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CEMENT

by

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CEMENT

INTRODUCTION AND BRIEF SUMMARY

Cement, like clay products, dates from somewhere beyond history's opaque curtain. The basic idea of cement whether it be used in the chinking of an aborigine's stone hut, in the building of an Egyptian pyramid, or in the construction of a children's wading pool, is first "stickiness" followed by the hardening of the cement to a desired degree. Some organic substances like certain glues and gums, which also fall into the category of cements, seem to have the inherent quality of stickiness. They vary, however, through wide limits in the degree to which they can be made to set or harden. Some of the inorganic cementing materials like carbonates, silica or silica gels, ferric oxides and calcium sulphates may not seem very sticky but under proper conditions they have strong tendencies to set or harden while holding tightly to the objects with which they are in contact.

In this chapter only the carbonate cements--the so-called hydraulic cements, of which portland cement is by far the most important, are considered. These are the cements referred to when "cement plants" are mentioned and they are the subjects of published figures on the value of production of portland and other hydraulic cements.

The manufacture of natural cement started in Kansas at Fort Scott eighty years ago and portland cement manufacture began with a rush in 1900. Approximately a dozen cement plants were built in the succeeding ten years. All were in the southeastern Kansas "natural gas belt" except one near Hays in Ellis County. Competition, consolidations, and vagaries of the cement industry in the last 40 years have reduced the number of plants until the Kansas industry for perhaps two decades has consisted of the half dozen present plants (Figure). They are modern, well established operations. They make standard high quality products more than 50% of which are shipped outside of the State.

PRINCIPAL TYPES OF CEMENT, WITH HISTORICAL BACKGROUNDS

There are three general types of hydraulic cements: pozzolan, natural, and portland.

Pozzolan cement, oldest of the three types, was developed in Italy at least 2000 years ago and was named after the Italian town, Pozzuoli, where the raw material called pozzuolana, a partially divitrified volcanic glass, was quarried. When properly prepared the mud or mortar would set or harden in air or under water. At present there is considerable technical interest in pozzolans especially as admixtures with portland cement to reduce the cost of the latter and for other reasons such as reducing the amount of heat generated during setting. The heat generated sometimes leads to cracking and shrinkage difficulties.

Although pozzolan cements are still being manufactured to some extent in Europe they have been largely supplanted by portland cement in this country.

Natural cements were developed in northern Europe centuries after pozzolans were in common use in the Mediterranean countries. Natural cement differs from portland mainly in that carefully selected raw materials are burned practically "as is" and at somewhat lower temperatures without such close controls of thermal conditions or additives as are maintained in portland cement manufacture.

Certain valuable characteristics such as smooth working, and moisture and acid resistance are claimed for some of the natural cement products.

Portland cement, at least the name "portland," as applied to cements, dates from 1824 when the idea originated in England. The process, vastly improved in detail, is basically the same today.

In modern practice portland cement may be described as a type of hydraulic cement containing closely controlled amounts of three main mineral ingredients: lime (CaO), alumina (Al_2O_3), and silica (SiO_2)---with some lesser components or impurities. Commonly a rather impure limestone plus a proper quantity of

shale supply the necessary chemical requirements. Setting properties are reasonably controlled by additives or by adjusting chemical or thermal conditions in manufacture. The U. S. Bureau of Mines divides portland cement into several varieties including (1) general use and moderate heat, (2) air-entrained, (3) high early strength, (4) low heat, (5) oil well, (6) sulphate-resisting, (7) white, and (8) portland-pozzolan. The names suggest their principal uses.

TECHNOLOGY

The technology of portland cement is far too complex to include here in any detail. The principal raw materials, commonly impure limestone with enough shale or clay (alumina-bearing substance) to suit, are crushed, mixed, burned to a clinker--almost to the fusion point, in a kiln; the clinker is finely ground--either wet or dry, mixed, usually with certain additives mainly to control setting; and packaged or shipped in bulk to the consumer.

During calcination or the burning of the raw materials to a clinker, much carbon dioxide is driven off from the limestone. Quick lime would thus be produced if the limestone were pure. With much alumina and some iron present, however, complex calcium salts, mainly silicates, aluminates, and ferrites are produced by the near-fusion, and these salts seem in part to react to form still others. After the clinker is ground, a retarder, usually gypsum, to prevent too rapid setting is added.

To make concrete, portland cement, sand, and gravel--in some such common porportion as 1:3:5--are carefully mixed and enough water added to bring about setting. Seemingly the added water produces gels of hydrous compounds which in setting crystallize and interlock, binding the component particles together. At the same time the water causes some chemical action among the tricalcium and dicalcium silicate, the tricalcium aluminate and the ferrites. Hydration of the tricalcium aluminate is believed mainly to cause the generation of heat which is so objectionable during the setting of concrete.

RAW MATERIALS FOR CEMENT MANUFACTURE

As various types of hydraulic cements are sold on specifications or standards set and checked by the National Bureau of Standards or the American Society for Testing Materials, raw materials for cement manufacture must be carefully selected, mainly for their principal chemical requirements.

Table , showing the tonnages of raw materials used in the United States in producing portland cement, also indicates their very common nature and very wide distribution over the country. The table shows that limestone is by far the most important source material for portland cement, although numerous combinations of raw materials are used in different sections of the United States. One California plant is making portland cement from sea shells with the alumina and silica being largely supplied from mud dredged up from the bottom of San Francisco Bay.

Table shows roughly the principal chemical components required in raw materials for common portland cement manufacture.

Commonly about 3 percent of gypsum is mixed into the final dry cement to control (retard) setting.

Mineral flotation is commonly used--mainly for the elimination of excess silica as quartz--in the cement industry where it is desirable or necessary to improve the quality of the raw materials.

WORLD PRODUCTION OF HYDRAULIC CEMENTS

The United States in its 150 plants turns out more than one-third of all hydraulic cements produced in the world (omitting Russia whose production is not known), according to the U. S. Bureau of Mines Yearbook, 1948.

Table shows the production of the leading countries and the world production (1948) estimated at 97,130,000 metric tons (or 569,500,000 barrels of 376 pounds each, as cement is reckoned in the United States).

THE CEMENT INDUSTRY IN THE UNITED STATES

Up to 1900, natural cement (or "American rock cement," or "natural rock cement" as it was then called) had for the most part supplied users in this country since earliest pioneer days. It was made from natural raw materials mainly impure limestone and shale which approached the desired chemical composition. Portland cement although more costly to produce was coming into increasing demand in the late 1890's.

In the year 1900 the production of portland cement in the United States for the first time exceeded that of natural cement. The production of each at that time was about 8,400,000 barrels yearly for the entire country which is about equal to the Kansas production of portland cement in 1950. Since 1900 the amount of portland cement produced in the country has continued to exceed the production of natural cement.

Table shows the status of the industry and of cement production at the beginning of the century and at the century mid-point. It should be noted that the average annual capacity of portland cement plants in 1950 is roughly 10 times their capacity about 50 years ago.

The price of cement in 1950 was less than twice its price in 1900, a condition almost unique among items of commerce in these times of spiraling prices. At present, the cement industry is sixth in the country among mineral industries. The 15-fold increase in the total production of hydraulic cement in the United States since 1899 is explained rather largely by the demand for concrete highways and for concrete in the building construction trades.

THE KANSAS CEMENT INDUSTRY

History. — Hydraulic cement was being made in Kansas in the 1850's (Mudge, 1866, p. 25), but the first going concern to weather the difficulties of the passing years up to the present was established in 1868 at Fort Scott. This operation never leaving the Thomas family, has produced natural cement almost

without interruption for 83 years, which probably is a record for Kansas mineral industries. Stone houses built by Kansas pioneers were "laid up" mainly with hydraulic lime as mortar, although some of the mortars--due to the impurity of the limestones burned--doubtless had most of the staying qualities of natural cement.

By 1900, natural cement production in the United States had passed its crest and was on the decline in public demand, its place taken by the more uniform, although more expensive, portland cement. The first Kansas portland cement plant, at Iola, began production in 1900, and the decade which followed saw a great surge of portland cement production in the State. A dozen plants were built and Kansas rose to fourth place in the nation in point of output. Only Pennsylvania, Indiana, and California exceeded the Kansas production in 1910.

These 12 Kansas plants were in production in 1910:

United Kansas Portland Cement Company with plants at Iola, Neadesha, and Lehunt near Independence.

Iola Portland Cement Company, Iola.

Western States Portland Cement Company, Independence.

Fredonia Portland Cement Company, Fredonia.

Monarch Portland Cement Company, Humboldt.

Ash Grove Lime and Portland Cement Company, Chanute.

Altoona Portland Cement Company, Altoona.

Great western Portland Cement Company, Mildred (north of Moran).

Bonner Brand Portland Cement Company, Bonner Springs.

Yocemento Portland Cement Company, Yocemento (Ellis County).

Since 1910 there have been plant consolidations, improvement and enlargements, and changes in names and ownerships--and some abandonments; but the pattern of portland cement production has not changed materially in the State except that there has been no production in Ellis County for more than 20 years.

Manufacture is confined to the eastern one-fifth of Kansas.

The industry in 1950. -- Six companies were producing portland and one company natural cement in Kansas during 1950 (Figure). They are:

	Plant at
1.* Ash Gove Lime and Portland Cement Company	Chanute
2. Consolidated Cement Corporation	Fredonia
3. Fort Scott Hydraulic Cement Company (natural cement)	Fort Scott
4. Lehigh Portland Cement Company	Iola
5. Lone Star Cement Corporation	Bonner Springs
6. The Monarch Cement Company	Humboldt
7. Universal Atlas Cement Company	Independence

These plants are modern, efficiently-run operations, making the usual types of cement products. At the Chanute plant, for example, the "Ash Grove" brand of products includes regular portland, air-entrained portland, 1-day high-early-strength portland, "Quickard" portland, "Dura White Waterproofed" portland, and masonry cement; the Fredonia plant of the Consolidated Cement Corporation supplies regular, air-entrained, and high-early-strength portland, and masonry cement. The Fort Scott plant of the Fort Scott Hydraulic Cement Company produces masonry cement, natural cement, "Realite" (nonstaining) cement, and also does a substantial business in ground limestone for mineral filler and feeding purposes, in agricultural fertilizer, and in crushed stone for structural, road, and railroad purposes.

All of the portland cement plants in the State use gas fired, rotary kilns; the natural cement plant at Fort Scott uses a shaft kiln. Standby facilities--burning oil or coal--are maintained in case of short gas supply.

The Consolidated Cement Corporation at Fredonia, the Fort Scott Hydraulic Cement Company, and the Monarch Cement Company are Kansas companies; the other cement operations in the State are branch plants of companies with head offices in other states. The Universal Atlas Cement Company is a subsidiary of the U. S. Steel Corporation.

* Numbers refer to locations shown on Figure 1.

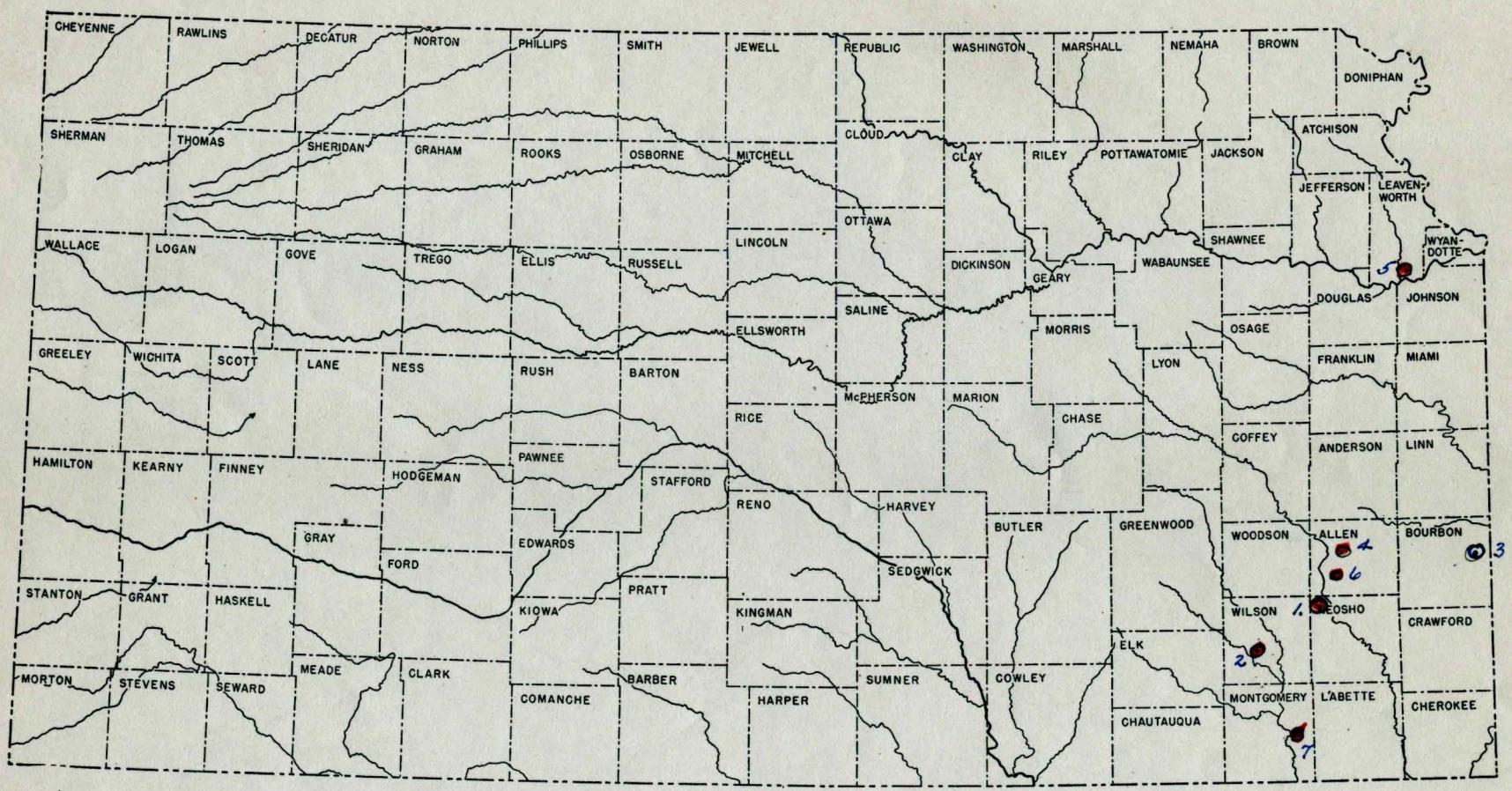

Figure — Kansas hydraulic cement plants, 1950. For company names see page ___.

The estimated combined annual capacity of Kansas portland cement plants as of December 1950 was 9,407,000 barrels* (U. S. Bureau of Mines, December, 1950), and production in that month was at 92 percent of capacity. In the same month, total annual capacity of U. S. plants was estimated (same authority) to be 259,892,000 barrels and production was at 87 percent of capacity.

Table gives the aggregate capacity of Kansas portland cement plants for several years. In 1948, Kansas ranked eighth in cement production among the states, being exceeded (in order of production) by Pennsylvania, California, Texas, New York, Michigan, Ohio, and Missouri. (Indiana's production is not revealed; it might exceed that of Kansas).

Statistics of Kansas cement production. -- Table shows details of recorded cement production in Kansas, and Figure shows essentially the same data graphically.

The graph immediately reveals the variable character of the cement market. In general, each dip indicates a period of financial stringency or depression, as in 1907 and in the early 1930's; and each peak shows a time of above normal prosperity and business expansion, or a war. By and large, the graph suggests a poorly stabilized industry.

Production of natural cement is known to have started in 1868, probably with a few hundred barrels for that year. The following year the one Fort Scott plant in question "had a capacity of 10 barrels per day. (Blackmar, 1912, p. 303). Its production for 1869 probably was 1,500 to 2,000 barrels. From then until 1887 the record is obscure.

It has been necessary to conceal production records for natural cement for 40 years in order not to reveal the output of the one or two plants. The figures for natural cement are given nevertheless up until 1910, showing that the total Kansas production is not great, probably about percent of the total portland cement produced in the State since 1900.

* In the 1880's and perhaps continuing a little later, it was customary to record production of portland cement as "400-pound barrels," and natural cement as "300-pound barrels." Nowadays, the U. S. Bureau of Mines' statistics of both portland and natural cement are in barrels of 376 pounds, but natural cement producers commonly report their output in barrels of 280 pounds).

Kansas raw materials for cement making. -- Two favorable factors largely accounted for the fact that early development of the portland cement industry in Kansas was more rapid than it was in contiguous states: (1) readily available, cheaply-mined limestone and shale, and (2) ample, very low cost natural gas for fuel.

Low magnesian, rather impure limestone, and clay or shale--almost ideal raw materials for portland cement--are so widely distributed in the east half of Kansas that selection of a plant location handy both to raw materials and rail transportation is comparatively easy. Four series of rocks outcropping in Kansas are suitable for hydraulic cement manufacture: (In ascending geologic order).

Mississippian. This series is exposed at surface in the extreme southeast corner of the State in Cherokee County and consists of parts of the Boone limestone within which lie the well-known lead and zinc ores of the Tri-State area. The rock is a light-gray cherty limestone, medium to coarsely crystalline in texture. It has not been used as cement rock, but should supply essential requirements.

Pennsylvanian. All Kansas hydraulic cement at present is made from Pennsylvanian limestone and shales.

No effort has been made to classify all of the Pennsylvanian limestone units in Kansas for their cement-making properties, as the reserve tonnages in the most popular formations now utilized are regarded as inexaustible. The following Pennsylvanian formations or members supply Kansas cement plants at the present time: (In ascending order).

Natural cement is made at Fort Scott from the Blackjack Creek limestone member of the Fort Scott limestone formation, which immediately overlies the lower Pennsylvanian Cherokee shale. A thin coal bed mined along with the cement rock furnishes all or part of the fuel necessary for calcination--at a slightly lower temperature than that used in making portland cement.

Near Independence, the Drum limestone, where it has thickened to about 50 feet, is burned for cement manufacture.

In the Iola-Humboldt-Chanute area, the Raytown member of the Iola limestone (Kansas City group), and usually a portion of the overlying Lane shale to supply alumina or alumina and silica, are extensively quarried for the cement mills.

The Argentine member of the Wyandotte limestone (Kansas City group) is used mainly for cement rock near Bonner Springs. Some overlying Island Creek shale is mined and mixed with the limestone.

The Stanton limestone of the Lansing group of rocks is variable in thickness ranging from about 10 to 90 feet and averaging 42 feet. It is burned in a cement plant near Fredonia.

Table shows typical analyses of the limestone units used in Kansas for hydraulic cement production. T

Permian. These rocks, consisting largely of limestones and shales, form a belt roughly 75 miles wide, crossing eastern Kansas from north to south. Included in this series are a dozen limestones which somewhere along their outcrops in the State have fair to excellent possibilities for use as cement rock. The list includes among others (ascending order) the Long Creek, Red Eagle, Neva, Cottonwood, Bader, Crouse, Wreford, Fort Riley, Towanda, Winfield, and Herington. Available analyses by the Geological Survey of Kansas on several of those limestones listed show approximate average percentages of principal oxides as: CaO 50 + percent, MgO 0.5 to 1.0 percent, Al_2O_3 1.3 percent, and SiO_2 5.0 to 7.0 percent. Locally, some of them carry too much magnesia; at some points chertiness would preclude their use as cement rock. The limestone members vary considerably in thickness when followed laterally.

Upper Cretaceous. The Fort Hays limestone member of the Niobrara chalk formation, with some underlying Carlile shale, was used for portland cement manufacture at Yocemento in western Ellis County for many years. The Fort Hays

using raw materials from a limestone-shale bed 25 feet thick would in 50 years consume rock from a quarry of only 300 acres or less in extent. This is evidenced by the size of present Kansas cement plant quarries most of which have been active nearly 50 years and none of which is believed to exceed about 150 acres in extent.

The economics of cement manufacture rather dictates, then, that the concept of reserves be one of "spot" tonnage in one locality. There are so many such localities in Kansas along the outcrops of the well-known limestones listed--and doubtless others which have not been tested, that further discussion of reserve tonnage is believe to be entirely unnecessary.

TRENDS, ECONOMIC ASPECTS, AND FUTURE OUTLOOK FOR THE KANSAS CEMENT INDUSTRY

Portland cement is a typical and well-known "low unit value" commodity. It rates with steel, coal, sand and gravel, gasoline, sulphur, talc, gypsum, salt, lime fertilizer, phosphate rock, etc., in that its market value is but a few cents (or less than 1 cent) per pound. Such commodities are low-priced mainly because (1) plants of very large capacity are required to produce them economically--as in the cases of steel, gasoline and cement; or (2) they occur in usable form very widely distributed in nature and can be mined and distributed very cheaply.

Although the methods of manufacturing portland cement have undergone practically no change in many years, the mid-century point seems to represent a transition in respect to the cost of building new plants. Whereas, in the middle 1930's the cost of building new cement plants in the United States was figured at $3.00 or $4.00 per barrel-year capacity, and the cost during the war years--the earlier 1940's--had increased to perhaps $5.00 * per barrel-year capacity. Plants recently built in the United States and calculations based on recent additions or improvements to Kansas plants indicate that the present cost of new cement plant construction is of the order of $6.00

to as high as $11.00 per barrel-year depending on the size of the plants and on other factors. An average might be $7-8.*

The average size of portland cement plants in Kansas approaches one and one-half million barrels a year capacity. That is roughly the average size for the United States. It is unlikely that construction of a new cement plant of less than 800,000 barrels per year capacity could be justified in any part of the United States under present conditions. That would mean a plant of 6 or 8 million dollars investment as a minimum. At the present time (1952) conservative estimators are in the habit of upping their construction estimates by as much as 50%, as was necessary during war times to cover uncertainties arising from slow material deliveries, labor uncertainties and delays in general. So, for purposes of estimation $10.00 per barrel year of capacity should not be far out of line for a new plant in Kansas or elsewhere in this country at the present time.

Factors that might be cited as favoring installation of new cement capacity in localities that seem to have possibilities are:

1. Portland cement is a well-known, standardized product that requires no introduction to the trade or sales promption (except as to brand) as does some new or unstandardized product.

2. There does not seem to be any new product that possibly could be developed that would render portland cement obsolete or too expensive to use in places where it is now employed.

3. Methods of manufacture, technology, and types and mixtures of raw materials are so well known and so reasonably standardized as to remove most uncertainties.

4. Portland cement use is "within the trend." That is, in respect to highway and building construction, its two greatest uses, demands in general are increasing. Architects prophesy that within one or two decades, satisfactory houses of some type of concrete construction will be much more common than now. To accomodate present trends in highway car and truck transportation, more and thicker concrete highways are likely to be built.

5. The U. S. Supreme Court's decision of April 26, 1948 in the basing-point suit is understood to have had the effect of easing somewhat the competitive position of a plant in a given trade area by partially relieving it of seemingly unfair competition from low-cost distant plants. It is said (U. S. Bureau of Mines, 1948, p. 214) that, "The cement companies, in general, have abandoned the multiple-basing-point delivered price and are selling their product at prices F. O. B. the shipping point or, if the purchaser desires, at a delivered price reflecting full freight charges from shipping point to destination."

6. Labor cost, a variable and uncertain factor in many industries, is a comparatively small fraction of the unit cost of cement production.

Factors that might be cited as unfavorable to the installation of new cement-making capacity are:

1. Plant installation requiring such relatively high capital outlay is commonly regarded at the outset as speculative.

2. Cement plants usually make only one important product: cement (occasionally or rarely with lime or compressed carbon dioxide as by-products), and are not readily convertible at times of low demand to the manufacture of other products.

3. Cement is a product of notoriously variable demand, as indicated by Figure 7. So, over a period of years, production averages considerably less than capacity. This requires overbuilding of plants to anticipate peak production.

4. As transportation costs almost invariably are likely to affect adversely commodities of low unit value, the location of new plants is controlled by a combination of raw materials availability, market, and transportation facilities. Exceptions: Where water shipment is possible as on the Great Lakes and on the Gulf Coast.

As to the future of the cement industry in Kansas, it should, over a period of years, be a lucrative business. Reasons suggestive of this view are:

1. The state, counties, and municipalities are either disposed or committed to substantial street, highway, and building programs which will consume a considerable amount of cement.

2. Industrialization in Kansas is on the increase at a moderate but seemingly sound pace that suggests projection into the future of considerable cement consumption for private, public, and industrial building purposes.

3. The Kansas cement industry is well-established, produces well-known brands, and, with high grade raw materials that need no benefication, ~~and~~ with fuel at reasonable cost, it is in a position to hold its own in this entire part of the Mississippi Valley country.

4. Industrialization is "moving westward" in Kansas. The Wichita area and western Kansas are becoming more industry-conscious. This trend, incidentally, may give justification for a new cement plant much farther west in Kansas than present installations. The idea would require serious and detailed market and transportation studies. The increasingly large use of cement for oil and gas well drilling, and demands by the petroleum industry for cheaper and a more certain supply of the material, lend point to serious consideration of a new cement plant located in central or western Kansas.