MECHANIZATION BRICK INDUSTRY

WORKS PROGRESS ADMINISTRATION

F. C. HARRINGTON
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NATIONAL RESEARCH PROJECT

on

Reemployment Opportunities and Recent Changes
in Industrial Techniques

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THE WPA NATIONAL RESEARCH PROJECT ON REEMPLOYMENT OPPORTUNITIES AND RECENT CHANGES IN INDUSTRIAL TECHNIQUES

Under the authority granted by the President in the Executive Order which created the Works Progress Administration, Administrator *Harry L. Hopkins* authorized the establishment of a research program for the purpose of collecting and analyzing data bearing on problems of employment, unemployment, and relief. Accordingly, the National Research Program was established in October 1935 under the supervision of *Corrington Gill*, Assistant Administrator of the WPA, who appointed the directors of the individual studies or projects.

The Project on Reemployment Opportunities and Recent Changes in Industrial Techniques was organized in December 1935 to inquire, with the cooperation of industry, labor, and governmental and private agencies, into the extent of recent changes in industrial techniques and to evaluate the effects of these changes on the volume of employment and unemployment. *David Weintraub* and *Irving Kaplan*, members of the research staff of the Division of Research, Statistics, and Finance, were appointed, respectively, Director and Associate Director of the Project. The task set for them was to assemble and organize the existing data which bear on the problem and to augment these data by field surveys and analyses.

To this end, many governmental agencies which are the collectors and repositories of pertinent information were invited to cooperate. The cooperating agencies of the United States Government include the Department of Agriculture, the Bureau of Mines of the Department of the Interior, the Bureau of Labor Statistics of the Department of Labor, the Railroad Retirement Board, the Social Security Board, the Bureau of Internal Revenue of the Department of the Treasury, the Department of Commerce, the Federal Trade Commission, and the Tariff Commission.

The following private agencies joined with the National Research Project in conducting special studies: the Industrial Research Department of the University of Pennsylvania, the National Bureau of Economic Research, Inc., the Employment Stabilization Research Institute of the University of Minnesota, and the Agricultural Economics Departments in the Agricultural Experiment Stations of California, Illinois, Iowa, and New York.

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June 6, 1939

Colonel F. C. Harrington
Works Progress Administrator

Sir:

The report *Mechanization in the Brick Industry*, transmitted herewith, describes the changes in production techniques that the industry has experienced in the past 50 years. The changes of the last 20 years are analyzed in some detail.

Although the improvements in machines and in manufacturing techniques were limited largely to refinements in design and to the addition of relatively inexpensive auxiliary equipment, the cumulative effect of these minor changes on the amount of labor required per unit of product was considerable. In addition, the industry has benefited from the general technological progress since 1920 which resulted in the use of more wear-resistant metals and ball and roller bearings in brick-making machinery, in widespread electrification, and in the mechanization of clay-pit operations.

From the standpoint of the industry's capital outlays, it is notable that during the early and middle 1920's equipment purchases were made in the expectation of stable or increased demand and were concentrated on major production units. After the peak of production was passed in 1925, and particularly after 1929, the emphasis gradually shifted from increasing output to reducing production costs or to improving quality. In recent years the objective has been to accomplish these results without major capital investments, and the industry's equipment purchases have therefore centered mainly on devices that required small capital outlays relative to the economies which they made possible.

Much of the economy in labor utilization could not, however, be realized during the past 10 years because of the extremely low level of capacity at which the industry has been operating; in fact, the output per man-hour was actually lower in 1935 than in 1929. An upturn in the demand for brick is therefore bound to result in an appreciable increase of labor productivity and to reduce the amount of labor required to produce 1,000 common brick to much less than the 9 hours needed in 1925, the year of the last production peak.

During the last two decades brick manufacturing has also experienced a considerable concentration of production in a progressively declining number of plants. The technological base for this concentration was provided by the availability of equipment which can be used most economically in the larger establishments and under conditions of fairly continuous operation. The present low level of operations relative to the capacity of the brick-manufacturing plants is furnishing an important stimulus to further consolidation. In the past such concentration of production has often been the result of mergers of a number of plants in a given region, the shutting down of the least efficient plants, and the operation of only the more efficient establishments. Should the same procedure be followed in the future, the general level of productivity of labor is bound to be raised with little or no expenditures on machinery and equipment to help offset the reductions in labor requirements in the manufacture of brick.

Respectfully yours,

Corrington Gill

Corrington Gill
Assistant Administrator

C O N T E N T S

CHARTS AND ILLUSTRATIONS

TEXT TABLES

TEXT TABLES-*Continued*

PREFACE

Not only do technological changes exert an effect on employment conditions and on the investment of capital, but they are themselves affected by the sphere of economic relationships within which they occur. An analysis of the industrial applications of the principles of science and engineering must therefore also embrace the economics of their application and the economic conditions that affect their introduction. With this as an approach, the National Research Project has conducted a series of studies on types and rates of technological change.

Some of these studies centered on individual types of technological advance that affect many industries.[1] One deals with the growth of industrial research in the United States since the World War.[2] In others, an individual industry was selected as the unit of investigation, and the subject for study was the relationship of the economic requirements of the industry to the development and introduction of a variety of machines and production techniques. The present report is an example of this last type of study. Dealing with the brick-manufacturing industry, it is also a companion piece to the Project's broader study of production, productivity, and employment in the brick and tile industry[3] and presents a detailed picture of the mechanical improvements that were associated with the changes in productivity recorded in that volume.

The report was prepared by Alfred J. Van Tassel and David W. Bluestone. The field data used in this report were collected in cooperation with the National Bureau of Economic Research as part of the cooperative study on productivity and employment in the brick and tile industry. The series of "Studies in Equipment Changes and Industrial Techniques" are under the supervision of George Perazich. J. Van Horn Whipple organized the field work and supervised the editing of the materials collected. The completed manuscript was edited and prepared for publication under the supervision of Edmund J. Stone.

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[1]See, for example, the report by George Perazich and Others, *Industrial Instruments and Changing Technology* (WPA National Research Project, Report No. M-1, Oct. 1938).

[2]Report now in preparation by George Perazich.

[3]Miriam E. West, *Productivity and Employment in Selected Industries: Brick and Tile* (WPA National Research Project in cooperation with National Bureau of Economic Research, Report No. N-2, Feb. 1939).

We appreciate the cooperation of the machinery manufacturers who provided our field workers with records on which most of the data presented in this report are based. James P. Martin, Vice President of the Lancaster Iron Works, Inc.; W. E. Cramer, President of the Harrop Ceramic Service Company; and M. E. Holmes, Dean of the New York State College of Ceramics at Alfred University reviewed the manuscript and made suggestions for its improvement. The National Research Project is of course alone responsible for the content of the report and the conclusions reached.

DAVID WEINTRAUB

PHILADELPHIA
June 5, 1939

CHAPTER I

INTRODUCTION

The brick-manufacturing industry is decentralized in a large number of relatively small plants serving geographically limited markets. In the last boom year of the industry, 1925, more than 1,500 establishments produced an average output of only $117,500 each.[1] The most important reason for the decentralization of the industry is the low value of both the raw materials and the final product in relation to its bulk, which makes nearness to raw materials and markets the principal consideration in the location of a plant.[2]

Because transportation costs are high in relation to the unit value of the product, the geographical areas of competition are sharply limited, usually to metropolitan markets. Within these metropolitan areas plants operate on a rather highly mechanized level. For that large section of the industry which serves the smaller local markets productivity and the level of mechanization in individual plants are generally lower and vary widely.

The level of productivity of labor is, of course, determined primarily by the degree of mechanization of production if the extent of utilization of capacity is specified. Changes in the man-hour requirements per unit of production and in the total employment opportunities afforded by the brick industry during the past quarter of a century were examined in a study by Miriam E. West.[3] The present report is concerned primarily with the types of mechanization that have affected the level of labor productivity.[4]

Unit labor requirements are, however, only one factor affecting employment opportunities. In Miss West's report the problem of employment opportunities in the brick industry is

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[1] *Biennial Census of Manufactures: 1925* (U. S. Dept. Com., Bur. Census, 1928), p. 868.

[2] *Tile Clay Products Industry: Plant Location Factors* (New York: Metropolitan Life Insurance Company, Policyholders' Service Bureau, 1931), pp. 1-19.

[3] Miriam E. West, *Productivity and Employment in Selected Industries: Brick and Tile* (WPA National Research Project in cooperation with National Bureau of Economic Research, Report No. N-2, Feb. 1939).

[4] It has not been possible to consider such nonmechanical factors as payment systems, working conditions, and other managerial devices which frequently affect the organization of the factors of production and their productivity.

studied in its economic context, and the influence of production, market conditions, prices, and the financial structure of the industry, as well as other factors, is considered. Account is there taken of the employment afforded by the manufacture of fuel and machinery used in brick and tile production and by the transportation and distribution of brick.

The primary purpose of the present study is to throw light on the types and rates of mechanization which took place in the brick-manufacturing industry in recent years. An attempt will be made to answer the following questions: What machines or techniques have been principally responsible for reductions in unit labor requirements? How rapidly have the newer and more advanced machines and techniques been introduced? What types of machines and techniques have been replaced by more advanced alternatives? In particular operations and instances, what has been the magnitude of the reduction in unit labor requirements as the result of the introduction of newer equipment or techniques, and how large were the reductions in such production costs as labor, fuel, and power? What has been the relative rate of mechanization in the several departments of production? How has the rate of introduction of new equipment varied with fluctuations in the prosperity of the industry? What has been the major objective of equipment purchases at various stages of the economic cycle, that is, was the primary purpose to reduce production costs, to improve the quality of the product, or to expand the output of the plant?

Three major processes are employed in the production of common brick in the United States: the stiff-mud process, which accounts for about half the total production; the soft-mud process, which accounts for about 40 percent; and the dry-clay method.[5] These three processes are distinguished from each other by the method of shaping the brick. In the stiff-mud process the clay is forced out through a die in a continuous column which is then cut into proper lengths; in the soft-mud process the highly plastic clay is shaped in separate molds; in the dry-clay process dry clay is formed into brick and tile by being subjected to high pressure in individual molds. Only the first two methods will be discussed in this report. The dry-clay process is used for only a very small

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[5]William F. Kirk, *Productivity Costs in Common-Brick Industry* (U. S. Dept. Labor, Bur. Labor Statistics Bull. No. 356, 1924), p. 9.

proportion of common-brick production, and the data available are insufficient to permit analysis.

In both methods under consideration the first step is the excavation of the raw material, clay or shale, which is dug or, occasionally, mined or dredged. The next step is the grinding or crushing of it to suitable fineness. After it is rendered homogeneous by mixing, water is added. The clay is then ready for shaping. When this has been done, the brick are dried either in the open air or in heated drying sheds. They are then removed to the kiln, set, and burned at high temperature. After cooling, they are taken from the kiln either for storage or for shipment.

The first part of this report will deal with the technology of the brick industry prior to 1920. The remainder will cover the technical developments in the several departments of brick production after 1920.[6]

[6] In general, the analysis in this report refers to Miss West's definition of the brick and tile industry (production of common brick, face brick, vitrified brick, hollow building tile, and drain tile). The discussion of specific technological changes refers to brick-making machinery, but tile-making machinery is similar in nature.

CHAPTER II

HISTORICAL BACKGROUND PRIOR TO 1920

Table 1 and figure 1 summarize the development of the brick and tile industry in the United States and give an indication of the rate at which mechanization proceeded. Physical production increased more than 50 percent per decade from 1869 to 1909 but declined to 1921 and again after 1925. Output per wage earner rose about 20 percent per decade from 1869 until the peak of production in 1909 and then remained nearly level until about 1920. Data for the "Clay products (other than pottery) and nonclay refractories" industry, an industrial category somewhat more inclusive than that here designated as the brick and tile industry,[1] show an almost fourfold increase in installed horsepower per wage earner between 1889 and 1919.

These are the general indexes against which the more detailed discussion of mechanization will be traced: the industry served a constantly expanding market until 1909; the productivity of labor in the industry also rose continually; and the rate of introduction of power machinery was rapid and sustained, continuing even after 1909 when production was declining.

In the years preceding the Civil War the production process differed but little from the methods used since earliest historical times. Brickmaking was largely an outdoor occupation and brickyards usually operated only in the summer months. Hand methods were employed in the digging, tempering, and molding of the clay. Drying was done in the open air and kilns were constructed for each individual burning. Frequently the production of brick was carried on at the building site, the clay from the excavation being used as the raw material.[2]

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[1]The value of the five products whose manufacture is here assumed to represent the production of all brick and tile products comprised a decreasing proportion of the value of all products of the "Clay products (other than pottery) and nonclay refractories" industry in the period 1919-35, varying from 58 percent in 1919 to 28 percent in 1933 (based on *Census of Manufactures*). Nonclay refractories, however, make up a considerable and increasing part of the value of products of the "Clay products (other than pottery) and nonclay refractories" industry (see appendix, ftn. 6). The five products therefore represent a larger portion of brick and tile manufacture than is indicated by the percentages above.

[2]Henry C. Kleymeyer, "Soft Mud Brick - Some Reminiscences," *Brick and Clay Record*, Vol. 86, No. 4 (Apr. 1935), 134, 136.

Brickyards, as opposed to brick plants, were the characteristic production units.

Mechanization began with the clay-tempering or mixing operation. Formerly clay had been prepared in a "soak heap", the temperer mixing the wetted clay with a hoe. The pugmill operated by horse power, which eliminated this labor, held the clay in a wooden tub while rotating knives mixed or pugged the clay. The tempered clay was then thrust out of the pugmill in the condition required for molding.

Table 1.- PRODUCTION, WAGE EARNERS, AND OUTPUT PER WAGE EARNER IN THE BRICK AND TILE INDUSTRY, 1869-1935[a]

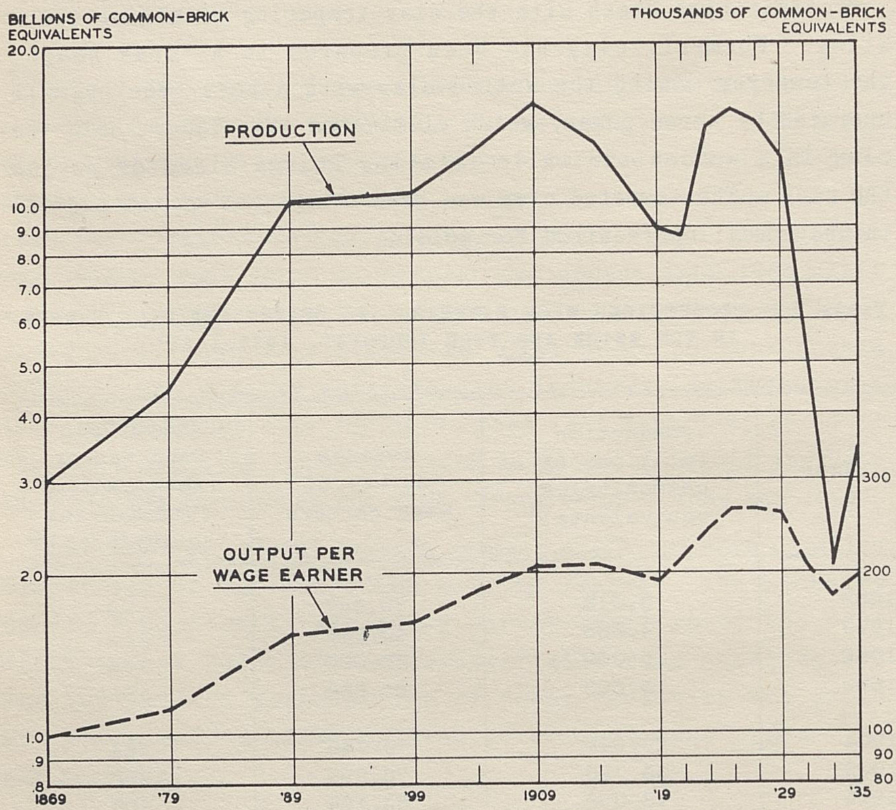
Year	Production (millions of common-brick equivalents)[b]	Average number of wage earners	Output per wage earner (thousands of common-brick equivalents)[c]
1869	3,012	30,347	99
1879	4,505	40,592	111
1889	10,009	65,020	154
1899	10,603	65,822	161
1904	12,948	70,246	184
1909	15,738	76,298	206
1914	13,098	63,189	207
1919	9,155	46,549	197
1921	8,752	41,361	212
1923	14,275	58,981	242
1925	15,388	58,050	265
1927	14,708	54,721	269
1929	12,581	47,771	263
1931	5,429	25,934	209
1933	2,035	11,165	182
1935	3,426	17,466	196

[a]As used in this table, "brick and tile" includes only five types of product: common brick, face brick, vitrified brick, hollow building tile, and drain tile. This classification is not used in other tables since a correspondingly precise break-down of data is not possible. Data are from Miriam E. West, *Productivity and Employment in Selected Industries: Brick and Tile* (WPA National Research Project in cooperation with National Bureau of Economic Research, Report No. N-2, Feb. 1939), p. 26.

[b]"Common-brick equivalents" is a unit of output, the concept of which is outlined in Miss West's study. In order to convert the production of a variety of clay products to a common measuring unit, the quantity of these products is expressed as the number of common brick which could be produced by the same expenditure of effort.

[c]Production divided by number of wage earners.

Figure 1.- PRODUCTION AND OUTPUT PER WAGE EARNER IN THE BRICK AND TILE INDUSTRY, 1869-1935



Based on table 1

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Mechanization of the tempering operation, however, was scarcely a revolutionary change in the production process. The first important impetus to thoroughgoing mechanization came with the introduction of a successful brick-molding machine. A soft-mud molding machine had been introduced in 1833,[3] but was immediately destroyed by the workers who saw in it a threat to their livelihood. This machine again found use in 1840, but not to any great extent. The predominance of hand molding was not seriously threatened until 1857, when a successful soft-mud molding machine was designed by Martin. This was followed in 1862[4] by Chamber's stiff-mud auger machine, which represented a fundamental change in design. Instead of using

[3]Ellis Lovejoy and H. B. Henderson, "Early Brickmaking and Some Old Brick Buildings in Virginia," *Clay Worker*, Vol. 94, No. 1 (July 1930), 19-23.

[4]Ellis Lovejoy, "Brick," *Encyclopaedia Britannica* (14th ed.; New York: Encyclopaedia Britannica, Inc., 1936), vol. 4, pp. 111-7.

separate molds, this machine extruded a continuous ribbon of clay through a die and required an accessory cutting table on which the column of clay was cut into bricks of the desired length. This machine, employing steam power, was capable of producing 100,000 bricks per day.

Thus, by the end of the Civil War the stage was set for the development of a mechanized brick industry. The major mixing and forming equipment, pugmills and brick-molding machines, were being introduced. Powerful steam engines, which had revolutionized production techniques in other fields by allowing the concentration of power machinery, began to find more extensive use; so did bucket elevators and other conveying devices used to handle the increasing volumes of raw material and finished product. The period of open-air production in brickyards was drawing to a close.

With the westward expansion of the country and the consequent need for construction materials, brick plants also had to be built in the new country in order to avoid exorbitant transportation costs. Chamber's stiff-mud auger machine, capable of a high volume of production, found increasing favor in the new plants in the Midwestern States. In order to break down the harder raw materials which were available in the new areas, more preliminary grinding equipment, such as crushers, grinders, and disintegrators, had to be employed.

Increased demand for brick was followed quickly by increased investment in the industry and expanded production. Heated drier sheds began to replace the traditional open-air method in order to decrease the time of drying. Attention was being given to kiln design in an effort to reduce fuel costs, and downdraft and continuous kilns were introduced. Where clay suitable for the soft-mud process was available, mold-filling machines began to come into general use.

The decade from 1879 to 1889 witnessed the most rapid increase in production in the history of the industry. Production more than doubled and by 1889 had reached a level higher than that which prevailed in the years around 1920. In the following decade, from 1889 to 1899, production increased by only 6 percent, but the most rapid rate of introduction of mechanical improvements and power in the industry's history is indicated. Data for the clay-products industries show that the installed horsepower nearly doubled from 1889 to 1899, a period in which horsepower per wage earner increased from 1.07 to 2.39. It appears, then, that in this decade the industry consolidated its previous production gains by a more complete mechanization of the manufacturing process. Certainly the period witnessed a marked increase in the use of mechanical equipment in brick plants.

The operations in the clay pit that had formerly been performed entirely by men using picks, shovels, and wheelbarrows began to be mechanized. Drills and blasting materials increased the productivity of labor in the clay pit, and horse-drawn cars on rails replaced wheelbarrows in transportation to the mill. In a few instances steam shovels and cable and locomotive haulage were introduced at these operations.

About 1900, open-air drying was giving way to artificial drying in sheds. In the newer plants the brick were stacked from the molding machine onto cars which ran on rails through the driers to the kilns, thus eliminating a separate handling in the drying process. The use of conveying equipment became common in the crushing and grinding and in the machine-house departments.

A few of the larger plants were making serious efforts to reduce fuel costs by proper kiln design. The continuous-burning method, whereby kilns were fired in succession and connected by flues in such a way as to employ the heat of cooling brick in the preheating of freshly set brick, was employed in some of the larger plants. In 1889[5] was introduced the tunnel kiln in which the brick were set on cars and conveyed through on rails. This eliminated most of the labor associated with the operations of tossing and setting the brick by hand in proper arrangement for burning. In some instances oil and gas were substituted for coal and wood, thereby reducing labor costs associated with firing the kilns. At other plants waste heat from cooling kilns, rather than direct or steam heat, was employed in the driers.

Production, which had failed to show a marked increase in the period 1889-99, had increased in 1909 by almost 50 percent over the 1899 level and was at the highest point ever achieved by the industry.

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[5]*Clay Products Cyclopedia and Equipment Catalog* (3d ed.; Chicago: Industrial Publications, Inc., 1926), p. 179.

Indicative of the mechanization taking place in the industry is the fact that this 48.4-percent increase in production was achieved with only a 15.9-percent increase in employment and a 14.6-percent rise in man-hours. At the same time the total installed horsepower increased by 78.6 percent in the clay-products industries, and the horsepower per wage earner by 42.3 percent.[6] After 1909 the trend of production in the industry reversed itself, and by 1919 production had declined from the crest in 1909 by over 40 percent to a level slightly below that which had prevailed in the industry in 1889.

For the most part, the mechanization between 1900 and 1920 represented the spread of those techniques which had been used in the most advanced plants in 1900. Particularly marked was the increased employment of mechanical equipment in the clay pit. Power shovels and cable and locomotive haulage were in general use by 1920. In the crushing and grinding operations the closed-circuit technique was being more widely employed. This technique involved the screening of the crushed product and the return of the oversize material to the crusher or grinder for further reduction. This addition, requiring only minor equipment changes, resulted in a substantial increase in output per machine-hour as well as per unit of power expended.[7] In this department and in the machine house also there was more extensive use of mechanical conveying equipment. In the brick-molding operation the technique was greatly advanced, principally by refinements in existing machines. Cutters employed in the stiff-mud process were now generally automatic in operation, a change which increased capacity in one instance from 62.5 to 100 tons per day.

In the soft-mud process, handling between the machine house and the drier was facilitated by the introduction of conveyors which carried pallets of green brick to the drier where they were stacked on specially designed racks. Other plants used drier cars on rails carrying the brick from the machine house through the drier. The labor associated with the transfer of

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[6] *Thirteenth Census of the United States: 1910*, Vol. X, "Manufactures: 1909" (U. S. Dept. Com., Bur. Census, 1913), p. 849. See ftn. 9.

[7] The closed-circuit method increases output per machine per hour as well as per unit of power expended. By removing particles as soon as they are ground sufficiently fine, it prevents their repeated regrinding, which occurs in the batch method, since in that system the entire batch must remain until the coarser particles are reduced in size. By removing the material as it is reduced to proper size, it allows more raw material to be added to a pan of limited capacity and hence increases the output of a machine per hour of operation.

these cars to the drier and from the drier to the kiln was considerably reduced by the introduction of self-propelled electric and gasoline transfer cars.

In general, there were few marked changes in burning technique between 1900 and 1920, except for the increased use of oil and gas. There was, however, a marked reduction in the labor requirements associated with the setting of brick in the kiln, accomplished in a number of plants in the Chicago area by the introduction in 1910 of mechanical brick-setting cranes.[8] Most of the larger plants in this highly competitive area adopted this system during the first year of its introduction. This equipment picked up an entire drying carload of bricks and set them in place in one operation, hence eliminating a great amount of labor.

Data on prime movers employed in the clay-products industries indicate that by 1909 the shift from the use of animal to steam power had been virtually completed. In that year the beginnings of a further advance were evident in a shift from the use of steam to that of electric power. Seven percent of the total horsepower requirements of the industry were supplied by electric motors in 1909. The shift to electric power proceeded rapidly during the following decade. By 1914, 20.4 percent of the total horsepower requirements were supplied by electric motors, and by 1919 this figure had risen to 34.0 percent.[9]

The significance of this shift to the use of electric power for about one-third of the requirements of the industry lies in the centralization of power generation in central stations from which power was purchased, or at one point in the plant, and the consequent displacement of labor. The use of electric motors facilitated the application of power to such new devices as setting cranes and transfer cars.

By 1920 production in the brick industry was firmly established on the basis of the modern factory system. In the clay pit especially, the general use of steam shovels and locomotive

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[8] NRP machinery-manufacturers survey (see appendix for a brief description of the survey).

[9] The data (based on *Census of Manufactures*) given here for 1914 and 1919 do not correspond to the data used later in discussing changes in type of power. This is because in 1914 the *Census of Manufactures* began to present separate statistics for the manufacture of pottery (and porcelain ware) and of brick, tile, and nonclay refractories. Since data are available for 1909 only for the industrial category including pottery, data for 1914 and 1919 are given here which apply to the comparable category. In 1914 the "Pottery" industry accounted for 4.8 percent of the rated horsepower of the "Clay-Products Industries."

or cable haulage of dump cars had eliminated the large amount of hand labor associated with the clay-pit operation of 1900. Many special-purpose machines were available for use, and some plants, such as the larger ones in the Chicago area, were operating on a highly mechanized basis. In these few plants even the most labor-consuming process, that of setting and unloading the kilns, had been mechanized. In general, however, this work was done by hand, and the level of mechanization of most of the industry did not approach that of the Chicago plants.

The advances in technology prior to 1920 had a marked effect on the productivity of labor. Man-hour requirements per unit of production were reduced by more than 50 percent between 1870, when the stiff-mud auger machine and the soft-mud mold-filling machine were just beginning to be generally employed, and 1920. In the later years of this period, 1889 to 1919, when most of the changes thus far discussed were first introduced, man-hour requirements were reduced from 17.3 to 12.6 per thousand brick.[10]

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[10] Miriam E. West, *Productivity and Employment in Selected Industries: Brick and Tile* (WPA National Research Project in cooperation with National Bureau of Economic Research, Report No. N-2, Feb. 1939), p. 108.

CHAPTER III

MECHANIZATION AND PRODUCTIVITY SINCE 1920

PRODUCTION AND PRODUCTIVITY

The character of mechanization in the brick industry during the period 1920-36, with which this report is primarily concerned, was strongly influenced by the fluctuations in the industry's production during this period and during the decade prior to 1920. Production declined steadily in each of the 3 census years following 1909, and in 1921 the industry was operating at only 57 percent of capacity. From 1921 to 1925 production increased rapidly, and by 1925 the industry was operating at capacity. After 1925 brick production declined slowly until 1929 and sharply thereafter. By 1933 production had declined to approximately the level of 1859, and only 13 percent of the industry's capacity was being utilized. By 1935 recovery had advanced the level of production slightly, but the industry was still operating at only 23 percent of capacity.[1]

As a result of these fluctuations in production and in the extent of utilization of capacity, the relationship of mechanical changes to the productivity of labor is often obscured. During the period of rising production from 1921 to 1925, man-hours per thousand common brick produced declined from 11.5 to 9.0 or by about 22 percent. With the decline of production after 1925 this reduction in unit man-hour requirements ceased, and by 1935 the ratio stood at 9.7 man-hours per thousand common brick, an increase of 7.8 percent over the 1925 level. The rise in unit labor requirements after 1925 may be attributed to the decline in the extent of utilization of capacity. Miss West estimates that had the industry continued to operate at capacity, the man-hour requirements per thousand common brick would have declined to 7.5 in 1935 or to 16.7 percent below the 1925 level.[2]

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[1] Miriam E. West, *Productivity and Employment in Selected Industries: Brick and Tile* (WPA National Research Project in cooperation with National Bureau of Economic Research, Report No. N-2, Feb. 1939), p. 112.

[2] *Ibid.*

During the war-decade drop in production a large number of plants shut down, and the subsequent spurt found the industry centralized in a much smaller number of hands than before. The high output of 1925 was achieved by the utilization of the productive facilities of only 1,528 establishments as compared with the 4,215 plants responsible for the approximately equal production of 1909. The decline of production during the 1930's further reduced the number of plants by over 50 percent so that in 1935 only 708 establishments reported to the *Census of Manufactures*.[3] A consideration of the basis for this centralization of production also affords an understanding of its significance with respect to mechanization. The wide range of competitive conditions between plants serving metropolitan markets and those serving the more restricted markets of the rural areas has its parallel in the wide range of productivity among individual plants. The least efficient plant surveyed in the NRP-NBER 1936 brick-plant survey had a man-hour ratio 6.4 times as high as that of the most efficient plant in 1928. This disparity increased during the depression until by 1935 the man-hour ratio of the least efficient plant was 27 times as high as that of the plant which was most efficient. Similarly, the average man-hour requirements per thousand common brick of the third quartile of plants in 1935 were 139.2 percent of those of the first quartile.[4]

The indications are that productivity of labor is higher in the larger plants. The NRP-NBER 1936 brick-plant survey showed that the man-hour ratio in plants with an annual capacity of 15 to 29 million common-brick equivalents was 14.5 percent lower than that in plants with an annual capacity of less than 15 million, whereas the ratio in plants with an annual capacity of more than 30 million was 40.2 percent lower than that of the group of smallest plants.[5] There were also indications of a positive correlation between the productivity of labor and the capital investment per unit of capacity in a few cases where data were available.[6]

It cannot be assumed, of course, that the elimination of plants has proceeded strictly on the basis of relative productivity

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[3] *Ibid.*, p. 12.
[4] *Ibid.*, p. 178.
[5] *Ibid.*, p. 120.
[6] *Ibid.*, pp. 124-5.

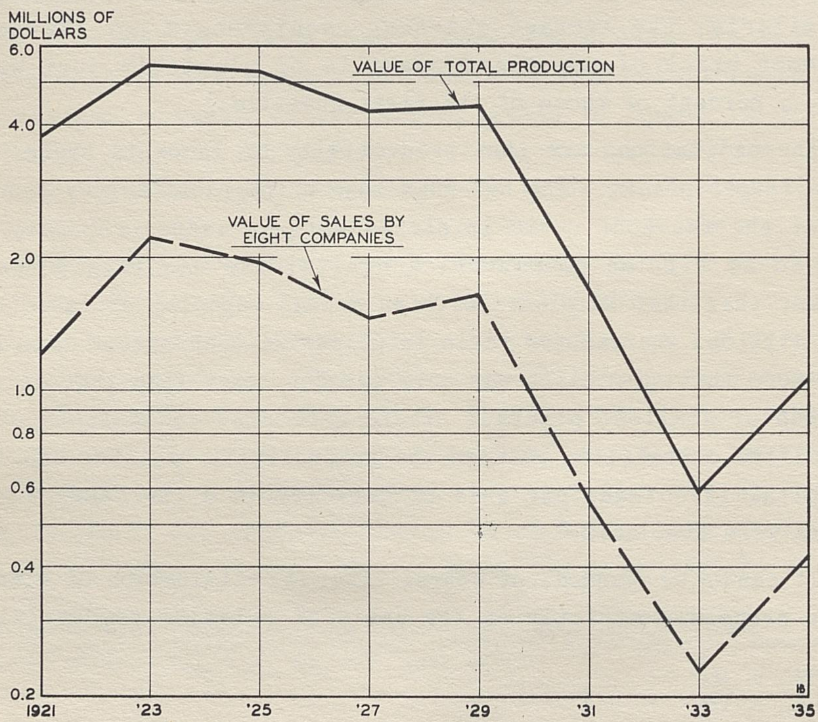
since, clearly, other factors must enter into consideration. On the other hand, there can be little question that relative productivity has played an important part in determining which plants within a given area remain in operation.

SOURCE OF DATA ON RATES AND TYPES OF MECHANIZATION

The preceding discussion provides a background for the examination of mechanization in the industry during the years 1920 to 1936. Here, the several types of technological developments will be traced through the various departments of the brick plant.

One quantitative measure of the rate of mechanization is the volume of sales of equipment to the industry. Sales data on individual machines and on classes of machines also make it possible to distinguish types of mechanization. The principal source of data used in this report is a field survey of the sales of manufacturers of equipment used by the brick and

Figure 2.- VALUE OF TOTAL PRODUCTION AND OF SALES OF CLAY-WORKING EQUIPMENT BY EIGHT COMPANIES, 1921-35



Based on table A-1 WPA - National Research Project M-14 tile industry. This survey will be designated hereafter as the NRP machinery-manufacturers survey.[7] It included five manufacturers of clay-preparation and machine-house equipment and three manufacturers of crushing and grinding equipment.[8]

As indicated by the NRP machinery-manufacturers survey, sales of brick and tile machinery rose to a peak in 1923, 2 years before the peak in brick production in 1925. Throughout the remainder of the 1920's equipment sales maintained a high level. After 1929, sales declined by 86 percent to a low point in 1933 corresponding to an 84-percent decline in brick production. Between 1933 and 1935, sales of brick machinery increased somewhat more rapidly than did brick production. In spite of this recovery, however, sales of brick machinery in 1936 were less than 37 percent of the average yearly sales during the 1920's.

Additional data on the extent of use of various production techniques were obtained in the course of a survey of 108 brick and tile plants conducted in 1936 by the National Research Project and the National Bureau of Economic Research and referred to hereafter as the NRP-NBER 1936 brick-plant survey.[9]

At 28 of these plants flow charts of the production process were obtained, affording an indication of actual operating practice in the industry in 1936. In addition, some data were obtained from almost all the plants on equipment changes and their effects on the labor requirements for particular operations. The plants covered are somewhat larger than the average for the industry as a whole. Since the larger plants frequently employ more advanced machines and techniques, it is likely that an analysis based on the methods employed by this rather small sample may overstate, to some extent, the degree of mechanization of the industry.

Still other material on clay-pit practices was obtained from a tabulation contained in a productivity survey of 71 plants made in 1922 by the U. S. Bureau of Labor Statistics and referred to hereafter as the BLS 1922 brick-plant survey.[10] Another survey of clay-pit methods at 120 plants by a trade

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[7]The field work was conducted by the National Research Project in cooperation with the National Bureau of Economic Research.

[8]See appendix for more detailed discussion of the survey.

[9]The data on man-hours, production, and productivity obtained in this survey were published in West, *op. cit.*

[10]William F. Kirk, *Productivity Costs in Common-Brick Industry* (U. S. Dept. Labor, Bur. Labor Statistics Bull. No. 356, 1924).

journal has been drawn on and will be designated as the Brick and Clay Record 1927 brick-plant survey.[11] Each of the surveys covered plants of somewhat larger-than-average size. Although the plants covered in the three surveys are not strictly representative of the industry as a whole, they represent samples of sufficient similarity to justify comparisons between the years of the surveys.

Machinery-sales data furnish the basis for most of the discussion, but material on equipment in use at operating plants enters prominently into the discussion of the clay-pit and the drying and burning departments. Throughout, the data from the NRP-NBER 1936 brick-plant survey furnish a point of reference, both for causes of labor displacement and for the extent of use of equipment. Finally, a thorough examination of trade journals in the field has furnished information necessary to supplement the survey data. The attempt has been made to construct from all these sources a picture of the rates and types of changes of production techniques in the brick and tile manufacturing industry.

CLAY PIT

Excavation

In 1920 the clay pits of the most advanced plants were being operated on a highly mechanized basis. The characteristic process in the larger plants usually involved the use of power shovels that loaded the clay onto side-dump cars drawn by gasoline locomotives. Where necessary, blasting was employed, the holes for the shots being mechanically drilled in most instances.

A substantial section of the industry, however, still employed the technique of 1900. In the most backward plants clay was blasted loose and then loaded by hand into horse-drawn carts. An indication of the extent to which hand loading was still being used is given in the BLS 1922 brick-plant survey, which showed that out of 71 plants, 19 were using hand shoveling and loading.[12]

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[11] "Clay Pit and Mine Methods," *Brick and Clay Record*, Vol. 70, No. 13 (June 21, 1927), 1002-25.

[12] Of the 52 plants employing mechanical methods, 45 used power shovels, 4 used draglines, 2 used scrapers, and 1 used a dredge to take clay from a river bottom. It was also shown that the soft-mud plants were slightly more backward than the stiff-mud plants, 30.8 percent of the soft-mud plants and 24.4 percent of the stiff-mud plants using hand loading.

Table 2.- INSTANCES OF THE EFFECTS OF MECHANICAL LOADING ON LABOR REQUIREMENTS IN THE CLAY PIT[a]

Equipment installed	Year of instal-lation	Number of men required per shift for loading		
		Before instal-lation	After instal-lation	Reduction (percent)
Steam shovel, $\frac{1}{2}$ cu. yd.	1918	7	2	71
Steam shovel, $\frac{3}{4}$ cu. yd.	1926	12	1	92
Electric shovel, $\frac{3}{4}$ cu. yd.	1923	9	3	67
Electric shovel	1930	7	2	71
Electric shovel, $\frac{5}{8}$ cu. yd.	1931	5	1	80
Gasoline shovel, $\frac{1}{2}$ cu. yd.	1927	8	1	88
Shale planer	1914	5	3	40
Shale planer	1920	7	2	71
Tructractor, 2 ton	1924	6	2	67

[a]Based on files of NRP-NBER 1936 brick-plant survey. Except for the last item, which replaced horses and carts, each of the specified installations replaced hand labor.

Some idea of the economies attendant on the use of mechanical loading devices is given in table 2, which presents instances of labor reductions reported at plants included in the NRP-NBER 1936 brick-plant survey.

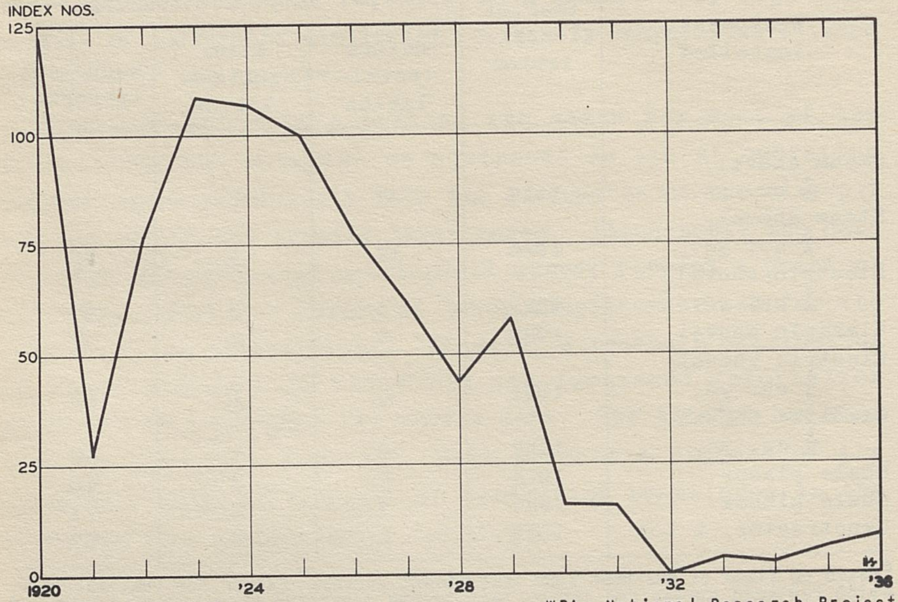
One plant in this survey reduced its labor force in the clay pit by 26 men when an electric shovel, locomotives, and clay cars replaced hand shoveling and wheelbarrows. This case illustrates the particularly striking economies that were obtained in those plants formerly employing the most backward techniques.

The types of changes illustrated in table 2 took place throughout the 1920's. That the rate of introduction of mechanical loading equipment was rapid during this decade is indicated in figure 3 and table A-7, which show the sales of power shovels and locomotive cranes to the brick and tile industry by three companies manufacturing excavating equipment.[13]

[13]For discussion of the size of these three companies see appendix.

Figure 3.- INDEX OF VALUE OF SALES OF POWER SHOVELS AND LOCOMOTIVE CRANES TO THE CLAY-WORKING INDUSTRIES, 1920-36

(1925=100)



Based on table A-7

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Table 3.- PROPORTION OF BRICK AND TILE PLANTS USING MECHANICAL LOADING EQUIPMENT, 1922, 1927, AND 1936

Brick-plant survey	Number of plants reporting on loading equipment	Plants using mechanical loading equipment	
		Number	Percent
BLS 1922	71	52	73.2
Brick and Clay Record 1927	120	116	96.7
NRP-NBER 1936[a]	26	25	96.2

[a] It is interesting to note that in the one plant which used hand loading this method was adopted in 1934 after the steam shovel previously in use had worn out. This instance may reflect the difficult financial position of the brick industry that makes operators reluctant to advance capital for even the minimum necessary replacements of worn-out equipment.

By the end of the 1920's mechanization of loading in the clay pit was practically completed, as will be seen from the three surveys summarized in table 3.

One important phase of the advance in production technique in the clay pit during this period, then, was the extension of mechanical methods to those plants which had employed hand methods in the clay pit in 1920. Another advance in production technique, in that large section of the industry employing mechanical methods in the clay pit, took a somewhat different form. By far the most important mechanical device employed in the loading operation is the power shovel. The period 1920-36 witnessed considerable advance in the design, operation, and efficiency of power shovels. Thus, in many instances, plants which replaced old equipment by new achieved reductions in production costs almost equal to those obtained by the shift from hand to mechanical methods.

A type of change reported frequently in the NRP-NBER 1936 brick-plant survey was that from steam-powered to electric- or gasoline-powered shovels. Steam shovels require the services of a fireman and of labor connected with the supply of water and fuel in addition to that of the operator. The adoption of electric- or gasoline-powered shovels enables clay-pit operators to dispense with these service functions and consequently shows marked advantages over the use of steam shovels. The three surveys mentioned previously reflect the shift from steam to other forms of power in mechanical shovels (see table 4).

Table 4.- DISTRIBUTION OF POWER SHOVELS USED IN CLAY PITS, BY KIND OF POWER, 1922, 1927, AND 1936

Brick-plant survey	Number of shovels	Percent of shovels using -		
		Steam power	Electric power	Gasoline power
BLS 1922	45	93.3	6.7	0
Brick and Clay Record 1927	102	58.9	30.1	11.0
NRP-NBER 1936	29	48.3	37.9	13.8

Thus, the major economies resulting from the shift from steam to other more economical forms of power appear to have been realized for the most part during the 1920's. This conclusion is in agreement with data on sales of power shovels to the industry, which show only a negligible volume since 1929 (see figure 3).

The shift away from steam-powered shovels was at first toward the electric-powered type, and during the first part of the 1920's the use of electric shovels increased rapidly. Then, about the middle of the 1920's the gasoline shovel began to gain favor. Thus, although there were no gasoline shovels in any plants surveyed in 1922, 11.0 percent of those surveyed in 1927 and 13.8 percent in 1936 used this type.

The rate of introduction of gasoline shovels seems to have stabilized in relation to the electric type. In both the Brick and Clay Record 1927 and NRP-NBER 1936 brick-plant surveys the percentage of gasoline to the total of gasoline and electric shovels was 26.7. That the electric type is of more recent introduction than the steam shovel and the gasoline type more recent than either is shown by the fact that in the NRP-NBER 1936 brick-plant survey the average age of shovels in use in the plants surveyed in 1936 was 20.5 years for steam shovels, 11.9 years for electric shovels, and 7.0 years for gasoline shovels.

Another important factor in the efficiency of power shovels is their size. At, or near, capacity operation, the operating cost of the power shovel per unit of output decreases with an increase in the capacity of the equipment. Labor costs in particular show little or no change with an increase in the capacity of the shovel. According to one manufacturer reporting in the Brick and Clay Record 1927 brick-plant survey, the total fixed and operating costs per ton of material dug were as follows for various-sized gasoline shovels: ½ cubic yard, 3.10 cents; ¾ cubic yard, 2.16 cents; and 1 cubic yard, 1.76 cents.

Medium-sized and small brick plants are not capable of utilizing the output of a large shovel operating at capacity. By far the most popular size of shovel is one with the ¾-cubic-yard dipper capacity. The survey in 1927 indicated the overwhelming popularity of this size and the survey of brick plants in 1936 on the whole substantiated this conclusion (see table 5).

The large shovels, of 2½ and 2¾ cubic yards of dipper capacity, which appear in the NRP-NBER 1936 brick-plant survey are all in four plants in the Chicago area owned by one of the largest brick companies in the country.

Table 5.- NUMBER OF PLANTS USING POWER SHOVELS, BY CAPACITY OF DIPPER, 1927 AND 1936

Dipper capacity (cubic yards)	Brick-plant survey		Dipper capacity (cubic yards)	Brick-plant survey	
	Brick and Clay Record 1927	NRP-NBER 1936		Brick and Clay Record 1927	NRP-NBER 1936
$\frac{3}{8}$	2	0	1	4	0
$\frac{1}{2}$	2	1	$1\frac{1}{4}$	1	0
$\frac{5}{8}$	3	4	$1\frac{1}{2}$	1	0
$\frac{2}{3}$	0	1	$2\frac{1}{2}$	0	3
$\frac{3}{4}$	67	15	$2\frac{3}{4}$	0	1
$\frac{7}{8}$	2	0			

Other significant reductions in operating labor have been achieved by such relatively minor changes as the mounting of power shovels on rails and the introduction of crawler treads. In one plant covered in the NRP-NBER 1936 brick-plant survey the substitution of a steam shovel mounted on flat wheels for one mounted on rails reduced the shovel labor force from four men to two by eliminating the two men associated with the laying of rails. In another plant covered in the same survey the substitution of a shovel mounted on crawler treads in place of one mounted on traction wheels eliminated the services of three men who had been previously required for laying down mats on which to move the shovel from place to place.

Among the miscellaneous mechanical implements other than power shovels employed in clay digging and loading, the shale planer is of particular interest. The shale planer consists essentially of a steel framework which supports a cutting chain carrying a series of knives that operate directly on the wall of the clay pit. The planer removes shale in small pieces suitable for immediate final grinding without further reduction. This equipment eliminates the necessity for blasting and for preliminary crushing. One brick plant surveyed in 1936 was able to eliminate the services of five men by the installation of a shale planer, and another was able to reduce the number of men required in clay excavation from five to three by the use of this equipment.

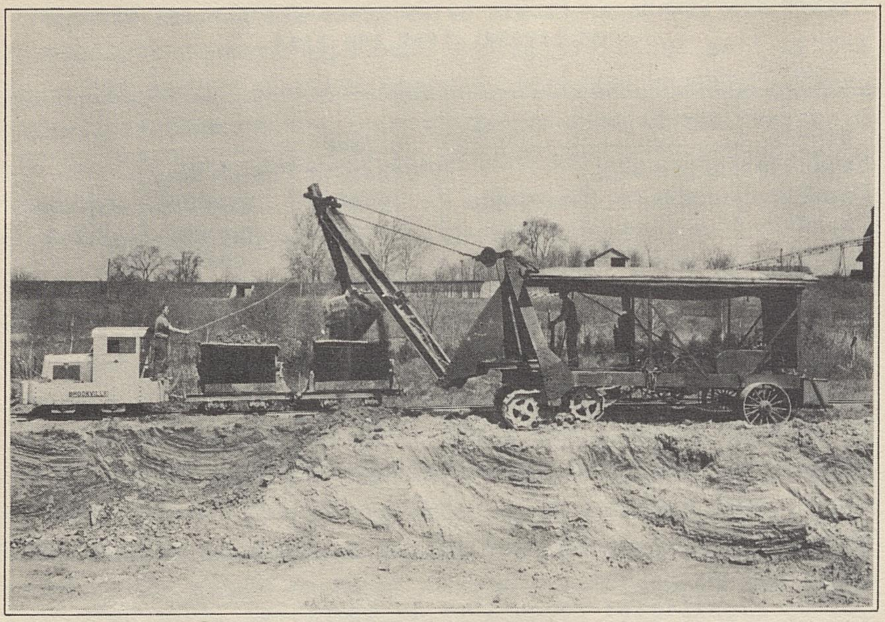

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FIGURE 4.- MECHANICAL EXCAVATING AND LOADING IN THE CLAY PIT

The clay cars, after having been loaded, are hauled by locomotive to the foot of the incline (shown in the background) leading to the clay-preparation department. The cars are hauled up the incline by cable.

Transportation

The transportation of clay from the pit to the crushing house is generally accomplished on rails by means of clay cars drawn by small gasoline locomotives. Frequently the clay cars are drawn up an incline to the crushing house by a hoist and cable. In a considerable number of plants where no locomotive is used the cable extends the entire distance from the loading place in the clay pit to the crushing house.

These two mechanical methods of hauling clay to the crushing house were employed in the great majority of the plants in 1920. At a considerable number of plants, however, the clay was hauled by horse-drawn cars or carts either to the bottom of the incline or all the distance to the crushing house. The decline in the use of animal power is indicated in table 6.

There also appears to be a trend, less marked, away from the use of cable haulage alone and toward the use of locomotives in combination with cable hauling.

It seems likely that the increased usage of locomotives in conjunction with cable haulage reflects the fact that the

Table 6.- PROPORTION OF BRICK AND TILE PLANTS USING ANIMAL POWER FOR HAULING FROM THE CLAY PIT, 1922, 1927, AND 1936

Brick-plant survey	Number of plants reporting on hauling methods	Plants using animal power for all or part of the hauling	
		Number	Percent
BLS 1922	71	11	15.5
Brick and Clay Record 1927	37	3	8.1
NRP-NBER 1936	22	1	4.5

Table 7.- PROPORTION OF BRICK AND TILE PLANTS USING ONLY CABLE HAULAGE FROM THE CLAY PIT, 1922, 1927, AND 1936

Brick-plant survey	Number of plants reporting on hauling methods	Plants using cable haulage only	
		Number	Percent
BLS 1922	71	23	32.4
Brick and Clay Record 1927	37	6	16.2
NRP-NBER 1936	22	5	22.7

extension of quarrying operations necessitates supplementary locomotive haulage. A locomotive, by shuttling more cars more rapidly between the shovel and the cable, may effect a greater degree of utilization of the shovel than is possible when only the cable is used.

The large economies attained by the mechanization of transportation are illustrated by several changes in the plants surveyed in 1936. One large plant succeeded in reducing the labor associated with clay transportation from 23 men to 5 by the introduction of a gasoline locomotive and clay cars. Another, which replaced horses and carts by a locomotive and clay cars in 1926, showed a resulting reduction in the transportation labor force from five men to one.

The net effect of the mechanization in the drilling, excavating, and transportation operations of the clay pit has been to reduce sharply the operating costs in this section of the brick industry. In the Brick and Clay Record 1927 brick-plant survey, data on clay-pit costs were available for 18 mechanized pits employing power shovels and locomotive- or hoist-drawn clay cars and for 3 plants in which hand excavating and horse-drawn carts were used. These data show a marked competitive advantage in favor of the mechanized plants. While the average labor cost for clay per thousand brick in the unmechanized pits was $0.894, that in the mechanized clay pits was only $0.311; over-all costs, including such factors as depreciation as well as operating expenses, were $1.621 per thousand brick in unmechanized pits as against $0.732 in those that were mechanized.

The considerable variations of costs among those plants employing mechanical equipment depend largely upon the size of the establishment. In general, the clay pits supplying the largest plants are the most efficient, as shown by table 8.

Table 8.- CLAY-PIT COSTS PER THOUSAND BRICK, BY CAPACITY OF PLANT, 1927[a]

Capacity of plant (thousands of brick)	Number of plants	Costs per thousand brick		
		Total	Labor	Power
0-40	7	$1.264	$0.506	$0.154
41-80	7	0.661	.317	.063
81 or over	4	0.564	.226	.066

[a]Data from Brick and Clay Record 1927 brick-plant survey.

In considering these figures, it should be remembered that the results are necessarily qualified by the small number of plants in the sample and by the fact that, because of the wide diversity of operating conditions in various plants, each capacity group shows in itself a wide variation. These figures indicate, however, that the greatest difference in costs lies between the small- and medium-sized plants and that the major difference of cost between the medium- and large-sized plants comes from the reduction in labor requirements.

The industry, especially that part of it represented by the larger plants, has had considerable difficulty in utilizing all its productive capacity in recent years. This has been particularly true since 1929, and this factor has probably served to modify the gains in productivity achieved by mechanization in the clay pit.

CLAY PREPARATION

In the preparation of clay for the molding operation the shale and lumpy clay as it comes from the clay pit is reduced to a finely ground and fairly homogeneous substance. The principal piece of equipment employed for this purpose in most stiff-mud plants has always been and still is the pan. Occasionally the pan is supplemented by a preliminary crusher, which reduces the larger pieces of clay or shale to a size more suitable for further reduction by the pan.

The most striking change in this technique of clay preparation has been the insertion of preliminary crushers into the flow ahead of the pans. In some plants the practice still prevails of breaking up the larger lumps of clay or shale by sledge. The elimination of this manual labor, by the introduction of preliminary crushers, in many instances accomplished marked reductions in the labor requirements. In the NRP-NBER 1936 brick-plant survey and in the trade journals there were reported, as a result of the installation of preliminary crushers, reductions in the labor force from 12 men to 2,[14] from 11 to 4,[15] from 10 to 5, and in two instances from 8 to 1.[16]

Even in those instances in which manual labor was not required for the primary reduction, significant economies were achieved by the addition of preliminary crushers. Preliminary reduction of the clay reduced the power requirements in the pan, made possible savings in the repair and maintenance of the pan by eliminating the strains imposed by large pieces of clay, and increased the pan capacity.[17]

In the soft-mud plants and in stiff-mud plants using more plastic clays which would clog a pan, clay preparation has

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[14] "Crusher, Elevator and Feeders Save Ten Men," *Brick and Clay Record*, Vol. 66, No. 13 (June 23, 1925), 986.

[15] "Why Do Preliminary Crushing?" *Brick and Clay Record*, Vol. 66, No. 13 (June 23, 1925), 983-6.

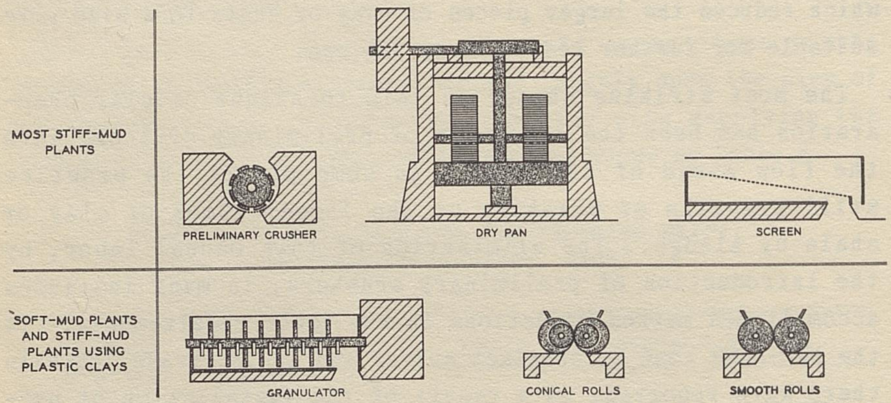
[16] NRP-NBER 1936 brick-plant survey.

[17] "Why Do Preliminary Crushing?" *loc. cit.*

generally been accomplished in several steps involving a granulator with revolving knives that cut up the soft clay, conical rolls that remove stones from the clay, and smooth parallel rolls that accomplish the final reduction. No change occurred in this process during the years 1920-36, the practice throughout this period favoring, in most instances, the use of multiple-stage reduction.

In the larger number of stiff-mud plants the marked tendency to improve performance by introducing gradual reduction is shown by an examination of the data on sales to the brick

Figure 5.- CLAY PREPARATION



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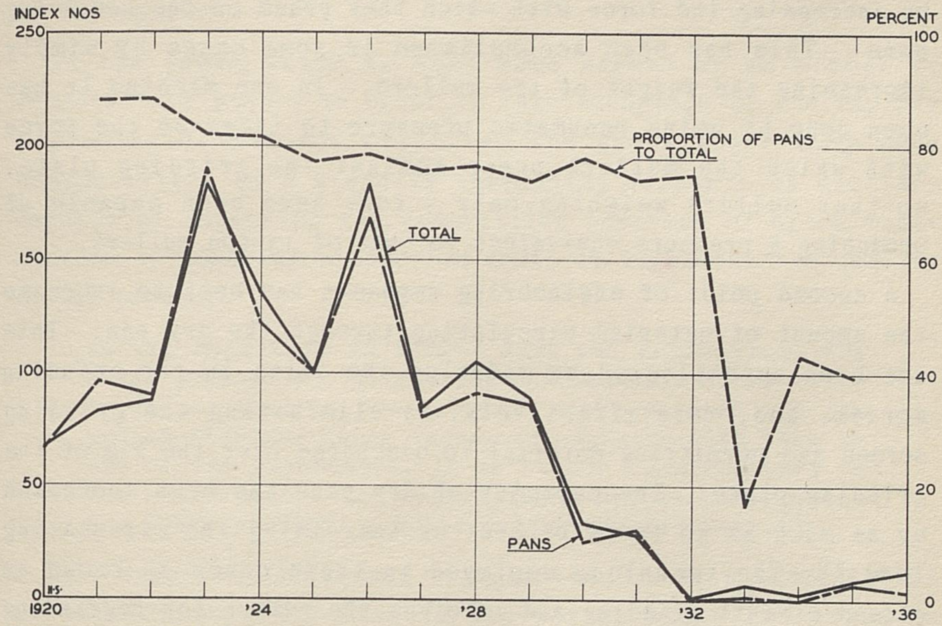
The dry pan is standard for grinding in most stiff-mud plants. The ground material drops through the slits in the floor plate or is discharged over the rim. It is then screened, and the coarse overtails go back to the pan for regrinding. Sometimes a preliminary crusher is used before the dry pan.

In soft-mud plants or in stiff-mud plants using plastic clays the gradual-reduction system is usually employed. It consists of a granulator whose revolving knives break up lumps of clay, a set of conical rolls to remove large stones and other hard objects which might injure the smooth rolls, and a set of smooth rolls to grind the clay to required fineness.

industry since 1920 of crushing and grinding equipment (table A-3 and figure 6). There was a tendency throughout this period to take advantage of the economies associated with the use of preliminary crushers auxiliary to the pan. This is indicated by the proportion of total sales of crushing equipment accounted for by pans, which shows that there has been a steady drop in the relative importance of pans. During the 1920's the percentage of total sales of crushing and grinding equipment accounted for by pans fell from 87.9 percent in 1920-22 to 76.5 percent in 1927-29. This decline was steady throughout

Figure 6.- INDEXES OF VALUE OF SALES OF CRUSHING AND GRINDING EQUIPMENT TO THE CLAY-WORKING INDUSTRIES, 1920-36

(1925=100)



Based on table A-3 WPA - National Research Project M-17

this period of substantial sales and indicates that brick plants were tending to install preliminary crushers in larger numbers throughout this period.[18] The marked decline in the relative importance of pans in the period 1934-36 continues this trend, although the significance of the data is qualified by the small volume of sales.

Some indication of the extent of the use of multiple-stage reduction is given by the NRP-NBER 1936 brick-plant survey. Of the 25 stiff-mud plants reporting on crushing equipment, 40 percent employed pans only, 20 percent used pans with preliminary crushers, and 40 percent accomplished the reduction in two or three stages involving the use of granulators and a variety of roll crushers. Only one of the six soft-mud plants employed the pan except for the regrinding of cull brick.

Since the pan remains the most important single piece of clay-grinding equipment, the improvements in its design which

[18] Of 33 stiff-mud plants reporting on equipment changes to the NRP-NBER 1936 brick-plant survey, 12 reported changes in the crushing department; of the 7 soft-mud plants reporting equipment changes, only 1 reported a change in the crushing department.

have taken place during these years are of considerable interest. One of the major points of emphasis of engineering design has been to increase the grinding power of the mullers by increasing the force with which they press on the revolving pans. This has been accomplished in some cases by simply increasing the weight of the mullers. In one machine it has been done by using pneumatic pressure to increase the force with which the mullers press against the grinding plate, so that mullers weighing only 3 tons have been capable of producing a pressure equivalent to that of 13-ton mullers.

A second point of engineering emphasis has been to increase the amount of material circulating through the dry pan. This has been accomplished by widening the slits in the grinding screen, and, more effectively, by eliminating the grinding screen and permitting material to discharge over the rim of the grinding plate. The capacity of dry pans has been increased by as much as 50 to 75 percent by increasing the circulating load.[19] The technique employed in these cases is known as closed-circuit grinding and involves the return for regrinding of coarse material which does not pass the screen, thereby eliminating the overgrinding of material and the resultant cushioning by the finely ground particles.

The net effect of the increase in the grinding force of the mullers and the increase in the discharge with closed-circuit grinding has been to decrease the power consumption and at the same time to increase the capacity of the dry pan.[20] The extent of use of the closed-circuit technique is indicated by the fact that of the 14 plants employing dry pans in the NRP-NBER 1936 brick-plant survey, 13 used the closed-circuit method.

MACHINE HOUSE

The machine house is the center of the forming operations involved in the production of brick. In discussing its mechanization, three periods may be distinguished since 1920: first, the years from 1920 to 1925, in which production was generally rising to the post-war peak in 1925; second, the years from 1926 to 1931, which represented a period of stable

[19] "Clay Preparation," *Brick and Clay Record*, Vol. 77, No. 14 (Dec. 30, 1930), 790, 793, 796-7.

[20] P. B. Read, "Developments in Dry Pan Construction," *Brick and Clay Record*, Vol. 65, No. 5 (Sept. 2, 1924), 322-3.

production until 1929 followed by a rapid decline; and third, the years from 1932 to 1936, which witnessed a recovery in brick production but to a very low level as compared with that of the 1920's.

As the years prior to 1925 were marked by an effort to rehabilitate plants in order to take advantage of the rapidly expanding demand for brick, so the years after 1925 were characterized by a steadily increasing emphasis on machines capable of improving the competitive position of brick manufacture by lowering production costs or improving the quality of the product.

> As the objective in former days was production, the chief purpose for developing new machines today is to lower the cost of production. Altho many of the improved machines carry increased capacity with them as one of its advantages, it is rather complementary to the real reasons for developing a new machine, which are lower production costs and better products.[21]

The essential difference between the two main processes of brick manufacturing lies in the way in which the brick is formed. In the stiff-mud process, clay is forced through a die in a continuous column and is then cut to proper lengths. The soft-mud process involves the use of a pugmill or other mixing mechanism and a brick machine which presses the clay into molds. The stiff-mud process involves a somewhat greater variety of equipment, necessitating the employment of a pugmill and auger machine from which the column of clay is extruded and a brick cutter which cuts the column of clay. Both processes employ such auxiliary equipment as conveyors and disk and apron feeders.

In 1920 the great majority of soft-mud brick plants used molding machines that required a great deal of hand labor. The only function performed by the typical machine at that time was that of pressing the clay into the molds. The work of sanding the mold, striking off the excess clay from the full mold, and bumping the mold to loosen the formed clay was performed by hand.

The AutoBrik machine, which performed all these tasks automatically, was introduced in 1920. This machine, which could

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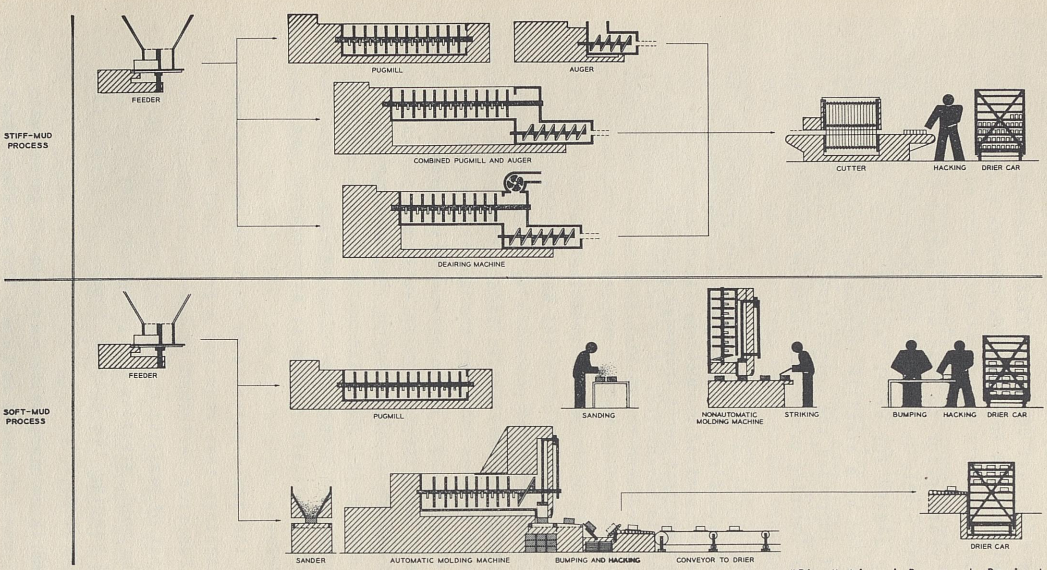
[21] "Better Clay Machinery is Making Old Types Obsolete," *Brick and Clay Record*, Vol. 74, No. 8 (Apr. 9, 1929), 535.

Figure 7.- MACHINE HOUSE



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The essential operations in forming brick by the stiff-mud process are feeding, pugging, extruding through a die, and cutting. The pugging and extruding are often combined in one machine, and the function of deairing may be included.

In the soft-mud process the clay is fed, pugged, and molded. The upper line shows the process when the nonautomatic machine is used. The men in this chart represent functions performed by hand, not the number of men employed. These operations are performed mechanically by the automatic molding machine shown on the lower line.

produce from 60,000 to 120,000 bricks per day,[22] approximately doubled the output of earlier machines and at the same time reduced the operating labor required. In some instances even more striking increases in output per machine were made: in one Hudson River Valley plant, 2 AutoBrik machines produced an output equivalent to that of 14 of the older units;[23] in another, 1 AutoBrik machine replaced 10 old machines with no decline in output;[24] in a third, the number of men required was reduced from 5 to 2.[25]

Information received from the manufacturer of these machines indicates that the sales were largest during the first 4 years of introduction. No information was available on the volume of sales in 1920. From 1921, sales increased to a peak in 1923 and then fell irregularly until 1928. During the years from

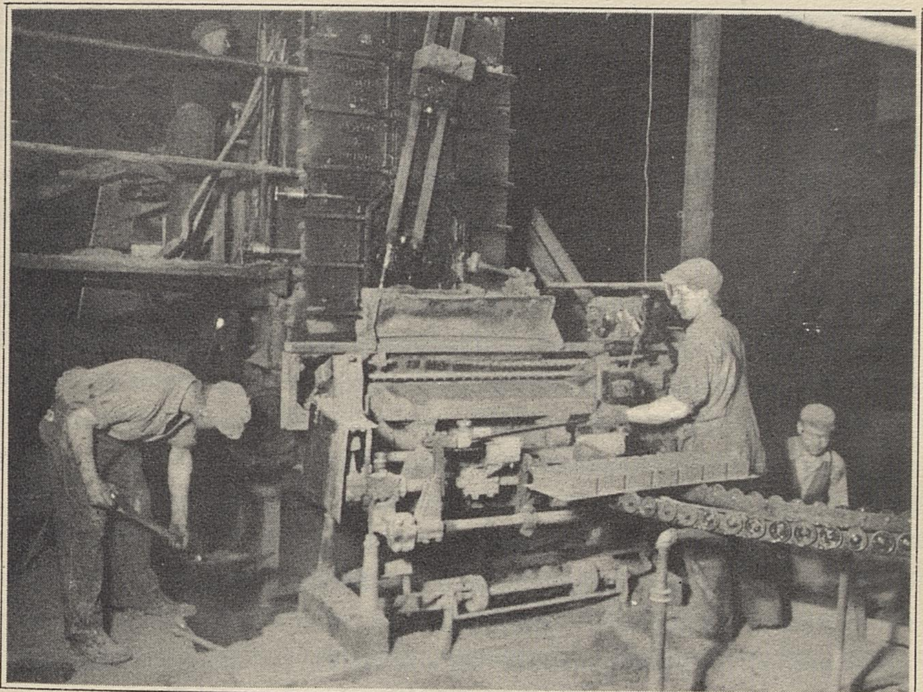

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FIGURE 8.- AUTOMATIC SOFT-MUD MOLDING MACHINE

The man in the foreground is placing a pallet in the machine. The green brick in the mold are automatically bumped onto the pallet which then slides down the gravity conveyor.

[22] *Clay Products Cyclopedia and Equipment Catalog* (3d ed.; Chicago: Industrial Publications, Inc., 1926), p. 275. Working days of 8 and 12 hours have been assumed.

[23] "A Revelation on the Hudson River," *Brick and Clay Record*, Vol. 63, No. 4 (Aug. 21, 1923), 259-63.

[24] From NRP-NBER 1936 brick-plant survey.

[25] *Ibid.*

1921 to 1928, 118 automatic machines were installed. After 1928, sales declined to a negligible amount and by 1936 had shown no tendency to recover. In the period from 1921 to 1936, 130 automatic machines were sold.[26]

In view of the savings possible with these machines, it is remarkable that the rate of introduction has not been more rapid. The rather slow rate of mechanization reflected by the history of this machine would seem to indicate that severe competition is limited to a relatively few areas, probably those serving metropolitan markets, and that in others it is possible for manufacturers to continue employing less efficient equipment. Over four-fifths of the automatic machines went to plants in the densely populated and highly competitive area constituting the States of New York, New Jersey, Pennsylvania, Connecticut, and Massachusetts, whereas only one-fifth of the nonautomatic machines were sold to plants in these States. Almost four-fifths of the largest automatic machines and over one-half of the medium-sized automatic machines were sold to New York plants, but less than one-fifth of the smallest automatic machines were sold to New York plants.

The failure of sales of this machine to recover by 1936 cannot be taken as an indication of market saturation; for it is certain that there are several hundred plants which could radically improve their efficiency by the replacement of soft-mud machines by an automatic machine. The growing demand in recent years for sand-faced colonial brick which can only be produced satisfactorily by the soft-mud process is an additional incentive to the purchase of the automatic machine. It is reported that a number of plants formerly operating with the stiff-mud process have recently purchased automatic soft-mud machines.[27] However, it would seem that a more substantial recovery of the brick industry is a prerequisite for a further rapid extension in use of this machine.

The automatic brick machine came at an opportune time for the soft-mud brick manufacturers, since the inefficiency of the older nonautomatic machines in comparison with the stiff-mud process had placed a severe handicap on soft-mud plants operating in competitive areas. Thus, machine-house

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[26] The 93 machines sold by 1925 were installed in 75 plants.

[27] Letter from the manufacturer, Aug. 16, 1938, in files of WPA National Research Project, "Studies in Equipment Changes and Industrial Techniques" section.

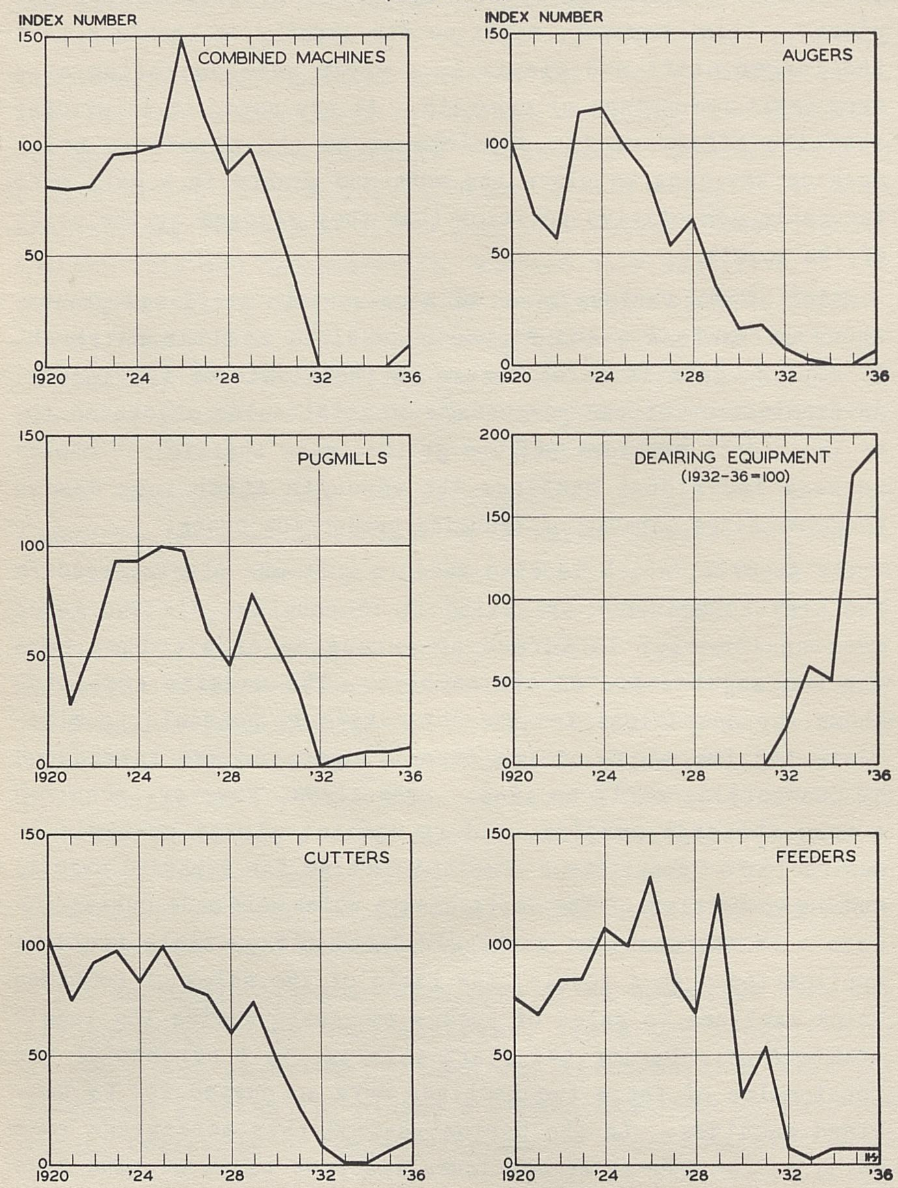
man-hours per thousand brick were 17.7 percent higher in soft-mud plants than in stiff-mud plants in 1922 according to the survey of the Bureau of Labor Statistics, and over-all unit man-hour requirements were 28.2 percent higher. The NRP-NBER 1936 brick-plant survey indicates that the over-all requirements of the soft-mud plants were only 6.8 percent higher and that the two largest soft-mud plants had even lower unit labor requirements than the group of large stiff-mud plants. This, however, might be due chiefly to the fact that the larger stiff-mud plants as a whole were operating at a very small percentage of capacity. At any rate, it is evident that the effect of the development of the automatic brick machine has been to place the soft-mud plants in a much more favorable competitive position than they enjoyed at the start of the 1920's.

Sales of the various kinds of machinery to stiff-mud plants, shown in table A-4 and figure 9, exhibit similar patterns, i. e., the peak in sales occurs in the middle of the 1920's. An examination of the percentage of total sales accounted for by individual machines (figure 9) indicates that in the choice between individual machines the emphasis after 1925 was on those machines capable of reducing production costs.

The pugmill, which is also used in soft-mud plants, renders the clay homogeneous by mixing it thoroughly. In the auger machine the clay is formed by extrusion of a column from the rectangular die of the machine. The machine combining these two operations and thereby making it possible to eliminate the functions of the pugmill operator was introduced by Chambers as early as 1892. Some clays, however, required a more thorough pugging, and it was not always possible or desirable to substitute a combined machine for separate pugmill and auger machines. The improvements which were made during the 1920's in the combined machine widened the possible field of application. As a result, the ratio of the sales of combined brick machines to sales of augers increased during the 1920's (table A-4). During the years 1920-22, 70.6 percent of the total sales of these two machines were accounted for by combined machines. In the period 1926-28 this percentage rose to 79.2; in 1929-31 it continued its rise to 86.9. The rise in the proportion of sales accounted for by combined machines was interrupted, however, during the period 1923-25. This period was one of rapid expansion in the production of brick which stimulated the return to production of many of the marginal plants which had ceased operating during the decline in production of the war years. In the rehabilitation of

Figure 9.- INDEXES OF VALUE OF SALES OF SELECTED TYPES OF EQUIPMENT TO STIFF-MUD BRICK PLANTS, 1920-36

(1925=100)



Based on table A-4

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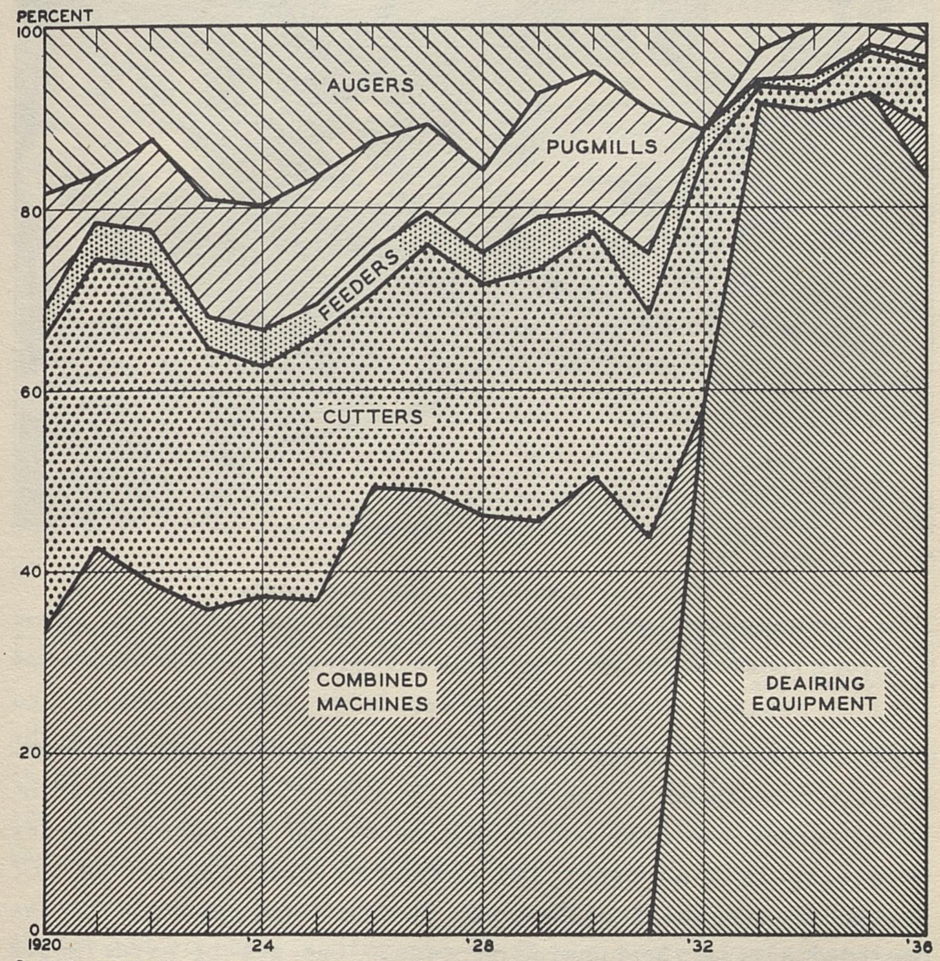
Figure 10.- PERCENTAGE DISTRIBUTION OF VALUE OF SALES OF SELECTED TYPES OF EQUIPMENT TO STIFF-MUD BRICK PLANTS, 1920-36



Based on table A-4

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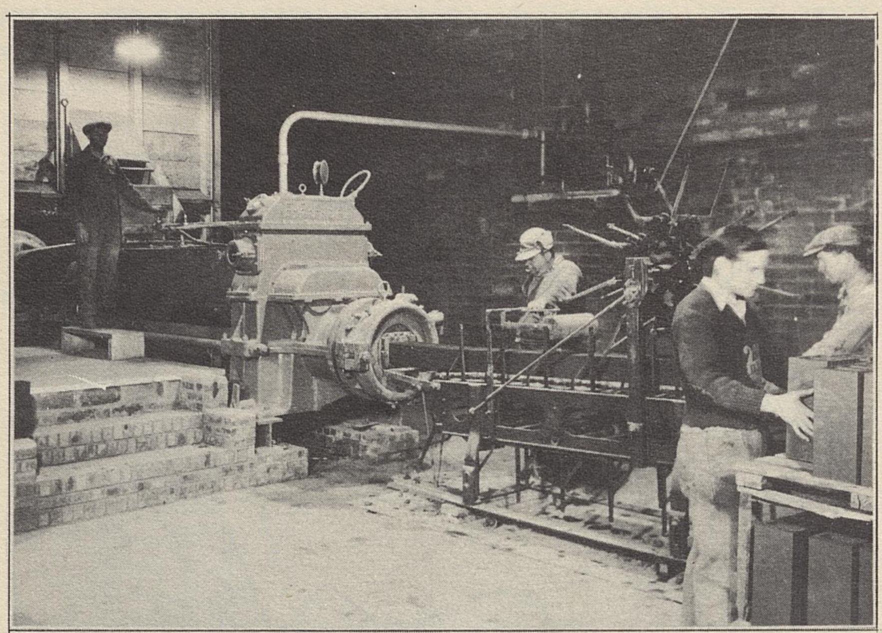
these plants it seems likely that replacements were held to a minimum, and there may have been some reluctance to discard both the pugmill and the auger machine in favor of a combined machine if either of the former was in working order.

The greatest advance in stiff-mud machine-house technique during the years 1920-36 was the introduction of deairing machines in 1932. This equipment was devised to reduce the high percentage of loss in the manufacture of brick caused principally by laminations in the brick due to uneven extrusion. It consists of the usual combined machine or auger



Fate-Root-Heath Co.

FIGURE 11.- PUGMILL, AUGER, AND CUTTER

The combined pugmill and auger is shown extruding the clay after it has been thoroughly pugged. The continuous column is then cut to proper length by a rotary cutter, and the lengths of hollow building tile are stacked onto drier cars.

with, immediately ahead of the die, a vacuum chamber which removes air occluded in the clay. The effect of this deaeration is to render the clay more homogeneous and workable, thereby resulting in a stronger and denser brick. Another effect is the reduction of blistering due to the expansion of the occluded air in the burning process. One set of experiments showed that the increase in the crushing strength after deairing was 31.8 percent for face brick and 21.4 percent for common brick.[28]

The reports from concerns that replaced old combined machines and augers with deairing machines or added deairing attachments to the old machines were by no means uniform since considerable experimentation was frequently necessary before deairing could be properly applied to certain clays. Nearly all plants, however, reported significant increases in the percentage of marketable brick. A large number of plants were also able to produce a stronger, denser, more uniform, and generally higher

[28] "De-airing of Clayware," *Brick and Clay Record*, Vol. 86, No. 1 (Jan. 1935), 12-6.

quality brick. A number of other plants found that they were able to employ raw materials which could not be worked by ordinary machines, and others stated that less pugging was required.[29] The several advantages of deairing meant, among other things, increased labor productivity since more units of marketable brick are produced with the same labor requirements.

The increase in the sales of deairing equipment was extremely rapid after the introduction of the equipment in 1932 (table A-4 and figure 9). The NRP machinery-manufacturers survey shows that sales for 1933 were more than two and one-half times those for 1932, that after declining in 1934, sales increased in 1935 to a value nearly three times that in 1933, and that in 1936 they increased by an additional 10 percent.

This increase was in large part due to the industry's partial recovery, which coincided with the period of introduction of deairing equipment. The increase in the sales of this equipment after 1932, however, was much more rapid than that of other items.

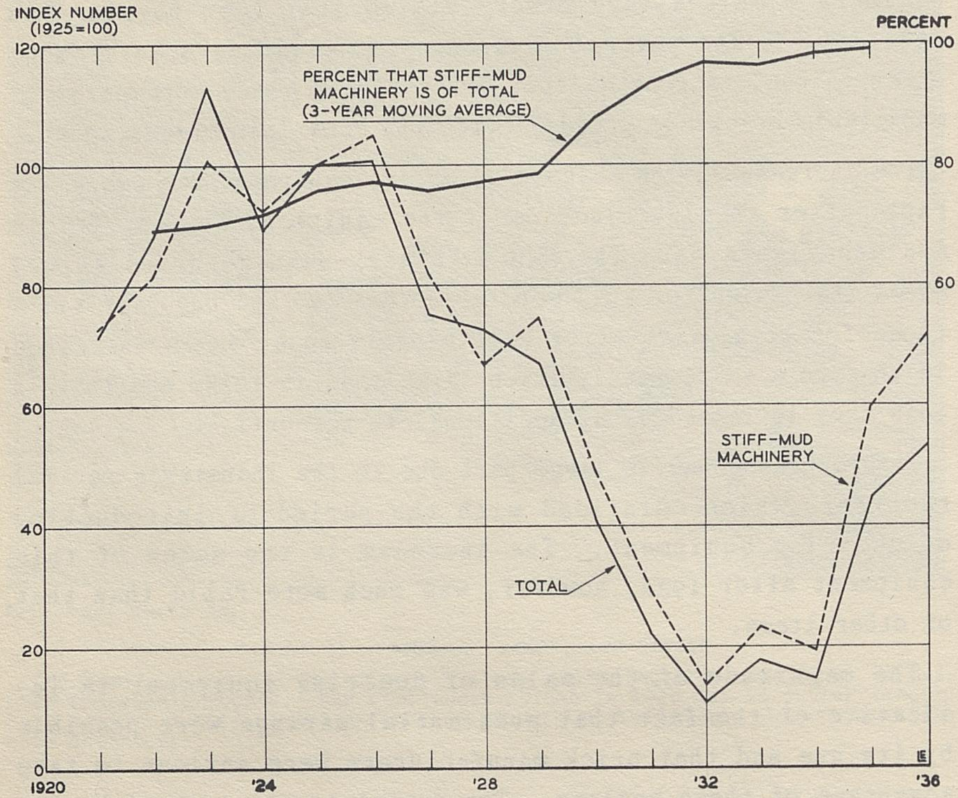
The magnitude of the sales of deairing equipment is indicative of the fact that substantial savings were possible by its use and that brick manufacturers were anxious to take advantage of these savings. The extent to which the industry is adopting this machinery is indicated by the fact that 11 of the 45 plants covered in the NRP-NBER 1936 brick-plant survey had installed deairing equipment since 1932.

The relative importance of the sales of brick-forming machines and accessories for the stiff-mud process has increased almost steadily throughout the period 1920-36 (table A-5 and figure 12).

This rise in the percentage of the total sales accounted for by stiff-mud equipment was due to the decline of the sales of soft-mud machinery rather than to the rise in the sales of stiff-mud machinery. The substantial sales of soft-mud machinery during the first half of the 1920's are a result of a campaign of modernization of soft-mud plants by the purchase of automatic brick machinery. Those brick plants

[29] The reduction in the amount of necessary pugging is indicated by the fact that the typical deairing machine is a combined machine, which usually means that a smaller pugging chamber is employed than in cases where a separate pugmill is used. Indeed, there has actually been some difficulty in adding deairing attachments to augers when preceded by a long pugmill since the clay was overpugged. One plant was able to substitute an 8-foot for a 22-foot pugging chamber with a corresponding reduction in horsepower requirements from 275 to 125 (*ibid.*, p. 16).

Figure 12.- INDEXES OF VALUE OF SALES OF STIFF-MUD AND SOFT-MUD EQUIPMENT, 1921-36



Based on table A-5

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installing automatic soft-mud machines succeeded in achieving a substantial reduction in their man-hour requirements. When they also operated on a highly mechanized basis in other departments, they achieved a level of labor productivity comparable to that of the most advanced stiff-mud plants. However, the soft-mud plants operating without the automatic equipment represented a generally older and less efficient section of the industry than that section comprising most of the stiff-mud plants and the soft-mud plants equipped with automatic machines. Most of those soft-mud plants which did not strengthen their competitive position by the purchase of automatic machinery during the period of rising production in the early 1920's were apparently in no position to do so during the period of restricted demand in the 1930's since this step required a sizeable investment. Therefore sales of soft-mud machinery declined particularly sharply after 1928 and failed to recover after 1932.

On the other hand, a continuous process of development in the relatively less expensive stiff-mud machinery encouraged modernization without producing a sharp rise in equipment sales. The development of deairing equipment in 1932 stimulated stiff-mud machinery sales at a time when the demand for soft-mud machinery was particularly weak.

A comparison of the sales of new machinery with the sales of repairs[30] (table A-6) throws additional light on the character of the mechanization in each of these periods. In the years from 1920 to 1925 brick production was increasing rapidly, and a large number of plants which had ceased operation during the wartime depression in brick production were forced to make repairs on other machinery in order to be able to operate at all. The effect of rather extensive rehabilitation is indicated by the fact that repair sales exceeded new-machinery sales for 1922-24. The period of stable production from 1926 to 1929 was marked by a high level of new-machinery sales which is probably indicative of an increased effort to achieve a favorable competitive position by the utilization of the cost-reducing features of new machines. It appears that from 1932 to 1936 the recovery of brick markets was not strong enough to call forth a large volume of rehabilitation work on idle plants, for during these years new-machinery sales represented 61 percent of the small total volume of sales.

Besides the more striking changes in machine-house equipment in both soft- and stiff-mud plants there have been a number of refinements in equipment which have had an important cumulative effect. Typical of such changes is the application of antifriction ball and roller bearings which have achieved savings in power of 20 to 30 percent and reduction in the quantity of lubricant employed of 70 to 80 percent.[31]

Better steels, direct-connected motors, housings made of cast steel rather than cast iron, double shafts in pugmills and augers, and multistream dies are characteristic improvements in brick machinery in recent years. The objectives of these changes have been, uniformly, to reduce lubrication, power, and equipment costs.

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[30] Repairs include sales of repair parts and charges for rebuilding.

[31] L. M. Klinedinst, "Anti-Frictioning of Heavy Duty Clay Machinery," *Brick and Clay Record*, Vol. 76, No. 5 (Mar. 11, 1930), 307-10.

> With the building of sturdier machines, with less wearing parts, better lubrication, use of bearings in consuming less power, the modern machine is achieving its purpose in helping to cut down the manufacturer's operating costs.[32]

DRYING

The green brick as it comes from the molding process contains a considerable quantity of moisture that must be removed before it can be set in the kiln. Soft-mud brick, in particular, is so plastic when it comes from the molds that it cannot be handled until after it is dried.

The use of artificial driers instead of open-air methods was introduced before 1920, but the elimination of open-air drying was made virtually complete in the period 1920-36. The widespread use of artificial drying had an effect on three aspects of production: the amount of labor associated with handling and transporting from the brick-molding machine to the drier and from the drier to the kiln, the generation of the heat required in the drier, and the control necessary for efficient use of the heat.

Artificial Drying

Traditionally, drying was accomplished by placing the brick on the ground in the open air or in sheds with roofs that were constructed in sections so that they could be either lifted to let in sun and air or closed to shut out rain. In the nineteenth century artificial drying was introduced in an effort to decrease the time of drying and hence to decrease inventories and the necessary drying area. Only 24 to 48 hours were required for artificial drying in 1936[33] compared with 7 to 10 days needed by the open-air method.[34]

By 1920 the majority of plants were using artificial drying. In the survey made by the Bureau of Labor Statistics in 1922 only 5 of the 45 stiff-mud plants dried the brick in the open air; of the 26 soft-mud plants, only 9 used natural drying, but 2 employed steam in addition to the open-air method. Of the 53 plants which reported on equipment changes in the NRP-NBER

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[32] "Better Clay Machinery is Making Old Types Obsolete," *loc. cit.*

[33] From NRP-NBER 1936 brick-plant survey.

[34] Kirk, *op. cit.*, p. 55.

brick-plant survey, 2 stiff-mud plants and 1 soft-mud plant showed a shift from open-air to artificial drying. In one, the labor required in the drying department was reduced from four men to one. Of the 28 plants for which flow charts were made in this survey, none employed open-air drying.

Handling in the Drying Process

The first operation in the typical system employed in stiff-mud plants is the hacking of the brick from the brick machine onto the drier cars. The cars, which run on rails, are then taken by a transfer car to the appropriate track leading into one of a series of tunnels that make up the drier. The cars are pushed into the tunnel, left until the drying is completed, and then transferred to a point near the kiln preparatory to setting. This system, which is employed at all the stiff-mud plants and at two of the six soft-mud plants surveyed in 1936, involves considerable labor in the initial loading of the drier cars. There are no indications of any widely adopted changes tending to reduce the labor of hacking brick from the machine to the cars in stiff-mud plants.

The principal advance in recent years has been the introduction of power-driven transfer cars, usually electric, which markedly reduce the time and effort required to carry the cars from the machine house to the drier track and then from the drier track to the kiln. Electric transfer cars were in use between the machine house and drier at 4 of the 27 plants covered in the 1936 survey and between the drier and the kiln at 10 of these plants.

At the soft-mud plants bricks leave the machine in a state too soft for individual handling. They are therefore discharged from the mold onto pallets which hold several bricks. These pallets are then either stacked on drier cars or carried directly to the drier by conveyor. In those plants in which the pallets are stacked on drier cars, transportation to the drier and from the drier to the kiln is accomplished in the same way as in stiff-mud plants. In these plants a significant reduction in labor has been accomplished by the introduction of electric transfer cars.

A system used in conjunction with the AutoBrik machine sharply reduces the handling labor by mechanizing the car-stacking operation so that the green brick are stacked onto cars automatically as soon as they come from the forming machine. This system appears to have found only limited application. Apparently, a larger number of soft-mud plants employ the system in which the pallets are carried by conveyor directly from the brick machine to the drier and then are stacked by hand on steam-pipe racks. After the drying is completed, the brick must then be transferred to cars for transportation to the kiln. This method is in use at four of the six soft-mud plants covered in the 1936 survey.

Fuel Economy

In stiff-mud plants the major emphasis during the years 1920-36 has been on fuel economy rather than on reduction in labor requirements. The most popular method for effecting this economy is the utilization of the waste heat from other departments, particularly the kiln. In the cooling of the kiln and its load of brick large quantities of heat have to be thrown off. By running tunnels from the kiln to the drier and

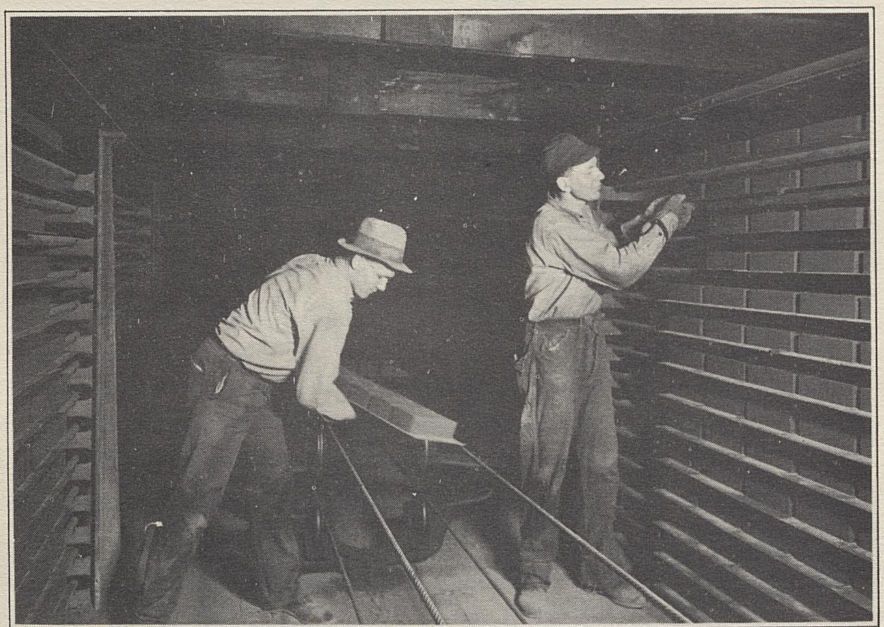

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FIGURE 13.- DRYING IN A SOFT-MUD PLANT

The pallets of brick are taken into the drier shed by cable conveyor. They are then placed in position on the steam-pipe racks by hand, care being taken not to touch the soft green brick. When sufficiently dried, they are taken to the kiln.

drawing off the hot air from the cooling brick it was found possible to accomplish the drying with a greatly reduced expenditure of fuel or without any fuel.

This system was first introduced almost simultaneously with artificial drying, but it was by no means general in 1920. Of the 40 stiff-mud plants surveyed by the Bureau of Labor Statistics in 1922 which employed artificial drying, only 15 employed waste heat for the supply of all or part of the thermal requirements of the drier. Of these 15, 7 supplemented the waste heat by steam and 1 by direct heat. None of the soft-mud plants used waste heat.

The shift to the use of waste heat was in full swing during the early 1920's and continued unabated thereafter. The change from direct or steam heat to waste heat was reported most frequently after 1929 when difficult operating conditions put a premium on all possible economies. In 1936 the use of waste-heat drying in stiff-mud plants appeared to have gained considerably in popularity, as indicated by the fact that it was employed in 17 of the 22 plants reporting in the NRP-NBER brick-plant survey on the type of heat employed. The average time required in drying was 42 hours at these 17 plants, varying from as low as 24 to as high as 60 hours. Sixteen of the plants using waste heat obtained it from the cooling kilns, and one used waste steam from the power plant. Three of the plants employing generated heat used steam, but the other two used direct heat from fires under the driers.

In the soft-mud plants the advance in drier technology appears to have been limited to the shift from the open-air to the artificial method. Steam is the most desirable form of heat for these plants since the steam pipes can be formed into convenient racks for the pallets of green brick. Of the 26 surveyed by the Bureau of Labor Statistics in 1922, the 17 soft-mud plants which employed artificial drying used generated steam as the source of heat. The six soft-mud plants which were covered in the NRP-NBER survey of 1936 all employed artificial drying and generated steam as the source of heat. The average time required by these six soft-mud plants for drying was 22 hours as compared with 42 hours for the stiff-mud plants employing waste heat.

Auxiliary Equipment

Besides these major changes in the technology of drying some effort was made to increase efficiency by the introduction of auxiliary equipment such as fans and temperature and humidity recorders and controllers. Induced-draft fans serve to increase the efficiency of drying by circulating the air in the drier. Sixty-five percent of the stiff-mud plants in the survey of 1936 used induced-draft fans, a good many of which had been introduced since 1920. None of the soft-mud plants were so equipped. The use of instruments in the drier was much more limited. Only 3 of the 22 stiff-mud plants reporting on this equipment in the 1936 survey employed any form of instrument in the drier. One of these three instruments was a temperature recorder, another a temperature and humidity recorder, and the third an automatic temperature and humidity recorder and controller. Of the six soft-mud plants surveyed in 1936, none employed instruments. This type of equipment seems to offer an opportunity for considerable savings and improvement in quality with a very small investment.

BURNING

In many ways the burning department is the most important one in the brick plant. The quality of the final product is largely determined by the skill with which this process is carried out, for it is in the kiln that the formed clay is burned into hardened brick. The fuel consumption is enormous in relation to the value of the product since from ½ to 1½ pounds of coal are used per brick produced.[35] In 1925 the manufacturers of clay products comprised the third largest industrial consumer of coal.[36] Labor costs are also very high, for in the great majority of plants every brick is handled individually in the setting operation, and the BLS 1922 brick-plant survey found that one-quarter of the total labor of the brick plant was expended in the burning department.[37] In addition, the process requires 5 to 10 days.[38]

[35] "Immense Saving with Continuous System of Burning," *Brick and Clay Record*, Vol. 56, No. 4 (Feb. 10, 1920), 322-5.

[36] Clay Products Cyclopedia and Equipment Catalog, p. 54.

[37] Includes setting labor.

[38] Kirk, *op. cit.*, p. 59.

The major objectives of technological effort in the burning department are economy in the use of fuel, reduction in the tremendous amount of labor involved, speeding up the process in an effort to attain a faster turn-over, and achieving these ends without a sacrifice in the quality of the brick. The attainment of these objectives during the period 1920-36 took the forms of the substitution of fundamentally different types of kilns for those in use and, more important, the addition of auxiliary equipment to, and modifications of, existing kilns.

Types of Kiln

During the early 1920's the great majority of plants employed rectangular kilns. Capacities range from 25,000 to 1,000,000 bricks, and the most usual size is from 400,000 to 600,000.[39] Most rectangular kilns are permanent structures, but at many plants, notably in the Chicago area, temporary or scove kilns are in use. Temporary brick walls for the permanent shed of the scove kiln must be erected for each individual burning after the bricks are set.

The round or beehive kiln was also in use in many plants at the beginning of the 1920's. It is relatively small with a maximum capacity of only 50,000 bricks[40] as compared with 1,000,000 for the rectangular type. In general, beehive kilns employ downdrafts and show a somewhat higher efficiency in the utilization of fuel than do the rectangular kilns. One advantage of the permanent beehive kiln over the rectangular scove kiln is that it does not require the labor necessary to set the kiln walls. This advantage is offset in most cases, however, by the fact that the cars can be run only to the narrow entrance of the beehive kiln, whereas in the rectangular type the loaded drier cars can usually be run into the kiln adjacent to the point of setting. Furthermore, the fireboxes are less centralized in the separate beehive kilns than in the rectangular kilns, and so the labor required for firing is greater.

In both types the fuel efficiency is low, and labor costs are quite high, affording abundant opportunities for improvement.

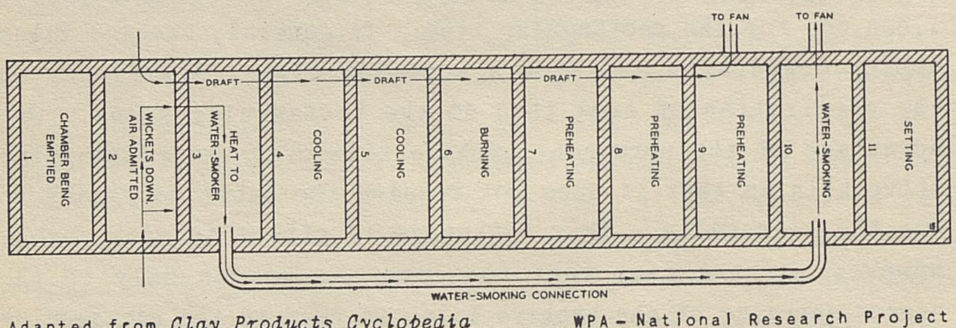
[39] *Ibid.*, p. 58.
[40] *Ibid.*

Ordinarily, with separate rectangular or beehive kilns, operation is intermittent. In each unit the brick are set and the fires started. The burning then proceeds in three major steps: first, water-smoking, in which a moderate temperature is used to drive out whatever moisture has been left in the brick from the drying process; second, the actual burning at a high temperature, in which chemical and physical changes in the clay of the brick bind the whole mass together; and third, the cooling, in which the fire is stopped and the heat remaining in the brick and in the kiln walls is allowed to dissipate.

There are three major sources of inefficiency in this process. First, fuel is required to heat the kiln in the water-smoking stage and to bring the kiln up to burning temperature. Second, during the burning the flue gases in the combustion chamber are ordinarily allowed to escape from the kiln without further utilization. Third, the large amount of heat left in the bricks and in the kiln walls at the end of burning is permitted to escape.

Striking economies have been effected by the application of a continuous system of burning whereby the flue gases

Figure 14.- CONTINUOUS SYSTEM OF RECTANGULAR KILNS



Adapted from *Clay Products Cyclopedia and Equipment Catalog*, 1926 ed., p. 162

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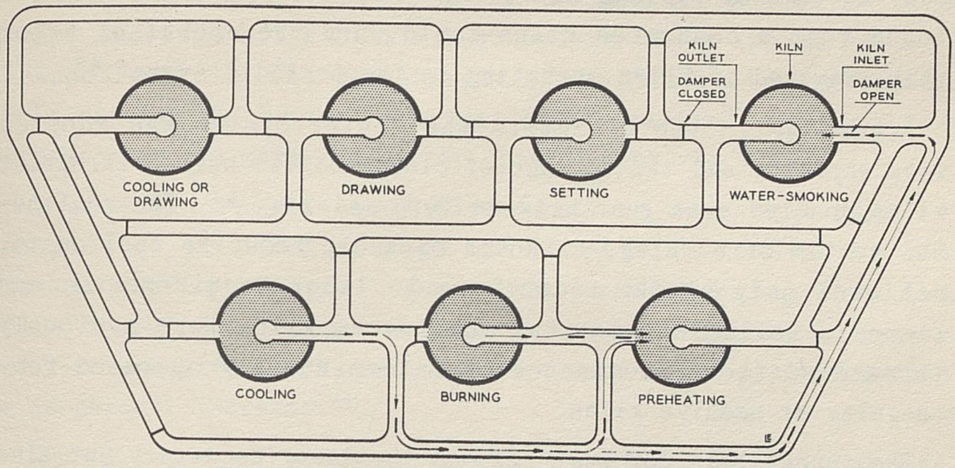
The continuous rectangular kiln is divided into a number of chambers. In only one chamber, number 6, are the fires actually lighted to maintain the final or burning temperature. The draft of air for the firing chamber is drawn through chambers 5, 4, 3, and 2, which contain burned brick in various stages of cooling, so that the cold air is preheated before reaching the combustion chamber. From the firing chamber the hot gases are drawn through chambers 7, 8, and 9 in order to preheat the thoroughly dried but unburned brick already set in those chambers. Chamber 10, used for water-smoking the freshly set brick, draws hot air only from the last two cooling chambers, since gas from the combustion chamber contains chemicals which would produce a scum on undried brick. In chamber 11 the green brick are being set, and in chamber 1 the completely cooled, finished brick are being unloaded. After the burning is completed in chamber 6, the same procedure is followed but shifted to the next chambers in rotation, the fire being lighted in 7, the water-smoking going on in 11, the green brick being set in 1, and the finished brick being unloaded from 2. Thus, all of the operations involved in the burning of brick are carried on continuously in this type of kiln.

Figure 15.- CONTINUOUS MINTER SYSTEM OF BEEHIVE KILNS



Adapted from *Clay Products Cyclopedia and Equipment Catalog*, 1926 ed., p. 208

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The operation of the beehive kilns connected in the Minter System is analogous to that of the continuous rectangular kiln described in the preceding diagram, except that the connection between chambers in various stages is made by means of tunnels. Heat from the cooling kiln is used for both preheating and water-smoking, and the hot flue gases from the burning kiln are drawn into the preheating kiln.

are used in preheating unburned brick and the heat of the cooling bricks is used to preheat the air of combustion and to water-smoke the green brick.

The continuous system of burning is applied to rectangular kilns by dividing them into chambers by means of temporary walls with the brick in each chamber in a different stage of the burning process. The operation of the continuous rectangular kiln is illustrated in figure 14. This continuous burning system is also applied to a group of beehive kilns by connecting them with a system of tunnels. The operation of this method, known as the Minter System, is illustrated in figure 15.

The Minter System has produced striking increases in the fuel efficiency of beehive kilns. Beehive kilns operated intermittently require from 1,000 to 1,500 pounds of coal per thousand bricks burned,[41] whereas the continuous system employs about 500.[42] It is also possible to achieve a larger output

[41] "Immense Saving with Continuous System of Burning," *loc. cit.*

[42] Reports of five plants using the Minter System give the following coal consumption per thousand brick produced: 519 (*ibid.*), 520, 519, 508, and 400 pounds ("Increasing Kiln Volume Without More Kilns," *Brick and Clay Record*, Vol. 61, No. 2 [July 25, 1922], 102-5). The average consumption for these five plants is 491 pounds.

with the same number of kilns, since the brick are preheated and the time of burning is therefore reduced. One brick plant found that 9 connected kilns could burn the amount of brick that required 16 kilns operating on the periodic system.[43]

According to the designers the Minter System was adopted very rapidly, and the tonnage of clay products burned in Minter kilns doubled each year between 1919 and 1923.[44] The continuous system of burning, although markedly reducing fuel costs, achieves only slight reductions in labor requirements, and there is no indication that continuous kilns have seriously threatened the predominance of intermittently operated rectangular or beehive kilns.

The tunnel kiln not only reduces the labor necessary but also offers a high degree of fuel efficiency, and for a time appeared to be making considerable headway in the industry. In this type of kiln cars are slowly pushed on rails through a tunnel-shaped kiln. The firing of the kiln is always carried out at one central point, so that there is no heat loss through the alternate heating and cooling of individual kilns or chambers as there is in all other types of continuous or intermittent kilns. Full use is made of the heat of cooling brick and of escaping combustion gases in preheating the air of combustion and the green brick. Thus the same measure of fuel efficiency is achieved as in the case of continuous kilns. The percentages of fuel savings when tunnel kilns were substituted for less advanced burning equipment are shown for the following five plants manufacturing the specified kinds of heavy clay products:[45]

Face brick	45.7
Roofing tile	60
Roofing tile	63.75
Face and fire brick	70
Common brick and tile	75

Substantial labor savings are also possible with this type of kiln since the setting of the brick on kiln cars from drier cars is carried on outside the kiln under the most favorable working conditions in terms of both productivity and the health of the workers involved. The designers claim a labor saving

[43] "Increasing Kiln Volume Without More Kilns," *loc. cit.*

[44] *Clay Products Cyclopedia and Equipment Catalog*, p. 209.

[45] *Ibid.*, p. 185.

of 10 to 20 percent due to this factor,[46] and reports from a plant manufacturing face brick and another producing face brick and fire brick show labor savings of 15 and 40 percent respectively.[47] The centralization of burners in the tunnel kiln enables the burner, the most highly skilled worker in the brick plant, to maintain closer control over the firing.

A greater percentage of first-quality brick can also be attributed to certain types of tunnel kiln because of the better firing control. One plant manufacturing face and fire brick reported an increase of 10 percent in the amount of first-quality brick, and another common-brick plant reported a 30-percent increase.[48]

In spite of these advantages, however, the indications are that the use of tunnel kilns is not rapidly increasing. There is an authentic record of only three tunnel kilns in operation in 1915; by 1926 there were more than 112 in use, of which 23 were burning heavy clay products such as brick and tile.[49] A recent estimate places the number of tunnel kilns employed in burning only face brick and common brick at 25 to 30,[50] which indicates that there has been no very rapid extension of their use since 1926.

A major factor operating against the more rapid installation of tunnel kilns until about 1935 has been their relatively high investment cost per unit of capacity, which was about twice that for other types of kiln.[51] In recent years the cost of construction has been reduced to between $15,000 and $18,000 for a car tunnel kiln with a capacity of 15,000 bricks each 24 hours, which is approximately the same as the cost of periodic kilns capable of an equivalent output.[52]

Also, the tunnel kiln achieves a reasonably high efficiency only when operated at, or very near, peak capacity. Because of the sharply restricted demand that has prevailed since 1929, it has proven impossible in most cases to achieve capacity

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[46]Letter, dated August 13, 1938, in files of WPA National Research Project, "Studies in Equipment Changes and Industrial Techniques" section.

[47]*Clay Products Cyclopedia and Equipment Catalog*, p. 185.

[48]*Ibid.*

[49]*Ibid., p. 180.*

[50]See ftn. 46.

[51]*Clay Products Cyclopedia and Equipment Catalog*, p. 180.

[52]See ftn. 46.

operation with the larger tunnel kilns capable of producing 50,000 to 60,000 bricks per day. Since about 1935 the manufacturers of tunnel kilns have been encouraging the installation of kilns with about a quarter to a fifth of this capacity; this enables the brick manufacturer to secure the efficiency of the tunnel kiln with the flexibility of a battery of periodic kilns.[53] Thus an effort has been made to remove the obstacles to extended use of tunnel kilns. The tunnel kiln, however, still involves a major investment that brick manufacturers have been reluctant to undertake under depressed conditions.

An idea of the relative importance of these types of kilns can be gained from the results of the NRP-NBER 1936 brick-plant survey. Of 30 plants, 15 used beehive kilns, 10 used scove kilns, 4 used rectangular kilns, and 1 used a continuous-chamber kiln. It is interesting to note that five of the plants employing beehive kilns had adopted these kilns during the years 1925-35, four of them after 1928. In all these plants the beehive kilns had replaced rectangular Dutch ovens and in one case had replaced kilns equipped with setting machines.

It seems extremely likely that these data reflect a general trend toward the increased use of beehive kilns. This return to favor seems entirely reasonable in view of the restricted demand for brick which has prevailed during recent years. The large capacity of the rectangular kilns under these conditions is likely to be more of a handicap than a virtue, and the flexibility of production possible with the small-capacity beehive kiln is particularly desirable under these circumstances. The necessity of operating both continuous kilns and the large tunnel kilns installed during the 1920's at nearly maximum capacity to achieve efficiency has probably served to discourage extension of their use. The replacement of older kilns by newer and more efficient ones generally involves a major investment, and the depressed condition of the industry has no doubt slowed down the improvement of burning methods through adoption of new basic equipment. The same consideration need not affect so seriously the application of the Minter System of continuous operation to existing beehive kilns.

[53] *Ibid.*

Auxiliary Equipment

The setting and unloading cranes of the mechanical setting system used at plants in the Chicago area and at a number of the larger eastern soft-mud plants are the most important labor-saving devices employed in the burning department. Cranes constitute an integral part of the scove kilns in which they are installed. In this system, the brick are lifted in carloads from the drier cars by the setting machine and set in place in the kiln without any hand labor. Unloading is similarly accomplished by machine. Since a tremendous amount of labor is otherwise involved in setting and unloading brick, particularly in the large scove kilns which prevail in the Chicago area, major reductions in labor requirements were achieved by the application of setting and unloading machines. One plant found that 13 men were capable of doing the work formerly requiring 30 men.[54] In three plants studied in the NRP-NBER 1936 brick-plant survey, each of which had installed two cranes, labor was reduced by more than one-half, in one case cutting the number of men required from 24 to 11, in another from 24 to 10, and in the third from 18 to 7. The manufacturers of the machine claimed that the services of 20 to 25 men could be eliminated by the addition of one of these machines in plants of average size.[55]

The bulk of these machines were installed in the Chicago area. Over two-thirds of the machines at Chicago plants were installed in 1910, the year of their introduction, and no further installations of this equipment were made in the Chicago area until 1925. This illustrates the way in which the drop in brick production affected the mechanization of the industry, for the further extension in the use of these machines after the initial wave of introduction had to wait until another period of peak production in the middle of the 1920's. The remainder of the installations in the Chicago area were made in the years 1926-29, after which there were no further installations of this equipment in the period surveyed.

The machines were installed principally in the plants of the largest companies operating in the Chicago area, under a licensing agreement whereby the equipment manufacturer

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[54] E. B. Miller, "What You Can See in Chicago Plants," *Brick and Clay Record*, Vol. 70, No. 3 (Feb. 1, 1927), 186-91.

[55] *Clay Products Cyclopedia and Equipment Catalog*, p. 191.

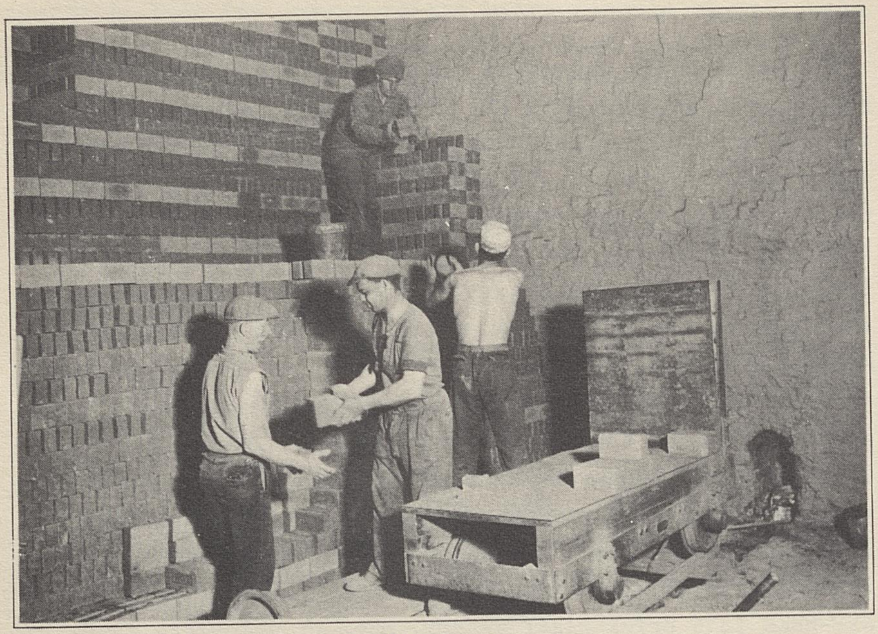

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FIGURE 16.- SETTING BRICK IN A RECTANGULAR KILN

Brick are usually hand-set by men working in pairs. The tosser takes the brick from the car and tosses them to the setter, who leaves air spaces between the brick as he sets them.

set quotas for the production of each plant installing this equipment. The two largest brick companies in the Chicago area employed over two-thirds of the total number installed between 1910 and 1936, and in 1936 their quotas allowed them the right to produce 84.2 percent of the bricks manufactured by all licensed companies. By the 1930's such companies produced 90 percent of the brick sold in the Chicago area.[56]

An important factor influencing the extent of use of the various types of kiln has been the introduction of auxiliary equipment which tends to improve the efficiency of periodic rectangular and beehive kilns. The low levels of production which have restricted the installation of such major units as kilns have not been so important a consideration in the application of auxiliary equipment.

Fans have been important pieces of auxiliary equipment employed in kilns. Used to produce a forced draft, they have

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[56] *Federal Trade Regulation Service*, "Court Decisions Supplement, 1932-1937" (7th ed.; Chicago: Commerce Clearing House, Inc., 1932-36), para. 7036, pp. 5124-30.

reduced the burning time by as much as 3 days[57] and have increased the average daily output of kilns 20 percent in one instance[58] and 47.1 in another.[59] An example of the results of the application of forced draft to kilns is the following case of a plant so equipped in 1931.[60] The first number following each item is for natural draft; the second, for forced draft:

Burning time (hours)	160	124
Coal per thousand bricks (lbs.)	2,200	1,600
Percentage of ware shipped	94.5	98.5

Portable fans have likewise had an important effect in speeding up kiln turn-over by reducing the time required for cooling. The time of cooling was reduced by from 24 to 48 hours through the use of fans in a number of instances.[61] Installations of forced-draft fan equipment were among the most frequently reported equipment changes in the NRP-NBER 1936 brick-plant survey.

Another type of auxiliary burning equipment introduced during this period was the pyrometer that aided the operator in the control of kiln temperature. An investment of a few hundred dollars for a pyrometer by one concern gave a fuel saving of $200 per month in addition to a 5-percent increase in the amount of first-quality product.[62] Other instances of pyrometer purchases have shown reductions of from 14 to 15 percent in the amount of unsalable brick.[63] Although the use of such instruments was practically unknown in 1920 in the brick industry, one-third of the plants covered in the NRP-NBER 1936 survey were equipped with pyrometers, 70 percent of which were of the recording variety.

Another important type of change has been the application of insulating materials to kilns to reduce the radiation losses. Reports from 25 plants indicate that fuel savings of

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57 Dean W. Taylor, "$10,000 Well Spent Saves Many Thousands Yearly," *Brick and Clay Record*, Vol. 65, No. 1 (July 8, 1924), 31-3.

58 "Fans and Fan Practice in Clay Industry," *Brick and Clay Record*, Vol. 75, No. 5 (Aug. 27, 1929), 278-89.

59 "When Forced Draft is Used," *Brick and Clay Record*, Vol. 67, No. 6 (Sept. 15, 1925), 408-9.

60 "A New Way to Use Fan Draft," *Brick and Clay Record*, Vol. 78, No. 5 (Mar. 10, 1931), 278, 280.

61 "Fans and Fan Practice in Clay Industry," *loc. cit.*; "A Romance in Industry," *Brick and Clay Record*, Vol. 62, No. 11 (May 29, 1923), 939 ff.; "100,000,000 Face Brick Annually," *Brick and Clay Record*, Vol. 63, No. 4 (Aug. 21, 1923), 253-7.

62 "Controller with Anticipatory Features," *Brick and Clay Record*, Vol. 77, No. 14 (Dec. 30, 1930), 806, 809.

63 NRP-NBER 1936 brick-plant survey.

from 15 to 25 percent were accomplished by insulation of walls and crowns of kilns, and 10 to 15 percent by insulation of crowns only.[64]

Type of Fuel Used

The nature of combustion equipment, an important type of auxiliary equipment, depends, of course, upon the type of fuel employed. It is therefore of interest to examine the relative importance of the several types of fuel, which are presented in table 9. There are no indications of any marked

Table 9.- DISTRIBUTION OF BRICK AND TILE PLANTS, BY TYPE OF FUEL USED AND PRODUCT, 1926[a]

Product	Approximate number of plants	Percentage distribution of plants by type of fuel used			
		Natural gas	Producer gas	Coal	Oil
Common brick	1,400	5	5	72	18
Drain tile	450	1	0	96	3
Hollow tile	425	2	0	93	5
Face brick	400	5	5	87	3
Fire brick	250	5	1	92	2
Paving brick	90	5	3	92	0
Sewer pipe	101	2	0	97	1

[a]Adapted from "Fuel in the Clay Industry," *Brick and Clay Record*, Vol. 70, No. 7 (Mar. 29, 1927), 535. The article does not specify the year to which the data refer. On the basis of the date of publication, the year to which the data refer is assumed to be 1926.

shift since 1926[65] in the types of fuel employed, and it therefore appears that oil is important as a fuel only in common-brick plants. Its importance is understated in table 9, for its use is predominantly in the larger plants, which account for a proportionately greater share of the total production. "Practically all common brick in California, Detroit, Chicago and Cleveland are burned with oil and the bulk of the Hudson River kilns are oil fired. . . . . about one-half of all of the country's common brick production is burned with oil."[66]

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[64]J. H. Kruson, "Insulated Kiln Saves 17% in Fuel," *Brick and Clay Record*, Vol. 63, No. 1 (July 10, 1923), 22-6.

[65]See table 9, ftn. a.

[66]"Fuel in the Clay Industry," *Brick and Clay Record*, Vol. 70, No. 7 (Mar. 29, 1927), 540.

The use of oil is one phase of the technological advantage of the larger plants. This advantage lies principally in the lower labor requirements associated with the burning of oil, which is estimated to produce a saving in firing labor in some instances of as much as 50 to 75 percent.[67] Furthermore, oil burning is more easily controlled and, therefore, produces a higher percentage of first-quality brick. One plant obtained 97 percent first-quality brick when burning with oil and only 75 percent when burning with coal.[68] Oil burning also requires less time than coal burning and in one instance the time was reduced from 10 days to 7,[69] in another instance from 150 hours to 102,[70] and in yet another from 8 days to 4.[71] Thus, although direct fuel costs are frequently higher with oil, burning costs including labor costs are generally lower.

Considerable reductions in labor costs and improvements in burning have been accomplished by the shift from steam atomization of oil to a system operated by compressed air. This shift has taken place very generally among the oil-burning plants. At one plant the cost of oil atomization was reduced by 27 percent as a result of this change, and three-quarters of this reduction was due to the elimination of the labor necessary to tend the boilers of the steam-atomization system.[72]

Although gas offers all the labor-saving, quality-improving, and time-cutting advantages of oil, it has found less extensive use in the most important sector of the industry, that which manufactures common brick. Labor reductions of 50 percent due to its use are not uncommon.[73] However, since gas is especially susceptible to careful control in the burning process, it has found much wider use than oil in the manufacture of special types of brick such as face, fire, and paving brick.

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[67] *Clay Products Cyclopedia and Equipment Catalog*, p. 59; transcript of hearing on Appeal from Order No. 123-13, Feb. 11, 1935, Structural Clay Products Industry, Industrial Appeals Board of NIRA, letter from Alfred J. Eno, Exeter, N. H., Feb. 1, 1933, pp. 4-11.

[68] Harry T. Horwell, "How We Burn Face Brick with Oil," *Brick and Clay Record*, Vol. 61, No. 10 (Nov. 14, 1922), 712-4.

[69] *Ibid.*

[70] "Oil Burning the Country Over," *Brick and Clay Record*, Vol. 69, No 1 (July 6, 1926), 30-3, 46, 48, 50, 52.

[71] *Ibid.*

[72] "Better Brick $100 Per Kiln Cheaper," *Brick and Clay Record*, Vol. 71, No. 5 (Aug. 30, 1927), 340-2.

[73] "City Gas Successfully Burning Brick," *Brick and Clay Record*, Vol. 70, No. 4 (Feb. 15, 1927), 292-3; "Burning Brick with City Gas," *Brick and Clay Record*, Vol. 65, No. 5 (Aug. 5, 1924), 167-8.

The relatively slight use of gas in common-brick plants is ascribable principally to the wide variations in the price of gas in different localities.

In recent years there has been some return to the use of coal as the result of the application of automatic stokers and pulverized-coal burners. Stoker-fired kilns have been reported to use 35 to 50 percent less coal and to increase the kiln capacity by 35 percent through the elimination of bag walls[74] in the side of the kilns.[75] Reduction in burning time of 15 to 40 percent has been accomplished by the use of stokers.[76] There is no indication to date, however, of a widespread adoption of stoker firing in the brick industry.

The use of pulverized coal has been productive of striking economies in a few plants. One plant found that only 288 pounds were required per thousand brick burned in a tunnel kiln and that pulverized coal had the same desirable qualities as oil in regard to control of burning.[77] The consumption of 288 pounds per thousand brick compares very favorably with that of 500 pounds per thousand brick in continuous kilns and 1,000 to 1,500 pounds in ordinary periodic kilns.[78]

UNLOADING OF KILNS AND TRANSPORTATION

Just as the setting of the kiln is a time- and labor-consuming operation, so the drawing of the burned brick from the kiln and its transportation to storage likewise require the services of many employees. The system in general use in plants employing beehive or continuous kilns is to load the brick into wheelbarrows for transportation to storage or to the loading platform.

In the more modern plants of the Chicago and Hudson River areas completely mechanical kiln unloading is employed in which overhead cranes pick up piles of over 1,000 bricks and transport them directly to storage or to means of transportation. At one yard such a mechanical loading machine

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[74] Bag walls are additional brickwork walls inside the kiln to prevent direct contact between fire gases and the brick to be burned.

[75] "Stoker Fired Periodic Kilns," *Brick and Clay Record*, Vol. 77, No. 9 (Oct. 21, 1930), 473, 506.

[76] *Ibid.*

[77] Frank M. Hartford, "A Successful Application of Powdered Coal as a Tunnel Kiln Fuel Firing Hard Fired Common Brick," *Journal of the American Ceramic Society*, Vol. 9, No. 10 (Oct. 1926), 684-9.

[78] "Immense Saving with Continuous System of Burning," *loc. cit.*

was found to be capable of loading a 7½-ton truck with 4,500 bricks in 3 to 4 minutes.[79] The advantage of this mechanical method over that of hand unloading and wheeling of the burned brick is indicated by the fact that at a Hudson River plant the cost of drawing and loading onto trucks was $1 per thousand when performed by hand as against $0.17 per thousand when loading by crane.[80]

In the Chicago plants temporary scove kilns are employed, and the burned brick are left in the kiln until they are shipped. This is the practice in many of the large soft-mud plants in the East as well. At other plants employing beehive or continuous kilns and at which it is the practice to unload to storage before shipping, the replacement of hand wheeling by electric lift trucks and tractors has reduced costs considerably. The introduction of such equipment resulted in the elimination of six men at one plant[81] and seven hand wheelers at another.[82]

At some plants a new method was introduced in 1935 which eliminates manual loading and unloading of delivery trucks. The final product is handled only once. When the brick are unloaded from the kilns, they are piled on wooden platforms in stacks of 1,000. This load is automatically lifted onto the truck by a built-in crane. The truck driver operates the loading and unloading process, accomplishing in 30 minutes the work otherwise done by two hand unloaders in 4 hours.[83]

A similar system in use at Hudson River brickyards is the container method of transporting brick. At the kiln brick are loaded into containers which hold 3,000 bricks, and are shipped in this container to New York City, the principal market for Hudson River brick. There the contents of the container are mechanically loaded into a motor truck for delivery to the job. By such methods the cost associated with unloading kilns, storing, and transporting brick has

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[79] Miller, *op. cit.*

[80] "Pallet and Electric Crane Saves $1.20 Per M on Unloading Costs," *Brick and Clay Record*, Vol. 72, No. 12 (June 5, 1928), 851-2.

[81] Harold J. Payne, "Would Electric Trucks Help You?" *Brick and Clay Record*, Vol. 67, No. 4 (Aug. 19, 1925), 256-9.

[82] "Truck System Eliminates Seven Men," *Brick and Clay Record*, Vol. 69, No. 4 (Aug. 17, 1926), 273-6.

[83] R. H. Berg, "No Human Hand Touches Our Brick From Kiln to Job," *Brick and Clay Record*, Vol. 87, No. 3 (Sept. 1935), 85-6.

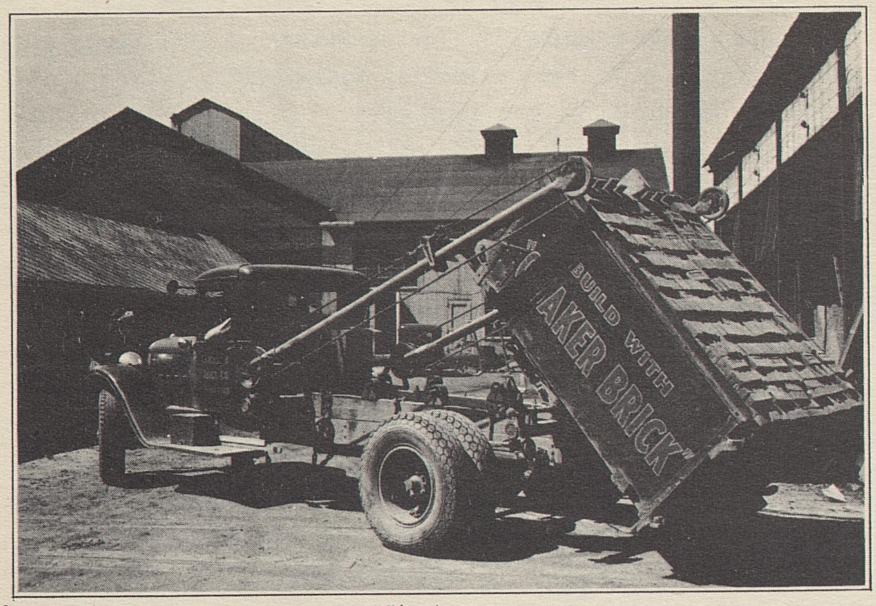

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FIGURE 17.– MECHANICAL TRANSPORTATION

The truck above has a special loading and unloading mechanism whereby it handles a truckload of brick as a single unit. The truck grips, picks up, carries, and unloads the whole load of stacked brick.

been considerably reduced. In 1928 this system was employed in handling over 90 percent of the output of 20 Hudson River brick plants.[84]

Hand wheeling to storage and hand loading, however, remain the most general practice. Of 23 plants reporting methods of loading in the NRP-NBER 1936 brick-plant survey, 11 used wheelbarrow transportation to storage, 6 used lift trucks or tractors and trailers, 2 employed overhead cranes, and 4 loaded trucks at the kiln for shipment direct to the user. Of the four plants which loaded trucks at the kiln, one employed a conveyor from the kiln to the truck and another a belt loader. In the larger plants, especially those serving the steadier demand of metropolitan markets, mechanization of the handling operations has been proceeding at a fairly steady rate. In this department of brick manufacture, as in the others, the different sections of the industry show wide variations in the techniques employed.

[84] "Shipping Brick in Containers is a Speedy System," *Brick and Clay Record*, Vol. 74, No. 2 (Jan. 15, 1929), 85.

POWER

The change in the type of power used to drive machinery in the brick industry during the 1920's was probably of importance equal to that of any single change in machinery that occurred during that period. The shift from steam to electricity as the dominant form of power effected savings in the labor of power generation, machine operation, and maintenance. In many cases the use of electric power was a prerequisite for the introduction of certain labor-saving machines.

Power data are available in the *Census of Manufactures* for the "Clay products (other than pottery) and nonclay refractories" industry, an industrial category which is more inclusive than the brick and tile industry[85] as defined in this report. The machinery and methods employed in the manufacture of brick and tile, however, are similar to those employed in the manufacture of other clay products; data for the more extensive industrial category are here used for an analysis of trends in the type of power employed in the brick and tile industry.

The most striking feature of the 1919-29 period was the great increase in the importance of electric-motor drives in the industry. In 1919 electric motors represented only 33 percent of the installed horsepower, whereas 10 years later they accounted for 69 percent. The extent to which this shift has taken place is corroborated by the NRP-NBER 1936 brick-plant survey. Of 29 plants reporting on type of power, 18 used purchased electricity entirely, 1 generated its own current, 6 used a combination of steam and purchased electricity, and 4 used steam power only.

Electric power began to find use in the brick industry shortly after 1900, when the adoption of steam power had become virtually complete. Its rise in importance took place at the expense of steam power; the percentage of the total installed horsepower accounted for by steam engines and turbines declined as that of electric motors increased. The effects of the substitution of electric power were scarcely less revolutionary than those of the earlier adoption of steam. Electric power effected a degree of centralization

[85] See chap. II, ftn. 1.

of power generation formerly impracticable and a transition to individually driven machines.

The use of electricity centralized the generation of power, particularly where power was purchased from central stations. Steam-operated brick plants sometimes required a number of steam engines, each with its crew of operators. The purchase of power eliminated this labor in the brick plant without a corresponding increase in the amount of labor employed in the much more efficient central stations; it also meant that less fuel was used to do the same amount of work because of the much higher fuel efficiency of central stations.

The trend toward the purchase of central-station power is evident in the data presented in table 10. In 1919, 79 percent of the rated horsepower of electric motors in the "Clay products (other than pottery) and nonclay refractories" industry was utilized by motors driven by purchased energy; by 1929 the percentage had increased to 93. Similarly, in 1919, 26 percent of the total installed horsepower in the

Table 10.- TOTAL HORSEPOWER OF THE CLAY PRODUCTS (OTHER THAN POTTERY) AND NONCLAY REFRACTORIES INDUSTRY, BY SOURCE OF POWER, 1919-29[a]

Year	Total rated horsepower	Percentage distribution of total rated horsepower, by source of power				Horsepower of electric motors driven by purchased energy as percent of horsepower of all electric motors	Rated horsepower of electric motors as percent of total rated horsepower
		Purchased electricity	Steam engines and turbines	Internal combustion engines	Other		
1919	405,157	26.1	69.6	4.3	0	79.4	32.9
1923	480,576	40.7	55.8	3.3	0.2	85.3	47.7
1925	517,204	49.6	45.6	4.7	0.1	88.9	55.7
1927	529,581	58.1	37.4	4.5	0	91.9	63.2
1929	533,887	63.8	31.6	4.5	0.1	92.8	68.8

[a]Data for 1919, 1925, 1927, and 1929 from *Fifteenth Census of the United States: 1930*, "Manufactures: 1929" (U. S. Dept. Com., Bur. Census, 1933), II, 853; data for 1923 from *Biennial Census of Manufactures: 1927* (U. S. Dept. Com., Bur. Census, 1930), p. 849.

industry represented motors driven by purchased electricity, and by 1929 this percentage had increased to 64.

In the much smaller section of the industry that employed electric power generated in the plant, the shift from steam power to electricity also effected some centralization of power generation. Whereas formerly the power of the plant may have been supplied by several steam engines driving different sections of the plant, the adoption of electricity generally concentrated the production of power in one steam engine and electric generator with a corresponding reduction in labor. This concentration of power production in plants generating their own electricity accounts in part for the increase in size of installed steam prime movers. Between 1919 and 1929 the average horsepower of installed steam prime movers increased from 102 to 127, or by 25 percent, as shown in table 11. Since, in general, the efficiency of steam engines increases with size, the rise in the average capacity of steam engines may reflect also the effort of plants employing steam power to take advantage of this characteristic.

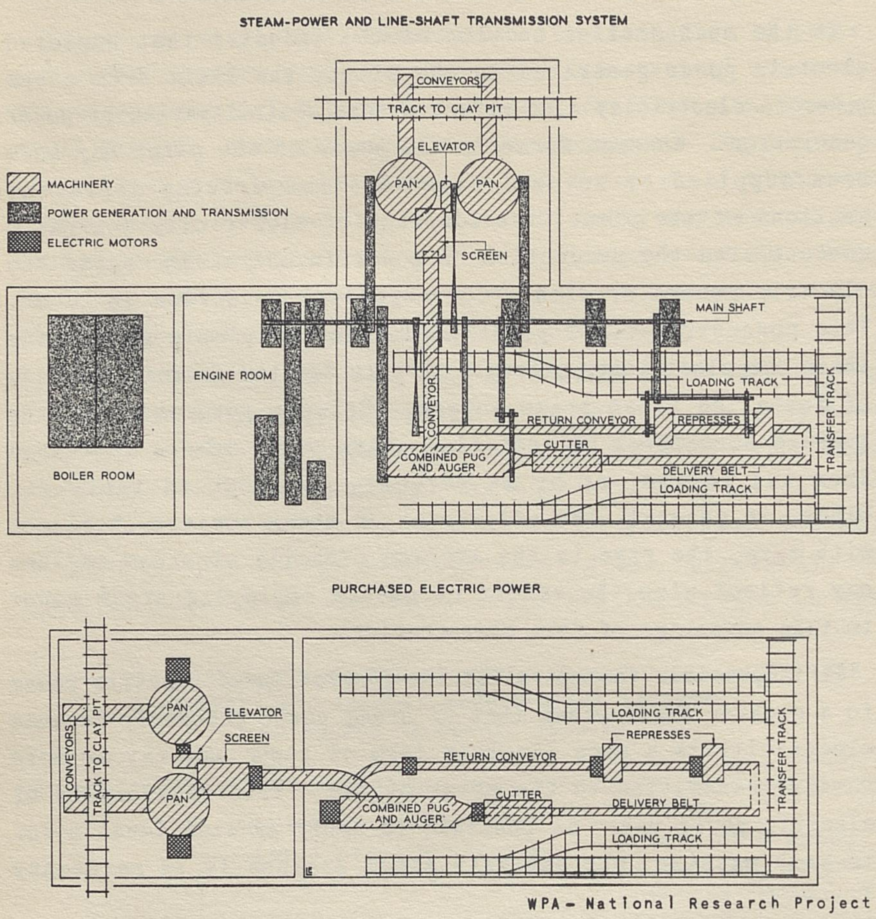
It is possible to centralize the generation of electric power to a greater degree than that of steam power precisely because electricity is a more flexible form of power and may be more easily transmitted to the point of use. This flexibility of electric power makes it possible to apply an individual motor to each machine, whereas with steam engines it is necessary

Table 11.- AVERAGE RATED HORSEPOWER OF PRIME MOVERS AND ELECTRIC MOTORS IN THE CLAY PRODUCTS (OTHER THAN POTTERY) AND NONCLAY REFRACTORIES INDUSTRY, 1919-29[a]

Year	Steam engines and turbines	Electric motors		
		All	Driven by purchased energy	Driven by energy generated in establishment
1919	101.8	27.6	31.1	19.2
1923	117.9	26.3	28.1	19.1
1925	118.0	26.0	28.0	16.4
1927	125.3	23.5	25.0	14.1
1929	127.0	21.4	22.5	13.3

[a]See table 10, ftn. a for sources.

Figure 18.- EFFECT OF ELECTRIFICATION



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The upper half of this diagram is the plan of a brick plant with its own steam plant and shaft-and-belt system of power transmission. The lower half shows the simplification possible in the same plant by the substitution of purchased electric power.

to transmit power from the engine to the machine through a cumbersome system of shafts, belts, and pulleys. The power losses due to friction and belt slippage in such a system sharply limits its efficiency and physical range of application. On the other hand, the line losses of an electrical wiring system within a plant are negligible, and an electrical system of power distribution is therefore far more efficient than a mechanical system.

The inflexible and clumsy apparatus required for the mechanical transmission of steam power forced the engineer in the earlier days to give first consideration in plant design to efficiency of power transmission rather than to flow of material. The use of individual motors now makes it possible to rationalize plant lay-out for the maximum productivity of labor, and for efficiency in the flow of materials. The latter is of special importance in the brick and tile industry where the bulk of the material handled is large in relation to its value. The individual motor can also be designed to fit exactly the requirements of the individual machine to which it is attached, and this likewise effects an important improvement in the efficiency of operation and thereby indirectly reduces labor requirements. Furthermore, lubrication and maintenance of the belts, pulleys, and shafting of the steam-power transmission system required considerable labor which was largely eliminated by the transition to individual electric motors.

Electric power employed through individual motors is more amenable to automatic and semiautomatic control, which means that labor requirements may be reduced by the application of control devices. The automatic synchronization of operation of the belt feeder and crusher illustrates the effect of this characteristic of electric power. Even such a simple control device as the electric push button may effect considerable savings of labor when substituted for the more cumbersome controls necessary with steam power. Finally, electric power, because of its flexibility, was very nearly a prerequisite for the use of such labor-saving devices as transfer cars, overhead cranes, and setting machines.

Electric power is not always applied to machines through individual motor drive, but it has been to an increasing extent in recent years. This is indicated by table 11, which indicates a steady decline in the average size of motors employed in the industry. The initial steps in electrification at many brick plants was to replace the steam engines with electric motors, each of which drove a number of machines through shafting and belting. The individual motors for each machine which were introduced in the later stages of electrification were, of course, smaller on the average than the earlier motors which drove a number of machines. The shift to individual drive was therefore the principal factor responsible for the decline in the average size of motors.

A comparison of the average sizes of motors driven by purchased electricity and by electricity generated in the plant tends to confirm this analysis. Plants which purchased power in the early years of electrification frequently contented themselves with replacing steam engines by large electric motors that continued to drive individual machines by means of shafts and belting. If this practice had been followed at plants which generated their own electric power, it would have meant the almost pointless interposing of a generator and electric motor between the steam engine and the mechanical power-transmission apparatus. Therefore, plants generating their own electric power generally proceeded directly to individual or small-group drive of machines.

Hence, in 1919, the average horsepower of motors driven by energy generated in the plant was lower by 12 than that of motors driven by purchased energy. Since that time, with the shift to individual drive in plants purchasing electricity and the extension of use of electric motors generally, the average horsepower of motors driven by energy from both sources has declined, and the difference in size has become less pronounced.

The purchase of power as opposed to the use of prime movers has considerably reduced the capital investment required. Where the need for an expansion or replacement of power-generating facilities arose, this factor has doubtless been an important consideration favoring the purchase of power, particularly since 1929.

CHAPTER IV

SUMMARY

From 1870, when the stiff-mud auger machine and soft-mud mold-filling machine were just beginning to be generally employed, to 1920 the man-hour requirements per thousand brick were reduced by more than 50 percent. The reduction of 27 percent from 1889 to 1919[1] was accompanied by major capital expenditures for such equipment as steam shovels and locomotives in the clay pit; cars, rails, transfer cars, and tunnel driers in the drying department; tunnel kilns, continuous kilns, and elaborate mechanical setting machines in the burning department; and electrical power equipment and handling machinery throughout the plant. The type of brick factory which was responsible for a major share of the total production in 1919 bore little relation either in capital investment or in productivity of labor to the brickyard of the nineteenth century. By 1920 many of the brick and tile plants were operating on a highly mechanized basis.

During the period 1920-36 the increase in the productivity of labor in the brick and tile industry tended to be obscured by the effects of the decline in production after 1925. Until 1925 the increased productivity reflected mainly the more extensive utilization of improved major production units in response to the demand for increased output. The high level of repair sales during the years 1922-24 was indicative of the need to rehabilitate plants which had been left idle or in disrepair during the war years and to restore output to former levels. At the same time substantial investments in major productive units, though made in the expectation of increased or relatively stable production, also achieved reductions in production costs. After the peak of production was passed in 1925, the objectives of capital expenditures began to change gradually until, under the conditions of sharply curtailed production, the emphasis after 1929 definitely shifted to the purchase of machines and auxiliary devices designed primarily

[1]Miriam E. West, *Productivity and Employment in Selected Industries: Brick and Tile* (WPA National Research Project in cooperation with National Bureau of Economic Research, Report No. N-2, Feb. 1939), p. 108.

to reduce production costs or to improve quality. The objective has been to accomplish these results without major capital investments. The replacement of major production units has been kept at a minimum and, where they were essential, the choice of the type of replacement has been dictated by considerations of cost reduction or quality improvement rather than increased output.

This is illustrated by an examination of the most important changes in the several departments that were responsible for the increase or maintenance of the level of labor productivity in the face of a low level of output relative to capacity. The productivity of labor in the substantial number of clay pits which operated on an unmechanized basis in 1920 was improved by increased use of power shovels and industrial locomotives. Since 1925 power-shovel sales have become increasingly limited and, when replacement has been necessary, attention has centered on such cost-reducing improvements as crawler traction and the more economical forms of power (electricity and gasoline) which reduce the labor of shovel operation.

Aside from the addition of preliminary crushers, there were few important improvements in clay-preparation machinery likely to achieve significant cost reductions. Sales since 1929 have been negligible.

In the machine house the most striking innovation was the automatic soft-mud molding machine, placed on the market in 1920. It represented the only fundamentally new development in any of the major productive units after the World War. The introduction, most rapid prior to 1925, of 118 machines between 1921 and 1928 radically increased the productivity of labor in these plants by eliminating several of the operations formerly required in soft-mud brick manufacture. In the Hudson River Area particularly, the installation of the automatic machine, accompanied by extensive reorganization (involving major capital investments) of the production process, raised the productivity of labor in large soft-mud plants to the level of productivity in the best stiff-mud plants.

In the stiff-mud plants the substitution of combined machines for separate pug and auger machines was an evident tendency in the latter half of the 1920's, and the sharp and steady increase in the sales of deairing machines which replaced the combined machine was one of the features of the recovery period after 1932. Although this equipment was usually sold as part of a complete brick-making machine, the auxiliary deairing device which effected reductions in cost and improvement of quality was the feature that made the large volume of the complete-machine sales possible.

In the drying department labor productivity was increased by an extension in use of electric transfer cars in stiff-mud plants, while conveyors accomplished the same end in soft-mud plants. The virtual elimination of open-air drying and the shift to waste-heat drying in stiff-mud plants, particularly after 1929, represented two phases of the effort to reduce costs. Such auxiliary equipment as induced-draft fans has found extensive use, and recording and controlling instruments have been introduced in a few plants.

In the burning department kiln design was a focus of interest during the 1920's, and large-capacity tunnel and continuous kilns became important factors. In recent years smaller kilns more suitable for irregular and diversified production have been favored. Improved fuel efficiency and labor productivity were achieved by the addition of such auxiliary devices as draft fans, pyrometers, insulation, and oil-pressure systems.

In the Chicago area, between 1925 and 1929, the installation of setting and unloading machines at additional plants raised the percentage of brick set by machine in that area to about 90 percent. Brick-setting machines entered eastern soft-mud plants during the 1920's.

The shift from steam to electric power had the effect of reducing the personnel associated with power generation and the maintenance of transmission machinery. The purchase of power reduced capital costs by eliminating the need for prime movers in the plant. The application of direct-connected motors increased the effective working speed of equipment in many instances and generally allowed for more efficient lay-out because of the elimination of the shaft and belting system for power transmission.

An outstanding feature of the period 1925-35 has been the reduction in the number of operating plants by more than 50 percent. The trend in the industry toward larger plants has accompanied the decrease in the number of plants since 1889.[2]

[2] *Ibid.*, p. 12.

In the past, the magnitude of transportation costs relative to production costs, together with regional differences in the nature of demand, have served to keep brick production scattered in plants located in most parts of the country. The average plant is small compared with those in other industries. The increasing urbanization of the population and a concomitant change in the dominant types and techniques of construction, however, have favored such products as face brick and hollow building tile, which are produced in plants of larger than average size and for a market that is primarily urban. Also, the decline in the relative importance of agriculture in the economy has resulted in a restricted demand for drain tile, which is produced in plants of smaller than average size and for a market which is primarily rural.

Thus, economic factors have favored increasing centralization of production in larger plants and within certain regions. The technological basis for this centralization is found in several items of labor-saving equipment associated principally with the larger plants, such as the automatic soft-mud machine and its automatic hacking machine, brick-setting and unloading machines, electric transfer cars, and compressed-air oil burners. The low level of capacity utilization that now prevails and the fact that the large plants are operating at a lower average percentage of capacity than the small plants[3] furnish an important stimulus to further concentration of the production in particular regions in the more efficient plants of those regions. In the past such concentration was often accomplished through mergers of a number of plants of a region with only the more efficient plants remaining open during the periods of restricted demand. Should the same procedure be followed in the future, the general level of productivity of labor in operating plants is bound to be raised without involving any considerable capital expenditures which would materially offset the consequent reductions in the labor requirements of brick manufacture.

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[3] *Ibid.*, p. 127.

APPENDIX

DESCRIPTION OF SURVEY DATA[1]

NRP MACHINERY-MANUFACTURERS SURVEY

Data were obtained in a field survey, covering 11 equipment-manufacturing companies, conducted by the National Research Project in cooperation with the National Bureau of Economic Research. From these companies was obtained the value of sales, for 1920 to 1936, of equipment used in the manufacture of brick and tile. Of these companies, eight produced clay-working (clay-preparing and machine-house) equipment and three produced excavating equipment.

Clay-Working Equipment Companies

For 5 of the 11 companies surveyed the data obtained refer to the value of sales of new clay-working machinery and repairs.[2] These five companies are among the seven largest producers of clay-working equipment.

For some of the companies sales were not available for a few years of the period 1920-36. For such years sales of the missing companies were estimated on the basis of the proportions that the sales of these companies comprised of the sales of the others in years for which the sales of all were available. One of these companies required such estimates for the period 1920-27. In one case estimates for the last 2 months of 1936 were made on the basis of the average for the first 10 months.

For 3 of the 11 companies surveyed the data obtained refer to the value of sales of selected types of new machinery only. These three companies together sold only about two hundred thousand dollars worth of such equipment over the entire period.

Data for one of the three companies were available only through the first 10 months of 1936; sales for the remaining months were estimated from the 10-month average.

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[1]Prepared by Julius M. Balick in collaboration with the authors.

[2]Repairs include sales of repair parts and charges for rebuilding.

Table A-1.- VALUE OF TOTAL PRODUCTION AND OF SALES SAMPLE OF CLAY-WORKING EQUIPMENT, 1919-36

Year	Value of total production[a]		Value of sales by eight companies[b]		Percent that eight-company sales are of total value
	Thousands of dollars	Index (1925=100)	Thousands of dollars	Index (1925=100)	
1919	3,187	60.2	n.a.	-	-
1920	n.a.	-	1,389[c]	71.5	-
1921	3,772	71.2	1,197[c]	61.6	31.7
1922	n.a.	-	1,771[c]	91.2	-
1923	5,508	104.0	2,208[c]	113.7	40.1
1924	n.a.	-	1,776[c]	91.5	-
1925	5,298	100.0	1,942[c]	100.0	36.6
1926	n.a.	-	2,040[c]	105.0	-
1927	4,308	81.3	1,462[c]	75.3	33.9
1928	n.a.	-	1,569	80.8	-
1929	4,402	83.1	1,651	85.0	37.5
1930	n.a.	-	903	46.5	-
1931	1,671	31.5	561	28.9	33.6
1932	n.a.	-	193	9.9	-
1933	591	11.2	229	11.8	38.7
1934	n.a.	-	324	16.7	-
1935	1,071	20.2	420	21.6	39.2
1936	n.a.	-	627[c]	32.3	-

[a]Represents all clay-working machinery. Data are from *Census of Manufactures: 1925* (U. S. Dept. Com., Bur. Census), p. 1031; *1929*, II, p. 1099; *1933*, p. 525; and *1935*, p. 1090.

[b]Data are from NRP machinery-manufacturers survey and cover sales of clay-working (clay-preparing and machine-house) equipment and repairs to the brick and tile industry by eight companies manufacturing equipment.

[c]Partly estimated.

n.a. Data not available.

Table A-1 presents a comparison of the value of sales of clay-working machinery as obtained from the foregoing eight companies[3] and the value of production of all clay-working machinery as reported to the *Census of Manufactures*. Examination of table A-1 reveals that the volume of sales obtained in the survey fluctuates closely with the value of total production. The percentage which the former series comprises of the latter varies between 32 and 40. The average for the entire

[3]The sales of clay-excavating equipment by three companies producing power shovels and locomotive cranes have not been included, since the census figures do not include excavating equipment.

period is 36.[4] It should be noted that the census values include machinery used exclusively in the production of clay products other than brick and tile. Such machinery is not included in the sales series.

The *Census of Manufactures* specifies two industries that manufacture products made of clay - the "Clay products (other than pottery) and nonclay refractories" industry and the "Pottery, including porcelain ware" industry. The former, which includes the production of brick and tile, has roughly 90 percent of the total rated horsepower of the two industries.[5] This proportion is not utilized exclusively in the production of clay brick and tile. Of the value of products of the "Clay products (other than pottery) and nonclay refractories" industry, between 5 and 20 percent represent the value of nonclay refractories.[6] Such products, however, are manufactured by processes other than those used to produce brick and tile,[7] and the equipment used in their manufacture is probably not included in the series for value of clay-working machinery. The sample sales series therefore accounts for a somewhat larger proportion of total production of brick and tile equipment than is indicated in table A-1.

The eight-company sales series was broken down by kinds of equipment sold by varying numbers of companies. The breakdowns are discussed below. Because data for several companies were not available for the entire period under consideration, partial estimates were required for these break-downs.

Crushing and Grinding Equipment.- Table A-3 presents the value of sales of crushing and grinding equipment. Such sales are presented in three categories - wet and dry pans; smooth-roll crushers; and granulators, disintegrators, and pulverizers - and are based on the records of seven companies.

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[4]Except for 1933, the survey series represents an increasing proportion of the census series in years for which the latter is higher than in the preceding census year; the survey series represents a decreasing proportion of the census series in years for which the latter is lower than in the preceding census year. An apparent reason for this relationship is that the survey series represents sales, whereas the census figures are for production. In years of rising sales, inventories may be depleted; in years of low sales volume, inventories may be built up.

[5]The percentages are 93.3 in 1919, 91.5 in 1923, 91.2 in 1925, 90.6 in 1927, and 89.6 in 1929, the last year for which data are available (based on *Census of Manufactures*).

[6]The percentages over the period 1923-35 range from 5.7 in 1924 to 19.1 in 1935. The movement of these percentages is almost steadily upward (based on *Census of Manufactures*).

[7]*Clay Products Cyclopedia and Equipment Catalog* (3d ed.; Chicago: Industrial Publications, Inc., 1926), *passim*.

Table A-2.- RELATIVE VALUE OF SALES OF CLAY-WORKING EQUIPMENT TO THE BRICK AND TILE INDUSTRY BY VARYING NUMBERS OF COMPANIES, 1920-36

Year	Index of sales (1925=100) by -				Percent of eight-company sales comprised by sales of -		
	Eight companies[a]	Seven companies[b]	Five companies[c]	Three companies[d]	Seven companies	Five companies	Three companies
1920[e]	71.5	62.1	71.2	76.7	66.1	98.6	52.0
1921[e]	61.6	54.8	61.9	66.3	67.7	99.5	52.1
1922[e]	91.2	92.4	91.4	81.5	77.0	99.3	43.3
1923[e]	113.7	114.6	113.3	101.9	76.7	98.7	43.4
1924[e]	91.5	87.6	91.7	91.2	72.9	99.3	48.3
1925[e]	100.0	100.0	100.0	100.0	76.1	99.0	48.5
1926[e]	105.0	109.9	105.3	104.7	79.6	99.3	48.3
1927[e]	75.3	76.8	75.7	81.0	77.6	99.5	52.1
1928	80.8	81.2	80.8	81.5	76.4	99.1	48.9
1929	85.0	91.4	85.6	89.9	81.8	99.7	51.2
1930	46.5	45.5	46.6	48.9	74.4	99.2	51.0
1931	28.9	28.3	29.2	36.8	74.4	100.0	61.7
1932	9.9	8.9	9.9	10.9	68.2	99.0	53.0
1933	11.8	11.8	11.8	14.5	76.1	99.4	59.8
1934	16.7	17.9	16.5	24.0	81.6	97.7	69.8
1935	21.6	23.3	21.5	31.1	82.0	98.5	69.8
1936[e]	32.3	36.6	32.0	50.5	86.3	98.2	75.7

[a]Computed from table A-1.
[b]Companies whose sales were used in constructing table A-3.
[c]Companies whose sales were used in constructing table A-4.
[d]Companies whose sales were used in constructing table A-6.
[e]Partly estimated.

Table A-3.- VALUE OF CRUSHING AND GRINDING EQUIPMENT SOLD TO THE BRICK AND TILE INDUSTRY BY SEVEN COMPANIES, 1920-36[a]

(Thousands of dollars)

Year	Total	Wet and dry pans	Smooth-roll crushers	Granulators, disintegrators, and pulverizers	Percent that pans are of total (3-year moving average[b])
1920	82	67[c]	2[c]	13[c]	-
1921	101	97[c]	2	2[c]	87.9
1922	107	91[c]	5	11[c]	88.2
1923	223	192[c]	10	21[c]	82.0
1924	165	123	15	27	81.6
1925	122	101	7	14	77.3
1926	223	170	7	46	78.6
1927	103	81	10	12	75.6
1928	128	92	4	32	76.5
1929	109	87	5	17	73.7
1930	41	26	6	9	77.8
1931	35	31	2	2	74.0
1932	1	0	0	1	75.0
1933	8	2	*	6	16.7
1934	3	0	0	3	42.9
1935	10	7	*	3	39.3
1936	15	4	1	10	-

[a]Data are from the NRP machinery-manufacturers survey and cover sales to the brick and tile industry by seven companies manufacturing crushing and grinding equipment. Of the seven, two make wet and dry pans, four make smooth-roll crushers, and five make granulators, disintegrators, and pulverizers.
[b]Weighted.
[c]Partly estimated.
*Less than $500.

Table A-4.- VALUE OF SALES BY FIVE COMPANIES OF SELECTED TYPES OF EQUIPMENT USED PRINCIPALLY IN STIFF-MUD BRICK PLANTS, 1920-36[a]

(Thousands of dollars)

Year	Total	Dealring equipment	Augers and combined pugmill and auger machines: Total	Augers	Combined machines	3-year percent that combined machines are of total	Pug-mills[b]	Cutters	Feeders[b]
1920	309	-	159	57[c]	102[c]		38[c]	102[c]	10[c]
1921	235	-	138	38[c]	100[c]	70.5	13[c]	75[c]	9[c]
1922	263	-	134	32[c]	102[c]		26[c]	92[c]	11[c]
1923	335	-	184	64[c]	120[c]		43[c]	97[c]	11[c]
1924	326	-	186	65	121	66.4	43	83	14
1925	339	-	181	56	125		46	99	13
1926	377	-	234	48	186		45	81	17
1927	287	-	171	30	141	79.1	28	77	11
1928	236	-	146	37	109		21	60	9
1929	269	-	143	20	123		36	74	16
1930	172	-	95	9	86	86.7	26	47	4
1931	105	-	56	10	46		16	26	7[c]
1932	32	18	4	4[c]	0[c]		0[c]	9[c]	1[c]
1933	52	48	1	1[c]	0[c]	-	2[c]	1[c]	*[c]
1934	45	41	0	0[c]	0[c]		3[c]	1[c]	1[c]
1935	152	141	0	0[c]	0[c]	-	3[c]	7[c]	1[c]
1936	185	154	14	3[c]	11[c]		4[c]	12[c]	1[c]

[a]Data are from NRP machinery-manufacturers survey and cover sales to the brick and tile industry by five companies manufacturing brick equipment. Of the five, two make deairing equipment, four make augers, four make combined pugmill and auger machines, five make pugmills, four make cutters, and four make feeders.

[b]Includes sales to soft-mud plants.

[c]Partly estimated.

*Less than $500.

Table A-5.- INDEXES OF VALUE OF SALES OF STIFF-MUD AND SOFT-MUD EQUIPMENT BY FIVE COMPANIES, 1921-36[a]

(1925=100)

Year	Total	Stiff-mud equipment	Percent that value of sales of stiff-mud equipment is of total (3-year moving average[b])	Year	Total	Stiff-mud equipment	Percent that value of sales of stiff-mud equipment is of total (3-year moving average[b])
1921	71.1	72.6	-	1929	67.0	74.4	78.4
1922	88.0	81.4	69.4	1930	40.9	49.5	87.3
1923	112.7	100.7	70.0	1931	22.0	29.3	93.1
1924	89.2	92.1	71.8	1932	10.7	13.8	96.8
1925	100.0	100.0	75.9	1933	17.8	23.1	96.3
1926	100.4	104.9	77.0	1934	14.6	19.4	98.1
1927	75.0	81.8	75.7	1935	44.7	59.9	98.8
1928	72.4	67.0	77.0	1936	53.4	71.3	-

[a]Data are from NRP machinery-manufacturers survey and cover sales to the brick and tile industry by five companies manufacturing brick equipment. Of the five, one manufactures soft-mud and all manufacture stiff-mud equipment. The figures used are based upon a selected series of machines.

[b]Weighted.

These seven companies accounted for from 66 to 86 percent of the eight-company sales series (table A-2).

Stiff-Mud and Soft-Mud Equipment.- The sales of selected types of machinery used principally in stiff-mud plants are presented in table A-4. These sales are presented in the following categories: Deairing equipment, augers, pugmills, combined augers and pugmills, cutters, and feeders. The figures presented are based on the sales records of five companies, which accounted for over 98 percent of the eight-company sales series (table A-2).

Of the five companies, one also produced soft-mud equipment. Since this company produces the AutoBrik machine, the fundamental piece of equipment used in further mechanizing soft-mud plants, the sales of this company are believed to represent adequately the purchase of soft-mud equipment. Table A-5 presents the trend in the relative importance of stiff-mud and soft-mud equipment. The value of equipment sales used in constructing table A-5 is based upon a selected series of

Table A-6.- VALUE OF SALES OF NEW MACHINERY AND REPAIRS SOLD TO THE BRICK AND TILE INDUSTRY BY THREE COMPANIES, 1922-36[a]

(Thousands of dollars)

Year	Total	New machinery	Repair parts	Percent that new machinery is of total
1922	767	253	514	33.0
1923	959	404	555	42.1
1924	859	426	433	49.6
1925	941	485	456	51.5
1926	985	543	442	55.1
1927	807	426	381	52.8
1928	766	394	372	51.4
1929	846	458	388	54.1
1930	460	213	247	46.3
1931	346	195	151	56.4
1932	102	49	53	48.0
1933	136	85	51	62.5
1934	227	146	81	64.3
1935	292	182	110	62.3
1936	475	286	189	60.2

[a]Repairs include sales of repair parts and charges for rebuilding. Data are from NRP machinery-manufacturers survey and cover sales to the brick and tile industry by three companies manufacturing brick equipment.

machines, equal to about one-fourth of the eight-company total shown in table A-1.

New Machinery and Repairs[8].- A comparison of the sales of new machinery and repairs is given in table A-6. Data are based upon sales of three companies, which represent from 43 percent in 1922 to 76 percent in 1936 of the eight-company sales series (table A-2).[9]

Excavating-Equipment Companies

In addition to the eight companies producing clay-preparing and machine-house equipment, three companies were covered which produced excavating equipment. Each of the companies manufactured power shovels, and one manufactured both power shovels and locomotive cranes. The data obtained are for sales to the brick and tile industry; they refer only to complete new units and, probably, some rebuilt units.

The brick and tile industry consumed only a small fraction of the power shovels and locomotive cranes produced by the three companies. Total sales of these products by the three companies, however, comprise a large portion of the value of total output of the two types of equipment (table A-7).

Repairs and resales make up a considerable portion of the sales of two of these companies; for the third, available data cover only new units.[10] The *Census of Manufactures* normally includes in its detailed production tables only new units and parts, listing receipts for repair work separately. It is therefore likely that the percentages shown in table A-7 are inflated.

The total-sales series was partly estimated. For one company the 1936 data were obtained for only 9 months; figures for the last 3 months were estimated on the basis of the monthly average for the first 9 months. For another company the figures for 1920 and 1936 were estimated on the basis of the ratios in 1921 and 1935 respectively of the sales of this company to the sales of the other two.

In the instance of sales by these companies to the brick and tile industry, however, only one estimate was needed. Such

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[8]Repairs include sales of repair parts and charges for rebuilding.

[9]The percentages fluctuated between 43 and 62, without evincing any trend, during the period 1920-32. In 1933 the percentage rose from 53 to 60, rose again to 70 in 1934, and then to 76 in 1936.

[10]See table A-7, ftn. b.

sales were available, for one company, for only the first 10 months of 1936; data for the last 2 months were estimated on the basis of the average for the first 10.

Table A-7.- VALUE OF TOTAL PRODUCTION AND OF SALES BY THREE COMPANIES OF POWER SHOVELS AND LOCOMOTIVE CRANES, 1919-36

Year	Value of total production[a] (thousands of dollars)	Value of sales by three companies			
		Total[b]		To brick and tile industry[c]	
		Thousands of dollars	Percent of value of total production	Thousands of dollars	Index (1925=100)
1919	15,368[d]	n.a.	-	n.a.	-
1920	n.a.	14,478[e]	-	650	122.2
1921	15,867[d]	5,422	34.2	146	27.4
1922	n.a.	9,074	-	409	76.9
1923	29,226[d]	14,112	48.3	577	108.5
1924	n.a.	11,648	-	568	106.8
1925	32,835[f]	12,547	38.2	532	100.0
1926	n.a.	13,005	-	413	77.6
1927	38,494[f]	12,742	33.1	329	61.8
1928	n.a.	14,878	-	232	43.6
1929	49,301	16,952	34.4	308	57.9
1930	n.a.	9,941	-	83	15.6
1931	20,442	8,183	40.0	82	15.4
1932	n.a.	3,507	-	0	0
1933	5,095	3,108	61.0	19	3.6
1934	n.a.	4,568	-	13	2.4
1935	13,295	6,282	47.3	32	6.0
1936	n.a.	8,218[e]	-	47[d]	8.8

[a] Based on *Census of Manufactures: 1925* (U. S. Dept. Com., Bur. Census), p. 1031; *1929*, II, 1099; and *1935*, p. 1076.

[b] Data are from NRP machinery-manufacturers survey and cover two companies manufacturing power shovels and one company manufacturing both power shovels and locomotive cranes. Data for the latter company are for new units only (no repairs or rebuilt equipment). Data for the former companies include repairs and resales. In the case of one, about 70 percent of the sales represented sales of new units, about 20 percent represented resales, and about 10 percent represented parts. In the case of the other, about one-third represented repairs.

[c] Includes complete units only. Some rebuilt units may be included. The company manufacturing both power shovels and locomotive cranes sold only the latter to the brick and tile industry.

[d] Data for locomotive cranes were not reported for 1919, 1921, and 1923. Values were estimated by multiplying the value of power shovels in these years by the 1925 ratio of the value of locomotive cranes (see ftn. f) to the value of power shovels.

[e] Partly estimated.

[f] Crawler and locomotive cranes were reported in combination in 1925 and 1927. The value of locomotive cranes only was estimated on the basis of the 1929 proportions.

n.a. Data not available.

NRP-NBER 1936 BRICK-PLANT SURVEY

Data were obtained in a field survey conducted by the National Research Project in cooperation with the National Bureau of Economic Research. The results of this survey are summarized in a report by Miriam E. West, entitled *Productivity and Employment in Selected Industries: Brick and Tile* (WPA National Research Project in cooperation with National Bureau of Economic Research, Report No. N-2, Feb. 1939).

One hundred and eight plants were surveyed, their major product being either common brick, face brick, paving brick, hollow building tile, or drain tile. Average annual production per plant for plants for which the information is available was 35 million common-brick equivalents in 1925, 24 million in 1927, 19 million in 1929, and 7 million in 1935.[11]

BRICK AND CLAY RECORD 1927 BRICK-PLANT SURVEY

This study, published in the *Brick and Clay Record* (Vol. 70, No. 13 [June 21, 1927], 1002-25) as an article entitled "Clay Pit and Mine Methods", is based upon 120 plants reporting on loading methods, 102 using power shovels, 82 reporting on shovel size, and 73 reporting on type of power utilized by shovels. The plants covered in the study made common brick and building tile; their size, as represented by annual production per plant, was 22 million brick (average for 36 plants which reported production).[12]

BLS 1922 BRICK-PLANT SURVEY

This survey covered 71 plants manufacturing common building brick. Of these plants, 45 used the stiff-mud process and 26 the soft-mud process. The average annual production per plant was 38 million brick.[12] The results of the survey are presented by William F. Kirk in *Productivity Costs in Common-Brick Industry* (U. S. Dept. Labor, Bur. Labor Statistics Bull. No. 356, 1924).

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[11] Plants studied in this survey tend to be larger than the plant of average size when the entire industry is considered. Average annual production in the industry (based on *Census of Manufactures*) was 10 million common-brick equivalents per establishment in 1925-29 and 5 million in 1935, according to Miss West's report (p. 98). See chap. II, ftn. 1.

[12] For average production of all plants see ftn. 11.

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This bibliography comprises largely material from technical periodicals which refer to the brick and tile industry. Most of the citations are presented in a topical division, according to the various phases of technique discussed in the report. In the general and historical section are also included some books and monographs dealing with less particularized aspects of the field.

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