UNITED STATES DEPARTMENT OF LABOR
L. B. Schwellenbach, *Secretary*
BUREAU OF LABOR STATISTICS
Ewan Clague, *Commissioner*

Labor Requirements for Construction Materials

PART I.—PORTLAND CEMENT

Bulletin No. 888–1

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Letter of Transmittal

UNITED STATES DEPARTMENT OF LABOR,
BUREAU OF LABOR STATISTICS,
Washington, D. C., November 5, 1946.

The SECRETARY OF LABOR:

I have the honor to transmit herewith a report on the labor requirements in cement production, a summary of which was published in the Monthly Labor Review for September 1946.

This is the first of a series of reports covering those industries which supply essential building materials. This study was made in order to measure the amount of "behind-the-line" employment which would result in the cement industry from any given level of construction activity.

This study, under the direction of Brunswick A. Bagdon, is based upon plant data collected by the field personnel assigned to the Labor Requirements Survey in the Regional Offices; the report was written by Alfred W. Collier and Clyde Stone in the Bureau's Division of Construction and Public Employment.

EWAN CLAGUE, *Commissioner.*

HON. L. B. SCHWELLENBACH,
Secretary of Labor.

Preface

This study, the first of a series covering those industries which supply essential building materials, has been made in order to measure the amount of "behind-the-line" employment which would result in the cement industry from any given level of construction activity.

Previous studies of man-hour requirements made by the Bureau in 1933, as a part of the program of the Federal Emergency Administration of Public Works, included steel, cement, lumber, and plumbing and heating supplies. For these products, information was collected from the primary sources for raw materials, transportation, manufacturing, and delivery to the construction site.

From 1935 to 1939 comparable studies were also made covering the following industries: Clay products, the transportation of construction materials, and the manufacturing and distribution of electrical goods. Today these studies, while of historical significance, have several serious limitations; namely, (*a*) new products have been developed which were not included in the previous report, (*b*) manufacturing methods have, in several instances, changed considerably, and (*c*) variations in volume of output as between the period of the thirties and the current time would result in marked variations in man-hour requirements.

Building construction was greatly hindered during the period following VJ-day, and by the middle of 1946 building activity still had not shown marked headway. However, the forecasts, both public and private, indicate peak activity in the months ahead. Housing programs are under way. Federal subsidies are being appropriated to speed up and increase the volume of the production of essential building materials. Construction workers are being demobilized from the armed services. Thus, everything points to a high level of activity in the building construction industry for some time to come.

This series of reports will provide accurate data on the man-hours required per unit of output and per unit of dollar value, for each of 50 important construction and building materials—both traditional materials such as dimension lumber, cement, and reenforcing steel, and newer materials such as plywood (included only incidentally in the previous reports), insulating material, and the commoner fabricated steel products for residential buildings. For each of the products included, comprehensive field data will be collected on the direct and overhead man-hours in production during a recent period, the output during this period, the quantities or value of materials, supplies and fuel consumed, in-bound and out-bound freight expenses, and, wherever possible, sales both directly to contractors and through distributors and dealers. From these data, total man-hour requirements, from extraction of raw materials to delivery of completed materials at the construction site, will be obtained for an extensive series of materials representative of the requirements for most types of construction; in addition, the data will permit reasonable estimates of man-hour requirements for a large number of other materials generally similar to those studied, but not sufficiently important for individual study (primarily highly specialized materials, and custom-order variants of common materials).

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United States Bureau of Labor Statistics

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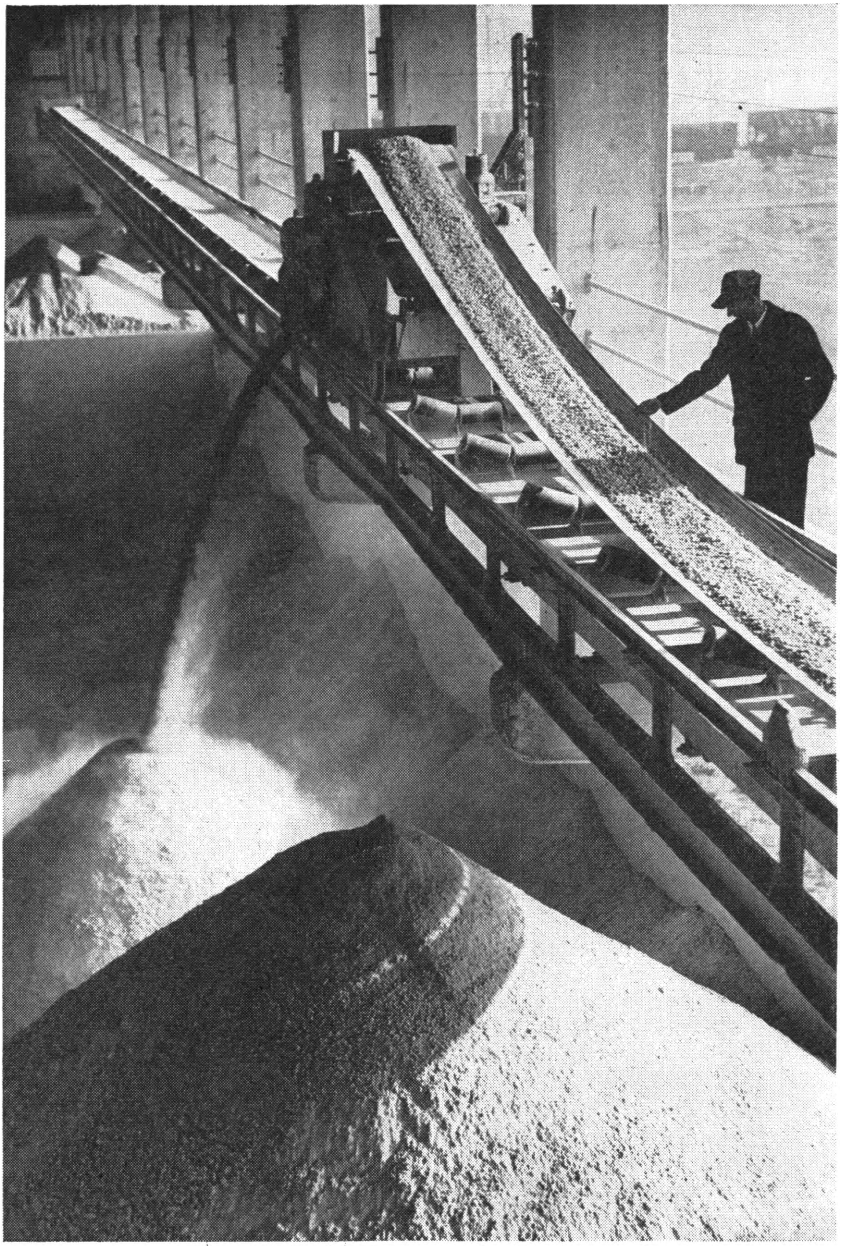

BY COURTESY OF MARQUETTE CEMENT MANUFACTURING CO

Fig. 1.—Inspector checking "crusher-run" cement making materials being delivered into a crane-way storage.

Labor Requirements for Construction Materials

PART I.—PORTLAND CEMENT

Introduction

One of the basic materials used in any construction program is portland cement. Because of this and because the industry was in a most favorable position to resume peacetime operations, the Bureau of Labor Statistics has selected the cement industry for its first in a series of studies of labor requirements for construction materials.

The first study of labor requirements in cement production made by the Bureau of Labor Statistics covered the man-hours required to manufacture 100 barrels of portland cement in 1934.[1] The current study revises these data for the year 1945 and the first quarter of 1946.

This study derives special significance from the fact that there is an anticipated large volume of construction of all types in 1946. Construction needs for 1946 are estimated to be approximately 131 million barrels of cement. The annual capacity of the cement industry is estimated at 220 million barrels, which could be increased to 280 million barrels by increasing the number of work shifts.[2] It is noteworthy that no apprehension regarding availability of cement as needed has been expressed in public or private analyses of the building material shortages.

CHARACTERISTICS AND BACKGROUND OF THE INDUSTRY

Portland cement is the product obtained by mixing proper proportions of finely ground materials containing calcium, silica, and alumina, burning the mixture until it approaches the melting point, then grinding the resulting material into a fine powder. Before or during the grinding process about 4 percent of gypsum or calcium sulphate is added for the purpose of regulating the hardening period of the cement when it is mixed with water.

The calcium-bearing materials may consist of limestone, cement rock, marl, oyster shell, chalk, or caustic soda waste; the silica-bearing materials may consist of clay, shale, blast-furnace slag, slate, or cement rock.

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[1] See Monthly Labor Review, March 1936 (pp. 564–577): Labor Requirements in Cement Production, by Bernard H. Topkis (reprinted as a separate, Serial No. R. 358).

[2] U. S. Department of Commerce, Construction and Construction Materials, May 1946 (p. 37). Estimates are based on maximum attainable production with allowances for maintenance, repairs, and unavoidable shut-downs.

Portland cement is one of a family of hydraulic cements which produces an artificial stone when hardened by combining with water. Since more than 98 percent of the cement produced in the United States is portland cement, this report will deal with that product only. Moreover, it was not found practicable to obtain separate data for the different types of portland cement, such as the general use, moderate heat, high early strength, low heat, sulphate resisting, oil well, white cement, portland-puzzolan, etc. All of these types with the exception of the general use and moderate heat cements are known as special-purpose cements, embodying certain special characteristics, and require special treatment in manufacture. The special purpose cements account for less than 10 percent of the total production of portland cement, and their effect upon man-hour requirements are relatively minor.

Among new trends in the cement industry is the growing interest in air-entrained cement. Air entrainment may be obtained by the use of regular or general use cement with an interground air-entraining agent or by means of an air-entraining agent added to the concrete at the mixer. A feature of air-entrained concrete is its greater resistance to disintegration and scaling, caused by freezing and thawing and salt applications, as compared with normal portland cement concrete. Its disadvantages lie in its somewhat lower flexural and compressive strength. In tests of concrete pavement the loss in strength was not great enough to cause failure while considerable durability was added by use of air-entraining agents.[3] New trends during the war years were directed toward uses of cement products as a substitute for scarce materials, for example, concrete beams, tanks, and joists to replace steel.[4]

Portland cement derives its name from its resemblance, when set, to a famous English building stone quarried in the Isle of Portland.[5] The name was first suggested by Joseph Aspdin, an English bricklayer, who is credited with discovering the principle of artificially mixing limestone and clay to form a product similar to portland stone. He was granted a patent for its manufacture by George IV in 1824.[6]

For nearly 43 years after the patent was granted to Joseph Aspdin, portland cement was manufactured only in England and on the Continent, and its entire production was consumed there. The first dribble of portland cement was imported from Europe to the United States in 1868. The imports increased rapidly and amounted to 92,000 barrels in 1878. By 1885 the imports reached 554,000 barrels.[7]

The first manufacturer of portland cement in the United States was David O. Saylor of Allentown, Pa., who was granted the first United States patent in 1871. The cement was so successful that by 1878 the United States Government specified Saylor's cement for the Eads Jetties at the mouth of the Mississippi River, the first important public works where domestic portland cement was used. Within 20 years after Mr. Saylor's original venture (by 1891), 16 portland cement mills

[3] Barbee, J. T., in Rock Products, Vol. 49, No. 3, pp. 69, 70.
[4] U. S. Bureau of Mines, Minerals Yearbook, 1944 (Cement).
[5] Hadley, Earl J.: The Magic Powder. New York, G. P. Putnam's Sons, 1945, p. 4.
[6] Idem, p. 13.
[7] Idem, p. 4.

were in operation in different parts of the country, especially in Pennsylvania, New York, Indiana, Texas, Oregon, and Michigan.[8]

In the two decades, 1900 to 1920, the complete mechanization of the industry was achieved. The introduction of the rotary kiln was perhaps the largest single factor. The dome kiln, into which a charge of raw materials was placed for burning and then withdrawn before the introduction of a succeeding charge, required excessive amounts of labor and delivered a product of varying quality. The shaft kiln provided continuity of operation but did not improve the quality of the product. The rotary kiln enabled continuous operation with a higher rate of production, eliminating shut-down periods for recharging, made possible an improved product of uniform quality as a result of better temperature control, and reduced labor and fuel requirements in the burning process. It also acted as an impetus to mechanization in other operations of the cement plant.

By 1920 the establishment of all basic techniques had been completed, and during the following 20 years efforts were directed toward improving these techniques for the purpose of reducing costs and producing cement of higher strengths and more uniform quality. The refinements in technique have been of little importance individually, but collectively have made possible substantial reductions in labor and fuel costs, and increased the efficiency of existing plants.[9]

MANUFACTURING PROCESSES

About 80 operations are necessary for the production of portland cement which meets modern specifications,[10] and throughout all operations careful checks are made to insure the uniformity and quality of the product. The initial step is the quarrying of the raw materials. The crushing of the quarried minerals, which initially may be of tremendous size, is done by self-contained units which reduce the minerals to about 3 to 4 inches in diameter.

After the crushing, the material is taken to the raw mill for raw grinding. This step is really a continuation of the crushing process, but because of the smaller size of the material, the machines are of a different type and may operate on a different principle from that used in the initial crushing. In raw grinding the material is reduced to such a degree of fineness that 95 percent of it will pass through a 200-mesh screen (40,000 openings per square inch). It is then conveyed to storage bins or silos where it is kept until ready for burning.

Rotary kilns are the most widely used in this country for the manufacture of cement. The kilns operate at a speed range of 1 to 3 minutes for each revolution. The slope of the kiln is pretty well fixed at one-half inch per foot. The raw material is fed into the upper end,[11] and the kiln is fired from the lower end.

[8] Hadley, Earl J.: The Magic Powder, New York, G. P. Putnam's Sons, 1945, p. 23.
[9] Mechanization in the Cement Industry, Report No. M–3, Work Projects Administration, 1939, p. 33.
[10] Monthly Business Review, Federal Reserve District No. 4 (Cleveland), Vol. 28, No. 5 p. 2.
[11] Pit and Quarry Handbook, 37th ed., 1944, p. 351.

Kilns range in size from 6 feet in diameter and 60 feet in length to 12 feet in diameter and 475 feet in length. The raw material, either in the form of a dry powder or a slurry containing from 30 to 50 percent of water, is fed into the upper end of the kiln, where intense heat (about 2,750° F.) produced either by powdered coal, gas, or fuel oil calcines the materials to unite them in a new chemical product, portland cement in clinker form.

As the clinker leaves the kiln it is sometimes air cooled or "quenched" by being passed over grates through which air is forced under pressure. This air "quenching" enables the clinker to be ground soon after leaving the kiln and assures a more uniform and better finished product. The cooler also serves to preheat the combustion air, resulting in a substantial fuel saving in firing the kiln.

The next step, sometimes referred to as finish grinding, reduces the clinker to extreme fineness. The grinding is done by ball, pebble, or tube mills. The ball mill is a cylindrical, horizontal, slow-speed rotating drum containing a mass of metal balls as grinding media. The pebble mill uses flint or other ceramic pebbles as the grinding media. The tube mill is so referred to because it is long in proportion to its diameter and, when first used in the industry, it used chiefly stone or ceramic linings and pebbles as grinding media. The diameter of the balls and pebbles is determined by the size of the feed and the fineness of the product desired.

Two methods are used in the manufacture of portland cement—the dry process and the wet process. In the dry process the materials are dried either separately or after proportioning and are then ground to a fine powder. Air separators or classifiers are sometimes used to segregate the coarse material from the fine particles, and the coarse material is returned to the mill for further grinding. The fine particles are conveyed to multiple storage bins or blending tanks ready for kiln burning.

In the wet process, instead of drying the raw materials, water is added at the time of grinding and the materials are reduced to a slurry. The exact chemical mixture for the desired quality of clinker is obtained by proportionate mixing or blending of different slurries in correction or blending tanks, and the mixture is then passed into storage tanks from which it is fed into the kilns.[12]

Industry opinion is divided as to the relative advantages of either the wet or the dry process. It would appear that the choice of methods is governed by the type of materials used. The wet process may be preferable where the materials are so wet as to make drying costly, where the materials may be so variable that an unusually good mix is required, and where the plant may be so located that suppression of dust may be imperative.

On the other hand, the advocates of the dry process claim that less power is needed for grinding where the dry process is utilized, that less fuel is needed for kiln burning, and that methods of suppressing the dust have been perfected.

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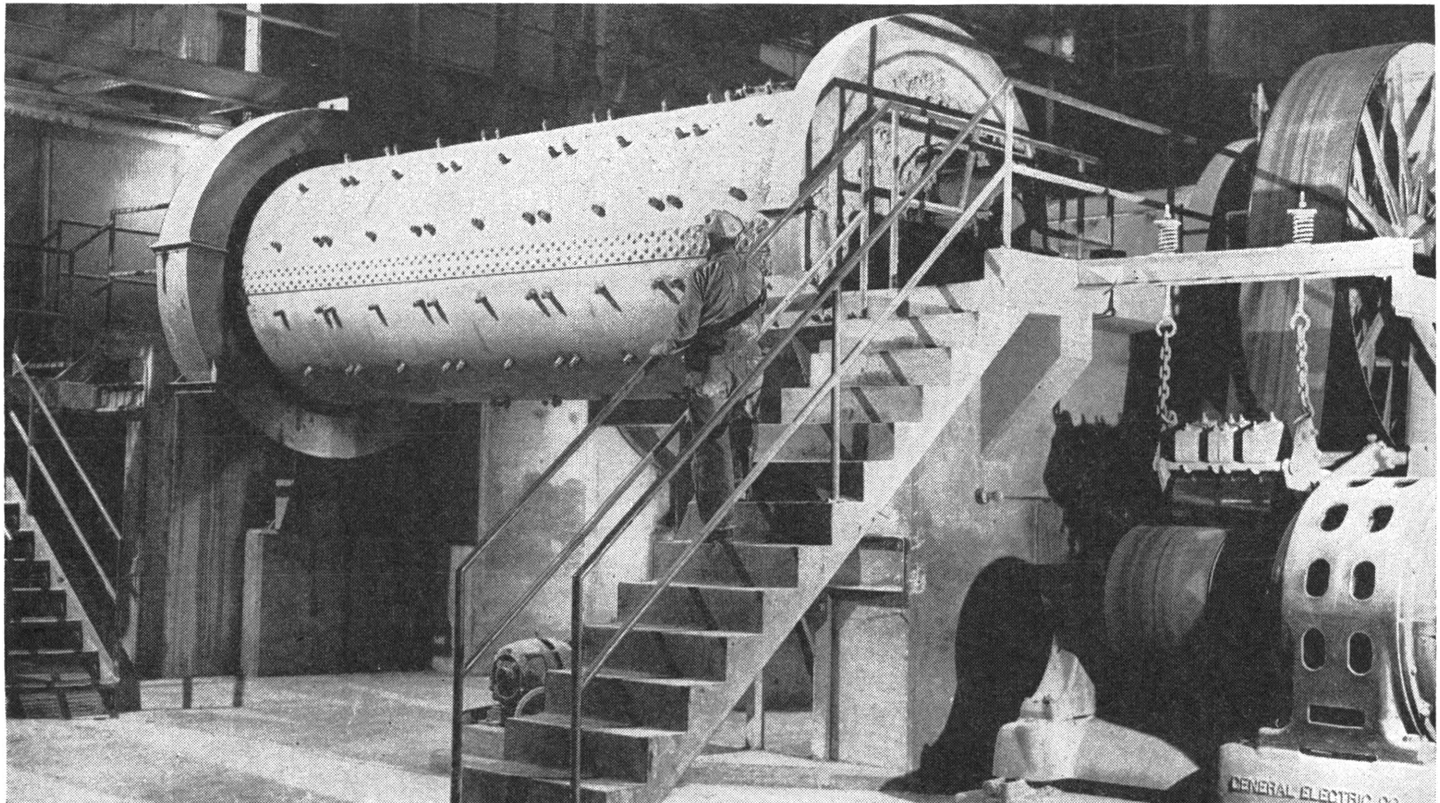
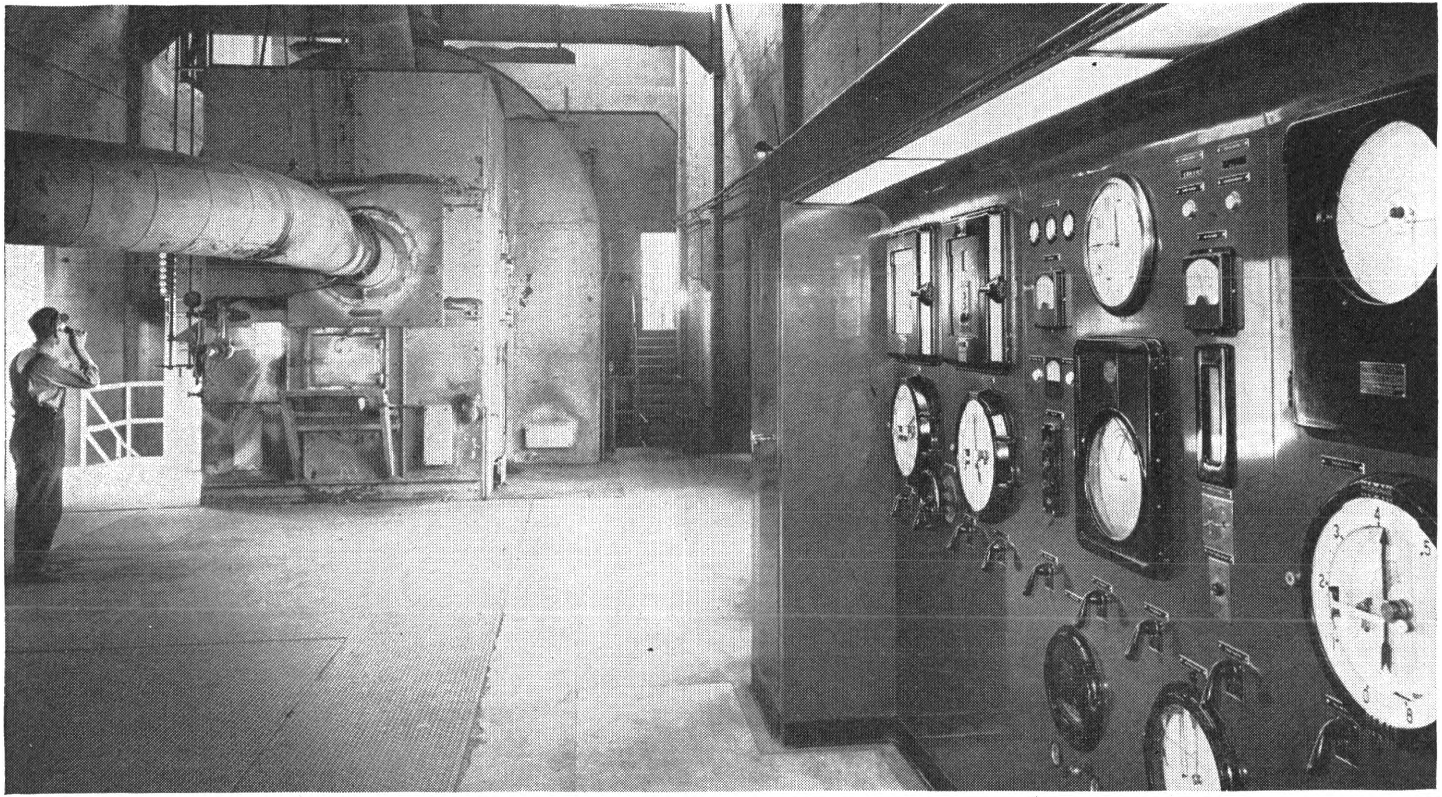
[12] Hadley, Earl J.: The Magic Powder, New York, G. P. Putnam's Sons, 1945, p. 310.



BY COURTESY OF MARQUETTE CEMENT MANUFACTURING CO.

Fig. 2.—Miller watching performance of one of the large raw grinding mills.



BY COURTESY OF MARQUETTE CEMENT MANUFACTURING CO.

Fig. 3.—Kiln burner checking critical burning operation in the largest cement kiln.

INDUSTRY COVERAGE AND METHODS OF DATA COLLECTION

The data presented in this report are based on a field survey of 52 plants. These constitute a stratified sample with respect to geographic location, size of plant, process of manufacture, source of electric power, and type of fuel consumed.

Data were collected for periods in 1945 and the first quarter of 1946. The characteristics of the sample are measured by comparison with those of the industry in 1945. The sample of 52 plants represents an annual production of 47,543,037 barrels, as compared with 102,804,884 barrels produced in 141 active plants in 1945. Of the 81 wet process plants and 60 dry process plants, active in 1945, 28 and 24, respectively, are included in this survey. In addition, 21 plants included in the sample generated 37.7 percent of all electric power produced in the cement industry and 38 plants accounted for 49.8 percent of all power purchased by the industry. Seven plants in the sample both purchased and generated their power requirements.

Upon selection of the sample, data were collected by field representatives located in the regional offices of the Bureau of Labor Statistics. These representatives made the necessary contacts with plant officials and, in the case of multiplant organizations, with management executives at the central office, in obtaining labor requirements data and valuable background information.

A normal period of the company's operation was decided upon and for the most part this was the calendar year 1945. However, because some companies had not resumed peacetime production and distribution until the latter part of 1945, a representative period was studied in 1946.

Man-Hour Requirements in Manufacturing and Mill Operations

The 52 plants surveyed in the study, forming the basis for this article, represent an aggregate annual rate of production of 47,543,037 barrels of cement, requiring a total of 23,020,523 man-hours of labor.

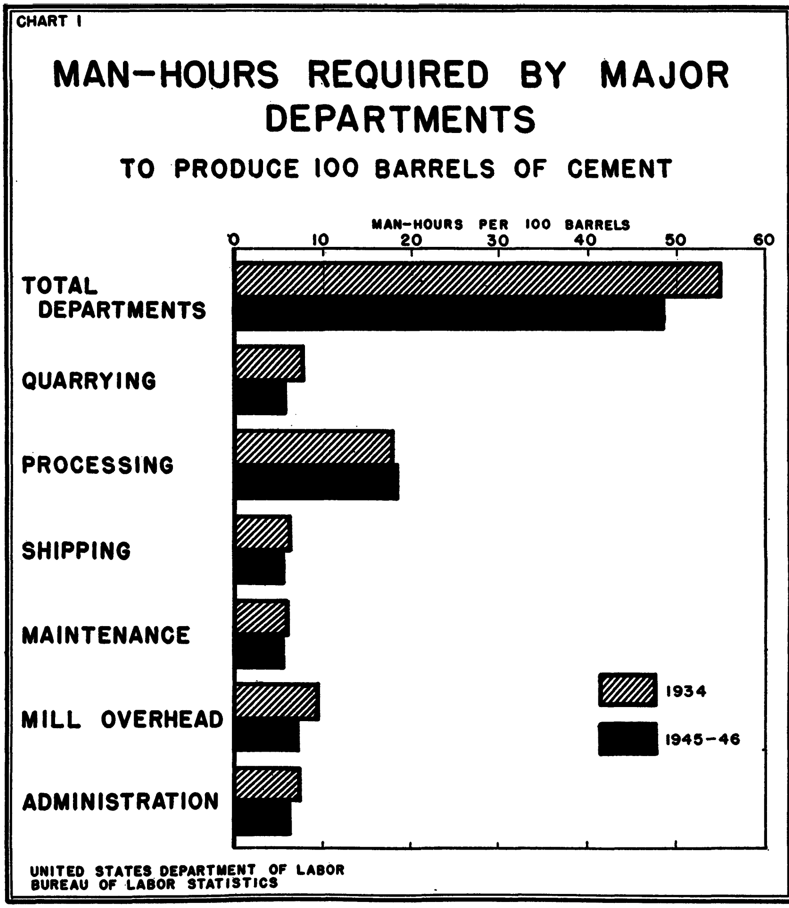
Table 1 shows total man-hours, for each of the major departments of the plants, and the man-hours required to produce 100 barrels of cement in 1945–46. Comparative data on man-hours per 100 barrels are also given for 1934.[13]

TABLE 1.—*Man-Hour Requirements in Cement Manufacture, 1934 and 1945–46*

Major departments of plants	Total man-hours (in thousands)	Man-hours per 100 barrels	
	1945–46	1945–46	1934
All departments	23,021	48.4	55.0
Quarrying	2,689	5.7	7.7
Processing	8,733	18.4	18.0
Shipping	2,581	5.4	6.3
Maintenance	2,629	5.5	[1] 6.0
Mill overhead	3,442	7.2	[1] 9.6
Administration	2,947	6.2	7.4

[1] Adjusted for transfer of yard operation from maintenance to mill overhead

[13] For 1934 study see Monthly Labor Review, March 1936 (pp. 564–577).



In general, fewer man-hours were required to produce 100 barrels of cement in 1945–46 than 12 years earlier. There were wide deviations from the average in some plants. The basic factors affecting labor requirements—such as rate of production, size of plant, age of plant, number and size of kilns, and degree of mechanization—in 1945–46 remain the same as pertained to the study made in 1934. Certain functions necessary for operation of the cement plant are performed by plant employees in some cases and thus appear as man-hour requirements, but in other instances appear only as cost items (for example, purchased electric power, purchased quarry materials, and contracts for shipping).

QUARRYING OPERATIONS

The materials obtained from the quarry are usually located on or adjacent to the plant site and man-hours necessary for delivery of these materials to the plant are included in the requirements shown for this department. Estimates of man-hours required for production and transportation of raw materials other than those obtained from the quarry are presented in a following section.

A substantial reduction in quarrying operations of 2.0 man-hours per 100 barrels of finished cement was effected between 1934 and 1945–46. In the 52 reporting plants, total man-hours in the 1945–46 period were 2,688,858, and the average per 100 barrels was 5.7 man-hours. The range in individual plants was from 1.2 to 19.7 man-hours per 100 barrels.

One reason for the reduction in man-hours in the past 11 years, as well as for the variation in man-hour requirements in this study, was the improvement in quarrying machinery. More general use of electric and Diesel-powered shovels with increased capacity and greater mobility was largely responsible. Steam shovels, which require an extra man for firing in addition to the operator are gradually being discontinued. In some plants the use of Diesel trucks has resulted in greater efficiency and flexibility in the quarrying operation.

PROCESSING DEPARTMENT

In 1945–46, 52 plants accounted for 8,732,921 hours of employment in the processing department. To process 100 barrels of cement required an average of 18.4 man-hours for all plants, an increase of 0.4 man-hours since 1934.

The data presented reflect only a slight change in man-hour requirements since 1934. This tends to understate the actual change in productivity, because specifications became more exacting in the intervening period. Technical improvements have kept pace with changes in specifications which required improvement in quality of the finished product, thus holding down the man-hour requirements per unit produced near the level shown for 1934. Considering the more exacting specifications, the fact that the data show little change in man-hour requirements in the two periods studied is indicative of a marked improvement in productivity for the processing department.

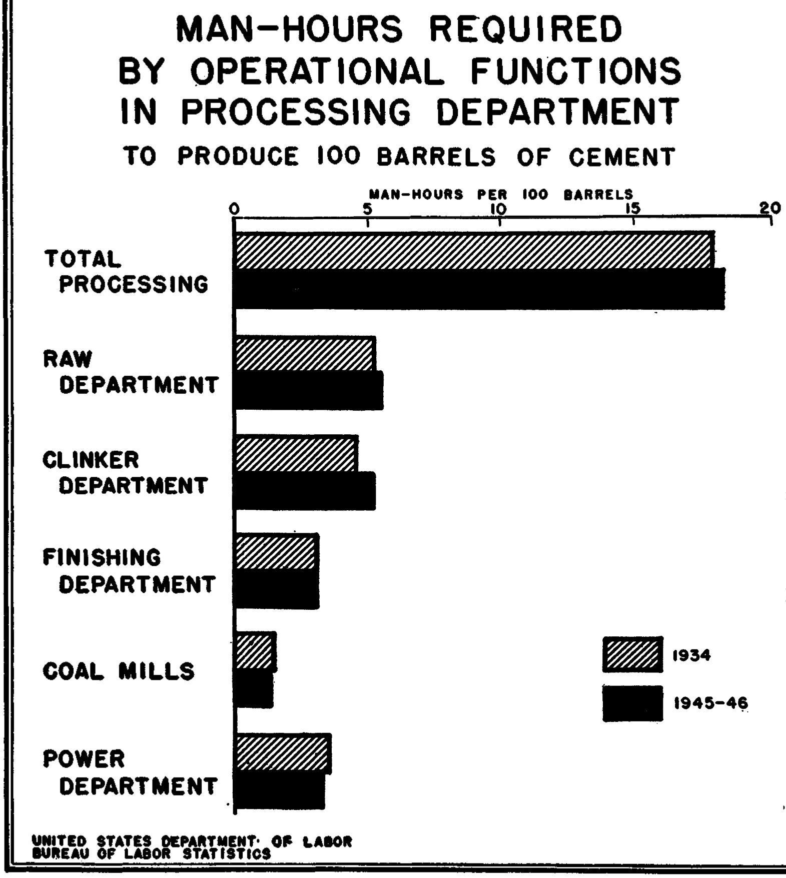
Labor turn-over and labor shortages were felt by all plants in this department until late in 1945. The effects of the war in drawing off trained men created acute labor shortages, which resulted in the use of inexperienced labor in semiskilled and skilled jobs and tended to limit reductions in man-hour requirements which might normally have occurred in processing operations. The trend is now being reversed as discharged servicemen return to their former employers and as activities in war industries terminate.

The processing department is divided into five operational functions or sections. The average number of man-hours expended per 100 barrels in 1945–46, by processing functions, as compared with the earlier study in 1934, were as follows:

	Man-hours per 100 barrels	
	1945–46	*1934*
All sections	18.4	18.0
Raw department	5.5	5.2
Clinker department	5.2	4.6
Finishing department	3.1	3.1
Coal mills	1.3	1.5
Power department	3.3	3.6

The raw department man-hour requirement per 100 barrels in 1945–46 was 5.5. This exceeded the requirement in 1934 by 0.3 man-hour. In the clinker department, where the raw materials are burned in the kiln, man-hours increased 0.6; and in the finishing department, where the clinker is finally pulverized, gypsum is added, and the finished product is produced, no change occurred in the man-hour requirement.

CHART 2



For each 100 barrels of output, 1.3 hours were expended in the coal mills, where coal is treated and prepared for firing of the kilns. This average is based on the production of all plants, without regard to type of fuel used. Variations are considerable among the cement plants, depending upon the type of fuel used. In plants where gas or oil is the primary fuel, there are no requirements for fuel preparation.

A break-down was prepared showing man-hours required for those plants which used coal exclusively as compared with those which used natural gas, fuel oil, or combinations thereof with coal. Plants which used coal exclusively required 2.0 man-hours of employment per 100 barrels, while those which used, in addition to coal, fuels which did not have to be treated (for example, oil and natural gas), had 1.1 man-hours per 100 barrels.

In the power department, 3.3 man-hours were needed for each 100 barrels of output. The average decrease since 1934 in this department was 0.3 man-hour. Data for this department can be separated into plants which generate their own power and plants which purchase power from a utility. The latter plants, in which the functions of the power department are limited to distributing the purchased energy, require relatively fewer man-hours.

Analysis of 43 reporting plants showed that 12 plants generated all the power they consumed. To produce 100 barrels of cement, these 12 plants required an average of 7.4 man-hours in the power department. Twenty-five plants purchased their power supply from local utilities and, accordingly, only 2.1 man-hours were required in their power departments. In addition to these two groups of plants, there were six which generated part of their power requirements. In most cases the amount of purchased power was considerably less than that generated and the man-hour requirement was 6.0 per 100 barrels of cement produced.

SHIPPING DEPARTMENT

The shipping department has two main functions: (1) Packing and loading and (2) bag handling and repairs. Upon completion of the manufacturing process, cement is stored in bulk in bins and silos and held for shipment. Depending upon instructions from the customer, shipments may be made in bulk, or in paper or cloth bags. Information gained in the field indicates that the trend among most cement plants is to increase shipments in bulk and in paper bags and to decrease shipments in cloth bags, eliminating not only some administrative expense involved in the accounting procedure for cloth-bag refunds and returns but also the cost of sorting, cleaning, and repairing returned bags.

In a special study of a portion of the sample, the shipments of 31 plants were analyzed. The total shipped by these plants during the period studied was 24,080,787 barrels. Of this total, 27.6 percent was shipped in bulk, 50.1 percent in paper bags, and only 22.3 percent in cloth bags. The above figure of 24,080,787 barrels represents 48.0 percent of the total shipments from the 52 plants.

In terms of man-hours of employment per 100 barrels of cement, 5.4 hours were required in the shipping operation during 1945–46. This is a decrease of 0.9 from the 6.3 man-hours reported in the 1934 study. Bag handling and repair accounted for 0.8 man-hour per 100 barrels, and packing and loading for 4.6 man-hours. Total man-hours in the shipping department for the 52 plants studied were 2,581,387. The range between plants was from 0.6 to 15.9 man-hours.

MAINTENANCE AND OVERHEAD

Maintenance.—In general, maintenance work includes the labor of the shop and repair gangs which overhaul the machinery during periods of shut-down. In 1945–46 yard employment data have been transferred to the mill overhead department. The man-hours required for maintenance operations are as follows:

	Man-hours per 100 barrels	
	1945–46	*1934*
Total maintenance	5.5	6.0
Shop	2.0	2.4
Repair gang	3.5	3.6

Man-hour requirements per 100 barrels for this department decreased 0.5 since 1934. This can be attributed largely to labor shortages and curtailment of maintenance operations during the war years, as well as through 1945. Information collected in the field indicates that plans for extensive maintenance operations on the part of many cement manufacturers will increase the man-hour requirements for this department in the immediate future.

Mill overhead.—Data showing the average number of man-hours charged to overhead, as compared with the 1934 survey, are given below:

	Man-hours per 100 barrels	
	1945–46	*1934*
Total mill overhead	7.2	9.6
Mill office	1.4	1.5
Storeroom	.5	.6
Laboratory	1.5	2.1
Superintendents and foremen	1.2	1.5
Watchmen	.6	.8
Yard	1.6	2.5
Miscellaneous labor	.4	.6

The labor shortage during the period studied was, as in the maintenance department, a large contributing factor in the decrease as compared with 1934. Greater reductions in employment can be expected in overhead operations than in production operations when labor shortages develop. Should an adequate labor supply lead to increased employment in this department, average requirements per unit produced may remain stabilized near the level here shown for 1945–46, if anticipated increases in the production of cement materialize.

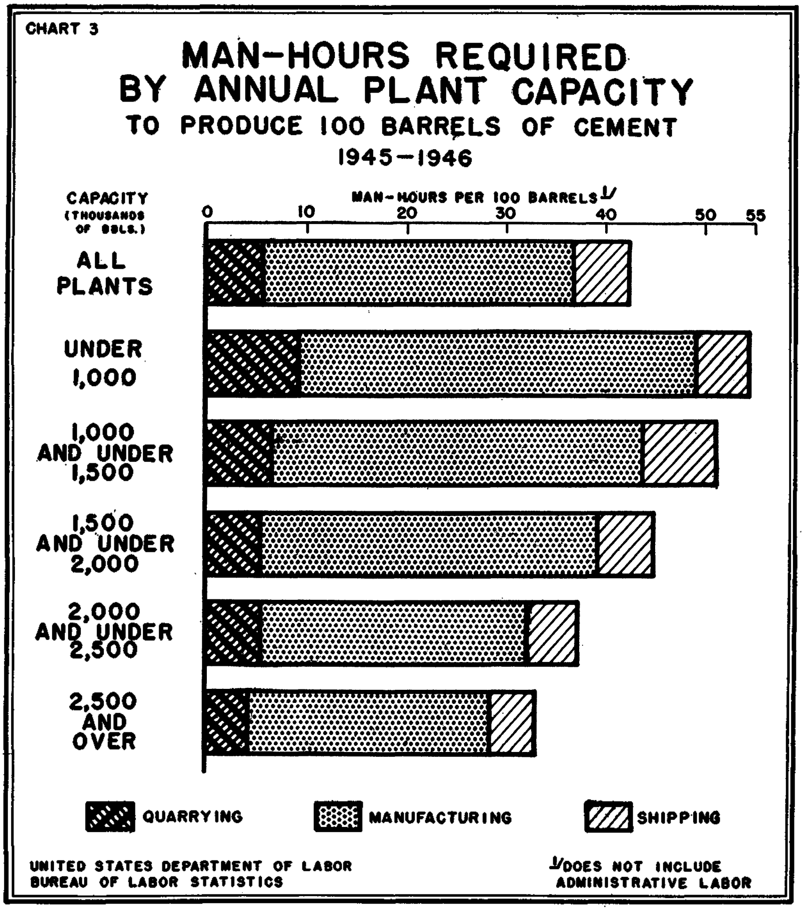
ADMINISTRATIVE DEPARTMENT

This department includes the employment necessary to operate the general offices and selling organizations. Because many plants kept inadequate man-hour records for these employees, a special study of 23 plants was made. Upon this basis, it was estimated that the average number of man-hours required per 100 barrels of production was 6.2, and that 2,946,633 hours of employment were required for the administrative functions in the 52 sample plants.

Variations in Labor Requirements

BY RATE OF OPERATION AND PLANT CAPACITY

In determining the man-hours necessary to produce 100 barrels of cement, the rate of operation and the plant capacity should be taken



into account. From table 2, it is apparent that as percent of capacity utilized approaches the maximum, the total man-hours required in all departments are generally lower. From table 3, it appears that the larger producers tend to show greater efficiency in manufacturing operations.

TABLE 2.—*Average Number of Man-Hours Required to Produce 100 Barrels of Cement in 1945–46, by Rate of Operation*

Percent of capacity utilized	Number of plants	Man-hours per 100 barrels			
		Total [1]	Quarrying	Manufacturing [1]	Shipping
All plants	52	42.2	5.7	31.1	5.4
Less than 40 percent	12	49.6	5.4	38.5	5.7
40 to 60 percent	24	50.3	6.8	37.2	6.3
60 to 80 percent	9	38.9	4.9	29.0	5.0
80 to 100 percent	7	25.4	4.6	16.6	4.2

[1] Does not include administrative labor.

The greatest variation in man-hours exists in the manufacturing process. In plants operating at more than 80 percent of capacity, as shown in table 2, only 16.6 man-hours per 100 barrels of production were required in manufacturing, whereas those operating at less than 40 percent of capacity required 38.5 man-hours. The average requirement for all plants was 31.1 man-hours.

Table 3 furnishes a break-down of the 52 plants of the sample according to capacity in 1945–46. Again, a wide range occurs in the manufacturing departments, with the largest producers reporting 24.7 man-hours per 100 barrels and the smallest 39.9.

Table 3.—*Average Number of Man-Hours Required to Produce 100 Barrels of Cement in 1945–46, by Annual Plant Capacity*

Capacity	Number of plants	Man-hours per 100 barrels			
		Total [1]	Quarrying	Manufacturing [1]	Shipping
All plants	52	42.2	5.7	31.1	5.4
Over 2,500,000 barrels	8	33.1	4.1	24.7	4.3
2,000,000 to 2,500,000 barrels	5	37.4	5.5	26.7	5.2
1,500,000 to 2,000,000 barrels	10	44.9	5.5	33.9	5.5
1,000,000 to 1,500,000 barrels	17	51.0	6.6	37.1	7.3
Under 1,000,000 barrels	12	54.2	9.3	39.9	5.0

[1] Does not include administrative labor.

BY GEOGRAPHIC AREAS

The variations in labor requirements among geographic areas, for the 52 plants studied, are shown in table 4. Plants in the Pacific States lead in productivity, with the plants in the Southeast next in order. On the basis of productivity, the relative position of plants in the Pacific States remains unchanged since 1934. Plants in the Mountain States show the highest man-hour requirements, 60.2 man-hours per 100 barrels. Plants in the Lehigh Valley area are nearest the average of all plants included in the survey with 41.1 man-hours per 100 barrels. Among the factors which affect the range of man-hour requirements by geographic areas are production rate, size of plant, age of plant and equipment, process of manufacture, and type of fuel used.

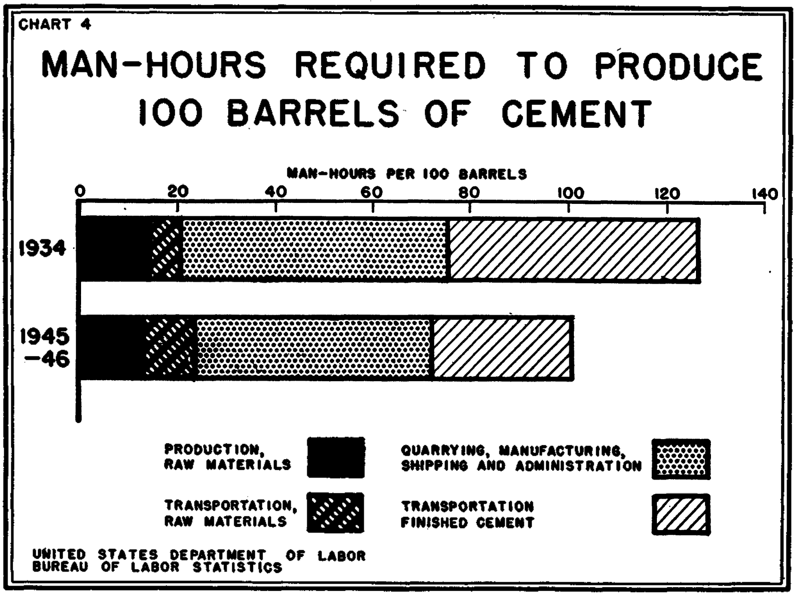
Table 4.—*Average Number of Man-Hours Required to Produce 100 Barrels of Cement in 1945–46, by Geographic Area*

Area	Number of plants	Annual production	Man-hours per 100 barrels			
			Total [1]	Quarrying	Manufacturing [1]	Shipping
		Barrels				
All areas	52	47,543,000	42.2	5.7	31.1	5.4
Pacific	6	9,012,000	24.6	4.8	16.0	3.8
Southeast	5	5,955,000	38.7	5.7	27.0	6.0
Lehigh Valley	4	5,485,000	41.1	5.3	29.8	6.0
Middle West	15	14,334,000	45.8	5.9	34.5	5.4
Northeast	6	3,887,000	47.4	4.9	37.0	5.5
Southwest	11	6,649,000	53.8	6.5	40.9	6.4
Mountain	5	2,221,000	60.2	7.5	46.1	6.6

[1] Does not include administrative labor.

Total Man-Hour Requirements for Production and Transportation

The preceding sections have developed in detail, from basic plant records, the man-hours required at the plant to manufacture 100 barrels of cement. The following section estimates the additional man-hours required to extract those raw materials not hitherto considered, to haul these materials to the plant, and to transport the finished cement to the construction site.



These operations (production of additional raw materials, and transportation), as indicated below, require an estimated 52.1 man-hours in addition to the 48.4 required at the plant. Thus, 100 barrels of cement delivered to a job site represent an over-all investment of approximately 100.5 man-hours of labor.

	Man-hours per 100 barrels	
	1945–46	*1934*
Total production and transportation	100.5	126.4
Raw materials, production	[1] 13.0	[1] 14.1
Raw materials, transportation	10.6	6.6
Quarrying, manufacturing, shipping and administration	48.4	55.0
Transportation, finished cement	28.5	50.7

[1] Includes purchased electric power.

PRODUCTION OF RAW MATERIALS

The materials used in cement manufacture are in the main (1) limestone, shale, clay, and other materials obtained from the plant's quarry, (2) gypsum, and (3) coal. Usually the first of these materials is obtained from a quarry located on or adjacent to a plant site, and this operation is covered in the man-hours required for the manufacturing process.

Required quantities (to produce 100 barrels of cement) of the materials not considered under manufacturing and mill operations, including power are shown in the statement following.

	Requirements per 100 barrels, 1945–46	
	Amount of materials	*Man-hours to produce quantities consumed*
Materials:[1] Total	-----	13.0
Gypsum	0.66 ton	.5
Coal	6.29 tons	8.3
Power (purchased)	1,355 kw.-hr.	4.2

[1] Steel, for which requirements were indicated in the 1934 study, is not represented here because its use in the finish grinding and cloth-bag tying operations has substantially decreased.

Gypsum.—The amount of gypsum—0.66 ton consumed per 100 barrels—was obtained by dividing 683,158 tons, the amount used in 1945 in cement manufacture, by the total 1945 production of cement, 102,804,884 barrels.[14] The man-hour requirements for producing 1 ton of raw gypsum, which were obtained by dividing total man-hours used in the production of gypsum (2,616,928) by the total number of short tons produced (3,761,234)[14] are 0.70. On this basis, the man-hour requirements for the gypsum used in 100 barrels of cement are 0.46.

Coal.—The amount of coal consumed per 100 barrels of cement was obtained by dividing the total amount used in 1945 in those cement plants using coal only (3,481,492 tons) by the total amount of cement produced in those plants (55,347,915 barrels[14]). The average coal consumption to produce 100 barrels of cement was 6.29 tons, or 125 pounds per barrel.

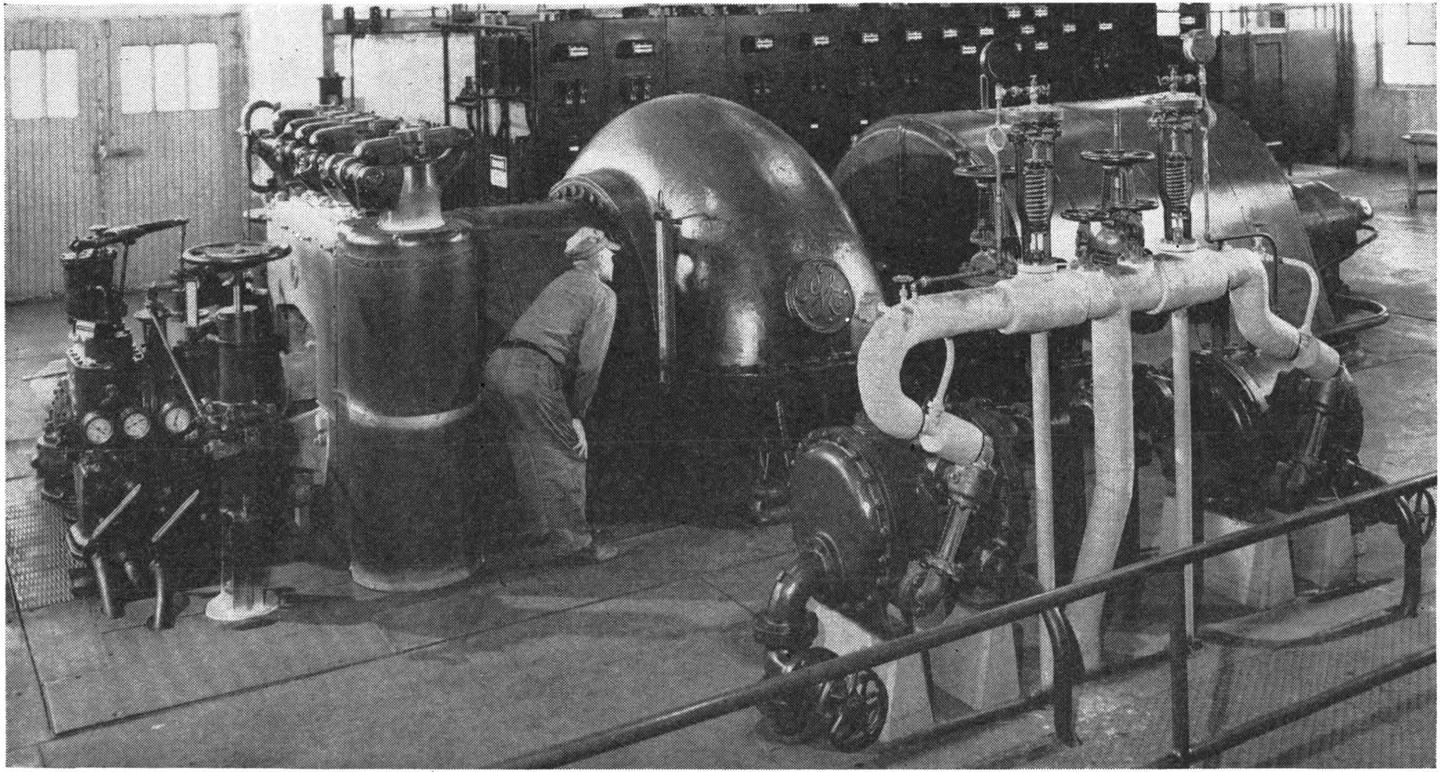
The U. S. Bureau of Mines estimates that 1.32 man-hours were required per ton for bituminous coal production in 1945. (The decrease from the 1.65 man-hours required in 1934 is confirmed by the Bureau of Labor Statistics productivity index for bituminous coal.) Thus, 8.30 man-hours were needed to produce the coal consumed in manufacturing 100 barrels of cement. This represents a slight overstatement of average fuel requirements, however, since some plants use natural gas and oil, the labor requirements for which it is assumed are less than those for coal.

Power.—The use of electric power is a vital factor in the production of cement. Power used in cement plants is either generated at the plant or purchased from utilities. The man-hour requirements for power generation at the cement plant are already included in cement plant operations. An estimate, however, is necessary for the amount of labor required to produce the energy purchased from utilities.

Of the 2,512,083,504[14] kilowatt-hours used in cement manufacture in 1945, 1,393,234,210[14] were purchased. Thus, although 2,445 kilowatt-hours of electric power were used per 100 barrels of cement produced, the average requirement in all plants for purchased power only was 1,355 kilowatt-hours.

The Bureau of Labor Statistics estimates that the average 1945 employment in privately operated electric energy generation and

[14] Source: U. S. Bureau of Mines.



BY COURTESY OF MARQUETTE CEMENT MANUFACTURING CO.

Fig. 4.—Attendant checking the important vacuum on a big turbogenerator. (A cement plant of average size consumes as much power as a city of 30,000 population.)

distribution stations was 205,000. These employees averaged 45.5 weekly hours for the year. The amount of power generated by privately operated plants during 1945 was 180.9 billion kilowatt-hours. Thus, the labor requirements for electric power were 2.68 [15] man-hours per thousand kilowatt-hours, or 3.63 man-hours for the amount of power necessary to produce 100 barrels of cement.

The total amount of coal used in electric power generation in 1945 was 74,747,968 short tons,[16] and the total power generated (all types of prime mover) was 222,433,981,000 kilowatt-hours.[16] Therefore, the average coal consumption was 0.33605 ton per 1,000 kilowatt-hours. Thus, it was estimated that 0.601 man-hour was expended on the fuel requirements for generating the electricity purchased to produce 100 barrels of cement. This fuel requirement is somewhat understated because substantial amounts of natural gas and oil are used in power generation, but no data were available to determine the man-hour requirements for gas and oil production. It is believed, however, that omission of these should introduce a comparatively slight error.

A total of 4.23 man-hours was thus required to produce the quantity of purchased electrical energy necessary to manufacture 100 barrels of cement.

Data were not available to estimate the employment created by all the purchases of cement mills for materials used in small quantities, such as sacks, lubricants, explosives, and repair parts. Inasmuch as quantities of these materials were very small in relation to total production of cement, the lack of these man-hour estimates would have negligible effect on the total estimate of labor requirements.

TRANSPORTATION OF RAW MATERIALS

In addition to the labor involved in extracting the raw materials, a substantial number of man-hours are required to transport them from their source to the cement plant. No direct measurement of these man-hours was attempted in the present survey, but published data of the Bureau afford a basis for computing rough estimates. These indicated that the requirements for the transportation of raw materials were as follows:

	Estimated man-hours per 100 barrels, 1945–46
Materials: Total	10.63
Coal	9.62
Gypsum	1.01

Coal.—An analysis, in 1937,[17] of the railway statistics of the Interstate Commerce Commission and the Bureau of Railway Economics

[15] This exceeds the estimate of 1.64 man-hours per kilowatt-hour for electrical energy generated in 1934, in spite of a sharp rise in the productivity index for electrical energy production over the 10-year period. However, the first survey took into account only generating plant employees, whereas the 1945 figure includes the requirements for all workers employed by power companies, including generating, distribution, maintenance, and other employees.

[16] Source: U. S. Federal Power Commission.

[17] See Monthly Labor Review, October 1937 (pp. 846–853): Labor Requirements in Rail Transportation of Construction Materials, by John A. Ball (reprinted as a separate, Serial No. R. 637).

indicated that approximately 1.53 [18] man-hours were needed in 1935 to transport one ton of bituminous coal for its average haul of 364 miles. Thus, the 6.29 tons of coal required in the manufacture of 100 barrels of cement (see p. 16) necessitates about 9.62 hours of labor by railroad workers.

Gypsum.—The labor requirements for the transportation of gypsum were not determined in the 1937 study. Therefore, to complete the estimate for the materials transportation requirements, it was assumed, from the distribution of gypsum deposits and the nature of the material, that the man-hours factor for bituminous coal could be substituted. On this basis, hauling to the plant the 0.66 ton of gypsum used in the production of 100 barrels of cement necessitated about 1.01 man-hours of labor. The total requirements for materials transportation to the plant were, therefore, approximately 10.63 man-hours.

TRANSPORTATION OF FINISHED CEMENT

The man-hours needed to transport finished cement from the plant to the point of use are summarized below:

	Man-hours for 100 barrels, 1945–46
Total transportation	28.47
From plant to railhead	16.17
From railhead to construction site	12.30

Plant to railhead.—Finished cement is transported from the plant by road, water, or rail. However, about 80 percent is currently hauled by rail [14] and, therefore, in the absence of data relating to the other carriers, the outbound transportation requirements are estimated solely with reference to the rail study previously cited. That study indicated that 0.86 man-hour was needed to move 1 ton of cement over its average haul of 198 miles. Thus 18.8 tons, the weight of 100 barrels of cement, require an average of 16.17 man-hours of employment for the haul from plant to construction site railhead. It will be noted that this represents a marked decrease from the 38.4 man-hours estimated in the earlier study of labor requirements in cement production. It appears, however, that this decrease is attributable chiefly to the inadequacy of the data on which the previous estimate was necessarily based, rather than to a sharp increase in freight-handling productivity. The transportation study referred to in this report was not then available, and the earlier estimate was therefore based on the freight charge statistics of the Interstate Commerce Commission.

Railhead to construction site.—In addition to the man-hours expended in the rail haul of the finished cement, labor was required to unload it from the freight car and to truck it to the construction site. The earlier estimates for these operations were 10.0 and 2.3 hours, respectively. Since no basis for revising these estimates are available, they

[14] Source: U. S. Bureau of Mines.

[18] Two series of index numbers relating to productivity in railroad freight transportation are maintained by the Bureau. One of these describes the changes in productivity in terms of the tons of freight moved per man-hour, and the other in terms of the car-miles of freight handled per man-hour. Since the former of these measures increases in the 10 years 1935–45, and the latter decreases, and since neither measure is applicable, in the absence of additional information, to the transportation requirements data developed in the 1937 survey, it seemed inadvisable to try to adjust this figure (1.53) for the change in productivity since the original study.

have been incorporated unchanged in the current survey. The total labor requirements for the haul from the railroad to the job site are therefore 12.3 man-hours.

Trend of Productivity, 1930 to 1945

According to data prepared by the U. S. Bureau of Mines, output per man-hour of quarrying and manufacturing labor in the cement industry increased from 1.79 barrels in 1930 to 2.59 barrels in 1942,[19] the year in which the highest rate of productivity has been achieved. The rather steady trend toward greater productivity was interrupted during the depression of the thirties and again during the war years.

Construction of new plants and modernization of many old ones appear to be largely responsible for the increase in output per man-hour during the first 8 years of the series shown below. Changes in productivity in recent years, however, tend to vary directly with the rate of capacity utilization. In 1942, when the highest rate of capacity utilization was reached, the number of barrels produced per man-hour was 2.59, whereas in 1944, when capacity utilization dropped sharply, the number of barrels produced was 1.99. In 1945, however, with increased production and plant utilization, output per man-hour again increased, reaching 2.10 barrels per man-hour.

The average number of barrels of cement produced per man-hour and the number of man-hours required in the production of 100 barrels for each year, 1930 to 1945, are shown below:

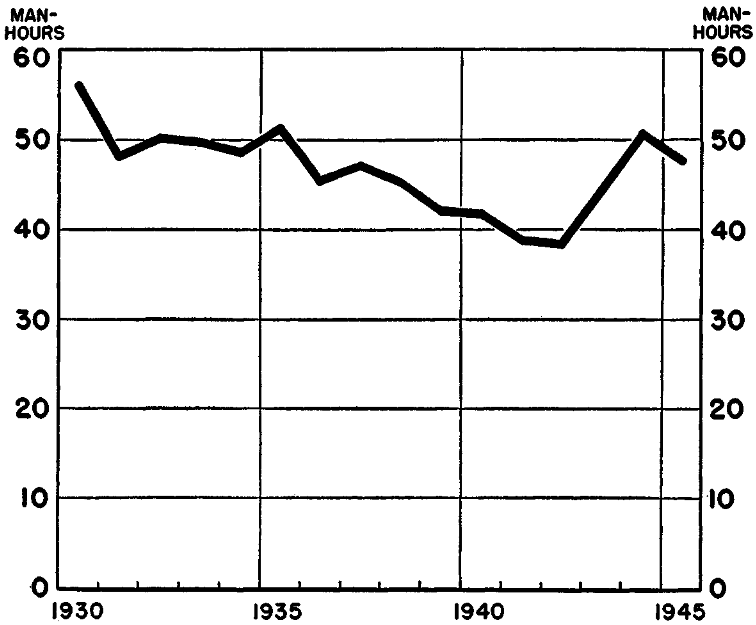
	Average number of—			*Average number of—*	
	Barrels produced per man-hour [1]	*Man-hours required to produce 100 barrels* [1]		*Barrels produced per man-hour* [1]	*Man-hours required to produce 100 barrels* [1]
1930	1.79	56.0	1938	2.21	45.3
1931	2.07	48.2	1939	2.38	42.0
1932	2.00	50.1	1940	2.40	41.7
1933	2.01	49.7	1941	2.57	38.9
1934	2.06	48.6	1942	2.59	38.5
1935	1.96	51.1	1943	2.25	44.4
1936	2.19	45.6	1944	1.99	50.3
1937	2.12	47.1	1945 [2]	2.10	47.6

[1] Data are from U. S. Bureau of Mines. Includes quarrying labor and all manufacturing labor except administrative.
[2] Preliminary.

[19] Except for materials quarried by cement plants, these data do not include the labor required in the production and transportation of raw materials, administrative labor in cement plants, or the labor required in transportation of the finished product to the construction site.

CHART 5

PRODUCTIVITY IN CEMENT MANUFACTURE



INCLUDES QUARRYING LABOR AND ALL MANUFACTURING LABOR EXCEPT ADMINISTRATIVE

UNITED STATES DEPARTMENT OF LABOR
BUREAU OF LABOR STATISTICS