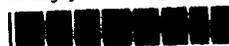


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**BUILDING RESEARCH**

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**ECONOMIC AND  
MANUFACTURING ASPECTS OF  
THE BUILDING BRICK INDUSTRIES**

BY

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AND

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1933

## BRICK MAKING INQUIRY COMMITTEE

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## PREFACE

ONE of the major functions of the Building Research Station of the Department of Scientific and Industrial Research is to provide a scientific service to the Building Industry. Part of its programme of work is concerned with research on materials, including heavy clay products. From time to time certain special problems in relation to these products have been referred to the Station, and specific investigations have been undertaken, for example, into the durability of terra cotta, the weathering of clay wares, efflorescence, the strength of brickwork, etc. But it has been realised that to deal effectively with such important and widely-used building materials as heavy clay products, it is necessary, as and when occasion permits, to carry out a comprehensive scheme of work. Such a scheme must cover matters which appeal directly to the industry, and on which scientific research in co-operation with the industry is likely to be fruitful. A scheme of these dimensions cannot be embarked upon lightly.

Impressed with these considerations, the Department decided that a survey should be made of the brick-making industries. This survey, it was contemplated, should comprise the study of all the available literature and statistics, and a first-hand inspection of typical manufactories, both at home and abroad. Attention should also be paid to research and educational institutions. In this way it was hoped to secure the necessary background to enable the formulation of a rational programme of research work into bricks and brickmaking.

A small Committee, the membership of which is given on p. ii, was set up to advise on the conduct of the survey. The detailed investigation itself was entrusted to Mr. A. Zaiman, B.A., F.S.S. and Mr. W. A. MacIntyre, B.Sc., A.R.C.Sc. The collection of data proceeded during 1930, and on its completion early in 1931, it was planned to publish a report in six parts, viz. : I. Economic

Aspects ; II. Processes of Manufacture ; III. Outstanding Technical Problems ; IV. Research and Technical Education ; V. Properties of Bricks and Brickwork ; VI. Programme of Research. Unfortunately, the preparation of the Report was held up by the untimely death, in May, 1931, of Mr. MacIntyre. It was then decided to issue parts I and II, which were nearly ready, as a separate publication. The actual issue of this publication has been further delayed by the decision to await the Final Report of the Census of Production of 1924 and the Preliminary Report for 1930 (both published in 1932). The statistics quoted in this Report refer mainly to 1930. In view of the catastrophic industrial conditions of 1931 and 1932, it has not been thought worth while to bring the figures up to date, as the features of industry in these years can hardly be regarded as representative.

Acknowledgments are due to the many firms who granted facilities for visits to their works, to the representatives of trade associations who freely gave information, to the members of Government Departments and Consular Officers who rendered assistance, and to Mr. A. E. Brown, B.Sc., who was kind enough to check the proofs and make valuable suggestions.

WILLIAM CECIL DAMPIER,  
*Chairman, Brick-Making Inquiry Committee.*

BUILDING RESEARCH STATION,  
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# ECONOMIC AND MANUFACTURING ASPECTS OF THE BUILDING BRICK INDUSTRIES

## Part 1—Economic Aspects

### 1. BRICKS—THEIR HISTORY AND PLACE IN BUILDING

ACCORDING to some etymologists the word "brick" is derived from the Teutonic *bricke*, a dish or plate; more authoritatively, however, its origin is ascribed to the Teutonic *brikan*, to break, whence the French *brique*, whose early meaning was a broken piece (of bread). Although the term is usually applied to material of burnt clay, its use to this meaning is not restricted. Thus, there is the concrete brick, the sand-lime brick, and so on. But in the present Report, whenever the term "brick" is used without qualification it is the clay material that is implied.

The origin of brick is lost in antiquity. Beyond doubt, however, the first brick was the adobe of sun-baked clay. The earliest burnt bricks found are those excavated on the sites of the ancient cities of Babylonia—the towers, great walls and palaces of the City of Babylon itself are still marked by huge mounds of burnt and unburnt brick. Inscribed bricks have been unearthed dating back 6,000 years to the reign of Sargon of Akkad (c. 3800 B.C.). Apparently the Babylonians and Assyrians attained a high degree of proficiency in brickmaking, particularly for decorative use with coatings of enamel or glaze. The bricks made by the Israelites in bondage in Egypt were sun-baked mixtures of Nile clay and chopped reeds or straw. Several kinds of bricks were made by the Greeks. It was the Romans, however, who established brick as a major material of construction. They introduced many structural forms. Their use of brickwork was very general, extending from the buildings of everyday life—merchants' houses, shops, taverns, workmen's huts—to impressive monuments, stately temples and sumptuous public edifices. At one time, Rome could be described as a "brick city."

The Roman Empire, with its powerful centralised Government, and far-flung network of communications throughout the Imperial provinces, exercised a tremendous influence in spreading the use of brickwork and masonry of a high standard. The Romans

carried their knowledge and methods throughout western Europe, and there is abundant evidence that they made bricks extensively in Germany and Britain.

So long as the Romans occupied Britain, the art of brickmaking flourished. But, on their withdrawal, brickwork and masonry construction languished along with other arts, crafts and industries. The Saxons were a pastoral people and erected very few buildings of a permanent character. Buildings designed for defence purposes were wanted quickly. There was a tendency to use materials that lay to hand, like timber and thatch, in preference to materials that required preparation and time for manufacture, as bricks then did more than to-day. The Normans introduced from France excellent masonry—chiefly in stone, but sometimes in brick as at Colchester. Here, as elsewhere during this period, much use was made by the Norman builders of brick remaining from the time of the Roman occupation. Building in stone or timber was growing scarcer, but stone continued to be used for the magnificent churches and cathedrals built during the Middle Ages.

The revival of brickmaking in England came in the 13th century. Little Wenham Hall, built in 1260, is considered the earliest remaining example of this revival. The bricks were there mixed with courses of stone and flint in walling. St. Nicholas Chapel, Coggeshall, built in 1290, represents the earliest attempt at brick architecture proper: jambs, mullions and lancet arches of the windows are all of brick. Considerable development in the use of brick came in the 15th century, but only for important edifices. Its popularity increased owing to the example set by refugees from the Low Countries and fashions introduced by the nobility who had lived in France. To some extent, however, its possibilities for domestic purposes were grasped and a style developed which is the most typical of English domestic styles. Brick was found to be a suitable filling for the half-timber framing of cottages and smaller houses. Tudor times also saw the introduction of characteristic diaper patterns and corbeling. During the reign of Henry VIII, brickmaking was brought to high perfection, as evidenced by the older portions of St. James' Palace and Hampton Court. Although bricks were used more and more in the 16th century, the smaller buildings, houses and shops, normally consisted of a timber framework filled in with lath and plaster. Geographically, however, the use of brick became more widespread than during the earlier Tudor era, particularly in the South Midland Counties. The Great Fire of London in 1666 gave a tremendous impetus to brickwork; London was largely rebuilt of brick. From then on, although with some rise and decline in architectural expression, brick became the staple building material throughout the country, except for some special edifices or in those districts where good brick earth was not readily procurable and building stone was plentiful, as in the broad belt of oolite strata which runs across the

country from Lincolnshire through Rutland, Northamptonshire, Oxfordshire and Gloucestershire to Somerset and Dorset.

The Dutch and Germans were the great brickmakers of Europe during the Middle Ages, although under the influence of Byzantine architecture the use of brick for churches, municipal buildings and monumental work was extensive in North and East Italy. There was a regression during the period of the Renaissance, in spite of the development of the flat-rubbed brick arch, and the real organic expression of brick in architecture either disappeared or deteriorated into a mere imitation of the forms characteristic of stone. A further lowering of classical taste and a break-up of traditions occurred in the Baroque and 18th century periods. There was further development with terra cotta and in the technique of stucco.

American brickmaking began very soon after the establishment of English settlements in Virginia and Massachusetts, somewhere between 1620 and 1639, although some of the bricks used were imported from England. Several brick houses were built by the Spanish in St. Augustine, Florida, with material imported from Spain. The bricks used in buildings erected on Manhattan Island in the year 1633 by a governor of the Dutch East India Company came from Holland. Imports from Holland and England continued for many years. While the manufacture spread slowly through the New England states, the home-made article remained for a long time inferior to that imported from Europe.

The bricks of old were by no means the more or less standardised, regular-shaped units of to-day. Many different sizes were used by the Romans: for the Forum at Pompeii, the usual brick was over 10 in. long,  $4\frac{1}{2}$  in. wide, and no more than 1 in. thick, while the arch brick was 15 in. long; and in Rome almost every size is found from 6 in. long and  $2\frac{1}{2}$  in. wide and less than 1 in. thick to units more than 60 in. long. In England there seems to have been a gradual change in thickness from 2 in. in the 15th century to  $2\frac{1}{4}$  in. in Tudor times, and to  $2\frac{1}{2}$  in. in the 17th century. Some attempts have even been made to date buildings by the dimensions of the bricks used. Taxation per unit caused a tendency to make bricks larger until limits were laid down by law. As will be described later (see pp. 11-13) the dimensions of modern bricks vary within each country, and more so from one country to another.

Subsequently, then, to the Fire of London, brick has been the main building material used in England for all types of structures, large and small, communal or domestic. Its supremacy has hardly been challenged save for special buildings in London and other large cities, and in definitely stone counties. After the Great War, owing to reasons associated with shortage of materials and labour in a period of intensive reconstruction, more attention came to be paid than hitherto to alternative materials for small houses.

The majority of the new systems developed involved the use of concrete, precast or poured, sometimes with special aggregates. Steel was also adopted, not only for external plates on timber frames, but also in other cases in the framework and roof members. Cast iron was tried for external plates. Mention should also be made of the use of timber, half-timber and concrete, sand-lime brick and the revival of traditional materials like rammed earth, hard chalk and chalk block. But none of the alternative methods proved cheaper than the normal ones, which involved the use of brick. According to Fremantle,<sup>u\*</sup> "In ultimate cost, like for like, having regard to their probable life and cost of maintenance, it is doubtful if any will compare with a well-built brick house." It may be remarked that even in the west districts of London, despite the fact that buildings on Crown lands are restricted to stone facings, brickwork is tending to preponderate for commercial buildings. Considerations of space sometimes favour the steel frame building, but it has been estimated by architects that for, say, a large block of flats, the steel-frame structure costs nearly one-fifteenth as much again as plain brick.

In Continental countries generally, the position is more or less the same as in Great Britain. Materials other than brick are exceptional in Holland, North Germany, Sweden and Denmark, and in many districts of France, Belgium and Switzerland. In Germany, concrete, timber and stone are strong competitors to brick in certain districts, and post-war alternative methods have, perhaps, gained a stronger hold; nevertheless, in contrast with the developing use of steel and glass for larger structures, there has been a revival of the traditional "klinker" brick, and in many new buildings this type of brick lends itself admirably to vivid architectural expression. In Sweden, also, brick architecture is finding new forms.

Conditions in the United States of America are different. Thus it comes as a surprise to Europeans to read the somewhat proud claim of a brick trade association that there is "a growing realisation that brick houses are not beyond the means of almost anyone who can own a house." Although New York constitutes the largest brick market in the world, it is estimated that only one in six houses at present built in the United States is of brick. The competition from concrete products, lumber, hollow tiles and synthetic bricks is acute. Concrete is most active as a competitor in larger construction work, especially industrial buildings. In certain areas the wooden-frame house remains predominant. On the other hand, where fire-zones have been established, brick has soon ousted most other materials. A new development, still in its infancy, is the steel-frame house, and it is not unlikely that steel or other metal will ultimately come to be widely adopted, at any rate for

\* These numbers relate to the List of References on page 61.

the special load-bearing parts of the structure. Masonry should, however, retain its ascendancy as facing material. As in Germany, steel and glass are being adopted for larger constructions, although at the same time there is the reverse innovation of all-masonry buildings without any windows. The competition explains why much of the activities of American brick-trade associations are concerned with extending the market for brick. It may be remarked incidentally that the number of bricks per occupant is much greater in domestic building than in office buildings, so that residential building offers the largest potential market. Thus, although 10 million common brick and one million face brick have, for example, been used in the 85-storey Empire State Building, which has become the highest sky-scraper in New York and will house 25 thousand people, the number of bricks corresponds only to, say, 3 thousand domestic bungalows. It is estimated that the market offers seven bricks to one in the ratio of structural brick possibilities as opposed to decorative, even though more and more bricks are being used for the facings of sky-scrapers.

Bricks are also being used as "forms" for concrete construction work, and for silos and other large storage structures. Multi-coloured briquettes are popular for open fireplaces, sundials, etc.

Some interesting innovations in the use of building brick may be mentioned. In France, one or two "architect brickmakers" are exploiting the warm colourings of brick in landscape gardening. Use is also being made in France, and to a small extent in England, of what may be termed "tile bricks" to cover up or match other brickwork. In America the brick-veneered wooden frame building is gaining popularity, and special brick "shingles" are being produced. Brickwork reinforced with steel along the mortar joints, or through holes in specially made bricks, is being seriously studied in America and Japan, and may provide great possibilities for the extended use of brick in all structural members subject to bending loads. (See page 27). An attempt to introduce it in England was made a few years ago. Enamelled bricks (corresponding to English glazed bricks) for external work, are, perhaps, more popular in the United States than in the United Kingdom, particularly owing to their suitability for the facing of sky-scrapers. Salt glazed bricks of light colour are also more prevalent in America than in England. Attempts have been made in the United States to produce light weight material especially for hollow blocks. The clay is either chemically "bubbled" before firing, or bloated by intense firing. "Haydite," a light weight aggregate for concrete is also a burnt clay product.

A description of the use of bricks in building would not be complete without some reference to the use of bricks which can be carved *in situ*. A good deal of carved rubber brickwork was executed in London when the Queen Anne revival was in vogue. Many examples of such carved bricks can be seen on the Belgian littoral.

## 2.—TYPES OF BRICK IN USE

### *Classifications and Descriptions*

Building bricks have been described or classified in various ways—according to the use to which they are put; their mode of manufacture; the position they took in the kiln; their physical properties; their texture, form, shape or colour; or other dominant characteristics.

For many purposes, a classification by usage is most helpful. Three main types would then be specified, *common*, *facing* (or front) and *engineering*. Common bricks are those serviceable for ordinary construction, and may either be within the structure, or more rarely, fronting a somewhat undecorative exterior. Face bricks, whether or not possessing a special surface finish or colour or texture, are devoted to exterior work. Engineering bricks are strong, hard-burnt units, corresponding to an extent with paving bricks, and suitable for brickwork carrying heavy loads, e.g., in railway bridges, conduits and the like.

Bricks are still made by hand in England, and in Continental countries, though not in the United States (except for most exceptional purposes, as for the reconstruction in Virginia of George Washington's birthplace). Machine made bricks can be divided into *soft mud*, *stiff mud*, (or plastic, wire-cut), *stiff plastic* (pressed, or repressed) and *semi-dry pressed*. (See pages 71–85, of Part II). The appellation *sanded* may be attached to those varieties for which the mould or clay surface is specially coated with sand.

*Arch* or *clinker* bricks denote those bricks which are taken from the top and sides of the kiln or clamp arches: they are hard, brittle and weak. Bricks taken from the interior of the kiln, and constituting the best of the burn, are described as *body*, *cherry* or *hard*. Pale or soft bricks taken from the exterior setting of the kiln would be termed *salmon*, *pale* or *soft*. These terms are more prevalent in the United States of America than in Western Europe. The content of a kiln is also classified in the United States into *firsts*, *specials*, *commons*, (or *commercials*) *culls* and *bats*.

It has been thought safer in standard specifications to classify bricks according to their physical properties. Thus, the American Society of Testing Materials in recommending a classification for this purpose divided bricks into vitrified, hard, medium and soft, depending on their absorption properties, compressive strength and modulus of rupture.\* Some note should perhaps be taken in future of chemical properties, e.g., content of soluble salts.

\* The modulus of rupture relates to stress on a beam, but is often taken as a guide to the strength of the material of which the beam is composed. The modulus of rupture of a beam is the calculated (hypothetical) breaking stress which would have been present in the extreme fibres, if the material remained elastic up to this stress.

Many confusing names are given to different qualities of bricks in Great Britain. "The term *stock* is now very loosely used :— (1) Commonly applied to any brick most generally produced in a locality. (2) To all yellow bricks, especially if "soil" has been mixed with the clay. (3) To red bricks, soiled and burnt in clamps. (4) In its original sense, to bricks moulded on a stock."<sup>(2)</sup> (i.e. a piece of board nailed on to the moulding table, and round which the mould fits). In the North of England a stock is also kiln wastage. *Hard stocks* are usually somewhat over-burnt, and most serviceable for footings. *Placebricks* in the past designated either the most under-burnt ordinary sort, or those made in a particular way (i.e. moulded in a level place). *Shippers* are sound bricks, but of imperfect shape, deriving their name from the fact that they often served as ships' ballast. *Grizzles* denote under-burnt bricks adequate for inferior work. *Shuffs* are cracked and defective, but the term is particularly applied to very weak, yellow stock bricks. *Rubbers, cutters or malms* are soft bricks suitable for modifying to special shapes and positions. *Moulded bricks* are special shapes for cornices and the like. *Burrs*, which are lumps which have vitrified or run together in the burning, are sought after for garden work and rough walling. *Blue bricks* are chiefly made in South Staffordshire and North Wales; and are of the best quality of engineering bricks. *Floating bricks* or *insulating bricks* are light and fairly strong, and are of importance for heat insulating purposes. *Rustics* are bricks with a rough textured surface; in the South of England (and more recently to an increasing extent in the North too) they are often multi-coloured. *Compass bricks* denote those where one edge is shorter than another, as, for example, in bricks for lining circular shafts. *Feather edge* (or *voussoir*) bricks, are similar, for use in arches.

In America the term *colonial* is applied to bricks that correspond to English multi-coloured rustics. *Tapestry, hightex* and *rug*, are also used to denote special surface bricks. Bricks made in imitation of English hand-made are known as *antique English*. Other terms used in America are *fancy* or *ornamental*. *Ashlar* brick denotes a structural brick, one edge of which is chiselled to resemble rock-faced stone. *Glazed bricks* are those fired after being dipped in, or sprayed with, special surface slips. The term *enamelled* seems reserved in the United States for those bricks which fall into a specific category for transport purposes; they are usually more carefully edged than those which are there termed glazed, and are dipped after being biscuit fired. *Salt glazed* bricks varying in colour from light to dark brown are produced by throwing common salt mostly into the fire boxes and occasionally through the crown of the kiln, towards the end of the burn.

Apart from logical classification or generic description, a few main types of brick are predominant in England and are usually referred to by special names. Of the common bricks, a large proportion

(possibly one half) are *Flettons*, made chiefly around Peterborough and Bedford by the semi-dry press process. The "*blaes*" of Scotland are made of clay, mixed with ashes and other coal residues. Of the facing bricks, *sand-faced red bricks*, *London stocks*, *Luton greys*, *Reading silver greys*, *Accringtons* and *Leicester* and *Yorkshire reds* are specially noteworthy. Hand-moulded, sand-faced red facing bricks have a richness of texture and gradations of colour that cannot be equalled by mechanical means; they remain the characteristic facing bricks of Great Britain. London stocks are yellowish or brown bricks made from clay mixed usually with washed chalk and screenings from domestic refuse; the chief centres of manufacture are Sittingbourne in Kent, Shoeburyness in Essex and Slough in Buckinghamshire; until recently they were always hand-moulded and clamp-burned, but a few manufacturers are now making them by the soft-mud process and burning them in kilns. Luton greys are traditional hand-made bricks produced in the Luton area, and are considered by many to be of rare beauty. Reading silver greys are somewhat similar. Accringtons, Leicester and Yorkshire reds are smooth, red bricks, either wire-cut or semi dry-pressed, which are very popular in the North of England and the Midlands. Although the term "engineering brick" usually calls to mind the pressed "Blue Staffords" (which are made in other districts besides Staffordshire) certain red or brown wire-cut bricks are of great strength and not less suitable for railway bridges, paving work, conduits, etc.

Each country has, in fact, its own characteristic bricks, the "klinker" of Germany, the "waal-stein" of Holland, the wire-cut and perforated bricks of the rest of the Continent. It might be mentioned that the "frog," i.e., the recessed portion in the bedding surface of a solid brick, familiar in English hand-made and pressed brick, is peculiar to England.

*Perforated bricks* are almost universal in France, Belgium and Switzerland. They are also popular in Germany and parts of the United States of America. The number of holes varies from 2 to 105 for a normal-sized brick, and 144 for a large brick. Many advantages are claimed for them; clay is saved; laminations may be avoided; drying facilitated; burning made easier, and above all, transport charges are reduced by upwards of 25 per cent. It is rather surprising that hollow, or perforated bricks, have not made better progress in England. Advance in this direction may be hindered either by prejudice or by the belief that their use involves greater quantities of mortar. (It would seem to be easy, however, so to dimension the holes of perforated bricks that no additional mortar is needed.) While it is true that an attempt has been made by one firm in England to exploit the cellular brick, this is an entirely different proposition, and bears some resemblance to the "one-hand" hollow block of Germany.

The *semi-dry pressed brick* (see pp. 84-85) is much more dominant in England than in any other country. As a rough estimate, the production in England of face and common semi-dry pressed building brick accounts for a third of the whole. The process is, however, used on the Continent for special paving bricks. In the United States of America and Canada, apart from enamelled, refractory and fire bricks, there has been a steady diminution in favour of wire-cuts in the production of building bricks by the semi-dry pressed process, since the peak was reached about 20 years ago. In 1922, it was estimated that 50 per cent. of the common bricks manufactured in the United States were produced by the stiff-mud process, 40 per cent. by the soft-mud, and 10 per cent. by the dry-pressed process. It is interesting to consider the reasons. Apparently, there is cause to doubt whether the drying process can be omitted except with particular types of shale and in peculiar circumstances, so that the system offers no economy on that score. In fact, if clay is used it may be necessary to dry it before grinding. Unless the clay is well ground, the burnt brick may prove to be too porous to be admitted in some districts for exterior work. If, therefore, all necessary care is exercised in the preparation, etc., the resultant product is too good and too expensive for a mass-production common brick: the system then yields a high-quality article suitable for best facing, engineering or paving purposes. An important point also is that a stiff plastic or wire-cutting unit can be worked at a much faster rate. Thus, a high rate of working for a single semi-dry pressed unit is 2,000 bricks an hour. Although the maximum South European rate of output from wire-cutting machines does not exceed 5,000 an hour, in the United States the machines are often guaranteed to do 12,000 an hour, and sometimes (with two columns) reach 42,000 an hour. Thus, to achieve comparable output, a whole battery of semi-dry pressed units is needed to compare with a single wire-cutting unit. Apart from initial cost, therefore, much more labour is wanted for the semi-dry press system, particularly when, as is done frequently in Continental works, automatic equipment is provided for conveying the wire-cut bricks to the drying sheds and kilns. The rate of output per man-hour under the different processes in various countries is dealt with more fully later. (See pp. 43-44.)

#### *Texture and Colour*

In recent years there has been a marked development in England, particularly in the South, in favour of multi-coloured rough-textured bricks. Smooth red bricks retain their popularity only in the North. The colours range from white, yellow, tan, brown, red, to purple, blue, black, grey, with variegated and mottled tints. Descriptions such as "autumtints," "cherry red," "brindled," "dark strawberry," "orange red plum," "silver grey," "golden grey," "pot pourri," "brown (or buff) mottled brindle," found

in catalogues, give an indication of the wealth of vivid and sometimes flamboyant colourings. Differences in width, form and colouring of mortar joints are also being exploited to extend the range of colour effects. Apparently, architects have been seized with a desire to obtain artistic expression in this way rather than by reverting to the intricate patternings in vogue in Mediæval times.

Added to this, manufacturers have met the demand for variation in surface finishes, so as to intensify light and shade. The rich texture of the hand-made brick, usually showing the creases or folds where the soft plastic mass has been compressed in the mould, has set the example to imitations by machine. But the machine has failed as yet to reproduce this antique texture. Nothing daunted, manufacturers have gone further, and have exaggerated natural rough texture in various ways, *e.g.*, by slicing off the original surface of the brick, by stippling with wire brushes, by nail or wire scratches, slight and deep, regular and irregular. Also, overburnt and misshapen bricks, once the refuse of the brickyard, have been eagerly sought by some architects, and utilised, it must be confessed not without some success, for special rustic effects.

Glazed bricks now provide a range of beautiful pure colourings as well as stippled effects.

By contrast, the bricks of the Continental countries, though differing amongst themselves, are of regular shape, smooth surface and uniform colouring. Even in Holland, despite the popular conception of "Dutch antique" or "waal-stein," the range of tones in brickwork is not very extensive.

But however far English manufacturers have proceeded in directions of multi-colourings and varying textures, they are greatly outdistanced by the American. Urged by the recent enthusiasm of architects for colour, they have achieved an amazing range of gradation in light shades—white, cream, stone, limestone grey to match natural stone, stone with "iron spots," fawn, iron buff, golden buff—as well as in vivid tints of tangerine, toasted brown, pale greens, reds, blues and purples. They have reproduced, for example, the tints of the sycamore and its foliage—red, grey, golden brown, green and fawn—all the blendings of the Pennsylvania forests at their loveliest in the autumn of the year. To obtain their colourings they have, on the one hand, used inferior fireclays or admixtures to the brick clay or shale, or have added commercially-prepared oxides, and on the other, have developed a high technique in flashing with zinc during the burning of the ware. A process has also been tried for electro-plating bricks; or for spraying them with metals. Particular mention must be made of the adoption in American sky-scrapers of flowing colour schemes, wherein hue is superimposed on hue, so that walls built of a dark shade of brick at their base tone gradually to a light shade in the upper courses of the buildings. Or again, contrasting shades of light and dark may be used in columns running to the height of the

building, thus emphasizing the vertical construction: a striking example is the American Radiator Building, with its tower of manganese and gold.

Great attention is also paid in the United States of America to the dimensions, character and colour of mortar joints—running from thin-buttered joints up to widths of as much as an inch, raked, stripped, struck or V-tooled, white, yellow, brown and black—so as to bring out all the shades and tones of the bricks and obtain a proper colour relation for the whole surface.

In textures likewise, the American manufacturers have gone to ultimate limits. Although they have been unable to simulate exactly the surface of the English hand-made brick, they have evolved corrugations by mechanically scoring the faces of the brick by nail, comb or wire, by tearing pieces with rotating knives, by stripping the skin and rolling the cracked pieces on again. The descriptions "tapestry," "rug," "raglan," "astrakhan," "bark" are no exaggerations. Not only are bloated and misshapen common bricks utilised for rugged effects, but they are occasionally set askew (or "skintled") with alternating recesses and projections, with squeezed-out mortar joints, producing intense contrasts of light and shade.

Glazed products have also attained a new excellence, and the colourings compare favourably with those in England. A special feature is the application of fritted glaze in luminous matt whites, mottles and blacks, particularly to larger blocks.

### *Modern Sizes*

Although legislation and taxation in England (in Elizabeth's reign and subsequently) may have determined the dimensions of bricks, there is every reason to believe that the sizes assumed by bricks have been largely controlled by custom and convenience for man-handling in masonry construction. There are considerable differences, nevertheless, from country to country, which are not ascribable to variations in raw material and methods of preparation and can only be assigned to national habits.

It would appear that countries where stone has never been available usually have smaller-sized bricks.

The differences in sizes are illustrated in Table I, compiled from the *Tonindustrie Kalender*,<sup>(3)</sup> 1930, and other sources.

In England, standard sizes for common bricks have been laid down by the Royal Institute of British Architects<sup>(4)</sup> in consultation with various bodies concerned. There are two standards, one for the South of England, where the maximum dimensions are:— $2\frac{1}{8}$  in.  $\times$   $4\frac{3}{8}$  in.  $\times$  9 in.; minimum:— $2\frac{5}{8}$  in.  $\times$   $4\frac{5}{16}$  in.  $\times$   $8\frac{7}{8}$  in., as settled in 1904, and another (where the maximum dimensions are given as:— $2\frac{1}{8}$  in.  $\times$   $4\frac{3}{8}$  in.  $\times$  9 in.; minimum:— $2\frac{7}{8}$  in.  $\times$   $4\frac{5}{16}$  in.  $\times$   $8\frac{7}{8}$  in.) agreed in 1919 for the Counties of Northumberland, Cumberland, Durham, Westmoreland, Yorkshire and Lancashire.

This variation from north to south is, perhaps, again due to the presence or absence of stone construction, or to local habits. Although occasionally common bricks are made smaller than the standard sizes, to cut down manufacturing costs, or sometimes bigger than standard so as to secure orders, the standards seem to have secured general, though not rigid, adherence. The question of a thinner brick was raised at a conference called by the Royal Institute of British Architects in 1928, but the proposal was not pursued. Facing bricks, 2 in. and  $2\frac{3}{8}$  in. thick, are, however, much used by some architects.

TABLE I.—*Sizes of Modern Bricks in Various Countries*

Country	Length of Sides in inches	Volume in cubic inches
Austria .. .. .	$11\frac{3}{8} \times 5\frac{1}{2} \times 2\frac{1}{2}$	156.4
Belgium (Average) .. .. .	$7\frac{1}{2} \times 3\frac{1}{2} \times 2$	52.5
„ (Walloon) .. .. .	$9\frac{3}{8} \times 4\frac{3}{4} \times 2\frac{3}{8}$	105.7
Canada (Standard) .. .. .	$8 \times 3\frac{3}{4} \times 2\frac{1}{4}$	67.5
Denmark .. .. .	$8\frac{3}{4} \times 4\frac{1}{8} \times 2$	71.2
England (Approximate general maximum)	$9 \times 4\frac{1}{2} \times 3$	121.5
France .. .. .	$8\frac{3}{8} \times 4\frac{3}{8} \times 2\frac{3}{8}$	89.6
„ .. .. .	$8\frac{3}{8} \times 4\frac{1}{2} \times 2$	69.1
Germany (National) .. .. .	$9\frac{7}{8} \times 4\frac{3}{4} \times 2\frac{1}{2}$	117.3
„ (Prussian) .. .. .	$11\frac{1}{4} \times 5\frac{1}{4} \times 3\frac{3}{8}$	199.3
„ (Bavaria) .. .. .	$11\frac{3}{8} \times 5\frac{1}{2} \times 2\frac{1}{2}$	156.4
„ (Saxony) .. .. .	$9\frac{7}{8} \times 4\frac{3}{4} \times 2\frac{3}{4}$	129.0
Holland (Waal brick) .. .. .	$8\frac{3}{4} \times 4\frac{1}{4} \times 2\frac{1}{4}$	75.6
„ (Rynsteine) .. .. .	$8\frac{3}{4} \times 4\frac{1}{4} \times 2\frac{1}{4}$	80.1
„ (Yselsteine) .. .. .	$7\frac{1}{8} \times 3\frac{3}{4} \times 1\frac{5}{8}$	56.8
„ .. .. .	$6\frac{1}{4} \times 3\frac{1}{4} \times 1\frac{5}{8}$	43.2
Italy (Average) .. .. .	$9\frac{7}{8} \times 4\frac{3}{4} \times 2$	93.8
„ (Naples) .. .. .	$11\frac{3}{4} \times 5\frac{3}{4} \times 1\frac{1}{4}$	76.0
Japan .. .. .	$8\frac{1}{4} \times 3\frac{7}{8} \times 2\frac{3}{8}$	75.8
Norway .. .. .	$11\frac{3}{4} \times 5\frac{3}{4} \times 2\frac{3}{4}$	185.6
Russia (Large) .. .. .	$11\frac{3}{8} \times 7\frac{1}{8} \times 3\frac{1}{8}$	253.3
„ (Small) .. .. .	$9\frac{3}{8} \times 4\frac{3}{4} \times 2\frac{3}{8}$	111.4
Spain .. .. .	$11 \times 5\frac{1}{2} \times 2$	121.0
Sweden (North) .. .. .	$11\frac{1}{4} \times 5\frac{3}{4} \times 2\frac{3}{4}$	185.6
„ (South) .. .. .	$9\frac{7}{8} \times 4\frac{3}{4} \times 2\frac{1}{2}$	117.3
„ (West) .. .. .	$9\frac{1}{4} \times 4\frac{3}{8} \times 2\frac{3}{8}$	96.1
Switzerland .. .. .	$9\frac{7}{8} \times 4\frac{3}{4} \times 2\frac{3}{8}$	111.4
U.S.A. (Standard) .. .. .	$8 \times 3\frac{3}{4} \times 2\frac{1}{4}$	67.5

In the United States, a survey made in 1922 showed that there were in existence 39 sizes of rough-faced brick, ranging in length from  $7\frac{1}{4}$  in. to  $8\frac{5}{8}$  in., in thickness from  $2\frac{1}{8}$  in. to  $2\frac{3}{4}$  in., and in width,  $3\frac{3}{8}$  in. to  $4\frac{1}{2}$  in., and 36 variations in the sizes of smooth-faced brick. Since then, the sizes have been standardised, 8 in.  $\times$   $3\frac{3}{4}$  in.

× 2¼ in., and specification checks have revealed that a very high proportion of the output now conforms to the simplified schedule laid down. Recently there have been suggestions for altering the schedule and adopting larger sizes to allow for standard-sized masonry openings. Despite the general adherence to standard dimensions, a tendency is noticed in the United States to manufacture larger sizes of bricks as specialities in order to secure more æsthetic effects.

In Canada, where standards have also been laid down (8 in. × 3¾ in. × 2¼ in.), a smaller brick is coming to be preferred, and the standards are not being closely followed.

### Weights

Weights of brick vary according to the type of clay used, the methods of manufacture, the size and the solidity. In England, engineering bricks average 8 to 10 lb., facing bricks, 6 to 8 lb.; Flettons, 5½ lb.; and London stocks, 6 to 7 lb. In the North-Eastern States of America, the bricks, which are usually small, average as little as 4lb. Great reductions in weight are effected when, as frequently on the Continent, the bricks are perforated.

### Prices

The last inquiry into the prices of building materials in England was made in 1920 by a sub-committee appointed by the Standing Committees of the Board of Trade on the Investigation of Prices and Trusts. The report of the Sectional Committee on the Brick Trade<sup>(5)</sup> contains the following comparisons of prices of bricks, pre-war and in 1920.

TABLE II.—*Prices of Bricks, Pre-War and in 1920*  
(Per 1,000 Bricks)

Locality	Average pre-war selling price	Average investigated cost during control (1918)	Average controlled price, (February, 1919)	Average contract price to the Government (June, 1920), at works
	s. d.	s. d.	s. d.	s. d.
Kent and Essex Stocks	35 0	—	—	—
Graded ..	—	—	48 6	—
1st Stocks ..	—	—	—	85 6
2nd Stocks ..	—	—	—	80 6
Single Roughs ..	—	—	—	59 6
3rd Stocks ..	—	—	—	50 0
Fletton .. ..	27 6	27 8½	39 5	51 0
Manchester ..	26 0	39 5	52 11	83 8
West of England ..	29 0	58 2	65 11	82 6

The Committee's review of the history of the trade is illuminating:—"In the years before the war the brick trade was far from being a profitable one.

"Over-production caused the market prices to be out of balance with the cost, and many brick manufacturers were forced to go out of business, while others continued under receiverships after failure. What little prosperity there was in the trade moved in cycles, but almost invariably the losses made counterbalanced the profits made in more prosperous years. Witnesses have stated that their firms experienced very bad times between the years 1900 and 1914, and bricks were sold at almost any price to get them out of the way. This, they stated, was largely accounted for by the operations of the Finance Act (of 1909) which prevented owners of estates from developing. When the Government required bricks for aerodromes, munition factories, etc., hopes were entertained of an improvement in the trade, and it was anticipated that an opportunity would arise for the trade to reimburse some of its losses of previous years, but control was instituted soon afterwards and costings were investigated by Government accountants and selling prices fixed on the basis of these costings.

"During the war the trade suffered severely, and a great number of firms were forced to close down their works. Those who carried on did so with great difficulty, and in most cases at a loss.

"The armistice found the trade in an even more deplorable condition, and the national output had been reduced to one-fifth that of pre-war; firms that had closed down during the war were faced with heavy expenses of restarting caused by dilapidations of buildings, water-logged kilns and depreciation of machinery."

Having in view the condition of the trade in pre-war years, with its fluctuations and uncertainties, the Committee felt "bound to add that pre-war selling prices do not form a fair basis on which the present selling prices should be judged."

Nevertheless, the Government has considered it necessary to keep under review the prices of bricks, along with those of other building materials, primarily because of the large expenditure from public funds on housing schemes. An inter-departmental committee was appointed in 1923 by the Minister of Health and the President of the Board of Trade to survey the prices of building materials, and this committee has continued to issue serial reports.<sup>(6)</sup> The prices quoted in these reports relate to Birmingham, Bristol, Leeds, Leicester, London, Manchester, Newcastle, Swansea, Dundee, Edinburgh and Glasgow. The London figures appertain first to special purchases made by the London County Council for their housing schemes, and are applicable to delivery on site, except those for facing bricks, which are for "in barge alongside private jetty," and secondly, to Willesden "delivered site." The records quoted in technical journals are, as a rule, for delivery at a railway station in London, e.g., King's Cross. In Fig. 1 are plotted the

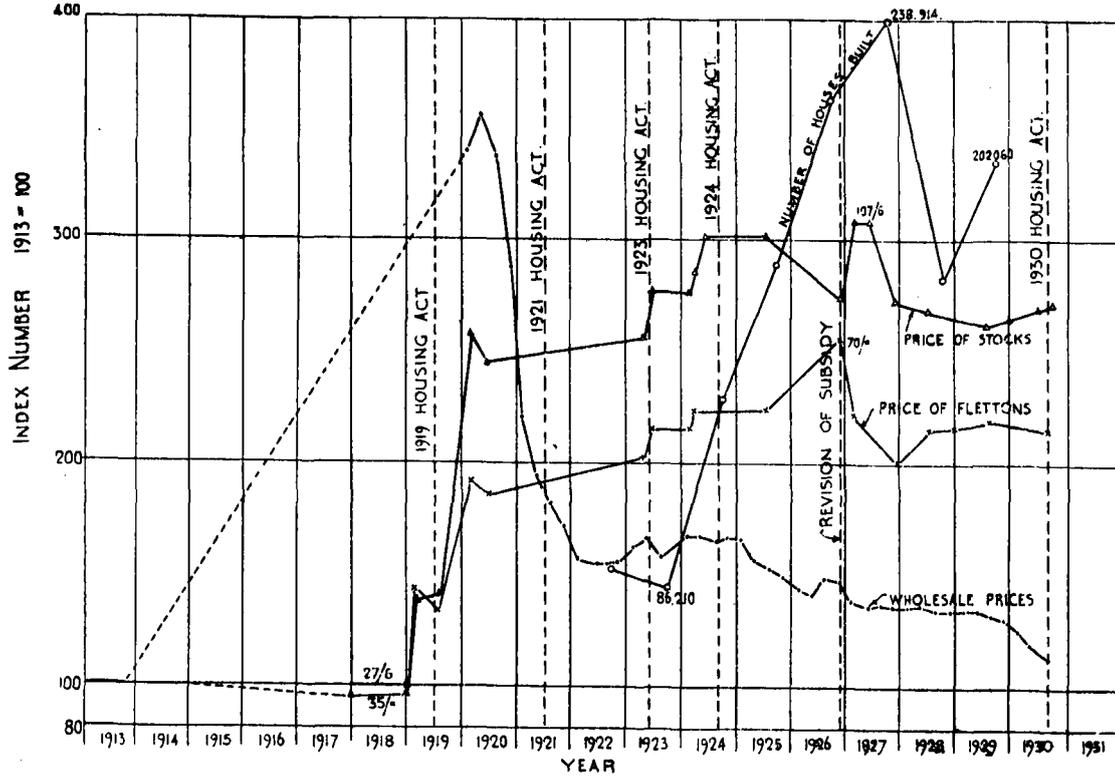


FIG. 1.—Movements of Brick Prices.

Note.—The Graph of the number of Houses built is based on a 1913, 1914 figure of 60,000 equated to the 100.

The peak and lowest prices of Stocks and Flettons are indicated in shillings per 1,000.

The General wholesale prices index is the quarterly average "Total not Food" Wholesale Price Index issued by the Board of Trade.

figures, taken from the committee's reports, of the prices of Flettons and London stocks, delivered Willesden, and show the movement of the prices of these staple bricks over a period of years.

It will be observed from the Figure that the prices for Flettons and London stocks have shown sudden changes. For comparison, the Board of Trade Index for wholesale prices of articles other than food is also plotted in the Figure.

The selling price of bricks fluctuates with the periods of trade depression and boom, but apparently within a smaller range than most other manufactured products. The various factors influencing the price of bricks, notably material, labour, fuel, transport, distribution costs, etc., are discussed later. (See pp. 37-53.)

The prices of the main classes of bricks per thousand at works current at the time they were visited in 1930 were roughly as follows:—commons, 30s. to 70s.; facers and engineering, 60s. to 140s.; London stocks, 80s.; glazed, £21. These prices are fairly comparable with those demanded for similar qualities of bricks in Continental countries and in the United States of America. Belgian ordinary bricks varying according to size, seem to range in price at works from 12s. to 21s. for small bricks to 32s. for larger sizes and for face bricks up to 50s. Prices of bricks imported from one country into another are apparently governed by the ruling prices in the country of destination. In France, the face bricks range in price from 40s. to 60s.; common bricks are about 20s. per thousand in Northern France. Dutch face bricks are about 50s. a thousand; German klinker bricks 35s. to 60s.; Swiss face bricks are approximately 60s. All these prices were quoted at the time the works in question were visited in 1930, so that they often relate to specific quality in a particular area; but there is reason to believe that they are not untypical.

Although quotations in the United States of America in 1930 are quite near English prices, it should be pointed out that the prices in America have fluctuated very widely and that 1930 was a year of intense depression—much more severe in the American brick trade than in that of Great Britain. Common bricks, which on general average of wholesale prices throughout the country were 25s. in 1914, 45s. in 1918, 80s. in 1920<sup>(7)</sup> dropped in 1930 to 40s.; face bricks averaging 48s. in 1914, 72s. in 1918, 82s. in 1919<sup>(7)</sup>, averaged in 1930 round about 60s., with the specials up to 80s.; enamel bricks (corresponding to English glazed) were about £19 a thousand, while the American glazed were about £10 a thousand. The wholesale price index for common brick (monthly average 1923-25 = 100) was 38·0 in 1913, 37·9 in 1914, 115·6 in 1920, 90·5 in 1928, 89·0 in 1929.<sup>(8)</sup>

### *Effect of Housing Schemes*

It is often thought that housing schemes have an effect on prices and productions. Certainly there is much talk of the effect in Berlin

of municipal schemes ; and again, the lack of public building in Belgium is said to be a contributory cause of the depression there in the brick trade ; although certain large schemes for the erection of public buildings are not infrequent in the United States, there is no Government intervention in the matter of housing, and this may account for the more intense depression in the American brick trade as compared with that in Great Britain. It may be relevant, therefore, to summarise here the various stages in housing legislation in Great Britain. Four stages can be discovered in the housing history of the post-war period. " First, the partnership between State and local authority inaugurated by the Housing, Town Planning, etc. Act 1919, with limited liability for local authority (produce of penny rate) and liability unlimited for the State (all the loss in excess of the produce of a penny rate). This partnership subsisted until June, 1921. Secondly, an interregnum between 1921 and 1923 during which State aid was withdrawn except for houses already approved for grant under the Act of 1919. Thirdly, the resumption in 1923, with the passing of the Housing Act of that year, of association between State and local authority, the State this time limiting its liability to a fixed sum per house for twenty years, leaving the liability on the rates unlimited, a reversal of the position under the 1919 Act. This stage is noteworthy also for the stimulus given to private enterprise to participate in the work of providing working-class houses and for the definite allocation of grants on a 50 per cent. basis in respect of the loss on schemes for the clearance of unhealthy areas. The fourth stage was reached with the passing of the Act of 1924, which did not supersede the Act of 1923, but authorised higher grants for forty years for houses complying with specified special conditions as to their letting and rent, and also permitted a biennial revision of the rates of grant for houses erected under either of the Acts mentioned. The first revision by which the rates of grant were reduced took effect on 1st October, 1927."<sup>(9)</sup>

The 1930 Act was chiefly directed to making more provision for dealing with unhealthy areas and for rehousing ; State grants were made available for the purpose to local authorities.

The inter-departmental committee on prices (see p. 14) was set up contemporaneously with the introduction of the 1923 Act. It should be remarked also that shortly after the end of 1923, with the change in Government, prior to the introduction of the 1924 Act, Ministers conferred with representatives of the building industry (employers and operatives), of the manufacturers of materials and of the local authorities on the general housing situation with particular reference to the means of providing an adequate supply of labour and materials for the carrying out of a full national housing programme. A programme of building over fifteen years came to be envisaged. Later, after the passing of the 1924 Act, local committees were set up, specially to develop and co-ordinate the supply of labour.

The four stages in housing history are indicated on Fig. 1.

The number of houses built in England and Wales with and without State assistance in each year ended 31st March, 1920 to 1930, are given below.<sup>(10)</sup>

TABLE III—*Number of Houses Built in England and Wales with and without State Assistance in each year ended 31st March, 1920 to 1930*

Years ended 31st March	Houses built by Local Authorities with State Assistance	Houses built by Private Enterprise		Total
		With State Assistance	Without State Assistance	
1920 .. ..	576	139	(a)	160,335
1921 .. ..	15,565	12,964	(b) 30,000	
1922 .. ..	80,783	20,288		
1923 .. ..	57,535	10,318	(c) 23,800	91,653
1924 .. ..	14,353	4,311	67,546	86,210
1925 .. ..	20,624	47,045	69,220	136,889
1926 .. ..	44,218	62,769	66,439	173,426
1927 .. ..	74,093	79,686	63,850	217,629
1928 .. ..	104,034	74,548	60,332	238,914
1929 .. ..	55,723	49,069	64,740	169,532
1930 .. ..	60,245	50,124	91,691	202,060

(a) The figures in this column exclude houses having a rateable value exceeding £78 (or £105 in the Metropolitan Police District).

(b) This figure is approximate only and includes the period March to September, 1922, exact statistics of unassisted building not being available.

(c) This figure is for the half-year September, 1922 to March, 1923.

### *Production*

The statistics available in respect of production of bricks in Great Britain are very scanty. The most authoritative information is that to be derived from the reports of the Census of Production. Below are given figures extracted from Preliminary Report No. 10 of the 1930 Census.<sup>(11)</sup>

It must be remembered that detailed returns were not required from firms employing 10 or fewer persons in 1930, and the particulars given below, both for 1930 and 1924, relate to firms employing more than 10 persons on the average. The production figure for 1924, including the small firms, was 4,066·1 million, showing that the small firms contributed 168·7 million; the total corresponding figure for 1930 might then be taken as almost 4,580 million.

The output of Flettons calls for special comment. In January, 1922, the monthly production of manufacturers in the Fletton area<sup>(6)</sup> was 22 million; in May, 1923, 33½ million; in June, 1923, 38 million, and in August, 1923, 40 million. The August, 1923, output

was thought to be maximum capacity. In 1930, however, the combine which controls the major part of the production of Flettons, said that they had attained an output of 1,200 millions a year! Truly a striking increase.

TABLE IV.—*Production of Building Bricks in Great Britain in 1930 and 1924*

Type of Building Brick	1930		1924	
	Quantity (million)	Value (£'000)	Quantity (million)	Value (£'000)
Glazed or enamelled	27·9	494	20·3	423
All other classes ..	4,385·4	10,381	3,877·1	10,706
Total ..	4,413·3	10,875	3,897·4	11,129

Apart from these statements, there are no authoritative figures published which would enable the movement of production to be examined over a period of years. There is probably no doubt, however, that annual output has been greatly influenced by Government housing policy, which determines to a considerable extent the volume of the domestic market.

Indexes of production covering building materials have been published from time to time in Belgium, Italy and Germany, but no separate indexes for brick are given. In Belgium, in the valley of Rupel alone, the production reached, in 1930, 1,500 millions. The output of bricks in France has expanded tremendously since the war, owing to new house construction and the reconstruction of devastated areas; no official figures of production are available, but an estimate of 1,750 millions for the three important areas of manufacture (Regions Libérées, Paris region, and Normandy and centre) would not be wide of the mark. In 1930, the output of Germany was of the order of 10,000 million ordinary bricks and 500 million klinker and facing bricks a year. The annual Swiss output was probably about 200 millions, that of Sweden roughly 250 millions, and that of Denmark about 300 millions.

Fuller data as regards production are available in respect of Canada and the United States of America. In 1927 the production of bricks in Canada amounted to 398 millions, valued at nearly 7 million dollars, as compared with 358 millions in 1926, to the value of 6½ million dollars. A complete account has recently been published, bringing up to date a previous report, on the ceramic industry of Ontario, which is one of the most important areas of brick manufacture in Canada. <sup>(12)</sup>

The production of common brick in the United States of America was 7,147 millions (value, 43,770 thousand dollars) in 1914, 4,852 millions (value, 82,216 thousand dollars) in 1920, 7,517 millions (value, 88,227 thousand dollars) in 1926, 6,413 millions (69,333 thousand dollars) in 1928. The production of face brick was 810 millions (9,290 thousand dollars) in 1914, 787 millions (19,441 thousand dollars) in 1920, 2,440 millions (44,516 thousand dollars) in 1926, and 2,412 millions (40,034 thousand dollars) in 1928.<sup>(8)</sup>

*Exports from the United Kingdom*

The exports of brick, made of brick earth or clay, from England during the years 1913 and 1919 to 1930, are given as follows in the Board of Trade Annual Statement of Trade :—<sup>(13)</sup>

TABLE V.—*Exports from the United Kingdom of Bricks made of Brick Earth or Clay*

Year.	No. in 1,000's	Value	Year	No. in 1,000's	Value
1913 ..	102,609	£ 365,485	1924* ..	5,926	£ 37,805
1919 ..	23,316	205,063	1925 ..	7,195	37,849
1920 ..	5,069	52,950	1926 ..	6,455	34,568
1921 ..	2,260	29,599	1927 ..	6,250	42,642
1922 ..	5,593	49,306	1928 ..	4,695	28,379
1923 ..	7,659	41,906	1929 ..	3,435	19,193
			1930 ..	3,311	20,607

\* From 1924 onwards the figures include Exports to the Irish Free State from Great Britain and Northern Ireland.

It will be seen that in 1913 the export trade was much larger than in any year from 1920 onwards, and that in fact the quantity exported in 1913 was over 30 times as great as that in 1930. Before the war, bricks were exported chiefly to Russia, the Netherlands and Italy, each country taking about the same quantity, but roughly half this quantity was also sent to each of the following countries :—Belgium, Germany, France, the United States and South America ; Sweden, Spain and Japan also provided a small export market ; over 30 millions were exported to British possessions. The fall in export after 1919 is probably attributable to the expanding domestic market then developing consequent on housing schemes, though prices and rates of exchange may also have affected the position. It would seem, nevertheless, that in favourable circumstances there is no reason to suppose that the brick trade is restricted to a domestic market, at any rate for certain special types.

*Imports into the United Kingdom*

The imports of bricks made of brick earth or clay from various countries into the United Kingdom in 1913 and onwards from 1920 are given in the Board of Trade Annual Statement<sup>(13)</sup> as shown in Table VI.

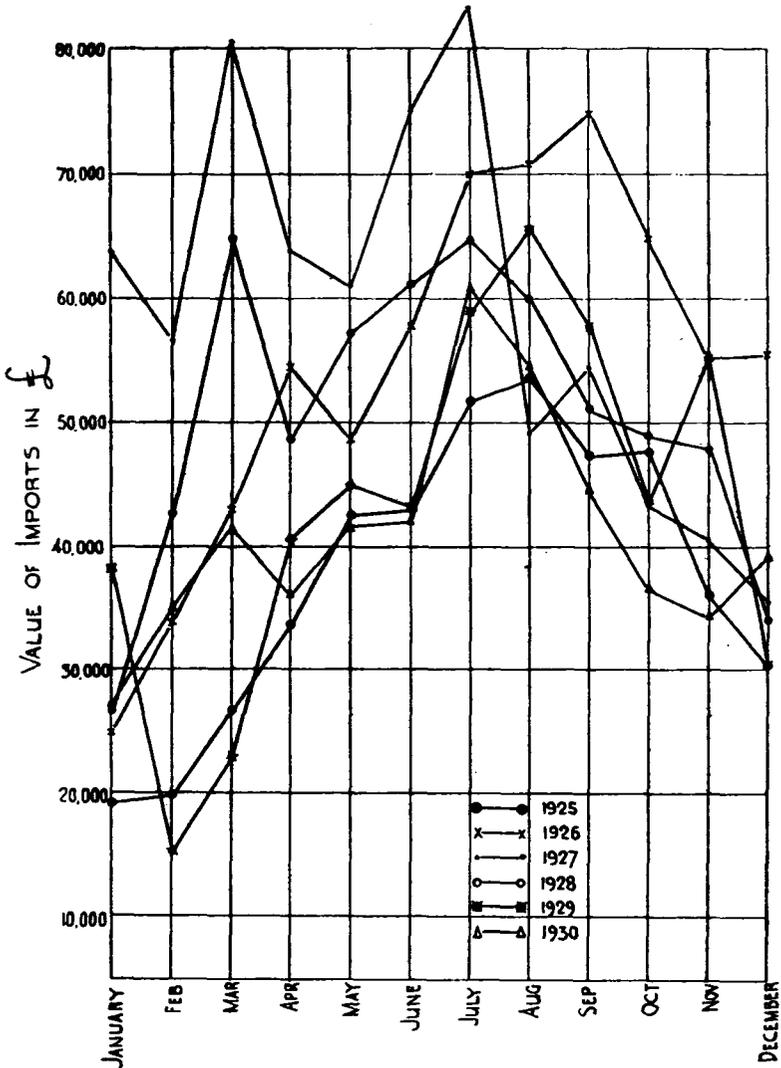


FIG. 2.—Imports of Bricks into the United Kingdom.

The monthly variations of imports during the years 1925 to 1930 are illustrated by the curves in Fig. 2.

The most striking feature of the movement of imports is the large and sudden increase in 1924. An increase, though not so large, occurred at the same time in a number of other building

TABLE VI.—Imports into the United Kingdom of Bricks made of Brick Earth or Clay

No. in 1,000's	1913	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930
1. Netherlands .. ..	—	—	—	3	280	98	6,815	33,796	26,275	33,897	22,641	23,110	8,115
2. Belgium .. ..	1,808	—	14	3,140	141	4,616	46,229	86,612	173,100	206,328	209,746	165,393	186,722
3. France .. ..	—	—	—	105	—	2,497	29,466	36,546	27,696	36,772	19,381	15,952	6,710
4. Other Foreign countries	*1,006	—	*23	672	114	161	2,505	1,913	1,732	1,438	601	1,379	1,112
5. British countries ..	—	—	—	—	—	—	27	89	89	9	3	191	153
Total .. ..	2,814	—	37	3,920	535	7,372	85,042	158,900	228,892	278,443	252,372	206,025	202,812
Value in £.													
1. Netherlands .. ..	—	—	—	14	1,270	214	18,259	90,700	70,664	88,335	58,517	64,541	23,627
2. Belgium .. ..	3,294	—	45	16,315	257	11,470	116,454	256,564	501,583	521,846	496,059	403,092	450,105
3. France .. ..	—	—	—	428	—	5,105	73,480	91,711	72,228	87,794	47,233	38,000	14,246
4. Other Foreign countries	*2,243	—	*66	4,487	435	892	8,587	9,504	7,129	7,084	2,992	5,808	3,502
5. British countries ..	—	—	—	—	—	—	207	115	146	31	15	712	524
Total .. ..	5,537	—	111	21,244	1,962	17,681	216,987	448,544	651,750	765,090	604,886	512,153	491,644

\* Including the Netherlands and France.

materials. The explanation seems to lie in the change in the housing situation. The 1923 Act stimulated private enterprise, and no doubt builders sought to buy in the cheapest market. Previously more control in the direction of using British products was exercised principally by local authorities, who were then mainly responsible for housing developments.

Another factor must, however, not be overlooked. The year 1922 saw a rapid recovery and development in the Belgian brick industry ; large numbers of new brick yards were opened. Furthermore, the exchange rates moved very favourably for export ; for whereas the pre-war rate was 25·22 francs to the pound sterling, the figure in 1920 was 50 ; in 1921, 51 ; in 1922, 58 ; in 1923, 88 ; and in 1924, 96.

The monthly fluctuations shown in Fig. 2 serve as a reminder not only of the seasonal character in some areas of brick manufacture, but also of the seasonal character of building operations in general.

The importation of foreign bricks into England, amounting in 1930 to about 4 per cent. of total production, has been keenly felt only in the southern and home counties (where it represents a serious proportion of the consumption), although criticism against the use of foreign bricks by local authorities has occasionally been made in other localities. Shortly after the war, the importations from abroad, which were promptly delivered, certainly eased the situation in England as regards supply, but there is no doubt that English manufacturers are now in a position to meet all domestic demands. It must be borne in mind that foreign works, manufacturing bricks wholly or partly of English size for export to England, may be controlled by English companies.

In view of the foreign competition, some attempts have been made to secure the imposition on foreign bricks of a duty under the Safeguarding of Industries Act, or to prohibit the use of foreign material in State-aided housing schemes. An application has been made for a sale or importation order, whereby bricks would be marked, either in the producing country or at the port of entry, with an indication of origin ; but after hearing the evidence for and against, and considering the methods of marking and possible difficulties that might arise in manufacture or in use, the application was refused.<sup>(14)</sup> Under the Import Duty Act, 1932, bricks became subject to the general *ad valorem* duty of 10 per cent.

#### *Imports and Exports in Other Countries*

The position in foreign countries as regards importations is influenced by ruling prices, freights, and tariff duties or other restrictive conditions. In the United States of America, according to the Tariff Information Survey Report of 1921,<sup>(7)</sup> duties on unglazed brick have ranged from 20 to 30 per cent., and on glazed brick from 20 to 45 per cent. ; in 1921 the duty was 10 per cent. on unglazed brick and 15 per cent. on the others, being the lowest

since 1883. Under the law passed in 1930, the tariff per 1,000 bricks became \$1.25 for common bricks and \$1.50 for glazed bricks, and it is anticipated that the provisions will be flexible. Bricks consigned to the United States must be marked with the country of origin. At one time, Belgian competition, particularly in the New York area, was very keen, but is now much less active. Germany abandoned all brick exports to the United States of America in 1927. Generally, the imports of bricks into the United States has dropped from over \$1,000,000 worth in 1926 to just over \$318,000 in 1929.

Bricks imported into Canada from the United States must also be stamped with the country of origin.

There seems to be a fair trans-border trade between Continental countries, e.g., from Belgium into France and Holland.

The Belgian export trade calls for special comment. The chief buying countries have been the United States of America, Great Britain and Holland. Some assistance has been given by the Belgian Government to the export trade, in connexion with the financing of freights and transport arrangements at special rates for wholesale traffic. The system as regards import into England is for influential brokers in London to buy up large shipments at their own risk. One Belgian combine controls a small fleet of ships which carry the bricks direct from the factory quays to London without transshipment. Another large Belgian works is held by English companies, and its whole output has usually been destined for English consumption.

### *Competing Materials*

Mention has previously been made of the materials competing with brick so far as the general economy of building is concerned. As these products affect tendencies in the development of bricks, further discussion seems desirable.

In England to-day, the main competition to building brick is from concrete products, sand-lime bricks, breeze-blocks, hollow clay blocks, terra-cotta and stone.

*Concrete.*—Competition between brick and concrete in housing schemes is not very active, although some systems embodying concrete construction have been used with success. In larger buildings, reinforced concrete competes with the steel frame as well as brick for structural members. Concrete competes with stone, terra-cotta and brick for facing work, particularly when the concrete is made up as a synthetic stone.

Cast concrete blocks compete effectively with the cheaper classes of brick for garden walling, etc., but they have not been extensively utilised for structural purposes. Many makers of concrete products manufacture small quantities of concrete bricks, to meet the needs of customers when purchasing large quantities of other cement products. One firm at least specialises in concrete

brick manufacture. The full extent of production at full capacity is no more than 100,000 a week. It is interesting to note that the firm in question, working a deposit of greensand, used a bed of sand exposed by the removal of the overlying clay for making stock bricks.

Although the subject of paving brick is outside the scope of this Report, it may be mentioned that the competition of cement has made itself more felt in paving work, and the general use of concrete flags must have taken a considerable volume of business from makers of paving bricks.

*Breeze-blocks.*—Concrete made up with breeze or other coal residues as aggregate is frequently used in slab form for partition walls. These slabs are cheap, form a good key for plaster, and hold nails easily. They are generally unsuitable for load-bearing purposes, unless forming part of a composite walling. Such systems of walling have been used with success on the Continent and in England in housing schemes. Certain dangers in the use of breeze-blocks must, however, be guarded against; these dangers are primarily due to the presence of unburnt coal of certain types which may give rise to extensive cracking and deterioration.

Some building codes prohibit the use of breeze-blocks in positions where they would come into contact with steel.

*Sand-lime bricks.*—Sand-lime bricks are made from a mixture of sand and hydrated lime. They are pressed into shape in moulds and then cured in a steam atmosphere under pressure. During curing, chemical action takes place between the sand and the lime, thus cementing the materials together. The process of manufacture can be described as a heavy chemical one, and lends itself to accurate control and rapid production.

In appearance, sand-lime bricks are white, cream or grey in colour, perfectly regular in shape and size, and of a texture varying from that of sandstone to that of an engineering brick. Pigments can be introduced, if desired, to colour the white bricks to any reasonable tint.

Sand-lime bricks can be used as a general substitute for ordinary burnt clay bricks. They can be used as a fair (and cheap) replacement of glazed bricks for the interior finish in school-rooms, corridors, etc. If well made, they have good weather-resisting properties.

It is not easy to give the cost of manufacture, but ruling prices are about the same as for clay bricks. Several manufacturers run plants for sand-lime bricks as well as for ordinary bricks.

A good sand-lime brick is a calcium-silicate brick; a bad one is merely calcium carbonate mixed with sand. It is not easy to tell good sand-lime bricks from bad by mere inspection or readily-applied tests. Conformity to a standard specification is essential.

Sand-lime bricks are perhaps more popular in the United States of America and Germany than in England. But their reputation is prejudiced by occasional instances of poor manufacture.

*Lime-slag bricks.*—A growing competitor to clay brick in Germany and France is the lime-slag brick, made from granulated slag with lime and hardened under steam pressure.

*Hollow blocks.*—In the United States of America and the Continent, hollow clay blocks, or, as they are sometimes called, structural tiles, are much used for walling and flooring purposes. There is a wide variety of designs, and it is impossible to generalise as to their efficacy. In England, the manufacture of hollow clay blocks—mainly for partitions—is on a relatively small scale. Competition with brick may become keener as the value of the hollow clay block comes to be more generally recognised, e.g., for the backing of panels in steel-framed buildings. Attempts are being made in Austria and Germany to manufacture closed hollow blocks.

*Terra-cotta and stone.*—Brick competes with terra-cotta and stone for the external facings of larger buildings. It is unlikely that the relative positions of these materials will change much in England or the Continent, but in the United States of America it is significant that the smaller units are becoming popular for skyscrapers, and that although the base of a building may be in stone, bricks matching the stone may be used for upper levels.

#### *Tendencies in Brick Development*

A number of tendencies in brick development have already been mentioned incidentally. For convenience they may be restated here.

The outstanding tendency in England and the United States of America is to adopt multi-colourings for facing bricks, and to take full architectural advantage of the vivid colouring available. On the Continent, regularity of colouring is more popular, although special live and warm tints are occasionally exploited. Bricks carved *in situ* are to be seen, especially on the Belgian littoral.

Unplastered brick for interiors is being popularised.

In contrast to the demand for standardisation, there is, particularly in the United States, a growing practice of promoting novelties, special shapes and sizes. At the same time there is an intense effort to secure regular sizes and accurate dimensions.

Bricks of light weight are increasingly in demand. Other materials are often added to clay to give a light-weight product. Except in England, perforated bricks are being adopted. The Fletton cellular brick, now finding favour in England, has no counterpart abroad other than the "one-hand" hollow block of Germany. Attention should, however, be directed to the new American structural tile, which practically consists of two standard sized bricks, kept together by a double web, so that one unit forms the entire thickness of the wall; the one block weighs no more than a common brick, but when laid takes the space of two and the design of the double web facilitates handling. Mention should also be made of the

" du brick " developed by one company in America, which is equivalent to  $2\frac{1}{4}$  standard sized bricks.

As previously indicated, most countries, apart from England, are using the semi-dry process less and less for common brick manufacture. A notable development in England is the manufacture of London stock bricks by machine, instead of by hand, and the use in the process of kilns instead of open clamps.

The most important structural feature in the development of brickwork is the intensive examination now being given in Japan, India and America to reinforced brickwork. The idea of giving to brick masonry, by means of metallic reinforcement, the tensile strength and resistance to shearing forces which are lacking in ordinary brickwork is not altogether new. In 1836 Brunel built two balanced sections of a cantilever arch over a central pier of brickwork with iron bar reinforcement. Reinforced brickwork falls essentially into two well defined classes. (a) masonry of ordinary building bricks in which the reinforcement consisting of steel bars or mesh is placed in the mortar joints at appropriate positions in the section ; and (b) masonry of solid or hollow clay blocks of various shapes and sizes provided with perforations or channels through which reinforcing rods are passed. The first class has been used with considerable success for some time past in India where many different types of structures have been erected with this material. Its possibilities are being actively explored in the United States of America where considerable experimental work seems to be in progress. The second class of reinforced masonry appears to be used to quite a considerable extent in Japan, on the Continent and in America, particularly for walls and floors.

### 3.—MANUFACTURERS

The report on the brick and fireclay goods in the 1924 Census of Production<sup>(15)</sup> is based on returns received from firms in Great Britain and Northern Ireland whose business in 1924 consisted wholly or mainly in the manufacture of bricks and fireclay goods other than pottery, including the extraction of brick earth or of fireclay from the firm's own workings or mines. The number of such separate returns was 1606. About 80 firms to which schedules were sent did not furnish returns. The number of returns, however, should not be taken as necessarily representing the number of establishments engaged in the trade. Firms that owned several establishments in which the same trade was carried on were generally permitted to make combined returns if they so wished, though some preferred to make a separate return for each of their establishments.

For the 1930 Census,<sup>(11)</sup> detailed returns were not required from firms employing ten or fewer persons. The published figures cover 1,187 establishments engaged in the brick and fireclay trades.

Returns for 1930 were said to be outstanding from establishments that employed in 1924 about 1,950 persons, or 3 per cent. of the total number recorded for that year by all firms employing more than 10 persons, while in 1924 an aggregate of 1,850 persons were employed in establishments whose returns were made on schedules covering 10 persons or less. As there are not a few small firms employing, say, six people in brickmaking, it is probable that the number of establishments not included in the 1,187 may reach 10 per cent. This would bring the number of possible returns up to about 1,350.

An independent examination from trade catalogues and other records of brickmaking establishments, whether engaged wholly or merely partly in brickmaking, not necessarily including fireclay workings, shows that, taking each brickworks with a separate address as an individual establishment, there were in 1930 something like 1,300 brickmaking plants scattered throughout England. At first sight, this figure does not seem reconcilable with the Census figure, as there are no doubt more than 50 fireclay establishments. The discrepancy is, perhaps, accounted for by the fact that the 1,300 includes, for example, works which are engaged mainly on tile making but have a small output of bricks.

An attempt has been made on the map in Fig. 3 to show the geographical distribution of brickworks in England and Wales. This mapping is, of course, incomplete, since the shading does not correspond to density of production. Each plant is shown with a dot, and the sizes of the dots are determined by the number to be placed in a given area, not by the output of the works represented. But it does enable some visualisation to be made of the main centres and districts of production and of the numbers of works per unit area.

### *Sizes of Works*

As recently as 40 to 50 years ago it was not uncommon in England for bricks to be made and burned on the site where houses were to be erected. This hand-to-hand system still persists, and is prevalent in Holland and France, but there is an increasing tendency to equip a works to serve not only its immediate neighbourhood but also districts and population centres at some distance away. Growth of modern transport (see p. 53) is mainly responsible for the change. Nevertheless, particularly in America, nearness to a large city is still a significant factor in the choice of location for new works.

Apart from brickmaking on the site, it is probably uneconomic to work to an output of less than, say, 100,000 a year. In fact, smaller works of significance might be grouped in the production range from 100,000 to 750,000. The next sized units might have an output up to 5,000,000 a year. A third grouping would be those with an output up to 12,000,000 a year. Finally there are the larger combines controlling outputs of hundreds of millions a year. The first group would probably have no mechanical equipment. The

second and third groups, where the majority of the works would have an output of around 3,000,000 and 10,000,000 respectively are convenient sized units whose needs are admirably suited for one, two or three batteries of mechanical equipment. 5,000,000 might be taken as a standard economic unit. The large combines may either indulge in mass production at different centres (e.g., as at

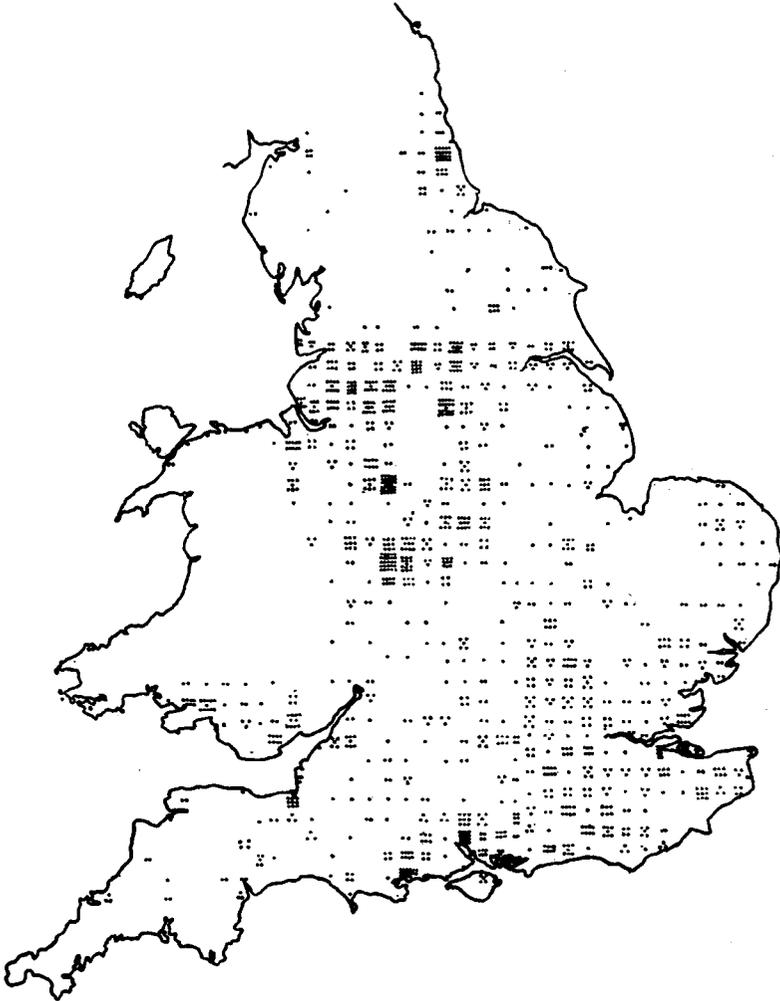


FIG. 3.—*Distribution of Brickworks in England and Wales.*

one of the common brick plants with an output of over 1,000,000 bricks a day) or they may be associations of moderate sized units.

A large combine is probably more suited to the manufacture of common bricks than of facing bricks. A works with a huge mass production capacity may be successful even in times of trade depression if transport rates are favourable; but the overheads

involved by keeping the works open may prove overwhelming. It is, therefore, by no means an agreed proposition that the larger works are more economic than those of moderate size, especially if transport rates are heavy. Moderate sized works must by no means be regarded as inferior in efficiency. Again, moderate sized works, with small variation range of raw materials and still governed to some extent by manipulative skill, may be able more easily to maintain good quality of production.

The tendency in England in the last 10 years has been for various companies to acquire works and maintain decentralised production. Only rarely is the purchased factory shut down and larger units established. The principal exception is in the manufacture of Fletton bricks, where not only have individual works been purchased, and retained possibly for special facilities in manufacture, but also consolidation and expansion has taken place on an immense scale. In 1922, a year before the amalgamation of Forders with the London Brick Company, the aggregate delivery of bricks, including those of all the works now owned by the London Brick Company and Forders, Ltd., was less than 300,000,000; since then, some works have been scrapped and rebuilt on up-to-date lines; some reconstructed and modernised; some consolidated into large units to give greater capacity; the production capacity is now stated to be 1,200,000,000 a year. In the manufacture of London stock bricks, it is noticeable that areas once important are now declining, and that manufacture elsewhere is being consolidated and expanded.

The main centres of manufacture of Flettons are Peterborough and Bedford, and their chief market falls within a defined area, the North of the river Thames, but including the whole of London. By reason of special railway facilities, the distributing centre for Fletton bricks in London is King's Cross Railway Station, and a certain price is charged at that centre with the addition of railway rates to the various consuming localities served therefrom.<sup>(6)</sup> More recently, Fletton bricks have secured markets with a wider area, reaching even the extreme North and South-West of England. As previously mentioned, yellow stock brick manufacture is more and more restricted to Kent, Essex and Buckinghamshire.

On the Continent, particularly in Holland and France, the system of making bricks on a building site is, as already stated, still prevalent.

The most important area in Belgium for brick manufacture, so far as export to England is concerned, is Boom near Antwerp. In the valley of the Rupel alone, the output is 1,500,000,000 a year, and individual plants have deliveries of upwards of 50,000,000. There are two powerful groups of manufacturers around Boom, and another powerful group around Charleroi.

Switzerland is highly syndicalised, and the overwhelming majority of brickworks belong either to a Central Union, or to a

French-Swiss Syndicate. These bodies control respectively yearly outputs of 200,000,000 and 40,000,000 bricks. The actual works themselves are of moderate size with a maximum output of, say, 20,000,000.

In Germany it is unusual to find a plant with a capacity of more than 20,000,000. Even so, in times of trade depression, smaller plants can continue working while larger works cannot afford to remain in operation.

In Holland, the largest plants are also of moderate size, say, 10,000,000 to 15,000,000. The main brick fields lie along the banks of the rivers.

In France, an output of 25,000,000 represents a very large works. An important combine in North France controlling an output of 120,000,000 common bricks a year, consists of a chain of plants with an average output not exceeding 10,000,000.

In Denmark, 270 brickworks are responsible for the total output of 300,000,000. In Sweden, whose annual output is 240,000,000, there are 150 large plants and 120 small; the plant production varies from 500,000 to 10,000,000 a year, many plants averaging 1,500,000 to 2,000,000.

Canada may be illustrated by the province Ontario, where there are 16 plants with a yearly production of over 5,000,000 bricks; 47 with 1,000,000 to 5,000,000; 22 with 500,000 to 1,000,000 and 60 under 500,000.<sup>17</sup> There are several consolidations under one management; these consolidations may serve a wide market, while the smaller plants do localised trade.

In the United States of America in 1928 there were 1,080 common brick establishments producing a total quantity of 6,413,000,000 a year, or an average of nearly 6,000,000 per plant.<sup>18</sup> The States of New York, and of Illinois, despite the fact that the plant along the Hudson River only works seasonally, had the largest outputs—1,165,000,000 for 77 establishments—1,144,000,000 for 64 establishments respectively, and their markets were highly localised, namely, New York City and Chicago. There were a fair number of common brick plants with an output from 5,000,000 to 7,000,000 which operated only in the summer. Pennsylvania had the largest number of plants—107—corresponding to an output of 456,500,000. Ohio, with 63 plants, had an output of 278,000,000 (average  $4\frac{1}{2}$  millions). For face brick manufacture, there were 459 establishments, with a total output of 2,412,000,000 (average  $5\frac{1}{2}$  millions). Ohio had the largest output—574,000,000 in 58 establishments (average 10 millions), with Pennsylvania next, 558,000,000, in 89 establishments (average  $6\frac{1}{2}$  millions). Illinois was third (275,000,000 in 33 establishments, average  $8\frac{1}{2}$  millions), and next, Indiana, 172,000,000 in 20 establishments (average  $8\frac{1}{2}$  millions). Iowa with 23 plants had an output of only 19,500,000.

The Illinois Brick Co., Chicago, represents a merging of 42 plants of which only 10 are now operating. One of the plants, with a

capacity of 600,000 in an 8-hour day, is probably the largest single unit in the world. The Bohnsack Company is a similar huge consolidation. The largest face brick plant does not exceed an annual output of 300,000,000. It is noticeable that in one important centre, two consolidated firms, making face bricks, control the whole area market.

The alteration that has taken place in the size of the manufacturing unit in the New York (Hudson River) area calls for special comment. In 1912 there were 136 establishments with a total output of 1,233,000,000 common bricks; in 1917, there were 99 plants with a total output of 584,000,000; in 1923, 74 with a total output of 900,000,000; in 1928, 63, with a total output of 1,240,000,000.<sup>(18)</sup> Several works have now yearly outputs from 30,000,000 to 60,000,000. Nevertheless, a few small seasonal plants still maintain operation.

### *Trade Associations*

After the strenuous individualism encouraged by the first stages of industrial revolution, many tendencies have operated to limit competition in industry in most countries of the world, through trade associations of various kinds. The increased size of establishments, greater cost of equipment, better transport, marketing, improved technique, patent rights, opportunities for advantage in securing raw materials, concentration on tariff questions, are all factors contributing to the formation of larger industrial units. General feeling is, in fact, now in favour of combination, rather than against it provided there is no unreasonable restraint of trade.

Circumstances in England have not assisted the trade association movement so much as they have done in Germany and the United States. The "Gentlemen's Agreement" as to prices has no doubt been common at all times, especially in local trade. The most usual methods adopted by associations in Great Britain which aim at limiting competition are the fixing of minimum prices and the pooling system in one or other form. Though "trusts" are to be found in British industry, few are of the pure trust type; some consist merely of companies bound together by exchange of shares; few are merely holding companies, and a few are entirely unified undertakings. Many are holding companies to some extent, and consolidations to some extent; while they may have allied themselves with other companies by means of exchanges of shares or interlocking directorates.<sup>(19)</sup> The trade association movement in Great Britain was fostered by Government contracts during the Great War. Under the Profiteering Act of 1919 (which lapsed in 1921) certain committees were set up with the object of reviewing particular industries, including that concerned with brickmaking.

The report<sup>(5)</sup> published in 1920, of a sectional committee of the sub-committee on Building Materials appointed under the Profiteering Act by the Standing Committees on the Investigation of Prices

and Trusts found the position as regards combination in the brick trade to be as follows :—

“ We find that there are now many associations in existence ; in fact, every district has its own, whose boundaries are determined by the similarity of clay and the method of manufacture.

“ The two principal associations are the Pressed Brick Manufacturers’ Association, which works the Fletton fields in the Peterborough District, and whose capacity is estimated at 450 million bricks per annum, and the Stock Brickmakers’ Association, which works the Stock Brick Fields in Kent and Essex and whose output varies from 250–300 millions per annum according to the season.

“ Roughly speaking, the purposes for which brick manufacturers combine to form these associations are as follows :—

- (1) To regulate selling prices with a view to maintaining them at a profitable level.
- (2) To regulate conditions of labour.
- (3) To protect the trade in their own particular locality.

“ Some of the smaller associations were formed during the war for the purpose of collective dealing with the Government with regard to costings and prices.

“ We have had before us no evidence to show that this fixation of prices by associations is detrimental to the interests of the consumer ; on the other hand, we have had evidence that it limits the profits of the Builders’ Merchants. This system cannot be regarded as illegitimate, but we are of the opinion that dangers may arise in the event of these groups of associations extending their activities by co-operation. In no case have we found arrangements or agreements between associations.

“ In the retail branch of the trade there are in existence several associations of Builders’ Merchants. Price lists, based on merchants’ cost prices and showing a fair margin of profit to the merchant, are issued monthly, and although no penalties, monetary or otherwise, are imposed, one of the conditions of membership is that members will not sell below these fixed prices.

“ In so far as the operations of these associations come within the scope of our enquiry, we have no evidence to show that any undue advantages have been taken.”

Since the date of this report, the position as regards trade combination in the brickmaking industries does not seem to have altered much, save in respect of the formation of large manufacturing units, as indicated in the preceding section. In most localities, manufacturers meet, either on an association or in friendly conference, and agree on price, though adherence to such agreements may not be very marked.

#### *National Federation of Clay Industries*

The most important trade association in England, so far as brickmaking is concerned, is the National Federation of Clay

Industries, which, of course, covers other clay products besides brick. This Federation was incorporated in August, 1928, and its main general object is to promote the welfare and to advance and protect the interests of all the trades concerned. Other objects are to review legislative matters, taxation and rating ; to deal with questions of building bye-laws ; to consider railway rates and traffic conditions ; to promote standardisation, technical education and research. While the Federation considers general questions relating to employment of labour, it is definitely precluded by its constitution from taking any part in the determination of actual rates of wages, neither is it empowered to take any part in the fixing of prices of the goods manufactured by its members.

The Federation has shown some interest in the conduct of scientific research, and makes a contribution to the work of the Government Building Research Station and to the work of the British Refractories Research Association.

The following are Association members of the Federation :— Scottish Employers' Council for Clay Industries ; Northern District Federation of the Building and Engineering Brick Trade of England and Wales and Affiliated Associations ; South Eastern Federation of the Building and Engineering Brick Trade of England and Wales and Affiliated Associations ; South Western Counties of England District Federation of Clay Industries and Affiliated Associations ; Birmingham Brick Masters' Association ; Dorset and Devon Stoneware Pipe-Makers' Association ; Enamel Association ; British Sanitary Fireclay Association ; Lancashire and District Fireclay Manufacturers' Association ; Leicestershire Brick Manufacturers' Association ; Midland Brick Association ; Midland Pipe Association ; National Association of Roofing Tile Manufacturers ; North Warwickshire Brick Association, Ltd. ; Nottingham and District Bricks Manufacturers' Association ; Potters' Association ; Refractories Association of Great Britain ; Sheffield Ganister Association ; Silica Brick Makers' Association ; Stock Brick Manufacturers' Association ; Stourbridge Firebrick Trade ; Terra Cotta Association ; Tyneside Firebrick Manufacturers' Association ; Walsall and District Brick Makers' Association.

#### *Ceramic Society*

The Building Materials Section of the Ceramic Society provides a medium for the dissemination and publication of the results of scientific and technical investigations of clay products.

#### *National Joint Industrial Council for the Clay Industries*

Matters relating to wages and work conditions are dealt with by the National Joint Industrial Council for the Clay Industries.

#### *Institute of Clayworkers*

The professional status of the industry falls within the concern of the Institute of Clayworkers.

### *National Association of Clayworks Managers*

Interchange of knowledge and supply of technical information amongst clayworks managers are the main concerns of this Association.

### *Continental Associations*

Although trustification has received encouragement from the general arrangements affecting German industry, the individualistic outlook in the brickmaking industries seems even more marked than in Great Britain. In France there is the Syndicat des Fabricants de Produits Ceramiques, which has two main objects, viz. :— the study of industrial, commercial, economic and social questions of interest to members or contributing to the progress of the industries, and secondly, the conduct of research and technical investigations, and in general, all matters or actions relating to manufacturing processes. The Syndicat maintains a Technical Information Service and Testing Laboratory in Paris. The Fédération des Fabricants de Briques et Matériaux de Construction de la Région du Nord de la France is a very live section of the Syndicat. In Belgium, apart from the grouping of large works on the coast in more or less family concerns, there is little trade combination. In Sweden, there are two associations: (1) Sveriges Tegel Industrie Förening, interested in the technical side of the industry, and (2) the brick cartel, Svenska Tegel Försäljnings, which has been in existence since 1922. The country is divided into 16 zones, having selling and pricing organisations of their own.

Switzerland is highly syndicalised (see pp. 30–31) and a regular price is assigned for bricks of defined quality; quotas of production are also laid down; no works can apparently install new plant without permission of the central body.

### *American Associations*

In spite of the Sherman Anti-Trust Act and the Clayton Act, cartelisation in various forms is very common in the United States of America. The trade association movement in general is extremely strong there, and it would almost seem that industries are content to leave the guidance of their business to these associations. The directing posts carry high salaries. The directorate is able to regard the industry concerned as a single unit and plan its development. The brick industry in the United States boasts two trade associations, namely, the Common Brick Manufacturers' Association of America, and the American Face Brick Association. The National Brick Manufacturers' Association has recently been consolidated with the Heavy Clay Products Division of the American Ceramic Society, becoming the Structural Clay Products Division of that Society, and a Clay Products Institute has been established to bring together the manufacturers and users of clay products, so that these products may be used correctly according to their merits. For other clay products there are the Structural Tile Associations,

the National Paving Brick Manufacturers' Association, the National Terra-Cotta Association, etc. In addition to the National Brick Associations there are local Associations, such as the New Jersey Clayworkers' Association, Southern Clay Products Association, Wisconsin Clay Products Association, etc. There are, perhaps, too many associations, and the question of one association for the heavy clay products of America is now being reviewed.

The Common Brick Manufacturers' Association of America and the American Face Brick Association are mainly concerned with promoting the market for clay wares. As has been explained earlier (see pp. 4-5) brick as a building material does not occupy in America the established position it does in England and the Continent: competition with other materials is keen. As part of this development campaign by the Associations, all technical data relating to brickwork are being collected and handbooks and pamphlets issued. There is a wide propaganda campaign for the use of brick. But the Associations hardly concern themselves at all with manufacturing processes. They do, however, compile suggestions relating to prices, costs of production, output and stocks. They do not attempt price fixing, as this would be illegal; but the dissemination, openly and fairly, of information as to cost of products, volume of production, prices, stocks and transport costs is apparently not unlawful when there is no attempt at concerted price fixing or restraining competition. The Associations also maintain credit lists, so as to give their members information as to financial stability of brick buyers. The Common Brick Manufacturers' Association has recently arranged for the certification of brickwork that reaches an appropriate standard. The Common Brick Manufacturers' Association and the American Face Brick Association support research fellowships at the Bureau of Standards and also at the Mellon Institute.

In Canada, the National Clay Products Association (recently reconstituted and extended into the Ceramic Society of Canada) is doing useful work in linking together the various interests affecting brick manufacture.

#### *Selling Arrangements and Publicity*

Many works sell direct to builders; many sell to merchants; a few put the whole of their output in the hands of a middleman. This system operates in all countries. Occasionally, two or three firms, not linked otherwise, may have a joint distributing agency. Merchants may keep large stores, particularly for small retail sales; but usually the stock is kept at the brickyard and deliveries are consigned direct from the yard.

According to the data collected for the United States Census of Distribution, 1929, for the manufacturing plants engaged primarily in making clay products and non-clay refractories to a value of 302 million dollars, 50·8 per cent. of the sales were made to

consumers (contractors, public utility companies, municipalities, home owners, etc.), while sales to dealers amounted to 42·7 per cent. ; 6·5 per cent. was sold to the manufacturers' own branches. Of these sales to dealers and consumers, 27 million dollars worth was made through manufacturers' agents, selling agents, brokers or commission houses, by 260 of the 1,749 plants making returns ; 96 of these plants sold their entire output in this way. These percentages seem to be largely governed by the common brick works ; for face brick plants the percentage sold through dealers was higher (about 64 per cent.) and consumers accounted for only 23 per cent.

There is an increasing tendency for British firms to employ travellers, or to issue their own catalogues, and many advertise in the Architects' Standard Catalogues or in Specification journals. A number of British associations and institutions jointly sponsor the issue of an illustrated periodical entitled " The Brick Builder ". In respect of publicity, British firms are not inferior to the Continental, or even to the American. In America, firms rely on their Associations for publicity. Occasionally, when dissatisfied with the marketing efforts of the merchant, who, of course, does not confine his attention to brick, they may supplement his efforts by their own salesmen. One particular form of advertising is prominent in the United States, namely, the display of small panels of brickwork in offices, etc. These panels are sometimes made up in handy form to be carried by travellers. Location road signs are also used to good advantage.

Special reference should be made to the Architects' Samples Corporation, New York, where space can be hired for the display of building materials. There is a similar institution in Berlin. Brick manufacturers are not slow in taking advantage of the facilities, and prospective buyers are enabled to see a complete range of available products presented on a fair scale. The Building Material Bureau, established by the Architectural Association in England, initiated a move in a similar direction, and this has now been followed by the opening of a Building Centre.

The Building Trades Exhibition, which takes place biennially in England, also affords an opportunity for advertising which many brick firms in England utilise in increasing numbers. An effort on a larger scale has recently been made in Germany, where Brick Exhibitions have been held. Judging from the press, it would appear that American brickmakers are likely similarly to utilise the opportunity afforded by the Chicago World Fair.

#### 4.—FACTORS IN COSTS OF PRODUCTION

Although the production costs in many industries in England have been authoritatively investigated, there is little published information on brickmaking. In the absence of facilities for collecting systematic data, the most that can be done here is to present

the salient factors in manufacturing costs of bricks; and the treatment of various items must perforce be unequal.

The heads of cost are materials (including fuel), wages and salaries; power, light and water, depreciation and maintenance; rates, property tax and social charges, and other charges and adjustments.

### *Materials*

Apart from equipment and labour costs in clay or shale winning, there is the question of additions such as sand, grog, chalk, water, barium carbonate, etc. For London stock bricks, the additions may comprise cinders and ashes from household refuse, etc. For a few special types of bricks, road sweepings are used. No data as to the costs involved are available, but with a few possible exceptions the cost of additions can form a small part only of the whole cost of manufacture.

Mention should be made of the royalties on rented properties. About 1s. per 1,000 bricks is said to be a fair measure of the value of royalty from common bricks, the lease running from 20–30 years; a very usual figure is 1s. 6d. per 1,000 for clays yielding facing bricks; and in industrial areas as much as 2s. 6d. is frequently paid for good quality clays.<sup>(20)</sup>

The extent to which fuel regulates the cost of brickmaking is dependent on the locality and process of manufacture, so that it is impossible to state with any accuracy any standard figures showing the relation of fuel to total costs.

In the manufacture of common bricks the quantity of coal used varies from about 4 to 7 cwts. per 1,000. A figure that is often quoted for the average for all types of brick, facing and common, and including allowance for power, is 10 cwts. per 1,000. But there are considerable differences according to the clay used, the size of the brick and the amount of drying and burning required. Some works utilise colliery dumps. The Fletton shales contain some carbonaceous matter and the fuel consumption for Fletton brickmaking may sometimes be little more than 1 cwt. per 1,000. For London stocks the cinders are the actual burning fuel though some coke is required to start the ignition.

According to the interim report on Prices, Costs and Profits of the Brick Trade,<sup>(6)</sup> the increases in the price of coal per ton in the principal districts from 1914 to 1920 were:—

TABLE VII.—*Price of coal per ton 1914 and 1920*

	1914	June, 1920
London .. .. .	15s.	50s.
Peterborough .. .. .	5s.—8s.	30s.
Manchester .. .. .	8s. 6d.	37s.
West of England .. .. .	14s. 9d.	44s. 8d.
Scotland .. .. .	8s.	30s.—37s. 6d.

with an average increase of nearly 270 per cent. It was suggested also that the coal supply was of inferior quality; lower calorific value necessitating the use of 25 per cent. more for burning and power.

It must be remembered that 1920 was a year of very exceptionally high prices and by no means typical of post-war conditions.

The average annual wholesale price of coal in the United Kingdom quoted in Statistical Tables relating to British and Foreign Trade and Industry<sup>(a)</sup> are as follows:—

TABLE VIII.—*Market quotations of certain kinds of coal and average pit-head prices in chief coal-mining districts of the United Kingdom, 1913 and 1924-30.*

(Per ton)							
Kinds	1913	1924	1925	1927	1928	1929	1930
<b>MARKET QUOTATIONS.</b>							
	s.						
South Wales Smokeless Ordinaries	20·15	25·87	23·16	19·67	17·54	18·47	18·25
South Wales, Smokeless Seconds	18·63	26·75	23·95	20·31	18·45	19·01	18·52
Durham Gas .. .. .	15·31	23·05	18·45	16·74	14·92	16·26	17·06
Durham Furnace Coke	21·37	28·16	21·54	21·21	17·63	20·84	18·16
Lancashire Best House	16·99	35·42	34·97	32·62	29·72	28·60	28·64
Yorkshire Best House (Leeds)	14·92	28·66	30·09	28·94	22·71	23·29	26·43
Yorkshire Hards (Sheffield)	12·72	23·12	18·02	16·81	14·51	15·29	14·56
Nottingham Best Brights	12·70	28·67	25·37	20·54	18·25	19·48	20·71
Nottingham Small Nuts	9·59	17·90	13·56	15·41	13·15	14·86	14·75
Fifeshire Screened Navigation	16·71	27·35	21·85	19·59	18·00	17·98	16·87
<b>AVERAGE NET SELLING VALUE AT MINES IN—</b>							
Northumberland ..	10·50	18·03	14·07	12·61	11·05	11·63	12·01
Durham .. .. .	10·49	19·48	15·64	13·57	12·04	12·60	12·89
South Yorks .. .. .	9·43	18·09	15·65	14·21	12·41	13·04	12·97
West Yorks .. .. .	9·43	18·71	16·92	15·57	13·51	14·00	13·95
Notts and North Derby	8·78	17·81	15·34	14·42	12·28	12·81	12·77
South Derby, Leicester, Cannock Chase and Warwick	8·93	18·48	16·61	16·27	13·92	14·51	14·34
Lancs., Cheshire and North Staffs.	9·92	19·82	19·09	17·35	15·52	15·87	15·82
South Wales and Monmouth:—							
Anthracite .. .. .	11·96	27·40	24·69	20·85	18·42	19·84	21·03
Other .. .. .	11·87	19·79	17·64	15·04	13·24	13·95	14·38
Rest of England and Wales	9·89	17·83	16·55	15·28	13·59	13·92	14·20
Scotland .. .. .	9·66	17·43	14·21	12·29	11·23	12·03	11·99
Great Britain .. .. .	10·13	18·84	16·37	14·61	12·85	13·43	13·59

(a) Large Steam.

(b) Barnsley Best Silkstone.

These figures cannot be related to those quoted earlier, but they serve to show the decline in price from 1924 to 1928 and the partial recovery in 1929.

Lump coal is still the main fuel used in English brickworks, but a number of plants use powdered coal, producer gas or oil. The use of washed coal is also leading to economies. The quantity of fuel used at a works depends on whether it generates its own power (using for example a low grade fuel for steam generation) and on the extent of electrification and source of electricity supply. Very few comparative data are available, since so much depends on the processes and equipment in use.

The statements that have been made from time to time in technical journals regarding the comparative costs of oil and coal in brickmaking are difficult to reconcile ; but the following seems a fair statement of the position. The general world trend of oil prices has of recent years been steadily downwards, and fuel oil may come within measurable distance of equality with coal, after taking all economic factors into account. During 1926 the average fuel oil price in England was 80s. per ton, in 1930 from 65s. to 70s. For quantities of over 100 tons (say) within a reasonable distance of main installations the price has been as low as 60s a ton. The cost at these prices is still markedly higher than the cost of coal, but it is claimed that the time of burning can be lessened, the number of unfired bricks reduced, labour saved in handling, and that kiln space is increased. In the near future the use of finely pulverised coal is likely to be considerably increased.

In the United States of America the relative costs of coal and oil are different from those in England, and oil is more extensively used. Natural gas is also employed to a considerable extent, and has been piped for distances up to 700 miles. Powdered coal is frequently employed. On the Continent, automatic stoking of continuous kilns is much more prevalent than in England, and powdered coal is used for fuel. Economies in fuel costs can be achieved by the mechanical handling of coal, the use of automatic feeders, etc. Apparently also it may be economical to work the brick plant on alternate days only ; or, again, to conduct grinding operations during the night.

As an illustrative summary of the past played by materials in the cost of production, it may be stated that of the manufacturing cost of common bricks in the United States, the overall cost of materials represents 39 per cent. on the average in the stiff-mud process, and about 35 per cent. in the soft-mud process.<sup>(22)</sup>

### *Utilisation of Waste*

It is perhaps convenient to include here reference to the receipts from the utilisation of waste material. Broken brick may be ground and used as grog, or sold as aggregate for concrete. In powdered form rubble finds a sale for the laying of tennis courts.

In certain districts on the Continent the ground brick is mixed in a separate plant at the brickworks itself with special types of cement and utilised in the manufacture of chimney pots and proprietary fire-resistant blocks. The clay-lime brick made by a similar process to that for the sand-lime brick, and utilising ground burnt clay instead of sand, is another form of waste utilisation.

### *Salaries*

Salaries and wages probably represent over 50 per cent. of the productivity costs in the brick industry.

Figures for the United Kingdom relating to wages cost in the brick and fireclay trades in 1924 are given in the Final Report of the Census of Production for that year<sup>(18)</sup>. For a group of firms employing 57 per cent. of the total operatives for the trades as a whole and with a net output of 58 per cent. of the aggregate net output recorded for the trades as a whole, the total wage bill represented about 56 per cent. of the value of their aggregate net output.

No figures for salaries are available, and it is only possible to make one or two general remarks. It would appear that responsible technicians in Continental works are paid lower salaries than their English confrères. Also, directors' fees seem to be lower and may be no more than a nominal payment for attendance at meetings. In the result, the general overheads on the Continent appear to be lighter. On the Continent and in the United States of America relatively young men often occupy positions of major responsibility. This may be attributed on the Continent to the earlier ages at which intellectual maturity may be reached, or in the U.S.A. to the different percentage of war wastage ; or it may be due to the greater appreciation of the value of technical education and to the better facilities provided, whereby the necessity for lengthy apprenticeship in the shops is avoided ; or it may be due to a greater belief in the capacity of youth and to earlier retirement of senior men.

### *Wages*

There are several methods in force for payment of manual workers. Some works are run almost entirely on a piece-rate basis ; others on an hourly. Many have a majority of men on hourly rates, and selected men (e.g., kiln burners, setters and drawers) on piece rates. Shift systems are also in operation. Several firms have bonus schemes and attach considerable importance to the incentive thereby given. Then there are some works that still retain a form of the Butty system, whereby one section of operations is leased out (say) to a foreman (or moulder, in hand brickmaking), who receives block payments and himself pays the individual members of his gang, though these operatives may appear on the firm's roll. Then there is the system, known in America (and in one or two places in England) as the " stint " system, in which a specified number of bricks must be produced per day, and pay is correspondingly at a level daily figure.

In 1914, the wages paid to the ordinary labourer engaged in the brick industry, averaged from 4*d.* to 6½*d.* an hour, representing a weekly wage of 18*s.* 8*d.* to 30*s.* for a 56-hour week.<sup>(5)</sup> In 1906, the average for male workers in the brick, tile, etc., industries, was 23*s.* 1*d.* and for female workers 10*s.* 7*d.*<sup>(21)</sup>

From an inquiry made by the Ministry of Labour in 1928, which covered 35,548 workpeople in the brick and tile industry, the average weekly earning was 51*s.* 2*d.* for the week ended 27th October, 1928.<sup>(25)</sup> In 1930, the normal hours for shift workers was 8 hours per shift and for day workers 48 hours per week.

A series of National Wages Awards and Agreements has been drawn up by the Interim Reconstruction Committee (now the National Joint Industrial Council) for the Clay Industries. Not all manufacturers have agreed to accept the Committee's awards, but many who have not formally given their agreement nevertheless follow the arrangements made. The cumulative effects of the awards (including the most recent reduction in June, 1931) is that male time-workers 21 years of age and over receive an advance over pre-war rates of 23*s.*, subject to a maximum wage of 46*s.* for a full normal working week. Taking the wages of the average male labourer as 24*s.* a week before the war, he is now receiving twice as much per week and works from 5 to 8 hours less.

The total average normal weekly earnings (inclusive of family allowances and other social allowances paid in cash) of skilled, semi-skilled and unskilled men, engaged in industry in general in France, Belgium and Germany is somewhat as follows :—<sup>(24)</sup>

TABLE IX.—*Weekly Earnings in Foreign Countries*

Country	Skilled men		Semi-skilled men		Unskilled men		Daily hours of work
	<i>s.</i>	<i>d.</i>	<i>s.</i>	<i>d.</i>	<i>s.</i>	<i>d.</i>	
France ..	51	6	40	3	32	2	8 hours (48-hour week or 56-hour week for continuous processes).
Belgium ..	53	9	38	10	30	10	8 hours (48-hour week).
Germany ..	68	6	52	10	47	0	Normally 8-hour day, but may contract to work up to 10.

Other evidence collected confirms that these figures do apply substantially to brickworks. In brickmaking, however, it should be noted that more women and boys are employed in some countries than in others. Thus in Belgium, particularly in the exporting area around Antwerp, women and boys form a large proportion of the total workpeople; and their wages rates are about half those of men.

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ERRATUM.

Page 42, line 19, *for* "maximum" *read* "minimum."

(12/4324) Wt. 2223—701 375 11/88 H. & S. Ltd. Gp. 12.

The productivity costs in the common brick industry in the United States were investigated in 1924 by the Bureau of Labour Statistics.<sup>(22)</sup>

The labour cost in the works examined represented on the average 53 per cent. in common brick manufactured by the stiff mud process and 56 per cent. by the soft mud, representing respectively \$3.28 and \$5.12 per thousand bricks. By far the highest production per man-hour under the stiff mud process is in plants located in or near Chicago; the highest under the soft mud process was in the plants in the Kentucky, Ohio and Pennsylvania area (see p. 44).

The average earnings and hours, etc., are tabulated in the report, by process, occupation and district. The average full-time earnings were \$24.72 per 58.3 hours in the stiff mud process plants, \$24.69 per 53.9 hours in the soft mud process plants, and \$18.48 per 61.6 hours in the dry clay process plants.

#### *Rate of Output*

Naturally, the output per man-hour varies widely in the different works, according to processes used and type of brick made. In England the largest output—for common bricks—appears to be of the order of 90 to 100 per man-hour; about 35 is a good average, and 25 is a fair figure for a face-brick works. In a manufactory equipped with a completely up-to-date labour-saving installation, the output per man-hour should be about 115 bricks. In the particular case of hand-moulded bricks, a lower rate is the vogue, e.g., a stool of 6 (men and boys) would make 112 bricks an hour, i.e., 19 per operative. Apart from factories working to full capacity on a mass-production basis, it must not necessarily be assumed that moderate-sized works have low capacities per unit, or even that hand processes inevitably entail a small output per man.

The rates of output in Continental countries do not differ markedly from those ruling in Great Britain. Seasonal operations in the large works on the Belgian coast, and the higher proportion of women labour, make exact comparisons difficult. But for a production, say, of 50,000,000 a year, about 250 men and 100 women would be employed in summer, a total of 200 for some winter months, and practically none but kiln operatives at other times; taking 2,000 working hours for 300 operatives would give a rate of output of over 60 per man-hour.

More detailed figures are available in respect of the United States of America, and it appears that a much higher rate of output is attained there.

Modern face-brick plants in the United States would seem to reach easily an average production of over 100 per man-hour. But it is in common-brick manufacture that the differences are most striking.

In the Report on Productivity Costs in the Common-Brick Industry in U.S.A.<sup>(23)</sup> figures are given in respect of a number of factories inspected in 1924. The basis taken for the computation

of production-rate per man-hour is the number of employees actually necessary to operate all departments combined, multiplied by the number of hours the brick machine was in operation during the period covered; the aggregate man-hours so obtained was then used as the divisor of the number of thousand bricks produced by the machine during that period. The production-rate per man-hour was found to vary; for the stiff-mud process, from 85.9 to 359.9, with an average of 221; for the soft-mud process, from 51.5 to 214.4, with an average of 140.9. The dry-clay process gave a much lower average (92.5). Though this basis of computation may not seem to give a fair comparison with the figures quoted for Great Britain and the Continent, other data confirm the outstanding high output rate in the United States. And it must be remembered that the American figures relate to 1924, so that account must be taken also of improvements in more recent years.

The reasons for the high rate of output in American common-brick works demand closer study. By far the highest production per man-hour is in the stiff-mud process plants located around Chicago; next come the soft-mud process plants in Kentucky, Ohio and Pennsylvania (and probably, under recent developments, in the Hudson River area). The explanation undoubtedly lies in the improved machinery generally used, especially the mechanical handling of the product, as well as the character of the clay and the process of burning. In this connexion, reference should be made to the mechanical means used for setting and drawing the kilns. The bricks as they come from the machines are so stacked on the dryer cars, in units of about 1,000, that the whole unit can be lifted by means of a "fork" and an overhead crane. These units are set as such in "scove" kilns (up to 2,250,000 brick capacity) often fired with oil or natural gas. The burnt bricks are withdrawn by the fork and crane and loaded direct into railroad trucks. (See p. 93)

#### *Internal Transport and Layout*

A good layout allows efficient and economical working. It means that material can take a quick and easy course; labour is saved, as well as machine equipment and internal transport. Unfortunately, in England, many brickworks have grown up haphazard, and far too little regard is paid to economies that might be effected by proper re-planning and reconstruction. So far as internal transport itself is concerned, much labour and cost is saved, and rapidity of working is increased, by the installation of belt conveyors, or chains carrying trays, of cranes, mechanical grabs or other conveying equipment, and by means of mechanical loaders and unloaders. There is also the question of avoiding bad shapes or defects by the use of proper trucks or barrows. But it is impossible to give any figures of general application for the contributions to increased or decreased cost of production due to faulty or good layout and internal transport conditions.

*Power, light and water*

In the Preliminary Report No. 10 of the Census of Production, 1930, for the United Kingdom,<sup>(11)</sup> tables are given showing the capacity of (a) prime movers, (b) electric generators, and (c) electric motors at the brick and fireclay factories to which the returns relate. The figures are as follows :—

TABLE X.—*Power used in the brick and fireclay factories employing more than 10 persons in the United Kingdom, 1930*

(a) Prime Movers	1930	1924
Reciprocating steam engines :—	H.P.	H.P.
Ordinarily in use .. .. .	99,461	105,119
In reserve or idle .. .. .	6,398	6,080
Steam turbines :—		
Ordinarily in use .. .. .	3,539	156
In reserve or idle .. .. .	455	12
Other prime movers :—		
Ordinarily in use .. .. .	20,978	14,782
In reserve or idle .. .. .	2,989	1,266
Total—		
Ordinarily in use .. .. .	123,978	120,057
In reserve or idle .. .. .	9,842	7,358
(b) Electric Generators driven by	1930	1924
Reciprocating steam engines :—	K.W.	K.W.
Ordinarily in use .. .. .	8,825	4,660
In reserve or idle .. .. .	1,056	496
Steam turbines :—		
Ordinarily in use .. .. .	1,900	15
In reserve or idle .. .. .	250	—
Other prime movers :—		
Ordinarily in use .. .. .	1,988	1,378
In reserve or idle .. .. .	1,137	376
Total—		
Ordinarily in use .. .. .	12,713	6,053
In reserve or idle .. .. .	2,443	872
(c) Electric Motors driven by	1930	1924
Electricity generated in own works :—		
Ordinarily in use .. .. .	21,872	10,174
In reserve or idle .. .. .	2,840	1,232
Purchased electricity :—		
Ordinarily in use .. .. .	55,706	28,871
In reserve or idle .. .. .	3,205	2,257
Total—		
Ordinarily in use .. .. .	77,578	39,045
In reserve or idle .. .. .	6,045	3,489

The total quantity of electricity used in 1930 for all purposes at these factories was returned as follows :

	Million kilowatt-hours
Electricity generated at firm's works	31·7
Purchased electricity .. .. .	65·8
	97·5

In this connection the figures for the electrification in brick and clay products industries given by the British Electrical and Allied Manufacturers' Associations<sup>(25)</sup> are of interest :—

TABLE XI.—*Electrification in brick and clay products industries*

	Great Britain 1924	U.S.A. 1925	Germany 1925
Total capacity of primary motor power .. .. . (H.P.)	163,509	517,204	284,677
Total capacity of electric motor (H.P.)	42,106	288,246	106,471
Degree of electrification, per cent.	26	56	37

As regards relative costs of buying electric power and generating it privately, it would appear that if the balance is in favour of private generators, this does not necessarily mean that a private plant should be installed. The power user may find it a wiser policy to pay a premium for the privileges of being relieved of capital expenditure, worry as to load factors and doubt as to continuous supply. With improved arrangements for distribution of public supply, there will be an increasing tendency to abandon private installations.

Account must also be taken of the systems of charges available for public supply ; for example, maximum demand system or flat rate. The prices of public supply depend, of course, largely on distance from main power stations.

Loads should be kept under close observation so as to escape the extra charge involved by peak load over the time limit. One firm in the United States of America has arranged to do all grinding operations at night, thus reducing the over-rate considerably.

In connexion with the supply of steam power, it should be borne in mind that steam may be required for drying purposes. The costs introduced by water supply may be significant ; for example, when the clay pit requires special pumping, or where the boilers are affected and need constant cleaning.

According to A .B. Searle,<sup>(26)</sup> " so far as the cost of power is concerned, with engines of the types ordinarily used in brickworks, electricity can compete with steam when the former costs  $\frac{3}{4}$ d. per unit

and the latter is produced from coal costing 12s. per ton, provided no drying of goods is necessary. . . . A heavy or crude oil engine is reliable and economical. . . . An engine using town's gas is also a handy form of power, but the running cost on gas costing only 2s. per 1,000 c. ft. is twice that of a heavy oil engine of equal power. . . . A modern steam engine has a fuel cost equal to, if not higher than, that of a heavy oil engine and carries with it high labour costs and stand-by losses."

### *Depreciation and maintenance*

No English figures are available as to allowances for depreciation and repairs. According to A. B. Searle<sup>(30)</sup>, many brick manufacturers fail to allow for depreciation of works. "A suitable scale of depreciation per annum is 5 per cent. on drying and other sheds, and on the machine house; 6 per cent. on rails and on original cost of opening up ground, making roads, etc.; 7 per cent. on kilns and 10 per cent. on machinery—in addition to cost of repairs and renewals."

The Inland Revenue Department admits the following percentage rates for wear and tear allowance to building brick manufacturers:—

- (1) On steam engines, boilers, shafting, and on mixing and brick making machines, a normal rate of 5 per cent. on the written down basis.
- (2) On electrical plant, i.e., dynamos, motors, transformers, etc., and on crushing and grinding plant, a normal rate of 7½ per cent. on the written down basis.
- (3) All additions to and replacements of plant and machinery may be charged to capital provided that all renewals and replacements of parts which do not destroy the identity of the machine are to be allowed as a Revenue charge.
- (4) On kilns, no depreciation is allowed, but an allowance may be made in respect of the cost of repairs, and renewals and rebuilding of parts. Where it is necessary for a kiln to be entirely rebuilt the cost of such rebuilding is also to be allowed as a Revenue charge, but the cost of new kilns and of extensions is to be treated as capital.
- (5) For drying sheds, no definite and special arrangements are made.

Mention should also be made of the rule for obsolescence; when machinery is replaced by machinery of an improved type before it has been written down to scrap value by allowances for wear and tear, the unexhausted cost, less the sum realised by the sale, is treated as an allowance against revenue.

The American report on productivity costs of common brick<sup>(22)</sup> referred to earlier, puts the percentage due to repairs as about 8 per cent. A German estimate<sup>(23)</sup> is also 8 per cent. for repairs to equipment, while 2 per cent. is allowed for depreciation.

The cost of maintenance must vary greatly with the process of brickmaking in use and with the material available, as well as with the type of equipment.

### *Local Rates*

The total local rates levied in England and Wales in 1913-14 amounted to £71,000,000, and in 1927-28 was £167,000,000.<sup>(10)</sup> As, however, no distinction is made in these figures between rates levied on business premises as distinct from private householders, they do not indicate the burden of rates on industry. It was estimated, however, by the Balfour Committee<sup>(27)</sup> that local rates amounted in 1928 to 1 to 1½ per cent. of the total cost, or, say, 3½ to 5 per cent. of the total wages bill. These general rates may of course not be applicable, without considerable modifications, to the brick industry. Since that date, the burden of rates on industry has been mitigated under the Local Government Act of 1929 by the transference of a large proportion of the rates of manufacturing premises to Imperial taxation. Further, some brickworks, in addition to the alleviation of 75 per cent. afforded by this transfer, have gained from the derating of agricultural land.

It should be noted that for local rating, brickyards are grouped under mineral-producing hereditaments. The basic rate applied to the output for estimating the net annual value of hereditament in accordance with the statutory definition takes into account (a) the mineral rights in their existing stage of development; (b) the wayleaves, if any; (c) the surface land, the buildings, and the rateable plant, machinery and other appurtenances. For brickyards where the rateable equipment is considerable, the basic rate includes a factor which reflects the annual value of such equipment; this factor is found by dividing the annual value of the rateable equipment (ascertained usually by applying to its effective capital value a commercial rate of interest appropriate to the circumstances) by its normal maximum capacity. The amount of the rate on output thus varies considerably, e.g., from less than 1s. to over 3s. per thousand in different types of works.

### *Social Service Charges*

The Social Services to be here considered are the National Health and Unemployment Insurance Schemes, Workmen's Compensation and the Widows and Orphans and Old Age Contributory Pensions Scheme. A wholesale contribution by employers to this service is a form of public charge on industry, which has materially increased since the war. The employers' contribution

is now 9*d.* per man for health insurance and 8*d.*\* for unemployment insurance, etc., per week. From estimates made by the Balfour Committee<sup>(19)</sup> the amount of these social charges are now more than double those in 1913, while the proportion they bear to the total costs of production has risen by about two-thirds. It should be remarked also that if the Unemployment Fund becomes bankrupt and loans have to be raised, the extra charge becomes a national burden, rather than a direct burden on employers of labour.

The costs of social services are represented as above merely as money costs; no consideration is here given to the economic benefit produced by such welfare schemes on general industrial efficiency.

### *National Taxation*

Schedule A property tax, levied in Great Britain, is analogous to local rates in its incidence on costs of production.

There is no doubt that in general the indirect influence of high taxation on industry is much more important than its direct effects. At the same time, the direct effect on costs, though small in relation to the aggregate burden, may, in some cases, be far from negligible, in spite of the fact that income-tax is intended to be levied on the surplus, after costs have been met. For example, salaries and fees may have to be fixed at high levels to furnish adequate remuneration for the staff employed. Moreover, a high rate of taxation may have very serious effects on competitive power, both by diminishing the fund out of which the bulk of the national savings is accumulated and extensions and improvements of industrial plant are provided and also by discouraging enterprise and initiative.

It is regrettable that the available material is insufficient on which to found any reliable statistical conclusions regarding the burden of taxation in different countries. As explained in the Report of the First Committee of Experts appointed by the Reparations Commission,<sup>(20)</sup> "the comparison of statistics of total taxation, national and local, in each country presents many technical difficulties. Moreover, statistics of total material income and income per head are at present either very defective or wholly lacking." In the Report of the Committee on National Debt and Taxation,<sup>(21)</sup> the Committee write, in reference to the post-war period up to the end of 1927, that they think "it may be said definitely that the burden of taxation was heavier in Great Britain than in any other European country, and very much heavier than in the United States." But they were not prepared to make a measured comparison of figures and regarded it as dangerous to draw facile inferences from particular statistics.

\* Increased as from 5th October, 1931, to 10*d.* but the rates of benefits have been reduced.

### *Transport Charges*

Costs of freight are a very important item of costs in the brick-making industry. The general level of railway rates is now about 64 per cent. above the 1914 level. The subject of transport conditions is dealt with more fully in a separate section (see pp. 53-57).

### *Selling Costs*

Maintenance of offices, sales and managerial staff, costs of distribution of products and of advertising, form contributory items to the overhead costs of production. It is impossible to give any figures of general application, but the usual commission charged by a firm of merchants contracting to sell the whole output of a works is 10 per cent. on sales realised, including risk of bad debts.

### *Capital and Profits*

Although figures are from time to time published of the registered capital and profits of individual firms, no general figures relating to the brickmaking industry in England are available. Recently one technical journal<sup>(30)</sup> has begun the issue of tables of "Share Lists."

Most companies appear to have increased their capital in recent years. Thus, the London Brick Co. & Forders, Ltd., with a capitalisation of £1,000,000 in 1923, raised its capital to £1,400,000 in 1928, and £2,000,000 in 1929. Some dividends have been as high as 20 per cent., even in times of general trade depression, though some figures may appear unduly high owing to low capitalisation.

According to the 1920 Interim Report on the Prices, Costs and Profits in the brick industries,<sup>(6)</sup> profits were even then low in proportion to the amount of capital involved. "If the whole average profit on the bricks used in the erection of a house under the housing scheme be eliminated, the cost per cottage would not be reduced by more than £10."

It may be estimated that the capital required to establish a modern brickworks, taking as a unit an output of 5 million bricks per annum, is upwards of £4,000 for each million. This figure includes all preliminary costs of formation of company, purchase of land, installation of works, development costs, and working capital.

### *Budgeting and Costing Systems*

An important method of control of costs of production is through accurate budgeting and costing. It is not easy to evolve a system which will cover brickmaking in all its processes. But a number of firms in England have realised the value of costing in keeping check on production and reducing indirect overheads, and have instituted monthly and sometimes weekly systems of a fair degree of efficiency. In this respect, British brickworks stand favourable comparison with those of Continental countries. Even in the

United States of America it needs an energetic campaign, on the part of trade associations, for example, to establish budgetary methods.

An interesting pamphlet on Budget Methods of the Brick and Clay Industry has been issued by the Metropolitan Life Insurance Company, Policy Holders' Service Bureau, U.S.A.<sup>(31)</sup> The basic factors in developing a comprehensive budget are stated to be :—

- (1) *Period* for which estimates may be made.
- (2) *Minimum profit* considered essential, for distribution as dividends, addition to reserves or for reinvestment in plant, etc.
- (3) *Sales Volume*, quantity and cash, in groups.
- (4) *Selling and Administrative costs*.
- (5) *Production cost* broken down into departments and co-ordinated.
- (6) *Additional Financing*, if any, required.

Monthly comparisons of the budget, with actual operating cost give the management an appreciation of the value of executive policy.

The American Face Brick Association<sup>(32)</sup> has issued a cost and accounting manual to its members, giving a complete and detailed explanation of the methods of cost finding from the accountant's standpoint, together with a complete plan of the book-keeping required. The Common Brick Manufacturers' Association has compiled cost analyses for various yards ; a copy of one of their statements is reproduced in Table XII.

### *Summary*

It is not possible to present in any complete form the scanty figures that are available in respect of the significant items in the costs of production. The tables published by the American Common Brick Manufacturers' Association, as illustrated by Table XII, furnish a summary from one angle. Other figures cited are for cost of materials (35 per cent. of manufacturing cost), labour (50 per cent.) depreciation and maintenance (8 per cent.), but these figures are not necessarily mutually exclusive. For the brick and fireclay trades in the United Kingdom, the Census of Production, 1930, indicates (subject to correction) the cost of materials used as 5,808 thousand pounds, the net output being 14,080 thousand pounds ; while the wages paid (as suggested by sample) amounted to 7½ million pounds. No general statistics can be quoted in regard to cost of power and lighting, freight, administrative overheads.

It may be of interest here to refer to the review by K. Frohn (published in 1929) of 10 years' work of the Rhineland Brickmakers' Association.<sup>(33)</sup> As a result of an official examination, the basic

TABLE XII.—Cost Analysis for Month of May, 1929.  
Common Brick Manufacturers' Association—Cleveland.

		UPDRAFT KILNS OPERATED ALL YEAR AROUND																													
Code No.	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51			
Annual Output in Millions	26	24	13	10	10	20	19	23	13	20	45	47	45	38	7	20	8	40													
Clay Mining	20		.10	.17	.27	.34		1.20	.26		.12	.15													.77		.75				
Transporting	21							.20																							
Brick Making	22		1.90	1.20	1.20	1.20		4.70	1.10		.20	1.70		1.70		2.10		1.20								1.20	1.20	2.00			
Drying	23		.11	.20	.20	.20		2.20	.20		.20	.20		.20		.20		.20								.27	1.20	1.20			
Burning	24		1.20	1.20	.20	1.10		1.20	.20		.27	.10		.20		.27		.20									1.20	1.20	1.20		
Stacking	25		2.11	2.04	.20	1.14		2.21	.20		1.20	.27		1.21		2.04		1.20									2.04	1.20	1.20		
Yard Overhead	40		1.20	4.11	1.27	1.20		1.71	1.27		1.20	1.27		2.70		2.21		1.20									1.20	1.20	1.20		
Total			16.78	12.20	5.53	6.13		16.73	4.00		4.70	6.01		7.20		16.24		10.20									10.20	12.20	12.20		
Administrative	43		1.20	2.11	2.27	1.20		.70	2.27		2.27	2.27		2.27		2.20		1.27									1.27	1.27	1.27		
Inventory Cost		6.22	12.17	12.20	6.20	6.22	11.20	17.20	6.22		6.12	6.22	10.20	11.22	12.20	12.20	12.20	12.20	11.20	12.20							12.20	11.20	12.20		
Selling	50		1.21	.20	1.24	1.21	.20	1.20	.20	1.21		1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21							1.21	1.21	1.21		
Loading	52		.20	.70	.20	.20	.20	.20	.20		.20	.20	.20	.20	.20	.20	.20	.20	.20	.20							1.20	.20	1.20		
Total Cost at Yard		16.78	14.00	15.27	16.22	11.20	12.20	16.22	16.12		16.20	11.20	11.20	11.21	12.20	12.20	12.20	12.20	12.20	12.20							12.20	11.20	12.20		
Sales Price at Yard		15.20	12.70	16.20	11.20	6.20	16.10	12.10	12.70		12.20	12.20	12.20	12.20	11.20	11.20	12.20	12.20	12.20	12.20							12.20	12.20	12.20		
Profit per M		1.20	.20	1.12	.20			.20	.20		.20	.20	.20	.20	.20	.20	.20	.20	.20	.20							.20	.20	.20		
Loss Per M		N/O					1.10	1.20	2.21					1.21	1.20	1.21	1.20	1.21	1.20	1.21							1.21	1.20	1.21		
		N/O					N/O				N/O			N/O		N/O		N/O													

		SUMMER YARDS														DOWN DRAFT KILNS															
Code No.	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	
Annual Output in Millions	3	6	10	6	5	7	7																								
Clay Mining	20		.05	.20	.40	.45	.20	.20	.20	1.00				.25																	
Transporting	21									.20																					
Brick Making	22		1.27	2.20	1.12	1.17	1.21	1.20	1.27	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Drying	23		1.21						1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21
Stacking	24		1.11	1.23	1.16	1.06	.20	1.20	.20	.21	1.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20
Burning	25		4.10	6.20	2.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Yard Overhead	40		7.20	6.20	6.21	6.20	7.20	4.10	4.12	6.20	4.70	7.20																			
Total			14.72	18.47	12.70	11.12	12.24	11.22	12.21	12.20	12.20	12.27	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20
Administrative	43		2.70	2.20	2.22	2.24	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20
Inventory Cost		14.20	17.42	11.22	10.12	12.20	14.20	12.21	12.17	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20
Selling	50		1.20	1.20	1.20	1.21	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20
Loading	52		1.24	1.40	1.20		.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20
Total Cost at Yard		16.22	19.22	14.12	12.22	14.12	14.20	12.21	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20	12.20
Sales Price at Yard		14.20	17.21	20.20	12.17	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22	12.22
Profit Per M				2.20		1.27	.27	.24			.20	6.11																			
Loss Per M		1.21	2.21		.20			1.20	7.20																						
		N/O																													

N/O—Plant Not Operating.

N/B—Operating Not Burning.

\* Yards were Shut Down for Repairs.

cost was taken to be determined by wages and fuel. Allowing 25 working hours and 7-10 cwts. of coal per 1,000 bricks (the coal was admittedly of inferior quality), an overhead of 54 per cent. was allowed as a proper charge. This 54 per cent. overhead was made up as follows :—6 per cent. machinery repairs ; 5 per cent. oil, grease, leather, tools and lighting ; 4 per cent. administration and salaries ; 2 per cent. travelling, telephones, printing and miscellaneous ; 3 per cent. fire insurance ; 3 per cent. raw materials ; 1 per cent. breakages ; 2 per cent. bad debts, rebates, penalties, etc. ; 2 per cent. railway siding (maintenance and fees) ; 20 per cent. income, land and building taxes, unemployment and health insurance, workmen's compensation, corporation tax, professional and trade association fees, etc. ; 2 per cent. depreciation ; 2 per cent. repairs to kilns and buildings and 2 per cent. welfare services.

Individual factors of cost are meaningless without comparisons of equipment, mechanical handling processes, etc. Such comparisons are dealt with more fully in Part II of the Report. The general conclusion that emerges is that where labour is cheaper and fuel is expensive, efficiency can be achieved by hand-operating processes with a chain of unit plants of moderate size ; where labour is costly and fuel is cheap, the highest form of efficiency is attained by mass production in single unit plants.

An item in the economic structure of the industry is its method of finance and banking facilities. It would appear that funds are more easily available on the Continent and in the United States for reorganisation of industry than they are in the United Kingdom. Payments on account of reparations have also facilitated reorganisation in some Continental countries.

## 5.—TRANSPORT

There is no doubt that the development of modern transport systems has assisted in the transformation of the brick industry. The once universal small works serving local building sites, and sending materials by horse-drawn carts, is now at one extreme of the range of units comprising the industry. At the other end, is the huge combine designed for mass production and wide-distribution of products by rail, road or water. Bricks are heavy, and, despite modern transport facilities, their weight still determines the dimensions of the market of any particular firm. In America, for example, it is estimated that about 28 per cent. of the amount for which bricks are sold at destination is freight.

### *Railways*

In England considerable quantities of brick are transported by rail. Thus, in 1929, the railways carried about 5,700,000 tons—bricks, blocks and tiles. Many works have their own railway sidings.

It should be realised that under the principles now guiding the fixing of railway rates, goods are classified on a system based principally on their value or ability to pay, but conditioned to an extent which varies considerably with different goods, by their convenience of carriage. The present classification and system of rates and charges based thereon may be said to be a combination of value, packing and weight. Exceptional rates are freely quoted, but such rates must not be less than 5 per cent. or more than 40 per cent. below the standard rates without the approval of the Railway Rates Tribunal.

The classification of bricks in the General Railway Classification as determined by the Rates Advisory Committee, in accordance with Section 29 of the Railways Act, 1921, is as follows :—

Building, <i>solid</i> , not glazed or enamelled—	
Clay, common .. ..	Class 5 (6 ton lots and upwards)
Fireclay, common .. ..	„ 7 (4 tons)
Quartzite rock (Gannister) .. ..	„ 10 (2 tons)
Building, <i>hollow</i> , not glazed or enamelled—	
Clay, common .. ..	Class 6 (6 tons and upwards)
Fireclay, common .. ..	„ 7 (4 tons)
Quartzite rock (Gannister) .. ..	„ 10 (2 tons)
Building, salt glazed .. ..	Class 6 (6 tons and upwards)
	„ 7 (4 tons)
	„ 10 (2 tons)
Glazed or enamelled .. ..	Class 7 (4 tons)
	„ 10 (2 tons)

NOTE.—If not in casks or cases, salt-glazed bricks and glazed or enamelled bricks are carried as damageable goods not properly protected by packing.

An analysis of the traffic invoiced by the railway companies during the week ended 24th March, 1928, shows that the average lengths of haul of brick traffic and the average receipts for that period were as follows :—<sup>(34)</sup>

TABLE XIII.—*Brick Traffic on Railways, 1928*

	Average length of haul	Average receipt ton-mile	Average receipt per ton
	Miles	Pence	s. d.
Bricks in Class 5 .. ..	62·70	1·38	7·2
Bricks in Class 6 .. ..	74·24	1·55	9·7
Bricks in Class 7 .. ..	98·55	1·74	14·3

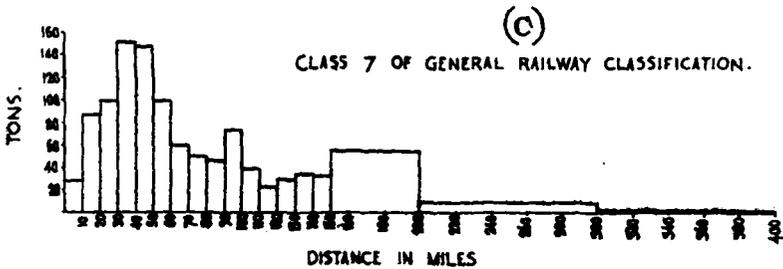
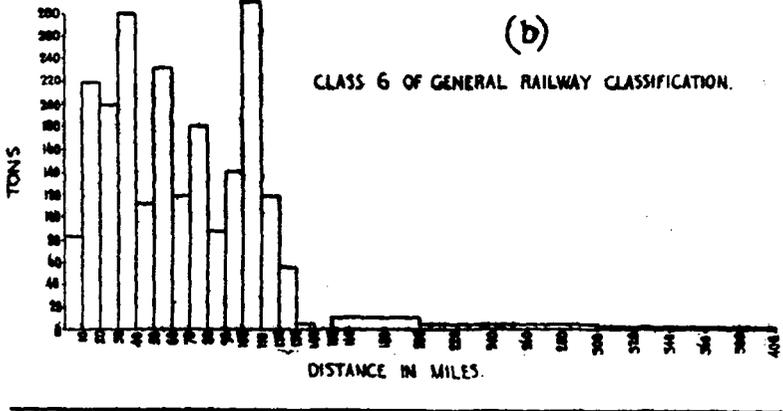
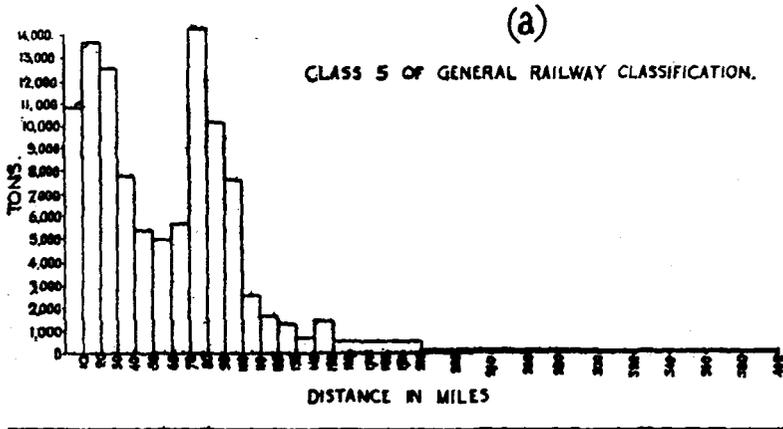


FIG. 4.—Railroad Transport of Bricks in Great Britain.

It is of interest to consider the number of tons of bricks of the various classes sent by rail to distances (station to station) of 1-10 miles, 11-20 miles, 21-30 miles, and so forth. The numbers are plotted in Figs. 4a, b, c. It will be seen that the "popular" distances for class 5 bricks fall roughly into two ranges 1-40 miles and 71-100 miles; for class 6, there are several ranges of distance which are

very popular ; most of class 7 bricks are hauled between 20 and 60 miles.

It is rather surprising that railway transport is still used to such an extent for small haulages (1-10 miles). More recent figures would, however, probably show the modern development of heavy road traffic. On the other hand, it is noticeable that freightage remains a barrier to long distance transport, so that the local character of the brick industry persists as a strong characteristic despite certain important exceptions.

The sizes of trucks used in England are probably smaller than those used on the Continent and in America. The maximum for mineral transport is about 20 tons, as compared with 30 and sometimes 50.

The introduction of containers, which are provided by some English railway companies, is being taken advantage of by several brickworks. These containers fit into the trucks and can be taken out and placed on lorries, thus helping to minimise risk of damage and reduce the amount of handling.

On the Continent, the use of railways for transport of bricks depends very much on local conditions. In Germany, Switzerland and France, the conditions are, perhaps, little different from those in England ; but in Holland the canals and rivers are excellent lines of conveyance. On the Belgian littoral the bricks for export are delivered direct on to barges and steamers.

In the United States of America it would appear that about 10 per cent. (say 400,000 carloads) of common brick are sent by rail and 95 per cent. (say 165,000 carloads) of face brick. But road transport is becoming more competitive.

For special wares straw packing and heather are often used in England. In America special paper (e.g. indented paper separators) is sometimes employed to ensure against breakage ; or again steel strapping.

### *Roads*

The number of goods vehicles in England has arisen from 151,000 in 1922 to 334,000 in 1930. Of this increase, the greatest part seems to be due to the growth in the number of vehicles owned and operated by manufacturers and traders for the haulage of their own products, and in the number of contractors working exclusively for particular trades.

Road transport of brick is much used in England for hauls up to 50 miles, and even for longer distances. A few works have abandoned railway transport for short distances, despite the fact that they have their own sidings. But no exact statistics are available and it is impossible to compare charges with those of the railways.

According to evidence given before the Royal Commission on Transport, 1931<sup>(35)</sup> the long distance road haulage of the transport

industry has developed in well-defined sections which (excluding trading concerns with fleets for operating their own haulage) may be summarised as follows :—

- (1) Well-organised companies owning fleets of vehicles.
- (2) Owner drivers or individuals operating two or three vehicles.
- (3) Clearing houses.

The first group are well organised. In the second, the owner driver " is almost forced to accept any rate that may be offered and is certainly tempted to canvass for traffic at a rate which will obtain the traffic irrespective of whether the transaction is a paying proposition in the long run for himself." Prices are undercut. The position of clearing houses hardly calls for comment here. Generally, the conditions obtaining in the business of road haulage are seriously lacking in uniformity.

*Rivers and Canals*

A very small proportion of English bricks are transported by water, although it has been contended that canals offer the greatest potentialities for economic brick traffic. In Holland, the canals and rivers are extensively used, and river haulage is adopted in other parts of the Continent and in the United States of America.

6.—LABOUR CONDITIONS

*Numbers*

According to the Census of England and Wales for 1921,<sup>(30)</sup> the numbers of people engaged in the manufacture of bricks and tiles (not glazed) fire bricks and fire-clay goods were :—

TABLE XIV.—*Census of Occupations in England and Wales, 1921. Manufacture of Bricks and Tiles (not Glazed Tiles), Fire Bricks and Fire Clay Goods*

Occupation.	England and Wales.	
	Male.	Female.
1. Production. Repair and maintenance ..	38,770	4,703
2. Transport and communication .. ..	2,251	21
3. Commerce and finance (not clerical) ..	199	2
4. Professional .. .. .	25	—
5. Domestic .. .. .	26	60
6. Draughtsmen and clerical .. .. .	1,006	397
7. Warehousemen and packers .. .. .	186	63
8. Stationary engine drivers, &c. .. ..	1,548	—
9. Others (mainly labourers) .. .. .	7,907	232
Total .. .. .	51,918	5,478

These figures may be compared with the figures in the Preliminary Report No. 10 of the Census of Production, 1930,<sup>(1)</sup> which include also clay and enamel wares and show the average number of operatives and of administrative, technical and clerical staff employed in 1930 and 1924 and by firms that made returns in schedules for the Brick and Fireclay Trade in the United Kingdom.

TABLE XV.—*Persons Employed in Brick and Fireclay Trades, United Kingdom, 1930*

Persons employed	Males		Females		Males and Females	
	Under 18	All Ages	Under 18	All Ages	Under 18	All Ages
1930.						
Operatives (average for the year)	6,233	61,903	641	4,157	8,874	66,060
Administrative, &c. (as at October 18, 1930)	336	3,638	66	519	402	4,157
Total .. ..	8,569	65,541	707	4,676	9,276	70,217
1924.						
Operatives (average for the year)	7,819	57,495	1,000	5,684	8,819	63,179
Administrative, &c. (as at October 18, 1924)	466	3,910	92	564	558	4,474
Total .. ..	8,285	61,405	1,092	6,248	9,377	67,653

*Note.*—Allowances must be made for the fact that in 1930 only firms employing more than 10 persons made the returns and that some figures are still outstanding; approximately 3,800 should, therefore, be added to the total, making an aggregate of (say) 74,000.

### *Earnings*

The earnings in principal industries have been specially investigated by the Ministry of Labour, and summaries of the results are given in the 20th Abstract of Labour Statistics, 1931.<sup>(2)</sup> The figures given for the brick and tile trades show that the average earnings for the workpeople was 51s. 1d. to 51s. 2d. for the weeks in October during which the statistics were collected.

As already stated, national rates of pay are agreed by the Interim Reconstruction Committee (now the National Joint Industrial Council).

These awards and agreements indicate advances in June and November, 1918, in May and December, 1919, April and October in 1920, and on 6th June, 1924; reductions were made in May and October, 1921, in March and September, 1922, and in June, 1931. The cumulative effect of these changes has already been given (see p. 42). Although many firms who have not formally expressed their adherence to these awards conform to the arrangements, many others do not. In the North of England definite rates are laid down by trade unions for the various types of operatives employed. Large firms in the South of England draft their own schedules, sometimes dividing the men into skilled and unskilled categories, and allowing pay of the order of 1s. extra for night duty. Piece rates may amount to 16s. to 18s. a thousand, subject to a guaranteed hourly rate. Separate contracts are sometimes made for setters and drawers with a guaranteed minimum.

Various methods of payment are in force, in England as well as in countries abroad. These have been described earlier (see pp. 41-43).

### *Hours*

Forty-eight hours a week for day workers and 8 hours per shift for shift workers are those agreed upon or recognised by organisations and employers of workpeople in the brick industries in England. In some areas the hours worked in summer are longer than those worked in winter (e.g., 49 in summer and 45 in winter). Some instances have been noted where considerably longer working hours than the average are in force. It is very exceptional (except around Peterborough) for any operatives other than kiln-men to work night shifts.

### *Trade Unions*

Although hand brickmaking requires considerable skill, and within the brickyard the leading hands form a group of skilled, half-skilled and unskilled workers, yet brickmaking was always regarded in England as a "very mean employ," and the brick-makers had a worse reputation for violence than any other branch of the building trades. When machinery was introduced in brick-making in 1861, there was an outbreak of rioting and machine breaking. Very few of the men were admitted to the local clubs (the fore-runners of the trade unions), and the rest were sometimes little more than unorganised general labourers. Trade Unionism is still weak in the brickmaking industries, except in one or two districts in the North of England. Such operatives as do belong to unions are in the General Workers' Union, or, exceptionally, e.g., around Bristol, in the Dockers' Union.

As in the brick, pottery and clay industries as a whole, there were **six** registered unions at the end of 1930, with 19,924 members and an income of nearly £30,000, most of them presumably related to the pottery industries.

Trade Unionism is similarly weak in Continental countries and **in** the United States of America, save in special areas, for example, the Boom district of Belgium and around Chicago in the United States. The working agreement in force in the Chicago area covers every detail of production and lays down stringent provisions.

### *Recruitment*

For certain grades of manipulative skill some difficulty is being experienced in securing the right type of labour in England. In hand-moulding processes it used to be customary for the son to follow his father's calling. But this sequence is becoming less common. Again, the firing control of some kilns requires a special technique based on experience, and new recruits are becoming scarce.

In France there has been no unemployment, and even a serious dearth of workmen for the brick industries; Chinese labour is occasionally employed and immigrants have been attracted from Jugo-Slavia, Czecho-Slovakia and other countries to supplement French operatives; Italian labour is less easy to obtain than formerly. It is of interest to note that where negroes are employed in American brickworks they are usually about the same in numbers as white workpeople, and receive the same rates of pay.

Boys and women are occasionally employed in England for machine operations, e.g., taking the bricks off the moving band. But the extent to which they are employed in this way is far less than that in certain parts of the Continent, e.g., around Antwerp and in Switzerland.

Apprenticeship to the brick trades does not call for special comment.

### *Welfare Conditions*

Workmen in Great Britain are, of course, participants in benefits under the Factory Acts, Workmen's Compensation Acts, Widows' and Orphans' and Old Age Insurance, as well as Unemployment and Health Insurance schemes.

A question which has aroused some discussion is whether the regulations in regard to silicosis apply to brick manufacture, but, subject to a decision in law, it would appear that this is not the case, except in the manufacture of silica bricks.

State schemes of social services have not been developed on the Continent or in the United States of America to the same extent as in Great Britain. Family allowances have, however, been introduced in France and Belgium. In Germany, there is a highly-developed system of social insurance covering invalidity and old

age, sickness, accident and unemployment, together with an extensive system of poor relief.

It may be mentioned that in some works which operate seasonally on the Continent, workers leave the brickworks during the winter months and return to agriculture. In one district in Belgium these workers receive unemployment pay from the municipality during these slack seasons.

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## Part II—General Processes of Manufacture

### 1.—RAW MATERIALS

**A**LTHOUGH it is probably true that a good brick can be made out of any material of a clayey or shaly nature, in the present state of knowledge the methods which would have to be adopted are not always economically practicable, and the clays which can be commercially exploited for the manufacture of bricks have, despite their abundance in England, a fairly restricted occurrence. It should be borne in mind that it is not advisable to instal works on deposits which are of inferior quality or which contain notable proportions of impurities of a harmful character.

Brick clays may have a wide range of composition, texture and physical properties. They include, for example, such extremes as very plastic Ball or London clays, and sandy marls and alluviums which barely cohere when squeezed in the hand.

In the manufacture of facing bricks, it is preferable if a single clay can be satisfactorily used, but some amount of blending is frequently required. The same is true, too, of common bricks, but in this case economic considerations rarely allow of blending being done. It may happen that the general run of the pit will give a blend sufficiently uniform throughout to be used, or different seams may have to be extracted separately and used in different proportions; sometimes, too, small quantities of foreign materials are added for different purposes; and there is the occasional necessity of separately extracting and rejecting deleterious materials such as flint, limestone, sandstone and iron ore.

The chief objects of blending are :—to secure sufficient plasticity to enable the bricks to be formed conveniently; to enable the bricks to dry rapidly and evenly; to produce a mixture which will bond at a reasonably low firing temperature; to produce particular textures and colours; and to counteract harmful ingredients which may be present in the clay.

All clays undergo contraction between the wet and the fired conditions; consequently a knowledge of the shrinkage in the various portions of the process of manufacture is necessary in the blend of clays for any type of ware. It is characteristic of clays that shrinkages that may be expected or known to occur bear some relation to the geological age of the deposits. Alluvial clays and clays with the free silica present in relatively large grains shrink more in drying than other deposits, and when burned do not shrink or sinter. The marls and shales on the contrary, of the Tertiary and Carboniferous periods, shrink less in drying and a good deal in burning, it being necessary to ensure complete sintering.

The constitution of clay is still unknown. A theoretical substance "clayite," which has sometimes been identified with the mineral kaolinite, has been postulated as an essential constituent of all clays. Kaolin, however, is very different from ordinary clays in many respects, particularly in its low plasticity. Indeed, the characteristic properties of common clays, on which their commercial development depends, must be derived, at any rate in great measure, from the minor constituents or essential impurities which they contain. These constituents are, for the most part, lime, magnesia, alkalis, iron and silica, but very little is known of the form in which they exist in the clay. They act as fluxes and lower the fusion point of the "clayite," and so enable the material to be burned at a lower temperature, and they also impart characteristic colours to the finished ware.

Although the minor constituents mentioned are essential to the commercial value of a clay, they may easily become injurious if present in too great quantity, or in the wrong form, and there are other impurities which may make a clay very difficult to work, if not actually useless. As a part of the technique of brickmaking consists in the proper manipulation of these impurities, it is desirable to give a brief account of the manner in which they may act.

Lime may be present in an extremely finely-divided form evenly distributed throughout the clay. In this state it is harmless. Sometimes it is intentionally added to the clay, in the form of a suspension; it may act as a flux, or help to produce a particular colour, or to flocculate a highly plastic clay and so improve its working qualities. Frequently, however, it occurs in the form of carbonate, in masses, as calcite crystals, fossils, nodules or concretions, and is then very troublesome. On burning, the carbonate is converted into quicklime, and the quicklime, in the course of air slaking, is gradually converted into hydrate with a considerable volume expansion, which often results in shattering the brick. Unless these carbonate impurities can be removed in any way, the clays in question require very fine grinding for their successful treatment. Lime may also occur as calcium sulphate (gypsum or selenite). So compounded it usually remains unaltered in the finished brick, in which case it may be a potential source of fluorescence, or, if the firing temperature be high enough, a part may decompose, yielding lime; instances are met with in which the original sulphate is in large fragments and the lime produced slakes in the air with the results described above. Another action observed with insufficiently ground sulphate is that this material, which is dehydrated during firing, rehydrates on exposure to the atmosphere, with expansion and disruption of the bricks.

Magnesium appears to be of less general occurrence than the other accessories, but may be the cause of very troublesome fluorescence.

Alkali compounds are generally present in the clay and sometimes in the tempering water. They are important as fluxing agents, but are also a frequent cause of dryer scum, kiln scum and floescence.

Silica occurs naturally in most clays either in an extremely finely-divided form intimately associated with the clay particles, or as a sand.

Iron is one of the most valuable of the essential impurities. It is responsible for most of the colour variations obtained, and acts as a flux without, generally, having an injurious effect. It may occur in various states of chemical composition and of subdivision, and on these, rather than on the total quantity present, depends the colour of the final product. Some clays, however, contain iron in the form of sulphide (pyrites), which is a frequent source of trouble; it may give rise to sulphurous gases during firing and so cause scum on the surface of the bricks; it may produce unsightly black specks in the brick, or help to form "black core"; or, if the brick is not sufficiently oxidised in burning, may lead to the formation of ferrous sulphate, and consequently to the rust-staining of both bricks and mortar.

Various foreign materials are used for special purposes. Sand is often added to a clay in order to control the workability of a batch, and, by giving a more open texture to the brick, to facilitate the operations of drying and burning. On heating, however, sand undergoes certain crystalline transformations; the resulting products are, under certain conditions, rather unstable and may cause cracking while the bricks are cooling. It is for this reason, and partly on account of the difficulty of grinding to the requisite fineness, that sandstone nodules which may occur with the clay are frequently rejected. In hand brickmaking, sand is used to dust the moulds, so that the bricks may leave them properly when moulded and retain sufficient on the surface to give the characteristic bloom. In a good moulding sand, the shape and size of the grains should vary within reasonably narrow limits. With most facing bricks the sand also serves the purpose of imparting the desired colour. Sands with suitable properties appear to be rather scarce, and often have to be transported considerable distances. In one type of brick, macadam road sweepings (which are rather expensive) are said to be the only known material producing the particular effect desired. Chemical stains, such as spent oxide of iron and manganese oxide, are often added to the moulding sand or even to the clay.

Another ingredient of some bricks is breeze or coal residues. In London stock bricks, breeze is added purely for its fuel value; it is obtained from house refuse, and is consequently of very variable quality. In other cases the breeze is added primarily to reduce burning costs but also to impart a dark colour to the finished brick, due to its reducing effect on the iron content. Generally, ordinary

commercial breeze is used for the purpose, and the nature of the breeze may affect the quality of the brick.

In making facing bricks from marls, barium carbonate may be added to prevent the formation of scum in the dryer or kiln, although its efficacy in the latter is open to dispute. Both the ground mineral and the precipitated synthetic material are in use and are generally added dry to the raw clay. Owing to the extremely low solubility of barium carbonate a large surface factor is necessary to ensure efficient operation, and for this reason, only the precipitated material is of real value in brickmaking. The use of a barium suspension in the tempering water is more satisfactory.

Grog is usually burnt clay which is added to the raw clay batches instead of sand to form a matrix round which the plastic clay can contract. This enables a considerable amount of control to be exercised over the porosity and other properties of the ware. In this respect it is similar to sand, but is free from the defects of that material. In England the grog is obtained mainly from kiln wastage, and though its use is practically confined to the manufacture of special material such as architectural terra cotta, it is sometimes used in building bricks, e.g. to blend in with the batch for grinding when the raw clay is rather wet.

Argillaceous beds of all geological ages, from recent Alluviums down to Coal Measure Shales are used in England. The earlier Palæozoic rocks appear to be almost untouched. So far as it has been possible to ascertain, the oldest material which has been tried is a Cambrian shale; at Stockingford, near Nuneaton, where there are the remains of an old roofing tile factory situated on a bed of Cambrian shale, the smallness of the excavation suggests that the works had only a very short life, and an existing firm in the neighbourhood reports that when they extended their excavations and included this shale, they had a great deal of trouble in drying and burning their ware, and had to discontinue the use of that particular bed. The use of an Old Red Sandstone clay in South Wales is also reported.

The conditions appear to be similar in Western Europe, where all the works visited were using deposits of Carboniferous age or later, with the exception of one firm manufacturing mainly paving bricks from a Devonian shale. It might seem from this that the oldest clays are not suitable for commercial development, but it is conceivable that they might be made so by specially designed methods of preparation. In North America, older rocks dating at least to the Ordovician period are used extensively, and it appears, from recent literature that a Cambrian shale is being used for glazed wares.

Another striking feature about American practice is the very extended use made of fireclays of varying degrees of refractoriness, either alone or blended, for the manufacture of facing bricks; the use of this material greatly extends the range of colours available. (See p. 10.)

Occasionally, waste materials are utilised for the manufacture of common brick. Thus in parts of the Black Country, e.g. in the neighbourhood of Dudley and Wednesbury, practically all the common bricks are made from waste shale heaps from old ironstone workings; not only is the gathering of the material very cheap, but the carbonaceous content of the shale is sufficiently high to reduce appreciably the fuel costs of burning the bricks. Another example of waste utilisation is afforded by the manufacture of common bricks by fire brick manufacturers; it sometimes happens that a good fireclay seam is too narrow to enable it to be profitably extracted for its own value, but by utilising inferior material adjacent to it, the exploitation of the fireclay seam can be made profitable. Similarly, in colliery areas, shale which would otherwise be wasted, is ground with mine refuse, etc., and made into bricks which sell very cheaply. (It should be noted, however, that modern methods of coal mining have had the effect of reducing, almost to the vanishing point, the amount of shale brought to the surface. It is the more general practice now to leave the shale, unavoidably dislodged in coal winning or gallery piercing, in the workings.) In another case, the argillaceous washings and overburden from a gravel works are being used; here the disposal of the waste presented considerable difficulty, which was overcome by allowing the clay to settle out of the washings in "wash backs," until stiff enough for use in brickmaking. Another interesting illustration is afforded by a works near London, on which the land was nearly exhausted. The pit was filled with London clay from the excavations for an underground railway, and this is now being worked by means of a special plant so long as the dump remains. A similar use might be made of waste fireclay material in England. In Belgium, a large cement works is finding a profitable use for its thick clay overburden in the manufacture of bricks.

The added materials have already been described, and there is no marked difference in any of the countries visited. The main variation is to be found in clamp-burned bricks. In some French and many American works, no fuel is added to the green bricks, except perhaps for the outside twelve inches of the clamp. Chemical stains appear to be used abroad rather more than in England; thus in Germany various forms of iron and other metallic residues are used in manufacturing the special "klinker" brick, and in North America extended use is made of manganese, particularly in conjunction with the light burning fire clays, to produce mottled effects.

There is considerable diversity in the sites on which brickworks are erected. The governing factor is mainly, of course, the available clay, and most works are erected on the deposit to be used, but occasionally the location is naturally dictated by transport facilities or proximity to a market. The last is an important factor in America, where works are often established some distance out of a town, in the direction of probable future development, and in many such cases existing transport facilities are rather poor.

## 2.—EXCAVATION

The great bulk of clays used for brickmaking are obtained from open pits and quarries, but occasionally, particularly when fireclay is used for facing bricks, recourse must be had to mining; in some areas, too, shale from coal mines, which would otherwise be a dead loss for excavation, is used for common bricks.

Where the geological structure is complicated, or where for any other reason careful selection is necessary, hand getting is the general practice, but otherwise mechanical excavators are in fairly common use. When the material is sufficiently soft, the pit face may be attacked direct, in which case the machine may be of the cable type, or, if the nature of the ground be suitable, a dredger or bucket type can be used. These machines have the great advantages that they scrape a uniform sample from the whole face of the pit, and gather the material in small fragments in good form for subsequent stages of preparation. When it is possible to attack the clay from the surface, ditching machines and plough-shovel or scraper tractors can be used satisfactorily under certain conditions.

Power shovels and grabs are perhaps the most used forms of excavator, the latter being employed mainly to gather material which has been previously blasted. These machines are economical to work, and can often be manipulated to extract large boulders which would otherwise have to be removed by hand, but they suffer from the disadvantages of less even sampling, and throwing more work on the crushing and grinding equipment.

Any of the above machines can be used for the removal of overburden. Stripping is also occasionally done by a hydraulic jet.

In the majority of the English works visited there is no appreciable overburden, but occasionally there is a thick covering, the disposal of which may present a serious problem. Apart from the expense of removing and dumping large volumes of useless material, the overburden sometimes consists of matter which would be injurious to the clay, and then great care is necessary to remove it completely without contaminating the underlying beds. Sometimes the sale of a part of the overburden will pay for the complete cost of removal and occasionally the whole can be disposed of at a profit; in one works the overburden was being sold as washed sand and gravel and gave a net annual profit of about £500. Generally speaking, however, it is rarely that the overburden can be used: with one large firm making pressed bricks, the cost of removing and dumping the overburden is often higher, per tonnage, than that of winning the brick clay and carrying it to the mill; this material might possibly be dried out at very little extra cost, and treated in the same way as the main clay. If land is leased on

royalty, the top soil, and overburden also if it is thin, is conserved, and replaced, as excavations extend on the floor of the pit, so that the land can again be used for agricultural or similar purposes after expiry of the lease.

In other countries, overburden appears to be a much more serious problem, and sometimes as much as 40 or 50 ft. has to be excavated, frequently at a complete loss. An extreme example is afforded by a Dutch works making a great range of quality of ware from facing bricks to glazed tiles, where about 35 ft. of sand and gravel are removed in order to obtain clay from a bed of 8 to 10 ft. in thickness. Another example is afforded by a common brick works near Berlin, with an annual output of between 5 and 6 million bricks, where from 4 to 20 ft. of overburden is hand excavated and washed. In North America, overburdens of up to 40 ft. in thickness are quite common, although a fair amount is disposed of at a profit. Excavation is entirely mechanical, and in two works visited gravel is washed away by hydraulic power.

Although in English brickworks overburden is generally less troublesome than it is in other countries, this is frequently more than offset by a complicated geological structure. In none of the foreign works visited were the beds at more than a gentle dip, while in some English works, strong contortions and faulting occur and the beds cannot be followed continuously for any appreciable distance. This may be to some extent the reason for the comparative rarity of mechanical excavators in England, but many pits have been seen where these appliances could be installed with advantage. Most of the excavators are of the navy or shovel type; a few dredger or bucket excavators are in use, while in the works visited drag lines were confined to the removal of the overburden. The general method in England is hand excavation with or without blasting, and with this is frequently associated the selection and rejection of impurities; in common brick works, however, impurities such as limestone fossils and selenite which occur in small individual amounts, but sometimes in appreciable aggregate quantity, are often gathered in with the clay, and eventually find their way into the bricks, except for a few more prominent lumps which may be removed by hand from the grinding pan. In Continental works, hand excavation is still adopted to some extent, but mechanical appliances are very largely used, even in quite small works. In one Swiss works, where excavators were considered impracticable, pneumatic spades have recently been tried out with success, and their use is being extended. They are used to a limited extent in England. Pneumatic drillers are also finding increasing employment in connection with blasting operations.

In American practice, excavation is complicated by the fact that fireclays are extensively used in facing brick manufacture, and the material is mostly mixed, although sometimes this is partly

compensated for by the fact that the associated coal can be satisfactorily used in the kilns. In one case the fireclay mine was 50 miles away from the yard. Hand excavation is used to a small extent only, mainly for the loading of hard shale, which requires blasting; a notable exception is found in the State Penitentiary plants where labour is plentiful. Excavators are occasionally used in series, two or more machines dumping the clay on to a composite pile, where it is roughly mixed and moved by a mechanical grab for loading. There appears to be a tendency to replace navvy excavators by shale planers and the like where the clay is suitable; one firm reported that three men and a planer removed 400 tons of clay daily against 250 tons gathered previously by three men and two steam shovels, and at the same time the grinding costs were reduced 50 per cent. owing to the finer state in which the clay was delivered to the mill. Surface clays, which are extensively used in parts of the United States, are won by a simple excavator or ditcher, drawn by tractor or mule. In a few common brick works along the Hudson River, part or the whole of the clay is obtained by dredging the river bottom; although at these points the river is tidal, and the water appreciably saline, the salt content does not appear to have any effect on the clay, and the river mud bricks are indistinguishable from those made from pit clay.

There are pronounced differences in the conveyance of the raw clay to the mill. In England, when mechanical transport is employed, cable or chain hoists are predominant; on the Continent cables and small locomotives are used about equally, while in America petrol or steam-drawn cars are favoured.

### 3.—WEATHERING

In the earlier days of brickmaking, it was the invariable custom to expose all clay to the weather for a period before commencing actual brick-making operations. An Act of Edward IV in 1477 made it compulsory on tile makers to weather their clay from November to March, while according to a Proclamation of Charles I, in 1625, earth for brickmaking was to be dug "between the feast of St. Michael the Archangel and St. Thomas the Apostle." 10 George III, c. 49, consolidating previous Ordinances governing brickmaking, states that "all clay which shall be dug in England to make bricks for sale shall be turned up between the first day of February and the time of beginning to make such bricks," while London brickmakers were allowed to dig clay at any time, provided it was turned once before being used.

At the present time, weathering is becoming rare and used only in hand moulded facing brick manufacture of seasonal type. The "turning" to which so much importance was attached, is only rarely carried out.

To obtain the maximum results from weathering, the clay should be exposed in small heaps, not more than two feet high, and turned over at intervals, the clay being watered in dry weather, so as to expose it equally to the action of the atmosphere. When this is done for a lengthy period (which may range from six months to two years, according to the nature of the clay) it produces three results. The clay is broken down into small lumps which permit of easy milling, the plasticity of the clay is increased, giving a better bonding in the final product, and part of the impurities is removed or made evident. The removal of a few of the impurities, such as calcium and sodium from complex silicates, is not of much importance to brickmakers, but finely divided pyrites may be converted into soluble iron sulphate and carried away, while the same mineral in massive form becomes coated with a hydrate of iron which makes it more conspicuous, and so more easy of removal.

In all countries weathering of the raw clay is diminishing, without necessarily being even partially replaced by extra mechanical preparation. In the south of England, the clay is usually weathered in fairly large heaps, but as it is turned over once or twice before the final preparation it becomes fairly well exposed to the elements and is weathered moderately well.

In other countries, too, weathering is almost confined to the clays required for special facing bricks or particular ware such as German "klinker" bricks. Sometimes it is retained for accidental reasons, as in the case of small seasonal works making facing and common bricks, where the clay can be won in the summer only, and has to be left throughout the winter for the next season's operations. One outstanding exception was found in a common brick works in Ohio, where the clay is weathered for six months because of the definite improvement effected in the quality of the product.

### *Sumping*

In a few places, clay is stored under water for a period or made into a slip, mixed with any necessary ingredients, and allowed to settle and consolidate in large "backs" or pits. Such clays when stiff enough can be made into bricks without any further preparation. This is the common practice in the manufacture of London stock bricks, but otherwise was observed in only two works, one in England utilising washed clay from a gravel pit, and in a small face brick works in France.

## 4.—PREPARATION

When considering preparation proper, it is necessary to distinguish between common and facing bricks, and also between the different methods of manufacture. The stages of preparation may be grouped broadly into grinding, screening and tempering, and the degree to which each is carried out depends upon the manufacturing

process to be adopted, and this is, in turn, largely dependent on the working properties of the clay.

The different methods of manufacture may be classified as follows :—

- (a) Hand moulding.
- (b) Full plastic or soft mud (mechanical) manufacture.
- (c) Plastic wire-cut or stiff mud.
- (d) Stiff plastic.
- (e) Semi-dry-pressed.
- (f) Dry dust.

The essential difference in the clay batches required for each of these processes lies in the amount of water present in the clay or added as tempering water during manufacture, but it is impossible to draw any sharp boundaries between the various divisions. The amount of added water required depends on the nature of the clay, and has, in fact been suggested as the basis of a measurement of plasticity ; thus, one clay may become fully plastic when mixed with 15 per cent. of water, while another clay may require as much as 30 to 40 per cent. of water to reach the same consistence.

Most clays as delivered to the works, even when they have been subjected to efficient weathering, are too coarse for treatment without being reduced to a finer state of subdivision. Except when the clay has been won by a shale planer or bucket excavator, as mentioned above, the amount of reduction required is generally considerable, and it may be necessary to perform the crushing and grinding in two or more stages.

### *Grinding*

The efficiency of the grinding has a considerable effect upon the final product. It is essential, whatever method of manufacture be adopted, to have a considerable proportion of fine material present, as the fines help to secure a well bonded product, partly by filling the interstices between the larger grains, and partly because the finest material sinters more readily than the coarse and so enables coalescence of the particles to take place at a lower temperature, or, alternatively, allows a greater degree of incipient vitrification with the same heat treatment. On the other hand, an excess of fines must in certain cases be avoided, as it may greatly increase the drying difficulties, or result in too dense a brick. When fairly wet batches are used, the water tends to break up the clay and hold a sufficiency of fine particles in suspension, but with semi-dry-pressed bricks (see p. 84) the necessary fineness can be secured only by the grinding plant.

Of crushers, the jaw and single roll crusher are probably the most popular. Each of these forces the clay against a breaking plate, and the roll may be either smooth or lugged. Jaw crushers are suitable only for use with almost dry rocky marl or shale, while

rollers are capable of dealing with a larger range of materials. Other machines for this purpose, each with their own features for special conditions, are the double roll, ring roll, gyratory and hammer crushers; the ring roll crusher is used mainly in the later stages of grinding, while the last two are only occasionally found on brick-works. When the clay used contains an excess of stones and similar impurities it must be given a preliminary treatment in a clay cleaner or stone remover.

The final reduction in size usually takes place either in a pan mill, or in a system of multiple high-speed rollers, or combinations of the two are used at different stages.

Great contrasts are to be found in the general methods used in the grinding and allied stages in different countries. The slow-moving rollers so much used in English works are found in no other country.

#### (a) *Wet Grinding*

Some clays are sufficiently soft and easily worked as won to require very little treatment, and for these a wet pan is sufficient for the first stage of the preparation.

In England, the wet pan is sometimes of the solid bottom type with two heavy rollers or mullers, and water is added through a tap or hose at the discretion of the operatives. The general rule, however, is to use a pan mill with one or a number of grids in the bottom through which the ground clay is pressed by the rollers. On the Continent, the solid bottom pans are used about equally with perforated pans for wet grinding, and they are sometimes mounted vertically in pairs; in some popular forms a very effective result is produced by a heavy muller passing over a very thin layer of the clay.

Rollers running at high speeds are largely used for the preparation of soft clays: they are usually mounted in pairs, and are frequently in banks of two or three, with or without intervening treatments. In England, each pair rotates at slow speed. Continental practice is different. Rollers are frequently used in the first stage in the preparation, owing largely to the fine state of division in which the clay is delivered to the mill, and the rollers are usually independently driven at differential speeds and set very close together, revolving much more rapidly; this gives a very efficient tearing action to the mass, and results in a more intimate blending of the clay and water.

Many clays undergo these stages of preparation after preliminary treatment in the ways described later. This is particularly the case in North America, where direct wet grinding is rather rare.

#### (b) *Dry Grinding*

The predominant dry grinding apparatus is the perforated pan mill, of which several types are in use. The whole of the bottom may be perforated, alternate segments may be solid and perforated,

there may be a solid plate, with only one perforated segment of  $60^\circ$  or  $90^\circ$ , or the wheels may run on different tracks, the outer over a solid plate and the inner over perforations; the last appears to be the most efficient. In England the dry pan differs from the wet pan in that the pan revolves at a good speed, while the rollers revolve on a main shaft held always in the same vertical plane, but free to lift and drop in that plane. The rollers play on an inner ring of solid metal, while the ground material is swept on to an outer ring of perforated metal acting as a screen. Pieces of material too large to pass the perforations are swept back on to the inner ring for further grinding. On the Continent there is a distinct leaning towards mills of the last kind above mentioned. In North America considerable attention has been paid to grinding problems, and some interesting new machines have been developed within recent years, notably in the introduction of heavy-duty grinders and, more recently, a rim discharge grinder. The former, as its name implies, is a very heavy, large-capacity machine of great output, which is claimed to effect a great reduction in grinding costs; in one works, one of these pans, which had been installed four years, replaced five ordinary 9-ft. pans. The rim discharge grinder also results in appreciable economies; in two works where these had been installed in place of ordinary 9-ft. dry pans, the power consumption was halved in each case, and the output increased by 40 and 65 per cent., respectively.

In ordinary pans it is difficult to prevent the perforations from clogging if the material is damp. A reduction in output then results. This tendency can be partly reduced by tapering the perforations; when this is done, however, the gradual wear of the plate increases the size of the holes, and thus allows an objectionably high proportion of coarse material to pass. Other methods are adopted such as providing the plates with slots in place of perforations. It is also customary to form the outer ring of the pan with sections having varying sizes of perforations. The rim discharge grinder tends to overcome the defects of the English mill.

Roll ring pulverisers are used to a considerable extent in grinding the tailings from the screens, as they are found to give a higher proportion of fines and obviate clogging of the pan itself.

The use of high speed differentially-driven rolls is but slowly gaining ground in England, while on the Continent it is universal. Their efficiency is unquestioned and their adoption by English works should be much extended.

It is rather remarkable that, until quite recently, all the working parts of machinery have been fully exposed to the heavy dust of the grinding room, with a resultant reduction in efficiency and increase in wear and tear. But within recent years, enclosed gearings have been introduced. Although at present they are almost confined to America, their manufacture in England has recently commenced.

Another American feature in connection with the preliminary preparation of the clay, which may conveniently be mentioned here, is the development of stone removers. Owing largely to the prevalence of limestone pebbles in vast deposits of otherwise suitable glacial clays which occur in the neighbourhood of several large centres, e.g., Chicago, the satisfactory preparation of the clay presented a very serious problem. After several years' experimenting, the trouble appears to have been overcome satisfactorily. A good example of this was seen in two of the yards of one firm producing machine-made clamp-burned stocks. The clay, which is very bad, is almost identical in the two works. The introduction of the stone removers effected a considerable improvement, although small fragments which still remained gave occasional trouble; in one of the works a pair of very close-set high-speed differential rolls were installed after the stone removers, and these appear to have completely solved the problem. Several bricks were selected at random from three clamps; there was no sign of a lime-blow or of visible lime in the interior, and the sizes of all the bricks were remarkably uniform, being well within the usual limits of tolerance.

A brief description of these stone-removing machines may be of interest. Occasionally one sees conical rolls, either plain or grooved, similar to those in general use in Europe, but they are being replaced as a result of the success of the newer machines. In one very popular form, the clay is fed—usually from a crusher which separates out the large stones—into a special pug mill with a narrow mouthpiece and high-speed knives; this forces the clay against two smooth, cylindrical rollers, set one-thirty-second of an inch apart and working at the rates of 400 and 600 revolutions per minute, respectively. Directly between the pug and the rolls, at an adjustable distance from the latter, is a slow reciprocating prong, which flicks out the stones without removing any appreciable quantity of clay. Attached to a special shafting is an emery wheel, by means of which the wheels can be trued as required; on an average, each wheel requires two hours' attention per month.

The greatest difference between English and foreign practice, in this stage of manufacture, is in the method of feeding the pans. In England, except in newer works, the clay is generally tipped direct into the pan just as it comes from the pit, either direct from wagons or shovelled from a heap at the side; this places an irregular load on the machine, and greatly reduces the efficiency of the grinding. Occasionally pans are fed by mechanical means, such as conveyor belts, worm feeders, apron feeders or reciprocating plates, but although they have the advantage of supplying the pan continuously, the material is generally of very different sizes, and consequently the machine still sustains shocks. It is a general principle of all grinding methods that the best results are obtained by reduction in stages, but this does not seem to be sufficiently appreciated in the brick industry.

In all but four of the Continental works seen, mechanical feeders were in use, and in the two yards in which the raw clay was in large lumps, preliminary crushers were installed. The pan feeders were generally of the conveyor belt or apron type, and were themselves loaded from proportional feeders, which deliver from three to five ingredients in predetermined volumes. These machines are in use to a limited extent in England.

In the American works, mechanical feeding of the pans was universal, and stage grinding is the general rule. Sometimes the first stage takes place at the pit or mine mouth, a practice which was introduced at Ruabon many years ago, and for this a gyratory, cone or jaw crusher is generally employed; in the mill, jaw roll crushers, heavy kibblers and disintegrators are used. Enclosed pulverisers appear to be rather rare, but in some works the coarse tailings from the screens are returned to a roll-ring pulveriser or a disintegrator. In another works the final grinding of the coarse dry clay was done in high speed differential rolls. It is fairly common practice to have a separate machine for grading tailings, in order to avoid the inefficiency resulting from the simultaneous grinding of material of disparate sizes. A description of the grinding methods seen would not be complete without reference to a very progressive firebrick works, where the grinding pans were arranged in a closed circuit, the dust being collected and used. In one Canadian works, all grinding is done at night, in order to reduce the power cost.

An outstanding feature of American works is the large amount of storage room set aside for either lump or ground clay, or both. Even in works where excavation is carried out uninterruptedly the whole year round, storage capacity for three and four months' output is not uncommon. Besides helping greatly towards continuity of production, the storage of such large quantities results in increasing the homogeneity of the clay, particularly when there is a tendency towards appreciable variation in the beds. Different clays are invariably stored in separate bins and subsequently blended. A good example of this is to be found in a Pennsylvania facing brick works with a daily output of 50,000; the various shales are crushed at the mine mouth and fed on to a reciprocating plate feeder which discharges to a broad belt conveyor leading to a large store room in which each clay is stored separately. Four reclaiming belts are fitted under the floor, so arranged that any combination of belts can be used while the store is being filled; the clay is raked on to these belts as required, and raised to a belt conveyor feeding the grinding pan. In some works clay is gathered from the store by means of a grab bucket.

### *Screening*

Dry ground clay, as it comes from the pan, is always unsuitably graded, and the oversize material has to be screened out. There are three types of screen in use, fixed, revolving and vibrating. The

simplest is the fixed piano wire screen, which consists of a series of parallel steel piano wires tightly stretched on an inclined frame : it has the advantage of giving the highest output for the space occupied, but gives an inconstant grading and generally a rather high proportion of medium and coarse material. A logical development is the fixed mesh screen, in which the clay falls over an inclined woven or perforated mesh ; this gives better grading than the piano wire screen, but it has a smaller output, and requires more attention for cleaning. Both these screens should have baffle plates or similar means of distributing the clay evenly over the mesh ; the size of the product can be regulated by the width of the mesh and the angle of inclination of the screen.

Revolving screens are generally preferred in England. They consist of a revolving woven or perforated mesh mounted on a polygonal or circular frame, and set at a slight angle, whereby the clay travels down the length of the barrel by gravity. These screens have a large output, and can generally be kept clean by brushes or beaters permanently fixed outside the cages. Vibrating screens consist of meshes set at a low angle of inclination, the descent of the clay being assisted by a vibrating mechanism ; compound screens which grade the material into different sizes are occasionally found. These screens are generally the most expensive to install, but have a high efficiency ; in particular they produce a good separation of the finest material, a good proportion of which from other types of screen clings to the coarser material and is returned for regrinding.

Most screening plants are designed to return the tailings to the original grinding pan, but better results are obtained by using a separate grinding machine.

There are no very marked national characteristics with regard to screening practices except for a tendency on the Continent to cut out the screening stage and take the ground clay direct to the tempering plant ; this again is probably accounted for in part by the type of excavators used. In Europe generally, fixed screens appear to be most popular ; in England these are mainly of the piano wire or mesh type, while on the Continent, piano wire, mesh and perforated plates are used about equally. In America, most firms appreciate the value of the screening process, and favour the vibrating type.

### *Tempering*

An adjustment in the moisture content of a raw clay is always necessary before the material is ready for forming, and in plastic manufacture water usually has to be added.

As previously mentioned, the first addition of water takes place in the grinding pan, but frequently, tempering is done as a separate stage or stages ; the choice depends very largely upon the ease with which the clay and water combine, some clays requiring the heavy weight of a pan mill to produce an intimate mixture.

One of the earliest forms of machine is the tempering pan, in which the clay and water are churned up by means of four blades; it is satisfactory with only a very restricted number of clays, and is but rarely seen. The double shafted differential mixer is now almost universally employed for tempering; this machine consists of an open trough containing two shafts on which is mounted a series of blades which wedge the clay and water into a more or less homogeneous mass. In a few cases seen the mixer had only one shaft. Water may be added through a tap at one end, through perforated pipes at an end or along the barrel, or from a set of fine roses evenly distributed over the whole of the mill; the last method gives the most satisfactory results. Plain water may be replaced wholly or in part by a suspension of barium carbonate or a solution of a barium compound, although this, and other additions such as stains, are often added in the solid form to the clay before it enters the pug mill. The control of the water supply may be either manual or automatic. In some works the use of hot water for tempering has been introduced; certain advantages are claimed for this, such as superior bonding, ease of forming and more ready drying, but there is not at present sufficient experience on which to base any conclusions.

In the manufacture of semi-dry-pressed bricks, the tempering presents some difficult problems. Even under the most favourable conditions, the quantity of water to be added is so small that it is difficult to obtain a homogeneous mixture. For tempering the ground material a very fine atomised spray is necessary to prevent aggregation of the particles. A further and still more difficult problem, arises from the fact that in inclement weather, the clay, as won, is too damp for the pan mill. It is common practice in such cases to add some dry clay. The only really satisfactory method of tempering clays for the semi-dry process appears to be to commence with a wet clay, and to heat it until the moisture content is reduced to the required amount.

Mention must be made in passing, of the old custom of treading the tempered clay with bare feet, which, if still practised, persists only to a very small extent.

### *Souring*

A description of clay preparation would not be complete without a reference to the process of souring or ageing, although this is not often adopted in brick works practice.

The process consists in storing the tempered and pugged clay in the dark under conditions which prevent the evaporation of moisture. It tends to induce a more even distribution of moisture throughout the mass of the clay and an increase in plasticity; in some cases at least, the porosity and permeability of the finished body are definitely reduced. The process also affords an opportunity for the clay to settle down after pugging; with some types of clay this

is very important, as the clay when formed immediately after pug-ging without a rest period may develop defects such as pronounced warping and cracking during drying.

Souring was not regularly practised for brickmaking in any of the works visited, but occasionally a large batch of a particular blend of clay was pugged at one time, and so obtained an accidental souring period of a few days.

#### *Mechanical and Instrumental Control*

It is the general practice at present for the control of the various stages of the preparation to depend upon the skill and judgment of the different operatives. Even with the greatest knowledge and care, variations in the output are likely to arise, and it seems very doubtful if it will be possible adequately to replace the best existing craftsmen. The question of mechanical and instrumental control is therefore becoming of increasing importance. Unfortunately, the group of processes comprising the preparation stage is not so well adapted to control as some of the other stages, but a considerable improvement in uniformity can be secured with some of the appliances found in use mainly in America. The first of these is the automatic feeder, which by supplying material at an even rate, subjects the machinery to an even load, and leads to less wear than hand-fed machines with a constantly varying load. The feeders are generally of the apron, reciprocating plate, disc, screw or belt conveyor type according to the nature of the work they have to do. Automatic blending of materials can be obtained in a variety of ways. A highly esteemed type of machine on the Continent is one in which the lump clay is fed into a multi-compartment apron feeder, the output from each section being regulated by the height of the gate; the blended materials are then ground together. A simple form is a modified disc feeder; this normally consists of a revolving plate, which receives material through a central spout and feeds it through an opening in a surrounding drum; by placing the spouts eccentrically different materials may be drawn from storage and measured simultaneously. An improvement is the American poidometer, which may be used for clay or grog blending, but is more usually employed for the addition of chemicals such as barium carbonate or stains; the belt and its contents are weighed on a balance arm containing a weight which can be adjusted to the desired position; and there is a connection to a gate regulating the supply of material. Some of these machines have a liquidometer attachment, by means of which the supply of tempering water is automatically adjusted, in a similar way, to the amount of dry clay passing over the belt; some of the attachments are automatically compensating for the water content of the clay as delivered from the pit. Finally, the consistence of a batch in the mixer, if driven electrically, may be controlled by an ammeter fitted to the mill; the power consumed is in inverse ratio to the water content of the batch, and

once the optimum consistence has been determined for any clay, the mill can readily be run at this figure.

Of the above types of mechanical and instrumental controls few are to be found in English or Continental works, but they are finding a place in several outstanding American works.

## 5.—FORMING

It has already been mentioned that there are six methods of making bricks. These can be classified in three groups, which it will be convenient to consider separately.

### *Slop-moulding, Full-plastic Processes*

The oldest methods of brickmaking are by slop and full-plastic moulding, as these are the only methods suitable for hand making. Roughly speaking, in the former method the clay is mixed with as much water as it can hold without deforming when it is removed from the mould, while in the fully plastic methods, the tendency is rather to use the minimum quantity of water consistent with an easily workable mixture. Slop moulding requires more skill in moulding, and calls for a longer drying period, but a rather more uniform and better bonded product is obtained than with the full-plastic methods; the art of true slop moulding is nearly extinct.

The method of manufacture is practically the same in both cases. The tempered clay is heaped on the bench and a suitable wad is cut from it. This is wedged, or thrown on a sanded table and worked into a suitable shape, when it is thrown into the mould, which has been previously dipped in water or dusted with sand, or, very rarely, coated with oil. The excess clay is then removed with a wire bow, or a "strike" (a plain wood bar dipped in water) and incorporated with the next wad, while the green brick is transferred to a pallet, which is loaded on to a barrow and wheeled off to the drying ground.

The moulds are of wood or metal (usually the former) and are of two types, a stock mould, which consists solely of four sides, or a box mould, which is fitted with a bottom. The stock mould is by far the commoner, and is usually placed on the bench round a small raised platform (the "stock"), on which is a raised rectangular slip to form a "frog" or panel on the brick.

The traditional arrangement, which is still found in some stock brick works, consists of a "full stool" of six, a temperer, moulder, flatty, off bearer, barrow loader and pusher out. This method gives very satisfactory results with a highly-trained team, working in close co-operation, but may easily become disorganised. Owing possibly to the shortage of learners, the stools are often much

reduced, and it is not uncommon to find one man doing all the work alone.

The large excess which is often thrown into the mould is generally considered necessary to fill the corners well, expel any air present, and give a good texture to the brick. A great deal of the art of rapid moulding lies in the successful manipulation of a small wad with the consequent reduction of fatigue.

It is doubtful if any real slop-moulded bricks are now made. The primitive methods followed in the Luton area for producing the characteristic Luton greys may be considered to fall into this category. The method has probably fallen into disuse because of the extra skill required in moulding, the longer time needed for drying the wares, and the tendency to get unsatisfactory surfaces on the finished bricks.

Generally, the tempered clay is carried by hand to the working bench, but in one works at least the pug mills are arranged so as to deliver the clay to the right hand of each moulder of a "stool." Apart from this, the methods of hand moulding, where practised in England and on the Continent, are almost identical in all works. In the United States of America hand moulding is unknown save where it is resurrected for a particular purpose, as in the copying of hand-made bricks for the rebuilding of Washington's birthplace in Virginia.

### *Soft-mud Process*

A fully-plastic batch also lends itself to machine making by what is called, particularly in America, the soft-mud process. In this a row of moulds is mechanically dusted with sand in a rotating drum and passed to a power-driven moulding machine. In one type the clay is delivered from a pug mill and wiped into the moulds, and in another the clay is forced in, by a piston motion. The moulds are inverted on to pallets, and the pallets carried away, while the moulds return for sanding.

The soft-mud process is only applicable to mild clays which require little preparation, e.g., the alluvial clays or clay washed out of sand and gravel pits, or dredged from river beds. This is the obvious process to select in the manufacture of London stock bricks by machine, instead of by hand. On the Continent, the process does not find much vogue, but it plays a big part in brick-making in the United States, particularly in the Hudson River area and in Kentucky, Ohio and Pennsylvania.

Although the methods are in essence the same, there is wide variation in the capacity of the different machines. Small ones take a row of three moulds, require about 5 horse-power to drive, and can make (say) 8,000 bricks a day. Large ones (generally in America, but there is one in use in England) take 10 moulds, require 75 horse-power, and make 120,000 a day. In the large units, the moulds are bumped mechanically so as to loosen the brick

from the moulds. No satisfactory method has, however, yet been achieved for feeding the pallets automatically to the machine, or for carrying them away after the bricks have been deposited on them from the moulds.

### *Plastic, Wire-cut or Stiff-mud Process*

In the wire-cut process, clay is delivered to an auger machine, or, as it is called in England a horizontal pug mill machine, in which it is conveyed by inclined knives forming a spiral and extruded through a suitably-shaped die at the end of a converging mouth-piece ; the continuous wad of clay thus produced is cut into brick lengths in one or more stages. The die is usually lubricated with oil, steam, or water, and the column may also be lubricated with water or oil on leaving the mouthpiece. In the older machines, a suitable length of column is cut off by hand, and rapidly transferred on rollers to a cutting table, where it is cut manually either by pushing the length of clay against a series of vertical wires mounted on a frame, or by drawing the wires down on the clays. In some side-cut machines, the final cutting is done in two stages, the first cut going about two-thirds of the way through the brick, and the second cut completing the forming and cutting through the next portion of the column, which has been brought against the side of the first piece ; this double operation is required by some clays which would leave jagged edges on the brick if the wire were to cut through an unsupported face. There are a few semi- and fully-mechanical cutters of this type. Their mode of action always results in end pieces of the cut length of column being surplus ; these end pieces are returned to the auger machine and incorporated in the oncoming batch.

Several automatic cutters are available which work directly on the complete column as it leaves the die. These are popular on the Continent and in the United States of America. One group of such machines cuts the bricks off singly, the speed of the cutting wire being governed by the rate of travel of the column, thus avoiding any wastage ; one machine of this type operates in connection with a mechanical loading device, by means of which the bricks are not touched by hand until they are dried and ready to set in the kiln ; other types of single-brick cutter consist of a wheel with the cutting wires mounted on the periphery. Another type, which is a development of the manual cutting table described earlier, consists of a long circular frame containing three sets of cutting wires radially disposed, and cutting up to 18 bricks at once.

When intended for use as facing bricks, the smooth surface of wire-cut bricks is frequently considered objectionable, and many devices to procure a mechanical roughening have been designed. These textures are applied to the column immediately it leaves the die. The appliances are very varied, and include such things as a rather loose wire cutting just below the surface, a series of metal

pencils, fixed on reciprocating scrapers followed by a roller, or miniature lawn mower blades ; sand may also be rolled or blown into the surface.

Unless proper precautions are taken, wire-cut bricks are rather subject to lamination. The action of the auger and expelling worm cuts the mass of clay just before it reaches the die. In certain clays the cut so made does not become obliterated by the pressing together of the clay "in the die." It therefore tends to open slightly during drying and burning, and so forms cracks in the mass of the finished bricks. These show on the bed of the bricks and take a quasi-curved form. They are called in the trade "core cracks." When a core-cracked brick is broken, the interior shows up the cracking still further in the form of laminations. The lamination is aggravated in some clays by the fact that the mass of clay rotates in the mouthpiece of the machine. In such cases, the laminations may sometimes be cured by grooving the mouthpiece in a direction parallel with the pug mill shaft. Various precautions have been suggested, such as de-airing the plastic clay, fitting wings at the end of the auger to counter-cut the clay and press the original cut faces together, placing baffles in the mouthpiece to equalise the speed of different parts of the clay column, and lubricating the mouthpiece by oil, water, steam, etc. The shape and dimensions of the worm and die box require to be modified, by trial, for each clay.

In wire-cutting machines, the pugging of the clay and its extrusion should preferably be performed by two separate units ; this separation of function is common in foreign practice, and is probably responsible in part for comparative freedom from laminations.

The wire-cut process lends itself to a fast rate of output. In the United States of America, with special geared machines and using a double column of clay, a rate as high as 42,000 an hour is being obtained. It should be pointed out also that in Continental "full-automatic" practice, the wire-cut bricks are conveyed automatically to pallets, loaded by special devices to the driers and likewise specially conveyed to the kilns.

### *Stiff Plastic Processes*

There are two distinct methods of manufacturing plastic pressed bricks. In one, the wire-cut brick, usually after a short drying period, is put through a re-press ; in the other, the clay batch is fed straight to the machine and is manufactured by what is known as the stiff plastic process. For pressed wire-cuts, particularly when the bricks are dried out to a semi-plastic consistence, a hand press is sometimes used. It is claimed that the hand press makes a better brick than the mechanical press ; there is definite advantage in being able to wheel the press to required parts of the drying shed, so that the bricks can be pressed and completely dried where they stand, thus saving transport and the consequent risk of damage.

For fully mechanical pressing, by which is meant the stiff plastic process—which is more popular in England than on the Continent or in the United States of America—there is a great variety of machines which for the most part differ only in minor mechanical details. The clay (usually a shale or hard marl) is ground to powder in the dry condition and then tempered. The batch passes from a mixer, or preferably, two successive mixers incorporated in the train of machinery, to a rough shaper, from which it is transferred to the die box and pressed. In some machines a second pressing is given, and as a longer pressure is often required for this, the machine is sometimes synchronised to press two bricks at once.

#### *Semi-dry and Dry-dust Processes*

The dry-dust process is used mainly for some floor and wall tiles, but is occasionally employed in the manufacture of special glazed bricks, by means of hand machines. Some paving bricks are made by this process on mechanical presses. Dry-dust is actually a misnomer, because even in the process called by this name the clay still contains sufficient moisture to ensure adherence of the fine particles when pressed. In the semi-dry process, the screened clay is collected from a hopper and automatically fed into a deep mould by a reciprocated container which passes under the press head. The pressing pistons of the moulds are heated, generally by steam, but occasionally by electricity, to ensure that the beds of the green bricks do not stick to them; pressure may be applied to the top, or top and bottom, and some machines are designed to give two or three pressings of different durations.

In a modern modification of this process which enables it to be applied to plastic clays, the raw damp clay is heated in a rotary dryer until the moisture content is reduced to the required amount, and is then ground; in this way wet plastic clays can be successfully formed by the semi-dry process, and the difficulty of obtaining a uniform moisture content by tempering the clay during the early stages is almost completely overcome.

There are certain difficulties connected with the process; for instance, to obtain a really dense body in bricks made by this process, a proportion not less than 25 per cent. of very fine clay should be present, and for the best results, the particle sizes of the batch should be proportioned according to the nature of the clay used; there is a great liability too, for air to be entrapped during the pressing, and to overcome this, pressure should be applied at properly designed intervals, or the forming should take place in a vacuum; finally, the semi-dry process gives normally a rather porous brick, and to obtain a degree of vitrification equal to that obtainable with a wire-cut brick of the same clay, a higher firing temperature is necessary. On the other hand, carefully made semi-dry pressed bricks, have the undoubted advantages of perfect regularity of shape and size. It would seem, on the whole, that

except in particularly favourable circumstances, the semi-dry process is not suitable for cheap manufacture in mass of common brick; the precautions which have to be taken, in other cases, make it economical only for facing bricks, paving bricks, glazed bricks or firebricks.

The extent to which the semi-dry process is applied varies in different countries (see p. 9). The Fletton brick in England is the outstanding example of a common brick made by this process.

## 6.—DRYING

The drying of green bricks is the first stage in their conversion into a durable form, and for the reasons touched on earlier, it is desirable that this drying should be as thorough as possible. In practice, the process is continuous, but actually, with nearly all clays, the drying takes place in two stages. The first of these is accompanied by a pronounced shrinkage, and the clay retains its dark colour; this corresponds roughly to the degree of drying known as "leather-hardness." In the second stage, during which the brick lightens in colour, moisture is expelled to a point at which it is in equilibrium with the surrounding conditions, while the accompanying volume change is nearly negligible. The ideal condition to be aimed at, particularly during the first stage of drying, is the maintenance of a low moisture gradient throughout the brick; otherwise unequal shrinkage resulting from different rates of drying will set up stresses which may crack or deform the ware. The addition of non-plastics, which was mentioned above (p. 66) in discussing the raw materials of the industry, serves to obviate, or at least minimize, these troubles; the open texture which they impart to the clay body permits a more ready movement of water (including water vapour) to the exterior, and also reduces the amount of shrinkage which can take place, as these materials undergo no appreciable volume change on drying. In general, the more plastic a clay, the more difficult is its efficient drying, but the behaviour of clays in this respect is very variable, and it has been found that two clays of identical chemical constitution may be at the extreme ends of a range of safe drying speeds. It has also been found that different drying schedules are required for the same clay when made up by different processes.

Several drying methods are available, and the choice depends upon a variety of factors, such as the characteristics of the clay, the nature and cost of the ware, climatic conditions of the yard, fuel supply and cost and character of the labour.

### *Natural drying*

The simplest of all systems, and one largely followed in England and on the Continent, even, sometimes, when the climatic conditions are unsuitable, is that of natural drying. This method is used

particularly on seasonal works, and drying is usually performed in hacks or on racks. A hack is generally in the form of a small raised platform about two inches high, often of brick or brick rubble and sand, on which the green bricks are set on edge in two rows, a variable width apart, to heights ranging from six to fourteen courses.

In order to vary the circulation of air through the pile when partly dried, and to give a more equal exposure of different parts of the bricks, the hack is "skintled" once or twice during the course of the drying; this consists in rearranging the bricks, or some of them, wider apart in diagonal fashion. In works which make only in spring and summer, but burn throughout the year, bricks intended for winter firing are usually hacked much more openly, and are sometimes stored in sheds in a dry condition until required in the kiln.

Protection from the elements is usually obtained by permanent or portable roofing of timber, felt or straw, with portable side screens of reeds, straw, &c. The taller hacks are usually built up in permanent sheds, and in these the bricks are not skintled. When natural drying is done on racks, these are always under permanent cover.

It is obvious that natural drying cannot be subjected to any appreciable control; the time of drying may be very variable, and may be too long to keep pace with the kiln capacity; the final moisture content depends very largely upon the conditions obtaining at the time of setting the bricks in the kiln; very high wastage, too, may result from adverse weather. The drying period may be from 3 to 6 weeks.

Before leaving the question of natural drying, it is interesting to consider the evolution of the industry. When brickworks increased in size, it would appear that there were two lines of development open so far as the drying process was concerned. These were either to instal artificial dryers, or to push natural drying to its logical extension. In Belgium particularly, the second course has been followed, and it is rather staggering at first to see the miles upon miles of drying sheds in the brickworks around Antwerp. This is not to say that they are not economical and efficient. Careful attention has been given to transport and labour saving; the bricks are rapidly and easily conveyed to and from the stacks, and manual labour is reduced to a minimum.

### *Artificial Dryers*

Most bricks in England, Western Europe and America are now dried in artificial dryers, the object of which is to dry the bricks at a minimum fuel cost in the shortest possible time, consistent with the safety of the ware. Artificial dryers can conveniently be grouped under four headings: hot floor, room, intermittent chamber and continuous (or tunnel). The first are used mainly for special ware, such as terra-cotta, refractories, sewer pipe, tiles, &c., but are

occasionally found on brickworks. The rooms are frequently used for other purposes, particularly moulding, which means that the drying can only be carried out at comfortable working temperatures, and consequently is very prolonged; also, traffic through the shed, and the occasional necessity for strong ventilation, introduce conditions which may have an adverse effect upon the drying. The hot floor, *i.e.*, a flat floor of concrete or iron plates heated by flue gases or steam, is more extensively used in England for plastic brick drying than any other type. The other two types of dryer are used for one purpose only, and are capable of complete isolation and control of temperature, ventilation and humidity. This is of great importance, and within recent years many efficient dryers incorporating more or less humidity control have been designed.

In dryers incorporating the humidity principle, the brick is heated up in a highly humid atmosphere, so that no evaporation can take place, until the bricks have a uniform temperature of about 90° F. throughout, and the vapour pressure in the bricks equals that in the surrounding atmosphere; at this stage the humidity in the chamber is reduced, so that rapid evaporation can take place. The details of the drying schedule in the first period must be fitted to the peculiarities of the clay, and if this predetermined schedule is not maintained, shrinkage stresses are set up.

#### *Hot Floor Dryers*

In hot floor dryers, the floor, which is generally of brick or concrete (rarely sheet iron), is maintained at the maximum practicable temperature by means of steam flues or of pipes carrying the products of combustion of coke or ashes. The ware is set directly on the hot floor. Even when the bricks are placed in single rows the drying is very unequal, and when, to economise floor space, the bricks are piled up, the difference becomes more pronounced, owing largely to the difficulty of securing adequate ventilation.

#### *Room Dryers*

In the second type of dryer, the room is evenly heated to a moderate temperature, and the bricks are dried by a slow movement of warm air, the ventilation being produced generally by louvres along the ridge of the shed or by ridge ventilation. In the most primitive forms, heating is by means of open grates, or stoves along the floor of the shed, but in most dryers of this type, steam or hot air pipes, radiation from floor and walls, or the direct entry of hot air or gases, provided they are not injurious to the ware or workmen, are used. For some kinds of ware, *e.g.*, sewer pipes and sanitary ware, the heating and control installation may be rather elaborate, but when the better forms of this type of dryer are used on brickworks, the required conditions are obtained by placing a latticed floor of timber over the heated masonry floor or heating pipes below floor level.

### *Intermittent Chamber Dryers*

Intermittent dryers consist generally of a series of parallel corridors, each of which is filled and emptied as a unit. The heating and ventilating systems are varied, as are also the nature and amount of control which can be exercised over the conditions. Distinction must be made between those using natural and artificial draught, and the method by which the requisite degree of humidity is obtained in the chamber. The bricks may be set on cars, but are more usually placed on pallets which rest either on the heating pipes, or on ledges on the side walls. Pipe racks are generally heated by steam, but occasionally waste heat is used; in the other types steam or exhaust gases may be circulated through pipes in the chambers, or waste heat from the kilns may be led in direct. Only the cooling gases from the kilns are used, unless the ware is not seriously affected by sulphurous gases, in which case the whole of the kiln exhaust can be used for drying. In the pipe rack type of drier, natural ventilation is the rule, while in the others mechanical ventilation is necessary; some dryers, however, use a combination of natural and artificial ventilation.

### *Continuous or Tunnel Dryers*

Continuous or tunnel driers are always kept at the same temperature, or temperature gradient, and the ware moves progressively through them on cars. A few of these dryers are heated by flues between the tracks, but mainly steam or waste gases are used; in a few installations where only cooling gases from the kiln are used, these are admitted to the dryers in direct contact with the ware, but generally the heat supply is led through pipes. In the older types, which do not make a feature of humidity drying, natural ventilation is used, but in the more modern forms, where varying degrees of control over the conditions are required, mechanical ventilation is employed. In some elaborate forms of dryers used, particularly for high grade ware, the tunnel is divided into zones each with its own ventilation system, the air being re-circulated in its own zone as far as practicable.

### *Instrumental Control*

Various instruments are available for the accurate regulation of the drying process. These are invaluable in working out the best drying schedule, and enable the drying to be carried out with perfect uniformity once the schedule has been determined. The appliances are concerned mainly with the measurement of temperature, draught and humidity.

Ordinary thermometers are used in all types of dryer, although they are only rarely seen in continuous dryers. In room dryers, the temperature may be kept about a uniform reading, or the inflow of heat may be adjusted according to the difference between the

internal and external temperatures. Periodic dryers often have thermometers attached to each door so that they can be read without opening the chamber. Tunnel dryers of both types are most conveniently controlled by distant reading thermometers; these are usually of the thermocouple type and may be indicating or recording. The more complicated continuous dryers require a chain of thermometers throughout their length. In waste heat dryers it is a common practice to measure the temperature of the entering gases, and obtain an approximate regulation of the (unmeasured) temperature in the dryer by adjustment of the cold air damper.

Some dryers, especially in America, can be fitted with thermostatic control. The simplest of these is the direct fired radiant heat drier, burning oil or pulverised coal; here the supply of fuel is readily adjusted by the temperature at a selected spot in the drier. The admission of steam can be regulated in a similar way, the control device working on the steam valve. The most convenient way of automatically controlling the temperature of waste heat dryers is by connecting the thermostat to the fan damper.

For control of the ventilation through the dryer, an ammeter in the fan circuit is very useful; once the meter has been calibrated, the column of air passing through the dryer is known with a fair degree of precision, and the meter reading is kept at the desired figure by adjusting the hot and cold air dampers. For calibration purposes, anemometers are invaluable, and they can be used themselves as a rough control of dryer draught; they can also be employed in tunnel dryers for discovering dead spots in the ventilation system.

Measurement of the moisture content is of importance in some dryers employing the humidity principle. Many types of instrument are available, but the only ones which appear to be really satisfactory, particularly in the hotter dryers, are those based on the wet and dry bulb thermometer; these have a further advantage in that they can readily be adapted to distant reading instruments. By connecting these instruments to sprays, automatic regulation of humidity can readily be obtained.

## 7.—BURNING

The final and most important stage in the manufacture of bricks is the burning; this falls naturally into three periods, the last two of which overlap to some extent. The three stages are water-smoking, re-heating and full firing. A certain time, which varies for each clay, or even for the same clay when made up in different ways, is required for each stage, since not only must the heat penetrate into the interior of each brick, but a definite period must be allowed for

the completion of the reactions which take place at each stage. For this purpose, a specific firing schedule must be established for each clay according to the type of kiln used for burning.

### *Water-smoking*

During the water-smoking period, which is complete when the bricks have reached the boiling point of water throughout, the uncombined water, *i.e.*, that which was originally present as such in the clay, and that which was added during the course of manufacture but not completely evaporated during drying, is driven off ; this may represent from six to one-half per cent. of the weight of the green brick, according to the efficiency of the drying.

It is important for satisfactory burning of the ware, that all the uncombined water be driven off in this first period. As in drying, an even moisture gradient is desirable, although it is of less consequence, except in the case of stiff plastic and semi-dry-pressed bricks which present their own problems. With these bricks the drying is usually done in the kiln ; if, as is frequently the case, the kiln is very hot at the time of setting, the outer skin will dry rapidly and visible cracks may be produced immediately ; on the other hand, minute cracks, which are not visible during setting, may develop, and extend appreciably during the course of firing.

The chief difficulty during the water-smoking period is the adequate removal of the steam, except in the comparatively rare instances where mechanical draught is used. The first bricks to feel the heat give up some of their moisture, which is deposited on unwarmed bricks in their vicinity ; when the heat penetrates to these adjacent bricks the moisture has to be re-evaporated, and the steam tends to act as a blanket, reducing the already feeble draught ; the condensed moisture dissolves sulphuric gases from the kiln atmosphere, leading frequently to the formation of unsightly scum. Pronounced temperature differences between various parts of the kiln may be set up, and persist until near the end of the firing. In such cases the initial draught should be stimulated by lighting fires in the base of the stack, coupling two or more kilns to one stack, or by special appliances for the rapid exhaust of the water vapour. In burning continuous kilns, as will be mentioned later, special means are used to prevent this condensation and excess of water vapour.

### *Pre-heating*

When all the uncombined water has been expelled from the green bricks, the temperature can be raised rapidly to about 500° C. as no chemical or physical transformations take place up to this temperature, and the heat is used in heating up the bricks ready for the full fire period. Between 500° and 750° C., rather more care should be exercised in view of pronounced chemical changes which occur between these limits. The carbonaceous matter and sulphur

of pyrites are then burned off, ferrous compounds are oxidised to ferric, carbonates commence to decompose, the molecular structure of the clay is broken down, and the chemically combined water of the hydrated minerals is driven off. Considerable quantities of gas may be expelled during this period. To secure that the requisite chemical reactions may be assured during this stage, it is necessary for the air in the kiln to penetrate into the interior of the bricks, and for the gaseous products of the reactions to pass out of the bricks steadily, and be immediately removed from the chamber; a certain amount of time is required for the physical transformations to take place. The chief defects which may arise during this period are "black-coring" and "bloating." These defects are due to various causes; chiefly insufficient access of oxygen during the earliest oxidizing period and in some cases the inability of the chemically combined water to escape. The best way of dealing with them appears to be by ample ventilation of the kiln, and a sufficient firing period to enable the air to enter and the gases and water to escape freely from the bricks, before the next stage commences. If this is not accomplished, the gases and incomplete combustion products become sealed in the brick. The evolution of sulphur commences a little below  $400^{\circ}$  C. and it is mostly driven off before  $650^{\circ}$  C. is reached. Carbonaceous matter commences to burn off at  $450^{\circ}$  C. and may continue up to  $1,000^{\circ}$  C., but at low temperatures the oxidation is more rapid and complete, and the carbon must all be removed before the ferrous salts can become oxidized and sintering commence.

### *Full-firing*

The purpose of the last stage is to bond all the material together, and provided that the earlier stages have been completed satisfactorily, the degree of bonding developed if the burning is properly conducted depends mainly on the grinding and mixing of the clay. All clays have a temperature range through which sintering, shrinkage and general consolidation take place, before the clay actually commences to fuse and deform. With some clays, this range may extend over  $200^{\circ}$ , but with others, there may be a margin of only  $20^{\circ}$  to  $50^{\circ}$ . This is less than the temperature difference between different parts of some kilns, and consequently a certain proportion of bricks have to be underburned to avoid the upper courses being actually vitrified and losing shape. Very finely ground material tends to sinter at a lower temperature than coarse material, and consequently, the presence of a high proportion of fines, well distributed throughout the brick, will produce a good bond before the main part of the brick commences to fuse. It is during the sintering stage that the final shrinkage of the brick takes place.

Sandy alluvial clays are never heated to a sintering temperature, since the large silica content renders it unnecessary.

### *Brick Kilns*

The kilns in which bricks are burned are of five types, clamp, scove, periodic, continuous and tunnel. Periodic kilns can be further divided into horizontal draught, up-draught and down-draught, though the first two varieties are nearly obsolete in brick-works.

#### *Clamp and Scove Kilns*

Clamp and scove kilns—the most primitive types of kiln—are still used to a great extent for burning common bricks and some special kinds of facing brick. Confusion sometimes arises from the fact that the words “clamp” and “scove” are used with reverse signification in different localities. In what follows, a clamp is taken to be a purely temporary structure, while a scove kiln, or (as it is called in England) a Scotch kiln, is one with three (or two) permanent walls; both have an open top, while some scove and English Scotch kilns have walls thick enough to contain fire boxes; the walling may extend to the full height of the bricks to be set, or it may not rise beyond the arches.

In both types of kiln there is usually a foundation of burned brick set dry to a height of two courses; above this the green bricks are stacked, leaving “arches”, which may be of any height up to about twelve courses, for the admission of air and fuel. When all the fuel is contained in the clamp, the arches are generally low.

In clamps, the whole stack is surrounded with a temporary skin of two layers of bricks, and the whole is daubed over. The skin may be made of green bricks, underburned bricks from a previous setting, or the same bricks may be used repeatedly until they disintegrate. The methods of stoking and firing vary considerably. Part or all of the fuel may be incorporated in the brick in the form of breeze, thin layers of which are also spread between successive courses throughout the kiln, while in places the breeze content of the bricks is reduced and the layers are partly replaced by coal or briquettes placed in recesses in the permanent foundation. In some cases the use of fuelled bricks is confined to the skin, and the kiln is fired entirely by oil. When a sufficient number of bricks has been set, the fire may be started and the setting continued vertically, horizontally or in both directions. Externally stoked kilns are completely set before firing commences. The capacity of clamp kilns varies from 500,000 to 2,500,000 in the United States of America.

In burning clamps the atmosphere acts as a chemically reducing agent the whole time, and no control is available except by the method of setting and a certain amount of checking of draught by means of sand spread over the top course.

It is interesting to reflect here also as to the two lines of development open at one time to the evolution of the burning process in

brickmaking. The simple evolution was from small clamps to larger and larger ones; the alternative was to break away and attempt special firing installations, periodic kilns, and tunnel kilns. In England, clamps have never grown to big dimensions and traditional methods for firing them have remained almost unchanged throughout the centuries. The clamps are always hand set and hand drawn. It is usual to mix the fuel with the clay in the bricks, complete the stack and then fire. French practice (*e.g.*, around Dunkirk) is different; the rule there is to place fuel nodules in recesses in the foundations, set six courses (say) of burned brick over the whole base of the clamp, then four green courses and then fire. The clamps may be set semi-mechanically, waggons full of bricks being wheeled to an elevator, raised by ropes, and then carried along horizontally on a gantry over the clamp, while the kiln is on fire, to the point where the new layers are being placed by hand. The clamps in this method are built taller than in the English way and up to 100 courses high, so saving ground space. It is claimed that labour is reduced by 50 per cent., and that the whole clamp (1,000,000 bricks or more) is fired in one-third the time necessary for the English method. But it is in the United States of America that clamp burning (or, as it is termed there, "scove," burning) has reached the logical extreme. There, the largest scove kilns contain  $1\frac{1}{2}$  to  $2\frac{1}{2}$  million bricks, and, apart from the arches and external covering, they are set and drawn mechanically, and fired, when complete, by oil or gas. Bricks to the number of 1,000 are stacked carefully on a car. A lifting unit with a series of fingers grips the car load, is carried along by a crane, which spans the clamp, and delivers the group of bricks to the assigned place. After firing, the same lifting unit withdraws the group of bricks, and transports them, as desired, to stock, truck or barge. It should be pointed out that the cost of the installation is very heavy; in fact, the plant is usually hired on a royalty basis; so that the overhead expense would only seem justified for very large outputs.

One special point may be mentioned in relation to English scove or Scotch kilns. If the base is at ground level, they lend themselves to easy transport conditions. Lorries or carts can be driven through one open face into the kiln, so facilitating direct loading.

### *Periodic Kilns*

Periodic or intermittent kilns form the next step in the evolution of brick burning. They are permanent buildings with a more or less elaborate flue system leading to a fixed exhaust, and fired through grates or burners in the walls; occasionally kilns are built with a small stack to each grate. The whole fabric of the kiln has to be heated up and cooled down at each setting, and a great amount of heat is lost by radiation; a still greater waste of heat usually occurs through the exhaust of the waste and cooling gases through the stack; consequently these kilns are very expensive in fuel.

On the other hand, part of this waste heat can be drawn off and used for dryers or warming up other kilns, and, as will be seen later, periodic kilns can be used for special purposes for which other types can only rarely be adopted.

As previously mentioned, the down-draught kiln is the only type of periodic kiln of importance in the brick industry. It is designed so that the fire moves upwards to the crown of the kiln, passes downward through the ware and out through flues under the floor to the stack. There is a great variety of flue and damper designs, the objects of which are to expedite the removal of steam, control the firing schedule, and give uniform distribution of temperature throughout the kiln. The primary direction is imparted to the flames by means of a bag- or flash-wall, built just inside the kiln wall, and usually extending to the spring of the arch. (See Fig. 5.)

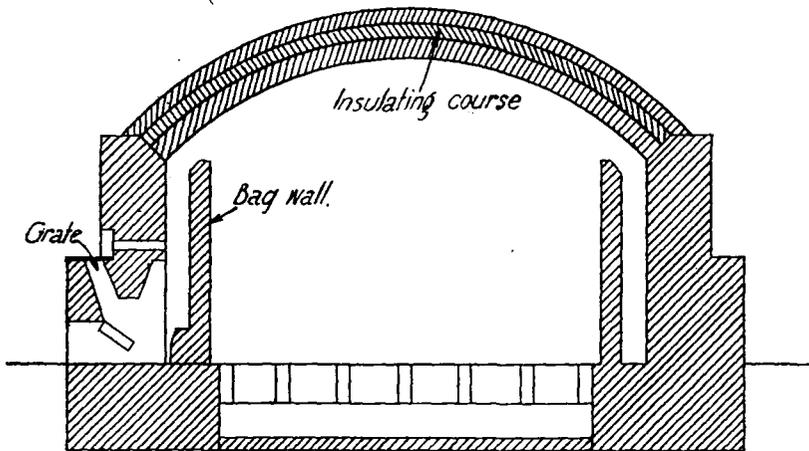


FIG. 5.—Section of Intermittent Down Draught Kiln.

Some types of ware, such as glazed bricks and terra cotta, which are liable to suffer damage if exposed direct to the flames, are heated in muffle kilns, in which the ware is set in an inner shell, and is heated solely by radiation of heat from muffle walls. On the other hand, blue engineering bricks require the opposite treatment, and must be brought into contact with a smoky reducing atmosphere; it is in such a case that the individual periodic kiln is of particular value, as it appears to be very difficult to procure and maintain the desired conditions in continuous or tunnel kilns.

Coal is by far the most general fuel used, but oil and gas are used largely in America. Stoking is almost invariably by hand.

Periodic kilns can be made to constitute a flexible system. For example, in American works, a battery of as many as twenty circular down-draught kilns may be arranged in two banks of ten with two chimney stacks in the middle upwards of 125 ft. high, used for

exhaust steam and fire gases only. The cooling gases are exhausted by special "goose necks," and are drawn along a large flue down one side of the kilns to the dryers. Under this system, the chimneys are always sufficiently hot to give the required draught in any kiln, and as large a proportion of the fuel as possible is used to economic advantage.

### *Continuous Kilns*

Continuous kilns were designed to reduce the heat losses inseparable from the periodic kiln, by circulating the kiln atmosphere through successive portions of the kiln until the temperature is reduced to a point at which the further exhaustion of the heat is uneconomical. Theoretically this is just above the dew-point, but in practice the gases are turned into the flue while they are at a sufficiently high temperature to create a sensible draught. Such temperature varies from 90° to 150° C.; at the same time, the air required for combustion is progressively heated in passing through the portions of the kiln in which burning is completed and which are cooled progressively by its passage.

The original continuous kiln invented by Hoffmann in 1863 was of annular form, but it soon developed into the more compact rectangular or oval kiln with two parallel tunnels connected at the ends. (Fig. 6.) Originally the tunnel was continuous with what is termed a barrel arch. Sections requiring to be separated in this type, which is still the most popular on the Continent, are coated at the ends with paper dampers. In England it was found expedient to construct permanent partitions with openings or "trace holes" forming the means of communication from one compartment to another. A plan of a chamber kiln is shown in Fig. 7. Still later the tunnel was divided into chambers by a series of transverse arches; an early development of this type of kiln was the invention of the zig-zag kiln (popular in Switzerland and other parts of the Continent) in which a greater length of fire travel is obtained in a given floor space (Fig. 8), while in some few types the two halves of the kiln are separate, and connected by underground flues. This arrangement is necessary when side furnaces are constructed. Coal, pulverized coal, oil and gas are all used. Coal may be either fed on to transverse grates or through holes in the crown leading into vertical firing pockets. This latter method is, in general, suitable only for common bricks. The zig-zag type, however, which is top fired, is successfully used for facing brick and tile burning.

Setting the green bricks is a most important feature of the operation of continuous kilns. The satisfactory travel of the fire depends entirely upon the proportion of voids left among the goods and the density of the setting must therefore be designed to obtain an adequate speed of travel while ensuring that the heat is distributed uniformly among the goods set in the chamber. Due

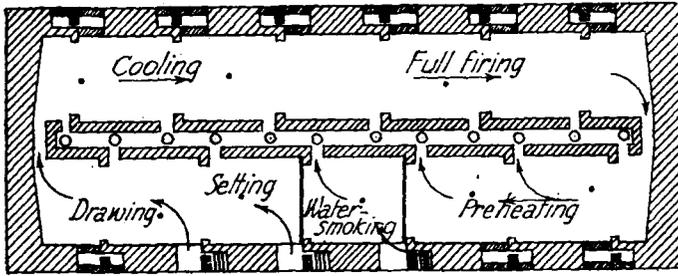


FIG. 6.—Plan of Continuous Kiln—Hoffman Type (showing mode of operation)

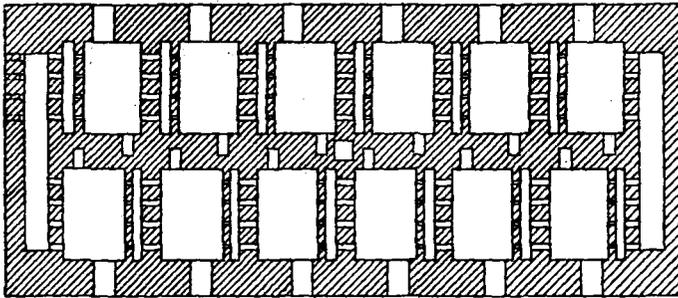


FIG. 7.—Plan of Chamber Kiln (Grate fired).

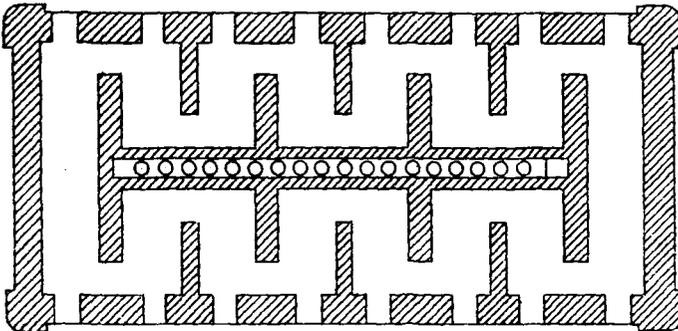


FIG. 8.—Plan of Continuous Zig-Zag Kiln.

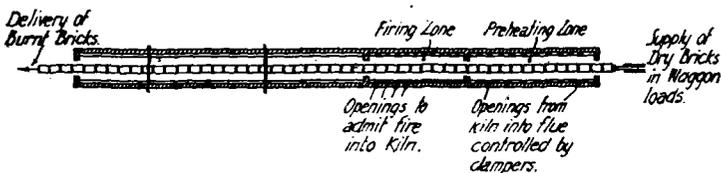


FIG. 9.—Plan of Operation of Tunnel Kiln.

regard must be paid to the strength and direction of the draught, and to the size, quality and ash content of the coal.

In continuous kilns, using natural draught, where all the three stages of firing are progressing simultaneously in different parts of the kiln, the problems arising from the presence of steam, which have already been mentioned in relation to periodic kilns, present themselves with still greater force. This is particularly the case in England with kilns in which bricks made by the plastic process are set direct from the press. They contain all the water of manufacture, some 12 per cent. in amount, in addition to other uncombined and combined water. The bricks therefore require to be dried and water-smoked before burning.

In continuous kilns burning these goods, two or even three chambers require to be isolated from the burning circuit. They are subjected to a preliminary drying process by means of hot air brought forward from the cooling chamber.

In a large number of English works, wire-cut bricks, dried on floors, are usually set in kilns with a proportion of the water of manufacture still contained in them. These bricks require similar treatment.

Even bricks set dry require this treatment in a less degree if it is desired to obviate scum on the faces. This is because the combustion gases of the main circuit contain the chemically combined moisture which has been driven off bricks in the preheating and burning stages. The newly set bricks being cold, condense this moisture on the surfaces and the moisture then absorbs the sulphurous gas (produced by combustion of the coal) which is contained also in the combustion gases. In order to obviate the condensation it is necessary to heat the newly set bricks to a temperature of about 160° F., at which point it has been found that condensation does not occur. This process, introduced by Hoffman himself so long ago as 1865, is practicable in all modern continuous kilns. Many English works, however, omit it—to the detriment of the appearance of their products.

Continuous kilns are more popular on the Continent and in England than in America. A marked difference, however, between English and Continental practice is the prevalence on the Continent of automatic stoking systems (see p. 103), and the greater prevalence there of mechanically induced (fan), instead of natural (chimney), draught.

### *Tunnel Kilns*

The latest development in the burning of clay ware is the rapidly extending use, especially in America and England, of the tunnel kiln (Fig. 9). The distinction between the continuous kiln and the tunnel kiln is made clear by the statement that in the former the goods are stationary and the fire travels and in the latter the fire is stationary and the goods travel. It is generally

supposed that the tunnel kiln is a new invention, but actually the tunnel kiln antedates the continuous kiln, the first recorded one being built for pottery work at Vincennes in 1751, and a few other forms came out at intervals up to the end of the 19th century. It was not until about 30 years ago, however, that the problems were more or less successfully solved and real progress made.

In tunnel kilns, the ware is set on cars, which pass continuously through a tunnel, the sections of which are maintained at graduated temperatures according to a predetermined firing schedule. In a very recent form, the annular shape of the original continuous kiln has been adopted and the floor of the kiln is in the form of a platform which revolves. The early forms of tunnel kiln were unsuccessful because of defects which retarded its adoption, but these have been overcome. It is still objected by some that first, the tunnel kiln is suited only for large continuous production, second, that the ware which can be burned is governed by the firing schedule to which the kiln is built and, third, that it is generally possible to obtain only an oxidizing atmosphere. Various kilns have been designed to obviate these drawbacks, and one kiln is claimed to have solved all three problems. Various ingenious arrangements have been tried in America for segregating a number of car loads while in certain positions in the kiln, or for directing the heat and air flows along special channels. The chief difficulty in the design of tunnel kilns is to secure a perfectly even temperature distribution throughout the ware. If this is not attained, the number of first quality goods is reduced. It also has the much more serious result of producing uneven shrinkage in the setting of the car, which may result in the goods falling and jamming the kiln; this difficulty, however, appears to have been completely overcome in most of the kilns now in use.

### *Kiln Operation and Control*

Some aspects of kiln operation have already been dealt with in describing the various types of kiln, but there are other points which can conveniently be discussed together with methods of instrumental control. Kiln operation is divided into the two main headings of stoking and draught, and the ease and certainty with which these can be controlled varies with different types of kiln.

#### *Draught Control*

The control of kilns working with natural or chimney draught is not easy, particularly those of the periodic type. The tendency which steam has to delay progress during the early stages of firing has already been mentioned, and even when a good initial draught has been established, generally the chief means of control is a damper at the base of the stack, the effective use of which is limited. The stacks of periodic kilns are usually quite short, and their action

is affected by atmospheric conditions ; this disturbance is much greater than is commonly supposed, and, particularly in exposed situations, may easily reach a degree which cannot be realised without definite instrumental records. In some works, protecting walls are built, in order to shield such kilns from strong wind.

The control of the ventilation of natural draught continuous kilns is fairly simple once the kiln has been started up, provided that the kiln is of good design and construction, and that the advance heating section is efficiently isolated from the remainder of the circuit. Many such kilns are too short for really effective operation and, as already mentioned, the damper control may be inefficient. Kilns operated with mechanically induced draught are more easily controlled and, provided the number of chambers is adequate, give a much increased output.

The regulation of draught in all types of kiln may be usefully controlled by draught gauges, of which there should be preferably at least two to each kiln. The instruments are a great aid to the correct manipulation of the dampers in periodic kilns. Apart from their use in the general run, of the kiln, draught gauges are also useful in determining the resistance which the flues afford to the passage of the gases, by the very simple method of measuring the difference in pressure between the base of the stack and the bottom of the kiln ; this is of importance during the water-smoking period. Gauges find similar applications on continuous kilns, where a further check is provided by the fact that in the passage of the air and gases through the kiln a position of " no draught " occurs which should always be maintained at the same relative position. The phenomenon of " no draught " does not signify stagnation or want of movement of the gases but exact balance of pressure in relation to the outer air. In mechanical draught systems, too, gauges are useful for checking the operation of the fans. When kilns of this type are being worked to a definite schedule, the condition of the flues can readily be ascertained by determining the pressures obtaining at various parts of the circuit, thus assisting in the correct maintenance of the firing cycle.

### *Firing Control*

The firing of kilns presents so many individual problems arising from the character of the ware, the nature of the fuel, the atmospheric conditions required during firing and the peculiarities of the kiln, that only a very brief treatment is possible here.

It must be realised at the outset that, unlike other furnace operations, it is not sufficient to attain the full firing temperature as soon as possible and maintain it for a specified time. The approach to full heat must be gradual, the rate of heating following a pre-determined curve as closely as possible. In addition, it is sometimes necessary in periodic kilns to vary between oxidizing and reducing conditions within the kiln during the course of a burn.

Consequently, although some departure from the standard heating curve is permissible, the whole course of firing demands the closest attention. As previously explained, various reactions occur during the course of firing, and each of these must be given time to be carried to completion. To secure this the whole contents of the kiln should be brought as nearly as practicable to a uniform temperature during the course of each group of reactions, and the temperature then allowed to rise gradually to its final figure. If the stages overlap in different parts of the same kiln, the reaction products from one stage may have a harmful effect when brought into contact with material at another stage. At the same time, it is desirable to keep the temperature permanently rising throughout, as even a local drop in temperature of, say, 20° C. may be attended by harmful results. Special precautions, too, are required to regulate the access of secondary (hot) and excess (cold) air needed, the one for the combination of the fuel and the other to provide for dilution of the intense heat of the furnace gases to the correct burning temperature. It will be seen, therefore, that there is a great deal of scope for control appliances in kiln firing.

Methods of fire control can be divided into three groups concerned respectively with the regulation of (1) temperature and heat treatment ; (2) products of combustion ; (3) fuel supply. The first is the most important.

There is no complete agreement as to the relative methods of " temperature " measurement, owing to the fact that the two main types of appliance are regarded as alternatives, whereas actually one supplements the other. The final heat treatment of clays is not a function of temperature alone, but of time, humidity, and temperature, and consequently a temperature record alone is not sufficient but should be taken with some definite measurement of the heat treatment to which the ware in the kiln has been subjected. Temperatures can readily be measured by one of the many pyrometers available, while the heat treatment must be determined in the case of clays which sinter by some kind of shrinkage test ; both of these will be described later. Some appliances, known under the general name of fusible pyrosopes, are supposed to combine the two measurements ; they consist of cones, bars or cylinders of various synthetic mixtures compounded to have fusion points at definite points, thus forming a regular temperature scale. Although these bodies give reliably constant results under standardized laboratory conditions, they are apt to give misleading results in the works, as the temperature at which they deform varies according to the rate of heating, the soaking period (*i.e.*, the length of time for which they are maintained at the peak temperature) and the condition of the surrounding atmosphere. Taken in conjunction with definite temperature records, however, these pyrosopes are of value, and the first two kinds have the advantage that their behaviour can be studied by a momentary

inspection through holes provided at suitable spots in the kiln ; the cylindrical records, which occupy a minimum of space, afford a very useful means of obtaining an idea of the heat treatment received by different parts of the kiln. The best method of firing control is undoubtedly by a combination of shrinkage measurements and temperature readings. The earliest form of shrinkage measurement, and one still very largely practised with considerable success, consists of determining the amount which the whole kiln setting has settled ; this is done by measuring the distance between the top of the setting and a reference mark on or above the crown of the kiln. The method is quite satisfactory for giving an average value, if measurements are taken at several points in the kiln, but, of course, fails in the event of a partial collapse of the kiln setting. Generally, settle is measured only during the final stage of burning to determine the completion of firing, but if the measurements be made periodically from the water-smoking period onwards, a fair degree of control can be exercised over all stages of the burn.

The progress of the final stages of firing is often directed by trial draws, which may be whole bricks, slabs of the materials under fire, or special discs of a standard synthetic body. Series of trial pieces are placed at as many different accessible positions in the kiln as practicable, and withdrawn for inspection at specified periods.

The measurement of high temperatures has now been brought to a high degree of perfection, and there are several instruments well adapted for use on kilns. They are of three main types, thermo-electric, radiation and optical ; of these the last are only suited for indicating, while the first can readily be used in conjunction with recording instruments which give a permanent and complete record of the burn. All the types of instrument are accurate and reliable, provided their purpose and manipulation are understood, all due precautions are observed, and the apparatus is properly maintained. It cannot be too strongly emphasized that the sole function of a pyrometer is to show the temperature of one point in the kiln and is not, in itself, an indication of the actual heat treatment. Recording pyrometers are invaluable in studying a new kiln or material, and once the firing schedule has been determined, a curve can be drawn up and followed by the foremen : these instruments also give a definite record of the operations of the firemen.

#### *Air Supply and Regulation*

Reference has been made above to the necessity of regulating the supplies of secondary and excess air to the kiln. It is obviously necessary to restrict this to the minimum, otherwise useless material is being warmed up and heat is lost. It is equally obvious that, in order to obtain full value from the fuel supplied, its complete combustion must be secured, except in the special cases where a strongly reducing atmosphere is temporarily required. It will be seen,

therefore, that in the ideal kiln it is necessary to strike a perfect balance. Actually in practice this theoretical ideal is never attained or attempted, as a certain excess of air over that required for perfect combustion has to be admitted in order to reduce the intense heat of combustion to the required burning temperature and to ensure a uniform oxidizing atmosphere throughout the kiln. The regulation of the air is generally left to the judgment of the head burner. The combustion of coal is a combination of two reactions, the oxidation of carbon to the monoxide (a gas burning with a blue flame) and the further oxidation of this to the dioxide; the first stage, if allowed to occur alone, is accompanied by the evolution of less than a third of the total heat of combustion, so a stack may be perfectly clear and still be wasting nearly three quarters of the available heat. For this reason, too much air is usually admitted than too little. Unfortunately, the stage at which indications of excess air entering through the fires become manifest to the trained eye depends very largely on the conditions obtaining at the time of the observation, and over a period of, say, a year, the losses which take place below the limit of visibility can be quite appreciable. Further losses, which may be of even greater magnitude, may occur through air leaking through the mortar joints if the kiln structure is not maintained in thoroughly good condition.

Ideally, the degree of combustion should be determined by measuring the oxygen content in the stack gases. But this is a laborious and skilled operation. Recourse, therefore, is generally had to determining the percentage of carbon-dioxide, which gives a good indication of the amount of excess air present, and has the great advantage that it can be performed mechanically on recording machines. These records serve another purpose in that they give a further check on the operations of the firemen.

There are three kinds of recording apparatus, absorption, weight and electrical. In the first type of apparatus, a volume of gas is drawn through a suitable chemical absorbent, and the volume of the residual gas measured; such apparatus requires a fair amount of maintenance. The weight apparatus is based on the fact that the specific gravity of flue gas varies as the content of carbon-dioxide, and is measured differentially by comparing the movements of two similar fans rotating in the stack gas and in the atmosphere, under standardized conditions. The third and most generally used form of apparatus depends upon the thermal conductivity of carbon dioxide; two similar coils are placed in the flue gas and in atmosphere and heated; one cools more rapidly than the other, a measure of the cooling, and consequently of the percentage of carbon-dioxide, being given by the difference in resistance of the two coils.

In connection with the composition of flue gases, there is another point which is of interest, although it is not directly

connected with control of combustion, and that is the content of sulphur dioxide in the gases. Most fuel contains sulphur, and consequently a proportion of the gas is present throughout the burn, but in addition, notable quantities may be evolved from the reactions taking place during the oxidation and vitrification stages, and it is desirable to evacuate these as rapidly as possible. A knowledge of the periods of evolution will, therefore, materially assist in correct manipulation of the draught. Unfortunately, there is no mechanical means of performing this analysis, and a laboratory apparatus of the Orsatt type must be used. Continuous, or even regular, readings are not necessary, as once the material temperatures have been discovered by tests, the ventilation can be regulated by the pyrometer readings. The apparatus can also be used, of course, for the more complete analysis of flue gases as a check on the general operation. This, however, is a refinement of procedure not, in practice, called for in brick manufacture.

### *Stoking*

Control of fuel supply can be obtained by means of mechanical stokers, or, where oil, gas or pulverized coal is used, by thermostatic control.

Coal fired periodic kilns are, generally speaking, hand fired; some attempts have been made to devise mechanical stoking appliances for these kilns with some promise of success, but it is probable that some time will elapse before they become available. At present they cannot be said to have got beyond the experimental stage. The chief development in mechanical stoking is in its application to top-fired continuous kilns. Containers with fine coal are placed over the feed holes of the portion of the kiln under fire, and small quantities of fuel are discharged into the kiln several times per minute or continuously through apertures which are mechanically opened; by adjusting the speed of the operating mechanism or the size of the aperture, the rate of firing can be regulated. It has been shown that a saving can be made thereby of 15 per cent. in fuel consumption and an increase attained of about 15 per cent. in speed of fire travel.

When mobile fuels are in use, a perfectly regular feed can be obtained by means of a thermostatically operated valve controlled pyrometrically; the rate of firing is regulated by manual adjustment of the thermostat, or the alteration can be made on a determined scale by means of a clockwork attachment.

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