1.39 H	1.52 H	1.67 H	1.93 H	2.17 H	2.41 H	2.77 H
2	73° 44.4’	1.33 H	1.43 H	1.56 H	1.69 H	1.86 H	2.04 H	2.22 H
2¼	82°13.4’	1.29 H	1.38 H	1.47 H	1.58 H	1.70 H	1.84 H	2.00 H
2.302	83° 58.5’	1.28 H	1.37 H	1.46 H	1.57 H	1.69 H	1.81 H	1.95 H
2½	90° 28.8’	1.26 H	1.33 H	1.42 H	1.51 H	1.60 H	1.72 H	1.82 H
2¾	98° 29.7’	1.24 H	1.29 H	1.37 H	1.45 H	1.53 H	1.63 H	1.73 H
3	106° 15.6’	1.22 H	1.26 H	1.33 H	1.41 H	1.48 H	1.57 H	1.63 H

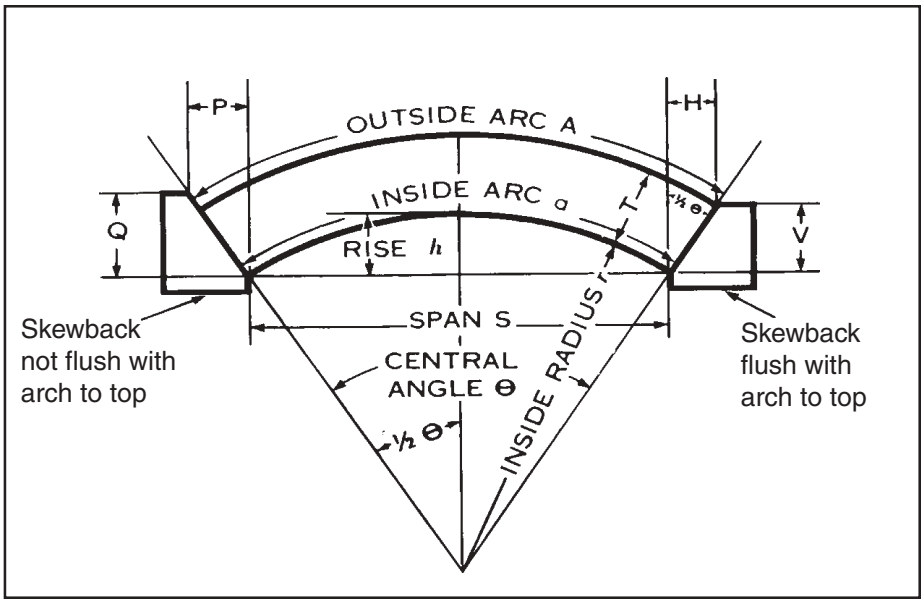
* H = Horizonal thrust, as determined from the previous table.
** Stress excessive.

REFRACTORY CONSTRUCTION CALCULATIONS

Calculations to determine the dimensions or numerical characteristics of refractory structures are not difficult. Generally, they involve three steps: (1) pick out the formula that produces the dimension or other number that you need; (2) substitute the numbers in your problem that fit the letter-variables in the formula; and (3) perform the arithmetic operations required by the formula. Remember, once the span and rise of an arch are decided, all other dimensions follow.

To use these formulas, all the algebra you need to know is that parentheses tell you to perform the arithmetic operation inside before carrying out the other operations.

All you have to know about trigonometry is that each sine, cosine or tangent is a *particular number* associated with one *particular angle*, and that an arcsine, arccosine or arctangent is a particular *angle* associated with a particular number. That allows you to go from number to angle, or from angle to number, or back and forth, depending on the requirements of the problem. Sines, cosines or tangents are found in tables of trigonometric functions or in pocket calculators.



Arches

Many pocket calculators will make calculation of arch parameters, i.e. numerical characteristics such as dimensions, quick and easy. Sine, cosine and tangent values are literally at your fingertips on many models. Solutions to arch problems involve nothing more than substituting numbers into the formulas and pushing buttons on the calculator. For example in the design previously specified:

Sine ½θ = S/2r = 12 (2 x 9.125)
= 0.6575
Arcsine 0.6575 = 41.11°
= ½ The Central Angle
The Central Angle = 82.22° = 82° 13'

The problem is no more difficult with paper, pencil and a table of trigonometric functions, but the multiplication, division and reference to the table take more time.

Arch Formulas

1. $r = S^2/8h + h/2$
2. $R = r+T$
3. $h = r - \sqrt{r^2-(S/2)^2}$
4. Sine ½ θ = S/2r
5. Tan ¼ θ = 2h/S
6. Tan ¼ θ = d/6
7. Part of circle = θ/360°
8. H = T Sine ½θ
9. d = 6 Tan ¼θ
10. $a_a = 6.2832r\,(\theta/360°)$
11. $A_a = 6.2832R\,(6/360°)$
12. V=T Cos½θ
13. P=QTan ½θ

Arch Symbols

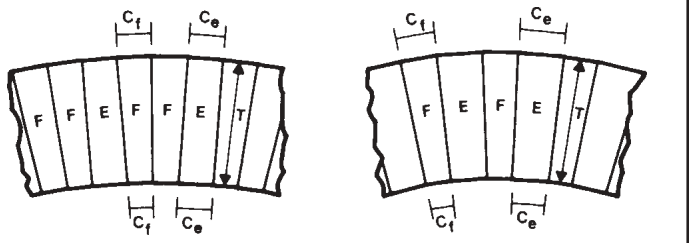
The following symbols and variables are used in the arch formulas:

a_a = Length of inside arc
A_a = Length of outside arc
R = Outside radius of arch
r = Inside radius of arch
S = Span of arch
d = Rise in inches per foot of span
h = Total rise of arch
T = Thickness of arch
θ = Central Angle (Theta)
H, V, P, Q = Skewback dimensions indicated in the Arch Constants table.

Rings

The number of brick of two sizes to form a ring can be calculated from formulas listed below. When one brick, E, is a straight, and the other, F, is a radial, use Formulas 1-a, 1-b and 1-c. When both brick, E and F, are radial with outside chord dimensions and inside chord dimensions unequal, use Formulas 2-a, 2-b, and 2-c. When both brick, E and F. are radial and the inside and outside chord dimensions of E differ from those of F, use Formulas 3-a, 3-b and 3-c for a single combination, and 4-a, 4-b, and 4-c for a series of combinations.

Ring Calculations



Inside Chord Dimensions
Combination of a Straight Brick (E) and a Radial Brick (F) to Form a Ring

Inside Chord Dimensions
Combination of Two Radial Brick (E and F) to Form a Ring. Brick E Turns a Large Diameter than Brick F

Ring Formulas

(1-a) $N_f = \frac{2\pi T}{C_f - c_f}$

(2-a) $N_t = \frac{\pi D_g}{C_e} = \frac{\pi D_g}{C_f}$

(3-a) $N_e c_e + N_f C_f = \pi D_g$

(4-a) $N_e = \frac{N_x}{D_e - D_f} (D_g - D_f)$

(1-b) $N_e = \frac{\pi D_g - N_f C_f}{C_e}$

(2-b) $N_e = \frac{\pi D_g - N_f c_f}{c_e - c_f}$

(3-b) $N_e c_e + N_f c_f = \pi d_g$

(4-b) $N_f = \frac{N_y}{D_e - D_f} (D_e - D_g)$

(1-c) $N_t = N_e + N_f$

(2-c) $N_f = N_t - N_e$

(3-c) $N_t = N_e + N_f$

(4-c) $N_t = N_e + N_f$

Ring Symbols

E = Either a straight brick or a radial brick used with a companion brick F; when brick E is radial it turns a larger diameter than brick F.

F = A radial brick, used with a companion brick E which may be either straight or radial; in the latter case, brick F turns a smaller diameter than brick E.

T = Radial dimension common to both brick E and F.

D_e = Outside diameter of ring formed by brick E.

D_f = Outside diameter of ring formed by brick F.

D_g = A given outside diameter larger than D_f, if brick E is radial D_g must lie between D_e and D_f.

d_g = A given inside diameter.

C_e = Outside chord dimension of brick E.

C_f = Outside chord dimension of brick F.

c_e = Inside chord dimension of brick E.

c_f = Inside chord dimension of brick F.

N_e = Number of pieces of brick E, when used in combination with brick F, to form a ring having a given outside diameter D_g.

N_f = Number of pieces of brick F, when used in combination with brick E, to form a ring having a given out side diameter D_g.

N_t = Total number of pieces of brick E and F used in combination to form a ring having a given outside diameter D_g.

N_x = Number of pieces of brick E required to form a complete ring having an outside diameter D_e.

N_y = Number of pieces of brick F required to form a complete ring having an outside diameter D_f.

BRICK SIZES AND SHAPES

Wherever furnace construction and operating conditions permit, refractory linings are typically constructed with brick of standard sizes and shapes. Standard materials cost less than larger, more intricate shapes and frequently are more serviceable. They are also more accessible, in that they are likely to be routinely stocked by the manufacturer.

The most widely used standard size for all types of refractory brick is 9 x 4 1/2 by 3 inches. Most brands offer larger sizes, as well. Special shapes, such as skewback brick, are important in the construction of numerous kinds of furnaces having sprung arches.

This section provides a comprehensive listing of standard brick sizes and shapes for a variety of furnace applications, as well as ring and arch combinations for standard size refractory brick. Additional sections address special shapes such as semi-universal ladle brick, brick counts for rotary kilns and rotary kiln brick shapes, including ISO, VDZ and CR two-shape systems for combination linings. Together, offer refractory users a ready reference of information governing furnace refractory lining and construction.

If you require a special shape which is not included in this booklet, please contact your Harbison-Walker representative. Harbison-Walker manufactures special shapes based on customer designs showing shape details and assembly in the furnace lining.

BRICK SIZES AND SHAPES

OVERVIEW

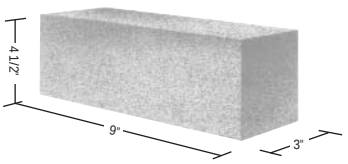
Refractory brick are classified on the basis of their form as Rectangular Shapes or Special Shapes.

Rectangular Sizes are brick of relatively simple design, with certain definite shapes, that are marketed in sufficient amounts to permit quantity production. Rectangular sizes are preferred wherever furnace construction and operating conditions permit. These brick cost less than longer and more intricate shapes.

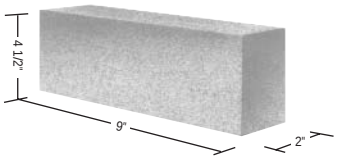
Special Shapes are refractory brick of special design of either simple or intricate form. Some special shapes may be considered as modifications of rectangular tile having the same overall dimensions.

For initial orders of special shapes, drawings showing complete details of the shapes, as well as their assembly in the furnace, should be included. The drawing and shape numbers should be provided on all subsequent orders.

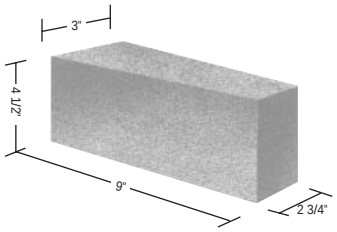
Nine-Inch Sizes (9 X 4 1/2 X 3)



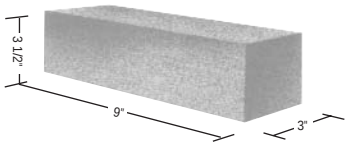
9 Inch Straight
9 X 4 1/2 X 3



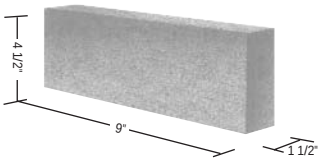
9 – 2 Inch Split
9 X 4 1/2 X 2



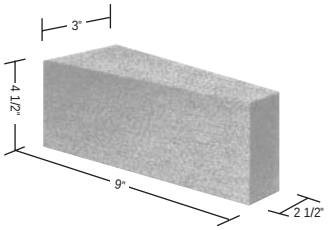
9 Inch No. 1 Wedge
9 X 4 1/2 X (3 – 2 3/4)



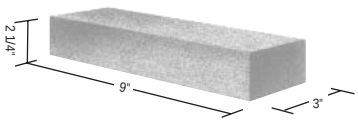
Small 9 Inch Straight
9 X 3 1/2 X 3



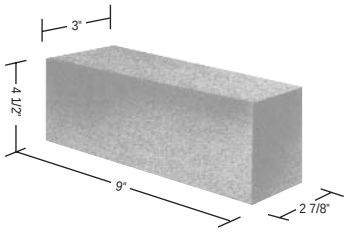
9 Inch Split
9 X 4 1/2 X 1 1/2



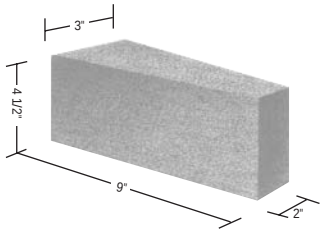
9 Inch No. 2 Wedge
9 X 4 1/2 X (3 – 2 1/2)



9 Inch Soap
9 X 2 1/4 X 3



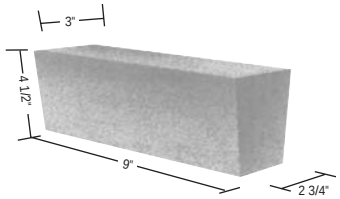
9 Inch No. 1-X Wedge
9 X 4 1/2 X (3 – 2 7/8)



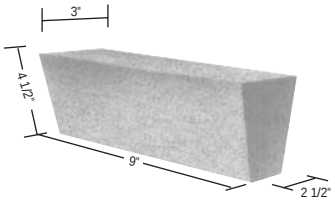
9 Inch No. 3 Wedge
9 X 4 1/2 X (3 – 2)

Brick Sizes and Shapes

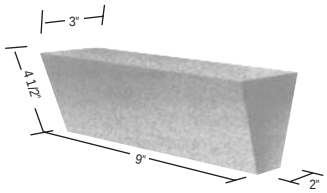
Nine-Inch Sizes (9 X 4 1/2 X 3)



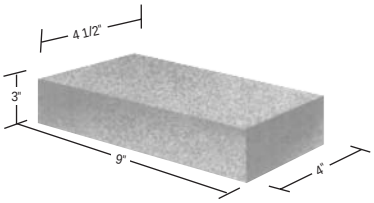
9 Inch No. 1 Arch
9 X 4½ X (3 – 2¾)



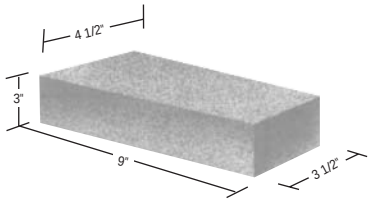
9 Inch No. 2 Arch
9 X 4½ X (3 – 2½)



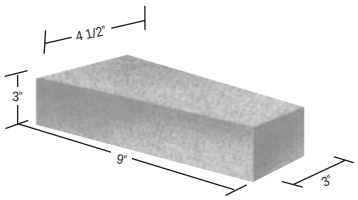
9 Inch No. 3 Arch
9 X 4½ X (3 – 2)



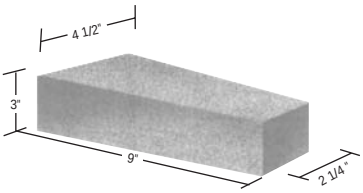
9 Inch No. 1 Key
9 X (4½ – 4) X 3



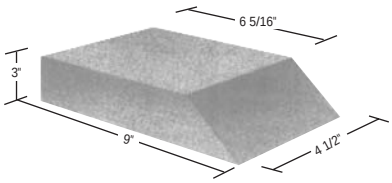
9 Inch No. 2 Key
9 X (4½ – 3½) X 3



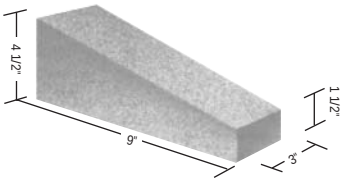
9 Inch No. 3 Key
9 X (4½ – 3) X 3



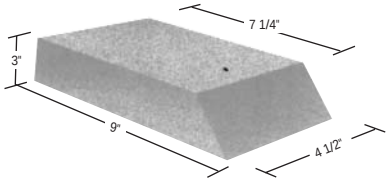
9 Inch No. 4 Key
9 X (4½ – 2¼) X 3



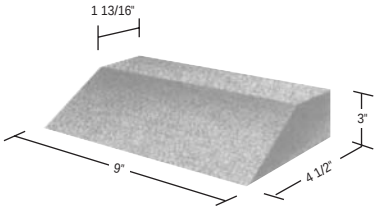
9 Inch – 48° End Skew
(9 – 6 5/16) X 4½ X 3



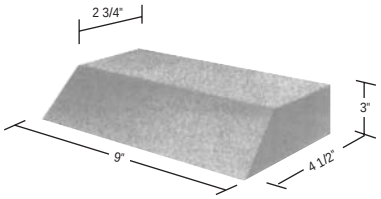
9 Inch Edge Skew
9 X (4½ – 1½) X 3



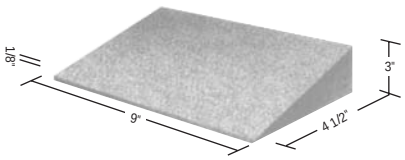
9 Inch – 60° End Skew
(9 – 7¼) X 4½ X 3



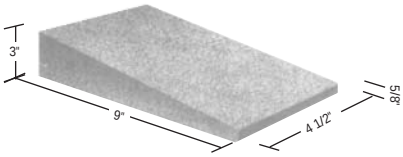
9 Inch – 48° Side Skew
9 X (4½ – 1 13/16) X 3



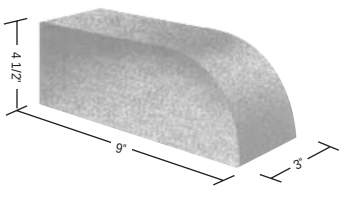
9 Inch – 60° Side Skew
9 X (4½ – 2¾) X 3



9 Inch Featheredge
9 X 4½ X (3 – 1/8)



9 Inch Neck
9 X 4½ X (3 – 5/8)

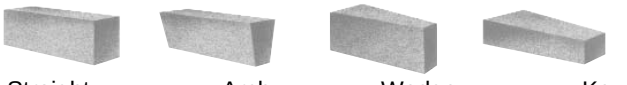


9 Inch Jamb
9 X 4½ X 3

BRICK SIZES AND SHAPES

High-Alumina, Basic and Silica Brick

TYPICAL STRAIGHT, ARCH, WEDGE AND KEY BRICK



Straight Arch Wedge Key

Sizes	Name	Dimensions (In.)	Equivalent
9 x 4½ x 2½ **9 x 3½ x 2½** **9 x 2¼ x 2½** **9 x 4½ x 2½**	Straight Soap 2" Split Split	9 x 4½ x 2½ 9 x 2¼ x 2½ 9 x 4½ x 2½ 9 x 4½ x 1¼	1.00 0.50 0.80 0.50
9 x 4½ x 2½	No. 1-X Wedge No. 1 Wedge No. 2 Wedge No. 1 Arch No. 2 Arch No. 3 Arch No. 1 Key No. 2 Key No. 3 Key No. 4 Key	9 x 4½ x (2½-2¼) 9 x 4½ x (2½-1⅞) 9 x 4½ x (2½-1½) 9 x 4½ x (2½-2⅛) 9 x 4½ x (2½-1¾) 9 x 4½ x (2½-1) 9 x (4½-4) x 2½ 9 x (4½-3½) x 2½ 9 x (4½-3) x 2½ 9 x (4½-2¼) x 2½	0.95 0.88 0.80 0.93 0.85 0.70 0.94 0.89 0.83 0.75
9 x 4½ x 2½	48° End Skew 60° End Skew 48° Side Skew 60° Side Skew Edge Skew Featheredge Neck Jamb	(9-6¾) x 4½ x 2½ (9-7 9/16) x 4½ x 2½ 9 x (4½-2¼) x 2½ 9 x (4½-3 1/16) x 2½ 9 x (4½-1½) x 2½ 9 x 4½ x (2½-⅛) 9 x 4½ x (2½-⅝) 9 x 4½ x 2½	0.88 0.92 0.75 0.84 0.67 0.53 0.63 0.89
9 x 4½ x 3 **9 x 3½ x 3** **9 x 2¼ x 3** **9 x 4½ x 1½**	Straight Sm. Straight Soap Split	9 x 4½ x 3 9 x 3½ x 3 9 x 2¼ x 3 9 x 4½ x 1½	1.20 0.93 0.60 0.60
9 x 4½ x 3	No. 1 Arch No. 2 Arch No. 3 Arch No. 4 Arch No. 1-X Wedge No. 1 Wedge No. 2 Wedge No. 3 Wedge No. 1 Key No. 2 Key No. 3 Key No. 4 Key	9 x 4½ x (3-2¾) 9 x 4½ x (3-2½) 9 x 4½ x (3-2) 9 x 4½ x (3-1) 9 x 4½ x (3-2⅞) 9 x 4½ x (3-2¾) 9 x 4½ x (3-2½) 9 x 4½ x (3-2) 9 x (4½-4) x 3 9 x (4½-3½) x 3 9 x (4½-3) x 3 9 x (4½-2¼) x 3	1.15 1.10 1.00 0.80 1.17 1.15 1.10 1.00 1.13 1.07 1.00 0.90
9 x 4½ x 3	48° End Skew 60° End Skew 48° Side Skew 60° Side Skew Edge Skew Featheredge Neck Jamb	(9-6 5/16) x 4½ x 3 (9-7¼) x 4½ x 3 9 x (4½-1 13/16) x 3 9 x (4½-2¾) x 3 9 x (4½-1½) x 3 9 x 4½ x (3-⅛) 9 x 4½ x (3-⅝) 9 x 4½ x 3	1.02 1.08 0.84 0.97 0.80 0.63 0.73 1.07
9 x 6 **Flat Back**	Straight Split No. 1 Arch No. 2 Arch	9 x 6 x 2½ 9 x 6 x 1¼ 9 x 6 x (3½-2½) 9 x 6 x (3½-2)	1.33 0.67 1.60 1.47
9 x 6 x 3	Straight No. 1 Arch No. 2 Arch No. 3 Arch No. 1-X Wedge No. 1 Wedge No. 2 Wedge No. 3 Wedge No. 1 Key No. 2 Key No. 3 Key	9 x 6 x 3 9 x 6 x (3-2¾) 9 x 6 x (3-2½) 9 x 6 x (3-2) 9 x 6 x (3-2⅞) 9 x 6 x (3-2¾) 9 x 6 x (3-2½) 9 x 6 x (3-2) 9 x (6-5⅜) x 3 9 x (6-4 13/16) x 3 9 x (6-3) x 3	1.60 1.53 1.47 1.33 1.57 1.53 1.47 1.33 1.52 1.44 1.20
9 x 6¾ x 3	Straight No. 1-X Wedge No. 1 Wedge No. 2 Wedge No. 3 Wedge	9 x 6¾ x 3 9 x 6¾ x (3-2⅞) 9 x 6¾ x (3-2¾) 9 x 6¾ x (3-2½) 9 x 6¾ x (3-2)	1.80 1.76 1.72 1.65 1.50
9 x 9 x 3	Straight No. 1-X Wedge No. 1 Wedge No. 2 Wedge No. 3 Wedge	9 x 9 x 3 9 x 9 x (3-2⅞) 9 x 9 x (3-2¾) 9 x 9 x (3-2½) 9 x 9 x (3-2)	2.40 2.35 2.30 2.20 2.00
12 x 4½ x 3	Straight No. 1 Arch No. 2 Arch No. 3 Arch No. 1-X Wedge No. 1 Wedge No. 2 Wedge No. 3 Wedge	12 x 4½ x 3 12 x 4½ x (3-2¾) 12 x 4½ x (3-2½) 12 x 4½ x (3-2) 12 x 4½ x (3-2⅞) 12 x 4½ x (3-2¾) 12 x 4½ x (3-2½) 12 x 4½ x (3-2)	1.60 1.53 1.47 1.33 1.57 1.53 1.47 1.33
12 x 6 x 3	Straight No. 1 Arch No. 2 Arch No. 3 Arch No. 1-X Wedge No. 1 Wedge No. 2 Wedge No. 3 Wedge No. 1 Key No. 2 Key No. 3 Key	12 x 6 x 3 12 x 6 x (3-2¾) 12 x 6 x (3-2½) 12 x 6 x (3-2) 12 x 6 x (3-2⅞) 12 x 6 x (3-2¾) 12 x 6 x (3-2½) 12 x 6 x (3-2) 12 x (6-5½) x 3 12 x (6-5) x 3 12 x (6-3) x 3	2.13 2.04 1.96 1.78 2.09 2.04 1.96 1.78 2.04 1.96 1.87
12 x 6¾ x 3	Straight No. 1-X Wedge No. 1 Wedge No. 2 Wedge No. 3 Wedge	12 x 6¾ x 3 12 x 6¾ x (3-2⅞) 12 x 6¾ x (3-2¾) 12 x 6¾ x (3-2½) 12 x 6¾ x (3-2)	2.40 2.35 2.30 2.20 2.00
12 x 9 x 3	No. 1 Arch No. 2 Arch No. 3 Arch Straight No. 1-X Wedge No. 1 Wedge No. 2 Wedge No. 3 Wedge	12 x 9 x (3-2¾) 12 x 9 x (3-2½) 12 x 9 x (3-2) 12 x 9 x 3 12 x 9 x (3-2⅞) 12 x 9 x (3-2¾) 12 x 9 x (3-2½) 12 x 9 x (3-2)	3.07 2.93 2.67 3.20 3.13 3.07 2.93 2.67

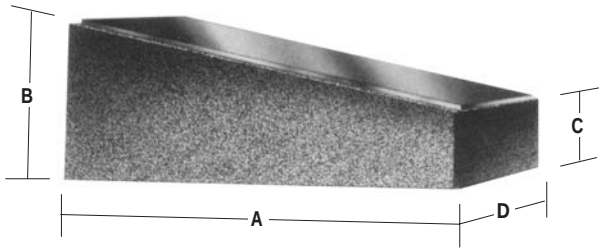
BRICK SIZES AND SHAPES

Sizes	Name	Dimensions (In.)	Equivalent
13 1/2 x 4 1/2 x 3	Straight	13 1/2 x 4 1/2 x 3	1.80
	No. 1 Arch	13 1/2 x 4 1/2 x (3-2 3/4)	1.72
	No. 2 Arch	13 1/2 x 4 1/2 x (3-2 1/2)	1.65
	No. 3 Arch	13 1/2 x 4 1/2 x (3-2)	1.50
	No. 1 Key	13 1/2 x (4 1/2-4) x 3	1.70
	No. 2 Key	13 1/2 x (4 1/2-3 1/2) x 3	1.60
	No. 3 Key	13 1/2 x (4 1/2-3) x 3	1.50
	No. 4 Key	13 1/2 x (4 1/2-2 1/4) x 3	1.35
13 1/2 x 6 x 3	Straight	13 1/2 x 6 x 3	2.40
	No. 1 Arch	13 1/2 x 6 x (3-2 3/4)	2.30
	No. 2 Arch	13 1/2 x 6 x (3-2 1/2)	2.20
	No. 3 Arch	13 1/2 x 6 x (3-2)	2.00
	No. 1-X Wedge	13 1/2 x 6 x (3-2 7/8)	2.35
	No. 1 Wedge	13 1/2 x 6 x (3-2 3/4)	2.30
	No. 2 Wedge	13 1/2 x 6 x (3-2 1/2)	2.20
	No. 3 Wedge	13 1/2 x 6 x (3-2)	2.00
	No. 1 Key	13 1/2 x (6-5) x 3	2.20
	No. 2 Key	13 1/2 x (6-4 3/8) x 3	2.07
	No. 3 Key	13 1/2 x (6-3) x 3	1.80
13 1/2 x 6 3/4 x 3	Straight	13 1/2 x 6 3/4 x 3	2.70
	No. 1-X Wedge	13 1/2 x 6 3/4 x (3-2 7/8)	2.64
	No. 1 Wedge	13 1/2 x 6 3/4 x (3-2 3/4)	2.59
	No. 2 Wedge	13 1/2 x 6 3/4 x (3-2 1/2)	2.47
	No. 3 Wedge	13 1/2 x 6 3/4 x (3-2)	2.25
13 1/2 x 9 x 3	Straight	13 1/2 x 9 x 3	3.60
	No. 1 Arch	13 1/2 x 9 x (3-2 3/4)	3.45
	No. 2 Arch	13 1/2 x 9 x (3-2 1/2)	3.30
	No. 3 Arch	13 1/2 x 9 x (3-2)	3.00
	No. 1-X Wedge	13 1/2 x 9 x (3-2 7/8)	3.52
	No. 1 Wedge	13 1/2 x 9 x (3-2 3/4)	3.45
	No. 2 Wedge	13 1/2 x 9 x (3-2 1/2)	3.30
	No. 3 Wedge	13 1/2 x 9 x (3-2)	3.00
15 x 4 1/2 x 3	Straight	15 x 4 1/2 x 3	2.00
	No. 1 Arch	15 x 4 1/2 x (3-2 3/4)	1.92
	No. 2 Arch	15 x 4 1/2 x (3-2 1/2)	1.83
	No. 3 Arch	15 x 4 1/2 x (3-2)	1.67
	No. 1-X Wedge	15 x 4 1/2 x (3-2 7/8)	1.96
	No. 1 Wedge	15 x 4 1/2 x (3-2 3/4)	1.92
	No. 2 Wedge	15 x 4 1/2 x (3-2 1/2)	1.83
	No. 3 Wedge	15 x 4 1/2 x (3-2)	1.67
15 x 6 x 3	Straight	15 x 6 x 3	2.67
	No. 1-X Wedge	15 x 6 x (3-2 7/8)	2.61
	No. 1 Wedge	15 x 6 x (3-2 3/4)	2.56
	No. 2 Wedge	15 x 6 x (3-2 1/2)	2.44
	No. 3 Wedge	15 x 6 x (3-2)	2.22
	No. 1 Key	15 x (6-5) x 3	2.56
	No. 2 Key	15 x (6-4 3/8) x 3	2.31
	No. 3 Key	15 x (6-3) x 3	2.00
15 x 9 x 3	Straight	15 x 9 x 3	4.00
	No. 1-X Wedge	15 x 9 x (3-2 7/8)	3.92
	No. 1 Wedge	15 x 9 x (3-2 3/4)	3.83
	No. 2 Wedge	15 x 9 x (3-2 1/2)	3.67
	No. 3 Wedge	15 x 9 x (3-2)	3.33

Sizes	Name	Dimensions (In.)	Equivalent
18 x 4 1/2 x 3	Straight	18 x 4 1/2 x 3	2.40
	No. 1-X Wedge	18 x 4 1/2 x (3-2 7/8)	2.35
	No. 1 Wedge	18 x 4 1/2 x (3-2 3/4)	2.30
	No. 2 Wedge	18 x 4 1/2 x (3-2 1/2)	2.20
	No. 3 Wedge	18 x 4 1/2 x (3-2)	2.00
18 x 6 x 3	Straight	18 x 6 x 3	3.20
	No. 1-X Wedge	18 x 6 x (3-2 7/8)	3.13
	No. 1 Wedge	18 x 6 x (3-2 3/4)	3.07
	No. 2 Wedge	18 x 6 x (3-2 1/2)	2.93
	No. 3 Wedge	18 x 6 x (3-2)	2.67
18 x 9 x 3	Straight	18 x 9 x 3	4.80
	No. 1-X Wedge	18 x 9 x (3-2 7/8)	4.70
	No. 1 Wedge	18 x 9 x (3-2 3/4)	4.60
	No. 2 Wedge	18 x 9 x (3-2 1/2)	4.40
	No. 3 Wedge	18 x 9 x (3-2)	4.00
21 x 6 x 3	Straight	21 x 6 x 3	3.73
	No. 1-X Wedge	21 x 6 x (3-2 7/8)	3.65
	No. 1 Wedge	21 x 6 x (3-2 3/4)	3.58
	No. 2 Wedge	21 x 6 x (3-2 1/2)	3.42
	No. 3 Wedge	21 x 6 x (3-2)	3.11
21 x 9 x 3	Straight	21 x 9 x 3	5.60
	No. 1-X Wedge	21 x 9 x (3-2 7/8)	5.48
	No. 1 Wedge	21 x 9 x (3-2 3/4)	5.37
	No. 2 Wedge	21 x 9 x (3-2 1/2)	5.13
	No. 3 Wedge	21 x 9 x (3-2)	4.67
Misc. Straights	Straight	9 x 6 x 2	1.07
	Straight	9 x 7 x 2	1.24
	Straight	9 x 7 1/2 x 2	1.33
	Straight	10 1/2 x 4 1/2 x 3	1.39
	Straight	10 1/2 x 4 1/2 x 4 1/2	2.10
	Straight	13 1/2 x 4 1/2 x 4 1/2	2.70
	Straight	18 x 6 3/4 x 3	3.60
	Straight	18 x 9 x 4 1/2	7.20

EAF Door Jambs/ Blast Furnace

METALKASE DOOR JAMB BRICK



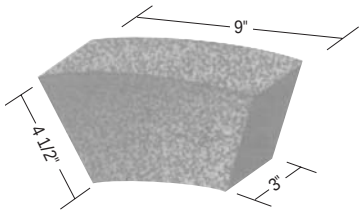
Name	A (In)	B (In)	C (In)	D (In)
DJ-1-3	9	4 1/2	1 1/2	3
DJ-2-3	9	6 3/4	3 3/4	3
DJ-3-3	9	9	6	3
BS-115-3	13 1/2	6 3/4	2 3/4	3
BS-116-3	13 1/2	9	5	3
DJ-18-1-3	18	6 3/4	2 3/4	3
DJ-18-2-3	18	9	5	3

BLAST-FURNACE BOTTOM BLOCKS
(18 X 9 X 4 1/2 Inches)
Number per course for blocks laid on end

Diameter of Hearth Jacket (Ft In)	No. of Blocks	Diameter of Hearth Jacket (Ft In)	No. of Blocks
17 6	897	27 6	2176
18 0	947	28 0	2255
18 6	999	28 6	2335
19 0	1053	29 0	2417
19 6	1108	29 6	2500
20 0	1164	30 0	2584
20 6	1222	30 6	2669
21 0	1281	31 0	2756
21 6	1342	31 6	2845
22 0	1403	32 0	2935
22 6	1467	32 6	3026
23 0	1531	33 0	3119
23 6	1598	33 6	3213
24 0	1665	34 0	3308
24 6	1734	34 6	3405
25 0	1804	35 0	3503
25 6	1876	35 6	3603
26 0	1949	36 0	3704
26 6	2023	36 6	3806
27 0	2099	37 0	3909

High-Alumina Circle Brick

Nine-Inch Sizes (9 X 4 1/2 X 3)

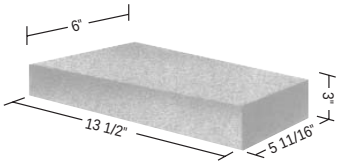


Circle Brick Number* (3 Inch)	Chord (Inch)	Number Per Ring
24 - 33 - 3	6 17/32	12
36 - 45 - 3	7 3/16	16
48 - 57 - 3	7 19/32	20
60 - 69 - 3	7 13/16	24
72 - 81 - 3	8	29
84 - 93 - 3	8 1/8	33
96 - 105 - 3	8 7/32	37
108 - 117 - 3	8 5/16	41
120 - 129 - 3	8 3/8	45

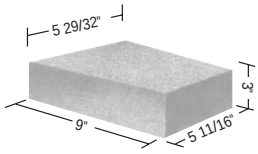
* The first two numbers of the Circle Number indicate the inside and outside diameters,respectively, of the ring producedby each shape. For example, 24 - 33 - 3 Circle Brick will produce a ring with a 24-inchinside diameter and 33-inch outside diameter for a 4½inch lining.

BLAST FURNACE KEYS

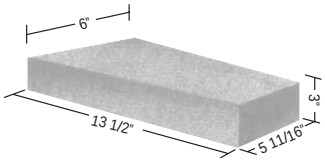
SHAPES FOR ALL-KEY BLAST FURNACE LININGS



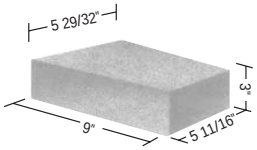
13 1/2-Inch – X-1



9-Inch – X-1



13 1/2-Inch – X-2



9-Inch – X-2

NOTE: Blast Furnace keys X-1 and X-2 are also regulary manufactured in 6, 10 1/2 and 15-inch lengths. The brick combinations for rings (see Brick Combinations for All-Key Linings table) are applicable for X-1 and X-2 keys of all lengths.

BRICK COMBINATIONS FOR ALL-KEY LININGS

Diameter Inside Brickwork (Ft In)	Number Required Per Ring		
	X-2	X-1	Total
13 3	98	—	98
13 6	96	3	99
13 9	95	6	101
14 0	95	8	103
14 6	93	13	106
15 0	91	18	109
15 6	89	23	112
16 0	87	28	115
16 6	85	33	118
17 0	84	37	121
17 6	82	42	124
18 0	80	48	128
18 6	79	52	131
19 0	77	57	134
19 6	75	62	137
20 0	73	67	140
20 6	71	72	143
21 0	70	76	146
21 6	68	82	150
22 0	66	87	153
22 6	65	91	156
23 0	63	96	159
23 6	61	101	162
24 0	59	106	165
24 6	57	111	168
25 0	56	116	172
25 6	54	121	175
26 0	52	126	178
26 6	51	130	181

Diameter Inside Brickwork (Ft In)	Number Required Per Ring		
	X-2	X-1	Total
27 0	49	135	t84
27 6	47	140	187
28 0	45	145	190
28 6	44	150	194
29 0	42	155	197
29 6	40	160	200
30 0	38	165	203
30 6	37	169	206
31 0	35	174	209
31 6	33	179	212
32 0	32	184	216
32 6	30	189	219
33 0	28	194	222
33 6	26	199	225
34 0	24	204	228
34 6	23	208	231
35 0	21	213	234
35 6	19	219	238
36 0	18	223	241
36 6	16	228	244
37 0	14	233	247
37 6	12	238	250
38 0	10	243	253
38 6	9	247	256
39 0	7	253	260
39 6	5	258	263
40 0	4	262	266
40 6	2	267	269
41 0	—	272	272

ELECTRIC FURNACE ROOF SHAPES

OVERVIEW

Electric furnace roofs may be constructed using many different shapes and combinations. The combination of standard size key-arch and key-wedge shapes with standard shapes design, and the two-shape (arch-key-wedge) brick design are the most common in electric furnace roof construction.

Annular rings are laid from the combinations for your specific roof design. Consideration must be given to the best design to provide cost-effective service life. The two-shape, triple taper brick uses two bricks that conform to the roof contour. Bricklaying is simplified using only two shapes, in that inventory levels may be reduced and faster installation is possible.

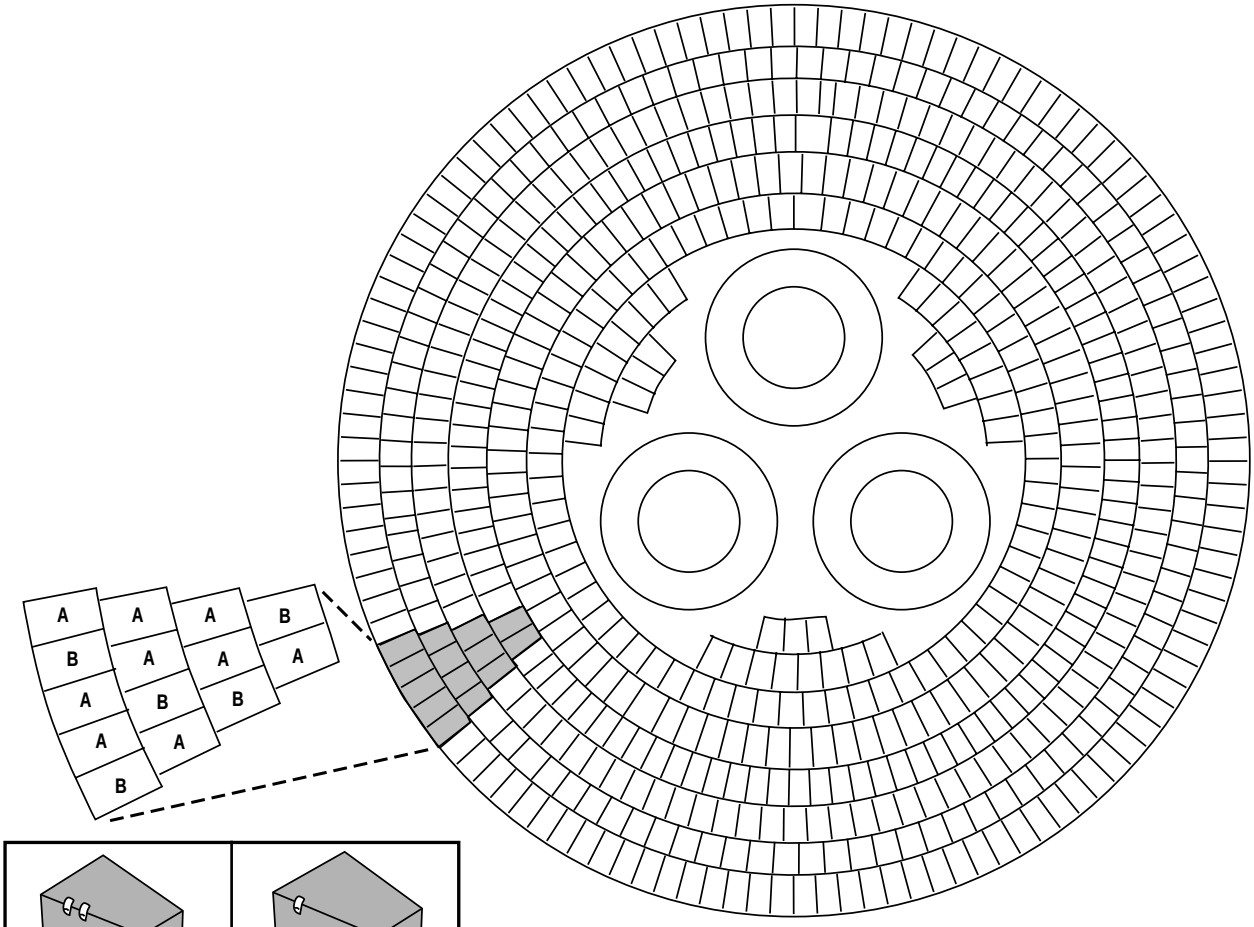
The chart below displays two-shape electric furnace roof brick combinations for 9-inch roof thicknesses. By combining both shapes, all annular rings for a given diameter can be calculated. The center of the range indicates the ideal spherical radius for the given system. Shape identification is done by a notching system at the cold end of the brick shape, as illustrated on p. 29. The two-shape system is also available in 13½-inch sizes for larger electric furnace roofs.

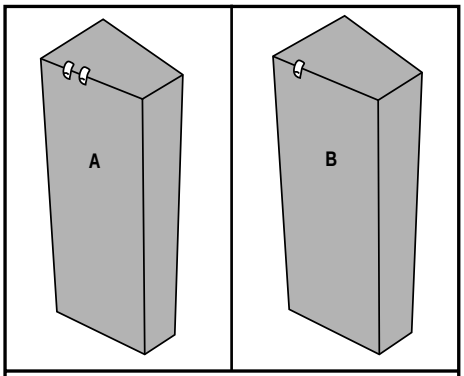
Providing your Harbison-Walker representatives with the dimensions of your electric furnace roof or a current drawing of your roof enables them to produce an accurate ring count and assembly detail.

ELECTRIC FURNACE ROOF-SHAPES
9 X 4½ X 3-Inch Arch-Key-Wedge Shapes

Spherical Radius Range	H-W Shape Designations
6’6” to 7’9”	HW-2721-B HW-2721-S
7’9” to 9’6”	HW-2746-B HW-2746-A
9’6” to 12’6”	HW-2745-B HW-2745-A
12’6” to 16’0”	HW-2592-B HW-2592-A
16’0” to 22’4”	HW-2704-B HW-2704-A

ELECTRIC FURNACE ROOF SHAPES

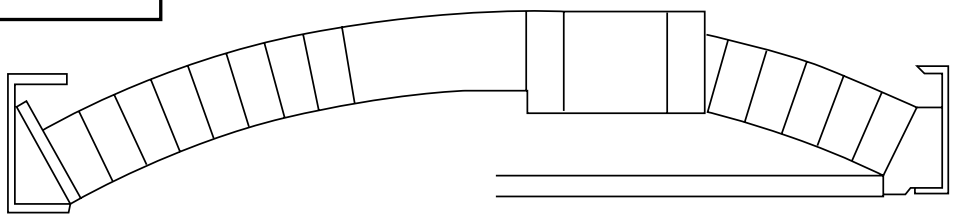




"A" and "B" Arch-Key-Wedge Brick

Two-Shape Electric Furnace Roof Construction

Two-Shape (arch-key-wedge) roof brick designs are available in a variety of 9-inch sizes to fit EAF roof contours and spherical radii.



SEMI-UNIVERSAL LADLE BRICK (SULB)

OVERVIEW

Harbison-Walker manufactures Semi-Universal Ladle Brick (SULB) in fireclay, high-alumina and basic refractories in four series of brick to line sidewalls of iron and steel teeming ladles of various diameters and configurations. All series can be produced in widths to construct linings 3 to 9 inches thick. A SULB lining usually includes a tilt back course to lay the rings square against the sloping sides of a ladle and one or more starter sets to start the upward spiral. For guidance in selecting the proper series for any ladle, the following chart identifies

Series	Ladle Diameter (Inch)
SU - □ - 20	45 to 70
SU - □ - 30	70 to 100
SU - □ - 45	100 to 140
SU - □ - 60	140 and Up

In all four series, the width of the brick, equivalent to the thickness of the lining, is positioned in the rectangular frame □. For example, a 5-inch thick lining in a ladle about 120 inches in diameter would require an SU 5-45 series brick. SULB's are also available in two additional thicknesses — 4-inch and 100 mm. A universal starter set that suits all series and wall thicknesses up to 7 inches is available. The 12-piece UL-7-SS12 set is illustrated below. A regular 18-piece starter set for 9-inch thick walls is also available.

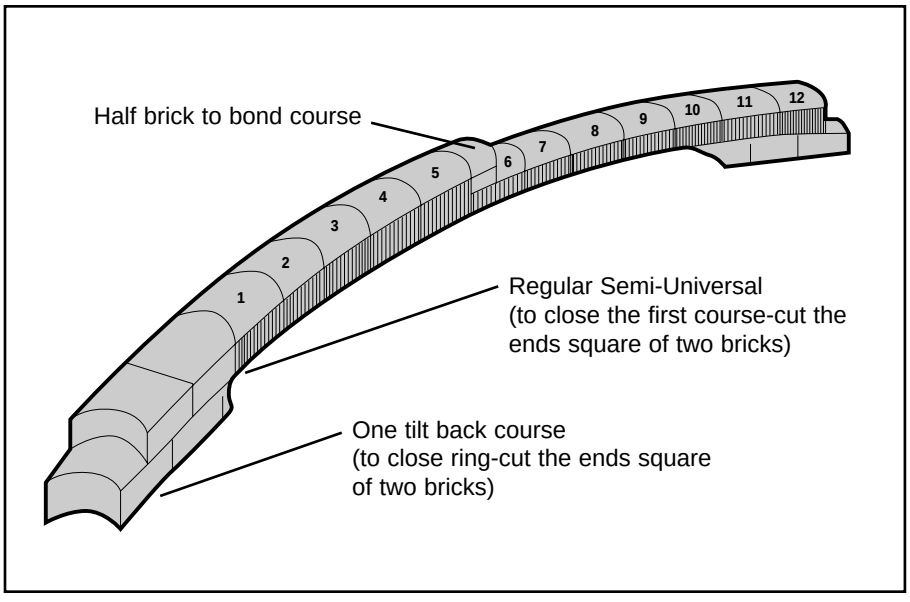
The number of SULB shapes required for a lining can be calculated by multiplying the average diameter of the ladle by 3.1416, then dividing by 8.25 (length of brick) to find the number per ring. The height in inches of the ladle wall divided by 3 equals the number of rings. The number of pieces per ring times the number of rings equals the total number of SULB shapes required.

For a ladle with an average diameter of 120 inches (outside diameter of SULB lining) and a height of 96 inches, the calculations follow:

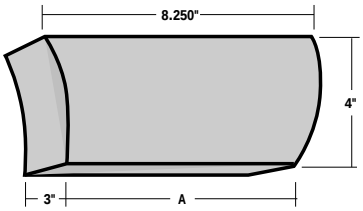
$$\frac{3.1416 \times 120}{8.25} = 46 \text{ pieces per}$$

$$\frac{96}{3} = 32 \text{ rings}$$

46 x 32 = 1472 SULB brick per lining



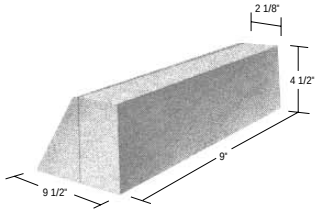
(All series for a 4-inch thick wall)



A	
Name	Size
SU 4-20	6.983
SU 4-30	7.414
SU 4-45	7.690
SU 4-60	7.831

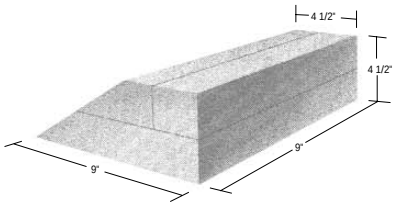
SKEWBACK SHAPES

NINE-INCH SIZES



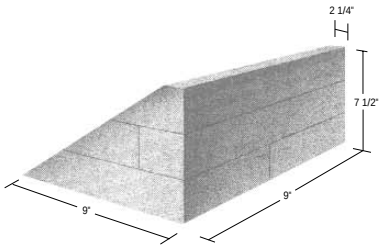
For Arch 4 1/2 Inches Thick
Rise 1 1/2 Inches Per Foot of Span
Central Angle 56° 8.7'

Skewback Consists of
1–9 Inch – 2 Inch Split
1–9 Inch Featheredge



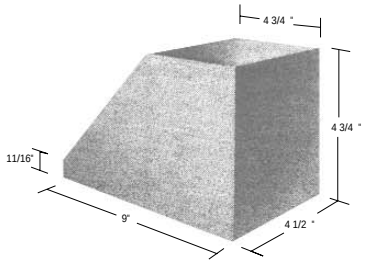
For Arch 4 1/2 Inches ThickRise 2.302 (2 5/16) Inches Per Foot of Span, Central Angle 83° 58.5'

Skewback Consists of
2–9 Inch – 48° End Skew
1–9 Inch – 48° Side Skew
1–9 Inch Soap

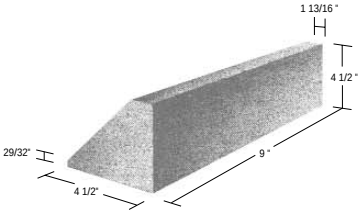


For Arch 9 Inches Thick
Rise 2.302 (2 5/16) Inches Per Foot of Span, Central Angle 83° 58.5'
Skewback Consists of
2 – 9 Inch – 48° End Skew
2 – 9 Inch – 48° Side Skew
1 – 9 Inch Soap

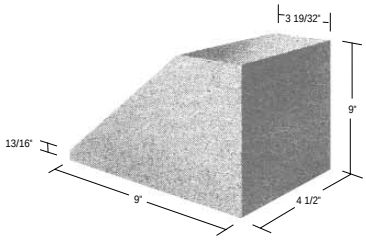
ADDITIONAL SIZES



Shape 56-9
For Arch 9 Inches Thick
Rise 1 1/2 Inches Per Foot of Span
Central Angle 56° 8.7'



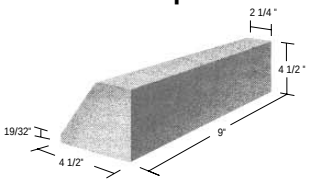
Shape 74-4 1/2
For Arch 4 1/2 Inches Thick
Rise 2 Inches Per Foot of Span



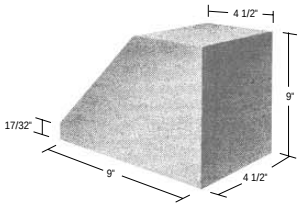
Shape 74-9
For Arch 9 Inches Thick
Rise 2 Inches Per Foot of Span
Central Angle 73° 44.4'

FOR ARCHES WITH 60° CENTRAL ANGLE

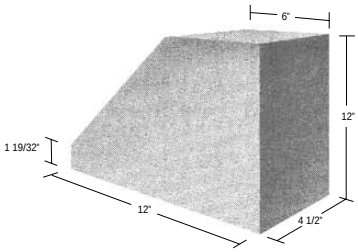
Rise 1.608 (1 19/32) Inches Per Foot of Span



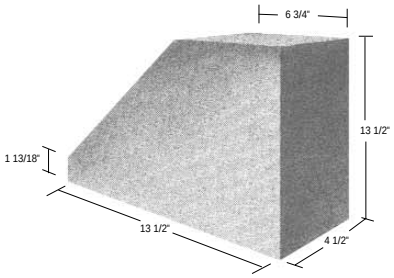
Shape No. 60-40 1/2
for Arch 4 1/2 Inches Thick



Shape No. 60-9
for Arch 9 Inches Thick



Shape No. 60-12
for Arch 12



Shape No. 60-13 1/2
for Arch 13 1/2 Inches Thick

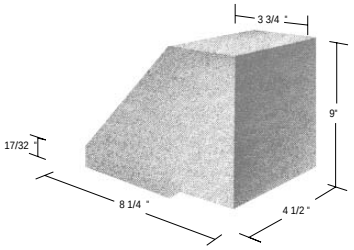
SKEWBACK SHAPES

SKEWBACK BRICK WITH CUTOUTS FOR STEEL ANGLE AND CHANNEL SUPPORTING FRAMEWORK

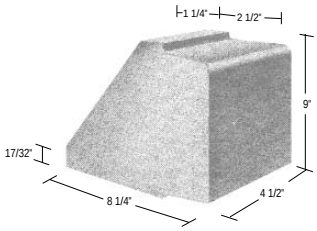
For Arches with 60° Central Angle
Rise 1.608 (1 19/32) Inches Per Foot of Span

STEEL ANGLE Maximum Dimensions		
Skewback	Shorter Leg (in)	Thickness (in)
60-9-A	4	3/4
60-12-A	6	1
60-13 1/2-A	8	1 1/8

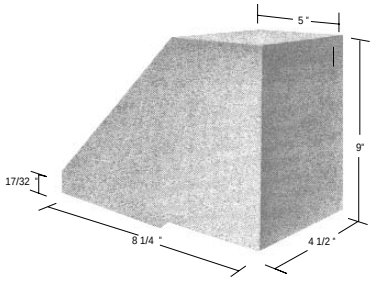
STEEL CHANNEL Maximum Dimensions			
Skewback	Channel Size (in)	Flange Width (in)	Web Thickness (in)
60-9-C	12	3 13/32	3/4
60-12-C	12	3 13/32	3/4
60-13 1/2-C	15	3 13/16	13/16



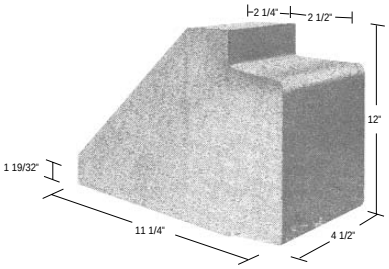
Shape No. 60-9-A
For Arch 9 Inches Thick



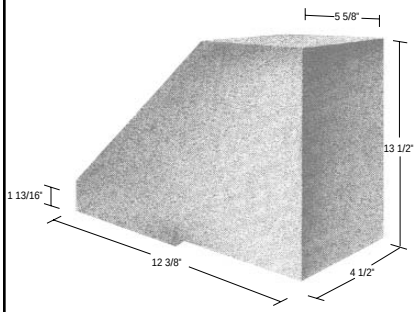
Shape No. 60-9-C
For Arch 9 Inches Thick



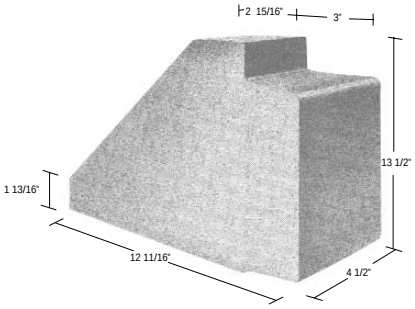
Shape No. 60-12-A
For Arch 12 Inches Thick



Shape No. 60-12-C
For Arch 12 Inches Thick



Shape No. 60-13 1/2-A
For Arch 13 1/2 Inches Thick



Shape No. 60-13 1/2-C
For Arch 13 1/2 Inches Thick

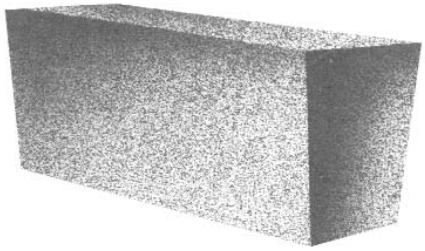
Note:
Brick Combinations required for arch construction are detailed in the tables starting on pages 71. These tables are useful for estimating the quantities of brick required for the construction of arches.

Brick Counts for Rotary Kilns

HIGH-ALUMINA BRICK

ROTARY KILN BLOCKS
Arch-Type (9 x 6 x 3½)

The numbers in the RKB column indicate the inside and outside diameters, respectively, of the ring produced by the shape. For example, RKB 162-A-174 will produce a ring with a 162-inch inside diameter and 174-inch outside diameter.



Ins. Dia. Kiln Shell	RKB Number	Inside Chord (In.)	Number Per Ring
3'-6"	30-A-42	2 1/2	37
4'-0"	36-A-48	2 5/8	42
4'-6"	42-A-54	2 23/32	47
5'-0"	48-A-600	2 13/16	52
5'-6"	54-A-66	2 7/8	58
6'-0"	60-A-72	2 29/32	63
6'-6"	66-A-78	2 31/32	68
7'-0"	72-A-84	3	74
7'-6"	78-A-90	3 1/32	79
8'-0"	84-A-96	3 1/16	84
8'-6"	90-A-102	3 3/32	89
9'-0"	96-A-108	3 1/8	95
9'-6"	102-A-114	3 1/8	100
10'-0"	108-A-120	3 5/32	105
10'-6"	114-A-126	3 5/32	111
11'-0"	120-A-132	3 3/16	116
11'-3"	123-A-135	3 3/16	119
11'-6"	126-A-138	3 3/16	121
12'-0"	132-A-144	3 7/32	126
12'-6"	138-A-150	3 7/32	132
13'-0"	144-A-156	3 7/32	137
13'-6"	150-A-162	3 1/4	142
14'-0"	156-A-168	3 1/4	148
14'-6"	162-A-174	3 1/4	153
15'-0"	168-A-180	3 9/32	158
15'-6"	174-A-186	3 9/32	164
16'-0"	180-A-192	3 9/32	169
16'-6"	186-A-198	3 9/32	174
17'-0"	192-A-204	3 9/32	179
17'-6"	198-A-210	3 5/16	185
18'-0"	204-A-216	3 5/16	190

To facilitate the keying of arch-type rotary kiln blocks, keying bricks of two-thirds thickness, RKA-2/3, and of three-quarters thickness, RKA-3/4, are made. Two of each keying brick should be ordered for each ring.

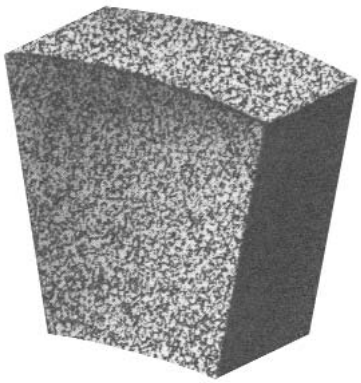
* All brick quantities per ring have been calculated from theoretical diameter turned by the brick to which a steel plate (1.5 mm thickness) has been attached.

BRICK COUNTS FOR ROTARY KILNS

HIGH-ALUMINA BRICK

ROTARY KILN BLOCKS
Nine-Inch Size (9 x 9 x 4)

The numbers in the RKB column indicate the inside and outside diameters, respectively, of the ring produced by the shape. For example, 48-66 RKB will produce a ring with a 48-inch inside diameter and 66-inch outside diameter for a 9-inch lining.



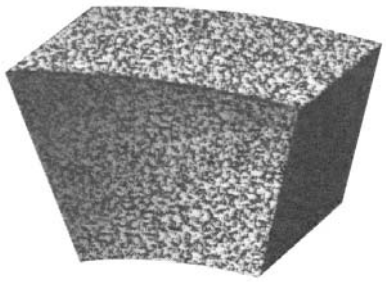
Ins. Dia. Kiln Shell	RKB Number	Inside Chord (In.)	Number Per Ring
5’-6”	48-66	6 17/32	23
6’-0”	54-72	6 3/4	26
6’-6”	60-78	6 17/16	28
7’-0”	66-84	7 1/16	30
7’-6”	72-90	7 3/16	32
8’-0”	78-96	7 5/16	34
8’-6”	84-102	7 13/32	36
9’-0”	90-108	7 1/2	38
9’-6”	96-114	7 19/32	40
10’-0”	102-120	7 21/32	42
10’-6”	108-126	7 23/32	44
11’-0”	114-132	7 25/32	46
11’-3”	117-135	7 13/16	48
11’-6”	120-138	7 13/16	49
12’-0”	126-144	7 7/8	51
12’-6”	132-150	7 29/32	53
13’-0”	138-156	7 31/32	55
13’-6”	144-162	8	57
14’-0”	150-168	8 1/32	59
14’-6”	156-174	8 1/16	61
15’-0”	162-180	8 3/32	63
15’-6”	168-186	8 1/8	65
16’-0”	174-192	8 5/32	67
16’-6”	180-198	8 3/16	70
17’-0”	186-204	8 7/32	72
17’-6”	192-210	8 7/32	74
18’-0”	198-216	8 1/4	76
18’-6”	204-222	8 9/32	78
19’-0”	210-228	8 9/32	80
19’-6”	216-234	8 5/16	82
20’-0”	222-240	8 5/16	84
20’-6”	228-246	8 11/32	86
21’-0”	234-252	8 11/32	88
21’-6”	240-258	8 3/8	90

BRICK COUNTS FOR ROTARY KILNS

HIGH-ALUMINA BRICK

ROTARY KILN BLOCKS
Six-Inch Size (9 x 6 x 4)

The numbers under the RKB column indicate the inside and outside diameters, respectively, of the ring produced by each shape. For example, 144-156 RKB will produce a ring with a 144-inch inside diameter and 156-inch outside diameter for a 6-inch lining.



Ins. Dia. Kiln Shell	RKB Number	Inside Chord (In.)	Number Per Ring
3'-6"	30-42	6 7/16	15
4'-0"	36-48	6 3/4	17
4'-6"	42-54	7	19
5'-0"	48-60	7 3/16	21
5'-6"	54-66	7 3/8	23
6'-0"	60-72	7 1/2	26
6'-6"	66-78	7 5/8	28
7'-0"	72-84	7 23/32	30
7'-6"	78-90	7 13/16	32
8'-0"	84-96	7 7/8	34
8'-6"	90-102	7 15/16	36
9'-0"	96-108	8	38
9'-6"	102-114	8 1/16	40
10'-0"	108-120	8 3/32	42
10'-6"	114-126	8 5/32	44
11'-0"	120-132	8 3/16	46
11'-3"	123-135	8 3/16	48
11'-6"	126-138	8 7/32	49
12'-0"	132-144	8 1/4	51
12'-6"	138-150	8 9/32	53
13'-0"	144-156	8 5/16	55
13'-6"	150-162	8 11/32	57
14'-0"	156-168	8 11/32	59
14'-6"	162-174	8 3/8	61
15'-0"	168-180	8 13/32	63
15'-6"	174-186	8 13/32	65
16'-0"	180-192	8 7/16	67
16'-6"	186-198	8 15/32	70
17'-0"	192-204	8 15/32	72
17'-6"	198-210	8 1/2	74
18'-0"	204-216	8 1/2	76
18'-6"	210-222	8 1/2	78
19'-0"	216-228	8 17/32	80
19'-6"	222-234	8 17/32	82
20'-0"	228-240	8 9/16	84
20'-6"	234-246	8 9/16	86
21'-0"	240-252	8 9/16	88

COMBINATION LININGS FOR ROTARY KILNS

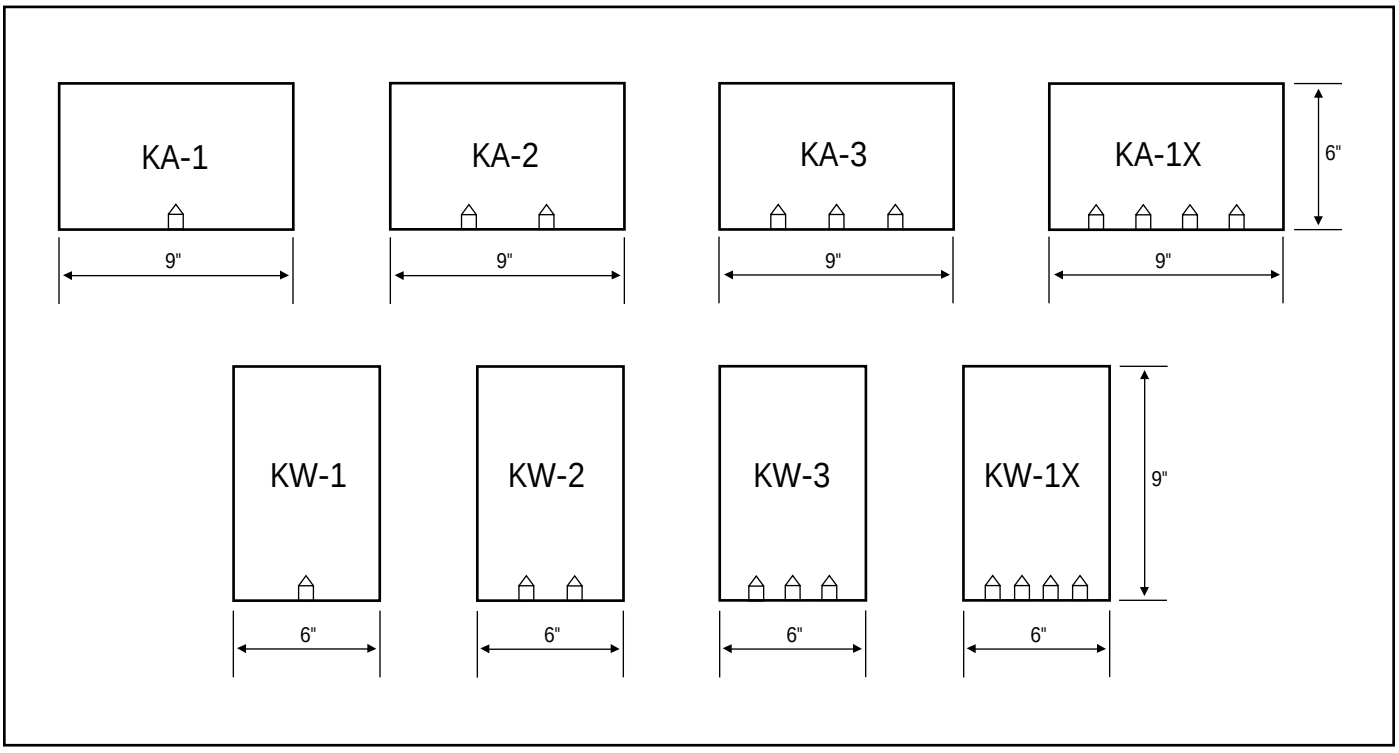
KA AND KW BLOCKS FOR ROTARY KILNS

Harbison-Walker developed the KA and KW system to simplify and eliminate problems associated with the linings of rotary kilns. KA and KW blocks are 9 x 6 x 4-inch kiln liners made in the arch or wedge shape for high-alumina brick. Each shape is furnished in four sizes, two of which will line any kiln (see chart below).

In addition, two thirds and three quarter splits are designed to work with all KA and KW linings to eliminate the need for cutting keys.

Using the proper combination of KA and KW blocks also can reduce shimming, thereby producing a tighter lining with less chance of dropout or spiraling. Because these shapes fit kilns of many sizes, operators with kilns of different sizes can reduce their in-plant inventories.

Kiln Diameter Combinations			
	6 to 8 feet	8 to 13 feet	13 to 21 feet
Linings 6 inches thick	KA-3, KA-2	KA-2, KA-I	KA-I, KA-IX
Linings 9 inches thick	KW-3, KW-2	KW-2, KW-I	KW-I, KW-IX



COMBINATION LININGS FOR ROTARY KILNS

Number of KA Blocks Required for Kilns

Diameters				Number Required Per Ring					Number Required Per Linear Ft				
Inside Lining		Inside Shell											
Ft	In	Ft	In	KA-3	KA-2	KA-1	KA-1X	Total	KA-3	KA-2	KA-1	KA-1X	Total
5	0	6	0	50	7	—	—	57	67	10	—	—	77
5	3	6	3	44	15	—	—	59	59	20	—	—	79
5	6	6	6	38	24	—	—	62	51	32	—	—	83
5	9	6	9	32	32	—	—	64	43	43	—	—	86
6	0	7	0	25	41	—	—	66	34	55	—	—	89
6	3	7	3	19	50	—	—	69	26	67	—	—	93
6	6	7	6	13	58	—	—	71	18	78	—	—	96
6	9	7	9	6	67	—	—	73	8	90	—	—	98
7	0	8	0	—	76	—	—	76	—	102	—	—	102
7	3	8	3	—	72	6	—	78	—	96	8	—	104
7	6	8	6	—	68	13	—	81	—	91	18	—	109
7	9	8	9	—	64	19	—	83	—	86	26	—	112
8	0	9	0	—	60	25	—	85	—	80	34	—	114
8	3	9	3	—	56	32	—	88	—	75	43	—	118
8	6	9	6	—	52	38	—	90	—	70	51	—	121
8	9	9	9	—	48	44	—	92	—	64	59	—	123
9	0	10	0	—	44	51	—	95	—	59	68	—	127
9	3	10	3	—	40	57	—	97	—	54	76	—	130
9	6	10	6	—	36	63	—	99	—	48	84	—	132
9	9	10	9	—	33	69	—	102	—	44	92	—	136
10	0	11	0	—	28	76	—	104	—	38	102	—	140
10	3	11	3	—	24	82	—	106	—	32	110	—	142
10	6	11	6	—	21	88	—	109	—	28	118	—	146
10	9	11	9	—	17	94	—	111	—	23	126	—	149
11	0	12	0	—	13	100	—	113	—	18	134	—	152
11	3	12	3	—	9	107	—	116	—	12	143	—	155
11	6	12	6	—	5	113	—	118	—	7	151	—	158
11	9	12	9	—	1	119	—	120	—	1	159	—	160
12	0	13	0	—	—	118	5	123	—	—	157	7	164
12	3	13	3	—	—	114	11	125	—	—	152	15	167
12	6	13	6	—	—	111	17	128	—	—	148	23	171
12	9	13	9	—	—	107	23	130	—	—	143	31	174
13	0	14	0	—	—	104	28	132	—	—	139	37	176
13	3	14	3	—	—	100	35	135	—	—	133	47	180
13	6	14	6	—	—	97	40	137	—	—	130	53	183
13	9	14	9	—	—	93	46	139	—	—	124	62	186
14	0	15	0	—	—	90	52	142	—	—	120	70	190
14	3	15	3	—	—	86	58	144	—	—	115	77	192
14	6	15	6	—	—	82	64	146	—	—	110	85	195
14	9	15	9	—	—	79	70	149	—	—	106	93	199
15	0	16	0	—	—	76	75	151	—	—	102	100	202
15	3	16	3	—	—	72	82	154	—	—	96	110	206
15	6	16	6	—	—	69	87	156	—	—	92	116	208
15	9	16	9	—	—	65	93	158	—	—	87	124	211
16	0	17	0	—	—	62	99	161	—	—	83	132	215
16	3	17	3	—	—	58	105	163	—	—	78	140	218
16	6	17	6	—	—	54	111	165	—	—	72	148	220
16	9	17	9	—	—	51	117	168	—	—	68	156	224
17	0	18	0	—	—	47	123	170	—	—	63	164	227
17	3	18	3	—	—	44	128	172	—	—	59	171	230
17	6	18	6	—	—	40	135	175	—	—	54	180	234
17	9	18	9	—	—	37	140	177	—	—	49	187	236
18	0	19	0	—	—	33	146	179	—	—	44	195	239
18	3	19	3	—	—	30	152	182	—	—	40	203	243
18	6	19	6	—	—	26	158	184	—	—	35	211	246
18	9	19	9	—	—	23	164	187	—	—	31	219	250
19	0	20	0	—	—	19	170	189	—	—	25	227	252
19	3	20	3	—	—	15	176	191	—	—	20	235	255
19	6	20	6	—	—	12	182	194	—	—	16	243	259
19	9	20	9	—	—	8	188	196	—	—	11	251	262
20	0	21	0	—	—	5	193	198	—	—	7	257	264
20	3	21	3	—	—	2	199	201	—	—	3	265	268

NOTE: When using KA - 1x shape, order two pieces each ring KW - $^{2}/_{3}$ x and KW - $^{3}/_{4}$ x to facilitate keying.

COMBINATION LININGS FOR ROTARY KILNS

Number of KW Blocks Required for Kilns

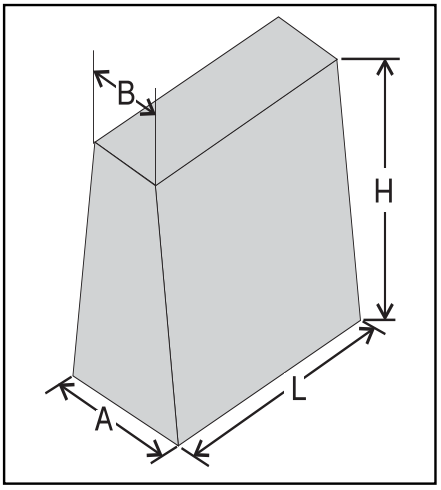
Diameters				Number Required Per Ring					Number Required Per Linear Ft				
Inside Lining		Inside Shell											
Ft	In	Ft	In	KW-3	KW-2	KW-1	KW-1X	Total	KW-3	KW-2	KW-1	KW-1X	Total
4	6	6	0	50	7	—	—	57	100	14	—	—	114
4	9	6	3	44	15	—	—	59	88	30	—	—	118
5	0	6	6	38	24	—	—	62	76	48	—	—	124
5	3	6	9	32	32	—	—	64	64	64	—	—	128
5	6	7	0	25	41	—	—	66	50	82	—	—	132
5	9	7	3	19	50	—	—	69	38	100	—	—	138
6	0	7	6	13	58	—	—	71	26	116	—	—	142
6	3	7	9	6	67	—	—	73	12	134	—	—	146
6	6	8	0	—	76	—	—	76	—	152	—	—	152
6	9	8	3	—	72	6	—	78	—	144	12	—	156
7	0	8	6	—	68	13	—	81	—	136	26	—	162
7	3	8	9	—	64	19	—	83	—	128	38	—	166
7	6	9	0	—	60	25	—	85	—	120	50	—	170
7	9	9	3	—	56	32	—	88	—	112	64	—	176
8	0	9	6	—	52	38	—	90	—	104	76	—	180
8	3	9	9	—	48	44	—	92	—	96	88	—	184
8	6	10	0	—	44	51	—	95	—	88	102	—	190
8	9	10	3	—	40	57	—	97	—	80	114	—	194
9	0	10	6	—	36	63	—	99	—	72	126	—	198
9	3	10	9	—	33	69	—	102	—	66	138	—	204
9	6	11	0	—	28	76	—	104	—	56	152	—	208
9	9	11	3	—	24	82	—	106	—	48	164	—	212
10	0	11	6	—	21	88	—	109	—	42	176	—	218
10	3	11	9	—	17	94	—	111	—	34	188	—	222
10	6	12	0	—	13	100	—	113	—	26	200	—	226
10	9	12	3	—	9	107	—	116	—	18	214	—	232
11	0	12	6	—	5	113	—	118	—	10	226	—	236
11	3	12	9	—	1	119	—	120	—	2	238	—	240
11	6	13	0	—	—	117	6	123	—	—	234	12	246
11	9	13	3	—	—	112	13	125	—	—	224	26	250
12	0	13	6	—	—	108	20	128	—	—	216	40	256
12	3	13	9	—	—	103	27	130	—	—	206	54	260
12	6	14	0	—	—	98	34	132	—	—	196	68	264
12	9	14	3	—	—	94	41	135	—	—	188	82	270
13	0	14	6	—	—	89	48	137	—	—	178	96	274
13	3	14	9	—	—	84	55	139	—	—	168	110	278
13	6	15	0	—	—	79	63	142	—	—	158	126	284
13	9	15	3	—	—	75	69	144	—	—	150	138	288
14	0	15	6	—	—	70	76	146	—	—	140	152	292
14	3	15	9	—	—	65	84	149	—	—	130	168	298
14	6	16	0	—	—	60	91	151	—	—	120	182	302
14	9	16	3	—	—	56	98	154	—	—	112	196	308
15	0	16	6	—	—	51	105	156	—	—	102	210	312
15	3	16	9	—	—	46	112	158	—	—	92	224	316
15	6	17	0	—	—	42	119	161	—	—	84	238	322
15	9	17	3	—	—	37	126	163	—	—	74	252	326
16	0	17	6	—	—	32	133	165	—	—	64	266	330
16	3	17	9	—	—	28	140	168	—	—	56	280	336
16	6	18	0	—	—	23	147	170	—	—	46	294	340
16	9	18	3	—	—	18	154	172	—	—	36	308	344
17	0	18	6	—	—	14	161	175	—	—	28	322	350
17	3	18	9	—	—	9	168	177	—	—	18	336	354
17	6	19	0	—	—	4	175	179	—	—	8	350	358
17	9	19	3	—	—	—	182	182	—	—	—	364	364

NOTE: When using KA - 1x shape, order two pieces each ring KW - 2/3 x and KW - 3/4 x to facilitate keying.

COMBINATION LININGS FOR ROTARY KILNS

CR COMBINATION LININGS

CR (Combination Ring) rotary kiln brick are designed to line kilns from 8 to 24 feet in diameter for a 9-inch lining thickness. The appropriate combinations of the two kiln liners are calculated for the best fit for the given diameter.



CR Series
Dimensions (Inches)

SHAPE	A	B	L	H
CR-89	$3^{1}/_{2}$	$2^{13}/_{16}$	6	9
CR-249	$3^{1}/_{2}$	$3^{9}/_{32}$	6	9

Combination Linings – CR Series

Kiln Diameter		CR-89	CR-249
Feet	Meters		
9’-10”	3.00	72	33
10’- 0”	3.04	71	35
10’- 2”	3.10	71	37
10’- 6”	3.20	69	43
10’-10”	3.30	67	48
11’- 0”	3.36	67	50
11’- 2”	3.40	66	53
11’- 6”	3.50	64	58
11’-10”	3.60	63	63
12’- 0”	3.66	61	66
12’- 2”	3.70	61	66
12’- 6”	3.80	59	74
12’-10”	3.90	57	79
13’- 0”	3.96	57	81
13’- 1”	4.00	56	83
13’- 5”	4.10	54	89
13’- 6”	4.12	54	90
13’- 9”	4.20	53	94
14’- 0”	4.26	51	99
14’- 1”	4.30	51	99
14’- 3”	4.34	50	102
14’- 5”	4.40	50	103
14’- 6”	4.42	49	105
14’- 9”	4.50	48	109
15’- 0”	4.58	47	112
15’- 1”	4.60	46	114
15’- 5”	4.70	45	119
15’- 6”	4.72	44	121
15’- 9”	4.80	43	124
16’- 0”	4.88	42	128
16’- 1”	4.90	41	130
16’- 5”	5.00	40	134
16’- 6”	5.02	39	136
16’- 9”	5.10	38	140
17’- 0”	5.18	37	143
17’- 1”	5.20	36	145
17’- 5”	5.30	35	150
17’- 6”	5.34	34	152
17’- 9”	5.40	33	155
18’- 0”	5.48	32	159
18’- 1”	5.50	32	160
18’- 4”	5.60	30	165
18’- 6”	5.64	29	167
18’- 8”	5.70	29	169
19’- 0”	5.80	27	175

To facilitate the keying of wedge-type rotary kiln blocks, keying bricks of two-thirds thickness, RKW-$^{2}/_{3}$, and of three-quarters thickness, RKW-$^{3}/_{4}$, are made. Two of each keying brick should be ordered for each ring.

ISO AND VDZ COMBINATION LININGS

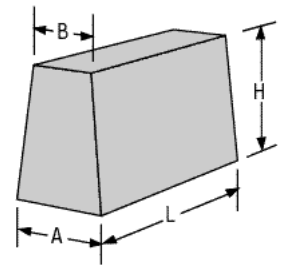
ISO and VDZ Combination Linings

Standard practice in many North American minerals processing plants is to use one brick of a size manufactured to fit a specific rotary kiln diameter. On the other hand, international practice is to use combination linings. Within practical limits, any rotary kiln can be lined with an appropriate combination of two kiln liners, one of which fits a kiln of larger diameter and the other a kiln of smaller diameter.

As good engineering practice, Harbison-Walker suggests brick blending ratios between 3:1 and 1:3 for the two-shapes. This helps to minimize the small amount of stepping which can occur, allowing for a better fit.

The principal advantages of combination linings are:

- *In plants which have several kiln sizes, the number of kiln liner shapes can be reduced, since two shapes in appropriate combintions will fit many kilns.*
- *Liner to liner contact is maintained, while following minor deformations in kiln shells. This results in a tight lining and minimizes the need for correcting shims.*



ISO Series - Dimensions (mm)	
L - running LENGTH	198
H - lining THICKNESS	160 180 200 220 250
A - BACK Chord (cold face)	103
B - INSIDE Chord (hot face)	VARIABLE

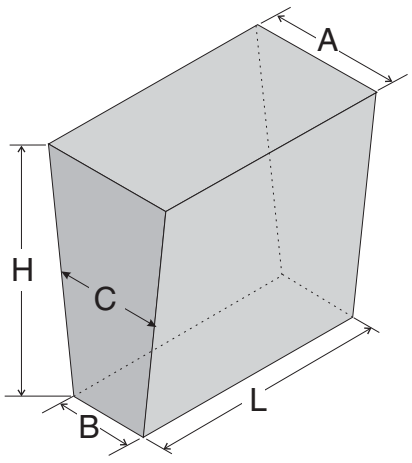
EXAMPLE: Designation 320 ISO

The first digit (3) denotes tapered brick which turn a circle of 3.0 meters diameter outside brickwork.

The last two digits (20) denote a lining thickness of 200 mm.

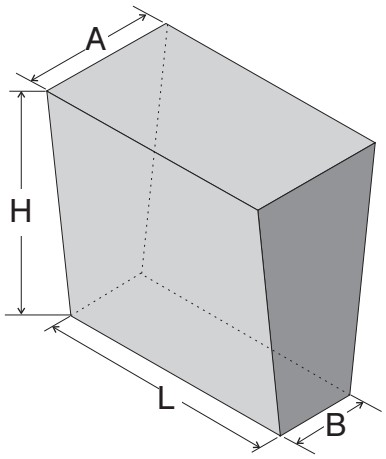
Using ISO series combination lining charts, combinations are made using outside diameter brickwork dimensions. A chart showing a 2M, 6M brick combination is for tapered brick which turn a diameter between 2.0 meters to 6.0 meters, in any lining thickness from 160 mm to 250 mm.

International System

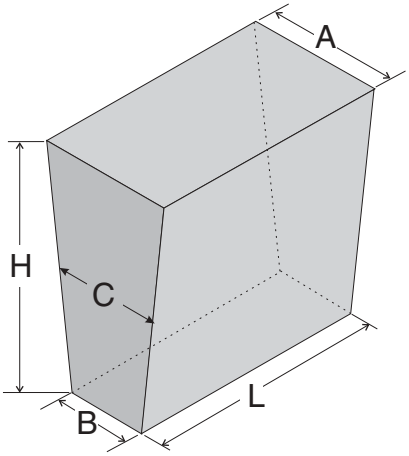


INTERNATIONAL SYSTEM			
		ISO	**VDZ**
BACK CHORD	(A)	103	VARIABLE
INSIDE CHORD	(B)	VARIABLE	VARIABLE
MIDDLE CHORD	(C)	VARIABLE	71.5
LENGTH	(L)	198	198
HEIGHT	(H)	160 180 200 220 250	160 180 200 220 250
BASIC LINING			X
NON-BASIC LINING		X	

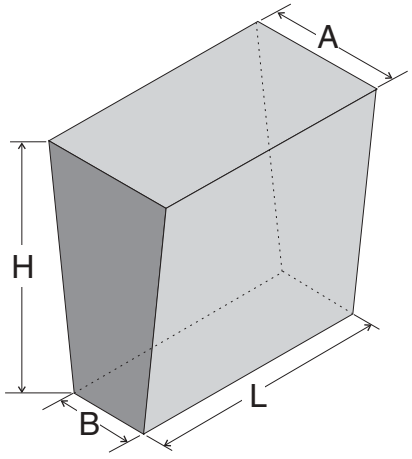
Schematic diagram showing critical dimensions of ISO and VDZ shapes



ISO brick outside chord (A) dimension is constant at 103mm (4.05”)

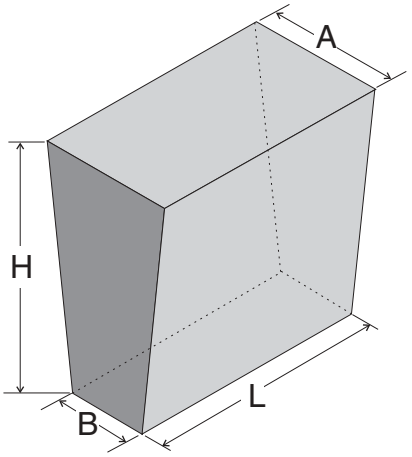


VDZ brick mean chord (C) dimension is constant at 71.5mm (2.81”)



ISO SHAPES						
SHAPE No.	DIMENSIONS				VOL.	TAPER
	A	B	H	L	dm^3	
216	103	86	160	198	2.99	17
716	103	98.3			3.19	4.7
218	103	84	180		3.33	19
718	103	97.7			3.58	5.3
320	103	89	200		3.80	21
820	103	97.8			3.98	5.2
222	103	80	220		3.99	23
322	103	88			4.16	15
622	103	95.5			4.33	11.5
822	103	97.3			4.36	5.7

ISO AND VDZ COMBINATION LININGS



VDZ SHAPES						
SHAPE No.	DIMENSIONS				VOL.	TAPER
	A	B	H	L	dm^3	
B-216	78	65	160	198	2.27	13
B-416	75	68			2.27	7
B-218	78	65	180		2.55	13
B-418	75	68			2.55	7
B-220	78	65	200		2.83	13
B-620	74	69			2.83	5
B-222	78	65	220		3.11	13
B-322	76.5	66.5			3.11	10
B-622	74	69			3.11	5

RECOMMENDED LINING THICKNESS	
ROTARY KILN DIAMETER	*RECOMMENDED BRICK THICK
<3.6M (12’-0”) I.D.	160 mm
Up to 4M (13’-6”) I.D.	180 mm
Up to 4.5M (16’-6”) I.D.	200 mm
Up to 5.8M (19’-0”) I.D.	220 mm
Over 5.8M (19’-0”) I.D.	250mm
*Recommendations are based on kiln diameter only, not taking operating data into consideration.	

RING COMBINATIONS

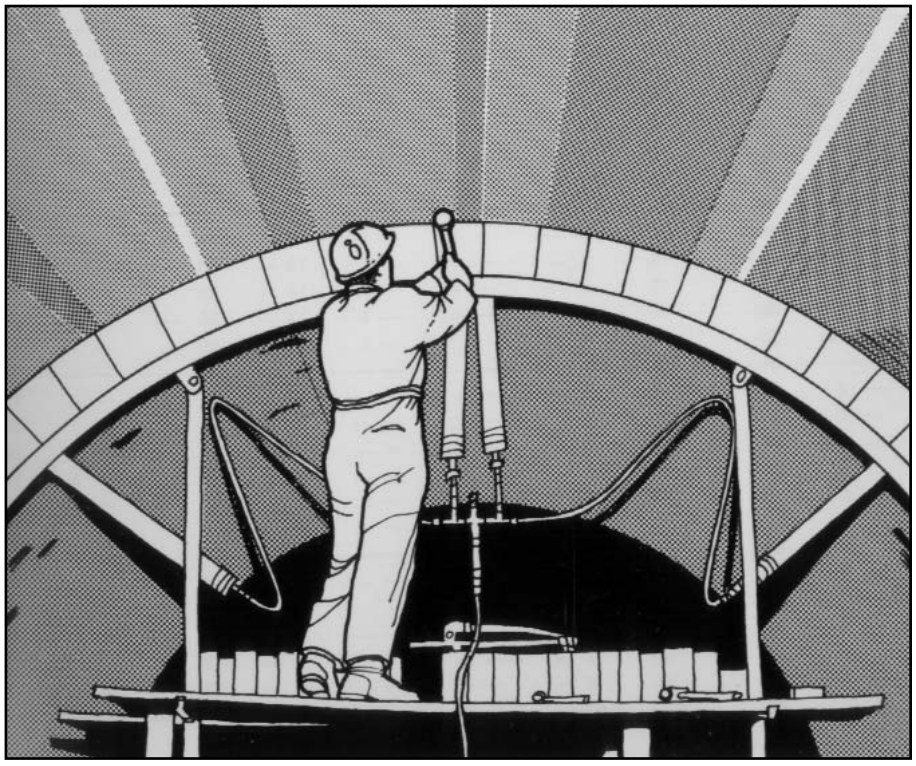
BRICK COMBINATIONS REQUIRED FOR RINGS

The tables on the following pages are useful in estimating the quantities of brick required for the construction of circular linings, roofs and arches. These tables give the combinations of brick sizes required for rings of given diameters.

In calculating the tables, no allowance was made for mortar or expansion joints or for size deviations of the brick. Fractional parts equal to or greater than one tenth of a brick were counted as an entire brick. For these reasons, the brick combinations shown may lay up to diameters which differ slightly from the theoretical diameters. The number of brick required for a ring, as given in the tables, may be slightly in excess of the number actually required.

In laying a ring course of brick, it is often necessary to cut one or two pieces, and in some instances several pieces, to complete the ring.

For brick combinations required for rings not shown in the following tables, or to calculate the ring combinations for brick of two different sizes, refer to the formulas found on page 19 which covers ring calculations.



RING COMBINATIONS

4½ Inch Lining - 2½ Inch Arch Brick 9 x 4½ x 2½ or 13½ x 4½ x 2½ Inch

Diam. Inside Brickwork Ft.	In.	Number Required per Ring No.3 Arch	No.2 Arch	No.1 Arch	Straight	Total
0	6	19	—	—	—	19
0	7	18	3	—	—	21
0	8	17	5	—	—	22
0	9	15	8	—	—	23
0	10	14	10	—	—	24
0	11	13	13	—	—	26
1	0	12	15	—	—	27
1	1	10	18	—	—	28
1	2	9	20	—	—	29
1	3	8	23	—	—	31
1	4	7	25	—	—	32
1	5	5	28	—	—	33
1	6	4	30	—	—	34
1	7	3	33	—	—	36
1	8	2	35	—	—	37
1	9	—	38	—	—	38
1	10	—	36	3	—	39
1	11	—	36	5	—	41
2	0	—	34	8	—	42
2	1	—	33	10	—	43
2	2	—	31	13	—	44
2	3	—	31	15	—	46
2	4	—	29	18	—	47
2	5	—	28	20	—	48
2	6	—	26	23	—	49
2	7	—	26	25	—	51
2	8	—	24	28	—	52
2	9	—	23	30	—	53
2	10	—	21	33	—	54
2	11	—	20	36	—	56
3	0	—	19	38	—	57
3	1	—	18	40	—	58
3	2	—	16	43	—	59
3	3	—	15	46	—	61
3	4	—	14	48	—	62
3	5	—	13	50	—	63
3	6	—	11	53	—	64
3	7	—	10	56	—	66
3	8	—	9	58	—	67
3	9	—	8	60	—	68
3	10	—	7	63	—	70
3	11	—	5	66	—	71
4	0	—	4	68	—	72
4	1	—	3	70	—	73
4	2	—	2	73	—	75
4	3	—	—	76	—	76
4	4	—	—	76	1	77
4	6	—	—	76	4	80
4	8	—	—	76	6	82
4	10	—	—	76	9	85
5	0	—	—	76	11	87
5	2	—	—	76	14	90
5	4	—	—	76	16	92
5	6	—	—	76	19	95
5	8	—	—	76	21	97
5	10	—	—	76	24	100

4½ Inch Lining - 2½ Inch Arch Brick 9 x 4½ x 2½ or 13½ x 4½ x 2½ Inch

Diam. Inside Brickwork Ft.	In.	Number Required per Ring No.3 Arch	No.2 Arch	No.1 Arch	Straight	Total
6	0	—	—	76	26	102
6	2	—	—	76	29	105
6	4	—	—	76	31	107
6	6	—	—	76	34	110
6	8	—	—	76	36	112
6	10	—	—	76	39	115
7	0	—	—	76	41	117
7	2	—	—	76	44	120
7	4	—	—	76	46	122
7	6	—	—	76	49	125
7	8	—	—	76	51	127
7	10	—	—	76	54	130
8	0	—	—	76	56	132
8	2	—	—	76	59	135
8	4	—	—	76	61	137
8	6	—	—	76	64	140
8	8	—	—	76	66	142
8	10	—	—	76	69	145
9	0	—	—	76	71	147
9	2	—	—	76	74	150
9	4	—	—	76	76	152
9	6	—	—	76	79	155
9	8	—	—	76	81	157
9	10	—	—	76	84	160
10	0	—	—	76	87	163
10	2	—	—	76	89	165
10	4	—	—	76	92	168
10	6	—	—	76	94	170
10	8	—	—	76	97	173
10	10	—	—	76	99	175
11	0	—	—	76	102	178
11	2	—	—	76	104	180
11	4	—	—	76	107	183
11	6	—	—	76	109	185
11	8	—	—	76	112	188
11	10	—	—	76	114	190
12	0	—	—	76	117	193
12	2	—	—	76	119	195
12	4	—	—	76	122	198
12	6	—	—	76	124	200
12	8	—	—	76	127	203
12	10	—	—	76	129	205
13	0	—	—	76	132	208
13	2	—	—	76	134	210
13	4	—	—	76	137	213
13	6	—	—	76	139	215
13	8	—	—	76	142	218
13	10	—	—	76	144	220
14	0	—	—	76	147	223
14	2	—	—	76	149	225
14	4	—	—	76	152	228
14	6	—	—	76	154	230
14	8	—	—	76	157	233
14	10	—	—	76	159	235
15	0	—	—	76	162	238

RING COMBINATIONS

9 Inch Lining - 2½ Inch Wedge Brick
9 x 4½ x 2½, 9 x 6¾ x 2½ or 9 x 9 x 2½ Inch

Diam. Inside Brickwork		Number Required per Ring				
Ft.	In.	No.2 Wedge	No.1 Wedge	No.1-X Wedge	Straight	Total
2	3	57	—	—	—	57
2	4	55	3	—	—	58
2	5	52	7	—	—	59
2	6	51	10	—	—	61
2	7	48	14	—	—	62
2	8	46	17	—	—	63
2	9	44	20	—	—	64
2	10	42	24	—	—	66
2	11	40	27	—	—	67
3	0	38	30	—	—	68
3	1	36	34	—	—	70
3	2	34	37	—	—	71
3	3	32	40	—	—	72
3	4	29	44	—	—	73
3	5	28	47	—	—	75
3	6	25	51	—	—	76
3	7	23	54	—	—	77
3	8	21	57	—	—	78
3	9	19	61	—	—	80
3	10	17	64	—	—	81
3	11	15	67	—	—	82
4	0	13	70	—	—	83
4	1	11	74	—	—	85
4	2	9	77	—	—	86
4	3	6	81	—	—	87
4	4	4	84	—	—	88
4	5	2	88	—	—	90
4	6	—	91	—	—	91
4	7	—	90	2	—	92
4	8	—	89	4	—	93
4	9	—	88	7	—	95
4	10	—	87	9	—	96
4	11	—	86	11	—	97
5	0	—	85	13	—	98
5	1	—	85	15	—	100
5	2	—	84	17	—	101
5	3	—	83	19	—	102
5	4	—	82	21	—	103
5	5	—	82	23	—	105
5	6	—	81	25	—	106
5	7	—	80	27	—	107
5	8	—	79	29	—	108
5	9	—	78	32	—	110
5	10	—	77	34	—	111
5	11	—	76	36	—	112
6	0	—	75	38	—	113
6	1	—	75	40	—	115
6	2	—	74	42	—	116
6	3	—	73	44	—	117
6	4	—	72	47	—	119
6	5	—	72	48	—	120
6	6	—	71	50	—	121
6	7	—	70	52	—	122
6	8	—	69	55	—	124
6	9	—	68	57	—	125
6	10	—	67	59	—	126
6	11	—	66	61	—	127

9 Inch Lining - 2½ Inch Wedge Brick
9 x 4½ x 2½, 9 x 6¾ x 2½ or 9 x 9 x 2½ Inch

Diam. Inside Brickwork		Number Required per Ring				
Ft.	In.	No.2 Wedge	No.1 Wedge	No.1-X Wedge	Straight	Total
7	0	—	66	63	—	129
7	1	—	65	65	—	130
7	2	—	64	67	—	131
7	3	—	63	69	—	132
7	4	—	62	72	—	134
7	5	—	61	74	—	135
7	6	—	60	76	—	136
7	7	—	59	78	—	137
7	8	—	59	80	—	139
7	9	—	58	82	—	140
7	10	—	57	84	—	141
7	11	—	56	86	—	142
8	0	—	56	88	—	144
8	1	—	55	90	—	145
8	2	—	54	92	—	146
8	3	—	53	94	—	147
8	4	—	52	97	—	149
8	5	—	51	99	—	150
8	6	—	50	101	—	151
8	7	—	49	103	—	152
8	8	—	49	105	—	154
8	9	—	48	107	—	155
8	10	—	47	109	—	156
8	11	—	46	111	—	157
9	0	—	46	113	—	159
9	1	—	45	115	—	160
9	2	—	44	117	—	161
9	3	—	43	120	—	163
9	4	—	42	122	—	164
9	5	—	41	124	—	165
9	6	—	40	126	—	166
9	7	—	40	128	—	168
9	8	—	39	130	—	169
9	9	—	38	132	—	170
9	10	—	37	134	—	171
9	11	—	36	137	—	173
10	0	—	35	139	—	174
10	1	—	35	140	—	175
10	2	—	34	142	—	176
10	3	—	33	145	—	178
10	4	—	32	147	—	179
10	5	—	31	149	—	180
10	6	—	30	151	—	181
10	7	—	30	153	—	183
10	8	—	29	155	—	184
10	9	—	28	157	—	185
10	10	—	27	159	—	186
10	11	—	26	162	—	188
11	0	—	25	164	—	189
11	1	—	24	166	—	190
11	2	—	23	168	—	191
11	3	—	23	170	—	193
11	4	—	22	172	—	194
11	5	—	21	174	—	195

RING COMBINATIONS

9 Inch Lining - 2½ Inch Wedge Brick
9 x 4½ x 2½, 9 x 6¾ x 2½ or 9 x 9 x 2½ Inch

Diam. Inside Brickwork		Number Required per Ring				
Ft.	In.	No.2 Wedge	No.1 Wedge	No.1-X Wedge	Straight	Total
11	6	—	20	176	—	196
11	7	—	20	178	—	198
11	8	—	19	180	—	199
11	9	—	18	182	—	200
11	10	—	17	184	—	201
11	11	—	16	187	—	203
12	0	—	15	189	—	204
12	1	—	14	191	—	205
12	2	—	13	193	—	206
12	3	—	13	195	—	208
12	4	—	12	197	—	209
12	5	—	11	199	—	210
12	6	—	10	202	—	212
12	7	—	10	203	—	213
12	8	—	9	205	—	214
12	9	—	8	207	—	215
12	10	—	7	210	—	217
12	11	—	6	212	—	218
13	0	—	5	214	—	219
13	1	—	4	216	—	220
13	2	—	4	218	—	222
13	3	—	3	220	—	223
13	4	—	2	222	—	224
13	5	—	1	224	—	225
13	6	—	—	227	—	227
13	7	—	—	227	1	228
13	8	—	—	227	2	229
13	9	—	—	227	3	230
13	10	—	—	227	5	232
13	11	—	—	227	6	233
14	0	—	—	227	7	234
14	6	—	—	227	15	242
15	0	—	—	227	22	249
15	6	—	—	227	30	257
16	0	—	—	227	37	264
16	6	—	—	227	45	272
17	0	—	—	227	52	279
17	6	—	—	227	60	287
18	0	—	—	227	67	294
18	6	—	—	227	75	302
19	0	—	—	227	83	310
19	6	—	—	227	90	317

9 Inch Lining - 2½ Inch Wedge Brick
9 x 4½ x 2¾, 9 x 6¾ x 2½ or 9 x 9 x 2½ Inch

Diam. Inside Brickwork		Number Required per Ring				
Ft.	In.	No.2 Wedge	No.1 Wedge	No.1-X Wedge	Straight	Total
20	0	—	—	227	98	325
20	6	—	—	227	105	332
21	0	—	—	227	113	340
21	6	—	—	227	120	347
22	0	—	—	227	128	355
22	6	—	—	227	135	362
23	0	—	—	227	143	370
23	6	—	—	227	150	377
24	0	—	—	227	158	385
24	6	—	—	227	165	392
25	0	—	—	227	173	400
25	6	—	—	227	181	408
26	0	—	—	227	188	415
26	6	—	—	227	196	423
27	0	—	—	227	203	430
27	6	—	—	227	211	438
28	0	—	—	227	218	445
28	6	—	—	227	226	453
29	0	—	—	227	233	460
29	6	—	—	227	241	468
30	0	—	—	227	248	475
30	6	—	—	227	256	483
31	0	—	—	227	263	490
31	6	—	—	227	271	498
32	0	—	—	227	279	506
32	6	—	—	227	286	513
33	0	—	—	227	294	521
33	6	—	—	227	301	528
34	0	—	—	227	309	536
34	6	—	—	227	316	543
35	0	—	—	227	324	551
35	6	—	—	227	331	558
36	0	—	—	227	339	566
36	6	—	—	227	346	573
37	0	—	—	227	354	581
37	6	—	—	227	362	589
38	0	—	—	227	369	596
38	6	—	—	227	377	604
39	0	—	—	227	384	611
39	6	—	—	227	392	619
40	0	—	—	227	399	626
40	6	—	—	227	407	634
41	0	—	—	227	414	641
41	6	—	—	227	422	649
42	0	—	—	227	429	656
42	6	—	—	227	437	664
43	0	—	—	227	444	671
43	6	—	—	227	452	679
44	0	—	—	227	460	687
44	6	—	—	227	467	694
45	0	—	—	227	475	702

RING COMBINATIONS

4 1/2 Inch Lining — 3 Inch Arch Brick
9 x 4 1/2 x 3 or 13 1/2 x 4 1/2 x 3 Inch

Diam. Inside Brickwork Ft	In	Number Required Per Ring: No. 4 Arch	No. 3 Arch	No. 2 Arch	No. 1 Arch	Straight	Total
0	4 1/2	15	—	—	—	—	15
0	5	14	1	—	—	—	15
0	6	13	3	—	—	—	16
0	7	12	5	—	—	—	17
0	8	11	7	—	—	—	18
0	9	10	9	—	—	—	19
0	10	8	12	—	—	—	20
0	11	7	14	—	—	—	21
1	0	6	16	—	—	—	22
1	1	5	18	—	—	—	23
1	2	4	20	—	—	—	24
1	3	4	22	—	—	—	26
1	4	3	24	—	—	—	27
1	5	1	27	—	—	—	28
1	6	—	29	—	—	—	29
1	7	—	28	2	—	—	30
1	8	—	26	5	—	—	31
1	9	—	25	7	—	—	32
1	10	—	24	9	—	—	33
1	11	—	23	11	—	—	34
2	0	—	22	13	—	—	35
2	1	—	21	15	—	—	36
2	2	—	20	17	—	—	37
2	3	—	19	19	—	—	38
2	4	—	18	21	—	—	39
2	5	—	17	23	—	—	40
2	6	—	16	25	—	—	41
2	7	—	15	27	—	—	42
2	8	—	14	29	—	—	43
2	9	—	13	31	—	—	44
2	10	—	12	33	—	—	45
2	11	—	10	36	—	—	46
3	0	—	10	38	—	—	48
3	1	—	9	40	—	—	49
3	2	—	8	42	—	—	50
3	3	—	7	44	—	—	51
3	4	—	6	46	—	—	52
3	5	—	5	48	—	—	53
3	6	—	3	51	—	—	54
3	7	—	2	53	—	—	55
3	8	—	1	55	—	—	56
3	9	—	—	57	—	—	57
3	10	—	—	56	2	—	58
3	11	—	—	55	4	—	59
4	0	—	—	54	6	—	60
4	1	—	—	52	9	—	61
4	2	—	—	51	11	—	62
4	3	—	—	50	13	—	63
4	4	—	—	49	15	—	64
4	5	—	—	48	17	—	65

4 1/2 Inch Lining — 3 Inch Arch Brick
9 x 4 1/2 x 3 or 13 1/2 x 4 1/2 x 3 Inch — Continued

Diam. Inside Brickwork Ft	In	Number Required Per Ring: No. 4 Arch	No. 3 Arch	No. 2 Arch	No. 1 Arch	Straight	Total
4	6	—	—	47	19	—	66
4	7	—	—	46	21	—	67
4	8	—	—	45	23	—	68
4	9	—	—	44	26	—	70
4	10	—	—	43	28	—	71
4	11	—	—	42	30	—	72
5	0	—	—	41	32	—	73
5	1	—	—	40	34	—	74
5	2	—	—	39	36	—	75
5	3	—	—	38	38	—	76
5	4	—	—	37	40	—	77
5	5	—	—	36	42	—	78
5	6	—	—	35	44	—	79
5	7	—	—	34	46	—	80
5	8	—	—	33	48	—	81
5	9	—	—	32	50	—	82
5	10	—	—	31	52	—	83
5	11	—	—	29	55	—	84
6	0	—	—	28	57	—	85
6	1	—	—	27	59	—	86
6	2	—	—	26	61	—	87
6	3	—	—	25	63	—	88
6	4	—	—	24	65	—	89
6	5	—	—	23	67	—	90
6	6	—	—	22	70	—	92
6	7	—	—	21	72	—	93
6	8	—	—	20	74	—	94
6	9	—	—	19	76	—	95
6	10	—	—	18	78	—	96
6	11	—	—	17	80	—	97
7	0	—	—	16	82	—	98
7	1	—	—	15	84	—	99
7	2	—	—	14	86	—	100
7	3	—	—	13	88	—	101
7	4	—	—	12	90	—	102
7	5	—	—	11	92	—	103
7	6	—	—	10	94	—	104
7	7	—	—	9	96	—	105
7	8	—	—	7	99	—	106
7	9	—	—	6	101	—	107
7	10	—	—	5	103	—	108
7	11	—	—	4	105	—	109
8	0	—	—	3	107	—	110
8	1	—	—	2	109	—	111
8	2	—	—	1	111	—	112
8	3	—	—	—	113	—	113
8	6	—	—	—	113	4	117
9	0	—	—	—	113	10	123
10	0	—	—	—	113	22	135
11	0	—	—	—	113	35	148
12	0	—	—	—	113	48	161
13	0	—	—	—	113	60	173
14	0	—	—	—	113	73	186
15	0	—	—	—	113	85	198

4½ Inch Lining — 3 Inch Circle Brick 9 x 4½ x 3 Inch

Diam. Inside Brickwork Ft	In	Number Required Per Ring 24-33-3 Circle	36-45-3 Circle	48-57-3 Circle	60-69-3 Circle	72-81-3 Circle	Total
2	0	12	—	—	—	—	12
2	1	11	1	—	—	—	12
2	2	10	3	—	—	—	13
2	3	9	4	—	—	—	13
2	4	8	5	—	—	—	13
2	5	7	7	—	—	—	14
2	6	6	8	—	—	—	14
2	7	5	9	—	—	—	14
2	8	4	11	—	—	—	15
2	9	3	12	—	—	—	15
2	10	2	13	—	—	—	15
2	11	1	15	—	—	—	16
3	0	—	16	—	—	—	16
3	1	—	14	2	—	—	16
3	2	—	13	4	—	—	17
3	3	—	12	5	—	—	17
3	4	—	11	7	—	—	18
3	5	—	9	9	—	—	18
3	6	—	8	10	—	—	18
3	7	—	7	12	—	—	19
3	8	—	5	14	—	—	19
3	9	—	4	15	—	—	19
3	10	—	3	17	—	—	20
3	11	—	2	18	—	—	20
4	0	—	—	20	—	—	20
4	1	—	—	19	2	—	21
4	2	—	—	17	4	—	21
4	3	—	—	15	6	—	21
4	4	—	—	14	8	—	22
4	5	—	—	12	10	—	22
4	6	—	—	10	12	—	22
4	7	—	—	9	14	—	23
4	8	—	—	7	16	—	23
4	9	—	—	5	18	—	23
4	10	—	—	4	20	—	24
4	11	—	—	2	22	—	24
5	0	—	—	—	24	—	24
5	1	—	—	—	22	3	25
5	2	—	—	—	20	5	25
5	3	—	—	—	18	8	26
5	4	—	—	—	16	10	26
5	5	—	—	—	14	12	26
5	6	—	—	—	12	15	27
5	7	—	—	—	10	17	27
5	8	—	—	—	8	19	27
5	9	—	—	—	6	22	28
5	10	—	—	—	4	24	28
5	11	—	—	—	2	26	28

4½ Inch Lining — 3 Inch Circle Brick 9 x 4½ x 3 Inch — Continued

Diam. Inside Brickwork Ft	In	Number Required Per Ring 72-81-3 Circle	84-93-3 Circle	96-105-3 Circle	108-117-3 Circle	120-129-3 Circle	Total
6	0	29	—	—	—	—	29
6	1	26	3	—	—	—	29
6	2	24	5	—	—	—	29
6	3	22	8	—	—	—	30
6	4	19	11	—	—	—	30
6	5	16	14	—	—	—	30
6	6	14	17	—	—	—	31
6	7	12	19	—	—	—	31
6	8	9	22	—	—	—	31
6	9	7	25	—	—	—	32
6	10	5	27	—	—	—	32
6	11	3	30	—	—	—	33
7	0	—	33	—	—	—	33
7	1	—	30	3	—	—	33
7	2	—	27	7	—	—	34
7	3	—	25	9	—	—	34
7	4	—	22	12	—	—	34
7	5	—	19	16	—	—	35
7	6	—	16	19	—	—	35
7	7	—	14	21	—	—	35
7	8	—	11	25	—	—	36
7	9	—	8	28	—	—	36
7	10	—	5	31	—	—	36
7	11	—	3	34	—	—	37
8	0	—	—	37	—	—	37
8	1	—	—	34	3	—	37
8	2	—	—	31	7	—	38
8	3	—	—	28	10	—	38
8	4	—	—	24	14	—	38
8	5	—	—	22	17	—	39
8	6	—	—	18	21	—	39
8	7	—	—	15	24	—	39
8	8	—	—	12	28	—	40
8	9	—	—	9	31	—	40
8	10	—	—	7	34	—	41
8	11	—	—	3	38	—	41
9	0	—	—	—	41	—	41
9	1	—	—	—	38	4	42
9	2	—	—	—	34	8	42
9	3	—	—	—	31	11	42
9	4	—	—	—	28	15	43
9	5	—	—	—	24	19	43
9	6	—	—	—	20	23	43
9	7	—	—	—	17	27	44
9	8	—	—	—	14	30	44
9	9	—	—	—	10	34	44
9	10	—	—	—	7	38	45
9	11	—	—	—	4	41	45
10	0	—	—	—	—	45	45

6 Inch Lining — 3 Inch Arch Brick
12 x 6 x 3 or 13 1/2 x 6 x 3 Inch

Diam. Inside Brickwork Ft	In	Number Required Per Ring: No. 3 Arch	No. 2 Arch	No. 1 Arch	Straight	Total
2	0	38	—	—	—	38
2	1	37	2	—	—	39
2	2	36	4	—	—	40
2	3	35	6	—	—	41
2	4	34	8	—	—	42
2	5	32	11	—	—	43
2	6	31	13	—	—	44
2	7	30	15	—	—	45
2	8	29	17	—	—	46
2	9	29	19	—	—	48
2	10	28	21	—	—	49
2	11	27	23	—	—	50
3	0	26	25	—	—	51
3	1	24	28	—	—	52
3	2	23	30	—	—	53
3	3	22	32	—	—	54
3	4	21	34	—	—	55
3	5	20	36	—	—	56
3	6	19	38	—	—	57
3	7	18	40	—	—	58
3	8	17	42	—	—	59
3	9	16	44	—	—	60
3	10	15	46	—	—	61
3	11	14	48	—	—	62
4	0	13	50	—	—	63
4	1	12	52	—	—	64
4	2	11	54	—	—	65
4	3	9	57	—	—	66
4	4	8	59	—	—	67
4	5	7	61	—	—	68
4	6	7	63	—	—	70
4	7	6	65	—	—	71
4	8	5	67	—	—	72
4	9	4	69	—	—	73
4	10	2	72	—	—	74
4	11	1	74	—	—	75
5	0	—	76	—	—	76
5	1	—	75	2	—	77
5	2	—	74	4	—	78
5	3	—	72	7	—	79
5	4	—	71	9	—	80
5	5	—	70	11	—	81
5	6	—	69	13	—	82
5	7	—	68	15	—	83
5	8	—	67	17	—	84
5	9	—	66	19	—	85
5	10	—	65	21	—	86
5	11	—	64	23	—	87
6	0	—	63	25	—	88
6	1	—	62	27	—	89
6	2	—	61	29	—	90
6	3	—	60	32	—	92
6	4	—	59	34	—	93
6	5	—	58	36	—	94
6	6	—	57	38	—	95
6	7	—	56	40	—	96

6 Inch Lining — 3 Inch Arch Brick
12 x 6 x 3 or 13 1/2 x 6 x 3 Inch — Continued

Diam. Inside Brickwork Ft	In	Number Required Per Ring: No. 3 Arch	No. 2 Arch	No. 1 Arch	Straight	Total
6	8	—	55	42	—	97
6	9	—	54	44	—	98
6	10	—	53	46	—	99
6	11	—	52	48	—	100
7	0	—	51	50	—	101
7	1	—	49	53	—	102
7	2	—	48	55	—	103
7	3	—	47	57	—	104
7	4	—	46	59	—	105
7	5	—	45	61	—	106
7	6	—	44	63	—	107
7	7	—	43	65	—	108
7	8	—	42	67	—	109
7	9	—	41	69	—	110
7	10	—	40	71	—	111
7	11	—	39	73	—	112
8	0	—	38	75	—	113
8	1	—	37	78	—	115
8	2	—	36	80	—	116
8	3	—	35	82	—	117
8	4	—	34	84	—	118
8	5	—	33	86	—	119
8	6	—	32	88	—	120
8	7	—	31	90	—	121
8	8	—	30	92	—	122
8	9	—	29	94	—	123
8	10	—	27	97	—	124
8	11	—	26	99	—	125
9	0	—	25	101	—	126
9	1	—	24	103	—	127
9	2	—	23	105	—	128
9	3	—	22	107	—	129
9	4	—	21	109	—	130
9	5	—	20	111	—	131
9	6	—	19	113	—	132
9	7	—	18	115	—	133
9	8	—	17	117	—	134
9	9	—	16	119	—	135
9	10	—	15	122	—	137
9	11	—	14	124	—	138
10	0	—	13	126	—	139
10	1	—	12	128	—	140
10	2	—	11	130	—	141
10	3	—	10	132	—	142
10	4	—	9	134	—	143
10	5	—	8	136	—	144
10	6	—	7	138	—	145
10	7	—	5	141	—	146
10	8	—	4	143	—	147
10	9	—	3	145	—	148
10	10	—	2	147	—	149
10	11	—	1	149	—	150
11	0	—	—	151	—	151
12	0	—	—	151	13	164
13	0	—	—	151	25	176
14	0	—	—	151	38	189

RING COMBINATIONS

6 Inch Lining — Rotary Kiln or Cupola Blocks 9 x 6 x 4 Inch

Diam. Inside Brickwork Ft	In	Number Required Per Ring		Total
		54-66	**60-72**	
4	6	23	—	23
4	7	20	4	24
4	8	15	9	24
4	9	11	13	24
4	10	8	17	25
4	11	4	21	25
		60-72	**66-78**	
5	0	26	—	26
5	1	21	5	26
5	2	17	9	26
5	3	13	14	27
5	4	9	18	27
5	5	4	23	27
		66-78	**72-84**	
5	6	28	—	28
5	7	23	5	28
5	8	18	10	28
5	9	14	15	29
5	10	9	20	29
5	11	5	24	29
		72-84	**78-90**	
6	0	30	—	30
6	1	25	5	30
6	2	20	10	30
6	3	15	16	31
6	4	10	21	31
6	5	5	26	31
		78-90	**84-96**	
6	6	32	—	32
6	7	26	6	32
6	8	21	12	33
6	9	16	17	33
6	10	11	22	33
6	11	6	28	34
		84-96	**90-102**	
7	0	34	—	34
7	1	28	6	34
7	2	23	12	35
7	3	17	18	35
7	4	11	24	35
7	5	6	30	36
		90-102	**96-108**	
7	6	36	—	36
7	7	30	6	36
7	8	24	13	37
7	9	18	19	37
7	10	12	25	37
7	11	6	32	38
		96-108	**102-114**	
8	0	38	—	38
8	1	31	7	38
8	2	25	14	39
8	3	19	20	39
8	4	13	26	39
8	5	7	33	40

NOTE: In orders, the complete names of the blocks desired should be given, as for example “54-66 RKB” or “60-72 Cupola.”

6 Inch Lining — Rotary Kiln or Cupola Blocks 9 x 6 x 4 Inch — Continued

Diam. Inside Brickwork Ft	In	Number Required Per Ring		Total
		102-114	**108-120**	
8	6	40	—	40
8	7	34	7	41
8	8	27	14	41
8	9	20	21	41
8	10	14	28	42
8	11	7	35	42
		108-120	**114-126**	
9	0	42	—	42
9	1	35	8	43
9	2	28	15	43
9	3	21	22	43
9	4	14	30	44
9	5	7	37	44
		114-126	**120-132**	
9	6	44	—	44
9	7	37	8	45
9	8	29	16	45
9	9	22	23	45
9	10	15	31	46
9	11	7	39	46
		120-132	**123-135**	
10	0	46	—	46
10	1	31	16	47
10	2	15	32	47
		123-135	**126-138**	
10	3	48	—	48
10	4	32	16	48
10	5	16	32	48
		126-138	**132-144**	
10	6	49	—	49
10	7	40	9	49
10	8	32	17	49
10	9	24	26	50
10	10	16	34	50
10	11	8	42	50
		132-144	**138-150**	
11	0	51	—	51
11	1	42	9	51
11	2	34	17	51
11	3	25	27	52
11	4	17	35	52
11	5	8	44	52

NOTE: In orders, the complete names of the blocks desired should be given, as for example “102-114 RKB” or “102-114 Cupola.”

6 Inch Lining — Rotary Kiln or Cupola Blocks 9 x 6 x 4 Inch — Continued

Diam. Inside Brickwork Ft	In	Number Required Per Ring		Total
		138-150	**144-156**	
11	6	53	—	53
11	7	44	9	53
11	8	35	18	53
11	9	26	28	54
11	10	18	36	54
11	11	9	46	55
		144-156	**150-162**	
12	0	55	—	55
12	1	45	10	55
12	2	37	19	56
12	3	27	29	56
12	4	18	38	56
12	5	9	48	57
		150-162	**156-168**	
12	6	57	—	57
12	7	47	10	57
12	8	38	20	58
12	9	28	30	58
12	10	19	39	58
12	11	10	49	59
		156-168	**162-174**	
13	0	59	—	59
13	1	49	10	59
13	2	39	21	60
13	3	29	31	60
13	4	20	40	60
13	5	10	51	61
		162-174	**168-180**	
13	6	61	—	61
13	7	51	10	61
13	8	41	21	62
13	9	30	32	62
13	10	21	42	63
13	11	10	53	63
		168-180	**174-186**	
14	0	63	—	63
14	1	53	11	64
14	2	42	22	64
14	3	31	33	64
14	4	21	44	65
14	5	11	54	65

NOTE: In orders, the complete names of the blocks desired should be given, as for example “138-150 RKB” or “138-150 Cupola.”

6 Inch Lining — Rotary Kiln or Cupola Blocks 9 x 6 x 4 Inch — Continued

Diam. Inside Brickwork Ft	In	Number Required Per Ring		Total
		174-186	**180-192**	
14	6	65	—	65
14	7	54	12	66
14	8	43	23	66
14	9	32	34	66
14	10	22	45	67
14	11	11	56	67
		180-192	**186-198**	
15	0	67	—	67
15	1	56	12	68
15	2	45	23	68
15	3	33	35	68
15	4	23	46	69
15	5	11	58	69
		186-198	**192-204**	
15	6	70	—	70
15	7	58	12	70
15	8	46	24	70
15	9	35	36	71
15	10	23	48	71
15	11	12	59	71
		192-204	**198-210**	
16	0	72	—	72
16	1	60	12	72
16	2	48	24	72
16	3	36	37	73
16	4	24	49	73
16	5	12	61	73
		198-210	**204-216**	
16	6	74	—	74
16	7	61	13	74
16	8	49	25	74
16	9	37	38	75
16	10	25	50	75
16	11	12	63	75
		204-216	**210-222**	
17	0	76	—	76

NOTE: In orders, the complete names of the blocks desired should be given, as for example “174-186 RKB” or “174-186 Cupola.”

6 Inch Lining — Rotary Kiln Blocks
9 x 6 x 4 Inch Arch Type —Two Shape System

Inside Lining Ft	Inside Lining In	Inside Shell Ft	Inside Shell In	Number Required Per Ring KW-3	KW-2	KW-1	KW-1X	Total
5	0	6	0	50	7	—	—	57
5	3	6	3	44	15	—	—	59
5	6	6	6	38	24	—	—	62
5	9	6	9	32	32	—	—	64
6	0	7	0	25	41	—	—	66
6	3	7	3	19	50	—	—	69
6	6	7	6	13	58	—	—	71
6	9	7	9	6	67	—	—	73
7	0	8	0	—	76	—	—	76
7	3	8	3	—	72	6	—	78
7	6	8	6	—	68	13	—	81
7	9	8	9	—	64	19	—	83
8	0	9	0	—	60	25	—	85
8	3	9	3	—	56	32	—	88
8	6	9	6	—	52	38	—	90
8	9	9	9	—	48	44	—	92
9	0	10	0	—	44	51	—	95
9	3	10	3	—	40	57	—	97
9	6	10	6	—	36	63	—	99
9	9	10	9	—	33	69	—	102
10	0	11	0	—	28	76	—	104
10	3	11	3	—	24	82	—	106
10	6	11	6	—	21	88	—	109
10	9	11	9	—	17	94	—	111
11	0	12	0	—	13	100	—	113
11	3	12	3	—	9	107	—	116
11	6	12	6	—	5	113	—	118
11	9	12	9	—	1	119	—	120
12	0	13	0	—	—	118	5	123
12	3	13	3	—	—	114	11	125
12	6	13	6	—	—	111	17	128
12	9	13	9	—	—	107	23	130
13	0	14	0	—	—	104	28	132
13	3	14	3	—	—	100	35	135
13	6	14	6	—	—	97	40	137
13	9	14	9	—	—	93	46	139
14	0	15	0	—	—	90	52	142
14	3	15	3	—	—	86	58	144
14	6	15	6	—	—	82	64	146
14	9	15	9	—	—	79	70	149
15	0	16	0	—	—	76	75	151
15	3	16	3	—	—	72	82	154
15	6	16	6	—	—	69	87	156
15	9	16	9	—	—	65	93	158
16	0	17	0	—	—	62	99	161
16	3	17	3	—	—	58	105	163
16	6	17	6	—	—	54	111	165
16	9	17	9	—	—	51	117	168
17	0	18	0	—	—	47	123	170
17	3	18	3	—	—	44	128	172
17	6	18	6	—	—	40	135	175
17	9	18	9	—	—	37	140	177
18	0	19	0	—	—	33	146	179
18	3	19	3	—	—	30	152	182

NOTE: For each ring, order two (2) pieces each KA-2/3 and KA-3/4 to facilitate keying. For additional information, see discussion of KA and KW Blocks for Rotary Kilns.

9 Inch Lining — 3 Inch Wedge Brick
9 x 4 1/2 x 3, 9 x 6 3/4 x 3 or 9 x 9 x 3 Inch

Diam. Inside Brickwork Ft	Diam. Inside Brickwork In	Number Required Per Ring No. 3 Wedge	No. 2 Wedge	No. 1 Wedge	Straight	Total
3	0	57	—	—	—	57
3	1	56	2	—	—	58
3	2	55	4	—	—	59
3	3	54	6	—	—	60
3	4	52	9	—	—	61
3	5	51	11	—	—	62
3	6	50	13	—	—	63
3	7	49	15	—	—	64
3	8	48	17	—	—	65
3	9	47	19	—	—	66
3	10	46	21	—	—	67
3	11	45	23	—	—	68
4	0	44	26	—	—	70
4	1	43	28	—	—	71
4	2	42	30	—	—	72
4	3	41	32	—	—	73
4	4	40	34	—	—	74
4	5	39	36	—	—	75
4	6	38	38	—	—	76
4	7	37	40	—	—	77
4	8	36	42	—	—	78
4	9	35	44	—	—	79
4	10	34	46	—	—	80
4	11	33	48	—	—	81
5	0	32	50	—	—	82
5	1	31	52	—	—	83
5	2	29	55	—	—	84
5	3	28	57	—	—	85
5	4	27	59	—	—	86
5	5	26	61	—	—	87
5	6	25	63	—	—	88
5	7	24	65	—	—	89
5	8	23	67	—	—	90
5	9	22	70	—	—	92
5	10	21	72	—	—	93
5	11	20	74	—	—	94
6	0	19	76	—	—	95
6	1	18	78	—	—	96
6	2	17	80	—	—	97
6	3	16	82	—	—	98
6	4	15	84	—	—	99
6	5	14	86	—	—	100
6	6	13	88	—	—	101
6	7	12	90	—	—	102
6	8	11	92	—	—	103
6	9	10	94	—	—	104
6	10	9	96	—	—	105
6	11	7	99	—	—	106

NOTE: This table can be used also for 13 1/2 x 9 x 3 inch arch brick by substituting Nos. 1, 2 and 3 arch brick for the corresponding wedge brick.

9 Inch Lining — 3 Inch Wedge Brick 9 x 4 1/2 x 3, 9 x 6 3/4 x 3 or 9 x 9 x 3 Inch–Cont'd.

Diam. Inside Brickwork Ft	In	Number Required Per Ring: No. 3 Wedge	No. 2 Wedge	No. 1 Wedge	Straight	Total
7	0	6	101	—	—	107
7	1	5	103	—	—	108
7	2	4	105	—	—	109
7	3	3	107	—	—	110
7	4	2	109	—	—	111
7	5	1	111	—	—	112
7	6	—	113	—	—	113
7	7	—	112	3	—	115
7	8	—	111	5	—	116
7	9	—	110	7	—	117
7	10	—	109	9	—	118
7	11	—	108	11	—	119
8	0	—	107	13	—	120
8	1	—	106	15	—	121
8	2	—	105	17	—	122
8	3	—	104	19	—	123
8	4	—	103	21	—	124
8	5	—	102	23	—	125
8	6	—	101	25	—	126
8	7	—	100	27	—	127
8	8	—	99	29	—	128
8	9	—	97	32	—	129
8	10	—	96	34	—	130
8	11	—	95	36	—	131
9	0	—	94	38	—	132
9	1	—	93	40	—	133
9	2	—	92	42	—	134
9	3	—	91	44	—	135
9	4	—	90	47	—	137
9	5	—	89	49	—	138
9	6	—	88	51	—	139
9	7	—	87	53	—	140
9	8	—	86	55	—	141
9	9	—	85	57	—	142
9	10	—	84	59	—	143
9	11	—	83	61	—	144
10	0	—	82	63	—	145
10	1	—	81	65	—	146
10	2	—	80	67	—	147
10	3	—	79	69	—	148
10	4	—	78	71	—	149
10	5	—	77	73	—	150
10	6	—	76	75	—	151
10	7	—	74	78	—	152
10	8	—	73	80	—	153
10	9	—	72	82	—	154
10	10	—	71	84	—	155
10	11	—	70	86	—	156

NOTE: This table can be used also for 13 1/2 x 9 x 3 inch arch brick by substituting Nos. 1, 2 and 3 arch brick for the corresponding wedge brick.

9 Inch Lining — 3 Inch Wedge Brick 9 x 4 1/2 x 3, 9 x 6 3/4 x 3 or 9 x 9 x 3 Inch–Cont'd.

Diam. Inside Brickwork Ft	In	Number Required Per Ring: No. 3 Wedge	No. 2 Wedge	No. 1 Wedge	Straight	Total
11	0	—	69	88	—	157
11	1	—	69	90	—	159
11	2	—	67	93	—	160
11	3	—	66	95	—	161
11	4	—	65	97	—	162
11	5	—	64	99	—	163
11	6	—	63	101	—	164
11	7	—	62	103	—	165
11	8	—	61	105	—	166
11	9	—	60	107	—	167
11	10	—	59	109	—	168
11	11	—	58	111	—	169
12	0	—	57	113	—	170
12	1	—	56	115	—	171
12	2	—	55	117	—	172
12	3	—	54	119	—	173
12	4	—	52	122	—	174
12	5	—	51	124	—	175
12	6	—	50	126	—	176
12	7	—	49	128	—	177
12	8	—	48	130	—	178
12	9	—	47	132	—	179
12	10	—	47	134	—	181
12	11	—	45	137	—	182
13	0	—	44	139	—	183
13	1	—	43	141	—	184
13	2	—	42	143	—	185
13	3	—	41	145	—	186
13	4	—	40	147	—	187
13	5	—	39	149	—	188
13	6	—	38	151	—	189
13	7	—	37	153	—	190
13	8	—	36	155	—	191
13	9	—	35	157	—	192
13	10	—	34	159	—	193
13	11	—	33	161	—	194
14	0	—	32	163	—	195
14	1	—	30	166	—	196
14	2	—	29	168	—	197
14	3	—	28	170	—	198
14	4	—	27	172	—	199
14	5	—	26	174	—	200
14	6	—	25	176	—	201
14	7	—	25	178	—	203
14	8	—	23	181	—	204
14	9	—	22	183	—	205
14	10	—	21	185	—	206
14	11	—	20	187	—	207
15	0	—	19	189	—	208
15	1	—	18	191	—	209
15	2	—	17	193	—	210
15	3	—	16	195	—	211
15	4	—	15	197	—	212
15	5	—	14	199	—	213

NOTE: This table can be used also for 13 1/2 x 9 x 3 inch arch brick by substituting Nos. 1, 2 and 3 arch brick for the corresponding wedge brick.

RING COMBINATIONS

9 Inch Lining — 3 Inch Wedge Brick 9 x 4½ x 3, 9 x 6¾ x 3 or 9 x 9 x 3 Inch–Cont'd.

Diam. Inside Brickwork		Number Required Per Ring				
Ft	In	No. 3 Wedge	No. 2 Wedge	No. 1 Wedge	Straight	Total
15	6	—	13	201	—	214
15	7	—	12	203	—	215
15	8	—	11	205	—	216
15	9	—	10	207	—	217
15	10	—	8	210	—	218
15	11	—	7	212	—	219
16	0	—	6	214	—	220
16	1	—	5	216	—	221
16	2	—	4	218	—	222
16	3	—	3	220	—	223
16	4	—	3	222	—	225
16	5	—	1	225	—	226
16	6	—	—	227	—	227
17	0	—	—	227	6	233
17	6	—	—	227	12	239
18	0	—	—	227	18	245
18	6	—	—	227	25	252
19	0	—	—	227	31	258
19	6	—	—	227	37	264
20	0	—	—	227	44	271
20	6	—	—	227	50	277
21	0	—	—	227	56	283
21	6	—	—	227	62	289
22	0	—	—	227	69	296
22	6	—	—	227	75	302
23	0	—	—	227	81	308
23	6	—	—	227	88	315
24	0	—	—	227	94	321
24	6	—	—	227	100	327
25	0	—	—	227	106	333
25	6	—	—	227	113	340
26	0	—	—	227	119	346
26	6	—	—	227	125	352
27	0	—	—	227	132	359
27	6	—	—	227	138	365
28	0	—	—	227	144	371
28	6	—	—	227	150	377
29	0	—	—	227	157	384
29	6	—	—	227	163	390
30	0	—	—	227	169	396
30	6	—	—	227	176	403
31	0	—	—	227	182	409
31	6	—	—	227	188	415
32	0	—	—	227	194	421
32	6	—	—	227	201	428
33	0	—	—	227	207	434
33	6	—	—	227	213	440
34	0	—	—	227	220	447
34	6	—	—	227	226	453
35	0	—	—	227	232	459
35	6	—	—	227	238	465
36	0	—	—	227	245	472
36	6	—	—	227	251	478

NOTE: This table can be used also for 13½ x 9 x 3 inch arch brick by substituting Nos. 1, 2 and 3 arch brick for the corresponding wedge brick.

9 Inch Lining — 3 Inch Key Brick 9 x 4½ x 3 Inch

Diam. Inside Brickwork		Number Required Per Ring					
Ft	In	No. 4 Key	No. 3 Key	No. 2 Key	No. 1 Key	Straight	Total
1	6	26	—	—	—	—	26
1	8	23	4	—	—	—	27
1	10	20	8	—	—	—	28
2	0	17	13	—	—	—	30
2	2	14	17	—	—	—	31
2	4	12	21	—	—	—	33
2	6	9	25	—	—	—	34
2	8	6	29	—	—	—	35
2	10	3	34	—	—	—	37
3	0	—	38	—	—	—	38
3	2	—	35	4	—	—	39
3	4	—	32	9	—	—	41
3	6	—	29	13	—	—	42
3	8	—	27	17	—	—	44
3	10	—	24	21	—	—	45
4	0	—	21	25	—	—	46
4	2	—	18	30	—	—	48
4	4	—	15	34	—	—	49
4	6	—	13	38	—	—	51
4	8	—	10	42	—	—	52
4	10	—	7	46	—	—	53
5	0	—	4	51	—	—	55
5	2	—	1	55	—	—	56
5	3	—	—	57	—	—	57
5	4	—	—	56	2	—	58
5	6	—	—	55	4	—	59
5	8	—	—	53	7	—	60
5	10	—	—	52	10	—	62
6	0	—	—	50	13	—	63
6	2	—	—	49	16	—	65
6	4	—	—	48	18	—	66
6	6	—	—	46	21	—	67
6	8	—	—	45	24	—	69
6	10	—	—	43	27	—	70
7	0	—	—	42	30	—	72
7	2	—	—	41	32	—	73
7	4	—	—	39	35	—	74
7	6	—	—	38	38	—	76
7	8	—	—	36	41	—	77
7	10	—	—	35	44	—	79
8	0	—	—	34	46	—	80
8	2	—	—	32	49	—	81
8	4	—	—	31	52	—	83
8	6	—	—	29	55	—	84
8	8	—	—	28	58	—	86
8	10	—	—	27	60	—	87
9	0	—	—	25	63	—	88
9	2	—	—	24	66	—	90
9	4	—	—	22	69	—	91
9	6	—	—	21	72	—	93
9	8	—	—	20	74	—	94
9	10	—	—	18	77	—	95
10	0	—	—	17	80	—	97
10	2	—	—	15	83	—	98
10	4	—	—	14	86	—	100

9 Inch Lining — 3 Inch Key Brick
9 x 4 1/2 x 3 Inch — Continued

Diam. Inside Brickwork Ft	In	Number Required Per Ring: No. 4 Key	No. 3 Key	No. 2 Key	No. 1 Key	Straight	Total
10	6	—	—	13	88	—	101
10	8	—	—	11	91	—	102
10	10	—	—	10	94	—	104
11	0	—	—	9	96	—	105
11	2	—	—	7	100	—	107
11	4	—	—	6	102	—	108
11	6	—	—	4	105	—	109
11	8	—	—	3	108	—	111
11	10	—	—	2	110	—	112
12	0	—	—	—	113	—	113
12	6	—	—	—	113	5	118
13	0	—	—	—	113	9	122
13	6	—	—	—	113	13	126
14	0	—	—	—	113	17	130
14	6	—	—	—	113	21	134
15	0	—	—	—	113	26	139
15	6	—	—	—	113	30	143
16	0	—	—	—	113	34	147
16	6	—	—	—	113	38	151
17	0	—	—	—	113	42	155
17	6	—	—	—	113	47	160
18	0	—	—	—	113	51	164
18	6	—	—	—	113	55	168
19	0	—	—	—	113	59	172
19	6	—	—	—	113	63	176
20	0	—	—	—	113	68	181
20	6	—	—	—	113	72	185
21	0	—	—	—	113	76	189
21	6	—	—	—	113	80	193
22	0	—	—	—	113	84	197
22	6	—	—	—	113	88	201
23	0	—	—	—	113	93	206
23	6	—	—	—	113	97	210
24	0	—	—	—	113	101	214
24	6	—	—	—	113	105	218
25	0	—	—	—	113	109	222
25	6	—	—	—	113	114	227
26	0	—	—	—	113	118	231
26	6	—	—	—	113	122	235
27	0	—	—	—	113	126	239
27	6	—	—	—	113	130	243
28	0	—	—	—	113	135	248
28	6	—	—	—	113	139	252
29	0	—	—	—	113	143	256
29	6	—	—	—	113	147	260
30	0	—	—	—	113	151	264
30	6	—	—	—	113	155	268
31	0	—	—	—	113	160	273
31	6	—	—	—	113	164	277
32	0	—	—	—	113	168	281
32	6	—	—	—	113	172	285
33	0	—	—	—	113	176	289
33	6	—	—	—	113	181	294
34	0	—	—	—	113	185	298
35	0	—	—	—	113	193	306

9 Inch Lining — 3 Inch Key Brick
9 x 6 x 3 Inch

Diam. Inside Brickwork Ft	In	Number Required Per Ring: No. 3 Key	No. 2 Key	No. 1 Key	Straight	Total
1	6	19	—	—	—	19
1	8	18	2	—	—	20
1	10	18	3	—	—	21
2	0	17	5	—	—	22
2	2	16	7	—	—	23
2	4	15	9	—	—	24
2	6	15	11	—	—	26
2	8	14	13	—	—	27
2	10	14	14	—	—	28
3	0	13	16	—	—	29
3	2	12	18	—	—	30
3	4	12	19	—	—	31
3	6	11	21	—	—	32
3	8	10	23	—	—	33
3	10	9	25	—	—	34
4	0	9	26	—	—	35
4	2	8	28	—	—	36
4	4	7	30	—	—	37
4	6	7	31	—	—	38
4	8	6	33	—	—	39
4	10	5	35	—	—	40
5	0	5	36	—	—	41
5	2	4	38	—	—	42
5	4	3	40	—	—	43
5	6	2	42	—	—	44
5	8	2	43	—	—	45
5	10	1	45	—	—	46
6	0	—	48	—	—	48
6	2	—	47	2	—	49
6	4	—	46	4	—	50
6	6	—	45	6	—	51
6	8	—	44	8	—	52
6	10	—	43	10	—	53
7	0	—	41	13	—	54
7	2	—	40	15	—	55
7	4	—	39	17	—	56
7	6	—	38	19	—	57
7	8	—	37	21	—	58
7	10	—	36	23	—	59
8	0	—	34	26	—	60
8	2	—	33	28	—	61
8	4	—	32	30	—	62
8	6	—	31	32	—	63
8	8	—	30	34	—	64
8	10	—	28	37	—	65
9	0	—	27	39	—	66
9	2	—	26	41	—	67
9	4	—	25	43	—	68
9	6	—	24	46	—	70
9	8	—	23	48	—	71
9	10	—	22	50	—	72

*NOTE: For brickwork of inside diameters less than 6 feet, involving the use of 9 x 6 inch No. 3 Keys which have a very sharp taper, a better bricklaying fit can be obtained by the use of the 9 x 4 1/2 inch Key-brick combinations.

9 Inch Lining — 3 Inch Key Brick
9 x 6 x 3 Inch — Continued

Diam. Inside Brickwork Ft	In	Number Required Per Ring: No. 3 Key	No. 2 Key	No. 1 Key	Straight	Total
10	0	—	21	52	—	73
10	2	—	19	55	—	74
10	4	—	18	57	—	75
10	6	—	17	59	—	76
10	8	—	16	61	—	77
10	10	—	15	63	—	78
11	0	—	13	66	—	79
11	2	—	12	68	—	80
11	4	—	11	70	—	81
11	6	—	10	72	—	82
11	8	—	9	74	—	83
11	10	—	8	76	—	84
12	0	—	6	79	—	85
12	2	—	5	81	—	86
12	4	—	4	83	—	87
12	6	—	3	85	—	88
12	8	—	2	87	—	89
12	10	—	—	90	—	90
13	0	—	—	91	—	91
13	6	—	—	91	4	95
14	0	—	—	91	7	98
14	6	—	—	91	10	101
15	0	—	—	91	13	104
15	6	—	—	91	16	107
16	0	—	—	91	19	110
16	6	—	—	91	22	113
17	0	—	—	91	26	117
17	6	—	—	91	29	120
18	0	—	—	91	32	123
18	6	—	—	91	35	126
19	0	—	—	91	38	129
20	0	—	—	91	44	135
21	0	—	—	91	51	142
22	0	—	—	91	57	148
23	0	—	—	91	63	154
24	0	—	—	91	70	161
25	0	—	—	91	76	167
26	0	—	—	91	82	173
27	0	—	—	91	88	179
28	0	—	—	91	95	186
29	0	—	—	91	101	192
30	0	—	—	91	107	198
31	0	—	—	91	114	205
32	0	—	—	91	120	211
33	0	—	—	91	126	217
34	0	—	—	91	132	223
35	0	—	—	91	139	230
36	0	—	—	91	145	236
37	0	—	—	91	151	242
38	0	—	—	91	158	249
39	0	—	—	91	164	255
40	0	—	—	91	170	261
41	0	—	—	91	176	267

9 Inch Lining — Rotary Kiln Blocks
9 x 9 x 4 Inch

Diam. Inside Brickwork Ft	In	Number Required Per Ring		Total
		60-78	**66-84**	
5	0	28	—	28
5	1	23	5	28
5	2	18	10	28
5	3	14	15	29
5	4	9	20	29
5	5	5	24	29
		66-84	**72-90**	
5	6	30	—	30
5	7	25	5	30
5	8	20	10	30
5	9	15	16	31
5	10	10	21	31
5	11	5	26	31
		72-90	**78-96**	
6	0	32	—	32
6	1	26	6	32
6	2	21	12	33
6	3	16	17	33
6	4	11	22	33
6	5	6	28	34
		78-96	**84-102**	
6	6	34	—	34
6	7	28	6	34
6	8	23	12	35
6	9	17	18	35
6	10	11	24	35
6	11	6	30	36
		82-102	**90-108**	
7	0	36	—	36
7	1	30	6	36
7	2	24	13	37
7	3	18	19	37
7	4	12	25	37
7	5	6	32	38
		90-108	**96-114**	
7	6	38	—	38
7	7	31	7	38
7	8	25	14	39
7	9	19	20	39
7	10	13	26	39
7	11	7	33	40

NOTE: In orders, the complete names of the blocks should be given, as for example "60-78 RKB."

9 Inch Lining — Rotary Kiln Blocks
9 x 9 x 4 Inch — Continued

Diam. Inside Brickwork Ft	In	Number Required Per Ring		Total
		96-114	**102-120**	
8	0	40	—	40
8	1	34	7	41
8	2	27	14	41
8	3	20	21	41
8	4	14	28	42
8	5	7	35	42
		102-120	**108-126**	
8	6	42	—	42
8	7	35	8	43
8	8	28	15	43
8	9	21	22	43
8	10	14	30	44
8	11	7	37	44
		108-126	**114-132**	
9	0	44	—	44
9	1	37	8	45
9	2	29	16	45
9	3	22	23	45
9	4	15	31	46
9	5	7	39	46
		114-132	**117-135**	
9	6	46	—	46
9	7	31	16	47
9	8	15	32	47
		117-135	**120-138**	
9	9	48	—	48
9	10	32	16	48
9	11	16	32	48
		120-138	**123-141**	
10	0	49	—	49
10	1	32	17	49
10	2	16	13	49

NOTE: In orders, the complete names of the blocks should be given, as for example "84-102 RKB."

9 Inch Lining — Rotary Kiln Blocks
9 x 9 x 4 Inch — Continued

Diam. Inside Brickwork Ft	In	Number Required Per Ring		Total
		123-141	**126-144**	
10	3	50	—	50
10	4	33	17	50
10	5	16	34	50
		126-144	**132-150**	
10	6	51	—	51
10	7	42	9	51
10	8	34	17	51
10	9	25	27	52
10	10	17	35	52
10	11	8	44	52
		132-150	**138-156**	
11	0	53	—	53
11	1	44	9	53
11	2	35	18	53
11	3	26	28	54
11	4	18	36	54
11	5	9	46	55
		138-156	**144-162**	
11	6	55	—	55
11	7	45	10	55
11	8	37	19	56
11	9	27	29	56
11	10	18	38	56
11	11	9	48	57
		144-162	**150-168**	
12	0	57	—	57
12	1	47	10	57
12	2	38	20	58
12	3	28	30	58
12	4	19	39	58
12	5	10	49	59
		150-168	**156-174**	
12	6	59	—	59
12	7	49	10	59
12	8	39	21	60
12	9	29	31	60
12	10	20	40	60
12	11	10	51	61
		156-174	**162-180**	
13	0	61	—	61
13	1	51	10	61
13	2	41	21	62
13	3	30	32	62
13	4	21	42	63
13	5	10	53	63

NOTE: In orders, the complete names of the blocks should be given, as for example "123-141 RKB."

9 Inch Lining — Rotary Kiln Blocks
9 x 9 x 4 Inch — Continued

Diam. Inside Brickwork Ft	In	Number Required Per Ring		Total
		162-180	**168-186**	
13	6	63	—	63
13	7	53	11	64
13	8	42	22	64
13	9	31	33	64
13	10	21	44	65
13	11	11	54	65
		168-186	**174-192**	
14	0	65	—	65
14	1	54	12	66
14	2	43	23	66
14	3	32	34	66
14	4	22	45	67
14	5	11	56	67
		174-192	**180-198**	
14	6	67	—	67
14	7	56	12	68
14	8	45	23	68
14	9	33	35	68
14	10	23	46	69
14	11	11	58	69
		180-198	**186-204**	
15	0	70	—	70
15	1	58	12	70
15	2	46	24	70
15	3	35	36	71
15	4	23	48	71
15	5	12	59	71
		186-204	**192-210**	
15	6	72	—	72
15	7	60	12	72
15	8	48	24	72
15	9	36	37	73
15	10	24	49	73
15	11	12	61	73
		192-210	**198-216**	
16	0	74	—	74
16	1	61	13	74
16	2	49	25	74
16	3	37	38	75
16	4	25	50	75
16	5	12	63	75
		198-216	**204-222**	
16	6	76	—	76
16	7	63	13	76
16	8	50	26	76
16	9	38	39	77
16	10	25	52	77
16	11	13	65	78

NOTE: In orders, the complete names of the blocks should be given, as for example "162-180 RKB."

9 Inch Lining — Rotary Kiln Blocks
9 x 9 x 4 Inch — Continued

Diam. Inside Brickwork Ft	In	Number Required Per Ring		Total
		204-222	**210-228**	
17	0	78	—	78
17	1	65	13	78
17	2	52	27	79
17	3	39	40	79
17	4	26	53	79
17	5	13	67	80
		210-228	**216-234**	
17	6	80	—	80
17	7	66	14	80
17	8	53	28	81
17	9	40	41	81
17	10	27	54	81
17	11	14	68	82
		216-234	**222-240**	
18	0	82	—	82
18	1	68	14	82
18	2	55	28	83
18	3	41	42	83
18	4	27	56	83
18	5	14	70	84
		222-240	**228-246**	
18	6	84	—	84
18	7	70	15	85
18	8	56	29	85
18	9	42	43	85
18	10	28	58	86
18	11	14	72	86
		228-246	**234-252**	
19	0	86	—	86
19	1	72	15	87
19	2	57	30	87
19	3	43	44	87
19	4	29	59	88
19	5	14	74	88
		234-252	**240-258**	
19	6	88	—	88
19	7	74	15	89
19	8	59	30	89
19	9	44	45	89
19	10	30	60	90
19	11	15	75	90
		240-258	—	
20	0	90	—	90
—				

NOTE: In orders, the complete names of the blocks should be given, as for example "204-222 RKB."

RING COMBINATIONS

9 Inch Lining — Rotary Kiln Blocks
9 x 6 x 4 Inch Wedge Type —Two Shape System

Inside Lining		Inside Shell		Number Required Per Ring				
Ft	In	Ft	In	KW-3	KW-2	KW-1	KW-1X	Total
4	6	6	0	50	7	—	—	57
4	9	6	3	44	15	—	—	59
5	0	6	6	38	24	—	—	62
5	3	6	9	32	32	—	—	64
5	6	7	0	25	41	—	—	66
5	9	7	3	19	50	—	—	69
6	0	7	6	13	58	—	—	71
6	3	7	9	6	67	—	—	73
6	6	8	0	—	76	—	—	76
6	9	8	3	—	72	6	—	78
7	0	8	6	—	68	13	—	81
7	3	8	9	—	64	19	—	83
7	6	9	0	—	60	25	—	85
7	9	9	3	—	56	32	—	88
8	0	9	6	—	52	38	—	90
8	3	9	9	—	48	44	—	92
8	6	10	0	—	44	51	—	95
8	9	10	3	—	40	57	—	97
9	0	10	6	—	36	63	—	99
9	3	10	9	—	33	69	—	102
9	6	11	0	—	28	76	—	104
9	9	11	3	—	24	82	—	106
10	0	11	6	—	21	88	—	109
10	3	11	9	—	17	94	—	111
10	6	12	0	—	13	100	—	113
10	9	12	3	—	9	107	—	116
11	0	12	6	—	5	113	—	118
11	3	12	9	—	1	119	—	120
11	6	13	0	—	—	117	6	123
11	9	13	3	—	—	112	13	125
12	0	13	6	—	—	108	20	128
12	3	13	9	—	—	103	27	130
12	6	14	0	—	—	98	34	132
12	9	14	3	—	—	94	41	135
13	0	14	6	—	—	89	48	137
13	3	14	9	—	—	84	55	139
13	6	15	0	—	—	79	63	142
13	9	15	3	—	—	75	69	144
14	0	15	6	—	—	70	76	146
14	3	15	9	—	—	65	84	149
14	6	16	0	—	—	60	91	151
14	9	16	3	—	—	56	98	154
15	0	16	6	—	—	51	105	156
15	3	16	9	—	—	46	112	158
15	6	17	0	—	—	42	119	161
15	9	17	3	—	—	37	126	163
16	0	17	6	—	—	32	133	165
16	3	17	9	—	—	28	140	168
16	6	18	0	—	—	23	147	170
16	9	18	3	—	—	18	154	172
17	0	18	6	—	—	14	161	175
17	3	18	9	—	—	9	168	177
17	6	19	0	—	—	4	175	179
17	9	19	3	—	—	—	182	182

NOTE: For each ring, order two (2) pieces each KW-2/3 and KW-3/4 to facilitate keying. For additional information, see discussion of KA and KW blocks for Rotary Kilns.

12 Inch Lining — 3 Inch Wedge Brick
12 x 4 1/2 x 3, 12 x 6 x 3 or 12 x 9 x 3 Inch

Diam. Inside Brickwork		Number Required Per Ring					
Ft	In	No. 3 Wedge	No. 2 Wedge	No. 1 Wedge	No. 1-X Wedge	Straight	Total
4	0	76	—	—	—	—	76
4	3	72	7	—	—	—	79
4	6	69	13	—	—	—	82
4	9	66	19	—	—	—	85
5	0	63	25	—	—	—	88
5	3	60	32	—	—	—	92
5	6	57	38	—	—	—	95
5	9	54	44	—	—	—	98
6	0	51	50	—	—	—	101
6	3	47	57	—	—	—	104
6	6	44	63	—	—	—	107
6	9	41	69	—	—	—	110
7	0	38	75	—	—	—	113
7	3	35	82	—	—	—	117
7	6	32	88	—	—	—	120
7	9	29	94	—	—	—	123
8	0	25	101	—	—	—	126
8	3	22	107	—	—	—	129
8	6	19	113	—	—	—	132
8	9	16	119	—	—	—	135
9	0	13	126	—	—	—	139
9	3	10	132	—	—	—	142
9	6	7	138	—	—	—	145
9	9	3	145	—	—	—	148
10	0	—	151	—	—	—	151
10	3	—	148	6	—	—	154
10	6	—	144	13	—	—	157
10	9	—	142	19	—	—	161
11	0	—	139	25	—	—	164
11	3	—	135	32	—	—	167
11	6	—	132	38	—	—	170
11	9	—	129	44	—	—	173
12	0	—	126	50	—	—	176
12	3	—	122	57	—	—	179
12	6	—	120	63	—	—	183
12	9	—	117	69	—	—	186
13	0	—	113	76	—	—	189
13	3	—	110	82	—	—	192
13	6	—	107	88	—	—	195
13	9	—	104	94	—	—	198
14	0	—	101	100	—	—	201
14	3	—	98	107	—	—	205
14	6	—	95	113	—	—	208
14	9	—	91	120	—	—	211
15	0	—	88	126	—	—	214
15	3	—	85	132	—	—	217
15	6	—	82	138	—	—	220
15	9	—	79	144	—	—	223

12 Inch Lining — 3 Inch Wedge Brick 12 x 4½ x 3, 12 x 6 x 3 or 12 x 9 x 3 Inch–Cont'd.

Diam. Inside Brickwork Ft	In	Number Required Per Ring: No. 3 Wedge	No. 2 Wedge	No. 1 Wedge	No. 1-X Wedge	Straight	Total
16	0	—	76	151	—	—	227
16	3	—	73	157	—	—	230
16	6	—	69	164	—	—	233
16	9	—	66	170	—	—	236
17	0	—	63	176	—	—	239
17	3	—	60	182	—	—	242
17	6	—	57	188	—	—	245
17	9	—	54	195	—	—	249
18	0	—	51	201	—	—	252
18	3	—	47	208	—	—	255
18	6	—	44	214	—	—	258
18	9	—	41	220	—	—	261
19	0	—	38	226	—	—	264
19	3	—	35	232	—	—	267
19	6	—	32	239	—	—	271
19	9	—	29	245	—	—	274
20	0	—	25	252	—	—	277
20	3	—	22	258	—	—	280
20	6	—	19	264	—	—	283
20	9	—	16	270	—	—	286
21	0	—	13	276	—	—	289
21	3	—	10	283	—	—	293
21	6	—	7	289	—	—	296
21	9	—	3	296	—	—	299
22	0	—	—	302	—	—	302
22	3	—	—	299	6	—	305
22	6	—	—	295	13	—	308
22	9	—	—	292	19	—	311
23	0	—	—	289	26	—	315
23	3	—	—	286	32	—	318
23	6	—	—	283	38	—	321
23	9	—	—	280	44	—	324
24	0	—	—	277	50	—	327
24	3	—	—	273	57	—	330
24	6	—	—	270	63	—	333
24	9	—	—	267	70	—	337
25	0	—	—	264	76	—	340
25	3	—	—	261	82	—	343
25	6	—	—	258	88	—	346
25	9	—	—	255	94	—	349
26	0	—	—	251	101	—	352
26	3	—	—	248	107	—	355
26	6	—	—	245	114	—	359
26	9	—	—	242	120	—	362
27	0	—	—	239	126	—	365
27	3	—	—	236	132	—	368
27	6	—	—	233	138	—	371
27	9	—	—	229	145	—	374

12 Inch Lining — 3 Inch Wedge Brick 12 x 4½ x 3, 12 x 6 x 3 or 12 x 9 x 3 Inch–Cont'd.

Diam. Inside Brickwork Ft	In	Number Required Per Ring: No. 3 Wedge	No. 2 Wedge	No. 1 Wedge	No. 1-X Wedge	Straight	Total
28	0	—	—	226	151	—	377
28	3	—	—	223	158	—	381
28	6	—	—	220	164	—	384
28	9	—	—	217	170	—	387
29	0	—	—	214	176	—	390
29	3	—	—	211	182	—	393
29	6	—	—	207	189	—	396
29	9	—	—	204	195	—	399
30	0	—	—	202	201	—	403
30	3	—	—	198	208	—	406
30	6	—	—	195	214	—	409
30	9	—	—	192	220	—	412
31	0	—	—	189	226	—	415
31	3	—	—	185	233	—	418
31	6	—	—	182	239	—	421
31	9	—	—	180	245	—	425
32	0	—	—	176	252	—	428
32	3	—	—	173	258	—	431
32	6	—	—	170	264	—	434
32	9	—	—	167	270	—	437
33	0	—	—	163	277	—	440
33	3	—	—	160	283	—	443
33	6	—	—	158	289	—	447
33	9	—	—	154	296	—	450
34	0	—	—	151	302	—	453
34	3	—	—	148	308	—	456
34	6	—	—	145	314	—	459
34	9	—	—	141	321	—	462
35	0	—	—	138	327	—	465
35	3	—	—	135	333	—	468
35	6	—	—	132	340	—	472
35	9	—	—	129	346	—	475
36	0	—	—	126	352	—	478
36	3	—	—	123	358	—	481
36	6	—	—	119	365	—	484
36	9	—	—	116	371	—	487
37	0	—	—	113	377	—	490
37	3	—	—	110	384	—	494
37	6	—	—	107	390	—	497
37	9	—	—	104	396	—	500
38	0	—	—	101	402	—	503
38	3	—	—	97	409	—	506
38	6	—	—	94	415	—	509
38	9	—	—	91	421	—	512
39	0	—	—	88	428	—	516
39	3	—	—	85	434	—	519
39	6	—	—	82	440	—	522
39	9	—	—	79	446	—	525

RING COMBINATIONS

12 Inch Lining — 3 Inch Wedge Brick 12 x 4½ x 3, 12 x 6 x 3 or 12 x 9 x 3 Inch–Cont'd.

Diam. Inside Brickwork		Number Required Per Ring					
Ft	In	No. 3 Wedge	No. 2 Wedge	No. 1 Wedge	No. 1-X Wedge	Straight	Total
40	0	—	—	76	452	—	528
40	3	—	—	72	459	—	531
40	6	—	—	69	465	—	534
40	9	—	—	66	472	—	538
41	0	—	—	63	478	—	541
41	3	—	—	60	484	—	544
41	6	—	—	57	490	—	547
41	9	—	—	54	496	—	550
42	0	—	—	50	503	—	553
42	3	—	—	47	509	—	556
42	6	—	—	44	516	—	560
42	9	—	—	41	522	—	563
43	0	—	—	38	528	—	566
43	3	—	—	35	534	—	569
43	6	—	—	32	540	—	572
43	9	—	—	28	547	—	575
44	0	—	—	25	553	—	578
44	3	—	—	22	560	—	582
44	6	—	—	19	566	—	585
44	9	—	—	16	572	—	588
45	0	—	—	13	578	—	591
45	3	—	—	10	584	—	594
45	6	—	—	6	591	—	597
45	9	—	—	3	597	—	600
46	0	—	—	—	604	—	604
46	3	—	—	—	604	3	607
46	6	—	—	—	604	6	610
46	9	—	—	—	604	9	613
47	0	—	—	—	604	12	616
47	3	—	—	—	604	15	619
47	6	—	—	—	604	18	622
47	9	—	—	—	604	22	626
48	0	—	—	—	604	25	629
48	3	—	—	—	604	28	632
48	6	—	—	—	604	31	635
48	9	—	—	—	604	34	638
49	0	—	—	—	604	37	641
49	6	—	—	—	604	44	648
50	0	—	—	—	604	50	654
50	6	—	—	—	604	56	660
51	0	—	—	—	604	62	666
51	6	—	—	—	604	69	673
52	0	—	—	—	604	75	679
52	6	—	—	—	604	81	685
53	0	—	—	—	604	88	692
53	6	—	—	—	604	94	698
54	0	—	—	—	604	100	704
54	6	—	—	—	604	106	710

12 Inch Lining — 3 Inch Key Brick 12 x 6 x 3 Inch

Diam. Inside Brickwork		Number Required Per Ring			
Ft	In	No.2 Key	No. 1 Key	Straight	Total
10	0	76	—	—	76
10	2	75	2	—	77
10	4	74	4	—	78
10	6	72	7	—	79
10	8	71	9	—	80
10	10	70	11	—	81
11	0	69	13	—	82
11	2	68	15	—	83
11	4	67	17	—	84
11	6	66	19	—	85
11	8	65	21	—	86
11	10	64	23	—	87
12	0	63	25	—	88
12	2	62	27	—	89
12	4	61	29	—	90
12	6	60	32	—	92
12	8	59	34	—	93
12	10	58	36	—	94
13	0	57	38	—	95
13	2	56	40	—	96
13	4	55	42	—	97
13	6	54	44	—	98
13	8	53	46	—	99
13	10	52	48	—	100
14	0	51	50	—	101
14	2	49	53	—	102
14	4	48	55	—	103
14	6	47	57	—	104
14	8	46	59	—	105
14	10	45	61	—	106
15	0	44	63	—	107
15	2	43	65	—	108
15	4	42	67	—	109
15	6	41	69	—	110
15	8	40	71	—	111
15	10	39	73	—	112
16	0	38	75	—	113
16	2	37	78	—	115
16	4	36	80	—	116
16	6	35	82	—	117
16	8	34	84	—	118
16	10	33	86	—	119
17	0	32	88	—	120
17	2	31	90	—	121
17	4	30	92	—	122
17	6	29	94	—	123
17	8	27	97	—	124
17	10	26	99	—	125
18	0	25	101	—	126
18	2	24	103	—	127
18	4	23	105	—	128
18	6	22	107	—	129
18	8	21	109	—	130
18	10	20	111	—	131

RING COMBINATIONS

12 Inch Lining — 3 Inch Key Brick
12 x 6 x 3 Inch — Continued

Diam. Inside Brickwork		Number Required Per Ring			
Ft	In	No. 2 Key	No. 1 Key	Straight	Total
19	0	19	113	—	132
19	2	18	115	—	133
19	4	17	117	—	134
19	6	16	119	—	135
19	8	15	122	—	137
19	10	14	124	—	138
20	0	13	126	—	139
20	2	12	128	—	140
20	4	11	130	—	141
20	6	10	132	—	142
20	8	9	134	—	143
20	10	8	136	—	144
21	0	7	138	—	145
21	2	5	141	—	146
21	4	4	143	—	147
21	6	3	145	—	148
21	8	2	147	—	149
21	10	1	149	—	150
22	0	—	151	—	151
22	2	—	151	1	152
22	4	—	151	2	153
22	6	—	151	3	154
23	0	—	151	6	157
23	6	—	151	10	161
24	0	—	151	13	164
24	6	—	151	16	167
25	0	—	151	19	170
25	6	—	151	22	173
26	0	—	151	25	176
26	6	—	151	28	179
27	0	—	151	32	183
27	6	—	151	35	186
28	0	—	151	38	189
28	6	—	151	41	192
29	0	—	151	44	195
29	6	—	151	47	198
30	0	—	151	50	201
30	6	—	151	54	205
31	0	—	151	57	208
31	6	—	151	60	211
32	0	—	151	63	214
32	6	—	151	66	217
33	0	—	151	69	220
33	6	—	151	72	223
34	0	—	151	76	227
34	6	—	151	79	230
35	0	—	151	82	233
35	6	—	151	85	236
36	0	—	151	88	239
36	6	—	151	91	242
37	0	—	151	94	245
37	6	—	151	98	249
38	0	—	151	101	252
38	6	—	151	104	255

13½ Inch Lining — 3 Inch Wedge Brick
13½ x 4½ x 3, 13½ x 6 x 3 or 13½ x 9 x 3 Inch

Diam. Inside Brickwork		Number Required Per Ring					
Ft	In	No. 3 Wedge	No. 2 Wedge	No. 1 Wedge	No. 1-X Wedge	Straight	Total
4	6	85	—	—	—	—	85
4	9	82	6	—	—	—	88
5	0	79	13	—	—	—	92
5	3	76	19	—	—	—	95
5	6	73	25	—	—	—	98
5	9	69	32	—	—	—	101
6	0	66	38	—	—	—	104
6	3	63	44	—	—	—	107
6	6	60	50	—	—	—	110
6	9	57	56	—	—	—	113
7	0	54	63	—	—	—	117
7	3	51	69	—	—	—	120
7	6	47	76	—	—	—	123
7	9	44	82	—	—	—	126
8	0	41	88	—	—	—	129
8	3	38	94	—	—	—	132
8	6	35	100	—	—	—	135
8	9	32	107	—	—	—	139
9	0	29	113	—	—	—	142
9	3	25	120	—	—	—	145
9	6	22	126	—	—	—	148
9	9	19	132	—	—	—	151
10	0	16	138	—	—	—	154
10	3	13	144	—	—	—	157
10	6	10	151	—	—	—	161
10	9	7	157	—	—	—	164
11	0	3	164	—	—	—	167
11	3	—	170	—	—	—	170
11	6	—	167	6	—	—	173
11	9	—	163	13	—	—	176
12	0	—	160	19	—	—	179
12	3	—	157	26	—	—	183
12	6	—	154	32	—	—	186
12	9	—	151	38	—	—	189
13	0	—	148	44	—	—	192
13	3	—	145	50	—	—	195
13	6	—	141	57	—	—	198
13	9	—	138	63	—	—	201
14	0	—	135	70	—	—	205
14	3	—	132	76	—	—	208
14	6	—	129	82	—	—	211
14	9	—	126	88	—	—	214
15	0	—	123	94	—	—	217
15	3	—	119	101	—	—	220
15	6	—	116	107	—	—	223
15	9	—	113	114	—	—	227

13½ Inch Lining — 3 Inch Wedge Brick 13½ x 4½ x 3, 13½ x 6 x 3 or 13½ x 9 x 3 Inch – Continued

Diam. Inside Brickwork		Number Required Per Ring					
Ft	In	No. 3 Wedge	No. 2 Wedge	No. 1 Wedge	No. 1-X Wedge	Straight	Total
16	0	—	110	120	—	—	230
16	3	—	107	126	—	—	233
16	6	—	104	132	—	—	236
16	9	—	101	138	—	—	239
17	0	—	97	145	—	—	242
17	3	—	94	151	—	—	245
17	6	—	92	157	—	—	249
17	9	—	88	164	—	—	252
18	0	—	85	170	—	—	255
18	3	—	82	176	—	—	258
18	6	—	79	182	—	—	261
18	9	—	75	189	—	—	264
19	0	—	72	195	—	—	267
19	3	—	70	201	—	—	271
19	6	—	66	208	—	—	274
19	9	—	63	214	—	—	277
20	0	—	60	220	—	—	280
20	3	—	57	226	—	—	283
20	6	—	53	233	—	—	286
20	9	—	50	239	—	—	289
21	0	—	48	245	—	—	293
21	3	—	44	252	—	—	296
21	6	—	41	258	—	—	299
21	9	—	38	264	—	—	302
22	0	—	35	270	—	—	305
22	3	—	31	277	—	—	308
22	6	—	28	283	—	—	311
22	9	—	26	289	—	—	315
23	0	—	22	296	—	—	318
23	3	—	19	302	—	—	321
23	6	—	16	308	—	—	324
23	9	—	13	314	—	—	327
24	0	—	9	321	—	—	330
24	3	—	6	327	—	—	333
24	6	—	4	333	—	—	337
24	9	—	—	340	—	—	340
25	0	—	—	336	7	—	343
25	3	—	—	333	13	—	346
25	6	—	—	330	19	—	349
25	9	—	—	327	25	—	352
26	0	—	—	324	31	—	355
26	3	—	—	321	38	—	359
26	6	—	—	318	44	—	362
26	9	—	—	314	51	—	365
27	0	—	—	311	57	—	368
27	3	—	—	308	63	—	371
27	6	—	—	305	69	—	374
27	9	—	—	302	75	—	377

13½ Inch Lining — 3 Inch Wedge Brick 13½ x 4½ x 3, 13½ x 6 x 3 or 13½ x 9 x 3 Inch – Continued

Diam. Inside Brickwork		Number Required Per Ring					
Ft	In	No. 3 Wedge	No. 2 Wedge	No. 1 Wedge	No. 1-X Wedge	Straight	Total
28	0	—	—	299	82	—	381
28	3	—	—	296	88	—	384
28	6	—	—	292	95	—	387
28	9	—	—	289	101	—	390
29	0	—	—	286	107	—	393
29	3	—	—	283	113	—	396
29	6	—	—	280	119	—	399
29	9	—	—	277	126	—	403
30	0	—	—	274	132	—	406
30	3	—	—	270	139	—	409
30	6	—	—	267	145	—	412
30	9	—	—	264	151	—	415
31	0	—	—	261	157	—	418
31	3	—	—	258	163	—	421
31	6	—	—	255	170	—	425
31	9	—	—	252	176	—	428
32	0	—	—	248	183	—	431
32	3	—	—	245	189	—	434
32	6	—	—	242	195	—	437
32	9	—	—	239	201	—	440
33	0	—	—	236	207	—	443
33	3	—	—	233	214	—	447
33	6	—	—	230	220	—	450
33	9	—	—	227	226	—	453
34	0	—	—	223	233	—	456
34	3	—	—	220	239	—	459
34	6	—	—	217	245	—	462
34	9	—	—	214	251	—	465
35	0	—	—	210	258	—	468
35	3	—	—	208	264	—	472
35	6	—	—	205	270	—	475
35	9	—	—	201	277	—	478
36	0	—	—	198	283	—	481
36	3	—	—	195	289	—	484
36	6	—	—	192	295	—	487
36	9	—	—	188	302	—	490
37	0	—	—	186	308	—	494
37	3	—	—	183	314	—	497
37	6	—	—	179	321	—	500
37	9	—	—	176	327	—	503
38	0	—	—	173	333	—	506
38	3	—	—	170	339	—	509
38	6	—	—	166	346	—	512
38	9	—	—	164	352	—	516
39	0	—	—	161	358	—	519
39	3	—	—	157	365	—	522
39	6	—	—	154	371	—	525
39	9	—	—	151	377	—	528

13½ Inch Lining — 3 Inch Wedge Brick 13½ x 4½ x 3, 13½ x 6 x 3 or 13½ x 9 x 3 Inch – Continued

Diam. Inside Brickwork		Number Required Per Ring					
Ft	In	No. 3 Wedge	No. 2 Wedge	No. 1 Wedge	No. 1-X Wedge	Straight	Total
40	0	—	—	148	383	—	531
40	3	—	—	144	390	—	534
40	6	—	—	142	396	—	538
40	9	—	—	139	402	—	541
41	0	—	—	135	409	—	544
41	3	—	—	132	415	—	547
41	6	—	—	129	421	—	550
41	9	—	—	126	427	—	553
42	0	—	—	122	434	—	556
42	3	—	—	120	440	—	560
42	6	—	—	117	446	—	563
42	9	—	—	113	453	—	566
43	0	—	—	110	459	—	569
43	3	—	—	107	465	—	572
43	6	—	—	104	471	—	575
43	9	—	—	101	477	—	578
44	0	—	—	98	484	—	582
44	3	—	—	95	490	—	585
44	6	—	—	91	497	—	588
44	9	—	—	88	503	—	591
45	0	—	—	85	509	—	594
45	3	—	—	82	515	—	597
45	6	—	—	79	521	—	600
45	9	—	—	76	528	—	604
46	0	—	—	73	534	—	607
46	3	—	—	69	541	—	610
46	6	—	—	66	547	—	613
46	9	—	—	63	553	—	616
47	0	—	—	60	559	—	619
47	3	—	—	57	565	—	622
47	6	—	—	54	572	—	626
47	9	—	—	51	578	—	629
48	0	—	—	47	585	—	632
48	3	—	—	44	591	—	635
48	6	—	—	41	597	—	638
48	9	—	—	38	603	—	641
49	0	—	—	35	609	—	644
49	3	—	—	32	616	—	648
49	6	—	—	29	622	—	651
49	9	—	—	25	629	—	654
50	0	—	—	22	635	—	657
50	3	—	—	19	641	—	660
50	6	—	—	16	647	—	663
50	9	—	—	13	653	—	666
51	0	—	—	10	660	—	670
51	3	—	—	7	666	—	673
51	6	—	—	3	673	—	676
51	9	—	—	—	679	—	679

13½ Inch Lining — 3 Inch Key Brick 13½ x 6 x 3 Inch

Diam. Inside Brickwork		Number Required Per Ring				
Ft	In	No. 3 Key	No. 2 Key	No. 1 Key	Straight	Total
2	3	29	—	—	—	29
2	4	28	1	—	—	29
2	6	26	4	—	—	30
2	8	25	6	—	—	31
2	10	24	8	—	—	32
3	0	23	10	—	—	33
3	2	21	13	—	—	34
3	4	20	15	—	—	35
3	6	19	18	—	—	37
3	8	18	20	—	—	38
3	10	17	22	—	—	39
4	0	16	24	—	—	40
4	2	14	27	—	—	41
4	4	13	29	—	—	42
4	6	12	31	—	—	43
4	8	11	33	—	—	44
4	10	9	36	—	—	45
5	0	8	38	—	—	46
5	2	7	40	—	—	47
5	4	6	42	—	—	48
5	6	4	45	—	—	49
5	8	3	47	—	—	50
5	10	2	49	—	—	51
6	0	—	52	—	—	52
6	2	—	51	2	—	53
6	4	—	49	5	—	54
6	6	—	48	7	—	55
6	8	—	46	10	—	56
6	10	—	44	13	—	57
7	0	—	43	16	—	59
7	2	—	41	19	—	60
7	4	—	40	21	—	61
7	6	—	38	24	—	62
7	8	—	36	27	—	63
7	10	—	35	29	—	64
8	0	—	33	32	—	65
8	2	—	31	35	—	66
8	4	—	30	37	—	67
8	6	—	28	40	—	68
8	8	—	26	43	—	69
8	10	—	24	46	—	70
9	0	—	23	48	—	71
9	2	—	21	51	—	72
9	4	—	19	54	—	73
9	6	—	18	56	—	74
9	8	—	16	59	—	75
9	10	—	14	62	—	76
10	0	—	13	64	—	77
10	2	—	11	67	—	78
10	4	—	9	70	—	79
10	6	—	8	73	—	81
10	8	—	6	76	—	82
10	10	—	5	78	—	83

*NOTE: For brickwork of inside diameters less than 6 feet, involving the use of 13½ x 6 inch No. 3 Keys which have a very sharp taper, appreciable cutting may be necessary in some cases to secure the best bricklaying fit.

RING COMBINATIONS

13½ Inch Lining — 3 Inch Key Brick
13½ x 6 x 3 Inch — Continued

Diam. Inside Brickwork		Number Required Per Ring				
Ft	In	No. 3 Key	No. 2 Key	No. 1 Key	Straight	Total
11	0	—	3	81	—	84
11	2	—	1	84	—	85
11	3	—	—	85	—	85
11	6	—	—	85	2	87
12	0	—	—	85	5	90
12	6	—	—	85	8	93
13	0	—	—	85	11	96
13	6	—	—	85	14	99
14	0	—	—	85	18	103
14	6	—	—	85	21	106
15	0	—	—	85	24	109
15	6	—	—	85	27	112
16	0	—	—	85	30	115
16	6	—	—	85	33	118
17	0	—	—	85	36	121
17	6	—	—	85	39	124
18	0	—	—	85	43	128
18	6	—	—	85	46	131
19	0	—	—	85	49	134
19	6	—	—	85	52	137
20	0	—	—	85	55	140
20	6	—	—	85	58	143
21	0	—	—	85	61	146
21	6	—	—	85	65	150
22	0	—	—	85	68	153
22	6	—	—	85	71	156
23	0	—	—	85	74	159
23	6	—	—	85	77	162
24	0	—	—	85	80	165
24	6	—	—	85	83	168
25	0	—	—	85	87	172
25	6	—	—	85	90	175
26	0	—	—	85	93	178
26	6	—	—	85	96	181
27	0	—	—	85	99	184
27	6	—	—	85	102	187
28	0	—	—	85	105	190
28	6	—	—	85	109	194
29	0	—	—	85	112	197
29	6	—	—	85	115	200
30	0	—	—	85	118	203
30	6	—	—	85	121	206
31	0	—	—	85	124	209
31	6	—	—	85	127	212
32	0	—	—	85	131	216
33	0	—	—	85	137	222
34	0	—	—	85	143	228
35	0	—	—	85	149	234
36	0	—	—	85	156	241
37	0	—	—	85	162	247
38	0	—	—	85	168	253
39	0	—	—	85	175	260
40	0	—	—	85	181	266

15 Inch Lining — 3 Inch Wedge Brick
15 x 6 x 3 or 15 x 9 x 3 Inch

Diam. Inside Brickwork		Number Required Per Ring			
Ft	In	No. 3 Wedge	No.2 Wedge	No.1 Wedge	Total
5	0	95	—	—	95
5	1	94	2	—	96
5	3	91	7	—	98
5	6	88	13	—	101
5	9	85	19	—	104
6	0	82	25	—	107
6	3	79	31	—	110
6	6	75	38	—	113
6	9	73	44	—	117
7	0	69	51	—	120
7	3	66	57	—	123
7	6	63	63	—	126
7	9	60	69	—	129
8	0	57	75	—	132
8	3	53	82	—	135
8	6	51	88	—	139
8	9	47	95	—	142
9	0	44	101	—	145
9	3	41	107	—	148
9	6	38	113	—	151
9	9	35	119	—	154
10	0	31	126	—	157
10	3	29	132	—	161
10	6	25	139	—	164
10	9	22	145	—	167
11	0	19	151	—	170
11	3	16	157	—	173
11	6	13	163	—	176
11	9	9	170	—	179
12	0	7	176	—	183
12	3	3	183	—	186
12	6	—	189	—	189
12	9	—	186	6	192
13	0	—	182	13	195
13	3	—	179	19	198
13	6	—	176	25	201
13	9	—	173	32	205
14	0	—	170	38	208
14	3	—	167	44	211
14	6	—	164	50	214
14	9	—	160	57	217
15	0	—	157	63	220
15	3	—	154	69	223
15	6	—	151	76	227
15	9	—	148	82	230
16	0	—	145	88	233
16	3	—	142	94	236
16	6	—	138	101	239
16	9	—	135	107	242

15 Inch Lining — 3 Inch Wedge Brick
15 x 6 x 3 or 15 x 9 x 3 Inch — Continued

Diam. Inside Brickwork Ft	In	Number Required Per Ring: No. 2 Wedge	No. 1 Wedge	No. 1-X Wedge	Total
17	0	132	113	—	245
17	3	129	120	—	249
17	6	126	126	—	252
17	9	123	132	—	255
18	0	120	138	—	258
18	3	116	145	—	261
18	6	113	151	—	264
18	9	110	157	—	267
19	0	107	164	—	271
19	3	104	170	—	274
19	6	101	176	—	277
19	9	98	182	—	280
20	0	94	189	—	283
20	3	91	195	—	286
20	6	88	201	—	289
20	9	85	208	—	293
21	0	82	214	—	296
21	3	79	220	—	299
21	6	76	226	—	302
21	9	72	233	—	305
22	0	69	239	—	308
22	3	66	245	—	311
22	6	63	252	—	315
22	9	60	258	—	318
23	0	57	264	—	321
23	3	54	270	—	324
23	6	50	277	—	327
23	9	47	283	—	330
24	0	44	289	—	333
24	3	41	296	—	337
24	6	38	302	—	340
24	9	35	308	—	343
25	0	32	314	—	346
25	3	28	321	—	349
25	6	25	327	—	352
25	9	22	333	—	355
26	0	19	340	—	359
26	3	16	346	—	362
26	6	13	352	—	365
26	9	10	358	—	368
27	0	6	365	—	371
27	3	3	371	—	374
27	6	—	377	—	377
27	9	—	374	7	381
28	0	—	371	13	384
28	3	—	368	19	387
28	6	—	365	25	390
28	9	—	361	32	393

15 Inch Lining — 3 Inch Wedge Brick
15 x 6 x 3 or 15 x 9 x 3 Inch — Continued

Diam. Inside Brickwork Ft	In	Number Required Per Ring: No. 1 Wedge	No. 1-X Wedge	Total
29	0	358	38	396
29	3	355	44	399
29	6	352	51	403
29	9	349	57	406
30	0	346	63	409
30	3	343	69	412
30	6	339	76	415
30	9	336	82	418
31	0	333	88	421
31	3	330	95	425
31	6	327	101	428
31	9	324	107	431
32	0	321	113	434
32	3	317	120	437
32	6	314	126	440
32	9	311	132	443
33	0	308	139	447
33	3	305	145	450
33	6	302	151	453
33	9	299	157	456
34	0	295	164	459
34	3	292	170	462
34	6	289	176	465
34	9	286	182	468
35	0	283	189	472
35	3	280	195	475
35	6	277	201	478
35	9	273	208	481
36	0	270	214	484
36	3	267	220	487
36	6	264	226	490
36	9	261	233	494
37	0	258	239	497
37	3	255	245	500
37	6	252	251	503
37	9	248	258	506
38	0	245	264	509
38	3	242	270	512
38	6	239	277	516
38	9	236	283	519
39	0	233	289	522
39	3	230	295	525
39	6	226	302	528
39	9	223	308	531
40	0	220	314	534
40	3	217	321	538
40	6	214	327	541
40	9	211	333	544
41	0	208	339	547
41	3	204	346	550
41	6	201	352	553
41	9	198	358	556

15 Inch Lining — 3 Inch Wedge Brick
15 x 6 x 3 or 15 x 9 x 3 Inch — Continued

Diam. Inside Brickwork		Number Required Per Ring			
Ft	In	No. 1 Wedge	No. 1-X Wedge	Straight	Total
42	0	195	365	—	560
42	3	192	371	—	563
42	6	189	377	—	566
42	9	186	383	—	569
43	0	182	390	—	572
43	3	179	396	—	575
43	6	176	402	—	578
43	9	173	409	—	582
44	0	170	415	—	585
44	3	167	421	—	588
44	6	164	427	—	591
44	9	160	434	—	594
45	0	157	440	—	597
45	3	154	446	—	600
45	6	151	453	—	604
45	9	148	459	—	607
46	0	145	465	—	610
46	3	142	471	—	613
46	6	138	478	—	616
46	9	135	484	—	619
47	0	132	490	—	622
47	3	129	497	—	626
47	6	126	503	—	629
47	9	123	509	—	632
48	0	120	515	—	635
48	3	116	522	—	638
48	6	113	528	—	641
48	9	110	534	—	644
49	0	107	541	—	648
49	3	104	547	—	651
49	6	101	553	—	654
49	9	98	559	—	657
50	0	94	566	—	660
50	3	91	572	—	663
50	6	88	578	—	666
50	9	85	585	—	670
51	0	82	591	—	673
51	6	76	603	—	679
52	0	69	616	—	685
52	6	63	629	—	692
53	0	57	641	—	698
53	6	50	654	—	704
54	0	44	666	—	710
54	6	38	679	—	717
55	0	32	691	—	723
55	6	25	704	—	729
56	0	19	717	—	736
56	6	13	729	—	742
57	0	6	742	—	748
57	6	—	754	—	754
58	0	—	754	7	761
58	6	—	754	13	767

18 Inch Lining — 3 Inch Wedge Brick
18 x 6 x 3 or 18 x 9 x 3 Inch

Diam. Inside Brickwork		Number Required Per Ring			
Ft	In	No. 3 Wedge	No. 2 Wedge	No. 1 Wedge	Total
6	0	113	—	—	113
6	1	112	3	—	115
6	2	111	5	—	116
6	3	110	7	—	117
6	6	107	13	—	120
6	9	104	19	—	123
7	0	101	25	—	126
7	3	97	32	—	129
7	6	94	38	—	132
7	9	91	44	—	135
8	0	88	51	—	139
8	3	85	57	—	142
8	6	82	63	—	145
8	9	79	69	—	148
9	0	76	75	—	151
9	3	72	82	—	154
9	6	69	88	—	157
9	9	66	95	—	161
10	0	63	101	—	164
10	3	60	107	—	167
10	6	57	113	—	170
10	9	54	119	—	173
11	0	50	126	—	176
11	3	47	132	—	179
11	6	44	139	—	183
11	9	41	145	—	186
12	0	38	151	—	189
12	3	35	157	—	192
12	6	32	163	—	195
12	9	28	170	—	198
13	0	25	176	—	201
13	3	22	183	—	205
13	6	19	189	—	208
13	9	16	195	—	211
14	0	13	201	—	214
14	3	10	207	—	217
14	6	6	214	—	220
14	9	3	220	—	223
15	0	—	227	—	227
15	3	—	223	7	230
15	6	—	220	13	233
15	9	—	217	19	236
16	0	—	214	25	239
16	3	—	211	31	242
16	6	—	207	38	245
16	9	—	205	44	249
17	0	—	201	51	252
17	3	—	198	57	255
17	6	—	195	63	258
17	9	—	192	69	261

18 Inch Lining — 3 Inch Wedge Brick
18 x 6 x 3 or 18 x 9 x 3 Inch — Continued

Diam. Inside Brickwork		Number Required Per Ring			
Ft	In	No. 2 Wedge	No. 1 Wedge	No. 1-X Wedge	Total
18	0	189	75	—	264
18	3	185	82	—	267
18	6	183	88	—	271
18	9	179	95	—	274
19	0	176	101	—	277
19	3	173	107	—	280
19	6	170	113	—	283
19	9	167	119	—	286
20	0	163	126	—	289
20	3	161	132	—	293
20	6	157	139	—	296
20	9	154	145	—	299
21	0	151	151	—	302
21	3	148	157	—	305
21	6	145	163	—	308
21	9	141	170	—	311
22	0	139	176	—	315
22	3	135	183	—	318
22	6	132	189	—	321
22	9	129	195	—	324
23	0	126	201	—	327
23	3	123	207	—	330
23	6	119	214	—	333
23	9	117	220	—	337
24	0	113	227	—	340
24	3	110	233	—	343
24	6	107	239	—	346
24	9	104	245	—	349
25	0	101	251	—	352
25	3	97	258	—	355
25	6	95	264	—	359
25	9	91	271	—	362
26	0	88	277	—	365
26	3	85	283	—	368
26	6	82	289	—	371
26	9	79	295	—	374
27	0	75	302	—	377
27	3	73	308	—	381
27	6	69	315	—	384
27	9	66	321	—	387
28	0	63	327	—	390
28	3	60	333	—	393
28	6	57	339	—	396
28	9	53	346	—	399
29	0	51	352	—	403
29	3	47	359	—	406
29	6	44	365	—	409
29	9	41	371	—	412

18 Inch Lining — 3 Inch Wedge Brick
18 x 6 x 3 or 18 x 9 x 3 Inch — Continued

Diam. Inside Brickwork		Number Required Per Ring			
Ft	In	No. 2 Wedge	No. 1 Wedge	No. 1-X Wedge	Total
30	0	38	377	—	415
30	3	35	383	—	418
30	6	31	390	—	421
30	9	29	396	—	425
31	0	26	402	—	428
31	3	22	409	—	431
31	6	19	415	—	434
31	9	16	421	—	437
32	0	13	427	—	440
32	3	9	434	—	443
32	6	7	440	—	447
32	9	4	446	—	450
33	0	—	453	—	453
33	3	—	449	7	456
33	6	—	446	13	459
33	9	—	443	19	462
34	0	—	440	25	465
34	3	—	437	31	468
34	6	—	434	38	472
34	9	—	431	44	475
35	0	—	427	51	478
35	3	—	424	57	481
35	6	—	421	63	484
35	9	—	418	69	487
36	0	—	415	75	490
36	3	—	412	82	494
36	6	—	409	88	497
36	9	—	406	94	500
37	0	—	402	101	503
37	3	—	399	107	506
37	6	—	396	113	509
37	9	—	393	119	512
38	0	—	390	126	516
38	3	—	387	132	519
38	6	—	384	138	522
38	9	—	380	145	525
39	0	—	377	151	528
39	3	—	374	157	531
39	6	—	371	163	534
39	9	—	368	170	538
40	0	—	365	176	541
40	3	—	362	182	544
40	6	—	358	189	547
40	9	—	355	195	550
41	0	—	352	201	553
41	3	—	349	207	556
41	6	—	346	214	560
41	9	—	343	220	563
42	0	—	340	226	566
42	3	—	336	233	569
42	6	—	333	239	572
42	9	—	330	245	575

RING COMBINATIONS

18 Inch Lining — 3 Inch Wedge Brick
18 x 6 x 3 or 18 x 9 x 3 Inch — Continued

Diam. Inside Brickwork		Number Required Per Ring			
Ft	In	No. 1 Wedge	No. 1-X Wedge	Straight	Total
43	0	327	251	—	578
43	3	324	258	—	582
43	6	321	264	—	585
43	9	318	270	—	588
44	0	314	277	—	591
44	3	311	283	—	594
44	6	308	289	—	597
44	9	305	295	—	600
45	0	302	302	—	604
45	3	299	308	—	607
45	6	296	314	—	610
45	9	292	321	—	613
46	0	289	327	—	616
46	6	283	339	—	622
47	0	277	352	—	629
47	6	270	365	—	635
48	0	264	377	—	641
48	6	258	390	—	648
49	0	252	402	—	654
49	6	245	415	—	660
50	0	239	427	—	666
50	6	233	440	—	673
51	0	226	453	—	679
51	6	220	465	—	685
52	0	214	478	—	692
52	6	208	490	—	698
53	0	201	503	—	704
53	6	195	515	—	710
54	0	189	528	—	717
54	6	182	541	—	723
55	0	176	553	—	729
55	6	170	566	—	736
56	0	164	578	—	742
56	6	157	591	—	748
57	0	151	603	—	754
57	6	145	616	—	761
58	0	138	629	—	767
58	6	132	641	—	773
59	0	126	654	—	780
59	6	120	666	—	786
60	0	113	679	—	792
61	0	101	704	—	805
62	0	88	729	—	817
63	0	76	754	—	830
64	0	63	779	—	842
65	0	51	804	—	855
66	0	38	829	—	867
67	0	25	855	—	880
68	0	13	880	—	893
69	0	—	905	—	905
70	0	—	905	13	918
71	0	—	905	25	930

ARCH COMBINATIONS

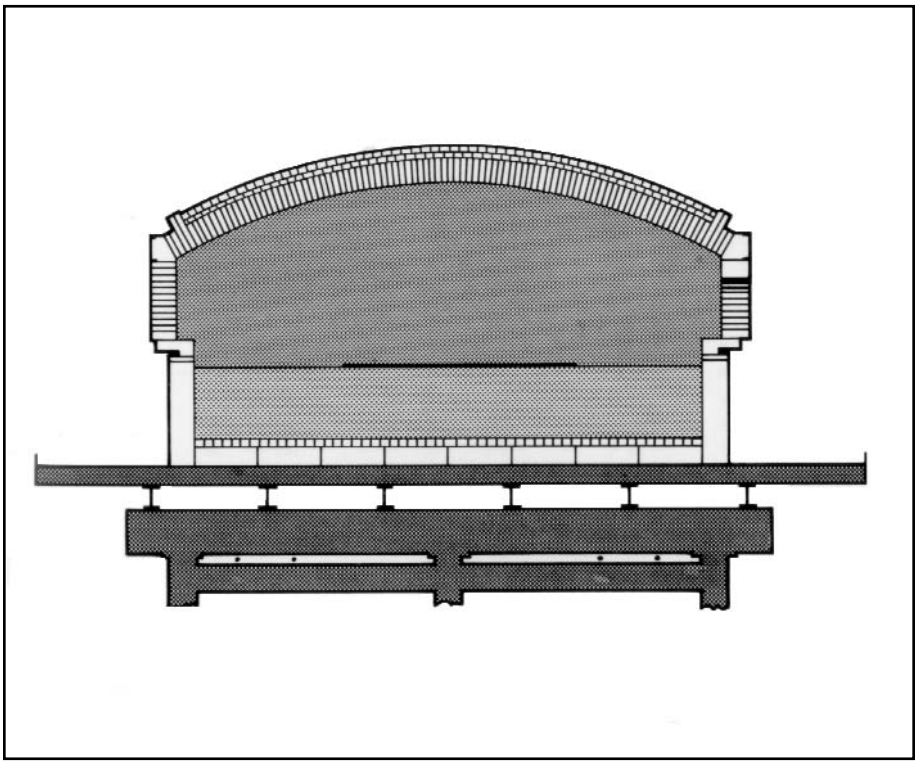
BRICK COMBINATIONS REQUIRED FOR ARCHES

The following tables are useful in estimating the quantities of brick required for the construction of arches. These tables give the combinations of brick sizes required for arches of given spans and rises.

In calculating the tables, no allowance was made for mortar or expansion joints or for size deviations of the brick. Fractional parts equal to or greater than one tenth of a brick were counted as an entire brick. For these reasons, the number of brick required for an arch, as given in the tables, may be slightly in excess of the number actually required.

In laying an arch course of brick, it is often necessary to cut one or two pieces, and in some instances several pieces, to complete the course.

For the brick combinations required for arches not included in the following tables, or to determine the dimensions or other numerical characteristics of arches, refer to the arch formulas found on page UR - 28, which detail arch calculations.



ARCH COMBINATIONS

4 1/2 Inch Arch Thickness — 3 Inch Arch Brick 9 x 4 1/2 x 3 or 13 1/2 x 4 1/2 x 3 Inch 2 Inch Rise Per Foot of Span

Span Ft	Span In	Rise Ft	Rise In	Inside Radius Ft	Inside Radius In	Number Required Per Course: No. 3 Arch	No. 2 Arch	No. 1 Arch	Straight	Total
1	0		2		10	6	1	—	—	7
1	1		2 5/32		10 27/32	5	2	—	—	7
1	2		2 11/32		11 21/32	5	2	—	—	7
1	3		2 1/2	1	0 1/2	5	3	—	—	8
1	4		2 21/32	1	1 11/32	4	4	—	—	8
1	5		2 27/32	1	2 5/32	4	4	—	—	8
1	6		3	1	3	4	5	—	—	9
1	7		3 5/32	1	3 27/32	3	6	—	—	9
1	8		3 11/32	1	4 21/32	2	7	—	—	9
1	9		3 1/2	1	5 1/2	2	8	—	—	10
1	10		3 21/32	1	6 11/32	2	8	—	—	10
1	11		3 27/32	1	7 5/32	2	9	—	—	11
2	0		4	1	8	1	10	—	—	11
2	1		4 5/32	1	8 27/32	1	10	—	—	11
2	2		4 11/32	1	9 21/32	1	11	—	—	12
2	3		4 1/2	1	10 1/2	—	12	—	—	12
2	4		4 21/32	1	11 11/32	—	11	1	—	12
2	5		4 27/32	2	0 5/32	—	11	2	—	13
2	6		5	2	1	—	11	2	—	13
2	7		5 5/32	2	1 27/32	—	10	3	—	13
2	8		5 11/32	2	2 21/32	—	10	4	—	14
2	9		5 1/2	2	3 1/2	—	10	4	—	14
2	10		5 21/32	2	4 11/32	—	9	5	—	14
2	11		5 27/32	2	5 5/32	—	9	6	—	15
3	0		6	2	6	—	8	7	—	15
3	2		6 11/32	2	7 21/32	—	8	8	—	16
3	4		6 21/32	2	9 11/32	—	7	10	—	17
3	6		7	2	11	—	6	11	—	17
3	8		7 11/32	3	0 21/32	—	6	12	—	18
3	10		7 21/32	3	2 11/32	—	5	14	—	19
4	0		8	3	4	—	4	15	—	19
4	2		8 11/32	3	5 21/32	—	3	17	—	20
4	4		8 21/32	3	7 11/32	—	3	18	—	21
4	6		9	3	9	—	2	20	—	22
4	8		9 11/32	3	10 21/32	—	1	21	—	22
4	10		9 21/32	4	0 11/32	—	1	22	—	23
4	11		9 27/32	4	1 5/32	—	—	23	—	23
5	0		10	4	2	—	—	23	1	24
5	6		11	4	7	—	—	23	3	26
6	0	1	0	5	0	—	—	23	5	28
6	6	1	1	5	5	—	—	23	7	30

4 1/2 Inch Arch Thickness — 3 Inch Arch Brick 9 x 4 1/2 x 3 or 13 1/2 x 4 1/2 x 3 Inch 1.608 Inch (1 19/32 Inch) Rise Per Foot of Span (60° Central Angle)

Span Ft	Span In	Rise Ft	Rise In	Inside Radius Ft	Inside Radius In	Number Required Per Course: No. 3 Arch	No. 2 Arch	No. 1 Arch	Straight	Total
1	0		1 19/32	1	0	4	2	—	—	6
1	1		1 3/4	1	1	4	3	—	—	7
1	2		1 7/8	1	2	3	4	—	—	7
1	3		2	1	3	3	4	—	—	7
1	4		2 5/32	1	4	3	5	—	—	8
1	5		2 9/32	1	5	2	6	—	—	8
1	6		2 13/32	1	6	2	6	—	—	8
1	7		2 17/32	1	7	2	7	—	—	9
1	8		2 11/16	1	8	1	8	—	—	9
1	9		2 13/16	1	9	1	8	—	—	9
1	10		2 15/16	1	10	1	9	—	—	10
1	11		3 3/32	1	11	—	9	1	—	10
2	0		3 7/32	2	0	—	9	1	—	10
2	1		3 11/32	2	1	—	9	2	—	11
2	2		3 15/32	2	2	—	8	3	—	11
2	3		3 5/8	2	3	—	8	3	—	11
2	4		3 3/4	2	4	—	8	4	—	12
2	5		3 7/8	2	5	—	7	5	—	12
2	6		4 1/32	2	6	—	7	5	—	12
2	7		4 5/32	2	7	—	7	6	—	13
2	8		4 9/32	2	8	—	6	7	—	13
2	9		4 7/16	2	9	—	6	7	—	13
2	10		4 9/16	2	10	—	6	8	—	14
2	11		4 11/16	2	11	—	5	9	—	14
3	0		4 13/16	3	0	—	5	10	—	15
3	1		4 31/32	3	1	—	5	10	—	15
3	2		5 3/32	3	2	—	4	11	—	15
3	3		5 7/32	3	3	—	4	12	—	16
3	4		5 11/32	3	4	—	4	12	—	16
3	5		5 1/2	3	5	—	3	13	—	16
3	6		5 5/8	3	6	—	3	14	—	17
3	7		5 3/4	3	7	—	2	15	—	17
3	8		5 29/32	3	8	—	2	15	—	17
3	9		6 1/32	3	9	—	2	16	—	18
3	10		6 5/32	3	10	—	1	17	—	18
3	11		6 9/32	3	11	—	1	17	—	18
4	0		6 7/16	4	0	—	1	18	—	19
4	1		6 9/16	4	1	—	—	19	—	19
4	2		6 11/16	4	2	—	—	19	—	19
4	3		6 27/32	4	3	—	—	19	1	20
4	6		7 1/4	4	6	—	—	19	2	21
5	0		8 1/32	5	0	—	—	19	4	23
5	6		8 27/32	5	6	—	—	19	6	25
6	0		9 21/32	6	0	—	—	19	8	27
6	6		10 7/16	6	6	—	—	19	10	29

ARCH COMBINATIONS

4 1/2 Inch Arch Thickness — 3 Inch Arch Brick
9 x 4 1/2 x 3 or 13 1/2 x 4 1/2 x 3 Inch
1 1/2 Inch Rise Per Foot of Span

Span Ft	Span In	Rise Ft	Rise In	Inside Radius Ft	Inside Radius In	Number Required Per Course: No. 3 Arch	No. 2 Arch	No. 1 Arch	Straight	Total
1	0		1 1/2	1	0 3/4	3	3	—	—	6
1	1		1 5/8	1	1 13/16	3	3	—	—	6
1	2		1 3/4	1	2 7/8	3	4	—	—	7
1	3		1 7/8	1	3 15/16	2	5	—	—	7
1	4		2	1	5	2	5	—	—	7
1	5		2 1/8	1	6 1/16	2	6	—	—	8
1	6		2 1/4	1	7 1/8	1	7	—	—	8
1	7		2 3/8	1	8 3/16	1	7	—	—	8
1	8		2 1/2	1	9 1/4	1	8	—	—	9
1	9		2 5/8	1	10 5/16	—	9	—	—	9
1	10		2 3/4	1	11 3/8	—	9	1	—	10
1	11		2 7/8	2	0 7/16	—	8	2	—	10
2	0		3	2	1 1/2	—	8	2	—	10
2	1		3 1/8	2	2 9/16	—	8	3	—	11
2	2		3 1/4	2	3 5/8	—	7	4	—	11
2	3		3 3/8	2	4 11/16	—	7	4	—	11
2	4		3 1/2	2	5 3/4	—	7	5	—	12
2	5		3 5/8	2	6 3/16	—	6	6	—	12
2	6		3 3/4	2	7 7/8	—	6	6	—	12
2	7		3 7/8	2	8 15/16	—	6	7	—	13
2	8		4	2	10	—	5	8	—	13
2	9		4 1/8	2	11 1/16	—	5	8	—	13
2	10		4 1/4	3	0 1/8	—	5	9	—	14
2	11		4 3/8	3	1 3/16	—	4	10	—	14
3	0		4 1/2	3	2 1/4	—	4	10	—	14
3	1		4 5/8	3	3 5/16	—	4	11	—	15
3	2		4 3/4	3	4 3/8	—	3	12	—	15
3	3		4 7/8	3	5 7/16	—	3	12	—	15
3	4		5	3	6 1/2	—	3	13	—	16
3	5		5 1/8	3	7 9/16	—	2	14	—	16
3	6		5 1/4	3	8 5/8	—	2	14	—	16
3	7		5 3/8	3	9 11/16	—	2	15	—	17
3	8		5 1/2	3	10 3/4	—	1	16	—	17
3	9		5 5/8	3	11 13/16	—	—	17	—	17
3	10		5 3/4	4	0 7/8	—	—	18	—	18
3	11		5 7/8	4	1 15/16	—	—	18	—	18
4	0		6	4	3	—	—	18	1	19
4	3		6 3/8	4	6 3/16	—	—	18	2	20
4	6		6 3/4	4	9 3/8	—	—	18	3	21
4	9		7 1/8	5	0 9/16	—	—	18	4	22
5	0		7 1/2	5	3 3/4	—	—	18	5	23
5	3		7 7/8	5	6 15/16	—	—	18	6	24
5	6		8 1/4	5	10 1/8	—	—	18	7	25
5	9		8 5/8	6	1 5/16	—	—	18	8	26
6	0		9	6	4 1/2	—	—	18	9	27
6	6		9 3/4	6	10 7/8	—	—	18	11	29

4 1/2 Inch Arch Thickness — 3 Inch Arch Brick
9 x 4 1/2 x 3 or 13 1/2 x 4 1/2 x 3 Inch
2.302 Inch (2 5/16 Inch) Rise Per Foot of Span

Span Ft	Span In	Rise Ft	Rise In	Inside Radius Ft	Inside Radius In	Number Required Per Course: No. 3 Arch	No. 2 Arch	No. 1 Arch	Straight	Total
1	0		2 5/16		8 31/32	7	—	—	—	7
1	1		2 1/2		9 23/32	6	1	—	—	7
1	2		2 11/16		10 15/32	6	2	—	—	8
1	3		2 7/8		11 7/32	6	2	—	—	8
1	4		3 1/16		11 31/32	5	3	—	—	8
1	5		3 1/4	1	0 23/32	5	4	—	—	9
1	6		3 15/32	1	1 15/32	5	4	—	—	9
1	7		3 21/32	1	2 3/16	4	6	—	—	10
1	8		3 27/32	1	2 15/16	4	6	—	—	10
1	9		4 1/32	1	3 11/16	3	7	—	—	10
1	10		4 7/32	1	4 7/16	3	8	—	—	11
1	11		4 13/32	1	5 3/16	3	8	—	—	11
2	0		4 19/32	1	5 15/16	2	9	—	—	11
2	1		4 25/32	1	6 11/16	2	10	—	—	12
2	2		5	1	7 7/16	2	10	—	—	12
2	3		5 3/16	1	8 3/16	1	11	—	—	12
2	4		5 3/8	1	8 15/16	1	12	—	—	13
2	6		5 3/4	1	10 7/16	—	14	—	—	14
2	8		6 1/8	1	11 29/32	—	13	1	—	14
2	10		6 17/32	2	1 13/32	—	12	3	—	15
3	0		6 29/32	2	2 29/32	—	11	5	—	16
3	2		7 9/32	2	4 13/32	—	10	6	—	16
3	4		7 11/16	2	5 29/32	—	10	7	—	17
3	6		8 1/16	2	7 13/32	—	9	9	—	18
3	8		8 7/16	2	8 7/8	—	8	11	—	19
3	10		8 13/16	2	10 3/8	—	7	12	—	19
4	0		9 7/32	2	11 7/8	—	7	13	—	20
4	2		9 19/32	3	1 3/8	—	6	15	—	21
4	4		9 31/32	3	2 7/8	—	6	16	—	22
4	6		10 3/8	3	4 3/8	—	5	17	—	22
4	8		10 3/4	3	5 27/32	—	4	19	—	23
4	10		11 1/8	3	7 11/32	—	3	21	—	24
5	0		11 1/2	3	8 27/32	—	3	22	—	25
5	2		11 29/32	3	10 11/32	—	2	23	—	25
5	4	1	0 9/32	3	11 27/32	—	1	25	—	26
5	6	1	0 21/32	4	1 11/32	—	—	27	—	27
5	8	1	1 1/16	4	2 13/16	—	—	27	—	27
5	10	1	1 7/16	4	4 5/16	—	—	27	1	28
6	0	1	1 13/16	4	5 13/16	—	—	27	2	29
6	6	1	2 31/32	4	10 5/16	—	—	27	4	31

ARCH COMBINATIONS

9 Inch Arch Thickness — 3 Inch Wedge Brick 9 x 4 1/2 x 3, 9 x 6 3/4 x 3 or 9 x 9 x 3 Inch 1 1/2 Inch Rise Per Foot of Span

Span Ft	Span In	Rise Ft	Rise In	Inside Radius Ft	Inside Radius In	Number Required Per Course: No. 3 Wedge	No. 2 Wedge	No. 1 Wedge	Total
1	6		2 1/4	1	7 1/8	9	1	—	10
1	7		2 3/8	1	8 3/16	8	2	—	10
1	8		2 1/2	1	9 1/4	8	2	—	10
1	9		2 5/8	1	10 5/16	8	3	—	11
1	10		2 3/4	1	11 3/8	7	4	—	11
1	11		2 7/8	2	0 7/16	7	4	—	11
2	0		3	2	1 1/2	7	5	—	12
2	1		3 1/8	2	2 9/16	6	6	—	12
2	2		3 1/4	2	3 5/8	6	6	—	12
2	3		3 3/8	2	4 11/16	6	7	—	13
2	4		3 1/2	2	5 3/4	5	8	—	13
2	5		3 5/8	2	6 13/16	5	8	—	13
2	6		3 3/4	2	7 7/8	5	9	—	14
2	7		3 7/8	2	8 15/16	4	10	—	14
2	8		4	2	10	4	10	—	14
2	9		4 1/8	2	11 1/16	4	11	—	15
2	10		4 1/4	3	0 1/8	3	12	—	15
2	11		4 3/8	3	1 3/16	3	12	—	15
3	0		4 1/2	3	2 1/4	3	13	—	16
3	1		4 5/8	3	3 5/16	2	14	—	16
3	2		4 3/4	3	4 3/8	2	15	—	17
3	3		4 7/8	3	5 7/16	1	16	—	17
3	4		5	3	6 1/2	1	16	—	17
3	5		5 1/8	3	7 9/16	1	17	—	18
3	6		5 1/4	3	8 5/8	—	18	—	18
3	7		5 3/8	3	9 11/16	—	18	—	18
3	8		5 1/2	3	10 3/4	—	17	2	19
3	9		5 5/8	3	11 13/16	—	17	2	19
3	10		5 3/4	4	0 7/8	—	16	3	19
3	11		5 7/8	4	1 15/16	—	16	4	20
4	0		6	4	3	—	16	4	20
4	1		6 1/8	4	4 1/16	—	15	5	20
4	2		6 1/4	4	5 1/8	—	15	6	21
4	3		6 3/8	4	6 3/16	—	15	6	21
4	4		6 1/2	4	7 1/4	—	14	7	21
4	5		6 5/8	4	8 5/16	—	14	8	22
4	6		6 3/4	4	9 3/8	—	14	8	22
4	7		6 7/8	4	10 7/16	—	13	9	22
4	8		7	4	11 1/2	—	13	10	23
4	9		7 1/8	5	0 9/16	—	13	10	23
4	10		7 1/4	5	1 5/8	—	12	11	23
4	11		7 3/8	5	2 11/16	—	12	12	24
5	0		7 1/2	5	3 3/4	—	12	12	24
5	1		7 5/8	5	4 13/16	—	12	13	25
5	2		7 3/4	5	5 7/8	—	11	14	25
5	3		7 7/8	5	6 15/16	—	11	14	25
5	4		8	5	8	—	11	15	26
5	5		8 1/8	5	9 1/16	—	10	16	26

NOTE: This table can be used also for 13 1/2 x 9 x 3 inch arch brick by substituting No. 1, 2, and 3 arch brick for the corresponding wedge brick.

9 Inch Arch Thickness — 3 Inch Wedge Brick 9 x 4 1/2 x 3, 9 x 6 3/4 x 3 or 9 x 9 x 3 Inch–Cont'd. 1 1/2 Inch Rise Per Foot of Span

Span Ft	Span In	Rise Ft	Rise In	Inside Radius Ft	Inside Radius In	Number Required Per Course: No. 2 Wedge	No. 1 Wedge	Straight	Total
5	6		8 1/4	5	10 1/8	10	16	—	26
5	7		8 3/8	5	11 3/16	9	18	—	27
5	8		8 1/2	6	0 1/4	9	18	—	27
5	9		8 5/8	6	1 5/16	8	19	—	27
5	10		8 3/4	6	2 3/8	8	20	—	28
5	11		8 7/8	6	3 7/16	8	20	—	28
6	0		9	6	4 1/2	7	21	—	28
6	1		9 1/8	6	5 9/16	7	22	—	29
6	2		9 1/4	6	6 5/8	7	22	—	29
6	3		9 3/8	6	7 11/16	6	23	—	29
6	4		9 1/2	6	8 3/4	6	24	—	30
6	5		9 5/8	6	9 13/16	6	24	—	30
6	6		9 3/4	6	10 7/8	5	25	—	30
6	7		9 7/8	6	11 15/16	5	26	—	31
6	8		10	7	1	5	26	—	31
6	9		10 1/8	7	2 1/16	4	27	—	31
6	10		10 1/4	7	3 1/8	4	28	—	32
6	11		10 3/8	7	4 3/16	4	28	—	32
7	0		10 1/2	7	5 1/4	3	29	—	32
7	1		10 5/8	7	6 5/16	3	30	—	33
7	2		10 3/4	7	7 3/8	3	30	—	33
7	3		10 7/8	7	8 7/16	3	31	—	34
7	4		11	7	9 1/2	2	32	—	34
7	5		11 1/8	7	10 9/16	2	32	—	34
7	6		11 1/4	7	11 5/8	2	33	—	35
7	7		11 3/8	8	0 11/16	1	34	—	35
7	8		11 1/2	8	1 3/4	1	34	—	35
7	9		11 5/8	8	2 13/16	—	36	—	36
7	10		11 3/4	8	3 7/8	—	36	—	36
7	11		11 7/8	8	4 15/16	—	36	—	36
8	0	1	0	8	6	—	36	1	37
8	6	1	0 3/4	9	0 3/8	—	36	3	39
9	0	1	1 1/2	9	6 3/4	—	36	5	41
9	6	1	2 1/4	10	1 1/8	—	36	7	43
10	0	1	3	10	7 1/2	—	36	9	45
10	6	1	3 3/4	11	1 7/8	—	36	11	47
11	0	1	4 1/2	11	8 1/4	—	36	13	49
11	6	1	5 1/4	12	2 5/8	—	36	15	51
12	0	1	6	12	9	—	36	17	53
12	6	1	6 3/4	13	3 3/8	—	36	19	55
13	0	1	7 1/2	13	9 3/4	—	36	21	57
13	6	1	8 1/4	14	4 1/8	—	36	24	60
14	0	1	9	14	10 1/2	—	36	26	62
14	6	1	9 3/4	15	4 7/8	—	36	28	64
15	0	1	10 1/2	15	11 1/4	—	36	30	66

NOTE: This table can be used also for 13 1/2 x 9 x 3 inch arch brick by substituting No. 1 and 2 arch brick for the corresponding wedge brick.

ARCH COMBINATIONS

9 Inch Arch Thickness - 3 Inch Wedge Brick 9 x 4½ x 3, 9 x 6¾ x 3 or 9 x9 x 3 Inch 1.608 Inch (1 19/32 Inch) Rise Per Foot of Span (60° Central Angle)

Span Ft	Span In	Rise Ft	Rise In	Inside Radius Ft	Inside Radius In	Number Required Per Course: No. 3 Wedge	No. 2 Wedge	No. 1 Wedge	Total
	6		2 13/32	1	6	10	—	—	10
1	7		2 17/32	1	7	9	1	—	10
1	8		2 11/16	1	8	9	2	—	11
1	9		2 13/16	1	9	9	2	—	11
1	10		2 15/16	1	10	8	3	—	11
1	11		3 3/32	2	11	8	4	—	12
2	0		3 7/32	2	0	8	4	—	12
2	1		3 11/32	2	1	7	5	—	12
2	2		3 15/32	2	2	7	6	—	13
2	3		3 5/8	2	3	7	6	—	13
2	4		3 3/4	2	4	6	7	—	13
2	5		3 7/8	2	5	6	8	—	14
2	6		3 1/32	2	6	5	9	—	14
2	7		3 5/32	2	7	5	9	—	14
2	8		4 9/32	2	8	5	10	—	15
2	9		4 7/16	2	9	4	11	—	15
2	10		4 9/16	3	10	4	11	—	15
2	11		4 11/16	3	11	4	12	—	16
3	0		4 13/16	3	0	3	13	—	16
3	1		4 31/32	3	1	3	13	—	16
3	2		5 3/32	3	2	3	14	—	17
3	3		5 7/32	3	3	2	15	—	17
3	4		5 11/32	3	4	2	16	—	18
3	5		5 1/2	3	5	2	16	—	18
3	6		5 5/8	3	6	1	17	—	18
3	7		5 3/4	3	7	1	18	—	19
3	8		5 29/32	3	8	1	18	—	19
3	9		6 1/8	3	9	—	19	—	19
3	10		6 5/32	4	10	—	19	1	20
3	11		6 9/32	3	11	—	18	2	20
4	0		6 7/16	4	0	—	18	2	20
4	1		6 9/16	4	1	—	18	3	21
4	2		6 11/16	4	2	—	17	4	21
4	3		6 27/32	4	3	—	17	4	21
4	4		6 31/32	4	4	—	17	5	22
4	5		7 3/32	4	5	—	16	6	22
4	6		7 1/4	4	6	—	16	6	22
4	7		7 3/8	4	7	—	16	7	23
4	8		7 1/2	4	8	—	15	8	23
4	9		7 5/8	5	9	—	15	8	23
4	10		7 25/32	5	10	—	15	9	24
4	11		7 29/32	5	11	—	14	10	24
5	0		8 1/32	5	0	—	14	10	24
5	1		8 3/16	5	1	—	14	11	25
5	2		8 5/16	5	2	—	13	12	25
5	3		8 7/16	5	3	—	13	13	26
5	4		8 9/16	5	4	—	12	14	26
5	5		8 23/32	5	5	—	12	14	26

NOTE: This table can be used also for 13½ x 9 x 3 inch arch brick by substituting No. 1, 2, and 3 arch brick for corresponding wege brick.

9 Inch Arch Thickness - 3 Inch Wedge Brick 9 x 4½ x 3, 9 x 6¾ x 3 or 9 x9 x 3 Inch Cont'd 1.608 Inch (1 19/32 Inch) Rise Per Foot of Span (60° Central Angle)

Span Ft	Span In	Rise Ft	Rise In	Inside Radius Ft	Inside Radius In	Number Required Per Course: No. 2 Wedge	No. 1 Wedge	Straight	Total
	6		8 27/32	5	6	12	15	—	27
5	7		8 31/32	5	7	11	16	—	27
5	8		9 1/8	6	8	11	16	—	27
5	9		9 1/4	6	9	11	17	—	28
5	10		9 3/8	6	10	10	18	—	28
5	11		9 1/2	6	11	10	18	—	28
6	0		9 21/32	6	0	10	19	—	29
6	1		9 25/32	6	1	9	20	—	29
6	2		9 29/32	6	2	9	20	—	29
6	3		10 1/16	6	3	9	21	—	30
6	4		10 3/16	6	4	8	22	—	30
6	5		10 5/16	6	5	8	22	—	30
6	6		10 7/16	6	6	8	23	—	31
6	7		10 19/32	6	7	7	24	—	31
6	8		10 23/32	7	8	7	24	—	31
6	9		10 27/32	7	9	7	25	—	32
6	10		11	7	10	6	26	—	32
6	11		11 1/8	7	11	6	27	—	33
7	0		11 1/4	7	0	6	27	—	33
7	1		11 3/8	7	1	5	28	—	33
7	2		11 17/32	7	2	5	29	—	34
7	3		11 21/32	7	3	4	30	—	34
7	4		11 25/32	7	4	4	30	—	34
7	5		11 15/16	7	5	4	31	—	35
7	6	1	0 1/16	7	6	3	32	—	35
7	7	1	0 3/16	7	7	3	32	—	35
7	8	1	0 5/16	7	8	3	33	—	36
7	9	1	0 15/32	7	9	2	34	—	36
7	10	1	0 19/32	7	10	2	34	—	36
7	11	1	0 23/32	7	11	2	35	—	37
8	0	1	0 7/8	8	0	1	36	—	37
8	1	1	1	8	1	1	36	—	37
8	2	1	1 1/8	8	2	1	37	—	38
8	3	1	1 1/4	8	3	—	38	—	38
8	6	1	1 21/32	8	6	—	38	1	39
9	0	1	2 15/32	9	0	—	38	3	41
9	6	1	3 9/16	9	6	—	38	5	43
10	0	1	4 1/16	10	0	—	38	7	45
10	6	1	4 7/8	10	6	—	38	10	48
11	0	1	5 11/16	11	0	—	38	12	50
11	6	1	6 1/2	11	6	—	38	14	52
12	0	1	7 9/32	12	0	—	38	16	54
12	6	1	8 3/32	12	6	—	38	18	56
13	0	1	8 29/32	13	0	—	38	20	58
13	6	1	9 11/16	13	6	—	38	22	60
14	0	1	10 1/2	14	0	—	38	24	62
14	6	1	11 5/16	14	6	—	38	26	64
15	0	2	0 1/8	15	0	—	38	28	66

NOTE: This table can be used also for 13½ x 9 x 3 inch arch brick by substituting No. 1, 2, and 3 arch brick for corresponding wege brick.

ARCH COMBINATIONS

9 Inch Arch Thickness — 3 Inch Wedge Brick 9 x 4 1/2 x 3, 9 x 6 3/4 x 3 or 9 x 9 x 3 Inch 2 Inch Rise Per Foot of Span

Span Ft	Span In	Rise Ft	Rise In	Inside Radius Ft	Inside Radius In	Number Required Per Course: No. 3 Wedge	No. 2 Wedge	No. 1 Wedge	Total
1	10		3 21/32	1	6 11/32	12	—	—	12
1	11		3 27/32	1	7 5/32	11	1	—	12
2	0		4	1	8	11	2	—	13
2	1		4 5/32	1	8 27/32	10	3	—	13
2	2		4 11/32	1	9 21/32	10	4	—	14
2	3		4 1/2	1	10 1/2	10	4	—	14
2	4		4 21/32	1	11 11/32	9	5	—	14
2	5		4 27/32	2	0 5/32	9	6	—	15
2	6		5	2	1	9	6	—	15
2	7		5 5/32	2	1 27/32	8	7	—	15
2	8		5 11/32	2	2 21/32	8	8	—	16
2	9		5 1/2	2	3 1/2	8	8	—	16
2	10		5 21/32	2	4 11/32	7	9	—	16
2	11		5 27/32	2	5 5/32	7	10	—	17
3	0		6	2	6	7	10	—	17
3	1		6 5/32	2	6 27/32	6	11	—	17
3	2		6 11/32	2	7 21/32	6	12	—	18
3	3		6 1/2	2	8 1/2	5	13	—	18
3	4		6 21/32	2	9 11/32	5	14	—	19
3	5		6 27/32	2	10 5/32	5	14	—	19
3	6		7	2	11	4	15	—	19
3	7		7 5/32	2	11 27/32	4	16	—	20
3	8		7 11/32	3	0 21/32	4	16	—	20
3	9		7 1/2	3	1 1/2	3	17	—	20
3	10		7 21/32	3	2 11/32	3	18	—	21
3	11		7 27/32	3	3 5/32	3	18	—	21
4	0		8	3	4	2	19	—	21
4	1		8 5/32	3	4 27/32	2	20	—	22
4	2		8 11/32	3	5 21/32	2	20	—	22
4	3		8 1/2	3	6 1/2	1	21	—	22
4	4		8 21/32	3	7 11/32	1	22	—	23
4	5		8 27/32	3	8 5/32	1	22	—	23
4	6		9	3	9	—	24	—	24
4	7		9 5/32	3	9 27/32	—	23	1	24
4	8		9 11/32	3	10 21/32	—	23	1	24
4	9		9 1/2	3	11 1/2	—	22	3	25
4	10		9 21/32	4	0 11/32	—	22	3	25
4	11		9 27/32	4	1 5/32	—	21	4	25
5	0		10	4	2	—	21	5	26
5	1		10 5/32	4	2 27/32	—	21	5	26
5	2		10 11/32	4	3 21/32	—	20	6	26
5	3		10 1/2	4	4 1/2	—	20	7	27
5	4		10 21/32	4	5 11/32	—	20	7	27
5	5		10 27/32	4	6 5/32	—	19	8	27
5	6		11	4	7	—	19	9	28
5	7		11 5/32	4	7 27/32	—	19	9	28
5	8		11 11/32	4	8 21/32	—	19	10	29
5	9		11 1/2	4	9 1/2	—	18	11	29
5	10		11 21/32	4	10 11/32	—	18	11	29
5	11		11 27/32	4	11 5/32	—	17	13	30

NOTE: This table can be used also for 13 1/2 x 9 x 3 inch arch brick by substituting No. 1, 2, and 3 arch brick for the corresponding wedge brick.

9 Inch Arch Thickness — 3 Inch Wedge Brick 9 x 4 1/2 x 3, 9 x 6 3/4 x 3 or 9 x 9 x 3 Inch–Cont'd. 2 Inch Rise Per Foot of Span

Span Ft	Span In	Rise Ft	Rise In	Inside Radius Ft	Inside Radius In	Number Required Per Course: No. 2 Wedge	No. 1 Wedge	Straight	Total
6	0	1	0	5	0	17	13	—	30
6	1	1	0 5/32	5	0 27/32	16	14	—	30
6	2	1	0 11/32	5	1 21/32	16	15	—	31
6	3	1	0 1/2	5	2 1/2	16	15	—	31
6	4	1	0 21/32	5	3 11/32	15	16	—	31
6	5	1	0 27/32	5	4 5/32	15	17	—	32
6	6	1	1	5	5	15	17	—	32
6	7	1	1 5/32	5	5 27/32	15	18	—	33
6	8	1	1 11/32	5	6 21/32	14	19	—	33
6	9	1	1 1/2	5	7 1/2	14	19	—	33
6	10	1	1 21/32	5	8 11/32	14	20	—	34
6	11	1	1 27/32	5	9 5/32	13	21	—	34
7	0	1	2	5	10	13	21	—	34
7	1	1	2 5/32	5	10 27/32	12	23	—	35
7	2	1	2 11/32	5	11 21/32	12	23	—	35
7	3	1	2 1/2	6	0 1/2	11	24	—	35
7	4	1	2 21/32	6	1 11/32	11	25	—	36
7	5	1	2 27/32	6	2 5/32	11	25	—	36
7	6	1	3	6	3	10	26	—	36
7	7	1	3 5/32	6	3 27/32	10	27	—	37
7	8	1	3 11/32	6	4 21/32	10	27	—	37
7	9	1	3 1/2	6	5 1/2	10	28	—	38
7	10	1	3 21/32	6	6 11/32	9	29	—	38
7	11	1	3 27/32	6	7 5/32	9	29	—	38
8	0	1	4	6	8	9	30	—	39
8	1	1	4 5/32	6	8 27/32	8	31	—	39
8	2	1	4 11/32	6	9 21/32	8	31	—	39
8	3	1	4 1/2	6	10 1/2	7	33	—	40
8	4	1	4 21/32	6	11 11/32	7	33	—	40
8	5	1	4 27/32	7	0 5/32	6	34	—	40
8	6	1	5	7	1	6	35	—	41
8	7	1	5 5/32	7	1 27/32	6	35	—	41
8	8	1	5 11/32	7	2 21/32	5	36	—	41
8	9	1	5 1/2	7	3 1/2	5	37	—	42
8	10	1	5 21/32	7	4 11/32	5	37	—	42
8	11	1	5 27/32	7	5 5/32	5	38	—	43
9	0	1	6	7	6	4	39	—	43
9	2	1	6 11/32	7	7 21/32	4	40	—	44
9	4	1	6 21/32	7	9 11/32	3	41	—	44
9	6	1	7	7	11	2	43	—	45
9	8	1	7 11/32	8	0 21/32	1	45	—	46
9	10	1	7 21/32	8	2 11/32	—	46	—	46
10	0	1	8	8	4	—	47	—	47
10	6	1	9	8	9	—	47	2	49
11	0	1	10	9	2	—	47	4	51
12	0	2	0	10	0	—	47	9	56
13	0	2	2	10	10	—	47	13	60
14	0	2	4	11	8	—	47	17	64
15	0	2	6	12	6	—	47	22	69

NOTE: This table can be used also for 13 1/2 x 9 x 3 inch arch brick by substituting No. 1 and 2 arch brick for the corresponding wedge brick.

ARCH COMBINATIONS

9 Inch Arch Thickness — 3 Inch Wedge Brick 9 x 4 1/2 x 3, 9 x 6 3/4 x 3 or 9 x 9 x 3 Inch 2.302 Inch (2 5/16 Inch) Rise Per Foot of Span

Span Ft	Span In	Rise Ft	Rise In	Inside Radius Ft	Inside Radius In	Number Required Per Course: No. 3 Wedge	No. 2 Wedge	No. 1 Wedge	Total
2	0		4 19/32	1	5 15/16	14	—	—	14
2	1		4 25/32	1	6 11/16	13	1	—	14
2	2		5	1	7 7/16	13	1	—	14
2	3		5 3/16	1	8 3/16	12	3	—	15
2	4		5 3/8	1	8 15/16	12	3	—	15
2	5		5 9/16	1	9 11/16	11	4	—	15
2	6		5 3/4	1	10 7/16	11	5	—	16
2	7		5 15/16	1	11 5/32	11	5	—	16
2	8		6 1/8	1	11 29/32	10	6	—	16
2	9		6 11/32	2	0 21/32	10	7	—	17
2	10		6 17/32	2	1 13/32	10	7	—	17
2	11		6 23/32	2	2 5/32	10	8	—	18
3	0		6 29/32	2	2 29/32	9	9	—	18
3	1		7 3/32	2	3 21/32	9	9	—	18
3	2		7 9/32	2	4 13/32	8	11	—	19
3	3		7 15/32	2	5 5/32	8	11	—	19
3	4		7 11/16	2	5 29/32	7	12	—	19
3	5		7 7/8	2	6 21/32	7	13	—	20
3	6		8 1/16	2	7 13/32	7	13	—	20
3	7		8 1/4	2	8 1/8	6	14	—	20
3	8		8 7/16	2	8 7/8	6	15	—	21
3	9		8 5/8	2	9 5/8	6	15	—	21
3	10		8 13/16	2	10 3/8	6	16	—	22
3	11		9 1/32	2	11 1/8	5	17	—	22
4	0		9 7/32	2	11 7/8	4	18	—	22
4	1		9 13/32	3	0 5/8	4	19	—	23
4	2		9 19/32	3	1 3/8	4	19	—	23
4	3		9 25/32	3	2 1/8	3	20	—	23
4	4		9 31/32	3	2 7/8	3	21	—	24
4	5		10 5/32	3	3 5/8	3	21	—	24
4	6		10 3/8	3	4 3/8	3	22	—	25
4	7		10 9/16	3	5 3/32	2	23	—	25
4	8		10 3/4	3	5 27/32	2	23	—	25
4	9		10 15/16	3	6 19/32	2	24	—	26
4	10		11 1/8	3	7 11/32	1	25	—	26
4	11		11 5/16	3	8 3/32	—	26	—	26
5	0		11 1/2	3	8 27/32	—	27	—	27
5	1		11 23/32	3	9 19/32	—	26	1	27
5	2		11 29/32	3	10 11/32	—	26	1	27
5	3	1	0 3/32	3	11 3/32	—	26	2	28
5	4	1	0 9/32	3	11 27/32	—	25	3	28
5	5	1	0 15/32	4	0 19/32	—	25	4	29
5	6	1	0 21/32	4	1 11/32	—	25	4	29
5	7	1	0 27/32	4	2 1/16	—	24	5	29
5	8	1	1 1/16	4	2 13/16	—	24	6	30
5	9	1	1 1/4	4	3 9/16	—	23	7	30
5	10	1	1 7/16	4	4 5/16	—	23	7	30
5	11	1	1 5/8	4	5 1/16	—	23	8	31

NOTE: This table can be used also for 13 1/2 x 9 x 3 inch arch brick by substituting No. 1, 2 and 3 arch brick for the corresponding wedge brick.

9 Inch Arch Thickness—3 Inch Wedge Brick 9 x 4 1/2 x 3, 9 x 6 3/4 x 3 or 9 x 9 x 3 Inch–Cont'd. 2.302 Inch (2 5/16 Inch) Rise Per Foot of Span

Span Ft	Span In	Rise Ft	Rise In	Inside Radius Ft	Inside Radius In	Number Required Per Course: No. 2 Wedge	No. 1 Wedge	Straight	Total
6	0	1	1 13/16	4	5 13/16	22	9	—	31
6	1	1	2	4	6 9/16	22	9	—	31
6	2	1	2 3/16	4	7 5/16	22	10	—	32
6	3	1	2 3/8	4	8 1/16	21	11	—	32
6	4	1	2 19/32	4	8 13/16	21	12	—	33
6	5	1	2 25/32	4	9 9/16	20	13	—	33
6	6	1	2 31/32	4	10 5/16	20	13	—	33
6	7	1	3 5/32	4	11 1/32	20	14	—	34
6	8	1	3 11/32	4	11 25/32	19	15	—	34
6	9	1	3 17/32	5	0 17/32	19	15	—	34
6	10	1	3 23/32	5	1 9/32	19	16	—	35
6	11	1	3 15/16	5	2 1/32	18	17	—	35
7	0	1	4 1/8	5	2 25/32	18	17	—	35
7	1	1	4 5/16	5	3 17/32	18	18	—	36
7	2	1	4 1/2	5	4 9/32	17	19	—	36
7	3	1	4 11/16	5	5 1/32	17	20	—	37
7	4	1	4 7/8	5	5 25/32	16	21	—	37
7	5	1	5 1/16	5	6 17/32	16	21	—	37
7	6	1	5 9/32	5	7 9/32	16	22	—	38
7	7	1	5 15/32	5	8 1/32	15	23	—	38
7	8	1	5 21/32	5	8 3/4	15	23	—	38
7	9	1	5 27/32	5	9 1/2	15	24	—	39
7	10	1	6 1/32	5	10 1/4	14	25	—	39
7	11	1	6 7/32	5	11	14	25	—	39
8	0	1	6 13/32	5	11 3/4	14	26	—	40
8	2	1	6 13/16	6	1 1/4	13	28	—	41
8	4	1	7 3/16	6	2 3/4	12	29	—	41
8	6	1	7 9/16	6	4 1/4	11	31	—	42
8	8	1	7 31/32	6	5 23/32	11	32	—	43
8	10	1	8 11/32	6	7 7/32	10	34	—	44
9	0	1	8 23/32	6	8 23/32	9	35	—	44
9	2	1	9 3/32	6	10 7/32	8	37	—	45
9	4	1	9 1/2	6	11 23/32	8	38	—	46
9	6	1	9 7/8	7	1 7/32	7	39	—	46
9	8	1	10 1/4	7	2 11/16	6	41	—	47
9	10	1	10 5/8	7	4 3/16	6	42	—	48
10	0	1	11 1/32	7	5 11/16	5	44	—	49
10	2	1	11 13/32	7	7 3/16	4	45	—	49
10	4	1	11 25/32	7	8 11/16	3	47	—	50
10	6	2	0 3/16	7	10 3/16	3	48	—	51
10	8	2	0 9/16	7	11 21/32	2	50	—	52
10	10	2	0 15/16	8	1 5/32	1	51	—	52
11	0	2	1 5/16	8	2 21/32	—	53	—	53
11	6	2	2 15/32	8	7 5/32	—	53	2	55
12	0	2	3 5/8	8	11 5/8	—	53	4	57
13	0	2	5 15/16	9	8 19/32	—	53	9	62
14	0	2	8 1/4	10	5 9/16	—	53	13	66
15	0	2	10 17/32	11	2 17/32	—	53	18	71

NOTE: This table can be used also for 13 1/2 x 9 x 3 inch arch brick by substituting No. 1 and 2 arch brick for the corresponding wedge brick.

ARCH COMBINATIONS

12 Inch Arch Thickness — 3 Inch Wedge Brick 12 x 4½ x 3, 12 x 6 x 3 or 12 x 9 x 3 Inch 1.608 Inch (1 19/32 Inch) Rise Per Foot of Span (60° Central Angle)

Span Ft	Span In	Rise Ft	Rise In	Inside Radius Ft	Inside Radius In	Number Required Per Course: No. 2 Wedge	No. 1 Wedge	No. 1-X Wedge	Total
6	0		9 21/32	6	0	21	9	—	30
6	3		10 1/16	6	3	20	11	—	31
6	6		10 7/16	6	6	19	13	—	32
6	9		10 27/32	6	9	18	15	—	33
7	0		11 1/4	7	0	17	17	—	34
7	3		11 21/32	7	3	16	19	—	35
7	6	1	0 1/16	7	6	15	21	—	36
7	9	1	0 15/32	7	9	14	23	—	37
8	0	1	0 7/8	8	0	13	25	—	38
8	3	1	1 1/4	8	3	12	27	—	39
8	6	1	1 21/32	8	6	11	29	—	40
8	9	1	2 1/16	8	9	10	31	—	41
9	0	1	2 15/32	9	0	8	34	—	42
9	3	1	2 7/8	9	3	7	36	—	43
9	6	1	3 9/32	9	6	6	38	—	44
9	9	1	3 11/16	9	9	5	40	—	45
10	0	1	4 1/16	10	0	4	42	—	46
10	3	1	4 15/32	10	3	4	44	—	48
10	6	1	4 7/8	10	6	3	46	—	49
10	9	1	5 9/32	10	9	1	49	—	50
11	0	1	5 11/16	11	0	—	51	—	51
11	3	1	6 3/32	11	3	—	50	2	52
11	6	1	6 1/2	11	6	—	48	5	53
11	9	1	6 7/8	11	9	—	47	7	54
12	0	1	7 9/32	12	0	—	46	9	55
12	3	1	7 11/16	12	3	—	45	11	56
12	6	1	8 3/32	12	6	—	44	13	57
12	9	1	8 1/2	12	9	—	43	15	58
13	0	1	8 29/32	13	0	—	42	17	59
13	3	1	9 5/16	13	3	—	41	19	60
13	6	1	9 11/16	13	6	—	40	21	61
13	9	1	10 3/32	13	9	—	39	23	62
14	0	1	10 1/2	14	0	—	38	25	63
14	3	1	10 29/32	14	3	—	37	27	64
14	6	1	11 5/16	14	6	—	36	29	65
14	9	1	11 23/32	14	9	—	35	31	66
15	0	2	0 1/8	15	0	—	34	33	67
15	3	2	0 17/32	15	3	—	32	36	68
15	6	2	0 29/32	15	6	—	32	38	70
15	9	2	1 5/16	15	9	—	31	40	71

12 Inch Arch Thickness — 3 Inch Wedge Brick 12 x 4½ x 3, 12 x 6 x 3 or 12 x 9 x 3 Inch–Cont'd. 1.608 Inch (1 19/32 Inch) Rise Per Foot of Span (60° Central Angle)

Span Ft	Span In	Rise Ft	Rise In	Inside Radius Ft	Inside Radius In	Number Required Per Course: No. 1 Wedge	No. 1-X Wedge	Straight	Total
16	0	2	1 23/32	16	0	30	42	—	72
16	3	2	2 1/8	16	3	29	44	—	73
16	6	2	2 17/32	16	6	28	46	—	74
16	9	2	2 15/16	16	9	27	48	—	75
17	0	2	3 11/32	17	0	25	51	—	76
17	3	2	3 23/32	17	3	24	53	—	77
17	6	2	4 1/8	17	6	23	55	—	78
17	9	2	4 17/32	17	9	22	57	—	79
18	0	2	4 15/16	18	0	21	59	—	80
18	3	2	5 11/32	18	3	20	61	—	81
18	6	2	5 3/4	18	6	19	63	—	82
18	9	2	6 5/32	18	9	18	65	—	83
19	0	2	6 17/32	19	0	17	67	—	84
19	3	2	6 15/16	19	3	16	69	—	85
19	6	2	7 11/32	19	6	15	71	—	86
19	9	2	7 3/4	19	9	14	73	—	87
20	0	2	8 5/32	20	0	13	75	—	88
20	3	2	8 9/16	20	3	12	77	—	89
20	6	2	8 31/32	20	6	10	80	—	90
20	9	2	9 11/32	20	9	10	82	—	92
21	0	2	9 3/4	21	0	9	84	—	93
21	3	2	10 5/32	21	3	8	86	—	94
21	6	2	10 9/16	21	6	7	88	—	95
21	9	2	10 31/32	21	9	6	90	—	96
22	0	2	11 3/8	22	0	5	92	—	97
22	3	2	11 25/32	22	3	3	95	—	98
22	6	3	0 3/16	22	6	2	97	—	99
22	9	3	0 9/16	22	9	1	99	—	100
23	0	3	0 31/32	23	0	—	101	—	101
23	3	3	1 3/8	23	3	—	101	1	102
23	6	3	1 25/32	23	6	—	101	2	103
23	9	3	2 3/16	23	9	—	101	3	104
24	0	3	2 19/32	24	0	—	101	4	105
24	3	3	3	24	3	—	101	5	106
24	6	3	3 3/8	24	6	—	101	6	107
24	9	3	3 25/32	24	9	—	101	7	108
25	0	3	4 3/16	25	0	—	101	8	109
25	3	3	4 19/32	25	3	—	101	9	110
25	6	3	5	25	6	—	101	10	111
25	9	3	5 13/32	25	9	—	101	11	112

ARCH COMBINATIONS

13½ Inch Arch Thickness — 3 Inch Wedge Brick 13½ x 4½ x 3, 13½ x 6 x 3 or 13½ x 9 x 3 Inch 1.608 Inch (1 19/32 Inch) Rise Per Foot of Span (60° Central Angle)

Span Ft	Span In	Rise Ft	Rise In	Inside Radius Ft	Inside Radius In	Number Required Per Course: No. 2 Wedge	No. 1 Wedge	No. 1-X Wedge	Total
6	0		9 21/32	6	0	27	3	—	30
6	3		10 1/16	6	3	26	5	—	31
6	6		10 7/16	6	6	25	7	—	32
6	9		10 27/32	6	9	24	9	—	33
7	0		11 1/4	7	0	22	12	—	34
7	3		11 21/32	7	3	21	14	—	35
7	6	1	0 1/16	7	6	21	16	—	37
7	9	1	0 15/32	7	9	20	18	—	38
8	0	1	0 7/8	8	0	19	20	—	39
8	3	1	1 1/4	8	3	18	22	—	40
8	6	1	1 21/32	8	6	17	24	—	41
8	9	1	2 1/16	8	9	16	26	—	42
9	0	1	2 15/32	9	0	14	29	—	43
9	3	1	2 7/8	9	3	13	31	—	44
9	6	1	3 9/32	9	6	12	33	—	45
9	9	1	3 11/16	9	9	11	35	—	46
10	0	1	4 1/16	10	0	10	37	—	47
10	3	1	4 15/32	10	3	9	39	—	48
10	6	1	4 7/8	10	6	8	41	—	49
10	9	1	5 9/32	10	9	7	43	—	50
11	0	1	5 11/16	11	0	6	45	—	51
11	3	1	6 3/32	11	3	5	47	—	52
11	6	1	6 1/2	11	6	4	49	—	53
11	9	1	6 7/8	11	9	3	51	—	54
12	0	1	7 9/32	12	0	2	53	—	55
12	3	1	7 11/16	12	3	1	55	—	56
12	4 1/2	1	7 29/32	12	4 1/2	—	57	—	57
12	6	1	8 3/32	12	6	—	56	1	57
12	9	1	8 1/2	12	9	—	55	4	59
13	0	1	8 29/32	13	0	—	54	6	60
13	3	1	9 5/16	13	3	—	53	8	61
13	6	1	9 11/16	13	6	—	52	10	62
13	9	1	10 3/32	13	9	—	51	12	63
14	0	1	10 1/2	14	0	—	50	14	64
14	3	1	10 29/32	14	3	—	49	16	65
14	6	1	11 5/16	14	6	—	48	18	66
14	9	1	11 23/32	14	9	—	47	20	67
15	0	2	0 1/8	15	0	—	46	22	68
15	3	2	0 17/32	15	3	—	45	24	69
15	6	2	0 29/32	15	6	—	44	26	70
15	9	2	1 5/16	15	9	—	43	28	71
16	0	2	1 23/32	16	0	—	41	31	72
16	3	2	2 1/8	16	3	—	40	33	73
16	6	2	2 17/32	16	6	—	39	35	74
16	9	2	2 15/16	16	9	—	38	37	75

13½ Inch Arch Thickness — 3 Inch Wedge Brick 13½ x 4½ x 3, 13½ x 6 x 3 or 13½ x 9 x 3 Inch – Continued 1.608 Inch (1 19/32 Inch) Rise Per Foot of Span (60° Central Angle)

Span Ft	Span In	Rise Ft	Rise In	Inside Radius Ft	Inside Radius In	Number Required Per Course: No. 1 Wedge	No. 1-X Wedge	Straight	Total
17	0	2	3 11/32	17	0	37	39	—	76
17	3	2	3 23/32	17	3	36	41	—	77
17	6	2	4 1/8	17	6	35	43	—	78
17	9	2	4 17/32	17	9	34	45	—	79
18	0	2	4 15/16	18	0	33	48	—	81
18	3	2	5 11/32	18	3	32	50	—	82
18	6	2	5 3/4	18	6	31	52	—	83
18	9	2	6 5/32	18	9	30	54	—	84
19	0	2	6 17/32	19	0	29	56	—	85
19	3	2	6 15/16	19	3	28	58	—	86
19	6	2	7 11/32	19	6	27	60	—	87
19	9	2	7 3/4	19	9	26	62	—	88
20	0	2	8 5/32	20	0	25	64	—	89
20	3	2	8 9/16	20	3	24	66	—	90
20	6	2	8 31/32	20	6	23	68	—	91
20	9	2	9 11/32	20	9	22	70	—	92
21	0	2	9 3/4	21	0	21	72	—	93
21	3	2	10 5/32	21	3	19	75	—	94
21	6	2	10 9/16	21	6	18	77	—	95
21	9	2	10 31/32	21	9	17	79	—	96
22	0	2	11 3/8	22	0	16	81	—	97
22	3	2	11 25/32	22	3	15	83	—	98
22	6	3	0 3/16	22	6	14	85	—	99
22	9	3	0 9/16	22	9	13	87	—	100
23	0	3	0 31/32	23	0	12	89	—	101
23	3	3	1 3/8	23	3	12	91	—	103
23	6	3	1 25/32	23	6	10	94	—	104
23	9	3	2 3/16	23	9	9	96	—	105
24	0	3	2 19/32	24	0	8	98	—	106
24	3	3	3	24	3	7	100	—	107
24	6	3	3 3/8	24	6	6	102	—	108
24	9	3	3 25/32	24	9	5	104	—	109
25	0	3	4 3/16	25	0	4	106	—	110
25	6	3	5	25	6	2	110	—	112
26	0	3	5 13/16	26	0	—	113	1	114
26	6	3	6 19/32	26	6	—	113	3	116
27	0	3	7 13/32	27	0	—	113	5	118
27	6	3	8 7/32	27	6	—	113	7	120
28	0	3	9	28	0	—	113	9	122
28	6	3	9 13/16	28	6	—	113	11	124
29	0	3	10 5/8	29	0	—	113	14	127
29	6	3	11 7/16	29	6	—	113	16	129
30	0	4	0 7/32	30	0	—	113	18	131
30	6	4	1 1/32	30	6	—	113	20	133

ARCH COMBINATIONS

15 Inch Arch Thickness — 3 Inch Wedge Brick
15 x 6 x 3 or 15 x 9 x 3 Inch
1.608 Inch (1 19/32 Inch) Rise Per Foot of Span
(60° Central Angle)

Span Ft	Span In	Rise Ft	Rise In	Inside Radius Ft	Inside Radius In	Number Required Per Course: No. 2 Wedge	No. 1 Wedge	No. 1-X Wedge	Total
6	3		10 1/16	6	3	32	—	—	32
6	6		10 7/16	6	6	31	2	—	33
6	9		10 27/32	6	9	30	4	—	34
7	0		11 1/4	7	0	28	7	—	35
7	3		11 21/32	7	3	27	9	—	36
7	6	1	0 1/16	7	6	26	11	—	37
7	9	1	0 15/32	7	9	25	13	—	38
8	0	1	0 7/8	8	0	24	15	—	39
8	3	1	1 1/4	8	3	23	17	—	40
8	6	1	1 21/32	8	6	22	19	—	41
8	9	1	2 1/16	8	9	21	21	—	42
9	0	1	2 15/32	9	0	20	23	—	43
9	3	1	2 7/8	9	3	19	25	—	44
9	6	1	3 9/32	9	6	18	27	—	45
9	9	1	3 11/16	9	9	17	29	—	46
10	0	1	4 1/16	10	0	16	32	—	48
10	3	1	4 15/32	10	3	15	34	—	49
10	6	1	4 7/8	10	6	14	36	—	50
10	9	1	5 9/32	10	9	13	38	—	51
11	0	1	5 11/16	11	0	12	40	—	52
11	3	1	6 3/32	11	3	11	42	—	53
11	6	1	6 1/2	11	6	10	44	—	54
11	9	1	6 7/8	11	9	9	46	—	55
12	0	1	7 9/32	12	0	8	48	—	56
12	3	1	7 11/16	12	3	7	50	—	57
12	6	1	8 3/32	12	6	5	53	—	58
12	9	1	8 1/2	12	9	4	55	—	59
13	0	1	8 29/32	13	0	3	57	—	60
13	3	1	9 5/16	13	3	2	59	—	61
13	6	1	9 11/16	13	6	1	61	—	62
13	9	1	10 3/32	13	9	—	63	—	63
14	0	1	10 1/2	14	0	—	62	2	64
14	3	1	10 29/32	14	3	—	61	4	65
14	6	1	11 5/16	14	6	—	60	6	66
14	9	1	11 23/32	14	9	—	59	8	67
15	0	2	0 1/8	15	0	—	58	10	68
15	3	2	0 17/32	15	3	—	57	13	70
15	6	2	0 29/32	15	6	—	56	15	71
15	9	2	1 5/16	15	9	—	55	17	72
16	0	2	1 23/32	16	0	—	54	19	73
16	3	2	2 1/8	16	3	—	53	21	74
16	6	2	2 17/32	16	6	—	52	23	75
16	9	2	2 15/16	16	9	—	51	25	76
17	0	2	3 11/32	17	0	—	49	28	77
17	3	2	3 23/32	17	3	—	48	30	78
17	6	2	4 1/8	17	6	—	47	32	79
17	9	2	4 17/32	17	9	—	46	34	80

15 Inch Arch Thickness — 3 Inch Wedge Brick
15 x 6 x 3 or 15 x 9 x 3 Inch — Continued
1.608 Inch (1 19/32 Inch) Rise Per Foot of Span
(60° Central Angle)

Span Ft	Span In	Rise Ft	Rise In	Inside Radius Ft	Inside Radius In	Number Required Per Course: No. 1 Wedge	No. 1-X Wedge	Straight	Total
18	0	2	4 15/16	18	0	45	36	—	81
18	3	2	5 11/32	18	3	44	38	—	82
18	6	2	5 3/4	18	6	43	40	—	83
18	9	2	6 5/32	18	9	42	42	—	84
19	0	2	6 17/32	19	0	41	44	—	85
19	3	2	6 15/16	19	3	40	46	—	86
19	6	2	7 11/32	19	6	39	48	—	87
19	9	2	7 3/4	19	9	38	50	—	88
20	0	2	8 5/32	20	0	37	52	—	89
20	3	2	8 9/16	20	3	36	54	—	90
20	6	2	8 31/32	20	6	35	57	—	92
20	9	2	9 11/32	20	9	34	59	—	93
21	0	2	9 3/4	21	0	33	61	—	94
21	3	2	10 5/32	21	3	32	63	—	95
21	6	2	10 9/16	21	6	31	65	—	96
21	9	2	10 31/32	21	9	30	67	—	97
22	0	2	11 3/8	22	0	29	69	—	98
22	3	2	11 25/32	22	3	28	71	—	99
22	6	3	0 3/16	22	6	26	74	—	100
22	9	3	0 9/16	22	9	25	76	—	101
23	0	3	0 31/32	23	0	24	78	—	102
23	3	3	1 3/8	23	3	23	80	—	103
23	6	3	1 25/32	23	6	22	82	—	104
23	9	3	2 3/16	23	9	21	84	—	105
24	0	3	2 19/32	24	0	20	86	—	106
24	3	3	3	24	3	19	88	—	107
24	6	3	3 3/8	24	6	18	90	—	108
24	9	3	3 25/32	24	9	17	92	—	109
25	0	3	4 3/16	25	0	16	94	—	110
25	3	3	4 19/32	25	3	15	96	—	111
25	6	3	5	25	6	14	98	—	112
25	9	3	5 13/32	25	9	13	100	—	113
26	0	3	5 13/16	26	0	12	103	—	115
26	3	3	6 3/16	26	3	11	105	—	116
26	6	3	6 19/32	26	6	10	107	—	117
26	9	3	7	26	9	9	109	—	118
27	0	3	7 13/32	27	0	8	111	—	119
27	3	3	7 13/16	27	3	7	113	—	120
27	6	3	8 7/32	27	6	6	115	—	121
27	9	3	8 5/8	27	9	4	118	—	122
28	0	3	9	28	0	3	120	—	123
28	3	3	9 13/32	28	3	2	122	—	124
28	6	3	9 13/16	28	6	1	124	—	125
28	9	3	10 7/32	28	9	—	126	—	126
29	0	3	10 5/8	29	0	—	126	1	127
29	6	3	11 7/16	29	6	—	126	3	129
30	0	4	0 7/32	30	0	—	126	5	131
31	0	4	1 27/32	31	0	—	126	9	135

18 Inch Arch Thickness — 3 Inch Wedge Brick
18 x 6 x 3 or 18 x 9 x 3 Inch
1.608 Inch (1 19/32 Inch) Rise Per Foot of Span
(60° Central Angle)

Span Ft	Span In	Rise Ft	Rise In	Inside Radius Ft	Inside Radius In	Number Required Per Course: No. 2 Wedge	No. 1 Wedge	No. 1-X Wedge	Total
8	0	1	0 7/8	8	0	36	4	—	40
8	3	1	1 1/4	8	3	35	6	—	41
8	6	1	1 21/32	8	6	34	8	—	42
8	9	1	2 1/16	8	9	32	11	—	43
9	0	1	2 15/32	9	0	31	13	—	44
9	3	1	2 7/8	9	3	30	15	—	45
9	6	1	3 9/32	9	6	29	17	—	46
9	9	1	3 11/16	9	9	29	19	—	48
10	0	1	4 1/16	10	0	28	21	—	49
10	3	1	4 15/32	10	3	27	23	—	50
10	6	1	4 7/8	10	6	25	26	—	51
10	9	1	5 9/32	10	9	24	28	—	52
11	0	1	5 11/16	11	0	23	30	—	53
11	3	1	6 3/32	11	3	22	32	—	54
11	6	1	6 1/2	11	6	21	34	—	55
11	9	1	6 7/8	11	9	20	36	—	56
12	0	1	7 9/32	12	0	19	38	—	57
12	3	1	7 11/16	12	3	18	40	—	58
12	6	1	8 3/32	12	6	17	42	—	59
12	9	1	8 1/2	12	9	16	44	—	60
13	0	1	8 29/32	13	0	15	46	—	61
13	3	1	9 5/16	13	3	14	48	—	62
13	6	1	9 11/16	13	6	13	50	—	63
13	9	1	10 3/32	13	9	12	52	—	64
14	0	1	10 1/2	14	0	11	54	—	65
14	3	1	10 29/32	14	3	9	57	—	66
14	6	1	11 5/16	14	6	8	59	—	67
14	9	1	11 23/32	14	9	7	61	—	68
15	0	2	0 1/8	15	0	7	63	—	70
15	3	2	0 17/32	15	3	6	65	—	71
15	6	2	0 29/32	15	6	5	67	—	72
15	9	2	1 5/16	15	9	4	69	—	73
16	0	2	1 23/32	16	0	2	72	—	74
16	3	2	2 1/8	16	3	1	74	—	75
16	6	2	2 17/32	16	6	—	76	—	76
16	9	2	2 15/16	16	9	—	75	2	77
17	0	2	3 11/32	17	0	—	74	4	78
17	3	2	3 23/32	17	3	—	72	7	79
17	6	2	4 1/8	17	6	—	71	9	80
17	9	2	4 17/32	17	9	—	70	11	81
18	0	2	4 15/16	18	0	—	69	13	82
18	3	2	5 11/32	18	3	—	68	15	83
18	6	2	5 3/4	18	6	—	67	17	84
18	9	2	6 5/32	18	9	—	66	19	85
19	0	2	6 17/32	19	0	—	65	21	86
19	3	2	6 15/16	19	3	—	64	23	87
19	6	2	7 11/32	19	6	—	63	25	88
19	9	2	7 3/4	19	9	—	62	27	89

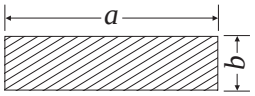
18 Inch Arch Thickness — 3 Inch Wedge Brick
18 x 6 x 3 or 18 x 9 x 3 Inch — Continued
1.608 Inch (1 19/32 Inch) Rise Per Foot of Span
(60° Central Angle)

Span Ft	Span In	Rise Ft	Rise In	Inside Radius Ft	Inside Radius In	Number Required Per Course: No. 2 Wedge	No. 1 Wedge	No. 1-X Wedge	Total
20	0	2	8 5/32	20	0	—	61	29	90
20	3	2	8 9/16	20	3	—	60	32	92
20	6	2	8 31/32	20	6	—	59	34	93
20	9	2	9 11/32	20	9	—	58	36	94
21	0	2	9 3/4	21	0	—	57	38	95
21	3	2	10 5/32	21	3	—	56	40	96
21	6	2	10 9/16	21	6	—	55	42	97
21	9	2	10 31/32	21	9	—	54	44	98
22	0	2	11 3/8	22	0	—	53	46	99
22	3	2	11 25/32	22	3	—	52	48	100
22	6	3	0 3/16	22	6	—	50	51	101
22	9	3	0 9/16	22	9	—	49	53	102
23	0	3	0 31/32	23	0	—	48	55	103
23	3	3	1 3/8	23	3	—	47	57	104
23	6	3	1 25/32	23	6	—	46	59	105
23	9	3	2 3/16	23	9	—	45	61	106
24	0	3	2 19/32	24	0	—	44	63	107
24	3	3	3	24	3	—	43	65	108
24	6	3	3 3/8	24	6	—	42	67	109
24	9	3	3 25/32	24	9	—	41	69	110
25	0	3	4 3/16	25	0	—	40	71	111
25	3	3	4 19/32	25	3	—	39	73	112
25	6	3	5	25	6	—	38	75	113
25	9	3	5 13/32	25	9	—	37	78	115
26	0	3	5 13/16	26	0	—	36	80	116
26	3	3	6 3/16	26	3	—	35	82	117
26	6	3	6 19/32	26	6	—	34	84	118
26	9	3	7	26	9	—	33	86	119
27	0	3	7 13/32	27	0	—	32	88	120
27	3	3	7 13/16	27	3	—	31	90	121
27	6	3	8 7/32	27	6	—	30	92	122
27	9	3	8 5/8	27	9	—	29	94	123
28	0	3	9	28	0	—	27	97	124
28	3	3	9 13/32	28	3	—	26	99	125
28	6	3	9 13/16	28	6	—	25	101	126
28	9	3	10 7/32	28	9	—	24	103	127
29	0	3	10 5/8	29	0	—	23	105	128
29	3	3	11 1/32	29	3	—	22	107	129
29	6	3	11 7/16	29	6	—	21	109	130
29	9	3	11 13/16	29	9	—	20	111	131
30	0	4	0 7/32	30	0	—	19	113	132
30	3	4	0 5/8	30	3	—	18	115	133
30	6	4	1 1/32	30	6	—	17	117	134
30	9	4	1 7/16	30	9	—	16	119	135
31	0	4	1 27/32	31	0	—	15	122	137
31	3	4	2 1/4	31	3	—	14	124	138
31	6	4	2 21/32	31	6	—	13	126	139
31	9	4	3 1/32	31	9	—	12	128	140
32	0	4	3 7/16	32	0	—	11	130	141

AREA AND VOLUME

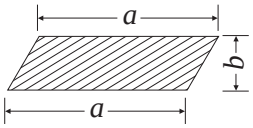
The following simple formulas make it possible to calculate the area and volume associated with most refractory structures. No matter how complex the shape of a figure, it is possible to derive a working approximation by dividing it by straight lines and arcs into a distinct number of units whose areas may be calculated and summed by simple arithmetic. Volumes of regular figures will equal the area of a surface multiplied by its length or height. Volumes of shells are inside volume subtracted from outside volume.

RECTANGLE



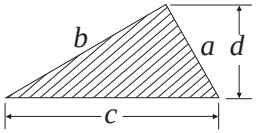
Area = ab

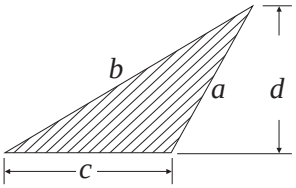
PARALLELOGRAM



Area = ab

TRIANGLE



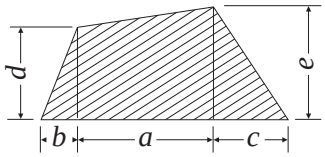


Area = $\frac{1}{2}cd$

Area = $\sqrt{s(s-a)\,(s-b)\,(s-c)}$

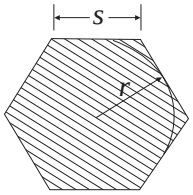
when $s = \frac{1}{2}(a + b + c)$

TRAPEZIUM



Area = $\frac{1}{2}$ [s(e+d)+bd+ce]

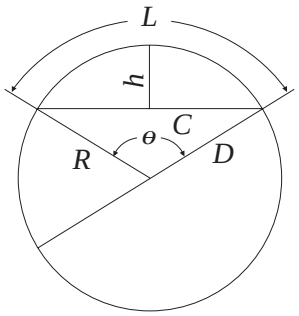
REGULAR POLYGON



Area = $\frac{1}{2}$ nsr
when n = Number of sides

Number of Sides	Area
6	$2.5981s^2 = 3.4641r^2$
6	$4.8284s^2 = 3.3137r^2$
6	$6.1818s^2 = 3.2757r^2$
10	$7.6942s^2 = 3.2492r^2$
12	$11.1962s^2 = 3.2154r^2$

CIRCLE



θ (Theta) = included angle in degrees.

π (pi) = 3.1416

Circumference = $\pi D = 2\pi R = 2\sqrt{\pi \times \text{Area}}$

Diameter, $D = 2R = 2\sqrt{\text{Area} \div \pi}$

Radius, $R = \frac{1}{2} D = \sqrt{\text{Area} \div \pi}$

Radius, R = Circumference $\div 2\pi$

Radius, $R = \frac{(C \div 2)^2 + h^2}{2h}$

Area = $0.7854D^2 = \pi R^2$

Chord. $C = 2\sqrt{h(D-h)} = 2R \times \text{sine } \frac{1}{2}\theta$

Height of Arc, $h = R - \sqrt{R^2 - (C \div 2)^2}$

Height of Arc, $h = R - \frac{1}{2}\sqrt{(2R+C)(2R-C)}$

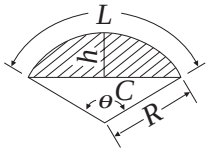
Length of Arc, $L = \frac{\theta}{360} \times 2\pi R = 0.017453R\theta$

$\frac{1}{2}\theta = 28.648L \div R$

Sine $\frac{1}{2}\theta = C \div 2R$

1° = 0.017453 Radians, 1 radian = 57.296°

SEGMENT OF A CIRCLE

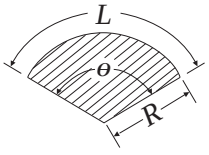


Tangent $\frac{1}{4}\theta = \frac{2h}{C}$

Area = $\frac{1}{2}[LR - C(R-h)]$

Area = $\pi R^2 \times \frac{\theta}{360} - \frac{C(R-h)}{2}$

SECTOF OF A CIRCLE



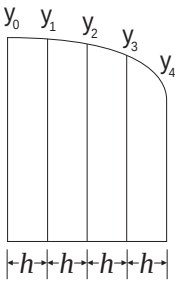
Area = $\frac{1}{2}LR$

Area = $\pi R^2 \times \frac{\theta}{360}$

Area = $0.0087266R^2\theta$

AREA AND VOLUME

THE TRAPEZOIDAL RULE

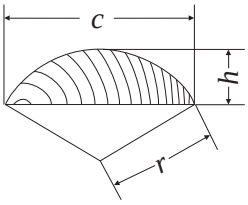


Area = $h(\frac{1}{2}y_0 + y_1 + y_2 + y_3 + \frac{1}{2}y_4)$ approximately

h = distance between equally spaced ordinates

y_n = length of appropriate ordinate

SEGMENT OF A SPHERE



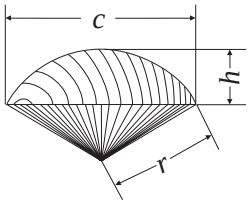
Spherical Surface =
$2\pi rh = 0.7854(c^2+4h^2)$

Total Surface = $0.7854(c^2+8rh)$

Volume = $\frac{1}{3}\pi h^2(3r-h) = 1.0472h^2(3r-h)$

Volume = $\frac{1}{24}\pi h(3c^2+4h^2) = 0.1309h(3c^2+4h^2)$

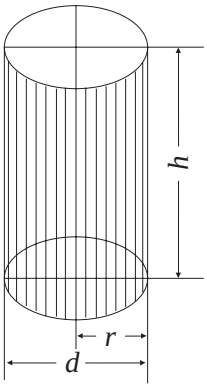
SEGTOR OR A SPHERE



Total Surface = $1.5708r(4h+c)$

Volume = $\frac{2}{3}\pi r^2h = 2.0944r^2h$

CYLINDER



Volume = $\pi h^2(3r-h) = 1.0472h^2(3r-h)$

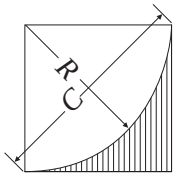
Cylindrical Surface =
$\pi dh = 2\pi rh = 6.2832rh$

Total Surface =
$2\pi r(r+h) = 6.2832r(r+h)$

Volume =
$\pi r^2h = \frac{1}{4}\pi d^2h = 0.7854d^2h$

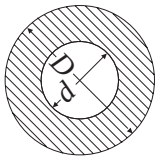
AREA AND VOLUME

SPANDREL



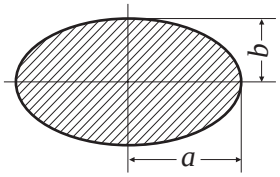
Area = $0.2146R^2$
Area = $0.1073C^2$

CIRCULAR RING



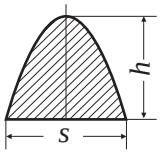
Area = $0.7854(D^2 — d^2)$
Area = $0.7854(D+d)\ (D—d)$

ELLIPSE



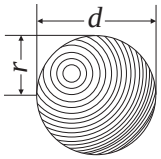
Area = $\pi ab = 3.1416ab$

PARABOLIC SEGMENT



Area = $\frac{2}{3}\ sh$

SPHERE

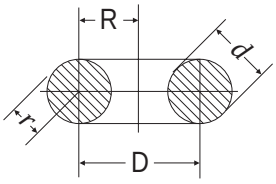


Surface = $4\pi r^2 = 12.566r^2 = \pi d^2$

Volume = $\frac{4}{3}\ \pi r^3 = 4.1888r^3$

Volume = $\frac{1}{6}\ \pi d^3 = 0.5236d^3$

RING OF CIRCULAR CROSS SECTION (Torus)

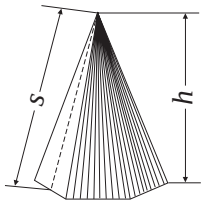


Area of Surface = $4\pi^2 Rr = 39.478Rr$

Volume = $2\pi^2 Rr^2 = 19.739Rr^2$

AREA AND VOLUME

PYRAMID



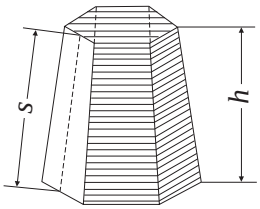
A = area of base

P = perimeter of base

Lateral Area = $\frac{1}{2}Ps$

Volume = $\frac{1}{3}$ Ah

FRUSTUM OF A PYRAMID



A = Area of base

a = Area of top

m = Area of midsection

P = Perimeter of base

p = Perimeter of top

Lateral Area = $\frac{1}{2}s(P+p)$

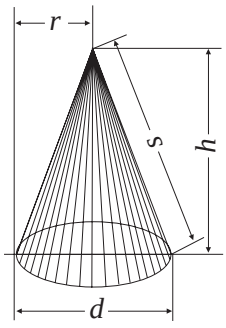
Volume = $\frac{1}{3}h(a+A+\sqrt{aA})$

Volume = $\frac{1}{6}h(a+A+4m)$

CONE

Conical Area = $\pi rs = \pi r\sqrt{r^2+h^2}$

Volume = $\frac{1}{3}\pi r^2 h$ = $1.0472r^2h$ = $0.2618d^2h$



FRUSTUM OF A CONE

A = Area of base a = Area of top

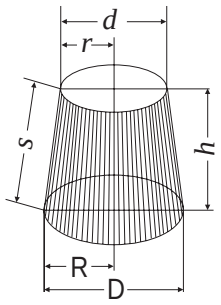
m = Area of midsection

Area of Conical Surface = $\frac{1}{2}\pi s(D+d)$

Volume = $\frac{1}{3}\pi h(r^2 + rR + R^2)$

Volume = $h(a + \sqrt{aA} + A)$

Volume = $\frac{1}{6}h(a + 4m + A)$



REFERENCE TABLE

Decimal Fractions of an Inch for Each 1/64			
Common Fraction	**Decimal**	**Common Fraction**	**Decimal**
		1/2	.5
1/64	.015625	33/64	.515625
1/32	.03125	17/32	.53125
3/64	.046875	35/64	.546875
1/16	.0625	9/16	.5625
5/64	.078125	37/64	.578125
3/32	.09375	19/32	.59375
7/64	.109325	39/64	.609375
1/8	.125	5/8	.625
9/64	.140625	41/64	.640625
5/32	.15625	21/32	.65625
11/64	.171875	43/64	.671875
3/16	.1875	11/16	.6875
13/64	.203125	45/64	.703125
7/32	.21875	23/32	.71875
15/64	.234375	47/64	.734375
1/4	.25	3/4	.75
17/64	.265625	49/64	.765625
9/32	.28125	25/32	.78125
19/64	.296875	51/64	.796875
5/16	.3125	13/16	.8125
21/64	.328125	53/64	.828125
11/32	.34375	27/32	.84375
23/64	.359375	55/64	.859375
3/8	.375	7/8	.875
25/64	.390625	57/64	.890625
13/32	.40625	29/32	.90625
27/64	.421875	59/64	.921875
7/16	.4375	15/16	.9375
29/64	.453125	61/64	.953125
15/32	.46875	31/32	.96875
31/64	.484375	63/64	.984375

REFERENCE TABLE

Conversion Table		
To Convert	**Multiply By:**	**To Obtain:**
BTU	7.7816×10^{2}	foot-pounds
BTU	2.52×10^{2}	gram-calories
BTU	2.52×10^{-1}	kilogram-calories
BTU/Hr	7.0×10^{-2}	gram-cal/sec
°C	(°C x 1.8) + 32	Fahrenheit
centimeters	3.281×10^{-2}	feet
centimeters	3.937×10^{-2}	inches
cubic centimeters	3.531×10^{-5}	cubic feet
cubic centimeters	6.102×10^{-2}	cubic inches
cubic centimeters	1.308×10^{-6}	cubic yards
cubic centimeters	2.642×10^{-4}	gallons (U.S. liquid)
cubic centimeters	1.0×10^{-3}	liters
cubic feet	2.832×10^{4}	cubic centimeters
cubic feet	1.728×10^{3}	cubic inches
cubic feet	2.832×10^{-2}	cubic meters
cubic feet	3.704×10^{-2}	cubic yards
cubic inches	16.39	cubic centimeters
cubic inches	5.787×10^{-4}	cubic feet
cubic inches	1.639×10^{-5}	cubic meters
cubic inches	2.143×10^{-5}	cubic yards
cubic meters	35.31	cubic feet
cubic meters	6.102×10^{4}	cubic inches
cubic meters	1.308	cubic yards
cubic meters	1.0×10^{3}	liters
cubic meters	2.642×10^{2}	gallons (U.S. liquid)
cubic yards	7.646×10^{5}	cubic centimeters
cubic yards	27	cubic feet
cubic yards	0.7646	cubic meters
°Fahrenheit	.556(F-32)	Centigrade or Celsius
feet	30.48	centimeters
feet	0.3048	meters
feet	3.048×10^{2}	millimeters
gallons	3.785×10^{3}	cubic centimeters
gallons	0.134	cubic feet
gallons	3.785×10^{-3}	cubic meters
gallons	4.951×10^{-3}	cubic yards
gallons	3.785	liters
grams	3.527×10^{-2}	ounces (avdp.)
grams	2.205×10^{-3}	pounds
grams/cm^3	62.43	pounds/ft^3
grams/cm^2	2.0481	pounds/sq/ft
grams-calories	3.968×10^{-3}	BTU

REFERENCE TABLE

Conversion Table - continued		
To Convert	**Multiply By:**	**To Obtain:**
inches	2.540	centimeters
inches	25.4	millimeters
kilograms	2.2046	pounds
kilograms/meters^3	6.243 x 10^{-2}	pounds/ft^3
kilometers	0.6214	miles (statute)
liters	3.531 x 10^{-2}	cubic feet
liters	61.02	cubic inches
liters	1.0 x 10^{-3}	cubic meters
liters	1.308 x 10^{-3}	cubic yards
liters	0.2642	gallons (U.S. liquid)
miles (statute)	1.609	kilometers
millimeters	3.937 x 10^{-2}	inches
ounces	28.349	grams
pounds	4.536 x 10^{2}	grams
pounds	0.4536	kilograms
pounds of water	27.68	cubic inches
pounds of water	0.1198	gallons
pounds/ft^3	1.602 x 10^{-2}	grams/cm^3
pounds/ft^3	16.02	kgs/meter^3
pounds/in^3	27.68	grams/cm^3
pounds/in^2	7.03 x 10^{-2}	kgs/cm^2
quarts (liquid)	9.464 x 10^{2}	cubic centimeters
quarts (liquid)	3.342 x 10^{-2}	cubic feet
quarts (liquid)	1.238 x 10^{-3}	cubic yards
quarts (liquid)	0.9463	liters
square centimeters	0.1550	square inches
square feet	9.29 x 10^{2}	square centimeters
square inches	6.452	square centimeters
tons (metric)	1000	kilograms
tons (metric)	2.205 x 10^{3}	pounds
tons (short)	9.0718 x 10^{2}	kilograms
tons (short)	0.9078	tons (metric)
yards	0.9144	meters

REFERENCE TABLE

Temperature Scale Conversions

to °C	Convert F or C	to °F
-17.78	**0**	32
-12.22	**10**	50
-6.67	**20**	68
-1.11	**30**	86
0.00	**32**	90
4.44	**40**	104
10.00	**50**	122
15.56	**60**	140
21.11	**70**	158
26.67	**80**	176
32.22	**90**	194
37.78	**100**	212
43.33	**110**	230
48.89	**120**	248
54.44	**130**	266
60.00	**140**	284
65.56	**150**	302
71.11	**160**	320
76.67	**170**	338
82.22	**180**	356
87.78	**190**	374
93.33	**200**	392
98.89	**210**	410
100.0	**212**	414
104.4	**220**	428
110.0	**230**	446
115.6	**240**	464
121.1	**250**	482
126.7	**260**	500
132.2	**270**	518
137.8	**280**	536
143.3	**290**	554
148.9	**300**	572
154.4	**310**	590
160.0	**320**	608
165.6	**330**	626
171.1	**340**	644
176.7	**350**	662
182.2	**360**	680
187.8	**370**	698
193.3	**380**	716
198.9	**390**	734
204.4	**400**	752
215.6	**420**	788
226.7	**440**	824
237.8	**460**	860
248.9	**480**	896
260.0	**500**	932
271.1	**520**	968
282.2	**540**	1004
293.3	**560**	1040
304.4	**580**	1076

to °C	Convert F or C	to °F
315.6	**600**	1112
326.7	**620**	1148
337.8	**640**	1184
348.9	**660**	1220
360.0	**680**	1256
371.1	**700**	1292
398.9	**750**	1382
426.7	**800**	1472
454.4	**850**	1562
482.2	**900**	1652
510.0	**950**	1742
537.9	**1000**	1832
565.6	**1050**	1922
593.3	**1100**	2012
621.1	**1150**	2102
648.9	**1200**	2192
676.7	**1250**	2282
704.4	**1300**	2372
732.2	**1350**	2462
760.0	**1400**	2552
787.8	**1450**	2642
815.6	**1500**	2732
843.3	**1550**	2922
871.1	**1600**	2912
898.9	**1650**	3002
926.7	**1700**	3092
954.4	**1750**	3182
982.2	**1800**	3272
1010	**1850**	3362
1038	**1900**	3452
1066	**1950**	3542
1093	**2000**	3632
1121	**2050**	3722
1149	**2100**	3812
1177	**2150**	3902
1204	**2200**	3992
1232	**2250**	4082
1260	**2300**	4172
1288	**2350**	4262
1316	**2400**	4352
1343	**2450**	4442
1371	**2500**	4532
1427	**2600**	4712
1482	**2700**	4892
1538	**2800**	5072
1593	**2900**	5252
1649	**3000**	5432
1704	**3100**	5612
1760	**3200**	5792
1816	**3300**	5972
1871	**3400**	6152
1927	**3500**	6332
1982	**3600**	6512

GLOSSARY

Abrasion of Refractories: Wearing away of the surfaces of refractory bodies in service by the scouring action of moving solids.

Absorption: As applied to ceramic products, the weight of water which can be absorbed by the ware, expressed as a percentage of the weight of the dry ware.

Abutment: The structural portion of a furnace which withstands the thrust of an arch.

Acid-Proof Brick: Brick having low porosity and permeability, and high resistance to chemical attack or penetration by most commercial acids and some other corrosive chemicals.

Acid Refractories: Refractories such as silica brick which contain a substantial proportion of free silica and which when heated, can react chemically with basic refractories, slags and fluxes.

Aggregate: As applied to refractories, a ground mineral material, consisting of particles of various sizes, used with much finer sizes for making formed or monolithic bodies.

Air-Ramming*: A method of forming refractory shapes, furnace hearths, or other furnace parts by means of pneumatic hammers.

Air-Setting Refractories: Compositions of ground refractory materials which develop a strong bond upon drying. These refractories include mortars, plastic refractories, ramming mixes and gunning mixes. They are marketed in both wet and dry condition. The dry compositions require tempering with water to develop the necessary consistency.

Alumina: Al_2O_3, the oxide of aluminum; melting point 3,720°F (2,050°C); in combination with H_2O (water), alumina forms the minerals diaspore, bauxite and gibbsite; in combination with SiO_2 and H_2O, alumina forms kaolinite and other clay minerals.

Alumina-Silica Refractories: Refractories consisting essentially of alumina and silica, and including high-alumina, fireclay and kaolin refractories.

Amorphous: Lacking crystalline structure or definite molecular arrangement; without definite external form.

Andalusite: A brown, yellow, green, red or gray orthorhombic mineral; Al_2SiO_5. Specific gravity 3.1 - 3.2. Decomposes on heating, beginning at about 2,460°F (1,350°C) to form mullite ($Al_6Si_2O_{13}$) and free silica.

Anneal: To remove internal stress by first heating and then cooling slowly.

Arc: As applied to circles, any portion of a circumference; as applied to electricity, the luminous bridge formed by the passage of a current across a gap between two conductors or terminals.

Arch, Flat: In furnace construction, a flat structure spanning an opening and supported by abutments at its extremities. The arch is formed by a number of special tapered brick, and the brick assembly is held in place by the keying action of the brick. Also called a jack arch.

Arch, Sprung: In furnace construction, a bowed or curved structure which is supported by abutments at the sides or ends only, and which usually spans an opening or space between two walls.

Arch, Suspended: A furnace roof consisting of brick shapes suspended from overhead supporting members.

Arch Brick: A brick shape having six plane faces (two sides, two edges and two ends), in which two faces (the sides) are inclined toward each other and one edge face is narrower than the other.

Ash: The noncombustible residue which remains after burning a fuel or other combustible material.

Attrition: Wearing away by friction; abrasion.

Auger Machine: A machine for extruding ground clays in moist and stiffly plastic form, through a die by means of a revolving screw or auger.

Baddeleyite: A mineral composed of zirconia (ZrO_2). Specific gravity 5.8. Melting point 4,890°F (2,700°C).
Bagasse: The fibrous material remaining after the extraction of the juice from sugar cane.

Ball Clay: A highly plastic refractory bond clay of very fine grain, which has a wide range of vitrification and which burns to a light color. Often high in carbonaceous matter.

Basic Refractories: Refractories which consist essentially of magnesia, lime, chrome ore or mixtures of two or more of these and, when heated, can react chemically with acid refractories, slags and fluxes.

Bauxite: An off-white, grayish, brown, yellow, or reddish-brown rock composed of a mixture of various amorphous or crystalline hydrous aluminum oxides and aluminum hydroxides (principally gibbsite, some boehmite), and containing impurities in the form of free silica, silt, iron hydroxides, and especially clay minerals; a highly aluminous laterite.

Bauxitic Clay: A natural mixture of bauxite and clay containing not less than 47% nor more than 65% alumina on a calcined basis.

Bentonite: A kind of clay derived from volcanic ash and characterized by extreme fineness of grain. Its main constituent is the clay mineral montmorillonite. It is somewhat variable in composition and usually contains 5 to 10% of alkalies or alkaline earth oxides. One type has the capacity for absorption of large amounts of water, with enormous increase in volume.

Bessemer Process: An older process for making steel by blowing air through molten pig iron, whereby most of the carbon and impurities are removed by
oxidation. The process is carried out in a vessel known as a converter.

Bloating: Swelling of a refractory when in the thermo-plastic state, caused by temperatures in excess of that for which the material is intended. Bloating impairs the useful properties of refractories. An exception to this rule occurs in one type of ladle brick (See Secondary Expansion).

British Thermal Unit (BTU): The amount of heat required to raise the temperature of one pound of water one degree Fahrenheit at standard barometric pressure.

Brucite: A mineral having the composition $Mg(OH)_2$. Specific gravity 2.38 - 2.40. A soft, waxy, translucent mineral which dissociates at moderate temperatures with the formation of MgO.

Bunker Oil: A heavy fuel oil formed by stabilization of the residual oil remaining after the cracking of crude petroleum.

Burn: The degree of heat treatment to which refractory brick are subjected in the firing

* ASTM Standard Definitions C 71-88; or ASTM "Tentative Definitions" are used where applicable.

process. Also, the degree to which desired physical and chemical changes have been developed in the firing of a refractory material.

Burning (Firing) of Refractories*: The final heat treatment in a kiln to which refractory brick are subjected in the process of manufacture, for the purpose of developing bond and other necessary physical and chemical properties.

Calcination: A heat treatment to which many ceramic raw materials are subjected, preparatory to further processing or use, for the purpose of driving off volatile chemically combined components and affecting physical changes.

Calcite: A mineral having the composition $CaCO_3$. Specific gravity 2.71 for pure calcite crystals. Calcite is the essential constituent of limestone, chalk and marble and a minor constituent of many other rocks.

Calorie (Large): One thousand small calories.

Calorie (Small): The amount of heat required to raise the temperature of one gram of water one degree Centigrade at standard barometric pressure.

Cap or Crown: The arched roof of a furnace, especially a glass tank furnace.

Carbon Deposition: The deposition of amorphous carbon, resulting from the decomposition of carbon monoxide gas into carbon dioxide and carbon within a critical temperature range. When deposited within the pores of refractory brick, carbon can build up sufficient pressure to destroy the bond and cause the brick to disintegrate.

Carbon Refractory*: A manufactured refractory comprised substantially or entirely of carbon (including graphite).

Carbon-Ceramic Refractory*: A manufactured refractory comprised of carbon (including graphite) and one or more ceramic materials such as fire clay and silicon carbide.

Castable Refractory: A mixture of a heat-resistant aggregate and a heat-resistant hydraulic cement. For use, it is mixed with water and rammed, cast or gunned into place.

Catalyst: A substance which causes or accelerates a chemical change without being permanently affected by the reaction.

Cement: A finely divided substance which is workable when first prepared, but which becomes hard and stonelike as a result of chemical reaction or crystallization; also, the compact groundmass which surrounds and binds together the larger fragments or particles in sedimentary rocks.

Ceramic Bond: In a ceramic body, the mechanical strength developed by a heat treatment which causes the cohesion of adjacent particles.

Ceramics: Originally, ware formed from clay and hardened by the action of heat; the art of making such ware. Current usage includes all refractory materials, cement, lime, plaster, pottery, glass, enamels, glazes, abrasives, electrical insulating products and thermal insulating products made from clay or from other inorganic, nonmetallic mineral substances.

Checkers: Brick used in furnace regenerators to recover heat from outgoing hot gases and later to transmit the heat to cold air or gas entering the furnace; so-called because the brick are arranged in checkerboard patterns, with alternating brick units and open spaces.

Chemically-Bonded Brick: Brick manufactured by processes in which mechanical strength is imparted by chemical bonding agents instead of by firing.

Chord: As applied to circles, a straight line joining any two points on a circumference.

Chrome Brick*: A refractory brick manufactured substantially or entirely of chrome ore.

Chrome-Magnesite Brick: A refractory brick which can be either fired or chemically bonded, manufactured substantially of a mixture of chrome ore and dead-burned magnesite, in which the chrome ore predominates by weight.

Chrome Ore: A rock having as its essential constituent the mineral chromite or chrome spinel, which is a combination of FeO and MgO with Cr_2O_3, Al_2O_3, and usually a small proportion of Fe_2O_3. The composition, which is represented by the formula $(Fe, Mg)(Cr, Al)_2O_4$, is extremely variable. Refractory grade chrome ore has only minor amounts of accessory minerals and has physical properties that are suitable for the manufacture of refractory products.

Clay: A natural mineral aggregate, consisting essentially of hydrous aluminum silicates (See also Fire Clay).

Colloid: (1) A particle-size range of less than 0.00024 mm, i.e. smaller than clay size; (2) originally, any finely divided substance that does not occur in crystalline form; in a more modern sense, any fine-grained material in suspension, or any such material that can be easily suspended.

Conductivity: The property of conducting heat, electricity or sound.

Congruent Melting: The change of a substance, when heated, from the solid form to a liquid of the same composition. The melting of ice is an example of congruent melting.

Convection: The transfer of heat by the circulation or movement of the heated parts of a liquid or gas.

Corbel: A supporting projection of the face of a wall; an arrangement of brick in a wall in which each course projects beyond the one immediately below it to form a support, baffle or shelf.

Corrosion of Refractories: Deterioration or wearing away of refractory bodies largely at their surface through chemical action of external agencies.

Corundum: A natural or synthetic mineral theoretically consisting solely of alumina (Al_2O_3). Specific gravity 4.00 - 4.02. Melting point 3,720°F (2,050°C). Hardness 9.

Course: A horizontal layer or row of brick in a structure.

Cristobalite: A mineral form of silica (SiO_2); stable from 2,678°F (1,470°C) to the melting point, 3,133°F (1,723°C). Specific gravity 2.32. Cristobalite is an important constituent of silica brick.

Crown: A furnace roof, especially one which is dome-shaped; the highest point of an arch.

Cryptocrystalline: A crystalline structure in which the individual crystals are so small that they cannot be made visible by means of the petrographic microscope, but can be seen with an electron microscope. Various so-called amorphous minerals are actually cryptocrystalline.

Crystal: (1) A homogeneous, solid body of a chemical element, compound or isomorphous mixture having a regularly repeating atomic arrangement that can be outwardly expressed by plane faces; (2) rock crystal.

* ASTM Standard Definitions C 71-88; or ASTM “Tentative Definitions” are used where applicable.

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Crystalline: Composed of crystals.

Dead-Burned Dolomite: A coarsely granular refractory material prepared by firing raw dolomite with or without additives, to a temperature above 2,800°F (1,538°C), so as to form primarily lime and magnesia in a matrix that provides resistance to hydration and carbonation.

Dead-Burned Magnesite: A coarsely granular dense refractory material composed essentially of periclase (crystalline magnesium oxide); prepared by firing raw magnesite (or other substances convertible to magnesia) at temperatures sufficiently high to drive off practically all of the volatile materials, and to affect complete shrinkage of the resultant magnesia, thereby producing hard dense grains which are entirely inert to atmospheric hydration and carbonation and free from excessive shrinkage when again subjected to a high temperature.

De-airing: Removal of air from firebrick mixes in an auger machine before extrusion by means of a partial vacuum.

Density: The mass of a unit volume of a substance. It is usually expressed either in grams per cubic centimeter or in pounds per cubic foot.

Devitrification: The change from a glassy to a crystalline condition.

Diaspore: A mineral having the theoretical composition $Al_2O_3 \cdot H_2O$ (85% alumina; 15% water). Specific gravity 3.45.

Diaspore Clay: A rock consisting essentially of diaspore bonded by flint clay. Commercial diaspore clay of the purest grade usually contains between 70 and 80% alumina after calcination.

Diatomaceous Earth: A hydrous form of silica which is soft, light in weight and consists mainly of microscopic shells of diatoms or other marine organisms. It is widely used for furnace insulation.

Direct Bonded Basic Brick: A fired refractory in which the grains are joined predominantly by a solid state of diffusion mechanism.

Direct Bonded Magnesite-Chrome Brick: A term applied to fired magnesite-chrome compositions when the amount of bonding mineral phase (silicates, forsterite, etc.) present in the matrix is sufficiently low that under microscopic examination the chrome ore grains appear to be bonded "directly" to the magnesite grains. The actual bonding mechanism in this instance is usually a combination of types, of which one may be direct (diffusion) bonding.

Division Wall: Wall dividing any two major sections of a furnace.

Dobie: A molded block of ground clay or other refractory material, usually crudely formed and either raw or fired.

Dolomite: The mineral calcium-magnesium carbonate, $CaMg(CO_3)_2$. Specific gravity 2.85 - 2.95. The rock called dolomite consists mainly of the mineral of that name and can also contain a large amount of the mineral calcite ($CaCO_3$).

Dry Pan: A pan-type rotating grinding machine, equipped with heavy steel rollers or mullers which do the grinding and having slotted plates in the bottom through which the ground material passes out.

Dusting: Conversion of a refractory material, either wholly or in part, into fine powder or dust. Dusting usually results from (1) chemical reactions such as hydration; or (2) mineral inversion accompanied by large and abrupt change in volume, such as the inversion of beta to gamma dicalcium silicate upon cooling.

Dutch Oven: A combustion chamber built outside and connected with a furnace.

Electron Beam Furnace: A furnace in which metals are melted in a vacuum at very high temperatures by bombardment with electrons.

Emissivity, Thermal: The capacity of a material for radiating heat; commonly expressed as a fraction or percentage of the ideal "black body" radiation of heat which is the maximum theoretically possible.

Erosion of Refractories: Mechanical wearing away of the surfaces of refractory bodies in service by the washing action of moving liquids, such as molten slags or metals.

Eutectic Temperature: The lowest melting temperature in a series of mixtures of two or more components.

Exfoliate: To expand and separate into rudely parallel layers or sheets, under the action of physical, thermal or chemical forces producing differential stresses.

Extrusion: A process in which plastic material is forced through a die by the application of pressure.

Fayalite: A mineral having the composition Fe_2SiO_4. Specific gravity 4.0 - 4.1. Melting point 2,201°F (1,205°C).

Feldspar: A group of aluminum silicate minerals with a general formula $MAl(Al,Si)_3O_8$ where M=K, Na, Ca, Br, Rb, Sr and Fe. The most important feldspars are: (1) the potash group, of which orthoclase and microcline (K) are the most common, and (2) the soda-lime group, of which albite (Na) and anorthite (Ca) form the end members of a continuous series of solid solutions. Specific gravity 2.55 - 2.76. Melting points 2,050 to 2,820°F (1,120° to 1,550°C).

Fillet: The concave curve junction of two surfaces which would otherwise meet at an angle. Fillets are used at re-entrant angles in the design of brick shapes to lessen the danger of cracking.

Firebrick: Refractory brick of any type.

Fire Clay: An earthy or stony mineral aggregate which has as the essential constituent hydrous silicates of aluminum with or without free silica; plastic when sufficiently pulverized and wetted, rigid when subsequently dried, and of sufficient purity and refractoriness for use in commercial refractory products.

Fireclay Brick: A refractory brick manufactured substantially or entirely from fire clay.

Flat Arch: An arch in which both outer and inner surfaces are horizontal planes.

Flint: A hard, fine-grained cryto-crystalline rock, composed essentially of silica.

Flint Clay: A hard or flint-like fire clay which has very low natural plasticity and which usually breaks with a smooth or shell-like fracture. Its principal clay mineral is halloysite.

Flux: A substance or mixture which promotes fusion of a solid material by chemical action.

Fluxing: Fusion or melting of a substance as a result of chemical action.

* ASTM Standard Definitions C 71-88; or ASTM "Tentative Definitions" are used where applicable.

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Forsterite: A mineral having the composition Mg_2SiO_4. Specific gravity 3.21. Melting point approximately 3,450°F (1,900°C).

Freeze-Plane: An irregular plane lying between the hot face and cold face of a refractory lining — any point on which the temperature corresponds to the freezing point of a liquid phase present on the hot face side of the plane.

Friable: Easily reduced to a granular or powdery condition.

Furnace Chrome: A mortar material prepared from finely ground chrome ore, suitable for laying brick or for patching or daubing in furnaces.

Furnace Magnesite: A mortar material prepared from finely ground dead-burned magnesite, suitable for use as a joint material in laying magnesite brick, and for patching or daubing furnace masonry.

Fused-Cast Refractories: Refractories formed by electrical fusion followed by casting and annealing.

Fused Quartz: Silica in the glassy state produced by melting clear quartz crystalline feed. It is clear without entrapped gas bubbles or other impurities or diluents. Synonyms include quartz glass and vitreous quartz.

Fused Silica: Silica in the glassy or vitreous state produced by arc-melting sand. It always contains gas bubbles. Synonyms include vitreous silica and silica glass.

Fusion: A state of fluidity or flowing in consequence of heat; the softening of a solid body, either through heat alone or through heat and the action of a flux, to such a degree that it will no longer support its own weight, but will slump or flow. Also the union or blending of materials, such as metals, upon melting, with the formation of alloys.

Fusion Point: The temperature at which melting takes place. Most refractory materials have no definite melting points, but soften gradually over a range of temperatures.

Ganister: A dense, high-silica rock (quartzite), suitable for the manufacture of silica brick. Confusion sometimes results from the use of this term, because it is also applied in some parts of the United States to crushed firebrick or to mixtures of either crushed firebrick or silica rock with clay, for use in tamped linings.

Gibbsite: A white or tinted monoclinic mineral; $Al(OH)_3$. Specific gravity 2.3 - 2.4.

Glass*: An inorganic product of fusion which has cooled to a rigid condition without crystallizing.

Grain Magnesite: Dead-burned magnesite in the form of granules, generally ranging in size from about 5/8 inch in diameter to very fine particles.

Grain Size: As applied to ground refractory materials, the relative proportions of particles of different sizes; usually determined by separation into a series of fractions by screening.

Grog: A granular product produced by crushing and grinding calcined or burned refractory material, usually of alumina-silica composition.

Ground Fire Clay: Fire clay or a mixture of fire clays that have been subjected to no mechanical treatment other than crushing and grinding.

Grout: A suspension of mortar material in water, of such consistency that it will flow into vertical open joints when it is poured on horizontal courses of brick masonry.

Gunning: The application of monolithic refractories by means of air-placement guns.

Halloysite: One of the clay minerals; a hydrated silicate of alumina similar in composition to kaolinite, but amorphous and containing more water; $Al_2Si_2O_5(OH)_4 \cdot 2H_2O$.

Header: A brick laid on flat with its longest dimension perpendicular to the face of a wall.

Heat-Setting Refractories: Compositions of ground refractory materials which require relatively high temperatures for the development of an adequate bond, commonly called the ceramic bond.

Hematite: The mineral Fe_2O_3 (red iron ore). Specific gravity 4.9 - 5.3.

High-Alumina Refractories: Alumina-silica refractories containing 45 % or more alumina. The materials used in their production include diaspore, bauxite, gibbsite, kyanite, sillimanite, andalusite and fused alumina (artificial corundum).

High-Duty Fireclay Brick: Fireclay brick which have a PCE not lower than Cone 31½ or above 32½ - 33.

Hydrate (verb): To combine chemically with water.

Hydraulic-Setting Refractories: Compositions of ground refractory materials in which some of the components react chemically with water to form a strong hydraulic bond. These refractories are commonly known as castables.

Illite: A group of three-layer, mica-like minerals of small particle size, intermediate in composition and structure between muscovite and montmorillonite.

Impact Pressing: A process for forming refractory shapes in which the ground particles of refractory material are packed closely together by rapid vibration.

Incongruent Melting: Dissociation of a compound on heating, with the formation of another compound and a liquid of different composition from the original compound.

Ingot Mold: A mold in which ingots are cast.

Insulating Refractories: Lightweight, porous refractories with much lower thermal conductivity and heat-storage capacity than other refractories. Used mostly as backing for brick of higher refractoriness and higher thermal conductivity. These materials provide fuel economy through lower heat losses, increased production due to shorter heat-up time, economy of space (size and weight) because of thinner walls and improved working conditions. Insulating refractories are available as brick or monoliths.

Inversion: A change in crystal form without change in chemical composition; as for example, the change from low-quartz to high-quartz, or, the change from quartz to cristobalite.

Isomorphous Mixture: A type of solid solution in which mineral compounds of analogous chemical composition and closely related crystal habit crystallize together in various proportions.

Jack Arch: See Arch, Flat.

* ASTM Standard Definitions C 71-88; or ASTM "Tentative Definitions" are used where applicable.

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Jamb: (1) A vertical structural member forming the side of an opening in a furnace wall; (2) a type of brick shape intended for use in the sides of wall openings.

Kaldo Process (Stora): An oxygen process for making steel.

Kaliophilite: A hexagonal mineral of volcanic origin; $KAlSiO_4$.

Kaolin: A white-burning clay having kaolinite as its chief constituent. Specific gravity 2.4 - 2.6. The PCE of most commercial kaolins ranges from Cone 33 to 35.

Kaolinite: A common white to grayish or yellowish clay mineral; $Al_2Si_2O_5(OH)_4$. Kaolinite is the principal constituent of most kaolins and fire clays. Specific gravity is 2.59. The PCE of pure kaolinite is Cone 35.

Key: In furnace construction, the uppermost or the closing brick of a curved arch.

Key Brick: A brick shape having six plane faces (two sides, two edges and two ends), in which two faces (the edges) are inclined toward each other and one of the end faces is narrower than the other.

K-factor: The thermal conductivity of a material, expressed in standard units.

Kyanite (Cyanite): A blue or light-green triclinic mineral; Al_2SiO_5. Specific gravity 3.56 - 3.67. Decomposition begins at about 2,415°F (1,325°C) with the formation of mullite and free silica.

Ladle: A refractory-lined vessel used for the temporary storage or transfer of molten metals.

L-D Process: A process for making steel by blowing oxygen on or through molten pig iron, whereby most of the carbon and impurities are removed by oxidation.

Limestone: A sedimentary rock composed essentially of the mineral calcite ($CaCO_3$) or of calcite mixed with dolomite, $CaMg(CO_3)_2$. Specific gravity 2.6 - 2.8.

Limonite: A mineral consisting of hydrous ferric oxides; the essential component of "brown ore." Specific gravity 3.6 - 4.0.

Lintel: A horizontal member spanning a wall opening.

Loss on Ignition: As applied to chemical analyses, the loss in weight which results from heating a sample of material to a high temperature, after preliminary drying at a temperature just above the boiling point of water. The loss in weight upon drying is called "free moisture"; that which occurs above the boiling point, "loss on ignition."

Low-Duty Fireclay Brick: Fireclay brick which have a PCE not lower than Cone 15 nor higher than 28 - 29.

Magnesioferrite: One of the spinel group of minerals; $(Mg,Fe)Fe_2O_4$. Rarely found in nature; usually constitutes the brown coloring material in magnesite brick. Specific gravity 4.57 - 4.65.

Magnesite: A mineral consisting of magnesium carbonate; $MgCO_3$. A rock containing the mineral magnesite as its essential constituent (See also Magnesite, Caustic and Dead-Burned Magnesite).

Magnesite Brick: A refractory brick manufactured substantially or entirely of dead-burned magnesite which consists essentially of magnesia in crystalline form (periclase).

Magnesite-Carbon Brick: A refractory brick manufactured of substantially magnesite (dead-burned, fused, or a combination thereof) and carbon, which may be in the form of various carbon-bearing materials. Conventional tar-bonded and tar-impregnated brick do not fall into this class. Magnesite-carbon brick are distinct in that carbon is present in the composition to provide specific refractory properties beyond filling pores or acting as a bond.

Magnesite, Caustic: The product obtained by calcining magnesite, or other substances convertible to magnesia, upon heating at a temperature generally not exceeding 2,200°F (1,205°C). The product is readily reactive to water and to atmospheric moisture and carbon dioxide.

Magnesite-Chrome Brick: A refractory brick which can be either fired or chemically bonded, manufactured substantially of a mixture of dead-burned magnesite (magnesia) and refractory chrome ore, in which the magnesite predominates by weight.

Magnesium Hydroxide: The compound of magnesium oxide and chemically combined water; $Mg(OH)_2$. Naturally occurring magnesium hydroxide is known as brucite.

Magnetite: A black, isometric, strongly magnetic, opaque mineral of the spinel group; (Fe, Mg) Fe_2O_4. Specific gravity 5.17 - 5.18. Melting point about 2,901°F (1,594°C).

Medium-Duty Fireclay Brick: A fireclay brick with a PCE value not lower than Cone 29 nor higher than 31 - 31 1/2.

Melting Point: The temperature at which crystalline and liquid phases having the same composition coexist in equilibrium. Metals and most pure crystalline materials have sharp melting points, i.e. they change abruptly from solid to liquid at definite temperatures. However, most refractory materials have no true melting points, but melt progressively over a relatively wide range of temperatures.

Metalkase Brick: Basic brick provided with thin steel casings.

Mica: A group of rock minerals having nearly perfect cleavage in one direction and consisting of thin elastic plates. The most common varieties are muscovite and biotite.

Micron: The one-thousandth part of a millimeter (0.001 mm); a unit of measurement used in microscopy.

Mineral: A mineral species is a natural inorganic substance which is either definite in chemical composition and physical characteristics or which varies in these respects within definite natural limits. Most minerals have a definite crystalline structure; a few are amorphous.

Modulus of Elasticity (Physics): A measure of the elasticity of a solid body; the ratio of stress (force) to strain (deformation) within the elastic limit.

Modulus of Rupture: A measure of the transverse or "crossbreaking" strength of a solid body.

Monolithic Lining: A furnace lining without joints, formed of material which is rammed, cast, gunned or sintered into place.

Monticellite: A colorless or gray mineral related to olivine; $CaMgSiO_4$. Specific gravity 3.1 - 3.25. Melts incongruently at 2,730°F (1,499°C) to form MgO and a liquid.

* ASTM Standard Definitions C 71-88; or ASTM "Tentative Definitions" are used where applicable.

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Montmorillonite: A group of expanding-lattice clay minerals containing variable percentages of one or more of the cations of magnesium, potassium, sodium and calcium. A common constituent of bentonites.

Mortar (Refractory): A finely ground refractory material which becomes plastic when mixed with water and is suitable for use in laying refractory brick.

Mullite: A rare orthorhombic mineral; $Al_6Si_2O_{13}$. Specific gravity 3.15. An important constituent of fireclay and high-alumina brick. Melting point under equilibrium conditions approximately 3,362°F (1,850°C).

Mullite Refractories*: Refractory products consisting predominantly of mullite ($Al_6Si_2O_{13}$) crystals formed either by conversion of one or more of the sillimanite group of minerals or by synthesis from appropriate materials employing either melting or sintering processes.

Muscovite: A mineral of the mica group; $KA_{12}(AlSi_3)O_{10}(OH)_2$. It is usually colorless, whitish or pale brown and is a common mineral in metamorphic and igneous rocks and in some sedimentary rocks.

Nepheline (Nephelite): A hexagonal mineral of the feldspathoid group; $(Na,K)AlSiO_4$. A common reaction product in furnaces wherein slags or vapors of high soda content come into contact with fireclay or high-alumina brick. Stable at 2,278°F (1,248°C) at which temperature it inverts to the artificial mineral carnegieite, which has the same composition, but a different crystalline form. Natural nepheline contains a small amount of potash. Specific gravity 2.67.

Neutral Refractory: A refractory material which is neither acid nor base, such as carbon, chrome or mullite.

Nine Inch Equivalent: A brick volume equal to that of a 9 x 4 1/2 x 2 1/2 inch straight brick (101.25 cubic inches); the unit of measurement of brick quantities in the refractories industry.

Nodule Clay: A rock containing aluminous or ferruginous nodules, or both, bonded by flint clay; called "burley" clay or "burley flint" clay in some districts.

Nosean (Noselite): A feldspathoid mineral of the sodalite group; $Na_8Al_6Si_6O_{24}(SO_4)$. It is grayish, bluish or brownish and is related to hauyne.

Nozzle Brick: A tubular refractory shape used in a ladle; contains a hole through which steel is teemed at the bottom of the ladle, the upper end of the shape serving as a seat for the stopper.

Olivine: (l) An olive-green, grayish-green or brown orthorhombic mineral; $(Mg,Fe)2SiO_4$. It comprises the isomorphous solid-solution series forsterite-fayalite. (2) A name applied to a group of minerals forming the isomorphous system $(Mg,Fe,Mn,Ca)\ 2SiO_4$, including forsterite, fayalite, tephroite and a hypothetical calcium orthosilicate. Specific gravity 3.27 - 3.37, increasing with the amount of iron present.

Overfiring: A heat treatment which causes deformation or bloating of clay or clay ware.

Oxiduction: Alternate oxidation and reduction.

Oxygen Process: A process for making steel in which oxygen is blown on or through molten pig iron, whereby most of the carbon and impurities are removed by oxidation.

Periclase: An isometric mineral; MgO. Specific gravity 3.58. Melting point approximately 5,070°F (2,800°C).

Perlite: A siliceous glassy rock composed of small spheroids varying in size from small shot to peas; combined water content 3 to 4 %. When heated to a suitable temperature, perlite expands to form a lightweight glassy material with a cellular structure.

Permeability: The property of porous materials which permits the passage of gases and liquids under pressure. The permeability of a body is largely dependent upon the number, size and shape of the open connecting pores and is measured by the rate of flow of a standard fluid under definite pressure.

Plasma Jet: Ionized gas produced by passing an inert gas through a high-intensity arc causing temperatures up to tens of thousands of degrees centigrade.

Plastic Chrome Ore: An air-setting ramming material having a base of refractory chrome ore and shipped in plastic form ready for use.

Plastic Fire Clay: A fire clay which has sufficient natural plasticity to bond together other materials which have little or no plasticity.

Plastic Refractory: A blend of ground refractory materials in plastic form, suitable for ramming into place to form monolithic linings.

Plasticity: That property of a material that enables it to be molded into desired forms which are retained after the pressure of molding has been released.

Pores: As applied to refractories, the small voids between solid particles. Pores are described as "open" if permeable to fluids; "sealed" if impermeable.

Porosity of Refractories: The ratio of the volume of the pores or voids in a body to the total volume, usually expressed as a percentage. The "true porosity" is based on the total pore-volume; "apparent porosity" on the open pore-volume only.

Power Pressing: The forming of refractory brick shapes from ground refractory material containing an optimum amount of added water by means of high pressure applied vertically in a power-driven press.

Pug Mill: A machine used for blending and tempering clays in a moist or stiffly plastic condition.

Pyrite: The most common sulfide mineral; FeS_2. Specific gravity 4.9 - 5.2. Color, brass-yellow. Used mainly for making sulfuric acid and sulfates.

Pyrometric Cone: One of a series of pyramidal-shaped pieces consisting of mineral mixtures and used for measuring time-temperature effect. A standard pyrometric cone is a three-sided truncated pyramid; and is approximately either 2 5/8 inches high by 5/8 inch wide at the base or 1 1/8 inches high by 3/8 inch wide at the base. Each cone is of a definite mineral composition and has a number stamped on one face; when heated under standard conditions it bends at a definite temperature.

Pyrometric Cone Equivalent (PCE)*: The number of that Standard Pyrometric Cone whose tip would touch the supporting plaque simultaneously with a cone of the refractory material being investigated when tested in accordance with the Method of Test for Pyrometric Cone Equivalent (PCE) of Refractory Materials (ASTM Designation C24).

Pyrophyllite: A mineral consisting of hydrated silicate of aluminum; $AlSi_2O_5(OH)$.

* ASTM Standard Definitions C 71-88; or ASTM "Tentative Definitions" are used where applicable.

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Pyroplasticity: The physical state induced by soaking heat which permits a refractory body to be readily deformed under pressure or by its own weight.

Quartz: A common mineral consisting of silica (SiO_2). Sandstones and quartzites are composed largely of quartz. Specific gravity 2.65.

Quartzite: A hard compact rock consisting predominantly of quartz. There are two types: (1) metaquartzite, a metamorphic rock usually derived from sandstone; and (2) orthoquartzite, a sedimentary rock consisting of grains of silica sand cemented together by at least 10 % of precipitated silica.

Ramming Mix: A ground refractory material which is mixed with water and rammed into place for patching shapes or for forming monolithic furnace linings; usually of a less plastic nature than plastic refractories.

Recuperator: A system of thin-walled refractory ducts used for the purpose of transferring heat from a heated gas to colder air or gas.

Refractories: Nonmetallic materials suitable for use at high temperatures in furnace construction. While their primary function is resistance to high temperature, they are usually called on to resist other destructive influences such as abrasion, pressure, chemical attack and rapid changes in temperature.

Refractory (adj.): Chemically and physically stable at high temperatures.

Refractory Clay: An earthy or stony mineral aggregate which has as the essential constituent hydrous silicates of aluminum with or without free silica; plastic when sufficiently pulverized and wetted, rigid when subsequently dried and of sufficient purity and refractoriness for use in commercial refractory products.

Regenerator: A refractory structure in which thermal energy from hot furnace gases is alternately absorbed by checker brick work and released to cold air or gas.

Regenerator Checkers: Brick used in furnace regenerators to recover heat from hot outgoing gases and later to release this heat to cold air or gas entering the furnace; so-called because of the checkerboard pattern in which the brick are arranged.

Rise of Arches: The vertical distance between the level of the spring lines and the highest point of the under surface of an arch.

Rock: A naturally occurring mineral aggregate consisting of one or more minerals. For example, quartzite rock is an aggregate consisting essentially of crystals of the mineral quartz; granite is an aggregate consisting essentially of spar and quartz.

Rotary Kiln: A cylindrical, refractory-lined, gas-fired kiln that rotates at an angle and in which the charge is introduced into the higher end and travels down the slope of the kiln to the discharge end.

Rowlock Course: A course of brick laid on edge with their longest dimensions perpendicular to the face of a wall.

Rutile: A mineral consisting of titanium dioxide (Ti_2O). Specific gravity 4.18 - 4.25.

Screen Analysis: The size distribution of noncohering particles as determined by screening through a series of standard screens.

Secondary Expansion: The property exhibited by some fireclay and high-alumina refractories of developing permanent expansion at temperatures within their useful range; not the same as overfiring. A behavior not to be confused with the bloating caused by excessive temperatures which impair the useful properties of a refractory.

Semi-Silica Fireclay Brick: A fireclay brick containing not less than 72% silica.

Serpentine: A group of rock forming minerals; $(Mg,Fe)_3Si_2O_5(OH)_4$. Specific gravity 2.5 - 2.7. Also, a common rock consisting essentially of serpentine minerals.

Silica: SiO_2, the oxide of silicon. Quartz and chalcedony are common silica materials; quartzite, sandstone and sand are composed largely of free silica in the form of quartz.

Silica Brick: A fired refractory consisting essentially of silica and usually made from quartzite bonded with about 1.8 to 3.5 % of added lime.

Silica Fire Clay*: A refractory mortar consisting of a finely ground mixture of quartzite, silica brick and fire clay of various proportions; often called silica cement.

Silicon Carbide: A compound of silicon and carbon; SiC.

Silicon Carbide Refractories*: Refractory products consisting predominantly of silicon carbide.

Sillimanite: A brown, grayish, pale-green or white orthorhombic mineral; Al_2SiO_5. Specific gravity 3.24. At about 2,785°F (1,530°C) it begins to dissociate into mullite and free silica.

Sintering: A heat treatment which causes adjacent particles of material to cohere at a temperature below that of complete melting.

Skewback: The course of brick, having an inclined face, from which an arch is sprung.

Slag: A substance formed in any one of several ways by chemical action and fusion at furnace operating temperatures: (1) in smelting operations, through the combination of a flux, such as limestone, with the gangue or waste portion of the ore; (2) in the refining metals, by substances, such as lime, added for the purpose of effecting or aiding the refining; (3) by chemical reaction between refractories and fluxing agents, such as coal, ash or between two different types of refractories.

Slagging of Refractories*: Destructive chemical action between refractories and external agencies at high temperatures resulting in the formation of a liquid.

Sleeves: Tubular refractory shapes used to protect the metal rod which holds the stopper head in the valve assembly of a bottom-pouring ladle.

Slurry: A suspension of finely pulverized solid material in water of creamy consistency.

Soapstone: A metamorphic rock consisting mainly of talc and derived from the alteration of ferromagnesian silicate minerals.

Soldier Course: A course of brick set on end; little used in the case of refractories except in the bottoms of some types of furnaces.

Solid Solution: A homogeneous crystalline phase with a variable composition. The most common solid solutions involve two or more substances having the same crystalline structure. However, the term can also refer to the solution of small proportions of a material in a seemingly unrelated substance.

* ASTM Standard Definitions C 71-88; or ASTM "Tentative Definitions" are used where applicable.

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Spalling of Refractories: The loss of fragments (spalls) from the face of a refractory structure, through cracking and rupture, with exposure of inner portions of the original refractory mass.

Specific Gravity: The ratio between the weight of a unit volume of a substance and that of some other standard substance under standard conditions of temperature and pressure. For solids and liquids the specific gravity is based on water as the standard. The "true specific gravity" of a body is based on the volume of solid material excluding all pores. The bulk or volume specific gravity is based on the volume as a whole, i.e. the solid material with all included pores. The apparent specific gravity is based on the volume of the solid material plus the volume of the sealed pores.

Specific Heat: The quantity of heat required to raise the temperature of a unit mass of a substance one degree.

Spinel: (1) The mineral composed of magnesium aluminate; $MgAl_2O_4$. Specific gravity 3.6. Melting point 3,875°F (2,135°C). (2) A group of minerals of general formula; AB_2O_4 where A represents magnesium, ferrous iron, zinc or manganese or any combination of these minerals and B represents aluminum ferric iron or chromium.

Spring Line: The line of contact between the inside surface of an arch and the skewback.

Sprung Arch: An arch which is supported by abutments at the side or ends only.

Stack Losses: The flue gas loss, the sensible heat carried away by the dry flue gas plus the sensible heat and latent heat carried away by the water vapor in the flue gas.

Stretcher: A brick laid on flat with its length parallel to the face of the wall.

Superduty Fireclay Brick: Fireclay brick which have a PCE not lower than Cone 33 and which meet certain other requirements as outlined in ASTM Designation C 27-84.

Suspended Arch: An arch in which the brick shapes are suspended from overhead supporting members.

Taconite: A compact ferruginous chert or slate in which the iron oxide is so finely disseminated that substantially all of the iron-bearing particles are smaller than 20 mesh. Typical analyses of the ore grade show total iron at 32%.

Talc: A hydrous magnesium silicate mineral; $Mg_3Si_4O_{10}(OH)_2$. Specific gravity 2.7 - 2.8. Hardness 1.

Thermal Conductivity: The property of matter by virtue of which heat energy is transmitted through particles in contact.

Thermal Expansion: The increase in linear dimensions and volume which occurs when materials are heated and which is counterbalanced by contraction of equal amount when the materials are cooled.

Thermal Shock: A sudden transient temperature change.

Tolerance: The permissible deviation in a dimension or property of a material from an established standard or from an average value.

Tridymite: A mineral form of silica; SiO2. Stable from 1,598 to 2,678°F (870 to 1,470°C). Specific gravity 2.26. An important constituent of silica brick.

Tweel: A refractory shape used to control the flow of molten glass from the glass tank to the tin bath in the float glass process.

Trough: An open receptacle through which molten metal is conveyed from a holding device or furnace to a casting mold or another receptacle.

Tuyere Brick: A refractory shape containing one or more holes through which air and other gases are introduced into a furnace.

TREFOIL® Heat Exchanger: A refractory construction in a rotary kiln with three openings which in cross-section are clover-shaped. Over its length, the TREFOIL heat exchanger divides the kiln into three equal parts, thus improving heat exchange between the charge and the hot combustion gases.

Vacuum Pressing: A method of forming brick shapes by which they are subjected to a partial vacuum during pressing in a power press.

Vermiculite: A group of micaceous minerals, all hydrated silicates, varying widely in composition; $(Mg,Fe,Al)_3(AlSi)_4O_{10}(OH)_2 \cdot 4H_2O$. When heated above 302°F (150°C), vermiculite exfoliates and increases greatly in volume.

Vesicular: Having a cellular structure; applied to fire clays which have become bloated by overfiring.

Vibratory Pressing: A process for forming refractory shapes in which the ground particles of refractory material are packed closely together by rapid impact-type vibrations of the top and bottom dies; also called impact pressing.

Vitrification: A process of permanent chemical and physical change at high temperatures in a ceramic body, such as fire clay, with the development of a substantial proportion of glass.

Warpage: The deviation of the surface of a refractory shape from that intended, caused by bending or bowing during manufacture.

Wedge Brick: A brick shape having six plane faces (two sides, two edges and two ends), in which two faces (the sides) are inclined toward each other and one end face is narrower than the other.

Wetting: The adherence of a film of liquid to the surface of a solid.

Wollastonite: A triclinic mineral; $CaSiO_3$. Specific gravity 2.9. Inverts at 2,192°F (1,200°C) to pseudowollastonite. Melts incongruently at 2,811°F (1,544°C).

Young's Modulus: In mechanics, the ratio of tensile stress to elongation within the elastic limit; the modulus of elasticity.

Zircon: A mineral; $ZrSiO_4$. Specific gravity 4.7. Begins to melt incongruently at 3,045°F (1,685°C) forming ZrO_2 solid solution plus liquid; completely melted at about 4,800°F (2,650°C).

Zirconia: Zirconium oxide; ZrO_2. Specific gravity 5.8. Melting point 4,890°F (2,700°C). Its chief source is the mineral baddeleyite.

* ASTM Standard Definitions C 71-88; or ASTM "Tentative Definitions" are used where applicable.

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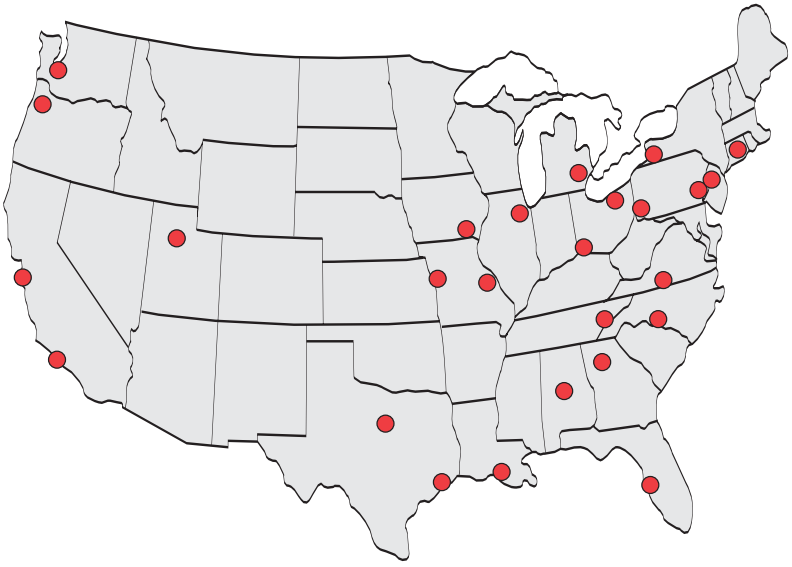

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