into the first stage of the tunnel kiln, where it travels through various temperature zones. A European manufacturer has recently patented a "rotary circular kiln" that can reportedly save up to 30% on fuel consumption. Bricks move through the kiln on a hydraulically controlled turntable. The system can capture and reuse 70 to 75% of the waste heat compared to only about 45% for tunnel kilns.

Burning consists essentially of subjecting brick units to gradually increasing temperatures until fusion chemically alters the structure of the clay. The burning process consists of six phases which are accomplished in the dryer kiln and in the preheating, firing, and cooling chambers of the burning kiln. The drying and evaporating of excess moisture are often called the water-smoking stage. This initial preheat may be done in separate dryers or, if high-fired glazes will not be added, in the forward section of the burning kiln. This exposure to relatively low temperatures of up to 400°F begins the gradual, controlled heating process. Dehydration, or removal of the remaining trapped moisture, requires anywhere from 300 to 1800°F, oxidation from 1000 to 1800°F, and vitrification from 1600 to 2400°F. It is only within this final temperature range that the silicates in the clay melt and fill the voids between the more refractory materials binding and cementing them together to form a strong, dense, hard-burned brick. The actual time and exact temperatures required throughout these phases vary according to the fusing characteristics and moisture content of the particular clay. Near the end of the vitrification phase, a reducing atmosphere may be created in which there is insufficient oxygen for complete combustion. This variation in the process is called flashing, and is intended to produce different hues and shadings from the natural clay colors. For example, if the clay has a high iron oxide content, an oxygen-rich fire will produce a red brick. If the same clay is fired in a reducing atmosphere with low oxygen, the brick will be more purple.

Figure 2-5 Tunnel kilns provide even heat distribution.

The final step in the firing of brick masonry is the cooling process. In a tunnel kiln, this normally requires up to 48 hours, as the temperatures must be reduced carefully and gradually to avoid cracking and checking of the brick.

2.1.9 Drawing and Storage

Removing brick from the kiln is called drawing. The loaded flatcars leave the cooling chamber and are placed in a holding area until the bricks reach room temperature. They are then sorted as necessary for size, chippage, and warpage tolerances, bound into "cubes" equaling 500 standard-size bricks, and either moved to storage yards or loaded directly onto trucks or rail cars for shipment.

2.2 CONCRETE MASONRY

The development of modular concrete masonry was a logical outgrowth of the discovery of portland cement, and was in keeping with the manufacturing trends of the Industrial Revolution. Although the first rather unsuccessful attempts produced heavy, unwieldy, and poorly adaptable units, the molding of cementitious ingredients into large blocks promised a bright new industry. With the invention and patenting of various block-making machines, unit concrete masonry began to have a noticeable effect on building and construction techniques of the late nineteenth and early twentieth centuries. Concrete masonry today is made from a relatively dry mix of cementitious materials, aggregates, water, and occasionally special admixtures. The material is molded and cured under controlled conditions to produce a strong, finished block that is suitable for use as a structural building element. Both the raw materials and the method of manufacture influence strength, appearance, and other critical properties of the block and are important in understanding the diversity and wide-ranging uses of concrete masonry products.

2.2.1 Aggregates

The aggregates in concrete block and concrete brick account for as much as 90% of their composition. The characteristics of these aggregates therefore play an important role in determining the properties of the finished unit. Aggregates may be evaluated on the basis of (1) hardness, strength, and resistance to impact and abrasion; (2) durability against freeze-thaw action; (3) uniformity in gradation of particle size; and (4) absence of foreign particles or impurities. A consistent blend of fine and coarse particle sizes is necessary to produce a mixture that is easily workable and a finished surface that is dense and resistant to absorption.

There are two categories of aggregates used in the manufacture of concrete masonry: *lightweight aggregates* and *heavyweight aggregates* (also called normal-weight). Early concrete masonry units were, for the most part, made with the same heavyweight aggregates as those used today. Well-graded sand, gravel, crushed stone, and air-cooled slag are combined with other ingredients to produce a block that is heavy, strong, and fairly low in water absorption. Heavyweight aggregates for concrete masonry are covered in ASTM C33, *Standard Specification for Concrete Aggregates.*

Efforts to make handling easier and more efficient led to the introduction of lightweight aggregates. Pumice, cinders, expanded slag, and other natural or processed aggregates are often used, and the units are sometimes marketed under proprietary trade names. Testing and performance have proved that lightweight aggregates affect more than just weight, however. Thermal, sound,