CLAY PLANT CONSTRUCTION AND OPERATION

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PREFACE

THE PROBLEMS confronting the clay products industry are naturally so numerous that an ordinary volume can only deal with a few of the larger ones. There can be no question whatever but that the industry as a whole faces more difficulties than any other, yet up to ten or fifteen years ago practically no scientific effort had been made to solve the greater portion of them.

As a manufacturing industry it has been also probably the most wasteful—wasteful of human, mental and financial effort. Only recently has economy, scientific economy been practiced by an appreciable part of the industry, and still greater efforts must be made in this direction if it is to compare with many other American industries, especially those with which it is in competition.

The entrance of the engineer into the industry is beginning to make itself felt and as confidence in his ability to help the clayworker in a practical way increases, far greater benefits will be derived. One of the greatest difficulties encountered heretofore by the engineer has been that he has only been called upon to "doctor" a "sick" plant, whereas he functions best when acting in a preventive capacity. On the other hand, ceramic engineers must realize that in order to do the industry and themselves the greatest amount of good a great deal of common sense must be mixed with their technical knowledge.

In writing the following chapters the author has attempted to explain in understandable English some of the problems of the manufacturer of structural clay products. Every effort has been made to avoid technical terms and formulae. Theories have also been avoided and plain practical facts presented. The author has tried to realize that it is not the ceramic engineer or the company employing him that requires assistance but the man who is trying to solve his own problems.

It is quite probable that some of the statements made will be criticised by both technical and practical men. To these it would be well to say that no attempt has been made to treat individual problems and that in order to receive help from this little volume the clay-worker must combine with it the experience he has received in the "School of Hard Knocks."

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CHAPTER I

Testing Clay Properties

TO MANY CLAYWORKERS the above subject will seem so elementary as to be almost, if not quite, above notice. That many prospective and actual clay plant owners, to say nothing of the army of farmers and promoters who have dabbled in clay, have so regarded the subject, is very evident from the vast number of "dead" clay products factories which dot the country.

The outsider is not to be greatly blamed for overlooking or utterly *ignoring* the necessity for a thoro testing of a property but, for the clayworker, there is absolutely no excuse, for he, of all others, knows the treacherous nature of his raw material. He has in many cases, however, handled the matter as he has handled his plant design, equipment and kiln construction—*with his eyes and ears shut.*

In looking about, it is really surprising to note the immense waste of money due directly to the erection of plants without first making the proper tests of the raw material it was proposed to use. A few instances will be of interest.

SPENT $250,000 ON STRENGTH OF SURFACE SAMPLES

A clay products company which had been in successful operation for twenty years found it advisable to sell its plant site and clay pit because of its value as real estate thru the growth of the adjacent city. With well on to a half million dollars in cash to its credit it sought another site in the vicinity. The manager and superintendent selected a promising piece of land within ten miles of the old plant which appeared to them to be in the same geological formation. A few *surface* samples were taken and made up at the old plant and these samples appeared to be all right. *Without any further tests, a quarter of a million dollars was spent in erecting a factory.*

As soon as the plant commenced operations it was found that the entire property was covered with a blanket of from two to six feet of the clay which had been tested, while beneath this was an entirely different clay. This latter deposit, while workable, would not dry safely under any circumstances.

The company has been experimenting for three or four years in an endeavor to use the material and, in so doing has used up its cash balance, mortgaged the plant and, worst of all, has lost a splendid business to its competitors.

The testing of this property—which was clay, not shale—would have been extremely simple. A hand auger would have divulged the useless material in the first hole sunk. Further than this, an appeal to the officials of the government geological department for information would have warned them off, for the geologists were thoroly familiar with the characteristics of this clay bed.

BUILT NEW PLANT WITHOUT ANY TEST WHATEVER

Another instance worthy of mention is that of a clayworker with years of experience who sold his plant and decided to erect another on a piece of property he had retained about a quarter of a mile from his old plant. *Without any tests whatever,* the plant was laid out and erected. The idea was to get the raw material from a hill at the rear of the factory, but it was soon found that this entire hill was covered with a glacial drift which was literally full of lime pebbles. Further tests showed that the plant itself had been erected upon the very best of the deposit and that that part of the flat land which had no buildings upon it had apparently been cut thru by an immense river or glacier and then filled with quicksand. The result was that the clayworker in question lost his interest in the company and is apparently out of the game for all time.

PROFITED NOTHING FROM COSTLY EXPERIENCE

A third instance is rather interesting because, in this case, the company involved owns a number of plants and had previously lost one soon after purchase thru the absolute disappearance of the shale deposit, this being replaced by a useless, stony clay. It would be expected that one such experience would make a company move cautiously, but this was not the case.

At one of the plants the shale became so hard as to be almost unworkable. It was therefore decided to move to another hill close by and there open a new pit. An expensive incline and tramway were installed and the pit opened. The first shale taken from the new opening was so high in lime as to be useless. After working thru a pretty thick deposit of this class of material, the shale become as hard as that in the old pit. The consequence was that after a large expenditure of money, the demoralization of a good organization and quite a long shutdown, the new opening was abandoned.

PECULIAR DEPOSIT FOOLED FIRE-BRICK CONCERN

It is a pretty well-known fact among ceramists and geologists that flint fire-clay occurs in lens-shaped deposits and that some of these, especially in the West, are quite small and irregular in distribution. Upon the discovery of one of these deposits, a company was organized to build a refractories plant. As it happened, the original deposit only contained a few hundred tons and, altho the property was thoroly searched for a further supply, none was found of sufficient refractoriness to meet the requirements. The plant was finally equipped to turn out other clay products, *but not until after the original investors had lost the money they put into it.*

"BIG MONEY" MAKES BAD MISTAKE

The promotions which have gone the road to ruin thru not properly testing the properties are innumerable. One of these instances, which was notable because of its size and the fact that the project was floated in one of the largest of the country's financial centers, is worth mention.

The plant was completed and operations commenced. It was then found that the ware could not be safely dried. Some of the best expert advice in the country was obtained, without results. Finally a railroad twenty-five miles long was built to a workable deposit, but it was soon found that the cost barred the products of the factory from the market.

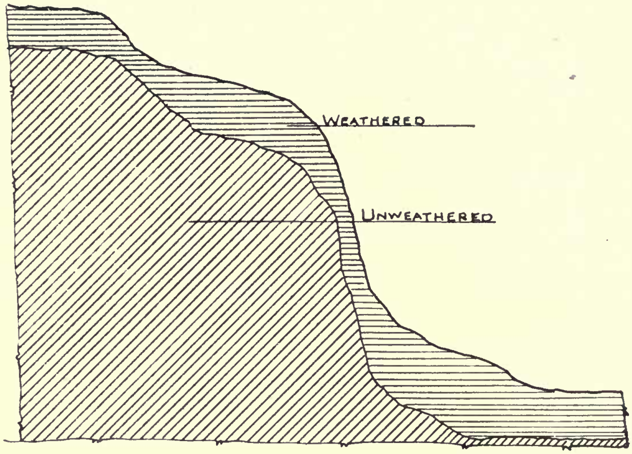


Fig. 1. Section Thru Hill Showing Weathered Material on the Surface.

The plant was soon abandoned and today the investors undoubtedly class clay products with salted mines and "wild cats" of all descriptions.

Enough of such cases could be recounted to fill a book, but the above will serve to show in a small measure how this very important problem is so often approached, even by those with years of experience behind them. It is small wonder, under these conditions, that the bankers of the country look upon the clayworking industry as one of the greatest risks with which they have to deal.

In the selection of a clay property many items must be considered. Among these is the topography, geology of the district, ware to be manufactured, location with regard to market, shipping facilities and water supply. These items bear a close relation to each other and must be considered as a whole rather than separately.

TOPOGRAPHY

It is generally recognized that it is better to win material from a hillside than to have to go below grade for it. In selecting a hillside in which to open a clay or shale bank there is the great advantage of using gravity in moving the mined material to the factory. There is also the advantage of drainage and big working faces which makes for economical shooting or steam shovel operations. These items count heavily in the cost, especially where sharp competition is to be met. It would not be wise for a company to select a site where it was necessary to open a pit below grade or a room and entry mine, if its nearby competitors had a hillside bank with its accompanying lower costs, unless there were other conditions directly connected with the mining operation which counter-balanced the first mentioned advantage. More modern equipment in pit and factory could not be relied upon to offset this point in his favor, for the competitor could modernize his equipment and still maintain the lead.

If, on the other hand, a site is selected which puts the company on an equal footing with its competitors or better still, gives it advantages, there can be no fear from this source under proper management.

GEOLOGY

A geological knowledge of the district containing the de-

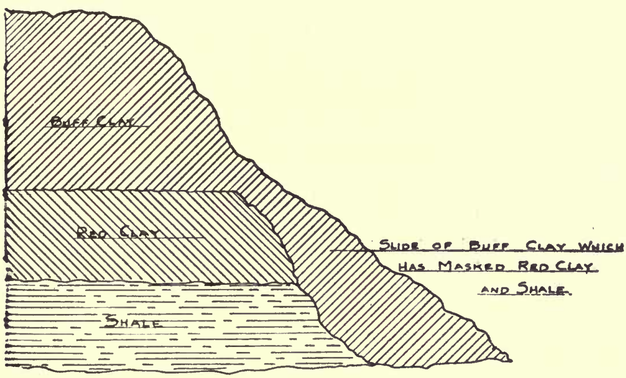


Fig. 2. Section of Hill Showing How Landslide Changes Surface Indications.

posit is valuable and important. It loses some of its importance after the property under consideration has been thoroly tested, but in many cases it is still important. In the fire clay areas, glacial areas and in districts where the stratification has been much disturbed, it is an item which must not be overlooked.

A company may test out an area that looks in the beginning as tho it were inexhaustible only to find out, in later years, that it must open up on other parts of the property. In some cases where this has been the case similar material has not been found or only by going great distances.

Most states now have a department of geology which is pretty thoroly versed in the formations within its boundaries and, as such information is for the public, there is no reason why a clayworker or prospective clayworker should not benefit by it.

WARE TO BE MANUFACTURED

It is, of course, primarily important that a company should know that the raw material on the property being considered is suited to the ware to be manufactured. If refractories are to be made, it is necessary to know that there is a sufficient quantity of clay in the deposit which comes up to a certain standard of refractoriness. If face-brick is the object, the materials must develop the desired colors. If hollow ware or pavers are required, the material must be suitable, *and there must be enough of it.* Even experts cannot determine these things from a small hand sample or a barrel of clay taken from the surface at some point on the property.

MARKET

In selecting a property the item of location in regard to market must be kept in mind. No matter how good the raw material may be, it has no value unless it can be delivered to the market either in its raw or finished state at a profit. Many plants have been built only to fail because this could not be done. The vast majority of factories in the structural products end of the business must have a local market which will absorb the greater percentage of their product. In only isolated cases is this condition reversed. The proximity of a market is, therefore, an important consideration.

In a few localities, especially in the far West, the plant is located at the market and the raw material shipped to it. Such a condition exists because the freight rates are lower on raw material than on finished products and because all of the plants supplying the market follow the same method.

SHIPPING FACILITIES

A clay products plant must have good shipping facilities, that is, it must have good railroad service. At the present date this is not a difficulty that is often encountered. Sometimes a plant will be located at such a distance from a railroad that a large expenditure is necessary to put in a spur. Sometimes from ten to thirty thousand dollars is spent in this way, the interest and maintenance necessarily being

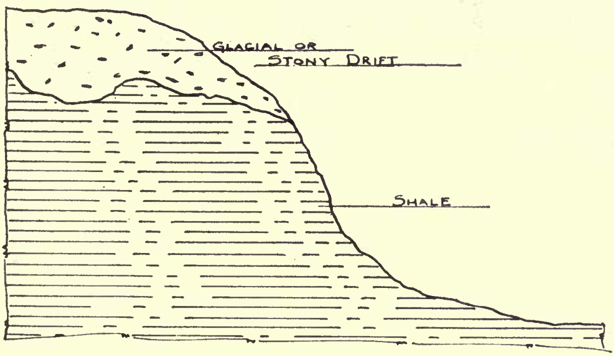


Fig. 3. Section of Hill Showing Overburden or Drift.

charged against the output. In such cases a great saving could often be made by locating the plant near the railroad and bringing the raw material to it on an industrial railroad or better still, locating a deposit of the same raw material nearer the railroad, as often can be done if an intelligent search is made.

Whenever possible, it is best to locate within reach of two competing railroads for while rates are generally fixed, the car supply will always be much better and the troublesome matter of switching charges at terminals can often be avoided thru the competitors absorbing them.

WATER SUPPLY

Plants do not often have to worry about a water supply but failure to look into this matter may lead to much trouble, especially in some parts of the country. A few years ago a large factory was erected on high ground and about ten miles from the nearest stream. Water for construction purposes was obtained from a driven well, the water from which was salty. No thot was given to this water until operations commenced, when it was found to be absolutely unfit for either boiler or tempering purposes. Months were consumed in an effort to locate purer water, but to no avail. There remained nothing to do but put in

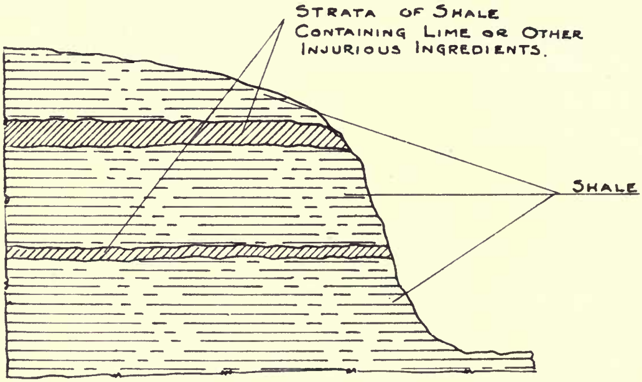


Fig. 4. Section of Hill Containing Seams of Worthless or Injurious Material.

expensive condensers or pipe to the stream ten miles away. Trouble arose among the stockholders over this location, with the result that *the plant stood idle for years until finally it was sold for about twenty-five per cent. of its cost.*

Having taken into account all of the above considerations, the matter of testing the property to determine the amount and value of the material to be used must be tackled. To dig up a few surface samples and send them to a clay machinery company or testing laboratory is utterly useless. Surface indications, as a rule, mean nothing so far as shales and clays are concerned.

WHY SYSTEMATIC SAMPLING IS NECESSARY

In the first place weathering will so change the characteristics of a shale or clay as to make it entirely different from the unweathered material below. Years of exposure to the elements will turn a hard, rocky shale into a soft plastic material which will show splendid working qualities, whereas the original unweathered material will resist every effort to turn it into ware. Also a buff burning clay or shale may weather into a red burning material, sometimes to a depth of six or eight feet. Weathering often leaches out of the surface material objectionable constituents which would otherwise prohibit its use. On the whole it might safely be said that the testing of weathered surface samples has caused more trouble and losses than any other item connected with the selection of a shale or clay deposit.

Land slides on hill sides have caused much trouble where surface samples have been taken. These slides sometimes extend over a large area and cover the material under them like a blanket. In some cases a large portion of a hilltop will have broken away and slid to the bottom. Beneath it the material may be useless. Under such conditions surface testing would show a far greater quantity of material available than is actually the case. It is on an occasion of this kind that a knowledge of the geology of the district becomes valuable, for with it, it would be readily recognized that something was out of place.

In the glacial areas surface indications count for little or nothing. Both hills and valleys are more often than not covered with a worthless drift. Only thoro drilling will disclose the material beneath, as it will also determine whether the overburden is too heavy to make the locating of a plant profitable.

Glacial, river and swamp deposits are so changeable as to make it absolutely unsafe to accept surface indications. The

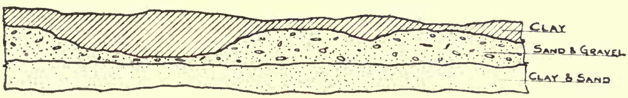


Fig 5. River Deposit Showing Varying Thickness of Strata.

very nature of these deposits indicate that they will contain strata or pockets of sand and gravel which may make the entire bed worthless. In the accompanying sketches, Figs. 1 to 6, some of the above described conditions are illustrated.

To properly test a property it should be laid out in squares similar to a checker board (Fig. 7). The side of each square should be 100, 200 or 300 feet. Each intersection should be numbered and at these points the drill holes should be located. It is, of course, only necessary to drill test holes at those intersections which come above the grade level or, if the bottom of the bed or deposit is known to come some distance up the hill sides, above that point. When the pit is to be opened below grade and the property is flat, a drill hole should be located at each intersection.

The kind of drill to use for the tests depends entirely upon the nature of the deposit. Soft shales or clays can be drilled with a hand auger drill, but where gravel seams or strata of stone occur in the formation, it will not work. A well drill will go thru any formation, but it has the disadvantage of churning up the material in the hole and it is, therefore, not altogether a safe instrument to use unless an expert is on the job to watch the results. The diamond drill is the best instrument for this kind of work but its use usually means a heavy expense.

HAND AUGER DRILL

When such a drill can be used, testing becomes a simple operation. The equipment costs very little. It merely consists of a wood auger of not too great a pitch about a foot long and 1½ and 1¾ inches in diameter. To this is welded a ½-inch steel rod about five feet long, the upper end of which is threaded with a pipe thread. A handle is provided that can be attached to this rod and which provides a good leverage. A sufficient number of sections of half-inch pipe are provided to lengthen out the drill as it goes down. These sections should be about four feet long. Each time the drill is run down a few inches it is pulled up and the borings which come with it are examined and preserved for further tests. If the holes are very deep it is necessary to provide some means of pulling out the long drill. A simple three-leg set-up over the hole with a block and tackle at the top will answer this purpose. Two men are required on the drill, as it becomes very difficult to turn it after it gets down a few feet.

WELL DRILL

If a well drill is used it is customary to employ some drilling company to do the work. In ordinary shales and clays such a drill will go down very fast. By its rate of progress the hardness of the various starta can easily be judged by an engineer but, as mentioned above, on account of the condition of the borings as they are lifted out, an inexperienced man could determine very little. As the borings come from the holes in a soft wet condition it is necessary to dry them in preparation for burning and drying tests. Of all the methods this one is probably the poorest, altho on a big job it will more than likely prove the cheapest.

DIAMOND DRILL

Diamond drilling is very expensive but the results obtained are really so superior to all other methods that a cautious company cannot afford to use any other. By this method a core is obtained which gives a complete story of the formation drilled thru. Strata of stone, coal and any changes in the clay or shale are shown exactly as they occur. The cores when preserved serve to show the management exactly what they may expect to encounter

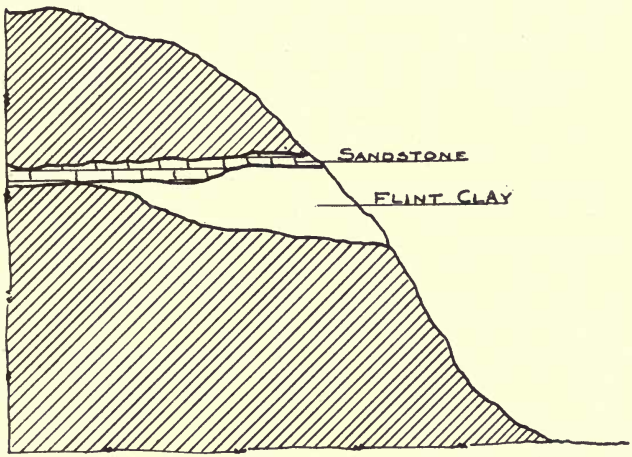


Fig. 6. Section of Hill Showing Remainder of Lense of Flint Clay.

and allows them to prepare for contingencies long before they have to be met.

Diamond drilling is done by companies organized for the purpose and the drills are in the hands of experts. The work is usually done at so much per foot, the price varying according to the material to be drilled thru.

From two to five thousand dollars spent in diamond drilling may seem like a large sum of money, but it is a small percentage of the cost of a modern plant whose success depends absolutely upon the raw material. Considering the number of companies that have been ruined or have in the end paid four or five times this amount in order to get out of difficulties caused by going into things blindly, it would seem to be the better part of wisdom to spend the money in the beginning, even tho the sum seems large. The item of removing overburden alone may amount to five or six thousand dollars a year and a company taxed with this expense would have probably selected a site elsewhere could they have seen beforehand what they were going up against.

Another drill, a sort of little brother to the diamond drill produces the same results, but is slower. Instead of using diamonds for the cutting edge, the bit is of tool steel with a cutting edge like a saw. This drill can be operated by hand or a gasoline engine and can be purchased for a few hundred dollars. The cores produced are very perfect but do not come out in such long sections. This, however, is not detrimental.

PRACTICAL TESTS NEXT STEP IN PROCEDURE

Having drilled the property thoroly, it is then necessary to secure sufficient material with which to make practical tests. If the cores or material from the drill holes show the deposit to be fairly uniform thruout, this is a simple matter. It is then only necessary to sink a pit thru the weathered portion on the surface or run an "open-cut" into the hillside and secure a sufficient quantity of the unweathered material to make a number of tests on the kind of equipment it is proposed to use. This quantity may vary from five barrels to a carload, according to the scope of the tests, the cautiousness of the company and the people making the tests. *It is utterly useless and a waste of time and money to attempt to get a test from a few pounds of material, as is sometimes done, and the man who is willing* to make a report on such a test and allow money to be staked upon such a report is a man to be avoided.

In order that a test may approach as near actual working conditions as possible, it should be made on full size equipment and on the types of ware it is expected to manufacture. It should be dried as nearly as possible under working conditions. The burning of the samples can safely be done in a test kiln, providing, of course, the tests are in the hands of a competent man.

CHECK DRILLING AGAINST WORKING SAMPLE

The material from the drill holes should be checked against the working sample in order to be certain that a variation in the deposit that would affect the working and other qualities, does not exist. Such check tests can be made in several ways. Chemical analysis will show up any decided variation and, coupled with a briquette test, in which the drying, shrinkage, burning and color qualities can be noted and compared, will provide data upon which a decision can be made.

When a formation is encountered which shows variations at different depths it is absolutely necessary that a test be made on each of the different materials. To neglect to do this may have serious consequences for it has been the encountering of variations in the bank or pit, *after a company has started operations,* that has caused so much trouble in the past. Along the Atlantic coast and in the mountainous regions of the West, from five to ten different kinds of clay may be encountered in a depth of forty or fifty feet.

Some exceptions can be made in the case of refractory fireclay deposits. These clays are valuable according to the degree of their refractoriness. Melting tests can be made from the cores and, there is hardly any necessity for other tests, altho they may be made as a precaution. In dealing with these clays, the drill holes should be placed very close together as a deposit may vary greatly in refractoriness, and instead of being continuous over a large area may consist of a number of small deposits, with barren areas between them.

COMPETENT ENGINEER SHOULD SUPERVISE TESTING

It is a safe and wise plan to have the entire work of testing the property and material done under the supervision of a competent engineer. It is a job for an expert and no one else, for no matter how thoroly the work of testing may be done, the report on the results will be of no value unless the man who makes it knows his business.

Testing of clays or shales should never be left to people

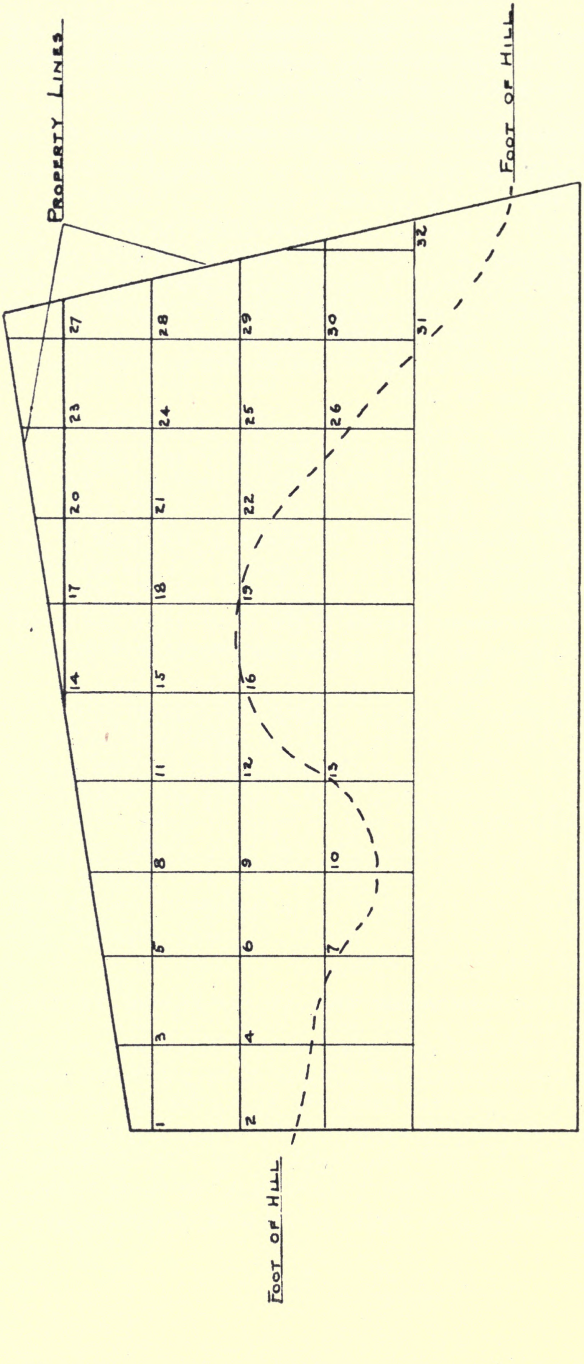


Fig. 7. Layout of Property for Drilling. Numbers Indicate Location of Test Holes.

who are interested in furnishing the plant equipment. No matter how conscientious they may be, in the nature of the case it is absolutely impossible for them to be unbiased. More often than not they are not to blame for misleading reports, as they often have no means of knowing the history of the samples sent them. The methods of testing used are also open to criticism. Material which will not make "nice appearing" ware when first run thru a machine is run over and over again until the desired results are obtained. This is not a practical test, for even a shale or clay with poor working qualities can be made to produce good ware, if it is worked over enough times.

A little more thought and care given to this department of the industry will save many dollars to investors, and it will place clayworking in a much better light with those financial interests whose assistance is becoming more necessary every year in order that it may keep pace with the other great industries in whose ranks it properly belongs.

CHAPTER II

Hollow Ware Dies

A FEW YEARS AGO, the average clayworker—or brickmaker—was not at all interested in the subject of hollow ware. Its manufacture was confined to comparatively few companies and what little knowledge on the subject that a few men possessed, was securely locked away and labeled "Trade Secrets."

As has often proved the case in industries other than clayworking—and, for that matter—in clayworking itself—these "secrets" contained so little real information as to be worthless to the industry at large; and so today, this important and rapidly growing line of clayworking finds itself attempting to progress with less basic knowledge, probably, than any other branch of the industry. For this reason, if none other, the matter of die construction and die adjustment has been brought into the limelight and an insistent demand for more knowledge is apparent.

The hollow ware manufacturers have made some progress during the past year or so, in fact, so much progress that literally hundreds of brickmakers have been tempted to "try their hand at the game." *It is these brick manufacturers, who for the most part, have taken up hollow ware as a side line, who are suffering most thru lack of knowledge on the subject of dies, or rather the lack of knowledge on the entire subject of hollow ware manufacture.*

Naturally, the simple thing to do when the decision is made to turn out a small tonnage of hollow ware, is to convert the brick machine into a hollow ware machine by simply buying a few dies constructed so as to fit the front of the machine. *Right here the trouble commences,* for a brick machine and a hollow ware machine are alike in appearances only.

Brick machines are built with taper barrels or fronts. This taper is designed for the express purpose of compressing the clay into as solid a mass as possible, in order that a dense bar may emerge from the die. In addition to tapering the barrel, in order to get the maximum bar density, the pitch of the auger in the nozzle is only increased enough to keep the area constant. This increase in the density of the clay is only prevented from doing injury to the barrel front or die, (or else relieving itself thru the hopper), by the fact that a brick die presents a fairly large opening—roughly forty square inches.

DIES DEVELOPED FROM SEWER PIPE INDUSTRY

In reviewing the history of the tile industry it will be found that for years all hollow ware was made on sewer-pipe presses. As is well known these presses are straight barrelled affairs—they have no taper in their entire length. This fact, and also the fact that the clay was pushed thru the die by a plunger, which gave a perfectly equal flow over the entire surface of the die, made them absolutely ideal hollow ware machines in this respect. Their one great drawback was the intermittent delivery.

When the demand came for increased capacities, the auger machine was resorted to. Observation soon disclosed the fact that the webs of tile made on the sewer-pipe press were of sufficient density for all practical purposes and that therefore previous compression in a tapered machine barrel was unnecessary. In addition it was soon found that in attempting to force the compressed clay thru the limited openings of a tile die, the dies and machines were frequently smashed, an excessive amount of horsepower consumed, and, most annoying of all, the clay frequently insisted on backing out thru the hopper in preference to going thru the die.

These observations led to the development of the modern auger hollow ware machine. This machine has a straight barrel, generally a continuous screw auger, the pitch of which is constant or increases toward the front, and a force feed attachment. Sometimes instead of the force feed, a pug-mill is attached which serves the same purpose. This machine does not compress the clay in any way except in front of the auger. The auger merely solidifies and expresses it to the die opening, giving at the same time the greatest speed with the least possible consumption of power.

The differences between the brick machine and the tile machine, altho seemingly slight, are really great, in fact, great enough in many cases to make the difference between success and failure.

Of course, considerable hollow ware is made on ordinary brick machines, but when they are used, the many troubles which are encountered when even the most perfect equipment is used, are magnified a hundred-fold, and what is more important, the user is losing the benefit of all the work and investigation that is at present going on in the effort to eliminate the troubles of this branch of the industry: For it is obviously impossible to get investigators to spend time experimenting with machines which they know to be unfit for the work required.

DIE TROUBLES MAY ORIGINATE ELSEWHERE

That successful die construction and adjustment is not confined to work on the dies alone, the author will attempt to point out in the following. The fact is, so many other items enter into the consideration, that the die might almost be considered as of secondary importance. Many clayworkers have spent months and even years and wasted thousand of dollars in experimenting with dies, *only to find that all of their trouble came from other sources,* which were overlooked because they were not understood.

On the other hand, adjusting a die so that it runs out ware that dries and burns safely is not enough. "Tonnage" is the cry in the tile industry, and *"tonnage" must be gotten.* It is therefore necessary to so build and adjust the dies that the greatest possible column speed may be reached. Many dies are built which will "run" successfully at a low speed, but when an attempt is made to get any respectable tonnage out of them, they are absolutely useless.

When a clayworker orders a hollow ware machine there is one item which should receive his most careful attention; that is, to see that the *auger or main shaft is absolutely central in the barrel.* It will even pay to make the trip to the factory before the machine is shipped in order to satisfy himself.

No one can estimate the amount of die trouble that has been caused, and the money lost, thru time consumed in taking off and putting on dies, and thru cracked ware, simply because this shaft was not properly located.

It is naturally expected that machines come from the factory in perfect condition, but in the past this has not always been the case. *The experienced tile makers look for such defects,* but the man who is just getting into the game is not very likely to look for trouble in the machine as soon as it arrives.

Very often the auger shaft on a used machine will be slightly sprung, and this is even worse than having it out of center. It is practically impossible to successfully make ware on a machine in this condition, as the auger changes the lines of pressure on each revolution.. In the case of the shaft which is not central, the pressure is always released at the point where the circumference of the auger is farthest from the sides of the barrel.

SPEED OF MACHINE—EFFECT ON DIES

The speed of the machine is a very important factor. A die may be built which will run out ware at a slow speed—say ten feet per minute—which will pass thru the dryer in perfect conditon. But if an attempt be made to speed up the machine so as to make fifteen feet per minute, the resulting ware is a dead loss.

Some clayworkers upon finding this to be the case, have provided for the machine a drive from a separate engine, or better still, from a variable speed motor. To resort to these methods in most cases, however, is foolish, to say the least. The clayworker who "goes after" such a die and so adjusts it that he gets from twenty to thirty feet per minute is more than repaid for the trouble taken.

When a machine is being driven too fast for a die, the latter invariably develops fast and slow areas. Sections of the die which give the least resistance to the clay flow, either thru webs or walls or the location of bridges, will be fast in proportion to other sections. In cases which are not bad, the ware may appear good enough to go into the drier, but will come out cracked. In extreme cases the column will tear up as it leaves the die. The remedy for this trouble will be taken up later in this chapter.

In determining the speed at which a machine should be driven, the raw material enters very little into the consideration. Of course, clays and shales vary enough to make some difference, but they are not the determining factor. When a machine is to be driven at constant speed, the most important point to be considered is the relation between the size of the largest die—or rather the largest tile—which will be made, and the capacity of the barrel of the machine.

When the auger is driven at too great a speed on a large tile, there is not sufficient compression in front of it to give equal pressure over the whole die. This is due to the large amount of openings in the die, the clay getting away comparatively too fast. There is practically nothing that can be done to a die to eliminate this trouble. With a lower speed, the clay gets a chance to gather between the auger and the die, the space forming a sort of reservoir, and it is then compressed and flows out evenly thru the die openings.

When a machine which can only be run at one speed is used to make a variety of sizes it is necessary to determine the speed acording to the size of the large tile. Many modern hollow ware plants have separate units for the large and small sizes, thus getting away from the difficulty. This, however, is not a general rule.

While it is obviously impossible to give the best auger speed on account of the great variety of raw materials, the speeds most widely used range from 20 to 25 R. P. M. In a few cases the auger is run up as high as 50 R. P. M., but such practice is condemned by hollow ware manufacturers generally. The machine or auger speed is another troublesome item in connection with the converted brick machine. Brick machines are always run at higher speeds than tile machines, or at least should be, and unless the machine speed is lowered for hollow ware, trouble is almost certain to ensue.

TYPES OF DIES

For all practical purposes hollow ware dies may be considered as being of two types, viz.: flat and tapered (see Fig. 8). Flat dies are always dry, but the tapered type may be either dry or lubricated. There is practically no difference in the methods of adjusting the two types when run dry, but difficulty is often experienced with lubricated dies, due to their complicated construction. True, they are less likely to give trouble when first started, but like all tile dies their "middle name is 'Trouble'". It may be well to note in this connection that the large manufacturers use dry dies, and this fact should be enough to convince beginners *that this kind of die is the best,* not only to begin with, but to stick to.

In the flat type the openings are almost always straight, i. e., the sides of the die plate and the sides of the cores are parallel thru the entire thickness of the die. In the tapered type the die tapers on all sides down to the face plate, thru the thickness of which only are the sides of the die parallel with the sides of the cores.

POINTS ON TAPER OF DIE

The taper or angle of the openings of a die present one of the most interesting problems in die construction and adjustment, in fact the *speed of the column issuing from any die is regulated by this taper or angle.*

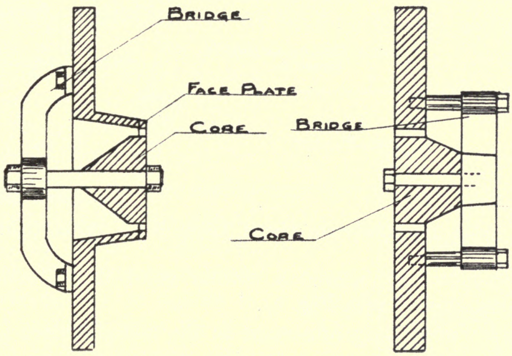


Fig. 8. The Two Types of Hollow Ware Dies.

When the tapered die was first introduced, the idea of the taper was to give a slight compression to the clay before it issued from the die plate. Each die manufacturer had his own ideas as to the amount of taper a die should have, depending somewhat upon the clay or shale that was to be worked.

A few of the more progressive hollow ware manufacturers have found that the amount of taper given a die is of the utmost importance. No rules or laws which might govern this can be laid down, *for each individual clay or shale requires a separate treatment;* that is—each clay or shale or mixture *will develop its greatest column speed when run thru a die with a certain taper.*

In some cases this taper is so slight as to be almost negligible, in others, it is considerable. In order to find the proper taper for any material, it is necessary to make a die of some soft material—preferably wood. It should be made with perfectly straight openings and the cores should be of the same material. When put on the machine the column speed should be noted constantly. As the clay wears away the material of which the die is made, the bar will speed up until a certain point is reached—*the peak*—after which the *speed will drop constantly.*

As soon as the column reaches the greatest speed, the angle of wear should be noted. Two or three trials may be necessary to determine this point, but when it is once obtained it may be worth thousands of dollars a year to a manufacturer. One of the important points to note is that as the

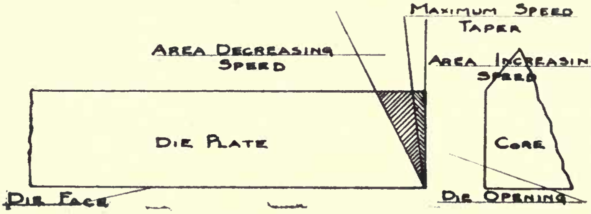


Fig. 9. Showing Maximum Speed Taper for a Theoretical Clay.

taper is increased beyond a certain point the column gets constantly slower (see Fig. 9).

This is exceedingly important to the manufacturer who is buying "stock" or ready-made dies. How does he know but that the dies he is buying have a taper far greater than his raw material will stand? Probably a die with more or less taper would increase his tonnage from twenty-five to a hundred per cent, especially on certain kinds of slow running tile. One thing should be borne in mind in this connection—no taper at all is far better than too much. The increase in column speed from the no taper point to the maximum speed taper is often little or nothing, *but beyond the maximum speed taper the column invariably slows down.*

In order to take care of the wear on the dies, some manufacturers build them with less taper than is required to produce the maximum speed, and allow the die to wear to the proper angle—passing which it is rebuilt or relined.

AVOID LONG MOUTH DIES

To make a die exactly right originally would mean that practically from the moment it was put on the machine it would get slower. The slowing down of the column is caused by the wedging effect which the clay gets in passing thru an opening which is wider at the point of entrance than at the point of exit. The mixture of clay grains and water can be compressed up to a certain point, but beyond that point no more compression is possible and the clay wedges as it attempts to pass thru.

A difficulty often experienced in the taper type die, and this is especially true of dies with considerable taper, is the springing of the cores out of positon. The great length of the cores and posts and the excessive compression within the die itself combine to make this a common trouble. Sometimes "spreaders"—small screws or pins (Fig. 10)—are used to overcome this difficulty, but care must be taken that these are not placed too close to the front of the die, as they will develop cracks in the ware. When cores are forced even a sixteenth of an inch out of place, the loss of ware in the dryer is likely to be great.

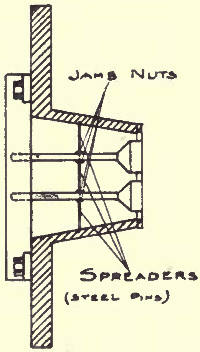


Fig. 10. Showing Spreaders for Keeping Cores from Shifting.

A long mouth die, or in other words, a long die, should be avoided whenever possible. A short die is much less likely to cause trouble, is lighter to handle, and consumes far less power. Clayworkers often contend that only one type of die will work on their particular material, when the fact is that they have never tried any other, nor tried to improve on the ones they use. It is simply a case of their having started with one type and continued to use it, altho it is quite possible that it may be the most troublesome type they could possibly use. Lack of initiative in this direction, as in many others in this industry, is responsible for much of the tile makers' trouble.

AFFECT OF RAW MATERIALS ON DIE

Raw materials, that is, the clay or shale which is used—naturally have a very considerable bearing on the type of die as well as on its construction and methods of adjustment. Some materials slip thru a die like so much grease, while others offer a very strong resistance. Furthermore, some materials can be run thru a die in a very soft condition, while others have to be very stiff. It is apparent that under these conditions, a wide variation in die construction is possible.

Where an easy running machine is used, the dies can be built very light, the bridge and posts being reduced to a minimum. On the other hand, where a hard running clay is used, or where it is necessary to run it very stiff, the bridges must be heavy and strong. Light die construction usually produces fast dies, while heavy construction tends to produce slow ones. As a general rule, it may be said that a die with considerable metal behind it will require more adjusting than one with less.

Every ounce of metal added to the back of a die offers resistance to the clay flow—in other words, acts as a baffle. It therefore pays well to closely study the raw materials available, in order to so handle them that the lightest possible construction may be used in the die and behind it.

It is a noticeable fact that weathered materials slip thru a die easier than unweathered materials. Most clay and shale banks have a covering of weathered material. When care is taken to get the *maximum percentage of this weathered material mixed with every load that goes to the pans,* the best results are generally obtained. When enough of this material is not available to get the best results, *unweathered material should be weathered whenever possible.*

Many clayworkers would be surprised at the results, in the way of increased column speed, the lowering of power consumption and the reduction of die wear that follow the use of material that has been given even a slight weathering, as compared with the results obtained with unweathered material.

A slight weathering may be given by shooting ahead at the bank with, of course, due precaution for the mixing of this material with that which is newer. Very often the addition of the small percentage of surface clay (when this is available) will have a beneficial effect upon column speed, power consumption and die wear.

Fineness of grain (or fine grinding) has a far greater effect on tile dies than most clayworkers realize. Coarse materials will invariably slow-up a die and, in most instances, make the column "drag" at the corners. The author has observed cases where new screen-plates in the pans, and new screens ahead of the pug-mill have "speeded-up" a whole set of dies from eight to ten feet per minute, and at the same time, eliminated the "dragged" corners. *Whenever a die slows down for no apparent reason, look at the plates in the pans and see if the screen-boy is attending to his business.*

It must be remembered, too, that the drying qualities of the raw material have a very considerable bearing upon the die and upon its proper adjustment. Some clays will go thru a dryer without loss, even when run on a die that is decidedly unbalanced. Others require dies that are in the most perfect adjustment. Cases are known where it seemed practically impossible to run ware on certain dies without excessive—it may be said prohibitive—dryer loss, and where it was found that various substances could be added to the clay that would make it work with these same dies, and without a marked dryer loss.

The most common of these materials is "grog"—ground-up burnt ware. This is ground in the pans with the clay or shale. Other substances very successfully used are tannic acid in crystalline form, common salt, raw limestone and slacked lime. *Sometimes less than one per cent of these substances will overcome very bad cases.* The raw limestone and salt have especially proved successful.

Even with clays which dry easily and with dies that are perfectly balanced, heavy losses will occur if ware is "rushed" thru the dryers. While there are materials which will not stand a progressive tunnel-dryer treatment, there are, fortunately, many that do not require the slower hot-floor or open-room treatment. Experiment, patience, and a great fund of common sense are important requisites—in fact, the onlv guides.

ONE VERY IMPORTANT POINT

Brickmakers and other clayworkers have, in many instances, unsuccessfully attempted to make hollow ware. After a comparatively short trial they have given it up, with the impression that the available raw materials were not suitable. In the writer's opinion, the clay was blamed for the fault in the men, who did not have the "stick-to-it" quality that is necessary to success.

The author believes it perfectly safe to say that *any material from which other structural products are made can be* *successfully used in the manufacture of hollowware.* Plants have been known to work for two years or more before successfully solving their problems, during all of that time meeting with a loss of from one-quarter to three-quarters of all of the ware that was made. *But in the end, they were able to successfully work the available raw material* and with losses that were very inconsiderable.

The surface clays of eastern Canada are unquestionably the most difficult to handle on this continent, no matter what products are made from them. In spite of this, four large plants are manufacturing fire-proofing from them, and are turning out a product that will compare favorably with anything in this line made at any other point in America, *and with less loss than the average American plant.*

These results were not accomplished without years of experimenting and a large money outlay, but they stand as a lasting record of what can be done with "impossible" materials, if the nerve and determination is there to make those materials "possible."

The "never-say-die" rule should be adopted by every clayworker who goes into the hollowware game. Before starting, however, he should get all of the information that it is possible for him to obtain, regarding his material. Then he should go after information relative to dies and machines. When he comes to the point where he must select one type of die, he should work with that type until he becomes acquainted with his own peculiar and particular requirements, and then, with the original die as a starting point, evolve a die that is suitable for his materials. Radical changes almost always mean starting all over again. It pays to go slow.

CHAPTER III

Factors Important to Dies

PROBABLY LESS IS KNOWN about scientific auger construction than about any other subject connected with the hollowware or brick industry. Practically all of the progress that has been made has been thru the efforts of the men who make clayworking machinery in their attempts to provide augers to suit the various materials that have been met with. No data is available and only a few general rules are adhered to. One thing, however, is known; that is, that *the design of an auger for hollowware should be different from that of an auger that is used in the manufacture of brick.* In the former, the diameter remains constant, with the pitch sometimes constant, but generally increasing; in the latter, the diameter decreases with the pitch constant, or increases only enough to maintain the area between the flights constant.

All three types of augers, single, double and triple wing are used. The single wing is the fastest, without question, but as a rule the die must be placed so far from the auger (in order to overcome the unequal flow and the lamination) that this advantage is lost. The single wing auger also has a great tendency to make dies flow fast in the center and to cause lamination. This often necessitates heavy baffling at that point, which reacts against speed.

As a general rule the single wing auger is to be avoided, especially by the man who is inexperienced. Equal pressure over the face of the die is hardest to get with this type, and warped ware—especially with thin shapes—often results from its use.

The double wing auger is most generally used and gives good results, altho there are cases where the triple wing has made a marked improvement over it. Theoretically the triple wing should be best and give the least amount of die trouble, on account of the even pressure given the column. Three wings, however, displace considerable clay in the machine barrel, which may be a serious matter where large tile are to be made. Also more friction is set up in the barrel and more power consumed, and where hard running clays are encountered this may seriously interfere with column speed.

In some cases, the auger is run thru the barrel as a continuous screw. This may be single part of the way and double the balance, or double all the way; in the case of a triple wing it may begin as a single under the hopper, then change to double and finally change to triple at the tip.

In other cases the screw is broken in the sections back of the tip or ordinary knives are used, as in a brick machine. Materials vary so much that only by experimenting in each case can the best type be determined. It will pay handsomely, however, to spend a little money in this direction, as results vary greatly in every case.

One of the most annoying troubles encountered in tile manufacture is due to *auger wear.* A die may be made to run perfectly and at a satisfactory speed with a new auger which has been run just long enough to get a polish, but this same die will begin to be troublesome as soon as the auger begins to wear at the circumference and a space is opened up between it and the barrel. This space around the auger offers a point of release for the clay and allows it to slip back, in other words, *it allows the pressure to be released at the outside corners and walls of the die,* while the center keeps up its speed.

The result is an unbalanced die and the necessity for baffles in the center. Just as soon, however, as a new auger is put on, the center is slow and these baffles must be removed or smaller ones substituted. Taking care of this auger wear is a serious problem and one that is met in practically no other branch of the industry.

ALLOY STEEL AUGERS.

In the author's opinion, hollowware manufacturers—especially the larger ones—who have made no move in this direction would do well to abandon the ordinary chilled semi-steel auger which loses its "skin" in a short time, and experiment with augers of alloy-steels such as manganese, chrome, nickel or vanadium.

Some have done this and given it up as a bad job simply because it took too long to give them a polish. The matter of polishing an auger is another annoying problem to the tilemaker, and one that can be eliminated to a great extent if he will tackle it in the right way.

Taking a certain die for example, which under good conditions will run 12,000 ft. per day; when a new auger is put on, this same die will run 5,000 ft.—probably the second day it will run 7,000 ft., the third day 10,000 ft. and on the fourth day, will be up to capacity.

The total loss of 10,000 ft. of ware or practically a day's

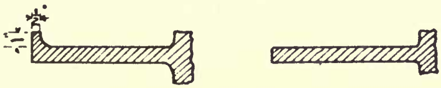


Fig. 11.—Section of Auger Flight With and Without Lip.

run with a value of, say, $250 is chargeable to "polishing the auger," and this may happen every twenty to fifty days, according to the raw material.

Now is such a loss necessary? Some tilemakers have come to the conclusion that it is. How many of the augers used come from the manufacturers with just the rough spots knocked off the casting with a grinding wheel? *Probably* 98 *per cent.* And where is the real polishing done? *In the machine, and at a cost of from* $200 *to* $500; for besides the actual loss in ware, the overhead expenses must be added and the increased power consumption of the machine.

Cutting down the expense is really a rather simple matter; if the auger had been polished before it went into the machine the trouble would be practically eliminated, for, as one of the clay machinery companies recently remarked in an advertisement: "The machine is not the place to polish the auger."

If the clayworker would insist on it and pay for it, undoubtedly the machinery people would polish the augers to a glasslike smoothness. If they will not or cannot, the clayworker can himself install a portable grinding and buffing wheel with a flexible shaft, at less than half the cost of polishing one auger in the machine, and with a labor cost of $5 or less, grind and buff every auger until it shines like a mirror. Of course, even with this done the auger will not get up to speed for a few hours or a day, but so little difference would be noted that the terrors of a new auger would be no more.

Tilemakers who are using an auger without a lip (Fig. 11), would do well to have one put on their pattern. Such a lip adds considerable life to the auger by keeping the edge from so rapidly wearing away.

When the barrel liners of a machine have worn to such an extent that considerable space is left around a new auger, it is time to consider a new set of liners. Worn liners have the same effect on a die as a worn auger, and tend to seriously decrease the life of an auger by allowing the clay to slip back around it. *One-half inch* is considered the maximum space that should be allowed around an auger and this is often too much.

DISTANCE OF AUGER FROM DIE

Hollowware machines are supplied with extension rings so that a die may be placed at its proper working distance from the auger. This distance is exceedingly important in die adjustment and much trouble comes from the fact that many clayworkers give the matter no consideration. Tile of no great variation in size can generally be run at the same distance, once the proper distance is determined. *But when there is a great difference in size the distance will change with the majority of raw materials.* The proper distances cannot be specified under any circumstances, as it is absolutely a matter of experiment. The type of machine, speed of machine, raw material and dies are all determining factors.

The increase or decrease in this distance will often correct die trouble without anything further being done. A die which will not make a single good tile when placed five inches from the auger tip may run splendidly at ten inches.

It should be borne in mind, however, that with each fractional increase in the distance of the auger from the die, the power consumption of the machine is greatly increased. It is therefore necessary to place the die *as close as possible and still get good results.*

Warping and cracking is often caused by having the die too close to the auger. This is due to the weave given the column by the auger. When the die is very close, this weave is noticeable as the column runs out; but at other times it does not show up until the ware is dry.

It is always well, therefore, when attempting to adjust a die to be sure the distance is correct, for in many cases nothing can be accomplished unless that is first made right.

Another matter connected with this distance (and very important in some cases where large tile are made) is that the space between the die and auger acts as a reservoir from which the clay is evenly forced thru the die by the "push" of the auger behind it. Unless this reservoir is large enough, or, in other words, *the bulk of the clay between die and auger is great enough,* the auger action or pressure is likely to be localized, the tendency being towards fast flow in the center and slower flow at the outside. This trouble is usually overcome by baffling the center of the die, which will necessarily slow the column and cut capacity. A correction can often be made by increasing the distance of die from auger without a reduction of speed.

It has become an accepted fact that in order to secure the best results, the barrel of the machine must be proportionate to the size of ware made with it. This means that a well designed hollow-ware plant will have at least two machines—one for the smaller tile and one for the larger.

Competent authorities seem to agree that for such tile as 4-in. by 12-in., 3-in. by 12-in. and 5-in. by 8-in. column covering, Denison tile, etc., the barrel should be 16-in. to 17-in. in diameter, while for the larger tile, the barrel should be only slightly larger than is required for the largest size.

The difficulty which arises when a large barreled machine is used for small tile is that the clay itself forms a tapering nozzle between auger and die, thereby creating the same conditions as are encountered in the use of a tapered nozzle machine. This causes excessive compression of the clay, and a reduction of the possible column speed.

FORCE FEED

The tile manufacturer has gradually come to the realization that a force feed apparatus of some sort is an absolute necessity. There are a number of these on the market and most of them have merit. Of course, where a pug-mill is combined with the machine it acts as a force feed apparatus.

Some raw materials absolutely require a mechanical force feed to assist the auger to keep up the necessary pressure behind the die. In these cases even constant hand punching at the hopper will not prevent the uneven pressure from causing much loss at the dryer.

There can be little question that in many cases where a man is kept constantly punching at the hopper in lieu of a mechanical feed, more or less mysterious die trouble occurs, due to constantly changing die pressure and flow. The cause may not be traced to this source, but it is reasonable to suppose that no matter how conscientious the "human force feed" may be (and it is often a boy who doesn't know what "conscientious" means) he will let up on his work at times. A car of ware comes thru the dryer in pretty bad shape in the midst of others in perfect shape. There is much theorizing as to the cause and very often everything is blamed but the right thing—the "human force feed."

Even where a mechanical feed is used, care must be taken

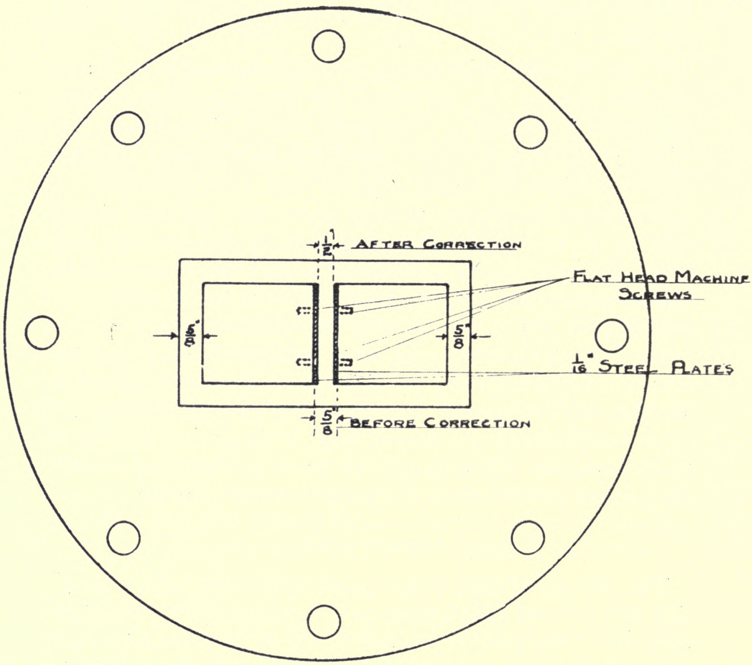


Fig. 12. Showing Method of Correcting Fast Flow in Center by Use of Steel Plates or Shims on Cores.

to make the pug-mill keep the hopper full or the same mysterious dryer losses will occur.

DISTRIBUTION OF METAL ON BACK OF DIES

In the foregoing the writer has attempted to treat in detail those factors outside of the dies which have an effect on die construction and adjustment. It will be readily seen that it is almost a hopeless proposition to successfully tackle the dies themselves unless some knowledge is possessed of the factors mentioned. And while a few clayworkers are so

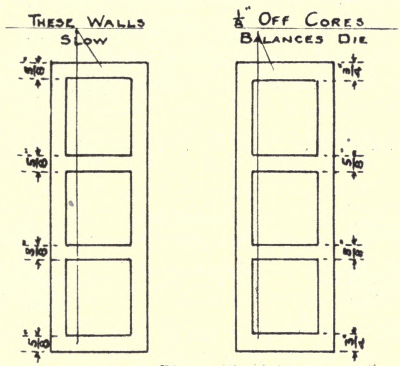


Fig. 13. Showing Method of Balancing Die by Opening Up Slow Walls or Webs.

fortunate as to have raw materials which can be literally "murdered" and which make the tile business seem like child's play, it is not so with the vast majority. The great trouble with the tile business is that a clayworker starts out with one die, generally a simple one, which may give little trouble, but inside of a year or two he finds himself with anywhere from ten to fifty dies, and in the meantime he has found his difficulties increasing and his lack of knowledge of the "fine points" very disconcerting.

Coming to the dies themselves, it is found that the distribution of the metal at the back, in the shape of bridges, cores, bridge-posts, nuts, studs, etc., has an important bearing on the working of them. It will be readily understood that anything placed back of the die opening, if only a single thin bridge, will interfere with the equal flow of the clay thru the die opening and also the speed of that flow.

It should therefore be the object of the die builder to reduce this interference to a minimum by making the bridges, posts, cores, etc., as light as the service required of them will stand. It is also important that these metal parts be distributed over the back of the die as evenly as possible.

This will balance the "interference" and cause the clay to flow evenly. If this is not done and the bridges (for instance) are concentrated over any particular part of the die, the resulting interference with clay flow at that point will produce a slow area. This will probably have to be counterbalanced by baffles over the fast areas, the result being that the column speed will be considerably reduced.

A close study of his dies in action, together with a little experimenting, will soon teach a clayworker to easily overcome many die troubles by a slight shifting of the bridges and posts.

Two instances that have come to the author's attention are

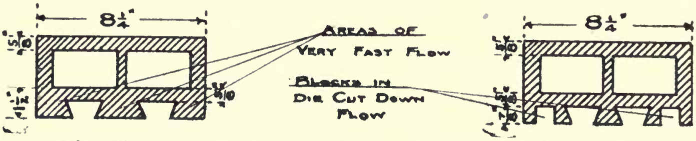


Fig. 14. On Left, Original Shape of Jamb Tile Die Decidedly Unbalanced. On Right, New Shape of Jamb Tile Die Perfectly Balanced.

cited; a partition-die allowed a fast flow in the center and was baffled at the point in order to balance it. The two outside bridges (it was a three core die) were moved ⅜-in. closer to the center. The cores were reset so that all webs and walls remained exactly as before. The result was a perfectly balanced die without the use of baffles, and which produced over 1,000 feet more ware per day.

In the other case the ⅞-in. nuts which held the bridges down on the bridge-posts were removed, and the bridges pinned to the posts instead. The removal of even this slight amount of metal, (about one pound) increased the die speed almost ten per cent.

It will invariably be found best to avoid baffling a die with metal plates if such a thing be possible. Sometimes it is not possible and then they must be resorted to. Generally it entails more work to get a balanced die by other methods, but it always pays if tonnage and power consumption count for anything.

When a new die is put on the machine it must get a certain amount of wear before it gets "set." The bridges, cores and other parts must get a polish before anything definite can be told as to the final results it will give. In such cases it is wise to use baffles where necessary. It may be found that after a short time it will run well enough without the baffles, but if it does not, a move should be made to correct its faults.

If, for instance, the middle cross-webs or web is very much faster than the balance of the die, a shim consisting of a thin piece of steel can be fastened to the cores, thus making the fast webs slightly thinner. Sometimes 1/32-in. will be enough (Figures 12 and 16). It is seldom that even ⅛-in. in web thickness will effect the sale or safety of a tile, so that this ordinarily cannot be an objection.

If, however, the webs cannot be made thinner (on account of reducing the safety factor) a thin cut on the sides of the cores next to the slow walls or webs, thus slightly increasing the thickness of these walls or webs, will have the same effect by speeding up the slow portions of the die, as is shown in Figure 13. When it is only a single wall or web that is slow, it is very easy and effective to open up the die at this point. This is very much better practice than baffling the entire die down to the speed of this slow portion.

Occasionally, a tile is of such a shape that one or more of its webs are very much thicker than all the others. Naturally such a die is very difficult to handle. A die of this type and a method of balancing it is shown in Figure 14. In the original, the wide wall was so much faster than the balance of the die that very large baffles were necessary. The resistance to the clay flow was so great that finally the die was broken. The second die works perfectly without the use of the baffles and is about five feet faster per minute.

SCORERS AND SCRATCHERS

The type of scorer or scratcher used has a very considerable effect on the die. Some form of dovetail grooving is used on almost all modern plants, but the methods of producing it differ. Whatever the design of the scorers, their shape has a tendency to drag at the walls of the tile, invariably slowing them.

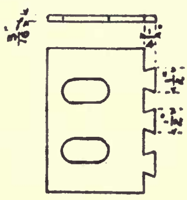


Fig. 15. Tool Steel Scorer, Adjustable.

As the grooving is absolutely necessary, the speed of the whole die must be made to conform to the grooved walls. However, the number of grooves make a very considerable difference and this may often be taken advantage of in adjusting a die. If a die has a slow wall on which are six grooves, a reduction to five or four may be all that is necessary to correct the trouble. Similarly a fast wall may be slowed down by the addition of one or more grooves or by the widening of them. When flat steel scorers are fastened on the outside of the die they can be moved in or out to make more or less resistance. (See Figure 15.) These are simple expedients and should be taken advantage of at every opportunity.

METAL BAFFLES

When it is impossible to take advantage of any other method, the metal plate must be resorted to to prevent local fast areas in a die. The plate is fastened to the die plate or bridge, according to the location of the trouble. This method of adjustment is very simple, but its use leads to increased power consumption, often a slow running columns, smashed bridges and sometimes smashed dies.

There are times when a metal baffle is absolutely necessary. A die may be so constructed that a thin core will be so exposed to the clay pressure that it shifts, thereby unbalancing the die. In such cases a small baffle is placed on top

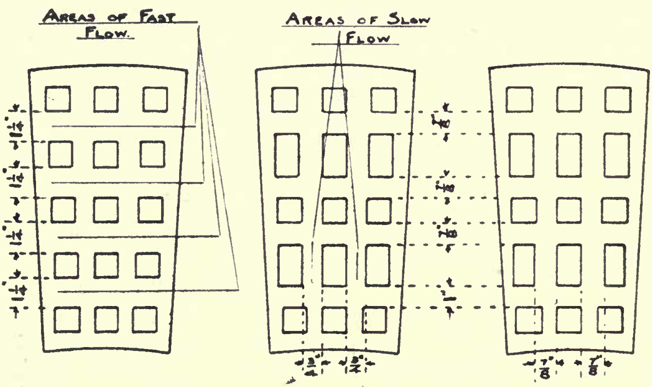


Fig. 16. On Left, Original Tile; in Center, First Attempt at Balancing; at Right, Second Attempt at Balancing, with Die Perfectly Balanced.

of the bridge in such a position that some of the pressure is taken off the exposed side of the core, allowing it to retain its normal position. Care should be taken to make a baffle as small as possible and still get desired results, and never to use a baffle until every other means has been exhausted.

BRIDGE CRACKS

Bridge cracks are the hollow-ware maker's bugbear. There is unquestionably more trouble from this source than any other, yet (strange as the statement may seem) it is often the easiest to overcome.

When the clay is parted by the bridge it must be given a certain distance and a certain amount of pressure in which to "weld" again. Some materials are of such a physical nature that they will do this in one inch of travel, while others require from three to six inches. In preventing bridge cracks the tapered die is supposed to have a decided advantage over the flat die, in that the clay is given a slight compression after passing the bridge. However, close observation of the two have failed to give either an advantage in this respect.

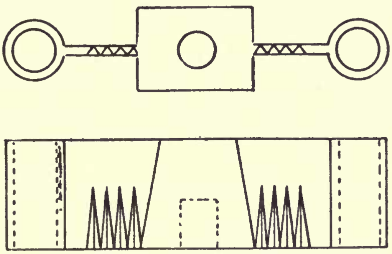


Fig. 17. Serrated Bridge to Prevent Bridge Cracks.

When a bridge crack occurs, one thing is shown plainly and that is that the clay had not sufficient opportunity to knit from the time it passed the bridge until it issued from the die, or putting it another way—the bridge was too close to the point of issue. Probably setting the bridge back a ½ in. would overcome the difficulty entirely or it might be necessary to move it three or four inches.

Materials vary so much in their knitting or "welding" qualities that only by experiment can the proper distance be determined. If a die turns out bridge cracked ware the bridges should be moved back a little at a time, until the trouble ceases, and cease it surely will when the proper distance is found. As a general rule, when once the proper distance is determined, all bridges can safely be placed at that distance, but occasionally some one die will require a separate treatment.

Various means are used to assist the clay in knitting. One of these is to serrate or "saw-tooth" the bottom of the bridges. (See Figure 17.) Another is to wrap a chain around the troublesome bridge. However, where it is necessary to resort to the latter device it is best to move the bridge back slightly, as the chain has to be constantly replaced. The temper of the clay may have a bearing on bridge cracking. Some material will knit readily when given a certain temper and refuse to knit when the clay is not so treated.

DIE WEAR

The openings in a die are subject to the constant abrasive action of the material forced thru them. Some materials being more gritty than others wear dies faster, but all dies wear out sooner or later. Just when a die is worn out and ready for the scrap-heap or the machine shop is a matter that is difficult to decide. Dies of the ordinary cast-iron variety, when built for speed, begin to slow up and act badly very quickly. With progressive manufacturers this "slowing up" means that the die is ready for the discard. Other manufacturers continue to use a die until it almost refuses to run a column. It will readily be seen that this is a short sighted policy, for not only does the loss of from two to ten (or more) feet per minute amount to a considerable tonnage in even a day's run, but the increased thickness of the walls and webs adds considerably to the cost of manufacture and to the freight when the ware is shipped.

As has been previously mentioned, when the angle of the die opening passes a certain point, the column begins to slow down, and it becomes increasingly slower as the angle becomes greater. Furthermore, the wear on the die plate and the cores so affects the flow that it becomes increasingly difficult to keep the die balanced.

As a well built die costs from $25 to $50 a tile maker has only to sit down and figure an equal loss in tonnage and cost to find out when his dies are worn out, no matter what the appearances may be.

Brickyard scrap piles are often fearful and wonderful sights, but most fearful and wonderful of all are the scrap heaps of some hollow-ware plants, especially some of the larger ones. It is undoubtedly good practice to withdraw from use a worn die, and *it is unquestionably bad practice to use a die which has to be thrown away.*

Quite a number of manufacturers have developed dies which, with minor repairs, practically last forever. In such dies the cores are lined with replacable tempered tool-steel plates. All wearing surfaces except the bridges are lined with the same material. Others line the dies and cores in the same way with mild steel or cast-iron. The author has never seen a type of dry die which could not be lined and relined in this way, altho the original relining might be difficult in some cases. However, if it is too difficult a proposition there can be no reason why the type should not be so modified as to permit of its being done and thus cut out a source of loss. At any rate, there can be no reason why ordinary cast-iron should be used at all. Far better wearing materials, which can be as easily machined, are available at up-to-date foundries, and case-hardening of most of the wearing parts is not a difficult matter. Unfortunately, to follow such suggestions increases the first cost of a die (possibly one-third) and this is almost always an objection to the clayworker, even tho such expenditures pay dividends in the long run.

TOOL STEEL DOES NOT SLOW UP DIE

Objection is heard in some quarters to the use of certain materials in die construction, for instance, tool-steel, it being often claimed that this material slows a die. After numerous experiments, the author cannot believe that this objection is valid, no matter what the qualities of the raw material may be. Such claims are generally based on theories or experiments which have never been followed thru, or are advanced by men who are afraid to step off the beaten paths they have trodden all their lives.

CHAPTER VI

Dryer Details

IT IS NOT THE INTENTION of the author to go into a lot of theoretical calculations pertaining to the evaporation of moisture, size of flues, vents and stacks, because such calculations are absolutely useless to the average clay-worker. It is rather the intention to stick almost entirely to constructional details and suggestions, and especially to those which are so often overlooked and which lead to those annoyances to which so many dryers are heir.

In the first place, dryer troubles would be far less frequent if, before constructing one, clay plant owners would consult with experts in this particular line. This does not mean consulting a man who has one particular type of dryer to build or sell, but rather consulting several of them and also obtaining the advice of an expert who has nothing to sell at all.

DRYERS REQUIRE MUCH CARE AND THOUGHT

There is no other part of a clay plant that requires so much care and thought in its design and construction as does the dryer. Any one of a dozen different makes of machines will grind the raw material or form the ware, and any one of a dozen kinds of kilns will burn it, but it is almost impossible to pick out, promiscuously, one of the many kinds of dryers available and not run against losses which at times are appalling.

A certain type of dryer may do splendid work on stiff-mud brick made of an easy drying clay, but will not work at all on those made of a tender clay. Again, one dryer will do excellent work on a stiff-mud brick, but will not dry successfully, soft-mud brick of the same material. One dryer of the tunnel type will handle successfully, hollow-ware on the continuous principle, while another tunnel dryer would have to be operated on the intermittent principle, in order to safely dry the same ware from the same clay.

Many clayworkers who have been long in the business are coming or have come to the realization that there is a great deal more to the drying end of the business than they had supposed. Some of them who have duplicated time and again, drying units which appeared to them to be best adapted to their particular case, have found that for years past it would have been possible to have installed systems which would have saved large amounts of money thru greater speed with smaller losses.

Putting aside the consideration of open-air dryers, the primary object of all artificial dryers is to *get rid of the moisture in the ware with the greatest speed at the lowest cost*, at the same time having due consideration for the safety of the ware. To obtain these results certain well-known principles or laws must be observed. Among the most important of these is the one requiring that all dryers must be so designed that the first stage of the drying be carried on *at very moderate temperatures and with only a slight movement of the surrounding atmosphere* or else in a *very moist atmosphere at higher temperatures and with a decided movement of the surrounding atmosphere.* Dryers designed to produce the latter conditions are, as a general rule, the most efficient in every respect. Those designed to produce the first mentioned conditions reproduce in reality, the conditions found in an open air dryer, their only advantage being a heating apparatus which makes them independent of weather conditions.

OPEN AIR DRYERS

In spite of the advances made by the industry in late years, more open-air dryers are in use than is generally supposed. Most of these, naturally, are to be found on plants using the soft-mud process which are operated only during the summer months. The drying is generally done in racks, the pallets being wheeled out on trucks and later again moved by trucks from the racks to the kilns.

The cost of drying under these conditions is quite high, in fact higher than in most artificial dryers. There are several reasons for this, the principal one being the several handlings necessary between the machine and kilns. On large plants, too, the drying racks cover a large area and the distances covered by the truckers is considerable. On many plants the investment in racks amounts to a large sum and the exposure to the elements causes excessive depreciation.

Many clayworkers using this method of drying have sought for a means of eliminating some of these bad features without going to the expense of erecting dryer buildings.

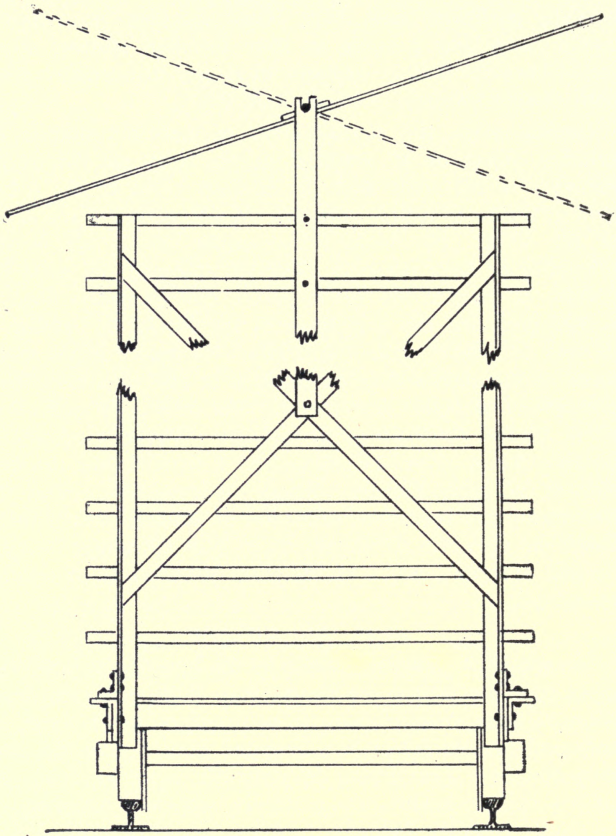


Fig. 18. Dryer Car with Weather Protector.

The following method is suggested as a method of overcoming the difficulties encountered with the racks. Any number of tracks of a length convenient to the layout of the plant are laid down in the open. Regular soft-mud rack cars, stiff-mud or hollow-ware cars are provided of exactly the same type and gauge as used in artificial dryers. Each car is provided with a removable sheet metal "roof" which can be tilted so as to protect the ware from rain and sun. The idea is shown in Fig. 18.

The greatest advantage of this system is that the ware is placed on the cars at the machine and not handled again until it is run into the kiln. There is also the great advantage of having both cars and rails ready for immediate use should it be decided to erect an artificial dryer at any future time. Other advantages are the decidedly lower upkeep on cars over wooden racks and the elimination of a very bad fire risk which, in most cases, is non-insurable.

INITIAL COST LITTLE GREATER THAN FOR RACKS

The difference in first cost is slightly in favor of the racks, but with the ever-increasing cost of lumber, this is not as much as would be supposed. Then, too, in case an artificial dryer is ever built, the investment in racks is a total loss whereas there is practically no loss in connection with the cars and tracks.

Very often a company starts out with insufficient capital to erect dryer buildings and permanent kilns and uses the open air method until able to afford better equipment. In such cases this method of drying is ideal, as there is no waste of capital involved.

The method is also useful on hollow-ware plants making large shapes which are difficult to dry safely in an artificial dryer. Such an open air system can be used during the summer months when a stock of the troublesome shapes can be laid in to carry over the winter months.

If necessary, a low wooden framework can be built on the outside of the two outer tracks, from the top of which rolls of canvas can be dropped to protect the outside cars from driving rains. The cars on the inside tracks are so close together that there is no danger to the ware from this source.

DRYER BUILDINGS

Whatever the type of artificial dryer built it must have walls and a roof. In many cases it has apparently been considered unnecessary to give a thought to the materials which have been used in the construction of the building. Lumber has been very popular, especially on the smaller plants. Brick has naturally been used most, while concrete, especially in roof construction, has had its share of users. Strange to say, hollow-tile has found favor with very few constructors.

Primarily, of course, the shell of the building is there for the purpose of preventing the escape of the heat to the atmosphere until it has done its work. It is not the idea of the clayworker that only part of the heat which he puts into the building shall do work; on the contrary, it is his earnest desire that all of it shall be utilized. Yet, in spite of this fact, how much effort is made to prevent radiation, to say nothing of more direct losses of heat? In not more, than one dryer in one hundred has there been the slightest effort

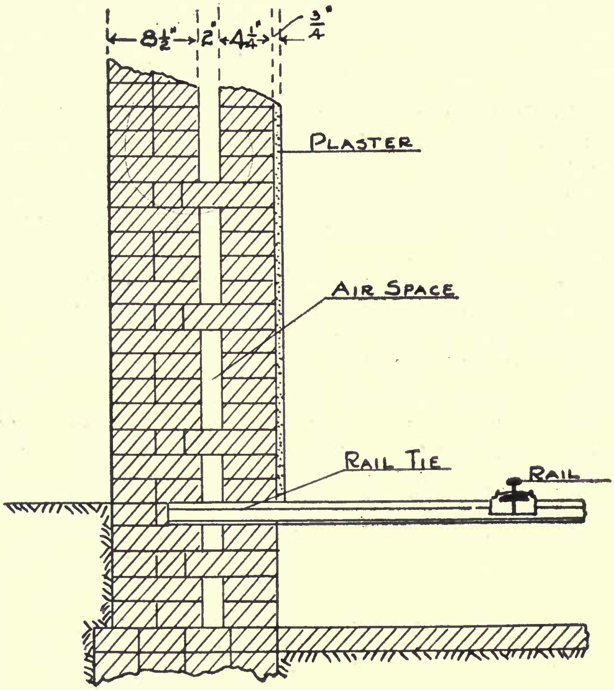


Fig. 19. Showing Outer Wall of Dryer with Air Space and Plaster.

made to prevent radiation losses, and this in spite of the fact that on the other ninety-nine plants the great cry is for more heat for drying purposes. At ordinary drying temperatures insulation of walls and roof is an extremely simple matter; one in fact, that does not even involve extra cost.

The use of lumber cannot be too strongly condemned for many reasons. In the first place, lumber anywhere about a clay plant increases the fire risk. When used in a dryer it is especially dangerous, for parts of the building are always as dry as tinder, and no matter what the method of heating may be, there is always a danger of a fire being started within the building itself. Frame buildings of this type are nearly always "thrown together" with the consequence that in a short time they become as open as a sieve. Even when care is taken to insulate the walls, the effort nearly always fails, due to green lumber and the temperature maintained within.

Even the lumber men, who formerly built all of their dryers of wood, are rapidly abandoning this type of construction. One lumber company recently made the statement that their new dryer, which was built of hollow-tile and had replaced an especially well-built frame dryer, was showing a saving of twenty-five per cent. in fuel and drying the lumber in twenty-five per cent. less time.

Of all the materials available, lumber is the least suited to the purposes of dryer construction.

BRICK WITH AIR SPACE FORMS GOOD DRYER WALL

Brick is an excellent material for wall construction, providing the walls are built with an air space. In a dryer building (while it is not necessary in order to carry the roof load unless the second floor is used) it is best to build the walls one and a half brick thick as shown in Fig. 19. It will be noted that the air space is broken by header courses. This is done to break up air currents which otherwise would be set up in the air space and which would have free flow from bottom to top of walls. It may seem strange to specify a coat of plaster on the inside of the outside walls, but this has been found to give such excellent results that sooner or later it is bound to come into general use. On test, the difference between the radiation thru a plastered and unplastered wall is really remarkable. A wall plastered on both sides will radiate twenty per cent. less heat, and a wall plastered on one side approximately ten per cent. less than an unplastered wall. Clayworkers who are now troubled with cold outside tunnels would do well to note this.

The plaster will adhere to the wall if brick having a good suction are used on the inside and the mortar joints are raked out so as to allow the plaster to key into them.

Concrete walls for dryers are without question, a failure. True, they will hold up the roof and prevent *all* of the heat from getting away, but on actual tests they have proved themselves to be poor insulators. In comparing the fuel consumption of the outside tunnels of two radiation dryers, one having twelve-inch walls of brick and the other twelve-inch walls of concrete, the concrete dryer showed a fuel consumption thirty per cent. higher than the brick dryer. Both dryers were identical except for the material in the walls and were drying the same ware. If it were possible to build comparatively thin concrete walls with an air space, the difficulty might be overcome, but while this is possible it is not practical.

Hollow-tile is the ideal material for dryer walls. It not only has all the strength necessary, but the cells provide the necessary air spaces and the tile are usually scored for plaster. It is not necessary to use No. 1 tile for this type of building as it is always possible to buy good seconds, if the clayworker does not manufacture tile himself, which will make an excellent job. When a tile wall is used it should be twelve inches thick and it is equally as important to plaster it as in the case of a brick wall.

Where dryer walls (not footings) extend below grade in order to protect flues, as is the case in radiation dryers and some waste heat and steam dryers, it is very necessary to have them absolutely waterproof. Due to the rapid evaporation on the inside of such walls, the amount of moisture drawn thru them is very great. This is generally made worse by the fact that eaves-troughs are seldom provided for the dryer buildings. The effect of moisture, and the radiation from outside walls combined, often decrease the efficiency of outside tunnels by one-half.

The walls below grade should be plastered on the outside with a mixture consisting of two parts sand and one of cement, which, after setting, should be given a good coat of tar. It should be borne in mind that this waterproofing below grade is as important as insulation above grade.

DRAINAGE

Clayworkers have become pretty well convinced of late that drainage of kiln bottoms is an absolute necessity, but not one in a hundred gives the dryer a thought in this connection.

Waste heat and radiation dryers are the types that suffer most in this respect. Waste heat flues and the under flues of the dryer building are more often than not, saturated with moisture during and after a wet spell. Moreover, it is a common thing to find a waste heat flue deliberately used as a drain for the surface water of a yard. *What sort of dryer efficiency can a clayworker expect who deliberately puts moisture from outside sources into a building which is designed to extract and conduct away moisture from the ware put into it?* There are some instances where it may not be possible to keep water out of the flues, but in most cases there is no excuse for its presence.

Waste heat flues should be drained in exactly the same manner as kiln bottoms, that is, by running drains under them and by draining surface water away from them.

The under-flue system of a dryer, whatever the type, should be underlaid with a series of drains that will conduct away every particle of moisture possible.

It is not uncommon to see plants on which the kiln bottoms are so well drained that they are always dry, but on which not the least precaution has been taken to drain the dryer and its flues. The result is that it is an impossibility to get dry ware during a wet spell, no matter how much fuel is used on the auxiliary heaters, and right there is a point. Does the average clayworker stop to figure why he uses so much more fuel in the auxiliary heater or else get so much more wet ware, in the spring, winter and fall? There is but one answer to that question and that is, *moisture in the flue system.*

CHAPTER V

Dryer Construction

MANY DRYERS which are otherwise well built have their efficiency greatly reduced thru having a poor roof. It is utter folly to expect a reinforced concrete or steel and brick roof from three to four inches in thickness to prevent excessive radiation and to keep out moisture. It is exactly the same proposition as building a kiln with a three-foot wall to prevent radiation and then covering it with a nine-inch crown. Any clayworker who has put a second story over his dryer tunnels and used it for drying purposes knows this from the fact that he can dry in the upper story almost as well as in the tunnels simply from the radiation thru the dryer roof. Furthermore, such a roof should be protected from the rain and snow by a protecting roof, otherwise a very large percentage of the moisture from this source is certain to find its way into the tunnels.

If it is proposed at some future time to put a second story over the tunnels in order to increase the drying capacity, as is often done on hollow-ware plants, a thin, solid roof over the tunnels is the proper construction, but if such is not the case, every effort should be made to so construct a roof that practically all radiation is prevented.

A roof which has been designed from the results of thoro laboratory experiments and is practically the last word in dryer roof design is shown in Fig. 20. As will be seen, it consists of two courses of four-cell six-inch hollow-tile with a layer of insulating felt between. The under side is given a coat of ¾-inch cement stucco mixed very lean and the top is coated with one inch of cinder concrete. Such a roof is unquestionably more expensive than the ordinary dryer roof, but its efficiency will soon pay any additional cost. The tile are supported on "T" irons spaced one-foot centers. This roof is a decided success in preventing radiation and its construc-

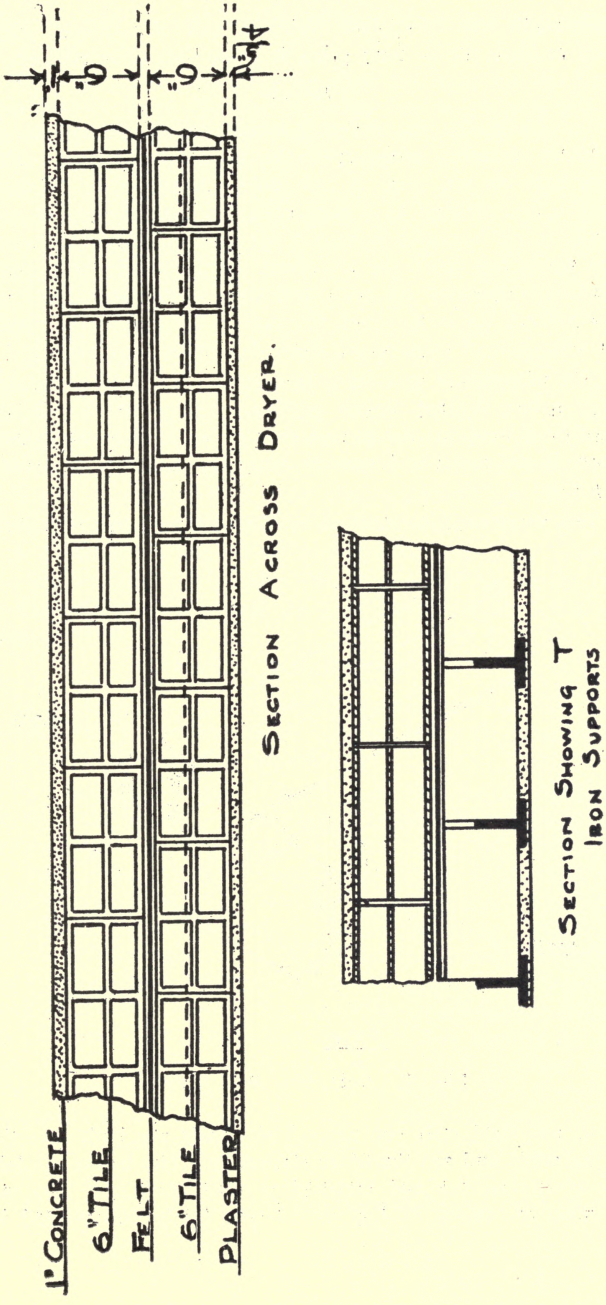


Fig. 20. Dryer Roof Design.

tion might well be copied. While a roof of four-inch partition or book tile is fairly good, it is too thin to be efficient.

RAILS

In considering the dryer it would hardly do to pass by without devoting some space to track construction. Putting cars on the track in hot tunnels is the curse of many plants, and strange as it may seem, no real efforts are ever made to *permanently* overcome the trouble. Many clayworkers would not credit the statement that there are some plants that have operated for years and have never had a dryer car jump the track in a tunnel, yet such is the case. It is simply another case of engineering methods against "any old way."

The atmosphere in a dryer is such that wooden ties will not hold spikes for any length of time. The moisture and heat combined tend to shrink and rot any kind of timber. Also there is the constant danger in many dryers of the ties catching fire.

The most modern method of overcoming these difficulties

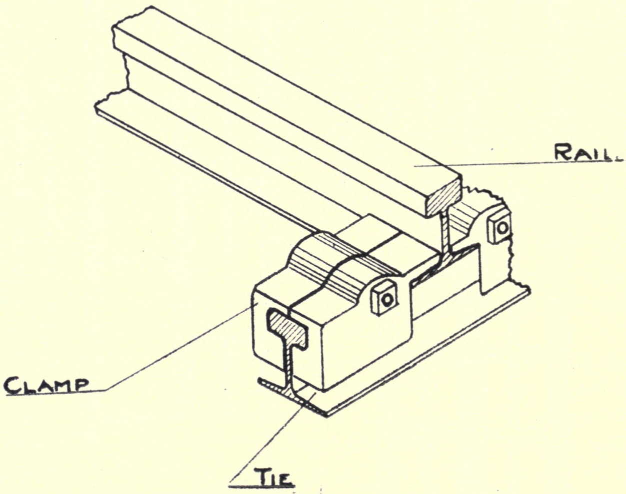


Fig. 21. Cast Iron Rail Clamp.

is to use steel rails for ties. These rails are built into the dryer walls and are therefore stationary. The tracks are laid on these rail ties and fastened to them with cast iron rail clamps, as shown in Fig. 21. Dryer tracks constructed in this way will be trouble-proof. Fig. 22 illustrates this method of construction.

The rails in dryers are very often too light for the work expected of them. Twenty to twenty-five pound rails will do much toward eliminating trouble, as there is no chance of their kinking under the weight they have to carry.

The grade or fall given the tracks in a dryer is an important item. It should be only just enough so that the transfer men are compelled to push a car without any great effort, all the way into a tunnel, or to pull a car out without having the cars behind rush out before giving a chance to block them. When too much grade is given the men will "shoot" a car into a tunnel with the result that when the moving car hits the stationary ones considerable ware is broken or damaged all the way down the line, to say nothing of the mess created on the tracks. Too little fall is also bad, for in that case the line of cars cannot be started without "bumping" them in much the same way that a locomotive takes up slack for a start. This results also in much damaged ware.

A grade of one foot in one hundred has proved to be good for the average dryer, altho with cars which run easily, this has sometimes been a little too much, and with hard running cars too little.

TUNNEL DIMENSIONS

In an open room dryer the dimensions are not very important, the main point to be watched being the keeping of the source of heat below the ware.

In tunnel dryers where the flow of heat is horizontal or partially so, the dimensions of the tunnels are extremely important. If there is any one thing that makes for inefficiency in many dryers it is the overlooking of this fact. In order that the heat in a tunnel may do efficient work, the car and ware must fit as tight as is practically possible. *Space over the top of the ware should be absolutely avoided,* for heated air always rises to the top, and if it is given an opportunity, most of it will flow over the top of the ware instead of around and thru it. Not only is heat wasted in this manner but the top courses of ware are dried first and often too fast with heavy losses as a result. In building tunnels it is therefore *absolutely necessary that the exact height of a loaded car of ware be known and only sufficient space left above to give clearance.*

On each side of the cars also *only sufficient space* should

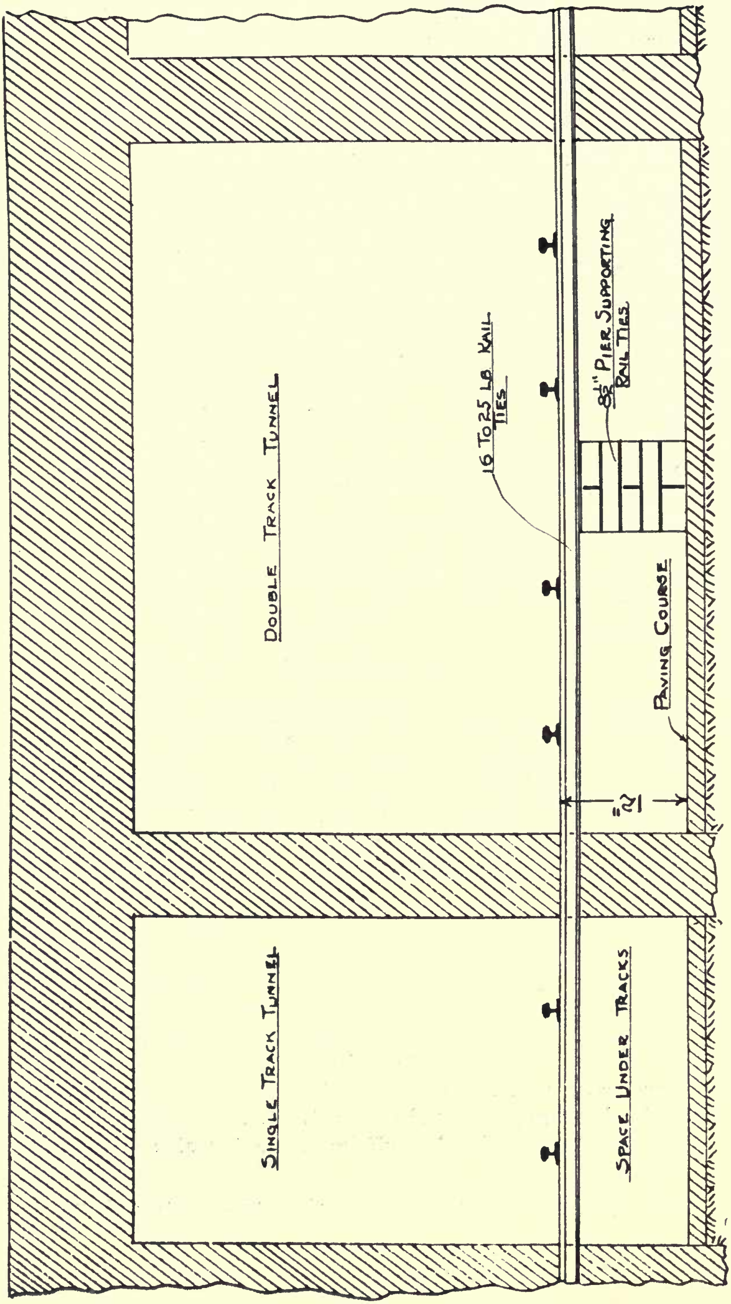


Fig. 22.—Showing Details of Single and Double Tunnel Construction.

be left to give good clearance, otherwise the air will take the path of least resistance and a large proportion of it will flow between car and walls without doing any work.

The design of the lower part of the tunnels is an item which is overlooked by nearly all dryer constructors. Even those who make the cars fit tight in a tunnel give very little thought to the creation of a flow of air beneath the cars or to the getting rid of the ware which is jarred or falls from the cars, and which in the average dryer is the cause of so many cars jumping the track.

If steel rail ties are used to support the tracks it is a simple matter to leave a space of one foot below the tracks the full length of the tunnels. This space offers a free path for the air flowing thru the tunnel which, combined with the natural tendency of the air to rise, gives exactly the condition in the tunnel which is most desired, namely, a circulation *thru and under the ware.*

Furthermore, this space allows all ware falling from the cars to accumulate *under the tracks instead of on them.* Even in dryers where there is much loss during transit thru the tunnels this space will only require cleaning out about once each year. Most clayworkers who have had experience with tunnel dryers will undoubtedly agree that if the space serves no other purpose, the fact that it will keep the tracks clean makes it a really worth while item in dryer design. This type of construction is also shown in Fig. 22.

The question of putting one or two tracks in a tunnel often comes to the fore. There can be no question that it is an extremely annoying thing to have a loaded car jump the track in a single tunnel dryer, especially where the cars fit fairly tight. Sometimes the cars will be in such a position that, due to the limited space in which the men have to work, it takes hours to get it on again. Much of this trouble is eliminated when double track tunnels are built, for by temporarily clearing one track, plenty of room is provided for several men to get around the wrecked car. A well designed double track dryer should be as efficient as a single track dryer and the advantage referred to above should carry weight when considering this question. It is also cheaper to construct.

DOORS

A vexing dryer problem is that of doors. Any number of different designs are in use, but each one of them seems to leave something to be desired. For single tunnels a pair of small outward swinging sheet steel doors to each tunnel is much in favor. Having two doors to each tunnel makes each of them very light, and as they swing out, a string of cars that may be accidentally started will part and pass thru them

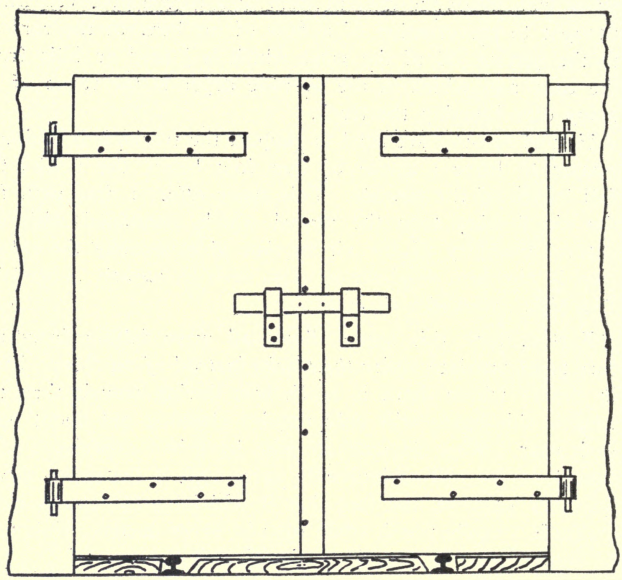


Fig. 23. Double Steel Doors.

without doing them injury. Such a pair of doors is illustrated in Fig. 23. The space between the rails, which is often left so that it admits much cold air, can be filled with a 2x4 with grooves cut for the wheel flanges. Where double tunnels are used the swinging steel door is not so successful as its weight is inclined to make it sag, thus causing trouble in dragging on the rails when opening or closing.

The counterbalanced door which is raised and lowered is a popular type, especially where the storage space at the cool and hot ends is limited, but it has the disadvantage of being battered or broken if the cars in the tunnel start and jamb it.

Another type which is less popular, but nevertheless successful, is the sheet steel door with the hinge at the top. This is swung open by lifting from the bottom. Cars striking it merely lift it without doing it any damage. However, for double tunnels it is quite heavy and this is a disadvantage, altho it can be counterweighed. This door can be fitted tight around the rails. Suspended hooks must be provided for holding it open while putting in or drawing cars. This type of door is shown in Fig. 24.

VENT STACK CONSTRUCTION

Many dryers, both of the tunnel and open room type are provided with a stack at the cool end. This acts in lieu of an exhaust fan. The question as to whether to use a fan or a stack is one that can only be decided by an engineer who has examined the proposition thoroly, but there is this to be said in favor of the stack—it does away with the fixed operating charge of a fan.

Vent stacks are often built of lumber, but when built in this way they are not a good, permanent investment. Stacks of brick or hollow-tile when well built are both permanent and of good appearance. This latter point is worth consideration at this time when all industries seem to be vieing with each other in their efforts to combine utility with beauty in factory buildings.

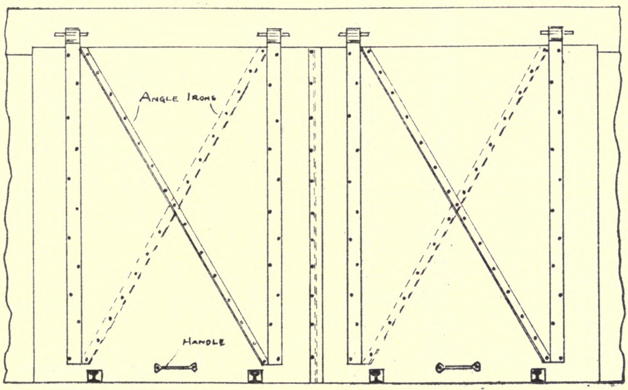


Fig. 24. Steel Moving Doors for Double Track Tunnels.

When building of brick or tile, the walls of the stack should be 8½ inches thick. As a vent stack for a ten-tunnel dryer or its equivalent in width offers a fairly large surface to the wind, it is safest to use cement mortar or at least a well spiked lime mortar.

On account of the varying and fluctuating temperatures of the vapors from a dryer, it is difficult to figure a dryer stack

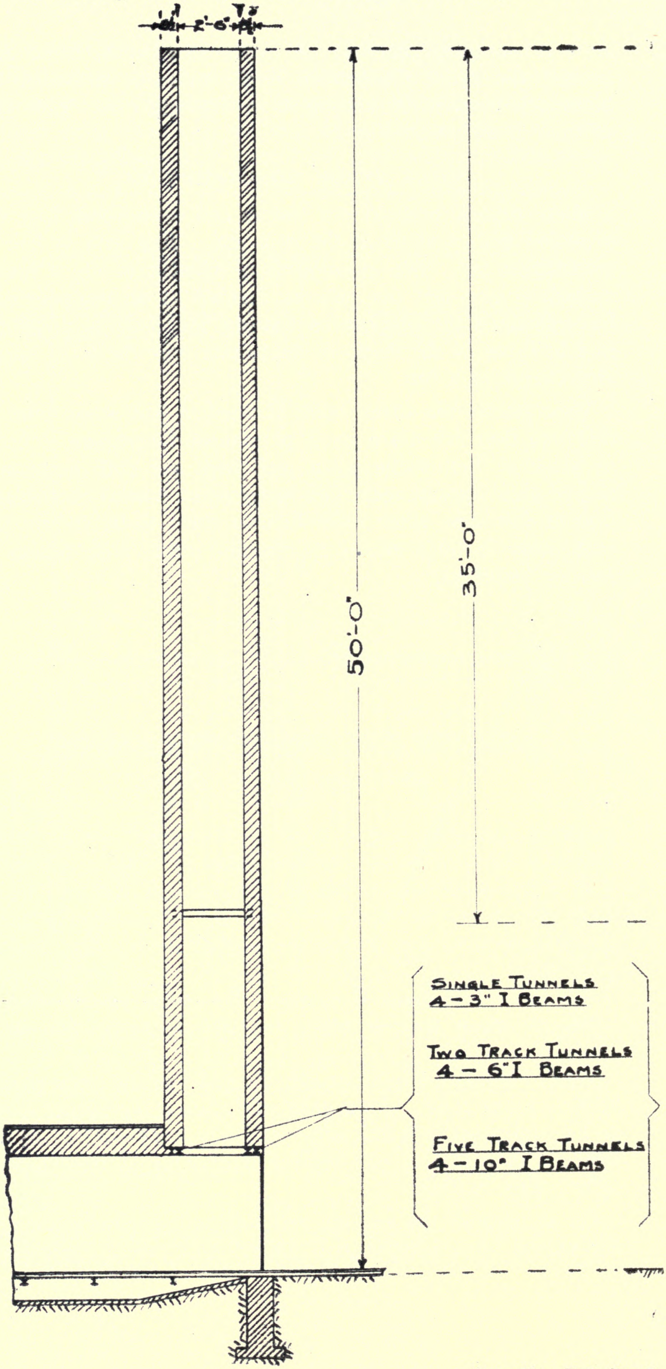
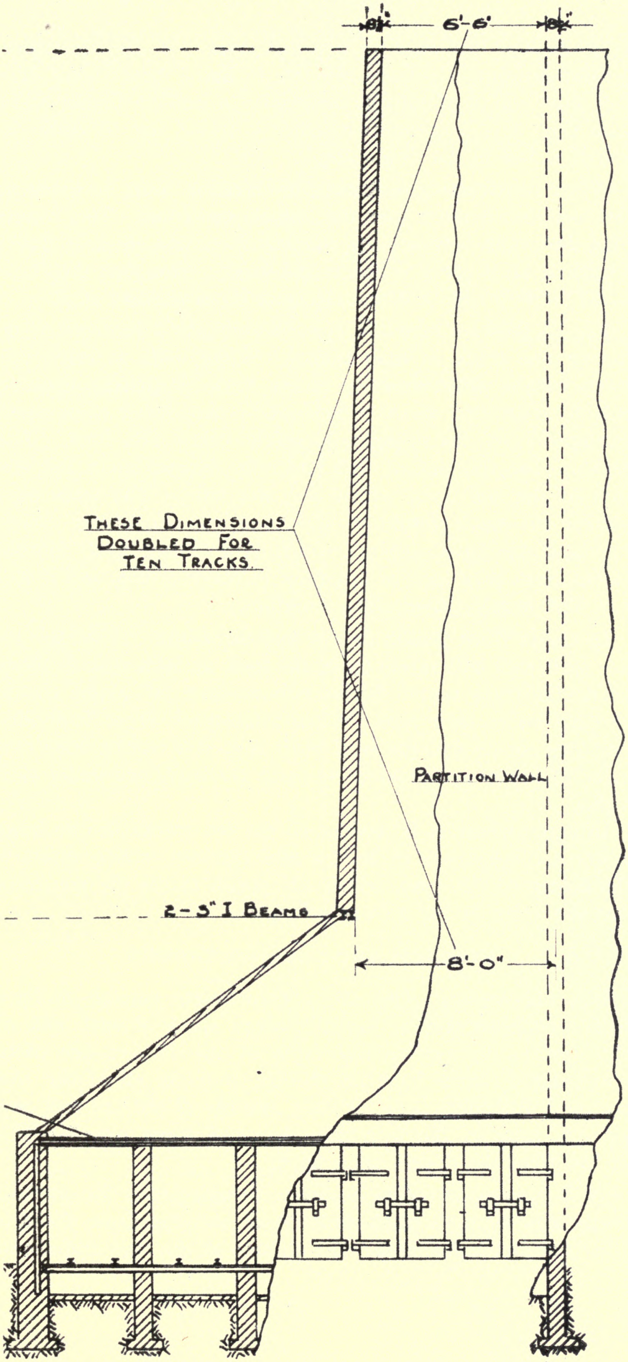


Fig. 25. Detail of



Brick Dryer Stack.

as is done in the case of a boiler stack. It has, therefore, become an almost general practice to build these stacks *fifty feet high.* If it should be necessary to build a higher stack than this, it is a question whether it would not be better to install a fan in the beginning.

When constructing a stack, consideration must be given to the fact that it must span the tunnels or rooms. This means that the walls between the tunnels or rooms directly under the stack must carry concentrated loads. Also that the stack walls directly over the tunnels must be carried on steel.

Fig. 25 shows a standard type of stack for a ten-track dryer having one track in each tunnel. When built of brick this stack weighs approximately ninety tons. Including the two outside walls this means that each of the eleven walls must be figured so that they will safely carry this load. The area of the foundation will naturally depend upon the nature of the soil upon which they are built. The walls supporting the stack should be laid up in cement mortar. Several collapses have occurred which have caused much damage to buildings thru lack of attention to these details, and it will pay well to give them close attention.

In single track tunnel dryers two three-inch "I" beams under each wall will safely carry the load, as each span is short. In double track tunnel dryers two six-inch "I" beams should be used under each wall. When a ten-track dryer is divided into two rooms and the steel must span five tracks, four ten-inch "I" beams are required to carry the load, two under each wall.

In cases where it is desired to put ten tracks in one large room it is necessary to build a pier eighteen inches square in the center of the span, which of course, makes the construction the same as for a five-track span.

STORAGE AND COOLING TRACKS

Few clayworkers who are not fortunate enough to have had experience with a liberal storage space at each end of the dryer fully realize the value of it. Dryers are often encountered which have no storage room at all at the cool end and probably room for only one car at the hot end, and this, in spite of the fact that plenty of space was available at the time the dryers were built.

It is always advisable to have storage room for at least three cars on each track at the cool end and from three to five cars at the hot end. The storage at the cool end allows for fluctuations in the speed of the setters, also for occasions when damp ware begins to show at the hot end and setting must be stopped, as is the case on many plants late in the afternoon. With a storage, the machine can keep running on extra cars which can be thrown in on the storage tracks be-

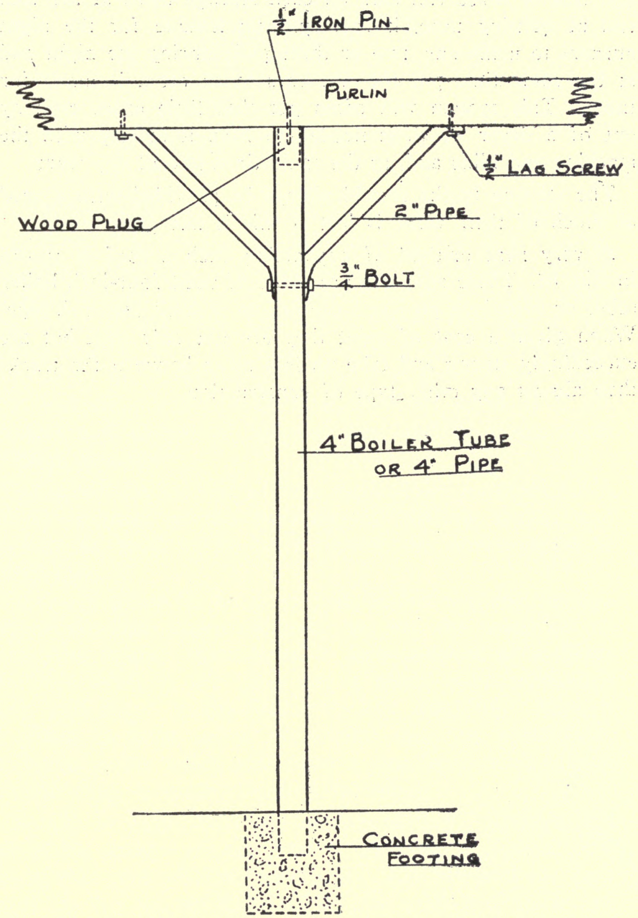


Fig. 26. Detail of Post for Drying Shed.

fore each tunnel and put into the dryer during the night when dry cars can be pulled.

A good storage at the not end allows tne transfer men to make a pull of several cars from each tunnel at a time, thus saving time and cutting down labor costs. The ware gets sufficient time to cool, and is therefore, handled more carefully by the setting crew. An important point to be considered also is that if extra cars are provided the capacity of the dryer can be materially increased. With the dryer full and two or three full cars on each storage track at the cool end at quitting time, it is very little trouble for the night burners to make one, two or three pulls during the night and at the same time put the wet cars in as room is made for them. This system will often get that little extra capacity out of a dryer which is needed to keep it in step with the machine and kilns and, at the same time, get all dry ware.

The storage tracks should always be provided with a roof as much of their value is lost if this is not done.

A very neat method of supporting such a roof is shown in Fig. 26. These supports are made of used four-inch boiler tubes or four-inch pipe and the braces of used two-inch pipe. When given a coat of paint they are not only neat but are exceedingly strong and take up less room between the tracks than almost any other type of construction.

CHAPTER VI

Setting Up-Draft Kilns

SETTING BRICK in up-draft kilns is a more complicated process than setting in down-drafts, and it is reasonably safe to say that there are far more methods of setting the former type than in the latter. Of these many methods, there is one that has found very little use in the United States, altho its many good points should commend it to the clayworker. This is known as the "tight bolt" method. When used in down-draft kilns, it is the simplest and fastest of all methods, and produces most excellent results.

The same can be said of this method for up-draft kilns, but on account of the necessity of setting arches and loose heads, as in all up-draft setting, the setters must be skilled men.

The good points in favor of this method are that, in that part of the kiln where the bolts are set, the brick are of more even shade; the setting is accomplished at a faster rate; the faces of the brick are a plain, even, unflashed color, and there is absolutely no kiln marking. Also, if the firing is done under occasional reducing conditions, the faces of the brick will show a red heart with brown or black ring—a much sought-after result.

As will be seen from the accompanying drawings, the legs of the arches are set three brick wide, a general custom in this type of kiln (up-draft). The brick in the center of the leg are set tight, while those on the outside are set as open as possible. When the overhangers are reached, they are set in tight and open courses, as shown, and between them the brick are set in regular tight-bolts. Above the brick which close the top of the arches an open course is set. This course should be very open, in fact, as open as possible and still prevent the brick above from breaking under the load.

Above this course the "tight bolts" begin and are carried up to within six courses from the top of the kiln.

"Tight bolts" consist merely of an absolutely tight bench of brick. In looking at this bench it presents a solid face of headers. Each bench is set one inch from the one behind, this one-inch space being left for the

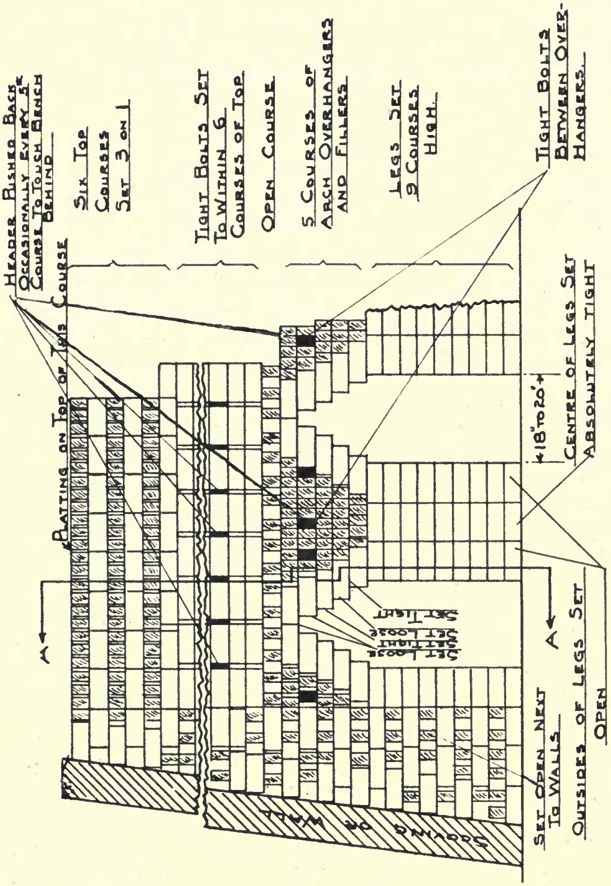
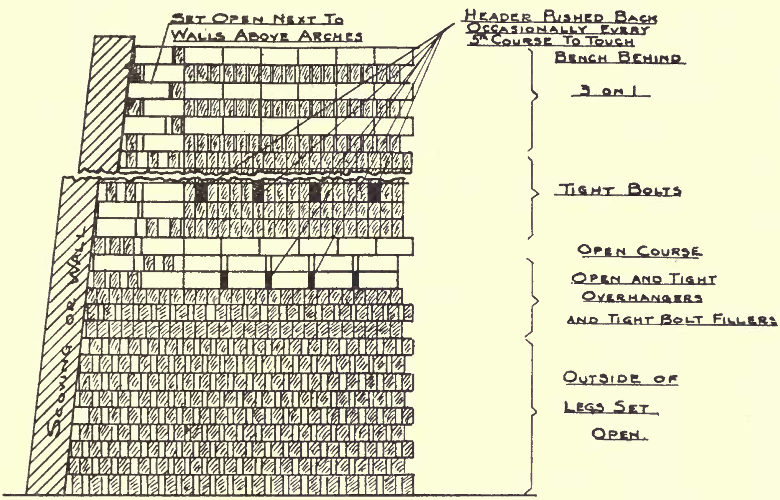


Fig. 27. Detailed Drawing of Setting Showing Method of Building Up the Arches and Laying the Platting on Top. The Section Thru "A-A" is Shown on the Opposite Page.

travel of the fire gases. In order to maintain this distance a "follow board" is used. This is a one-inch board with a couple or more leather handles on the top edge. As the bench is carried up, the board is drawn up and allowed to rest on a few brick shoved back from the bench which is being set. In order to prevent the benches from rolling, every fourth or fifth brick in every fourth or fifth course is shoved back until it touches the bench behind. This makes the setting perfectly stable. Care must be taken, of course, to carry up the benches perfectly straight.

FACILITATES HANDLING OF BRICK

In this method of setting the setter can pick up from the car or barrow all the brick he can hold between his two hands, drop them on the bench and push them back against



SECTION THRU A-A

Fig. 28. Cross-Section of Kiln Showing Again How Platting is Laid and the Loose Setting of the Outside Brick In the Arch Legs. This Drawing Also Shows the Solid Face of Headers Present by a Bench of "Tight Bolts."

the follow board. It is exactly the same as taking burned brick from the barrow and placing them on a hack.

The brick should be set loose next to the walls in order to pull the heat to this usually backward part of the kiln.

The six top courses should be set three on one and on top of this the platting is handled in the usual manner.

Upon first looking at a kiln set with "tight bolts" the average plant manager or superintendent would pronounce it "impossible." It is, however, used with great success in some sections of the country, and where this method of setting is followed, it would be utterly impossible to persuade the clayworkers to change to any other method. The average recovery of *No. 1 face-brick* from up-draft kilns set in this way is well over fifty per cent., and this in districts where the brick must compete with the output of modern continuous and down-draft kilns.

CHAPTER VII

Setting Down-Draft Kilns

SETTING THE KILN, or, to more properly state it, setting the ware in the kiln, has been a subject for study and experiment ever since the first kiln was built—or rather, ever since the first kiln was set. It has grown in importance as kiln structures developed, and, within the past decade has become a matter of vital importance.

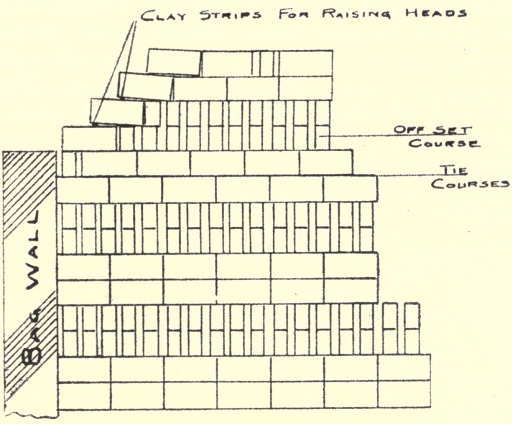


Fig. 29. Showing Method of Raising Heads.

This is due, in great measure, to the introduction of texture face-brick, for, fast following the early popularity of this material, hundreds of plants which had never before attempted the manufacture of anything but commons, became—at least partially—face-brick producers.

In the production of common-brick, the manner of setting was of little moment, so long as it insured a firm mass, frequent draft-passages and kiln capacity. But in order to secure good, merchantable face-brick, these manufacturers found it necessary to make radical changes in their setting methods—finding, indeed, that setting the kiln was fully as important as any of the preliminary processes of manufacture, and as the actual burning.

Nor is the interest confined to those brickmakers who have turned a part of their output from common- to face-brick, for many plants, hitherto exclusively devoted to the manufacture of smooth faced face-brick, have found that the introduction of the new matt surfaced product had a way of reversing old rules, and so these brickmakers were called upon to invent or adopt new ones.

The above, of course, refers entirely to the effect of the setting upon the appearance of the finished product. Another important item must be considered—the relation between the setting and the efficient operation of the kiln.

Kiln designers, some time ago, found that they could not successfully use the rules laid down for ordinary metallurgical furnace construction, because in considering firebox area, flue area and stack area and height, they must always figure on the dense checker work thru which the gases have to travel, downward, aided only by natural draft. Of necessity they worked out rules and ratios of their own, and in these rules and ratios the setting was taken fully into consideration. In a well designed, up-to-the-minute-kiln, therefore, the method or density of the setting makes very little difference, but there are thousands of kilns where it makes all the difference between success and failure.

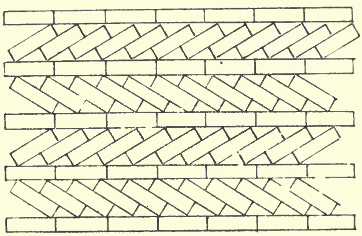


Fig. 30. Plan of "Herring Bone" and Skintle Course. All Brick Set on Edge.

EFFECT OF SETTING ON BURNING

In the first place the setting will be considered only from the standpoint of its effect on the operation of the kiln.

As a general rule, the setting of the ware has a greater effect in a round kiln than in a rectangular one. This is due to the fact that in the majority of round kilns the fire gases are compelled to travel about twice the distance

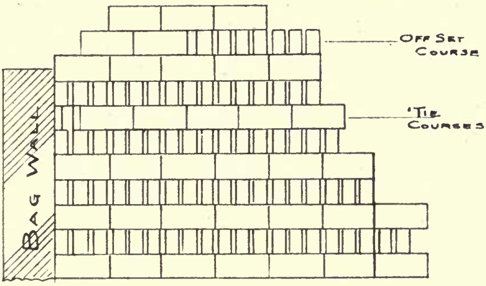


Fig. 31.—Front Elevation. Single Header and Stretcher.

from the fire-boxes to the center, as in a rectangular kiln. There is, then, far more opportunity for the gases to "short cut" into the flues and leave a cone of soft brick in the center, and this is exactly what happens in very many cases. The remedy is very simple—the benches should be tightened (brick set closer together) near the bag-walls and gradually loosened as the middle of the kiln is approached.

When this trouble occurs in a rectangular kiln the same remedy will overcome it. The effect of this is to baffle the gases near the fire-box and drive them toward the center—they naturally following the path of least resistance. "Cool" or "hot" spots are sometimes found to recur in certain places in a kiln. When such spots are located, they can practically always be eliminated thru changes in the setting. In the case of a "cool" spot, the setting should be "opened up" in order that more of the fire gases may be drawn to that particular point. A "hot" spot is treated in the opposite manner—the brick are set tighter at his point in order that less of the fire gases may pass thru it.

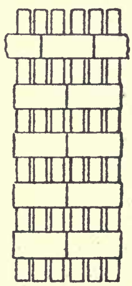


Fig. 32. Section Thru Bench.

The tightness or looseness of the setting—(these terms are used to designate the distance the brick are set from each other) has a very great effect on the burning qualities of many kilns. By setting too tight, in an effort to crowd a large number of brick into a kiln, the burning period is lengthened out of all proportion to the gain in holding capacity. The draft is cut to such an extent that "water settles" and "black cores" develop; the fuel consumption is unreasonably high, due to the length of the burn; overburned brick on the top, and underburned brick in the bottom are the rule. On the other hand, where the setting is too open, space is lost that is valuable, and considerable of the heat value of the fuel is wasted thru escaping too readily to the stack.

These things must be taken into serious consideration by the clayworker who would bring his plant to the highest point of efficiency.

EFFECT OF SETTING ON PRODUCTS

The setting of brick in the kiln is an all important factor in the quality of the finished product. It determines whether, under certain burning conditions, the face of the product will be of a clear color or flashed, and whether the flash covers part or all of the face. It also determines to a great extent how much of the ware will be marked in the burning. Just what methods are used to obtain the various results will be taken up in detail later.

SKILLED LABOR

There is probably no other department in a brick plant where as highly skilled labor is required as in the setting department. Setters must handle the brick rapidly and carefully, at a stage when these brick are more susceptible to damage than at any other. A great deal of a burners' trouble in having kilns "roll" or heads pulled into the fires, is properly chargeable to faults in the setting. Very often the blame is never placed where it belongs and the burner struggles along under a handicap he is unable to overcome.

A skilled setter should constantly keep in touch with his kilns by noting results as they are emptied. In this way he can often suggest improvements and can most certainly correct his own faults.

HEIGHT OF SETTING

Under varying conditions brick are set from twenty-two to thirty-six courses high. There are several determining factors which govern the height to which brick

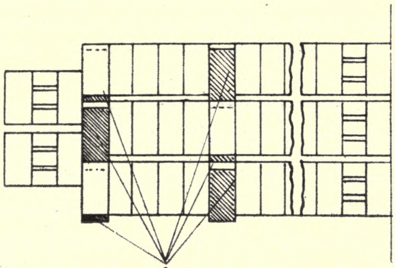


Fig. 34. Section Thru Bench, Tight Bolt Setting.

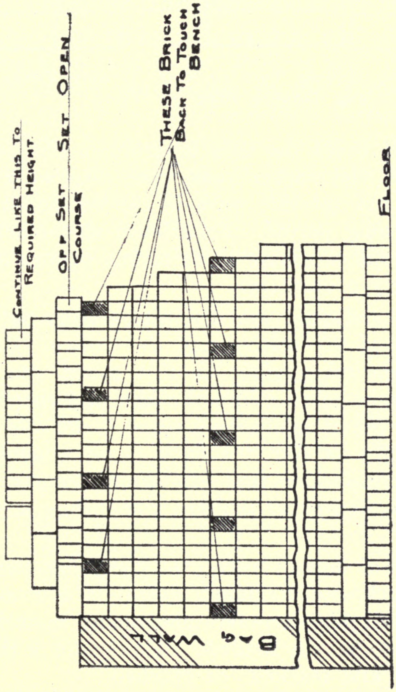


Fig. 33. Front Elevation of Tight Bolt Setting.

may be set. Principal among these are, the burning qualities of the kiln; the ability of the material to sustain loads while under high heats and the liability of water settles during the watersmoking period.

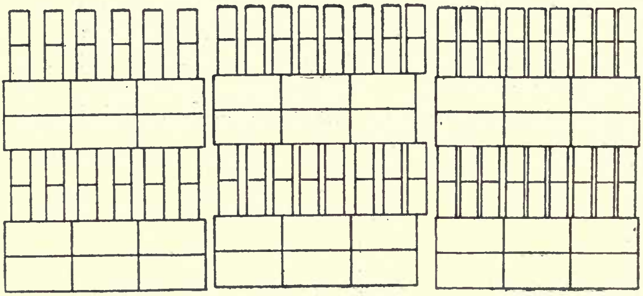


Fig. 35. Showing Double Two on One, Double Three on One and Double Five on Two.

In almost all cases the kiln determines the height of the setting. A clayworker soon finds that at a certain height he can get saleable ware in the bottom, and in a reasonable burning period. Experience also teaches him that to go beyond a certain point means overburned tops in spite of every precaution.

In any case, sufficient space should always be left between the top of the setting and the crown. Considerable combustion takes place in this space, due to unburned coal gases passing into the kiln and there mixing with free air. When combustion space is not allowed for, these gases will pass thru the brick in an unmixed state, resulting in considerable fuel loss and a longer burning period and also flashed or reduced ware when it may not be desired.

In some lines of manufacture, principally fire-clay shapes and paving block, the maximum height is determined by the material. At high temperatures many materials will deform when too heavily loaded. This results in the lower courses being "kiln marked" or crushed.

Kilns with poor draft are sometimes troubled with water settles in the watersmoking period. These are caused by the ware in the lower courses becoming so soft, thru the reabsorption of moisture from the gases, as to crush under their load. About the only remedy, unless changes are made in the kiln itself or the method of burning, is to reduce the setting height.

As a general rule the setting is "battered back" at the tops of the bag- or flash-walls, altho in some cases a little below. It is seldom good practice to run above the bags before battering, on account of the tendency of the fires to "pull" the brick into them. Where the brick are set unusually high, the upper part of the bag-wall is often built of checkerwork, sometimes laid up loose. The reason for this is that it is difficult to get even bottoms in some kilns if the bag-walls are too high. In such cases the checkerwork at the top acts merely as a brace for the setting, while not interfering with the burning.

PREVENTING SAGGING OF HEADS

What is popularly known as the "pull of the fires" on the setting is in reality not "pull" at all. It is due to the difference in the progression of the shrinkage between those brick close to the fires and those farther away. There is a difference in the progression, even in the length of a single brick, as the head of the brick towards the fire will start shrinking before the head that is away from the fire. This difference multiplied by the ten or fifteen brick of the top courses, gives a decided lean towards the fire, and under

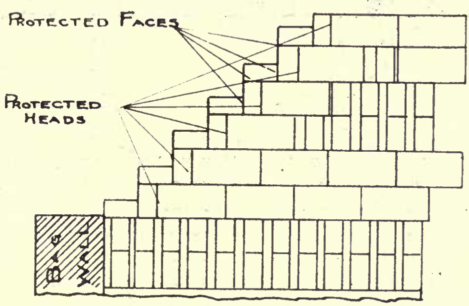


Fig. 36. Method of Protecting Heads from Flash.

certain conditions means a fire-box full of brick. This "tumbling" is often brought on by too rapid firing, the brick nearest the fires naturally catching the heat first and shrinking heavily before those in the body of the kiln.

When this trouble occurs only occasionally and at

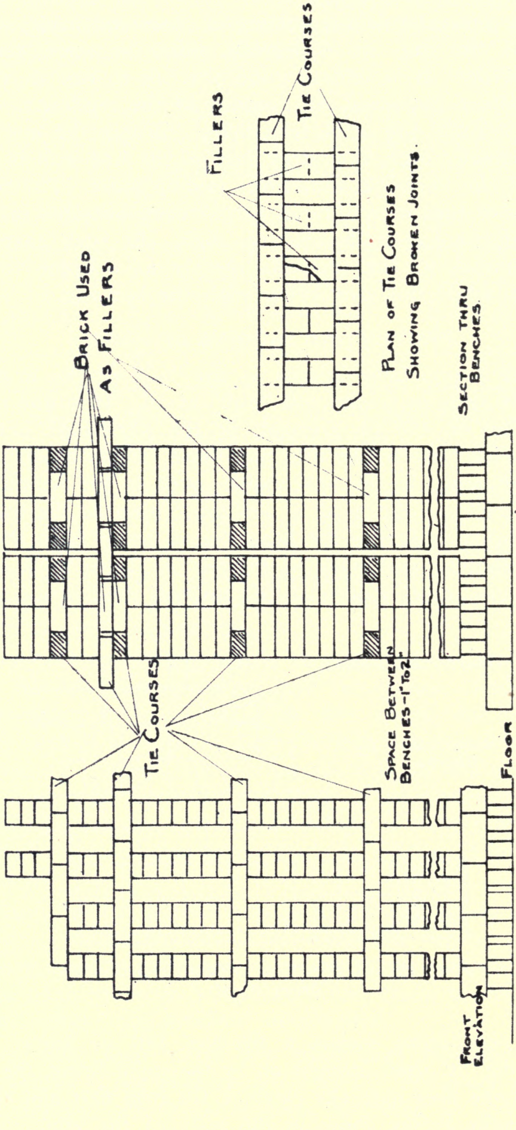


Fig. 37. Method of Setting Whole Kilns on Flat.

isolated furnaces, the commonest method of preventing a "tumble" is to temporarily stop firing the threatened furnace. If necessary, the fires should be drawn and cold air allowed to pass thru the furnace into the kiln. This method is very effective.

In cases where it seems practically impossible to prevent "tumbling" by any ordinary "tying in" of the heads, the following methods must be resorted to: Where round kilns are used, a ring three or four stretchers wide is set entirely around the kiln, close up to the bags. This ring is generally started at one side of the setting door and continued around the kiln to the other side of the door. The floor runners or brick on the floor are set so as to radiate from the center of kiln. All of the headers also radiate in the same way, while the stretchers run in circles. The entire ring is set as one bench and is securely tied together by the stretchers. When the top of the bag-wall is reached the batter is only carried up two or three courses and headers used there entirely. With extremely troublesome materials, two rings, one inside the other, are sometimes used. The inside ring is always carried up higher than the outside. Inside the ring or rings, the regular bench setting is used.

The author has never known of a case where this ring setting, if properly done, has not eliminated "tumbling." It is, of course, more expensive to set the ring than the bench on account of the extra time consumed.

In rectangular kilns, where the ring method is impossible, the benches are carried up as usual to the point where the trouble is encountered. Strips of clay, generally made from waste ends from the cutter, are placed under the ends of the stretchers nearest the fire, giving them a slope towards the center of the kiln. This is shown in Fig. 29. In most cases, this need only be done on one or two courses to make it effective.

LAYING OUT BOTTOM RUNNERS

The floor runner brick should always be set to conform to the type of bottom. In solid bottom, center well, round kilns they should be set radially, for if set across the kiln, with openings between for draft passage, the draft will short cut to the center, taking the path of least resistance.

In checker or riddle bottom kilns, the runners should be set so as not to interfere with the floor openings. Many kilns work badly for no other reason than that no attention is paid by the setters to the openings in the floor. Very often the erratic action of a kiln is due to this one thing. Setters should always be impressed with this fact and compelled to avoid setting brick over the openings.

Kilns are often so located that the top portion of the kiln must be wheeled out first, leaving the "bottom" until last. This "bottom" may consist of a varying number of courses. In order that these bottom courses may be wheeled over, without danger of their "rolling" under the running planks, it is necessary that a course of brick be set in such a manner as to make a firm false floor or wheeling course. A very good method of setting this "floor" is illustrated in Fig. 30. This is known as the "herring bone skintle." One course only is set in this manner, the courses below and above it being set in the regular way.

METHODS OF SETTING

For the purposes of describing them, the various methods of setting may be divided as follows: Common-brick

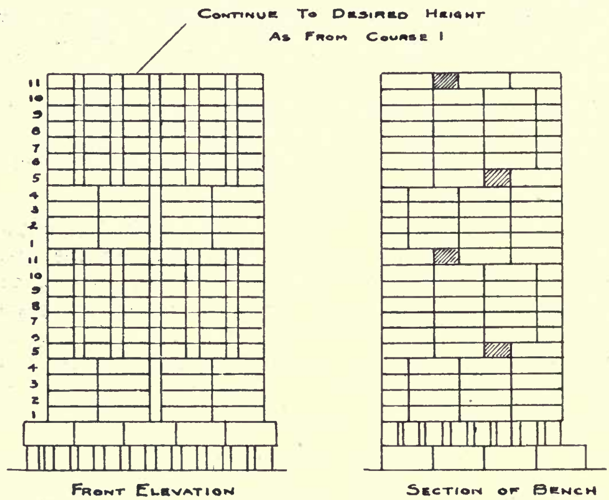


Fig. 38. Method of Setting Whole Kilns on Flat.

setting; unflashed face-brick setting; flashed face-brick setting and enameled-brick setting.

The price at which common-brick is sold demands that they be produced as cheaply as is possible and, as the color is not of primary importance it makes very little difference whether the face is flashed or unflashed. The alternate single header and single stretcher fills all requirements (Figs. 31 and 32). It is quick and can be done by setters with but little skill and, above all, it is a very

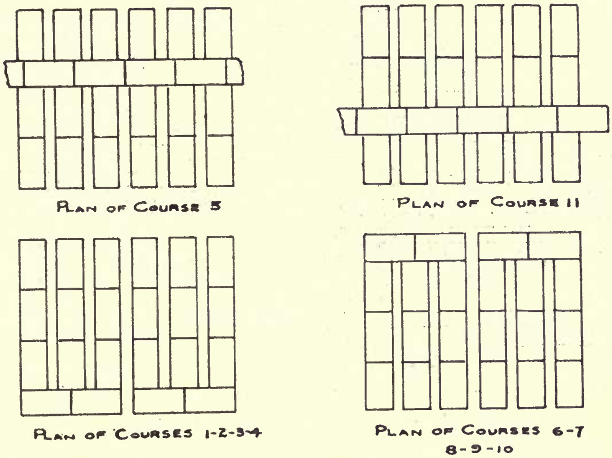


Fig. 39. Plan Views of Settings Shown in Fig. 38.

stable method. The question as to whether the brick should be set "two on one," "three on one" or "five on one" is simply one of kiln draft and must be determined for each individual case. This is also true with regard to the number of offsets or tie-courses and to the tieing in of the heads.

The simplest and quickest method of setting common-brick is known as the "tight bolt" method. It is little known in the United States, but is widely used in England and in Canada, in both up- and down-draft kilns. As will be seen, in Figs. 33 and 34, the brick are set in absolutely tight benches, *all headers,* running from bag-wall to bag-wall. These benches are set approximately one inch apart to allow for draft space and are kept from "rolling" by pushing thru an occasional brick in every fourth or fifth course, so that it just touches the bench behind.

The proper spacing of the draft spaces is made by a "follow-board," which is pulled up as the bench rises. This is merely an inch plank, with two leather handles, and it is supported by headers that are occasionally pushed thru as necessary. In rectangular kilns one "follow board" will answer the purpose, but in round kilns several are required to accommodate the benches of different lengths.

At first sight this method of setting appears to be impos-

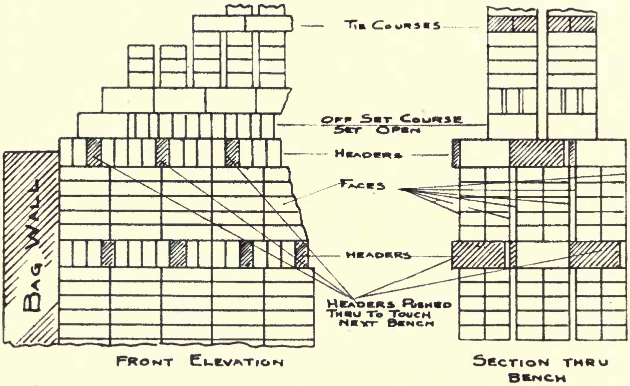


Fig. 40. Tight Bolt Flat Setting. Set Number of Header Courses to Suit Quantity Required.

sible. It gives the impression of cutting off all draft and of being too tight. However this is not the case. It is an old method and perfectly successful in every respect. Less skill is required in setting "tight bolts" than in any other method. It is extremely fast, as a setter can pick up as many brick as he can clamp together between his hands and lay them in place on the bench in one movement. There is absolutely no chance for "kiln marking" and the brick come out of the kiln with both faces of an even color.

UNFLASHED FACE BRICK SETTING

In spite of the increased demand for flashed colors there is still a good demand in some sections for brick of a clear color, both in dry-pressed, stiff-mud and soft-mud. To prevent flashing, it is of course necessary to protect the faces and heads. This is accomplished by "facing" the brick and "butting" the heads.

The well known forms of "double two on one," "double three on one," and "double five on two" are used, as shown in Fig. 35. With care in burning, this type of setting will accomplish the object sought for. It requires, however, the greatest skill, for all brick must be perfectly faced or many "seconds" will result. Care is also necessary, as with all setting, that after the first course is laid down all brick shall be set in perpendicular lines, in order that the fire gases may flow unchecked to the bottom.

Where burning can be done under continuous oxidizing conditions, as in cases where natural gas, producer gas or oil are used, the "tight bolt" method can be used with success. With this method only the heads are exposed to the gases under any circumstances, and if these are not flashed, there is the great additional advantage of having two faces to select from, with no chance of "kiln marks."

Protecting the heads exposed above the flash walls is one of the difficulties experienced in setting unflashed face-brick. One of the several methods used is shown on Fig. 36.

FLASHED FACE BRICK SETTING

Setting brick so as to get flashed faces presents many difficulties. In the first place, if entire kilns of flashed faces are required, the difficulty is often experienced of dealing with

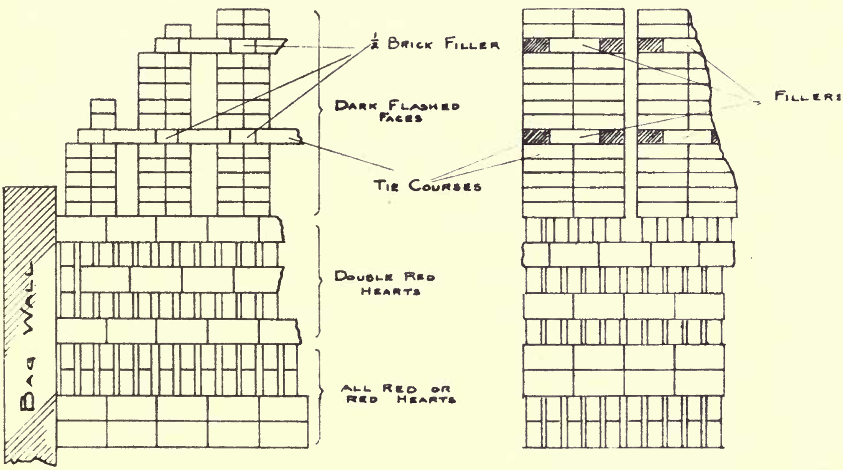


Fig. 41. Combination Flat and Edge Setting.

raw materials which will crack badly when set flat to any height. "Rolling" or "tumbling" often results with this method. The setting space is reduced and there is a greater tendency for brick to stick at vitrification temperatures, unless sand is used.

Fortunately the market for flashed brick has been educated to demand a wide variety of flash marks. This allows the manufacturer to set part of his kiln on edge and part on the flat. In fact, the more varied the setting the greater the variety of marking and color.

Figs. 37, 38 and 39, show two methods of setting entire kilns of brick on their beds or flat sides. The question as to how many brick can be set on each other before the coursing is broken by a "runner" or tieing course, and also to what height the setting can be carried, is one that must be determined for each material. No set rules can be laid down for this.

Another method, which was developed by the author and is an adaptation from the "tight bolt" method, is shown on Fig. 40. This has proved very successful, and is very stable, altho it gives only one flashed face. This, of course, is enough in a rough textured brick, but makes it undesirable for smooth face. It will be noted that the flashed heads are taken care of in the header courses. In the manufacturer of rough textured brick, it is generally the rule to set combination kilns, part on edge and part flat. The kiln is divided so as to provide the proper porportion of each or only so many are set on the flat as the material will allow. Fig. 41 shows a kiln set in combination.

CHAPTER VIII

Down-Draft Kiln Design

MUCH HAS BEEN WRITTEN on the subject of kilns and much remains to be written, but the author is sure that a vast majority of clayworkers will agree that helpful information on this subject has been exceedingly scarce. The reason for this has been that very little information dealing with the basic principles of kiln design has been published.

To all appearances the down-draft kiln is a simple affair. Yet it is with wonder and not a little awe that one goes about this continent and observes what a difficult and intricate proposition the average clayworker has made of it.

There are good reasons for this condition of affairs. In past years too little attention has been paid to kiln design and construction. As a general rule, when a new kiln was required or a change was made from the old up-draft to the down-draft type, the matter was left entirely to the superintendent, burner or brickmason. These men often had little idea of even the most simple principles underlying the burning of clay wares.

The fact remains therefore, that fully seventy-five per cent of the kilns of this type in use, and probably more, are not economical.

A kiln may be economically deficient in many ways—it may cost originally far more than it should; it may require high upkeep, which means not only repairs, but the loss while out of commission; it may produce a high percentage of defective ware; it may use a far larger amount of fuel than necessary, or require several days longer to burn than it should; it may require rebuilding before it has had a proper span of life. That a kiln—a practically perfect kiln—which eliminates all the above faults, can be designed and constructed at a reasonable cost, goes without saying.

It will be contended that a kiln which will work successfully on one clay and one class of ware will not work on others, and that it has been necessary to evolve special kilns for all of the different conditions. *This may be true in one case in one hundred, but not more.*

The fact must be apparent to all clayworkers who have given the matter thought and study that certain unbreakable rules govern the design and construction of all kilns, and that if these rules are not followed, a poor kiln will be the result. What clayworker with a number of differently designed kilns on his plant has not noticed that certain of these kilns give better results than others? Has it every struck you that these "good" kilns may be very nearly correct in principle, while the "poor" kilns are not?

TOO LONG A BURNING PERIOD

From experiments and investigations made, the author has come to the conclusion that the great majority of clayworkers are taking too much time in burning their ware. Most of the time is lost in the watersmoking and oxidizing periods. In many cases this is not so much due to faults in kiln design or construction as to poor burning methods. Often—thru fear—a burner unnecessarily prolongs the burn in the early stages. In such a case, of course, the fault lies with the man and the line of improvement is clear.

The author is quite certain that fully ninety per cent of the shales and clays on this continent can be burned off in six days or less, irrespective of the products produced. This includes the entire burning period from lighting the fires to the finish of the burn. *No exception is made in the cases where ordinary carbonaceous shales are used, in fact where the carbon content of a clay or shale is low, this period should be shortened, in the average case.* The author is quite aware that such a statement will draw forth a vast amount of criticism, for many clayworkers seem to take pride in the fact that they take from ten to twelve days to burn off a kiln, and even tho they were to be absolutely assured that their ware would finish in half the time, would not even give it a trial.

As a proof that the above contention is correct, the author would draw attention to the fact that whenever continuous kilns have replaced down-draft kilns, the burning period (the period during which the ware is under heat treatment) has been reduced to six days or less, except in isolated cases. The reactions which take place in a continuous kiln are not one bit different from those in any other type of kiln, and it is therefore reasonable to suppose that what can be done in one type of kiln can be done in any other.

Primarily, of course, in order that ware may be pushed thru a kiln safely at a rapid rate, it is necessary that the kiln be of proper design. The conclusions and designs set forth in this article are not based on theory, but actual observation and practice. They were decided upon as being the most nearly correct after observing the design and operation of several thousand kilns, located in many sections of the continent, and burning practically every variety of ware, from all sorts of raw material.

Kilns after this design, both round and rectangular, have maintained an average burning time of six days or less, on shale and fire-clay brick and shale block—not on one yard, but on several, located at widely separated points. The fuel consumption never exceeds 1,000 pounds per 1,000 common brick equivalent and the recovery of first quality ware averages ninety per cent or over.

In the following description the author will attempt to cover the important points on both round and rectangular kilns. It is not necessary to go into the relative merits of the two types, for it is largely a matter of personal choice, but it might be well to say that as regards cost *the rectangular type is slightly cheaper to construct per ton of holding capacity,* particularly when built in large units, while the round is considerably cheaper in upkeep (repairs).

DRAINAGE

Thoro drainage of the bottom is one of the most important points in kiln construction. Much poor ware is due to damp bottoms—perhaps more than to any other one cause, altho this point is often overlooked. No matter how good the natural drainage may be, put a network of drain-tile under and around each kiln, being sure the drains have a good fall. On yards where it is impossible to get natural drainage for kiln bottoms, put in a sump and keep it pumped out. The best kiln on earth will not give good results if the bottom is wet. Money spent for drainage will repay you many times over.

FOUNDATIONS

The mistake is often made of putting a kiln on shallow foundations. These should always be carried, at least, to a point slightly below the deepest flue. Very few buildings of any type are subjected to the racking a kiln gets, yet you would not think of building even a small house without carrying the footings at least a few inches below the basement floor level. The author has examined many kilns with

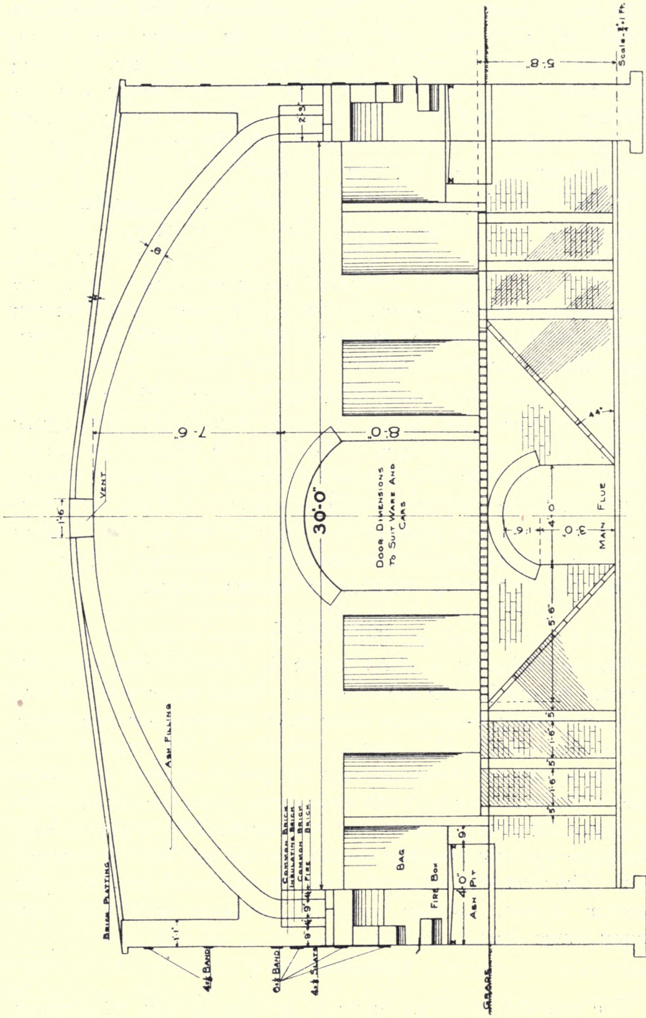


Fig. 42. Thirty Foot Round Kiln.

the bottom of the footings above the bottom of the flues and the result is always a shaky and tumbledown makeshift. If it is necessary to build the kilns on soft ground, observe the same rules in designing the foundation as would be followed in putting a brick building on the same ground. In making your calculations, do not forget to add the weight of the ware which the kiln will hold, to the weight of the structure itself.

BOTTOMS

In designing a kiln bottom the main points to be considered are: equal distribution of the gases; good draft, especially in the water-smoking period, and ease of cleaning. The first gives good ware over the whole bottom; the second quick burns, and the third saves tearing up the floor and keeps the kiln in commission the maximum amount of time.

Personally, the author is decidedly against the dead or solid bottom type of kiln. *Invariably it produces a higher percentage of defective ware and takes longer to burn.* The problem of keeping the flues clean does not enter into the consideration because this can be easily accomplished in a well designed riddle or checkered bottom.

In a checkered bottom kiln you get good distribution of heat and, with deep flues, good draft and easy cleaning.

Reference to Figs. 42 and 43 will show the method of laying out the bottom of a round kiln. By designing a deep, wide auxiliary flue running at right angles to the main or stack flue, thru the centre of the kiln, all of the secondary flues can be given a slope of approximately 45 degrees. Thus the latter will shed any sand, dirt or chips into the large flues, whence they are easily cleaned out thru the manhole. A much simpler bottom can be built by omitting the auxiliary flue, and sloping all secondary flues to the main flue, but in this case some of them will not have slope enough to shed and it will be necessary to rake them down at times. So far as the burning results are concerned there is very little difference.

It will be noted that the large flues are wide enough for the passage of a wheelbarrow and have height enough for a man to work in. The depth allows for a heavy accumulation of sand and dirt before it becomes necessary to clean out. Even where sand is used in setting, such a kiln will run for several burns without the draft being affected by choking. Another advantage is that such a kiln can be cleaned out while setting is going on, a decided advantage on a plant which is short of kiln room.

Reference to Figs. 44 and 45 shows the method of laying out a rectangular kiln bottom. All that has been said with reference to the round kiln applies to this type.

The author is well aware that, theoretically, deep flues are incorrect, but in this case theory and practice do not check.

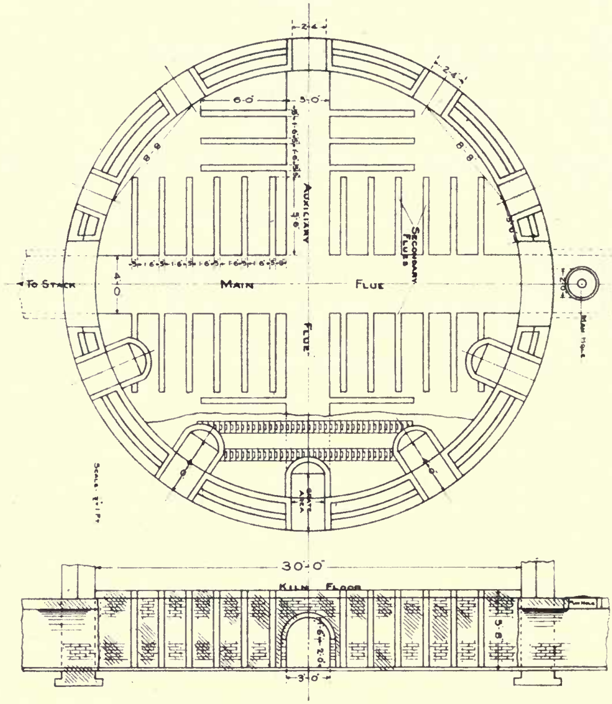


Fig. 43. Thirty-Foot Round Kiln Bottom.

In actual practice he has found the deep main flue to give a distinct advantage during the watersmoking period, *i. e.*, good draft and no water settle. *In kilns of this design there has never been the slightest sign of a water settle, even where the ware was set continually in a distinctly wet condition.* This is due to the fact that the dense, moisture-laden gases of the watersmoking period have a better opportunity of getting clear of the bottom courses than with shallow small flues.

Referring to the construction of kiln bottoms, the author would like to mention here the very bad practice of partially filling in the kiln excavation with earth, and then building the secondary flue walls or feathers on this filling. *If this is done you will have the trouble of at least partially rebuilding your bottom within six months.*

All filling should be done with hard burned brick or bats. If nothing else is used in the bottom and the masons are prevented from getting too generous with their mud, the original bottom will remain level for years. It is very good practice to allow the paving course to dip slightly toward the centre of the kiln. This will allow the ware to lean away from the fires and in a measure will tend to overcome the "pull" on the outside courses.

STACKS

Nothing detracts from the appearance of a yard more than

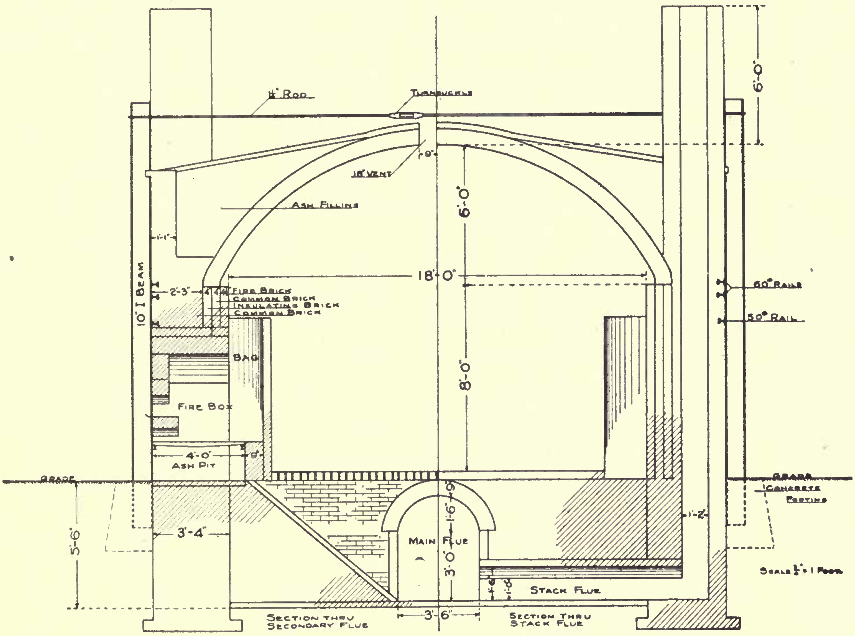


Fig. 44. Rectangular Kiln.

a number of cracked and shaky looking kiln stacks. Also, a poorly designed stack may cause what otherwise would be an efficient kiln to give poor results.

In round kiln construction a stack is generally built to serve two or four kilns. With rectangular kilns, the single or double stack may be used, but the multiple stack system is the cheapest and most popular.

Single stacks should always be built with a separate inner lining. (Fig. 46.) This lining need not be more than four

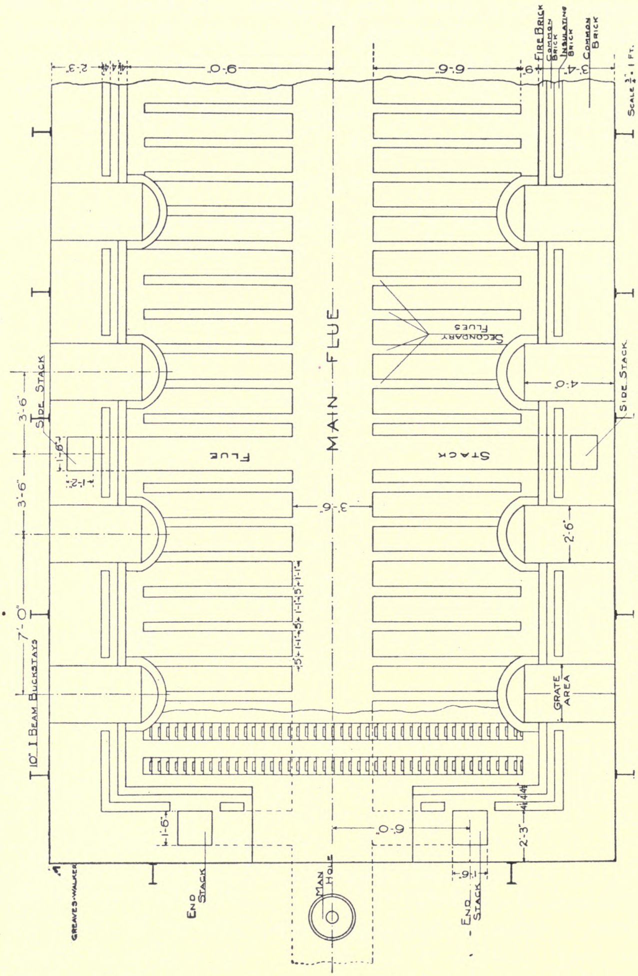


Fig. 45. Rectangular Kiln Bottom.

inches thick, and is separated from the outer casing by a three-inch air space. Occasional headers should be shoved out of the inner lining so as to just touch the outer shell.

This prevents the closing of the air space. In a stack built in this way the inner lining moves up and down freely with the expansion and contraction and prevents any cracking of the outer shell. When two or more kilns are attached to the same stack, a separate inner stack should be built for each kiln, for when two kiln flues enter the same stack flue, the draft of one is always affected detrimentally by the other. If the inner stacks are not built separately, as is often the case, but are only divided by a single wall, the temperature difference between the two sides will quickly wreck the entire inner stack.

Instead of carrying the inner stack up the total height, it is often carried only a few feet above the point where the flues enter. This practice is only completely successful when the inner lining is carried up at least two-thirds of the total height of the stack. This has been determined by experiments carried on by one of the larger clay products companies during the past decade.

HEIGHT OF STACK FOR KILN

It is now generally conceded by well informed kiln designers that a thirty-foot round kiln or a single stack rectangular kiln of equal capacity should have a forty-foot stack altho this can be slightly modified if the kiln is located on high ground.

The question of stack area is an extremely important one. The theory upon which ordinary stacks are built will not answer for kilns, and it was therefore necessary to find just what relationship existed between the grate area of a kiln and its stack. After a number of years of close observation and experiment the author has found that the best results on the single stack type of kiln are to be had by providing *one square foot of cross sectional stack area for each eleven square feet of grate area.* Thus, in a kiln with ninety square feet of grate area, a stack should be designed having a cross sectional area of approximately eight square feet. Other engineers reach approximately the same conclusions by different methods, but the one set forth seems to be the simplest yet devised and therefore the most useful.

A trouble found with most multiple stack kilns is that they generally have too many stacks. This is particularly the case with the earlier kilns of this type. In such cases a number of the stacks will "back draft," *i. e.,* draw the wrong way during various stages of the burn, thus prolonging it.

The author has bricked up half the stacks in kilns of this kind and easily reduced the burning time by one half.

On account of the more equal distribution of the draft and the fact that less work is required of them individually, the stacks on a multiple stack kiln need not be as high as for the single stack type. However, the ratio of stack area to grate area is larger. In the multiple stack type the proper ratio is *one square foot of cross sectional stack area to nine and two-tenths* (9.2) *square feet of grate area.*

It is good practice to provide one or two stacks at each end of a multiple stack kiln, no matter what the length. These stacks insure better draft at the wickets—spots to which it is unusually hard to pull the heat in any kiln. The stacks should be equally spaced, as nearly as possible, on each side of the kiln, and aside from the end stacks, one side stack should be provided for each three fire-boxes.

The proper draft will be obtained if the stacks are carried up to a point *six feet above the inside top of the crown.*

DAMPERS

There seems to be a great variance of opinion among clay-workers as to the best method of dampering a kiln, or as to whether a damper is necessary at all. Certainly the men who stand for the damperless kiln for all purposes cannot have had a wide experience, for it is obviously impossible to get the required results with all types of clay when no dampers are used. Instances of this would be dark flashed face-brick and salt-glazed ware. There is not the slightest doubt but that perfect results can be gotten without the use of dampers in some cases and under the direction of expert burners. However, since about one plant in fifty is equipped with experts, a kiln is required which can be handled by the kind of labor that is within reach of the forty-nine.

Many types of efficient dampers are available, but most of them present some difficulty in construction or operation. The hinged damper at the top of the stack is very good, but is not at all popular, principally on account of the constructional difficulties. The sheet damper, dropped into the stack flue or shoved into the stack, is very simple and very efficient, but when made of sheet or cast iron becomes very troublesome thru warping. When made of fire-clay slabs or brick it is is cumbersome and hard to handle.

Another type, but one very seldom used, is very efficient and is easy to operate, except in cases where much flashing is done. This is the wicket damper. It is merely an opening near the base of the stack equal in area to the cross

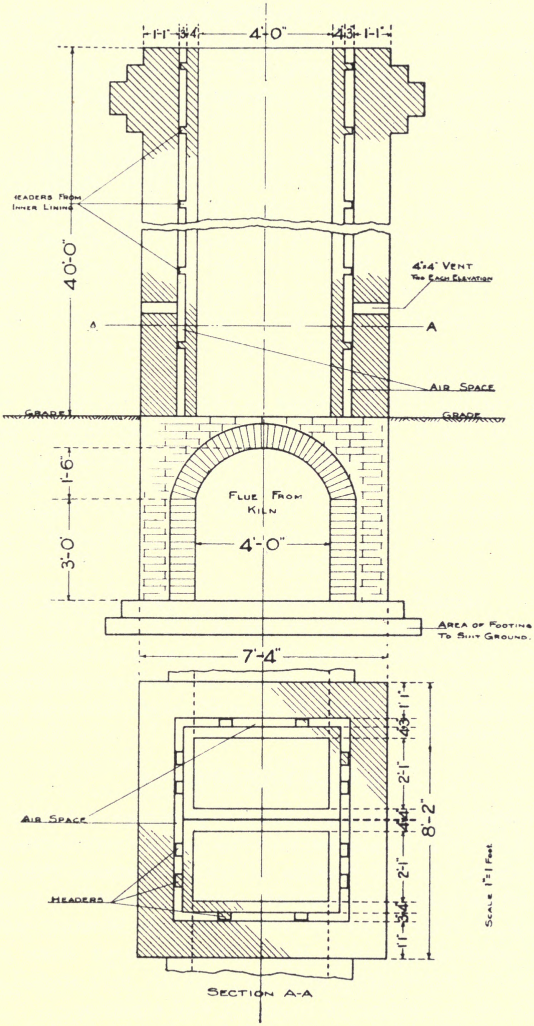


Fig. 46. Two-Stack Kiln.

section of the stack. When the kiln has full draft this opening is closed with brick, mudded over. As it becomes necessary to cut the draft the brick are removed from the wicket one at a time. The rush of air into the stack thru the opening thus made, cuts the draft in the kiln as effectually as tho a sheet had been shoved into the flue. If more draft is required after once cutting, the brick are put back in the wicket. In the single stack kiln it is necessary to choose between one of the above methods and put up with the difficulties encountered.

Multiple stack rectangular kilns are likely to require more dampering than the single stack round type, unless operated by expert burners. This is due to the fact that if the fires are allowed to get hotter in one part of a kiln than another, the heat from the balance of the kiln is naturally drawn towards this "hot spot." Some means must be used to correct this condition, of course, and the damper is usually resorted to, an effort being made to drive the heat to the cooler portions. The author does not wish to go on record as saying that a damper is necessary to correct such a condition (as it is not) *but the great majority of burners are not capable of handling the situation without a damper, and it therefore becomes a comparative necessity.* The design of the kiln has much to do with the case. Proper stack, flue and fire-box proportions tend to make it easier to control and prevent such conditions.

When dampers are necessary in a multiple stack kiln, the easiest and cheapest one to use is a flat sheet of iron laid on top of the stack. The stacks are, as a general rule, low enough to reach from the top of the wall or platting. Any of the methods suggested for a single stack kiln may be used on the multiple stack type.

WALLS AND CROWNS

Naturally there is no standard thickness for kiln walls, but there is a maximum limit to which it is necessary to build them. In the absence of reliable data on the subject of furnace construction in our own industry, it is necessary to look to other industries where the data is more complete. The metallurgical and other industries have done a vast amount of investigating and have recently paid special attention to the prevention of excessive wall radiation.

Three points are generally kept in mind by the clayworker when building a kiln; a wall of sufficient thickness to stand the strain; a wall of such thickness as to prevent excessive radiation and a wall thin enough to conform to good fire-box design. You can find kiln walls all the way from eighteen inches to six feet thick. The man who built the eighteen-inch walls fulfilled all the requirements of strength and got away from one difficulty—that of the concentration of heat in a deep fire-box—but he got into another difficulty. He had excessive wall radiation. The man who built the six-foot walls got away from excessive wall radiation, but concentrated the heat in his fire-boxes, thereby entailing heat losses in the walls and high repair charges thru the frequent burning out of his fire-box arches.

In determining the thickness of walls these difficulties must be borne in mind. Considered from all angles, *thin, straight* walls are the best, *if they can be insulated,* as in this case the fire-box is thrown inside the kiln and the fuel does not waste considerable of its energy in heating up and burning out the walls. The setting space lost by projecting the fire-boxes into the chamber, while a considerable item, cannot be compared with the saving of time, fuel and repairs during the life of a good kiln. If an uninsulated wall is built, it must be as thick as possible and still be compatible with good fire-box design.

As a general rule the walls of rectangular kilns are built thicker than those of round kilns. This is necessary on account of the difference in the method of ironing the walls. *The bands on a round kiln are much more efficient than the irons on a rectangular kiln.*

THE EFFICIENCY OF THE DOWN-DRAFT KILN

Before proceeding further with the discussion of this subject it would be well to look into the efficiency of the down-draft kiln. The author is pretty certain the following figures will surprise many clayworkers, even tho this data has been given wide publicity. The results represent heat balances taken on three kilns working under normal every-day conditions, and probably represent average conditions on the average yard, taken the country over. The work was done under the supervision of Prof. A. V. Bleininger of the United States Bureau of Standards.

Sewer Pipe Kiln—Burned to 2000° F.

Heat lost by flue gases (through stack)	18.60%
Heat lost by ashes	4.58%
Heat lost by radiation and cooling ware	71.10%
Heat actually used in burning ware	5.70%

Paving Brick Kiln—Burned to 2030° F.

Heat lost by flue gases	29.9%

Heat lost by ashes	3.9%
Heat lost by radiation and cooling ware	54.9%
Heat actually used in burning brick	11.3%

Building Brick Kiln—Burned to 2000° F.

Heat lost by flue gases	27.33%
Heat lost by ashes	3.51%
Heat lost by radiation and cooling ware	49.61%
Heat actually used in burning brick	19.55%

Experiments have shown that approximately 25% of the heat stored in a kiln just off fire, is recoverable for use in waste-heat drying. This, according to the above table, leaves approximately 25% a dead loss, due to radiation. Consider the last and best case in the light of these figures. *Roughly they mean that on the average yard, burning coal at* $2.00 *per ton, and using* 1,200 *pounds* (*or* $1.20 *worth*) *per thousand brick, only* 24 *cents in actual value is being actually used out of each* 1,200 *pounds. Actually* 96 *cents is being lost out of each* 1,200 *pounds, or* $1.60 *out of each ton.* A rather staggering loss. But the most important point is that out of each ton *fifty cents' worth is being lost thru the walls and crown.*

Taking the country over, it is the author's opinion that a good majority of the kilns are losing well over 25% of their efficiency thru the walls and crowns, and many of them are burning coal costing from $4 to $6 per ton.

Accepting the figures of 25% loss and $2.00 per ton, and allowing 1,200 pounds per thousand brick, using a thirty-foot round kiln with a holding capacity of 65,000 building brick, it will readily be seen that each time the kiln is burned off the amount of $19.50 is being generously thrown to the winds.

Now the question is—is this loss preventable? It is, to a very great extent, by the use of modern engineering methods as applied to furnace construction and heat insulation. Almost every industry but ours is making a serious attempt to prevent excessive radiation. Inquire what the steel maker, the modern foundry man, the automobile manufacturer, the brewer, baker and packer are doing along these lines. Ask Henry Ford if insulating his numerous furnaces did not help him cut his cost and price last year. Even the clayworkers, or some of the wise ones at least, insulate their steam pipes, boilers and sewer pipe presses. Even the furnace and heating flues or steam pipes in their homes are often insulated. *Why not the kilns?*

INSULATING THE KILN WALLS AND CROWN

For a number of years, metallurgical engineers have been experimenting on furnace walls, using various methods of construction and various materials. The dead air space or hollow wall has been thoroly tried and found wanting. This is not due to the dead air space itself, for all successful insulating is based upon it. The trouble is that *large* air spaces are not efficient at very high or very low temperatures, such as are found in furnaces or ice houses. The air space must be infinitesimal in size in order that circulation may not be set up when there is a temperature difference between two of its walls or sides. Also it is impossible to prevent leaks into large air spaces from the outside or inside, under the conditions existing in a furnace or kiln. Of course, this utterly destroys its usefulness.

It has been necessary, therefore, to find some material which had the properties of the hollow air space and would resist high temperatures, and at the same time would prevent the setting up of air currents. Several kinds of diatomaceous earth have been most successfully used, the one known as "Kieselguhr" being perhaps the best known. Most of this comes from California, where very large deposits exist. At the present time it is being manufactured into brick and blocks of standard fire-brick size and these brick are selling at a price only slightly higher than a good fire-brick. It is also used in its raw state in a furnace wall as is cork or sawdust in a fireless cooker or ice house.

One inch of this material has insulating qualities equal to *twelve inches of common-brick.* Therefore one brick is equal to twelve common-brick in thickness in a furnace wall. Numerous tests made in several of the university laboratories show that a four-inch lining of insulating brick in a furnace wall *which is under constant heat,* will *prevent* 50% to 75% of the radiation. In a kiln it should be even greater, as it is heated up only periodically. Taking the lowest percentage of saving—50%—and using the figures the writer has given for the loss on a kiln of brick—the result is a saving of $9.75 per kiln. In actual practice it would undoubtedly be greater than this, but accepting it, you have a saving of $234 a year on a kiln turning twice a month.

COST OF INSULATION

Now what will such a lining cost? In no section of the country should a 4½-inch lining of this material for a 30-

foot round kiln, cost in excess of $100 and in some sections not more than half this amount. As it will replace an equal amount of common-brick and the wall will be built considerably thinner, it can be conservatively figured that from $30 to $40 worth of common-brick will be replaced. This makes the cost of the lining from $60 to $70, amount that will be saved inside the first year, figuring only the saving on heat loss. To this saving must be added the increased speed in burning.

Fire-brick is often wasted in a kiln. Where temperatures not exceeding 2,000° Fahr. are used, as is often the case, it is not necessary to use nine inches of good fire-brick. Four-and-one-half inches is quite sufficient. Seldom do you find the fire-brick lining in a kiln touched, except over the eyes, even where very high temperatures are reached. In a round kiln it is not necessary to tie the fire-brick lining to the common-brick, as in this case the lining may expand and contract without reference to the main wall, and it is much easier to repair.

In such a kiln the shape will prevent it from pulling away if the brick are laid well. If the lining is tied in, it should be laid alternate headers and stretchers, or not to exceed two stretchers to each header. Greater spacing of the headers leads to their being broken off by the expansion, leaving the lining free. In a rectangular kiln it is always necessary to tie the fire-brick to the backing.

In a round kiln which is uninsulated, the proper depth of the fire-boxes must be considered in determining the thickness of the wall. For the best fire-box results it should not be over forty inches. The walls of rectangular kilns when uninsulated should not exceed forty-eight inches in thickness. When insulation is used, the round kiln wall may be twenty-seven inches and the rectangular kiln walls thirty-six inches. When possible, use porous brick in the interior of the wall, as they are better insulators than hard ones. It even pays to make up porous brick for this purpose by mixing a portion of sawdust or coal slack with the shale or clay.

CHAPTER IX

Down-Draft Kiln Construction

TOO LITTLE IMPORTANCE is given to the laying of the common-brick in kiln construction. The writer does not think it would be far wrong to say that *more than half the kilns built are practically wrecked within the first five years thru* poor workmanship. Little or no attention is paid to the proper tying together of the wall in an endeavor to make it act as a unit, and also very little attempt is made to allow for any expansion. Poor mortar is very often used and it is almost the rule to avoid the use of cement mortar. Ordinary lime mortar, as mixed by brickyard labor, is totally unfit for kiln construction. A 3 to 1 cement mortar with 10% lime putty added, is practically unequalled for this purpose. The wall should be thoroly bonded together and every precaution should be taken to prevent the masons from filling up large cracks and holes with mortar. The use of chips and small pieces of brick should also be avoided.

Various methods, some of which are theoretically good, have been devised to allow for the expansion of the walls and floors. In most cases, these, in actual practice, are very poor. Any expansion joint which can become filled with sand, mortar or chips, will only help to wreck the kiln. Allowing for the expansion in the vertical joints, by means of a mortar joint of the proper thickness is unquestionably the best method. This applies to both fire-brick and common-brick, *and necessitates the use of the trowel thruout.* In fact, the variation in shrinkage in fire-brick practically requires that the mud be applied with a trowel. This does not necessarily mean that the joint should be thick, for if it is made thin and each brick malleted down to a level, a far neater and more serviceable job can be gotten than by dipping. Furthermore, no more time is consumed in the laying.

Ironing of kiln walls is a question that is too often given too little attention or ignored. This is probably due to the fact that up to the time Prof. Harrops' article was published a short time ago, practically no data was available on the subject. It was simply a case of judgment or observation. You can find types ranging all the way from those tied up like a sore thumb with wire rope, or supported with log buckstays, to those sheathed with steel over the entire surface.

There is little good judgment in spending from $2,000 to $5,000 on a kiln and then for the sake of saving $100 or $200 cutting off from five to seven years of its life by skimping on the iron work. No matter how careful you may be in the construction of your kiln, if you do not sufficiently band or iron it, it soon becomes uneconomical. Cracks in the walls soon appear, thru which large volumes of cold air get into the kiln, and in a few years it may become so racked as to become practically worthless.

STEEL SHELL KILNS

For round kilns the steel shell is unquestionably the most efficient. It not only holds the brickwork absolutely in place, but cracks positively cannot open up. Add to this the fact that the shell is a good non-conductor and you have a list of favorable arguments that insure a good kiln thruout its entire life. There can be no question but that the steel shell kiln will give—in fact has given—far longer life than is possible in any other type. There is only one argument against it and that is first cost.

Next to the steel shell would come the kiln which is banded so as to catch every course of brick. This also is expensive, about as much so as the steel shell. It is necessary then, to consider the minimum amount of ironing necessary to keep the kiln in good condition. Using Harrops' method of calculating the size of a crown band necessary on a 30-foot round kiln, it is found that one band 6 in. x ⅛ in. is quite sufficient. However, the author has always considered the practice of using two bands at the crown seat good. Crown bands, especially light ones, sometimes break, and if two are used, one may break and still do no damage. The author, therefore, figures on two 6 in. x ¼ in. bands set three inches apart at the crown seat. Below them, one 6 in. x ¼ in. band is set at the furnace arch, just catching the top of the arch brick or block. Central between this band and the lower crown band is set another of the same size. Under these bands and spaced 9 inches apart, vertical slats

4 in. x 1/8 in. should be placed, extending around the kiln. These slats should be caught firmly under the lower crown band and the bottom band. Above the crown bands two 4 in. x 1/8 in. bands should be placed, but no slats are necessary. In a round kiln, with furnaces of the proper proportions, the distance between the furnaces is comparatively so small and the opportunity for expansion in all directions so large that irons are unnecessary to prevent deformation. Care however, must be taken to have the brick work particularly good at these points or poor results will follow.

IRONING RECTANGULAR KILNS

For ironing rectangular kilns 10 in. standard I-beams should be placed between each fire box, also two at each end. At the crown seat two sixty pound rails or one standard 8 in. channel should be set into the wall. At each end one rail or smaller channel should be placed at the same height. Below these, and in the same positions as described for bands on a round kiln, 50 pound rails or 6 in. channels should be used. Rails, when used, should be set with the bottom out.

The I-beams should be tied together with 1 1/4 in. rods across the crown. It is very important that these rods should always be kept tight enough to "sing" when tapped with a hammer. Many crowns are ruined by allowing these rods to slacken and remain loose. They have a bad habit of constantly stretching and require careful watching. A rectangular kiln crown is most liable to injury when cooling; during the firing period the rods are stretched and when the kiln cools down they do not return to their former length, thus allowing the crown to settle slightly after each burn. This soon results in a dangerous or wrecked crown.

THE KILN CROWN

The subject of the proper design and construction of a kiln crown is important also. If the clayworker can do away with the high cost of crown and furnace repairs, he will have very little to worry about as regards kiln upkeep.

Authorities agree that a down-draft kiln should have a life of fifteen years, i.e., it should not be necessary to rebuild the walls and crown during that period. The vast majority of kilns, without doubt, require at least two crowns during that time. There is something wrong then with the design or construction, or both.

It is on the smaller rural yards that are found the most glaring cases of poor crown design. These are generally too high, being built on the "hay stack" principal. On the larger plants, the writer has found the failures to be not so much an account of design, but principally due to poor construction.

CROWN SPRING ACCURATELY DETERMINED

The proper spring or circle of a crown for both round and rectangular kilns has been very accurately determined by experiment, altho it is quite apparent in looking around that many clayworkers do not take the trouble to find out what it is. For a round kiln it has been determined that the distance from a line drawn thru the points where the crown springs from the wall to the top of the inside of the crown should be one-fourth (¼) the diameter of the kiln. For a rectangular kiln this distance is one-third (⅓) of the inside width. These figures have not only been determined as the best for obtaining a crown with the longest life, but also as the best for burning results. It is a well known fact that a kiln with a high crown consumes more fuel per unit of ware, takes longer to burn and gives poorer bottoms than one with a lower crown. If the crown is too low the top ware is very likely to be over-burned or the capacity of the kiln decreased in an effort to avoid setting too close to it.

A question considerably discussed in recent years has been as to the proper method of starting the crown off the walls. There can be no question but that the skewback has dropped out of use to a very considerable extent, being replaced by an arc of a circle of very small radius up to the point where the proper circle of the crown is reached.

Harrop, in discussing this subject, proved that theoretically, the crown started on skewbacks exerted less total thrust on the crown bands than did crowns the other type, but that the thrust was exerted along a single line. In the case of a crown started from an arc, while the total thrust may be greater, this thrust is distributed over an area equal to the entire height of the starting arc, and at any given point is comparatively small. On a round kiln, should the crown bands break in the case of a skewbacked crown, the entire thrust of the crown is exerted along the line of the bottom of the skew with nothing but the friction of a single mortar joint to stop it from shearing off and causing collapse. However, where the arc is used, all of the backing, (which in this case is particularly heavy and should be well tied together), from the point where the crown starts to the top of the arc, must be pushed out before collapse can take place. Moreover, each brick in the arc is really a skewback and we therefore have the total friction offered by a number of mortar joints instead of a single one.

So far as actual practice is concerned, a number of instances have been reported where the arc has been used, in which crown bands broke under fire, and the crown did not suffer at all. On rectangular kilns it is harder to justify the use of the arc, but in this case also, it seems more reasonable to distribute the thrust over a large area of backing wall than to concentrate it on one point.

SUPPORT CROWN ON MAIN WALL

Another important point in starting a crown. *Instead of supporting the crown on the fire-brick inner lining, it should*

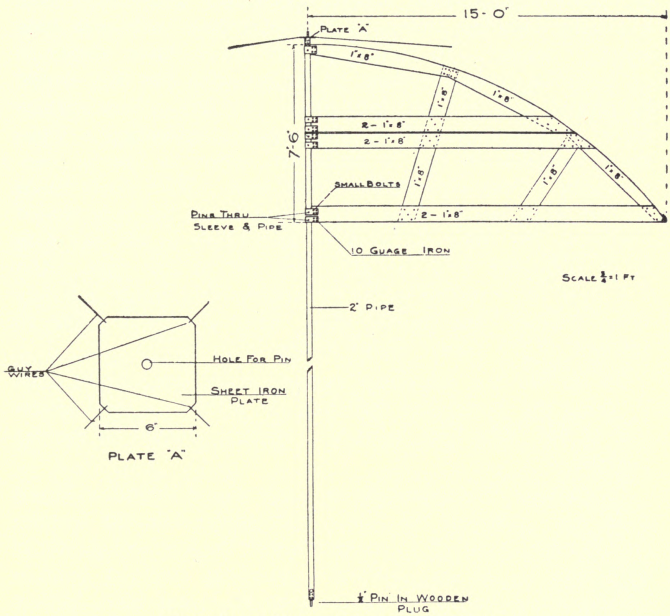


Fig. 47. Thirty Foot Kiln Sweep.

be set back on the main wall. Everyone has noticed that crowns invariably crack badly over each fire-box. This is partially due to the greater expansion over each eye and partially to the continued burning away of the lining at this point. Also it has been noticed that when it is necessary to repair the fire-brick lining over the fire-boxes, a portion of the crown often comes down during the tearing out process. If the crown is set back off of the lining and is entirely independent of it, most of the trouble will be overcome.

In building the crown of a rectangular kiln, the use of forms and lagging makes the obtaining of the proper circle easy. In round kiln construction several methods are used to obtain the correct circle. The accompanying plate (Fig. 47) shows a very simple one. One of the best features is that if a course of brick slips from its proper place, it must be put back before the guage will revolve. This prevents the mason from "slipping something over" when the superintendent is not around.

Designing a theoretically perfect crown will by no means give good results unless the workmanship is first-class. Even a poorly designed crown, if carefully built, will give long years of service. To build a perfect crown, there should be no variation in the shrinkage of the fire-brick and they should be dipped and malleted into place. In fact, where careful work is done in metallurgical furnace construction a minimum variation in size is demanded, often as low as one-sixteenth to one-eighteenth of an inch. With such brick, perfect work can be done with dipped brick, but it is almost pitiful to see some clayworkers attempting to use the fire-brick ordinarily sold for kiln purposes, in this way. And it is even more pitiful to see the crowns that result, not only when finished, but shortly after, when the brick begin to fall out or the crown begins to sag in spots.

By far the best job under average conditions, can be done by using the trowel and malleting the brick to a level coursing, at the same time using the smallest amount of mortar possible.

In the case of a round crown, each course should be keyed tight with a *driven* key. In a rectangular kiln the courses should be brought up to a point where the key will go about half way to its seat with the pounding received from a wooden hand mallet. It should then be forced home with a sledge hammer and wooden block. If more attention is paid by the superintendent or engineer to the keying up, much money and trouble will be saved through the longlived crown that will result. It is a job that should never be left to the mason's judgment.

Vent holes are sources of weakness in a crown. They should not be used, except at the top or in crowns built of special block.

Rectangular kilns, up to fifty feet in length, require only one expansion joint at each end and none in the middle. Over fifty and up to one hundred feet, an additional joint should be left in the middle. Expansion joints in crowns are invariably sources of weakness. The covering for an expansion joint should always be "built in" when possible.

The insulation of the crown is a matter well worth considering. Why a clayworker will build a four to six foot wall to prevent excessive radiation and then put a two inch lagging on a nine inch crown is a question that has no answer. Crowns can and should be insulated. If a thirteen inch wall is carried up from the base of the crown to within eighteen inches of the top and the space filled and tamped with fine, burnt out ashes, a very good insulation will be secured. Over this filling a lagging of brick should be laid and this covered with a coating of lime-cement mortar. Burnt out ashes, especially the light fluffy kind, make an excellent insulation and are generally procurable on a clay plant. Unburned carbon should always be removed.

FURNACES

The writer is well aware that this is a subject the gods themselves cannot agree on, and is not going to attempt to convince anyone that any particular type is the best. There are many good ones, when used under the proper conditions. The one described was selected after observing a large number, as being one of the best types for average conditions—fuel, labor and material considered.

A furnace to be adaptable to the average clay plant must be, first—so designed that it will properly combust ordinary or low grade fuels; second—capable of being efficiently handled by the average laborer; third—easy to control and to produce either reducing or oxidizing conditions; fourth—have a low up-keep. This is a pretty large order for any fire-box and the writer does not hesitate to say that most furnaces fall down on one or more of these propositions.

A very important item in kiln design is the ratio between grate area and kiln floor area. There are very definite limits to this ratio and if best results are to be obtained they must be observed.

The upper limit is *one square foot of grate area to four square feet of floor area;* the lower, *one square foot of grate area to eight square feet of floor area.* Observation of many of the best designed kilns on the continent lead the author to believe that a ratio of 1 to 7.5 is the best for average conditions. For the burning of fire-brick the ratio should approach the upper limit—1 to 4—while for handling a clay

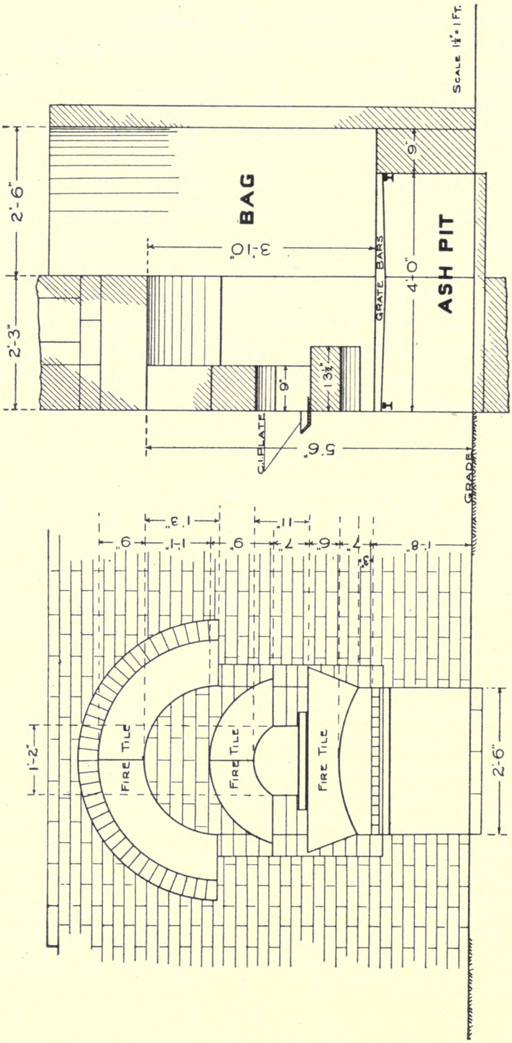


Fig. 48. Fire Box.

with a short vitrification range, the lower limit would be best.

For the best results in salt-glazing the limits should be confined between 1 to 6 and 1 to 8. In the great majority of cases 1 to 8 ratio is the best. In going below this point, dull ware will likely result, while to go above 1 to 6 generally means blistered, pimply ware, or at least a considerable percentage of it.

The higher the grate area—floor area ratio—the greater the care required in handling the kiln, especially near the finish of the burn, but increasing the grate area will invariably give greater burning speed.

Fig. 48 gives an idea of the furnace suggested. It will be noted that the grate bars are easily gotten at, and that the furnace is easy to clean and therefore likely to be popular with the firemen. It requires no doors, yet can be absolutely controlled, as a couple of shovels of slack will effectually close the feed hole, or it can be left partly or entirely open. Doors are however, decidedly advantageous on any firebox and perfect control and efficiency cannot be obtained without them. This furnace is so simple as to be very easy to keep in repair.

Especially should be noted the distance from grate bars to top of arch. This is important in any kiln furnace. Plenty of room is necessary over the fires if the necessity of constant repairs to the arch are to be avoided. A low fire-box confines the heat and heats up the kiln walls instead of the ware: a high one allows it to get into the kiln where it belongs.

Every clayworking plant wastes hundreds of dollars each year replacing furnace arches built of brick. If these arches are built of fire-clay shapes or blocks, this trouble will be eliminated and furnaces will stand for years without attention. Such shapes cost very little more than the equivalent in brick and are carried in stock by many of the fire-brick plants catering to the clayworker.

A word in closing about bag-walls. There are really not many types to select from. It is merely a question of round or square—high or low. The question as to whether a high or low bag is best, is one that must be decided according to conditions. It may be necessary to build a high bag to protect the ware from flashing; to throw the heat more to the center of the kiln; to prevent the ware from being drawn into the fire-boxes or to prevent melting.

So far as shape is concerned, the author does not think there is much question but that the semi-circular bag gives the longest life. In brick kilns, where the setting is run up tight against the bags the semi-circular type offers far greater resistance to crushing and the pull of the fires than the rectangular, and furthermore it is the most economical so far as floor space is concerned.

CHAPTER X

Continuous Kiln Foundations

ALTHO THE CONTINUOUS KILN has been used successfully for considerably more than a half century in Europe, it is still looked upon by the vast majority of American clay plant owners as an experiment. Nor does this idea disappear as rapidly as would be expected with the ever-increasing knowledge on the subject. As soon as a clay-worker becomes a convert and decides to build a kiln of this type, his neighbors, or at least many of them, immediately begin to figure about how long he can remain in business before the receiver steps in. They are not without justification in taking this attitude, but have very good reasons.

The continuous kiln was first brought to the attention of the American clayworker by Europeans who claimed to be kiln engineers and to have some particular design of kiln which was their own and which would produce marvelous results. These men were more often than not, simply brick masons who had helped to build a kiln or two, or burners who had operated them for a short period. The clay products manufacturers which these men managed to interest were the large plant owners of that period. This same type of clayworker is still the man most interested in the continuous kiln. Now, the conditions with which these kiln builders were confronted on this continent were entirely different from those in Europe. Instead of kilns of ten thousand daily capacity, those of from twenty to fifty thousand capacity were required, and these European brick masons, not being engineers, or at the most having a very limited training, were not equal to the occasion.

They did build kilns, but in such a way that the continuous kiln received a "black eye" from which it is still convalescing. Not only were most of these early kilns improperly designed, but the construction was worse than bad and many of them literally fell to pieces in a few years. Very few of those that did stand up to the work gave the results that were expected of them and, for a long time, it was thought that, while this type of kiln might be successful on small capacities, it would not do for large ones.

Another condition that has retarded the use of this kiln on the American continent is the fact that most of the information—in the shape of articles—that has come to the clayworker's attention has originated from European sources and has dealt with European methods and results. These articles make very interesting reading, but they have little effect in bringing the average clay plant owner to the point where he is willing to invest from forty to one hundred thousand dollars in a kiln.

As has been said, the great difference between American and European practice is the size of the units required. The small European unit was absolutely useless on this side and it therefore became necessary for the American engineer to solve the problems of the large unit. That he has solved this problem any man must admit who will look around with an open mind.

This perfecting of the kiln design, however, was not accomplished without great expense and trouble to the clayworkers who did the pioneering. The solving of large problems always costs money and, in this instance, the clayworker "paid the freight." This again acted as a setback to advancement.

It is the usual American practice for the clay products manufacturer to construct his own kilns whether they be clamp, down-draft or continuous kilns. While this practice has developed some very good designers and builders of down-draft kilns, it has produced very few men who know anything about either the design or construction of the continuous type. On the other hand, Europe has developed many first-class continuous kiln experts—men who can design, construct and operate a kiln, and turn it over to the clay plant owner in first class operating condition. Conditions, however, are rapidly improving on this continent in the direction of design, and kilns are now planned which will give perfect results under specified conditions, providing they are properly constructed and handled.

CARELESS BUILDING SPELLS DISASTER

Here the important question of construction comes to the front. Having created the condition under which he is his own down-draft kiln builder, the claymaker must now study continuous kiln construction. It is perfectly safe to say that fully ninety per cent. of the troubles encountered in the continuous kiln as it is built today, are due to con-

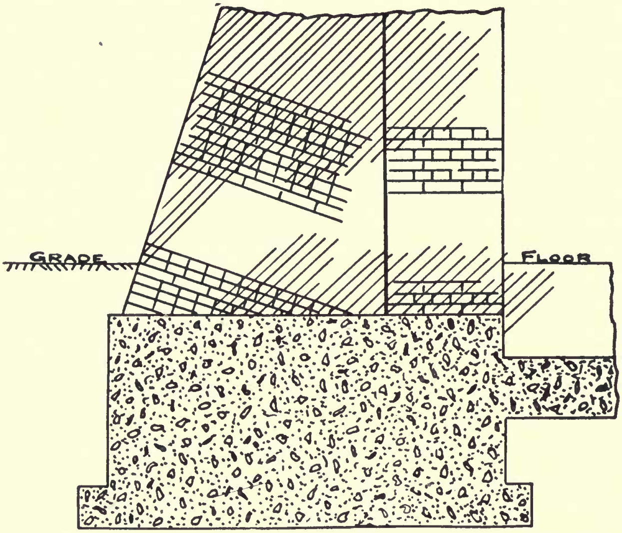


Fig. 49. Wrong Construction of Foundation for Batter Walls.

structional faults and not to faults in flue design as was formerly the case. How to impress the clayworker with the fact that the "thrown together," cheap, slipshod methods that have been used in down-draft kiln construction will not do in the building of a continuous kiln, is a problem. *That he must be impressed with that fact* in order to save himself and the industry from further losses, is certain. A glance at some of the continuous kilns only recently built, to say nothing of those which are now several years old, will be enough to convince anyone of their unstable construction.

The clayworker has not always been to blame for this, as in all probability, plans were closely followed. But a little thought and investigation would have convinced him that the designers had given little consideration or cared little about the results the kiln would give after a few years of service, or what the repair bill would be. Some of the poor construction has been due to the vicious practice of letting the work out on contract—*to the lowest bidder.*

There is no sort of construction known that offers better opportunities for "skinning" than a continuous kiln with its heavy walls and underground work. Some of the work done in this line has been criminal and many clayworkers are to-day bemoaning the fact that they did not know more about building when their kilns were erected.

The cost of a continuous kiln ranges from $25,000 to $300,000 and the clayworkers investing such amounts have every reason to expect that they will be permanent. If the same amount was to be expended in a modern building there would be no question whatever about the proper design, construction and inspection, yet in the case of a kiln, these things are admittedly neglected, and this in spite of the fact

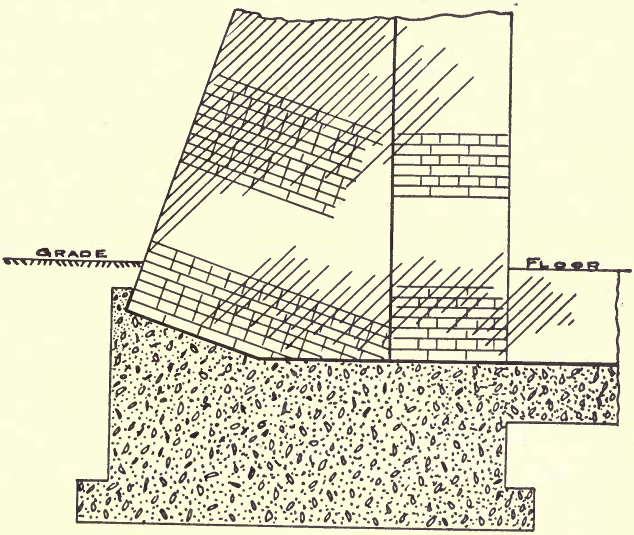


Fig. 50. Correct Construction of Foundation for Batter Walls.

that no other type of structure is subjected to such strains and "punishment."

Continuous kilns with advancing fire are of two types—gas-fired and coal-fired. Each type is built in two forms—chamber and tunnel. All of the continuous kilns in this country fall into one of these classes, no matter by what name they may be known. There is very little difference in the construction details of the various forms, altho the gas-fired kilns are the most complicated. Some of their features will be treated separately.

GOOD FOUNDATION VITALLY IMPORTANT

In designing and constructing the foundations of a continuous kiln two important points must be borne in mind, first, the weight of the structure, and second, its continual movement. When calculating the load the foundation will have to carry, the figures must always be based on the kiln filled with ware. During operation, there are some empty chambers but often, when closing down, the kiln is completely filled. *It is never safe* to figure on a load of less than one hundred pounds to the cubic foot, and it is much safer to figure one hundred and fifty pounds. The valley bottoms, on which kilns are generally located, are often composed of sand, sandy clay or clay washed from the hillsides. Very often these materials offer a very treacherous support for a heavy structure, especially *when every effort must be made to prevent unequal settling.*

If a shale or rock bottom cannot be reached without incurring great expense, an engineers' table should be con-

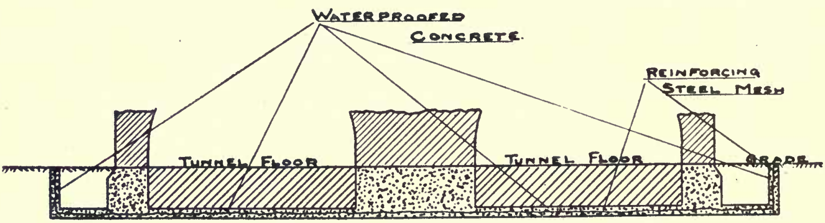


Fig. 51. Method of Constructing Weatherproof Bottom.

sulted to find the *allowable load for the type of material on which the kiln is to be built.* With this data and the weight of the kiln at hand, it should be a simple matter to figure the area which the foundation must cover in order to properly support the kiln. In cases where very soft ground is encountered, it is sometimes necessary to build a "raft" of concrete on which the structure will "float." This, of course, is very expensive but, in many cases, it is the best kind of an investment. Should there be any doubt whatever in the mind of the plant owner as to what load the ground will safely carry, a reputable engineer should be consulted.

A clayworker should never accept the foundation plans furnished by a kiln company or kiln builder *without checking them carefully*. Too often such plans are "standard"

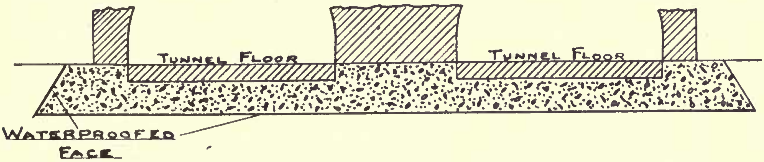


Fig. 52. Method of Constructing Weatherproof Bottom.

and were not drawn up with any reference to the particular job in hand. It will pay handsomely to be cautious.

A very bad habit into which kiln designers have fallen is that of considering only the walls as requiring foundation support. At times the floor and the flues beneath are built as tho entirely separate from the walls and as tho they were not expected to carry any load. This is a great mistake in any type of kiln, especially when it is built on soft ground. When the floors and flues of a continuous kiln are built in this way, the repair bill is likely to be staggering from the very beginning. A foundation heavy enough to support the flue walls, floor and ware *should always be provided* and should be part of the general foundation plan—not separate.

A mistake very often made in designing the kiln foundation is in not providing "backing" for the foot of the batter walls. By this is meant that the batter is started off on a smooth, flat surface with absolutely nothing to prevent it from shearing off at this point whenever it gets the expansion thrust. This is exactly what happens and there are many instances of these walls having moved from six inches to one foot from their original location. Fig. 50 shows a method of providing a footing for batter walls and Fig. 49 the usual, but wrong, method of starting off the foundations.

DRAINAGE AN IMPORTANT POINT

Proper drainage of the bottom, always an important point in any kind of kiln construction, is doubly important in the case of a continuous kiln. To be successful, a continuous kiln must be capable of advancing rapidly and, if it does not do so, it is nearly always the bottom that holds it back.

A vast majority of kilns of this type are built with solid

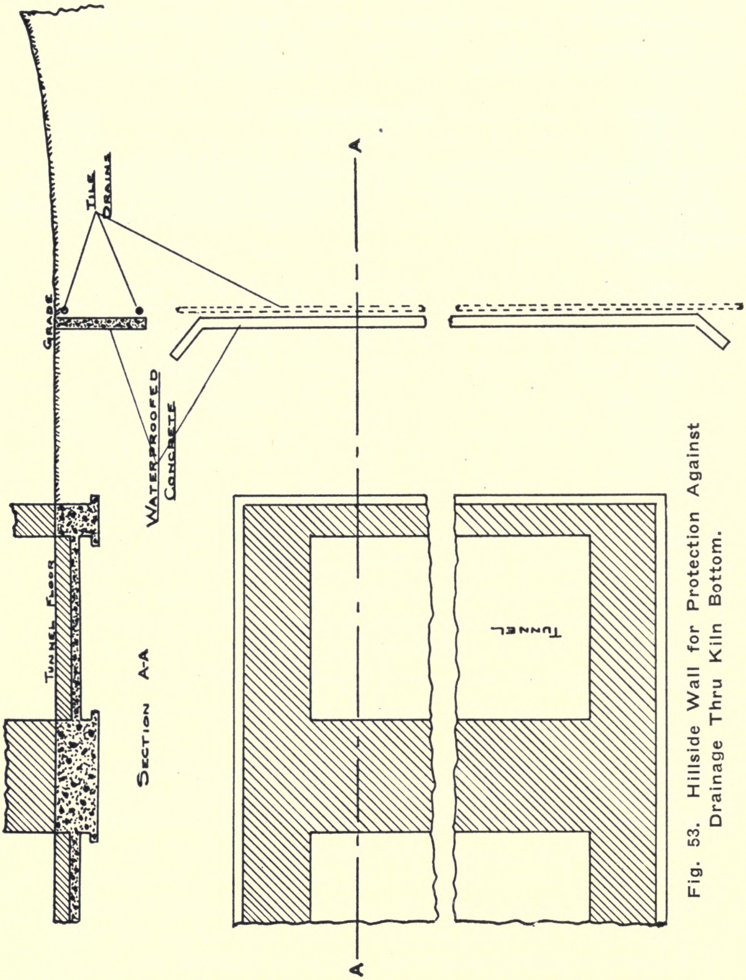


Fig. 53. Hillside Wall for Protection Against Drainage Thru Kiln Bottom.

floors, and for this reason the clayworker figures that moisture under the kiln will not bother him. This is not the case, however. When the kiln is under fire, heat sufficient to evaporate water will penetrate to a depth of at least ten feet. The water vapor thus formed is constantly drawn into the kiln by the slight vacuum existing in the chamber or tunnel. Sometimes the amount of this vapor is sufficient to make it impossible to get from three to six of the bottom courses much beyond the salmon stage. It is not only the loss of this ware that is serious, but under such circumstances the burning speed of the kiln is greatly reduced and consequently fuel and labor costs are higher.

A kiln bottom should be thoroly drained to a depth of ten or twelve feet by running four-inch tile drains from eighteen to twenty-four inches apart over the whole bottom of the kiln. The more fall these drains have, the better they will do their work. They should never have less than one per cent. All laterals should be run into one main drain of sufficient size to take care of the entire drainage system and the upper end of this main drain should be connected to the main draft flues. This will insure a slight circulation of air in the system and prevent any vapor from rising to the kiln floor.

Kilns are often built in localities where it is impossible to get a natural fall for a drainage system without great expense. In such cases all of the drainage water should be run into a well or sump and a pump provided to keep the water below the proper level. The cost of running the pump will be paid a hundred times over by the increased capacity and the higher quality of the ware.

Where it is necessary to locate a kiln on gravel and in close proximity to a stream on approximately the same level, it is necessary to surround it completely with concrete walls and bottom, as shown in Fig. 51. This concrete work should be thoroly and carefully waterproofed. Another method is to build the entire kiln on a thick bed of concrete which extends far enough out from the walls to insure dryness in the chambers or tunnel. This method is illustrated in Fig. 52.

When a kiln is to be located so as to have a hillside on one side and a stream on the other, provision must be made to take care of the drainage water which is bound to flow from the hill to the stream. Besides a regular drainage system under the bottom, a concrete wall should be erected between the kiln and the hill. This should be built a little more than the full length (or width as the case demands) of the kiln and should extend from the grade line to a depth of fifteen feet. On the side of this wall which faces the hill a drainage system should be installed that will catch all water flowing towards the kiln and divert it. Fig. 53 shows a plan and cross section of such a system.

CHAPTER XI

Continuous Kiln Walls

IT HAS BECOME the general practice to provide continuous kilns with roofs. These roofs very naturally shed a great deal of water during wet weather and, in the great majority of cases, no troughs or down-spouts are provided to carry away this water. To allow it to soak into the ground around the kiln is exceedingly bad practice. The damage done in this way in a single year will pay for properly troughing the kiln roof several times over. When a proper drainage system is provided for the kiln bottom, the roof water can be led into the main drain and thus be carried away.

Providing proper drainage is an expensive proposition, but the clayworker who is not prepared to go to such an expense would do well to stay away from continuous kilns until he is willing to make the expenditure. Nothing but regret has followed, and will follow, every attempt to "get by" without paying the price.

SIDE WALL CONSTRUCTION FOR TUNNEL KILNS

Two types of exterior walls are used in continuous kiln construction—the straight, buckstayed type like those of the ordinary rectangular kiln, and the battered type, with which no buckstays are used. There is practically no difference in cost, the additional thickness of the batter wall being about counterbalanced by the iron work of the straight wall. One decided advantage the straight wall has is the saving of yard room. It also has a far better appearance. The batter wall provides better insulation on account of its thickness, but there is no reason why the straight wall cannot be provided with four or more inches of insulating brick. Consideration should be given to the fact that with the thick walls the transfer men and wheelers must travel further. This takes time and is a fixed charge as long as the kiln lasts.

In deciding the construction to be used on the various walls, the type of kiln and the location of the wall must be carefully considered.

It is customary to build the side walls of a tunnel kiln with a one-in-three batter on the outer or exposed side, while the inner sides are vertical. In the past many kilns have been built with the outer and inner walls entirely separate, the space between being filled with clay, cinders, sand or rubbish. A large number of such kilns have become inefficient and some of them more or less complete wrecks on account of a lack of knowledge on the part of the builder, or poor workmanship.

The fact that the outer and inner walls expanded differently on account of the difference in temperature was also entirely overlooked, with the result that the brace walls were tied to both. These were quickly torn to pieces, leaving nothing but a lot of loosely packed rubbish to keep the walls at the proper distance and the crown of the tunnel in place. Moreover, the loose filling worked its way into the inner walls of the tunnel and quickly destroyed them. Kiln after kiln has either partially or entirely collapsed on this account with consequent condemnation of the continuous kiln.

The brace wall type of construction is to be condemned if for no other reason than it has been proven that in the vast majority of cases *not enough care will be taken to make a perfect job.* Another and very good reason is that when sufficient care is taken to make a good job, the cost will almost equal that for solid brick walls. As the principal idea of the heavy wall is insulation, *a thinner and stronger wall can be built solid, with an inner lining of insulating brick* that will not only give better results so far as insulation is concerned, but will give better burns, longer life, *and will cost less.*

As "filled" walls will continue to be built, it is deemed wise to describe the best method of construction which is shown in Fig. 54.

The outside or batter wall should be thirteen inches thick, with mortar joints at right angles to the face. It is not necessary to put in header courses closer than every fourth course. All brick should be hard and the mortar should be a mixture of three parts sharp, clean sand to one part Portland cement. To this may be added ten per cent. of lime putty to improve its troweling qualities. *Lime mortar should not be used under any circumstances* because the kiln will in all probability be under fire and subject to expansion strains before the mortar could reach its maximum strength, or anywhere near it. The inner or tunnel walls proper should be not less than twenty-seven inches thick and should be laid up with *alternate header and stretcher courses thruout.* No other bond should be used under any circumstances, for it must be remembered that these walls are continually "rolling" forward and backward thru expansion as the fire passes around the kiln. The inner side of the tunnel wall should be lined with brick of a refractoriness suitable to the material to be burned. *This lining should never be of common-brick.*

FIRE BRICK LINING ECONOMICAL IN LONG RUN

It is hard to estimate the amount of money that has been lost in the attempt to "save" a small amount on the lining by the use of common-brick. If low temperatures only are to be used, a cheap stiff-mud fire-brick will fill all requirements. If higher temperatures are to be attained, a better grade of brick must be put in. Seldom is it necessary or wise to use a high grade fire-brick for this work, unless the kiln is used for refractories. Second or third quality brick are sufficiently refractory in ninety-nine out of one hundred cases. Being dense and strong, they are much better suited to this class of work. In cases where only ordinary heats are used, the stretcher courses need only be faced with four inches of fire-brick. Back of the fire-brick, only first class hard brick should be used. The use of "bats" and soft culls in these particular walls is a great mistake.

The brick (both refractory and common) on the inner half or thirteen and one-half inches of the walls should be laid up in fire-clay, or fire-clay and shale dust. The horizontal joints should be as thin as it is possible to make them with a trowel and mallet. The vertical joints should be about one-fourth inch wide. These joints are made wider to allow for the horizontal expansion of the kiln. After burning, each joint will shrink about ten per cent. of its green width, and thus thousands of minute expansion joints are provided in the length of the kiln. The outside thirteen and one-half inches of this wall should be laid up in a mixture made of fifty per cent. three-to-one Portland cement mortar and fifty per cent. three-to-one lime mortar. This mixture has been found to give excellent results where both Portland cement and lime mortars have failed. A lime mortar would do the work if it really had a chance to harden before being subjected to heat. A clay mortar does not get sufficient heat in the outside half of the wall, to harden. It merely dries out and loses its bonding qualities.

Expansion joints one and one-half inches wide should be

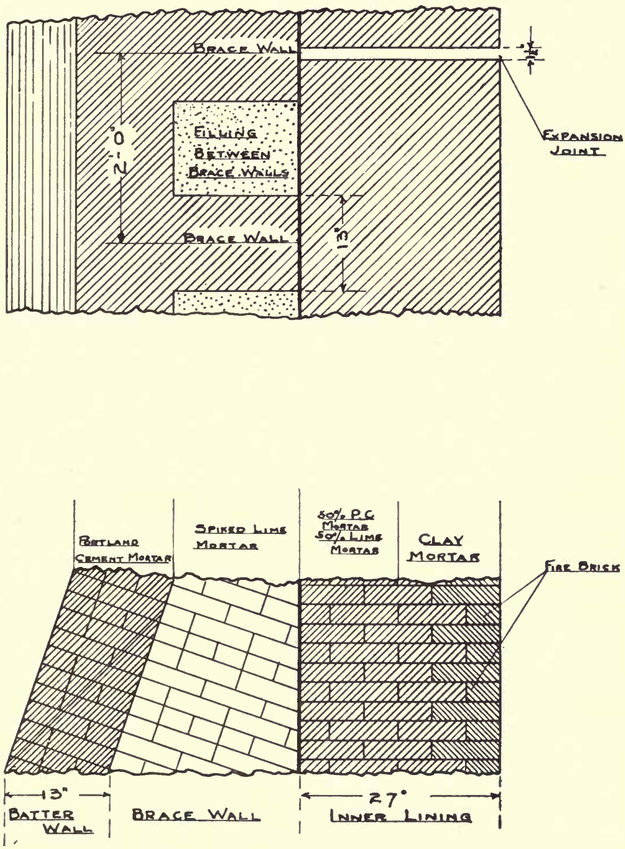


Fig. 54. Section of Wall.

left in the tunnel walls every twenty feet. *These should always be made to come in the center of one of the brace walls* which extend from the outside walls.

HOW BRACE WALLS SHOULD BE BUILT

Brace walls should be built between the batter walls and the tunnel walls on two-foot centers. These brace walls should be thirteen inches thick and tied to the batter walls, being bonded perfectly with them and the mortar joints continuing in the same direction. *These walls should not be tied to the tunnel walls.* If they are, they will be quickly torn to pieces by the expansion of those walls. However, they should be built solidly against the tunnel walls, for it must be remembered that they take the place of the irons on a

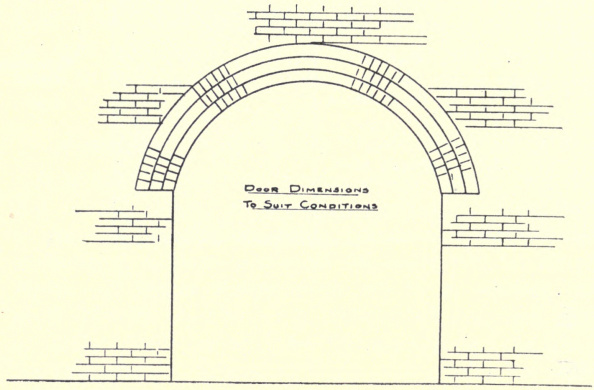


Fig. 55. Door Construction.

rectangular down-draft kiln. They not only keep the tunnel walls in place but take the thrust of the crown. It is for this reason that they must be built close together, if a long-lived kiln is to result.

Between the batter and the tunnel walls the spaces are filled with ground clay or a mixture of ground clay and sand. *This filling should be done as the walls rise,* but not before the brickwork is sufficiently strong to allow it to be *tamped lightly* to insure its being solid.

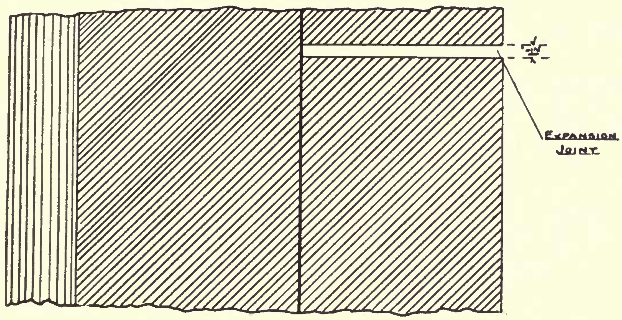
Shale or clay which has been put thru a dry pan or other grinder makes the very best filler. It should be just damp enough to form a ball when squeezed in the hand. The great advantage of such a filler is that it will harden to a solid mass and will not work into every crack in the brick-work and thus tear the kiln to pieces.

Words cannot be found that are strong enough to condemn the common practice of finishing up the walls and crowns and then dumping into the spaces, the excavation from the kiln bottom, "bats," rubbish and anything else that is handy or in the way. So-called kiln builders are often responsible for such jobs and the clayworker only allows it because of ignorance and inexperience.

Door walls should be thirteen inches thick and should be well tied to both batter and tunnel walls. A triple rowlock should be used in the door arches, which are shown in Fig. 55. Too much care cannot be used in the construction of the door walls and, even under the best of conditions, considerable attention must be given to them to keep them in good condition, especially where they tie into the tunnel walls.

SOLID BRICK BETTER THAN CLAY FILLING

A great improvement in the above described kiln construc-



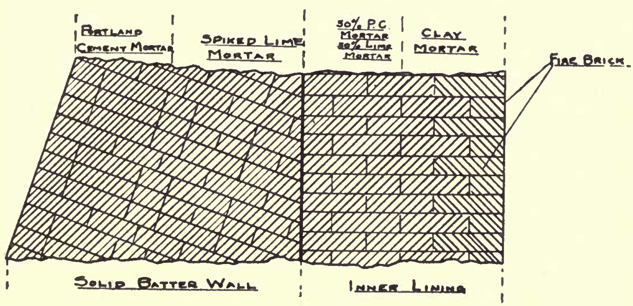


Fig. 56. Section of Solid Wall.

tion is the replacing of the clay filling between the batter and tunnel walls with *solid brick* as shown in Fig. 56 There is very little difference in cost, especially if No. 2 brick are available, as is often the case. Absolutely no difference should be made in the construction of the batter and tunnel walls, but the brace walls are left out and what might be termed a continuous brace wall is built in their stead.

The inner section of the wall is a continuation of the batter wall, the bond being continued thru the entire thickness.

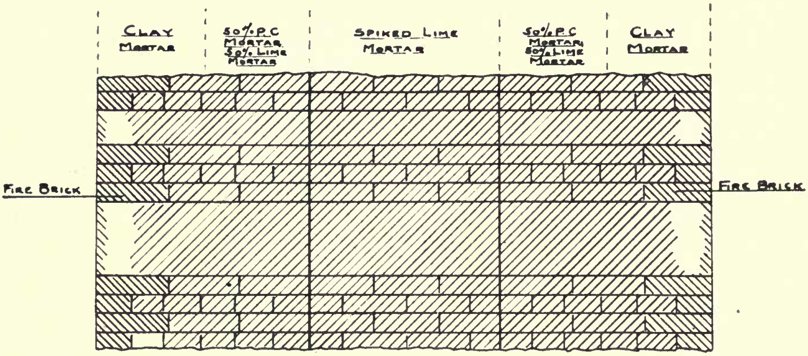


Fig. 57. Section Thru Inside Wall Double Tunnel Construction.

It should be built solidly against the tunnel wall *but not tied to it,* the latter being left free to move back and forth. Only the outside thirteen inches of the batter wall need be laid up in cement mortar, the balance being laid in lime-cement or "spiked" mortar. Great care must be taken to have all brick laid in *full mortar joints.* Laying the brick in courses and then slushing the mortar over the brick so as to fill the joints *will not do in continuous kiln construction.* Close, neat bricklaying should be insisted on and, instead of filling up wide joints or cavities with mortar, brick chips should be used. The use of "bats" in a thick wall is not to be condemned, providing it is not overdone. A course of "bats" *laid with the same care as is given whole brick,* and not used merely as a "filler" for a few hods of mortar, can be used quite frequently if they are *always tied top and bottom with whole brick.* To use course after course of "bats," as is often done, produces only poor results.

Where the double tunnel construction is used (two tunnels side by side) the filling between the tunnel walls should always be of solid brick. Each tunnel wall should be built *separately,* with the brick filling between independent of them, as shown in Fig. 57. *To tie these walls together will wreck any kiln very quickly.*

Both straight buckstayed and battered walls are used in the construction of the side walls of a chamber kiln. When battered walls are specified, the construction should be carried out in exactly the same way as described for the tunnel kiln. The expansion joints should be located at the points where the cross walls which separate the chambers are set into the side walls, as shown in Fig. 58. The same construction is used in straight wall kilns.

THIN INSULATED WALL BEST

When straight walls are to be used, several important factors should be borne in mind. Primarily, the thin straight wall is built to conserve yard room. If, therefore, such a wall is made very heavy, it defeats this purpose. On the other hand, one of the great advantages claimed for the continuous kiln is low radiation losses due to proper insulation. A thin brick wall is not a good insulator and the matter, therefore, resolves itself into a question as to whether the clayworker will build a thin, uninsulated wall and put up with a constant radiation loss; a thin insulated wall, which will give him yard room and practically prevent radiation losses; or abandon the idea of the straight wall and build the battered one.

Considered from every possible viewpoint—appearance, space, working conditions and rapidity of construction—the thin insulated wall is the best for the side walls of the chamber kiln. It must be remembered that this type of wall requires the utmost care in construction. Straight walls

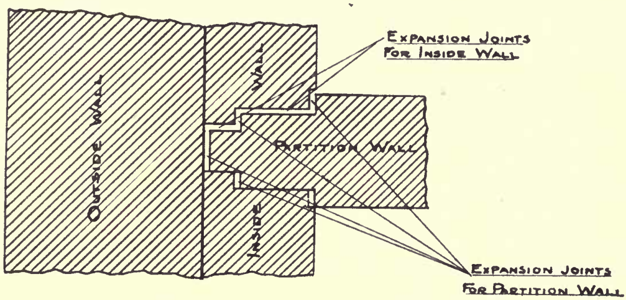


Fig. 58. Showing Location of Expansion Joints.

should never be less than thirty-six inches thick. Instead of building the inner wall separate from the outer, as in the tunnel kiln, the entire wall is tied together as in the case of a rectangular down-draft, *with alternate courses of stretchers and headers.* See Fig. 59.

The header courses should be continued thru the entire thickness of the wall. In the selection of fire-brick for the inner lining, the same rules regarding thickness and quality should apply as in the case of a tunnel kiln, described above. The inner thirteen and one-half inches of the wall should be laid up in fire-clay or fire-clay and shale, the outside thirteen and one-half inches in three-to-one Portland cement mortar with ten per cent. lime putty added, while the inner nine inches may be laid in 50-50 lime-cement mortar. The fire-clay should be laid exactly as described for the tunnel kiln.

Insulating brick should be used as the insulator. Four and one-half inches of this material would be sufficient, but in order to get a perfect bond, it is necessary to use four and one-half inches on the stretcher courses and nine inches on the header courses. They should be laid up as shown in Fig. 59, as they are not as strong as building brick and this construction is stronger than a straight bond.

URGE USE OF INSULATION BRICK

The use of insulating brick in kiln construction is still novel to American clayworkers. There is some reason (altho very little) why a man who is building a down-draft kiln costing from $2,000 to $4,000 should decide against their use. He may expect to be out of business in a few years—and possibly will be, if the balance of his plant is wasting as much money for him as his uninsulated kilns—or he may simply regard the down-drafts as a "hold over" until he can afford to build a continuous kiln. However, for the man who makes up his mind to spend from $25,000 to $300,000 on a continuous kiln, there is not the slightest excuse for overlooking this elementary principal of heat engine construction. A moment's consideration of the fact that *four inches* of this material is equal to from *thirty-two to forty-eight inches* and *nine inches* equal to from *seventy-two* to *one hundred and eight inches* of common-brick work, insofar as insulating qualities are concerned, should be enough to convince any man of intelligence that its use is absolutely necessary. It would be by all means advisable for the man who will not consider the use of this material, to abandon all thought of a straight wall and use the battered wall instead for, in the latter case, the design in itself will give him the insulation which is absolutely necessary for perfect results.

It must be admitted that the insulating brick, which are at present on the American market, have very little strength and, for this reason, some clayworkers, who have investigated them have been afraid to use them. It is not at all necessary for a clay plant owner to go into the market when requiring a brick of this kind. Almost anyone can make a good insulating brick on his own plant. The principal ingredient of the standard insulating brick is a diatomaceous earth

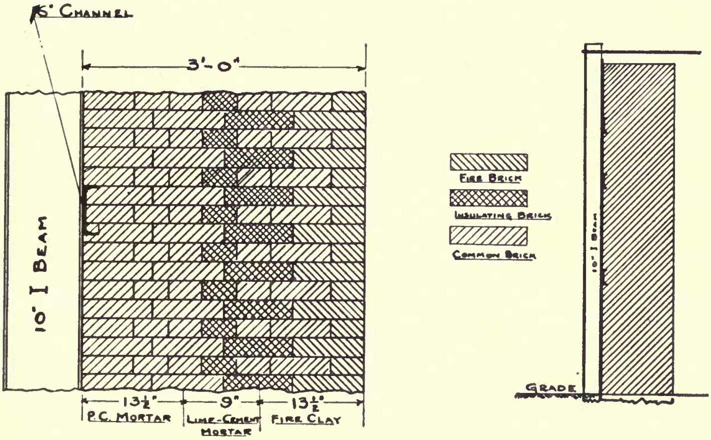


Fig. 59. Section of Straight Wall Kiln. Also Section Showing Iron Work.

known as "Kieselguhr." This material can be obtained in the raw state and any particular quantity of it mixed with any plastic clay and burned. Naturally the greater the quantity of kieselguhr used, the weaker will be the brick, as it is a non-plastic substance, but the greater will be its insulating value. However, almost any good plastic clay or shale will carry fifty per cent. or more of this material and still be as strong as many brick considered strong enough for kiln work. Another and cheaper method of making a fairly good insulating brick is to make a mixture of fifty per cent sawdust and fifty per cent clay or shale and burn it to a fair hardness. The burning out of the sawdust leaves a porous body that makes a good insulating brick of fair strength. Of course, each brick would not have the insulating value of standard insulating brick, but where they are used, the thickness of the insulating wall could be increased in proportion.

Ten-inch "I" beams should be used as buckstays in the construction of a straight wall chamber kiln. These should be space ten feet on centers for satisfactory results. The beams should be tied together at the top with one-and-one-half-inch rods having a turnbuckle in the center. The beams should be set in heavy concrete footings to a depth of at least three feet. Tying the beams to the bottom of the kiln walls by means of a ring bolt and a plate buried in the masonry, and eliminating the footings, as has been done on some American kilns, is *utterly useless.* It is simply fastening them to the wall they are supposed to hold in place.

Six-inch channels should be built into the face of the wall, flat side out, at the height of the door arch skewbacks,

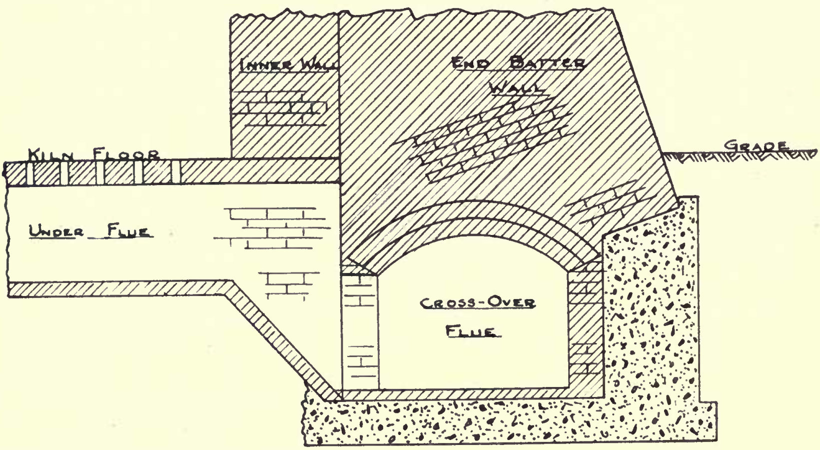


Fig. 60. Section of End Batter Wall Showing Cross-Over Flue.

and extending from door opening to door opening. One channel of the same size should be run the full length of the kiln just above the door arch, and another half way between it and the top of the kiln. See Fig. 59.

END WALLS OF TUNNEL AND CHAMBER KILNS

American practice is fast getting away from the original method of building circular or oval kilns with the chambers or tunnel running completely around the structure, on account of the inaccessibility of the end chambers. The setting of such kilns often offers no particular difficulty, but when the ware is to be loaded on cars, it means costly wheeling. The newer types are the double battery, single battery, or double tunnel single battery. In these kilns the "cross over" is made thru flues from one tunnel to another or one battery to another.

In the circular type there is often considerable trouble thru the end chambers or tunnels being compelled to take the expansion thrust of the entire kiln. When kilns are constructed in this manner the outside end walls must be built considerably thicker than the side batter walls, with special attention being given to that part of the wall which is to take the thrust of the floor and the crown. The batter should be the same as for the side walls, and the space between the lining and the outside wall should *always be of solid brick,* with the mortar joints continuing those of the batter wall right thru to the lining. In other words, a solid batter wall should be built from outside to lining. The lining should be built as in the side walls and of the same thickness, for in this part of the kiln also, the lining must be free to expand separately.

BUILD BATTERED END WALLS

In the case of the newer types, the end walls are always battered and are built straight across the end. This construction gives far greater stability than the circular end, and is much easier to hold in place. It must always be borne in mind that these end walls take an enormous thrust. Even small kilns are 150 feet long and some of the larger ones several hundred feet in length. The expansion of such a mass of brickwork will quickly wreck any but the best construction. In the case of the chamber kiln, where the chambers and crowns run at right angles to the side walls, the whole thrust of from eight to twenty crowns must be taken entirely on the ends, and any accident to these walls would mean the collapse of the crowns, like a house of cards. Examination of several kilns in which occasional brace walls and earth filling were used between the end batter walls and the lining, instead of solid brick, has shown that the thrust of a kiln is great enough to crush the mortar joints from between the brick, and in some cases, even the brick themselves were crushed to fragments. In each case, this happened in less than five years after the kilns were built.

The "cross-over" flues or those used to carry the heat from one tunnel to another, or one battery of chambers to another, are sometimes built within the end walls. Whenever a flue is to be built within these walls, it should be built so that the *top of the arch comes entirely below the floor level.* It will be seen that to build such flues where they will have to take some of the expansion thrust, is to invite disaster; in fact, practice has shown this to be the case. Fig. 60 shows the proper construction.

CHAPTER XII

Partition and Flue Walls

THE PARTITION WALLS, or the walls which divide the chambers, present no difficulties in the coal-fired kiln. They need not be very heavy, 22½ inches being sufficient. Their principal duty, aside from separating the chambers, is to support the crowns. As they are simply middle walls with a crown springing from each side, the thrust is equally balanced and need not be considered.

In the case of the one side gas-fired chamber kiln the conditions are different, however. In these walls are built the gas "down-takes" leading from the distributing flues, which flues are built between and parallel with the crowns. These "down-takes" are usually nine inches square and open at the bottom into the bag walls. Extreme care is necessary in the construction of these walls, or gas-leaks into the chambers, thru the brickwork, will cause serious annoyance and partial loss of control of the gas at the burners.

The only safe method of constructing these small flues in the walls is by the use of tongue and groove brick which are shown in Fig. 61. These brick, which are made by all the large refractory manufacturers, are provided with a tongue and groove much like ordinary flooring, and with them a *perfectly gas-tight joint can be made.* They have been used by the by-product coke oven builders for all gas conveying flues for years past, with excellent results. As yet, gas-fired kiln builders have not used them with the result that gas-leaks from built-in flues have been a serious drawback to kilns of this type.

As the partition walls are built up, the "down-take" flues should be carried up separately, as the tongue and groove brick will not bond with the standard shapes. This is really an advantage, as a crack, that might develop in the flue wall, would not then extend thru the partition wall proper. The flue walls need only be four and one-half inches thick and, as tongue and groove brick are made very exact in size on account of the nature of their use, they should be dipped in the mortar. The partition walls should be laid up with a trowel and mallet and the bond should be the same as the lining, alternate courses of stretchers and headers. They should be set into the side walls as shown in Fig. 58. When nine inch by nine inch "down-take" flues are used the total wall thickness should be thirty-six inches.

In the gas-fired and in some coal-fired chamber kilns, bag walls or pockets are built on one or both sides of each chamber and attached to the partition walls. These bag walls,

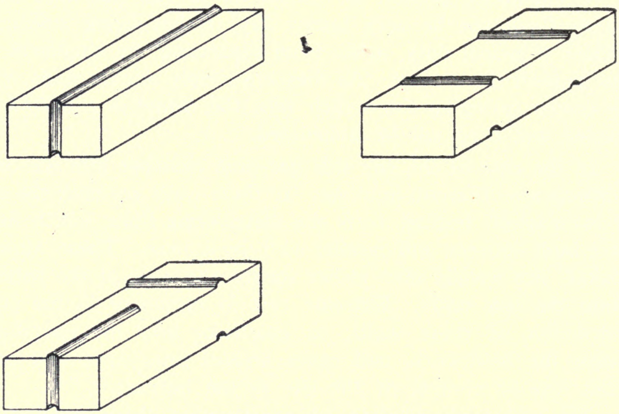


Fig. 61. Tongue and Groove Shapes.

being built comparatively close to the partition walls, are much more stable, and are not subjected to the same destructive influences as in the case of bags in the periodic kiln. These walls are often built the full length of the chamber with only a tie at the top and middle on each side of each burner or pocket. This is very poor practice. In such cases the flame is readily pulled to hot spots in the chamber, being carried along behind the continuous bag wall before it reaches the top. Thus the operator has difficulty in regulating the kiln. The bag wall may be built as a continuous wall, but it should be thoroly tied into the partition wall from top to bottom by means of four and one-half inch partitions placed between each burner or pocket as in Fig. 62. In some cases each burner or pocket is provided with an individual bag wall completely surrounding it. The face of a long bag wall should be nine inches thick and should be alternate header and stretcher courses. Bag walls in these kilns, when properly built, will last for years with only minor repairs.

FLUE CONSTRUCTION

The construction of flues in and around a continuous kiln is a problem of considerable magnitude insofar as making them trouble-proof is concerned. Many of the flues are very difficult to get at and repairing them is not an easy matter. In constructing a kiln, even from plans of good kiln engineers, this question of get-at-able-ness should be thoroly considered. It must be remembered that the kiln engineer is generally thru with his part when the kiln is complete. He is seldom, if ever, called upon to undertake the repairs which may be necessary a few years later. Very often a practical clay-worker with his experience with other types of kilns, can improve vastly on the ideas of the engineer when it comes to a question of flue location. The design of various flues is also important. Many kiln builders have only one idea in mind in designing a flue, no matter where it is located, and that is that the half circle arch is the strongest that can be built. This idea is perfectly logical when the flue has to carry a heavy load, or is located underground where it will be subjected to the bumping of carts or wagons. In cases where flues do not carry loads but are subjected to a thrust which tends to crush their sides in, the half circle arch is unquestionably weaker than one that is flatter. Experiments have shown that, for flues subjected to a thrust, the rise of the arch should be one-third the inside width. Such an arch acts as a brace for the walls and will keep them in place.

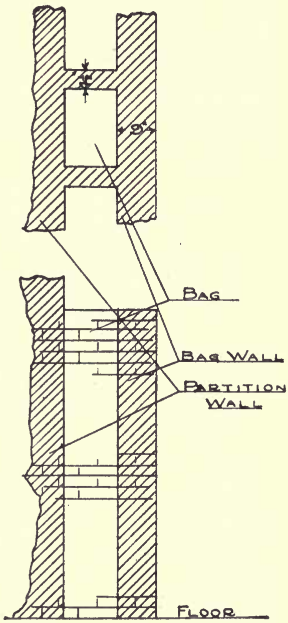


Fig. 62. Bag Wall.

Continuous kiln experts generally advise placing flues as low in the body of the kiln as possible. This has a tendency to make them less accessible, but at the same time less likely to be damaged by constant expansion and contraction. In the coal-fired kilns the only flues used are the main draft flue with its connections, and the watersmoking flues when provided. These flues offer no constructional difficulties and may safely be made part of the brickwork which surrounds them. Extra care should be taken when connecting one flue to another so that no break will occur. Care should also be taken, as in the case of all flues, to use the exact arch, wedge and rectangular shapes required to make a perfect arch. The use of straights alone will invariably lead to trouble and repairs. Provision should be made for getting into the main and watersmoking flues at various points for examination and repairs. It is no easy matter to have to tear out part of a wall or crown, or to remove several feet of filling, perhaps at a point where no trouble exists, to make a minor repair. Manholes, giving access to these flues, can be left so as to make it an easy matter to get into them.

A very different problem confronts the builder of a gas-

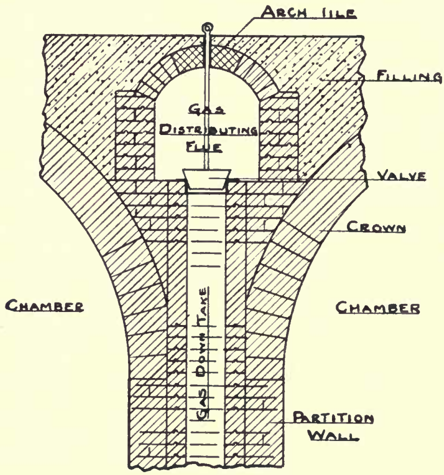


Fig. 63. Section Thru Gas Distributing Flue and Down Take.

fired kiln. In kilns of the latest design, all of the gas and watersmoking flues are carried in the walls. In the older models of the chamber type, the main gas flue and watersmoking flues were carried on top of the kiln. These flues were of steel with a fire-brick lining. This prevented loss of heat and gas-leaks, and as they could expand and contract freely without reference to the kiln, they gave absolutely no trouble.

BRICK GAS FLUES HARD TO BUILD

Carrying gas in brick flues which are subjected to considerable racking is a ticklish proposition, the construction of

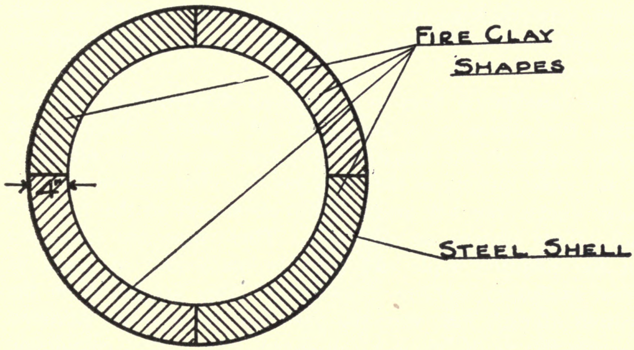


Fig. 64. Method of Lining Gas Flue.

such flues requiring the best kind of engineering and workmanship. The conditions in a kiln are entirely different from those in a by-product coke oven where brick gas flues are used very successfully. In the latter case the temperature surrounding the flues is practically constant and consequently the walls are not cracked, but in a kiln the temperature fluctuates with the location of the fire.

The walls of the main gas flue, which always runs the full length of the kiln, should be built of *tongue and groove brick,* should be nine inches thick, and have alternate header and stretcher courses. The floor of the flue should not be tied to the wall on which it rests but should be free. The arch should be built with extreme care and with the joints as thin as possible. *The walls of the flue must not be tied to the brickwork on each side.* This brickwork should be run up on each side of the flue with a straight, close joint, *without mortar* between it and the flue. If the flue is to be entirely surrounded by brickwork, that is, placed low down in the body of the kiln, another arch should be thrown over the flue arch, but entirely separate from it. Such a flue will be entirely free to move without reference to the adjacent brickwork, *and it must be free* if it is not to be a constant source of trouble and expense.

HOW TO CONSTRUCT WATERSMOKING FLUES

The watersmoking flues, when built in the body of the kiln, must be constructed in exactly the same way. As a general rule, no great pains are taken with these flues because they carry only hot air, but when poorly constructed, are often more of a nuisance than a help on account of the air leaks. Some watersmoking flues have been so poorly built, in both gas and coal-fired kilns, that their use has been entirely abandoned.

The distributing flues in a gas-fired chamber kiln are very often the source of a great deal of trouble. They are at right angles to the length of the kiln, so are not subjected to the same racking as the main gas flues, but receive a movement due to the hot gases within them and to the rise and fall of the crowns on each side. These flues are supported on the partition walls and must be made part of them, as from twelve to eighteen "down-take" flues are led from the bottom of each flue, thru the partition walls, to the burners. Usually the earth filling which covers the crowns, completely surrounds the sides and arch of each flue, so that they are free to move. When not carefully constructed they can cause much trouble and annoyance thru the gas leaking into the chambers and causing a loss of gas control.

TONGUE AND GROOVE BRICK MAKE TIGHT WALLS

These flues should be built of tongue and groove brick and should be nine inches thick. Brick should be dipped and malleted. The arches are particularly important. The gas control valves seat in the bottom of these flues and the valve stems extend up thru the arches by means of small holes. It is quite common for these stems to "freeze" in the holes thru an accumulation of tar around them. In such cases, it often takes all of a man's strength to pull them loose and, in doing this, the arch key is loosened, as the pull is directly with the key. In course of time the arch is loosened to such an extent that it must be rebuilt. This difficulty is entirely overcome by the use of large key blocks instead of ordinary arch or key brick. These blocks should be large enough and heavy enough to resist any ordinary pull against them. They are shown in Fig. 63.

When lining metal flues, it is far cheaper to have special circle blocks made that fit the steel shell exactly than to use brick. To line up a steel tube from one hundred and twenty-five to two hundred feet long with nine inch shapes is an enormous job and, when finished, is more often than not something of which to be ashamed. A mason cannot do good

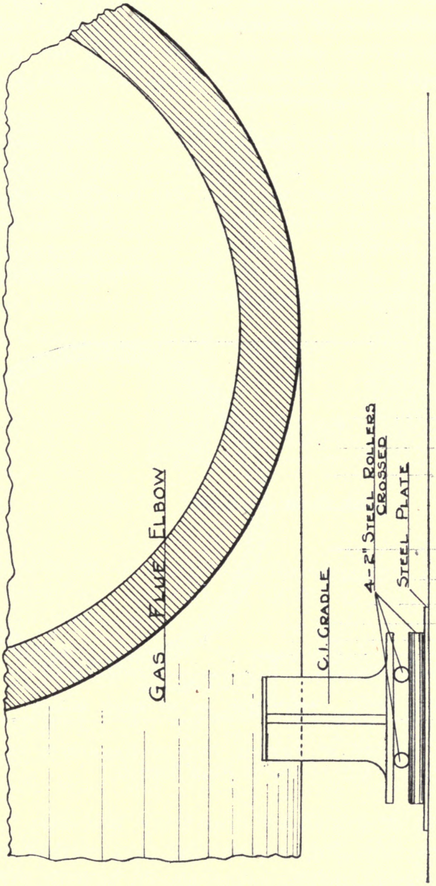


Fig. 65. Method of Taking Care of Expansion in Two Directions at Flue Elbows.

work with small units while sitting down or lying on his stomach, especially by lantern light. When quarter circle blocks of the correct circumference are used, they can readily be slipped into place without mortar and a good permanent job results. See Fig. 64.

ROLLERS PERMIT EXPANSION OF METAL FLUES

The expansion of metallic flues is taken care of by means of rollers which allow the flue to work back and forth freely. Special care should be taken at the points where these flues make a right angle turn. At such points two sets of rollers with a plate between should be provided in order that the flue may move in both directions. These rollers are laid at right angles to each other as shown in Fig. 65. Four two-inch steel balls laid between two plates will answer the same purpose, as in Fig. 66.

Where a metallic flue enters a brick flue, provision must be made to take care of the expansion of the former. If the metallic flue is tied into the brick flue it will quickly destroy the connection and often cause considerable damage to the surrounding brickwork. When the brick flue continues in the same direction as the metallic flue the latter should extend into the brick flue and be allowed to slide back and forth in it.

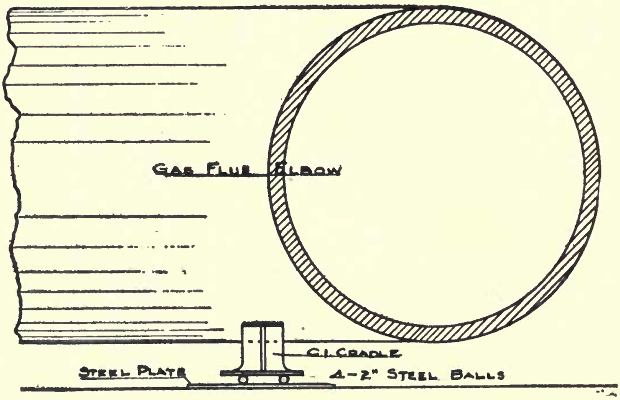


Fig. 66. Method of Taking Care of Expansion in Two Directions at Flue Elbows.

The joint is then mudded over when necessary. When a horizontal metallic flue is connected to a vertical brick flue, the bottom of the metallic elbow should be built with a wide flange. This flange should simply rest on the walls of the brick flue so that it may slide back and forth freely. In this case also the joint is simply mudded tight when necessary or closed with a sand seal as shown in Fig. 67.

BUILD UP-TAKES SEPARATE FROM KILN WALLS

When vertical brick flues or "up-takes" are built to convey gas from underground flues to flues in the upper part or on the top of the kiln, they should be made *entirely separate from the kiln walls.* Such flues are often heated to fairly high temperatures, especially during a "burn out," and they must be allowed to expand freely. They should be built eighteen inches thick with alternate courses of headers and stretchers.

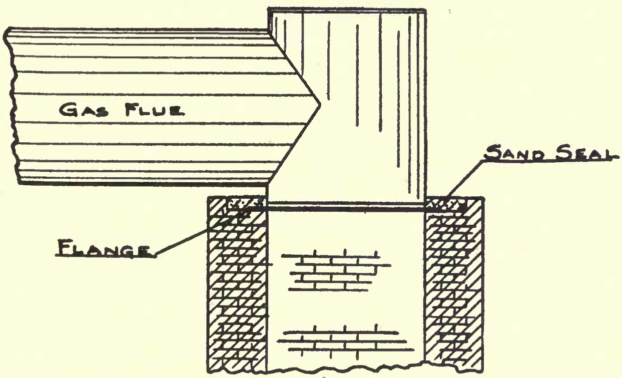


Fig. 67. Elbow on Brick Flue.

The corners should be fitted with three-inch angles for the entire height and these angles should be tied together every three feet with seven-eighths of an inch iron rods. The interior four and one-half inches should be of second quality fire-brick laid up in a mixture of fire-clay and shale, the balance of the wall being laid up in a three to one Portland cement mortar. The fire-brick in the lining should be hard and the joints thin. Producer gas has a tendency to "rot" soft brick and fire-clay mortar, and will destroy a flue in a few years, if the proper precautions are not taken.

Underground flues, with the exception of gas flues, serve the same purpose in both coal and gas-fired kilns. They are generally confined to main draft flues and "cross-over" or "return" flues. The latter are used to carry heat from one tunnel to another or from one end of a battery to the opposite end. These flues, being generally subjected to yard traffic, must be built with a high arch, preferably a half circle. Two points must be particularly borne in mind in constructing these flues—they should be as tight (free from leaks) as it is possible to make brick construction, and they must be very strong to carry the loads.

The draft flues are not subjected to high temperatures and, therefore, may be built of common-brick. The "crossover" or "return" flues are seldom subjected to more than 1,400 degrees Fahr., so that as a rule common-brick with a high melting point will serve for them. The best wall for all underground flues is one thirteen inches thick, with a header and stretcher on each course, the header being reversed on every course so that it is outside on one and inside on the next above as in Fig. 68. This bond breaks the vertical joints in such a way that none of them go thru the wall. The draft flues should be laid up in three to one Portland cement mortar entirely, while the heat flues should have the inside four inches laid in clay or shale mortar and the outside nine inches in Portland cement. All joints should be as thin as it is possible to make them.

EXPANSION JOINTS NECESSARY IN CROSSOVERS

When it is necessary to build "return" or "crossover" flues over fifty feet long, as in the case in the single battery kiln, or when two batteries are widely separated, expansion joints in the flues should be left every forty to fifty feet. If this is not done, the flues will wreck themselves in a few months, to say nothing of the effect on transfer tracks and pavements above them. This also applies to long underground gas flues which expand greatly when being "burned out."

When digging a trench for an underground flue it must only be wide enough for the flue to fit snugly. To follow the usual custom and dig a wide trench and afterwards fill along the walls with loose earth invariably results in a wrecked flue, for as soon as weight is put upon the arch the walls spread and the key of the arch is gone. More continuous kiln trouble results from air leaks in flues and walls than from all other sources combined, and many unsuccessful or partially successful kilns would work perfectly if the leaks could be stopped. An instance of this is a kiln which required two fans operating to capacity to get the required draft. The flues and walls, which were poorly constructed, were gone over thoroly. Repairs were made and leaks daubed up, with the result that one fan running three quarters speed gave sufficient draft and increased capacity.

Underground gas flues should be built in the same manner as other underground flues but should have a double arch, the upper ring being laid in cement mortar. On top of this arch a covering of sand several inches thick should be laid as a seal for the gas.

All underground flues should be completed before the main body of the kiln is put up. A number of serious collapses have taken place thru making excavations for underground flues in close proximity to the kiln walls after the kiln was well along. The weight of the kiln simply pushed the footings out as soon as the solid earth backing was removed in digging the trench. As some of the flue excavations are quite large and as the flues may as well be put in first as last, it pays to take no chances in this direction.

REGARDING THE CROWN OF THE KILN

The crowns are comparatively the most expensive part of the ordinary continuous kiln and it pays well to so construct them that they will be permanent. It has been the custom to build all these crowns as a half circle, on the supposition that such a crown had the greatest strength. This idea would have been correct if the load on the crown was the only consideration. However, it is the fire under the crown and the expansion that must receive first consideration and, on this account, the idea of the half circle crown has had to be revised. Another consideration is the kiln capacity. In both the tunnel and chamber types where the half circle crown is used, the skewback has to be set so near the floor line that the benches of ware commence battering after the first few courses. This not only cuts capacity, but makes the setting more expensive.

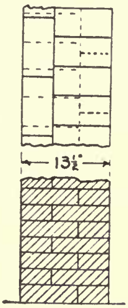


Fig. 68. Flue Wall Construction.

Experiments have shown that the same rules apply in continuous kiln crown construction as in rectangular down-draft construction. This means that the best crown has a height equal to one third the width of the tunnel or chamber. Such a crown not only gives good capacity, but the best burning results.

The crowns should be built in the most careful manner. The mortar, which, of course, should be fire-clay, should be laid on as thinly as possible with a trowel and each brick malleted down to the course level. With the brick ordinarily supplied for kiln work, it is impossible to lay up a permanent crown with dipped brick. The brick work, both straights and shapes, are of such uneven thickness that the difference cannot be made up without the use of a trowel, no matter how skilled the mason is. If a clayworker insists on dipping his brick he must specify the allowable variation in size that he will accept when buying the brick. In this way he may get what he wants, but in no other.

The proper number of wedges and straights should be used to make the arch come up perfectly. The key should fit so tight that it will not go more than half way to its seat when pounded with a hand mallet. It should then be driven home with a wooden block and sledge hammer. In the tunnel kiln the crown is not subjected to the severe flame flash that a periodic kiln crown gets above the flash walls. The heat is quite evenly distributed and the crown is heated up and cooled off under the best possible conditions. For these reasons a tunnel kiln crown, if well built and supported on good, well backed up walls, will have an exceedingly long life.

On top of the nine-inch crown proper a 4½-inch arch should be built. This may be of common-brick laid in clay or shale mortar. If the work on this false crown is well done, it will add considerable to the strength and life of the fire-brick crown. The spandrels should be brought up solid to the top of the crown.

EXPANSION JOINTS IN CROWN

Expansion joints two inches wide should be left in the crown every twenty feet at the same points at which the expansion joints in the lining occur. These joints should extend *thru the nine-inch crown only.* The 4½-inch false crown should cover the joints in the nine-inch crown but should have *one-inch expansion joints* left in it at other points twenty feet apart. On top of this joint a rowlock of brick should be laid as in Fig. 69. If the expansion joints extend thru the entire crown and are merely covered with a rowlock, trouble is almost certain to occur within a year or two. The constant movement of the crown shifts the loose brick covering the joints and finally one or more drop into them and wedge them apart, resulting in the shifting of the entire crown. Moveover, as the brick covering shifts, the earth filling begins to work its way into the joints with the same result. At the points where the false crown covers the expansion joints, fire-brick should be used instead of common-brick if the temperatures to be attained warrant it.

While a tunnel kiln crown built of nine-inch straights and shapes, with a covering arch of common-brick, will give perfect satisfaction when properly constructed, a *much better* but slightly more expensive crown can be built of 13½-*inch arch blocks made to order for the required radius.* These blocks cost only a little more than their nine-inch equivalent in standard brick, and should be as large as can be conveniently handled by the masons. The blocks should be marked by the manufacturer and laid up according to blueprint. Unquestionably, crowns built in such a manner represent the highest type of construction and, it is only because most clay plant owners prefer the path of least resistance and will not go to the trouble of ordering special shapes, that more such crowns are not built on either continuous or periodic kilns.

DROP ARCHES A SOURCE OF TROUBLE

Drop arches are usually a source of constant trouble in a tunnel kiln on account of the everlasting necessity of repairs. This is generally due to the use of standard brick. The best practice calls for an arch eighteen inches deep and it is a pretty hard matter to build these arches, and make them "stay put," with nine-inch straights and shapes. Splendid results have been obtained by the use of large eighteen-inch fireclay blocks. These blocks must be made to order and the units should be as large as possible for convenient handling. If the blocks are hard burned, of perfect fit, and are laid up with a dipped joint, drop arch troubles will disappear.

When coal-fired chamber kiln crowns are built of nine-inch brick, the same construction rules should be followed as have been laid down for tunnel crowns, but in this case there is far more reason for the use of the large blocks. In the tunnel kiln the arch is built in the direction of the greatest expansion and is not exposed to any great thrust from the sides, but in the chamber kiln the chambers are built at right angles to the length of the kiln and are subjected to linear expansion and to the thrust of the chambers on each side. This thrust has a tendency to "roll" them in the direction of the advance of the fire. Most of the crown deformation has been due to the half circle design, for it will be obvious to anyone that the higher the arch, the greater will be the ease with which it can be crushed out of shape. The fact that any movement which takes place in the crown must be in the mortar joints, is another reason for the use of large blocks as these eliminate a very large percentage of the joints.

In the coal-fired kilns the feed holes should be constructed of heavy, hard burned blocks made to fit perfectly in the crown. These feed holes are subjected to considerable wear and the use of standard brick will prove a source of continual repair expense.

GAS-FIRED KILNS HARD ON CROWNS

In the case of the gas-fired kiln, entirely different conditions are encountered. Whether they be fired on one side or both, the crowns are subjected to a constant flame bath during the firing period, the effect of which is severe. Experiments have been carried on long enough to determine the fact that the nine-inch crown *will not stand up* for any length of time under the conditions to which it is subjected. In this case there is no alternative, *the 13½-inch special block crown must be built.*

In the gas-fired kiln which has fires on only one side of the chamber, the cost of crown repairs has been staggering. All of these crowns have been built of nine-inch straights and shapes, and have had a half circle arch. The kilns have scarcely been put into service before the crowns began to flatten over the bag wall and inside of a few years, it has been the general rule that crown replacements and repairs began. Replacing a continuous kiln crown is not the comparatively simple matter of replacing a periodic kiln crown. In the former case it is necessary to remove and replace tons of filling, and often to rebuild flues which are disturbed, to say nothing of the necessity of bracing up the crowns on several chambers on each side of the one being repaired, to prevent collapse. The cost, therefore, amounts to about twice as much as would be the case in a periodic kiln crown of the same size.

There is not the slightest question but that a long-lived crown can be built on a kiln of the one-side-fire type, but it must be borne in mind that, being subjected to very severe and unusual conditions, every precaution in regard to design, material and workmanship must be taken. Any attempt to cheapen or slight the work will multiply the original cost many times over after a few years of operation.

In setting the forms for a crown it must be remembered that it will settle about one inch after the forms are removed. Due allowance must therefore be made for this settle.

BRACING OF CROWNS BETWEEN CHAMBERS

Bracing between the crowns of a chamber kiln is an important detail. In the coal-fired and double-gas-fired types it is very easy to brick up solidly between each crown and *this should be done.* When this is done it is almost a guarantee against any deformation.

In the case of the one-side gas-fired kiln the gas distributing flues interfere with solid bracing. In this case the distributing flues should be placed as high as possible and solid brace walls from one crown to another be built up to the bottom of the distributing flues. Any attempt to brace against these distributing flues will result in their being crushed, and this must be avoided.

Filling over the tops of the crowns should not be done un-

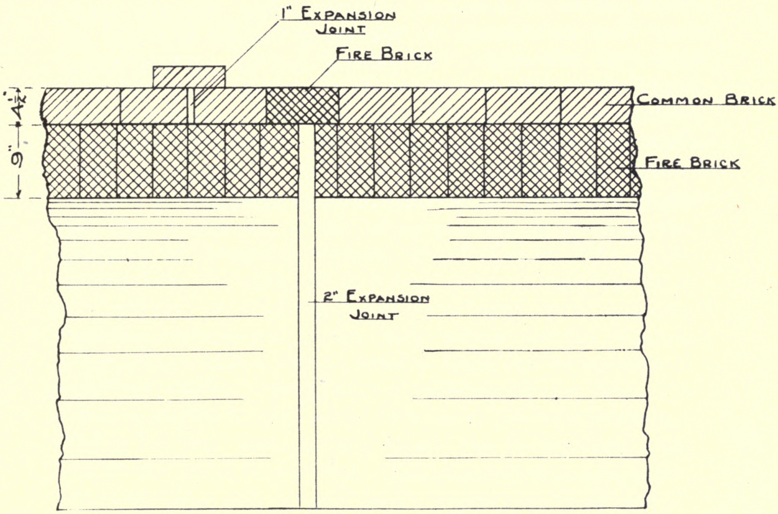


Fig. 69. Section of Crown Showing Expansion Joints.

til the entire battery or kiln is completed. The easiest method of doing this is to hoist a dump car to the top and run tracks the full length of the kiln. The material can then be spread evenly over the entire top. Many kilns have been badly damaged during the operation of filling thru commencing at one end and filling to the required depth before moving on. This throws an immense weight on one portion of the structure and creates a strain that, in extreme cases, may cause collapse.

This is especially true of chamber kilns. To concentrate a load on any one chamber at a time when much of the masonry is in a green state will invariably cause the crowns to "roll" and, in some cases, the movement has been so marked that portions of the kiln have had to be rebuilt.

As the filling is carried to the top it should be evenly distributed over the whole top from one end to the other. Primarily, this filling is intended as an insulator and naturally the thicker it is, the greater its insulating value. As a rule this filling should not be less than two feet thick over the highest point of the crown. It may be heavier if the plant owner is willing to stand the expense. The walls of the kiln must, of course, be brought up to the level of the top of the filling.

A covering of six inches of burnt out ashes next to the crown makes an excellent insulator, when they are available. For the balance of the filling, almost any sort of earth may be used. The platting on top of this filling should not be laid for six months or a year after the kiln commences operation if a good level floor is desired. The filling is bound to settle and shrink for a long time and nothing will prevent a poor, unsatisfactory job if the platting is put down at the time the kiln is built.

CHAPTER XIII

Kiln Roof and Producer House Construction

NO ATTEMPT will be made to describe chimney construction. Very few American clayworkers will consider the use of a chimney in connection with a continuous kiln, and the few who still believe that a chimney is cheaper than a fan, would do well to study the problem from all angles before making a decision.

It will be admitted, of course, that a fan is cheaper to install than a chimney, so the whole question revolves around the point of operating expense. In connection with a continuous kiln, the chimney is not as cheap to operate as at first appears. A chimney is always affected by atmospheric conditions, sometimes to the point where the fire scarcely moves, while with a fan a constant speed can be maintained under all weather conditions. A chimney always limits the kiln to a certain burning speed even under the best conditions. With a fan this "best chimney speed" can be increased from fifty to one hundred per cent. As the conduction and radiation losses on a kiln are practically constant under all operating conditions, this increased need reduces the proportionate heat loss. Also, with a fan, the waste gases can be exhausted at temperatures of from 50 degrees C. to 75 degrees C. when the kiln has a watersmoking arrangement, while for maximum efficiency the mean temperature of the gases in a stack must be maintained at 300 degrees C. This means that the exhaust gases at the base of the stack must be kept at from 400 degrees C. to 500 degrees C. to allow for cooling as they rise to the outlet. It will be seen that this item in itself is worthy of consideration and goes a long way towards overcoming the cost of fan operation.

The size of the fan is very important. Small fans should always be avoided on account of the high speed required. It is much more economical to install a large unit that can be operated at a low speed because the power required increases as the cube of the speed, which means that when speed is doubled, the power required is multiplied eight times.

FAN SHOULD HAVE COPPER BLADES

The best type of fan for continuous kiln work is the overhung induced draft or suction type. *The fans should always have copper blades and cast iron arms.* Sheet iron blades and mild steel arms are eaten away so quickly by the gases that they are practically useless. Even heavy copper blades require replacing every three or four seasons. Two fans should always be provided to prevent shut-downs. High speed engines or motors require repairs, belts will break and bearings burn out, but the kiln must be kept running, and it can only be kept running if an auxiliary fan is ready for instant use. When electric power is available on a steam operated plant it is a splendid plan to have one fan motor-driven, and one, engine-driven. In such a case it is almost impossible to have the kiln down for more than a few minutes at a time. On electrically driven plants variable speed motors should always be provided for the fans. The control such motors give, makes it almost unnnecessary to handle the dampers in order to regulate the draft. Also the results are more positive when the draft is regulated by the fan speed.

The fans should be covered with a brick housing, as a steel housing is quickly destroyed by the gases. In building such a housing, provision should be made for examining the fan from time to time and also removing it for repairs.

Even when using a fan, a discharge stack is necessary. Such stacks should be high enough to carry the gases well above the yard. When the stacks are low the waste gases drifting thru the yard and buildings will often seriously interfere with the work of the men.

SOME POINTS REGARDING ROOF CONSTRUCTION

Practically all continuous kilns are provided with roofs. These vary from the flimsiest kind of a shed structure to the best type of steel construction. The kiln roof presents a problem that is well worth a little of the clayworkers' consideration. It must be remembered that, as a rule, they are large affairs, a double battery kiln of fifty thousand daily capacity requiring a roof measuring approximately one hundred and twenty-five by two hundred feet; that they are generally a bad fire risk; are subject to a lifting wind pressure due to their not being protected by side walls; are exposed to the ordinary wind pressure and, in many instances, to very heavy snow loads. Consideration must also be given to the fact that the roof is subject to the radiation from the kiln. When built of green lumber, this heat will draw, strain and twist the trusses and timbers to such an extent that the roof is unable to withstand the hard service put upon it and collapses or partially collapses during a high wind or under a heavy snow load.

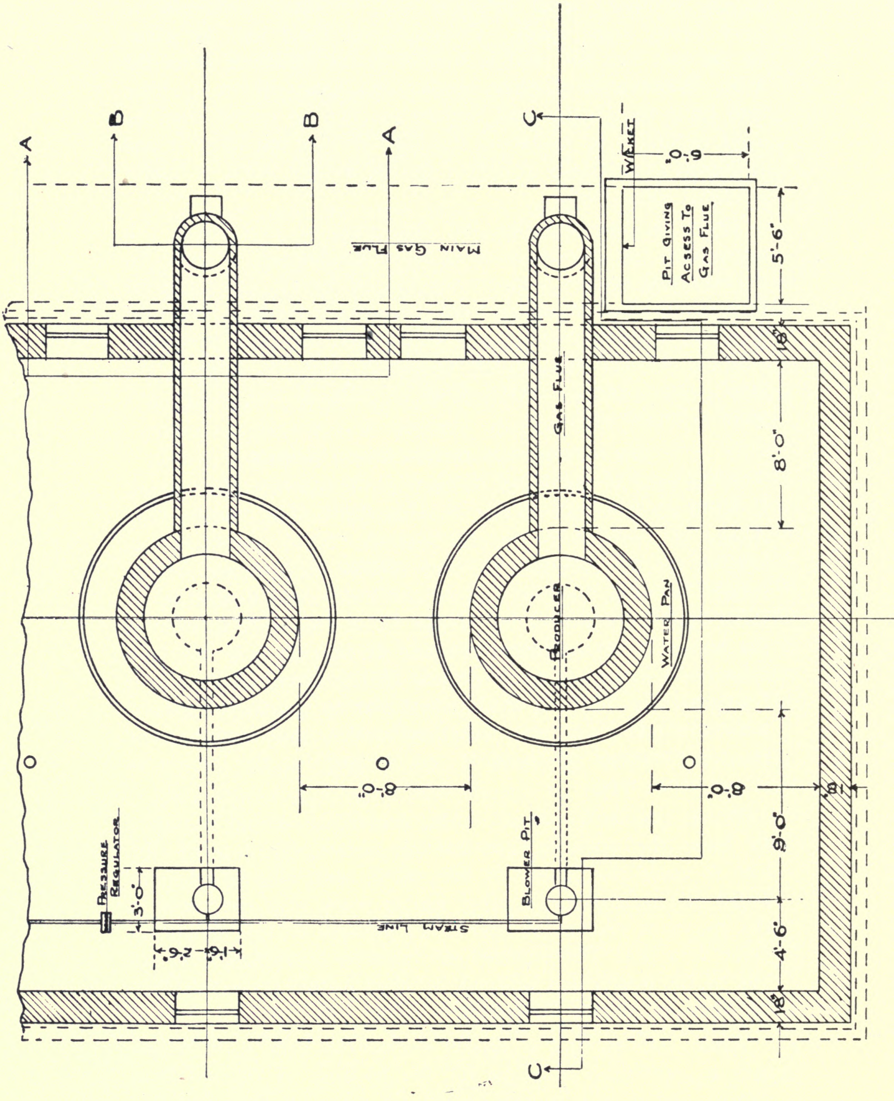
There is little question but that men of experience will agree that the wooden roof is to be condemned. Generally, its size and weight compels the use of heavy, uneconomical trusses which have a tendency to weaken under their own weight. Considering the cost of lumber, the high insurance rate or the inability to get insurance, and the upkeep, the steel frame, metal-covered roof is little, if any, more expensive in the end.

DO NOT BUILD DOUBLE HIP ROOFS

In the case of the double battery kiln it has been the custom to build roofs of the double or triple hip design. Such roofs should be avoided for several reasons. They are more expensive to construct because they require more material: the valleys between the hips collect and hold large quantities of snow, and it is almost impossible to so construct them that the water from melting snow and from rain will not leak onto the kiln to a greater or less extent after the roof is a few years old. It is by far the best plan to construct the roof with a single ridge, no matter what the span may be, for the same number of supports can be used for the trusses as in any other type.

When wooden roofs are built, great care should be taken to have the trusses high enough above the top of the kiln to avoid the danger of fire. Care must also be taken to avoid placing trusses or other timber work near the vents in the crown or crowns or near other parts of the kiln which become very hot. The exposed gas flues on a gas fired kiln are one of the points that must be watched in this respect as they get very hot during "burnouts."

When constructing a producer-gas-fired kiln it is necessary to provide a building for the housing of the gas producers, and it will be well to bear in mind the fact that this is one of the important parts of the plant. Up to very recently it was the custom to merely cover the producers with a wooden roof, the duty of which was to protect the operators


A
B
B
A
C
MAIN GAS FLUE
WICKET
6'-0"
PIT GIVING ACSESS TO GAS FLUE
5'-6"
18"
GAS FLUE
8'-0"
PRODUCER
WATER PAN
8'-0"
8'-0"
BLOWER PIT
PRESSURE REGULATOR
3'-0"
9'-0"
STEAM LINE
2'-6"
1'-9"
4'-6"
18"
C

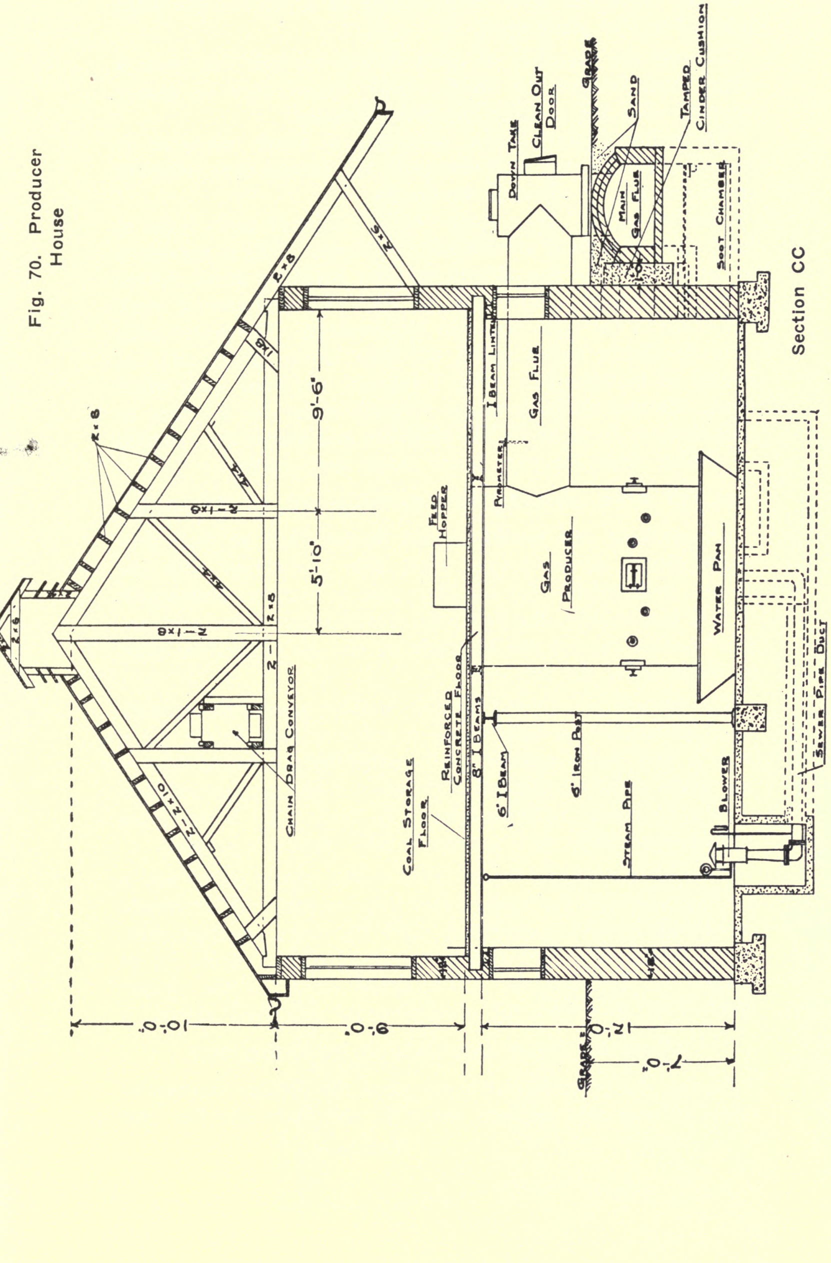


Fig. 70. Producer House

Section CC

from the weather. In the past few years, however, the efficient manufacture of the gas has been given considerable thought and study by a few of those interested in the subject, and the result has been the evolution of a modern gas plant adapted to clay plant work.

To suit the majority of cases it was realized that such a plant must involve the least possible expenditure of money coupled with the greatest possible efficiency.

The building itself should be strong, as nearly fireproof as possible, well lighted, well ventilated and should have sufficient space for proper working conditions.

The "clean out" floor should be so arranged as to leave at least eight feet clear around each producer. This is necessary on account of the use of long bars for breaking down clinker thru the cleaning doors, and the fact that men cannot work too close to the open doors in hot weather. The water pans or seals should be set up on the floor like a saucer and not buried so that the rim comes level with the floor as is often done. Setting them up makes it much easier for the men to pull clinkers from under the producer and makes the removal of clinker from the pans much easier and quicker.

BLAST PIPE CONNECTION SHOULD BE ACCESSIBLE

A man-hole and tunnel should be provided at each producer giving access to the blast pipe connection with the grate. It is possible for the blast pipe to become choked and, if it is inaccessible, the producer must be shut down and emptied before repairs can be made or else an excavation must be made under the producer.

The blower pits should be in a well-lit, accessible location. Each pit should be built so as to allow a man to get down into it and make repairs. All connections between blower and grate which are placed underground and are inaccessible, should be made of sewer-pipe. To bury light metal pipes underground leads to troublesome and expensive repairs.

Each blower should be provided with a steam gauge and a draft gauge, and the main steam line from the boiler should be provided with a regulating valve to insure constant pressure. Each pit should also be provided with a steam jet or ejector for keeping the condensation down to the proper level. Fig. 70 shows the arrangements described above.

AVOIDING SHUT DOWNS FOR BURNING OUT

During the operation of a gas plant the greatest accumulations of soot and tar are found in the main gas flue just

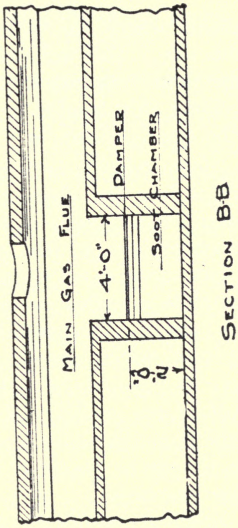
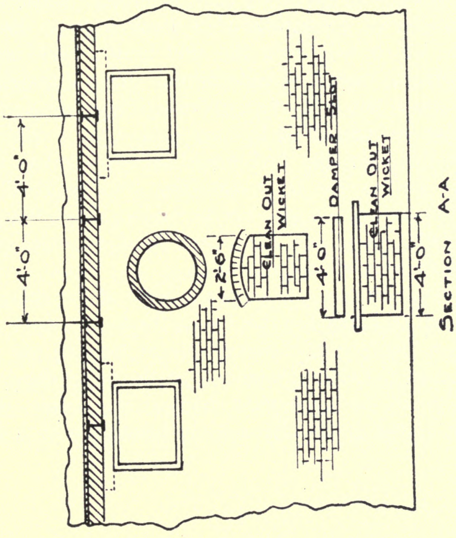


Fig. 71. Soot Chamber.



beneath the points where the "down takes" from each producer enter this flue. This accumulation chokes off the gas supply and occasions frequent shut-downs for burning out. A way of avoiding this trouble by providing a method for cleaning out the flue is shown in Fig. 71.

Under each "down take" is built a chamber which opens by means of wickets into the clean out floor of the producer house. The accumulating soot and tar falls into the upper part of this chamber onto an iron plate. As soon as a sufficient quantity has accumulated to interfere with the gas flow in the flue, the plate is pulled out and the soot and tar falls into the lower part of the chamber. The plate is then replaced and the lower wicket opened for the removal.

The main gas flue *should never be tied into or built tight against* the wall of the producer house. If this is done the expansion of the flue will either wreck itself or the wall. A cinder cushion should be provided between the flue and the wall to take the pressure.

All window openings on the cleanout floor should be near the ceiling to allow for the easy escape of gas and heat during the cleaning of the producers.

The floor of the charging room should be fireproof and capable of carrying a load of at least twenty-five tons for each producer. Shipments of coal cannot always be regulated and it is well to provide for ample storage to prevent expensive rehandling of fuel. Comparatively, so little fuel is required on the average plant that it scarcely pays to consider automatic feeding hoppers above each producer. However, a coal unloading device consisting of a track hopper, elevator and conveyor, which will drop the fuel beside each producer, is an investment worth consideration. Its value will depend, however, upon the size of the plant. The same sort of outfit should also be considered in connection with a coal-fired kiln, except in this case, the fuel would be conveyed to the top of the kiln. To say the least, handling coal by hand from the modern hopper bottom coal car to a point above the car's sides is a difficult, nasty job and some kind of mechanical handling has become almost essential.

Care should be taken to have the roof of the charging room high enough to allow for the use of the long pokers which are necessary. These pokers are nearly as long as the producers are high, and the roof, therefore, at the point above the poke holes, should be somewhat higher than this dimension, especially as the pokers have to be handled with a block and tackle.

A monitor should be built the entire length of the roof to allow for the escape of gas.

SMALL PRODUCERS BETTER THAN LARGE ONE

In determining the size of the producer to use it should be remembered that two small ones give far better results than one large one, or four small ones better results than two large ones. The small producer is much easier to handle in every way, and the greater the number of producers used, the more even is the gas flow. The fuel consumption is more likely to be lower on a number of small producers than on a few large ones because there is not the tendency to push the small ones in order to maintain the flow of gas. As one man can look after six six-foot producers without trouble, there is no labor to be saved by putting in a smaller number of large producers. In fact, there are some plants which are operating two nine-foot producers which require two and sometimes three men on each shift, while others are operating five six-foot producers with one man, and doing it easily.

As the design of gas producers has become a specialized branch of engineering, it is by far the best policy to have some company, specializing in this line, furnish producers when required. Each coal has its own peculiarities and there is *no producer made which will give satisfactory service in all cases,* and certainly no one who has not had very wide experience with different kinds of coal, is competent to design a producer for a plant where the number of different coals available are limited. It is possible, however, for experts to design successful producers for any kind of service, whether the fuel be wood, peat, lignite, anthracite, or clean or dirty bituminous coal.

Clayworkers erecting a continuous kiln of any type should *always* provide themselves with a competent inspector, and this inspector should preferably be an engineer. Merely putting a man on the job will not do; he must be a man with experience in masonry construction and engineering problems. Men of this kind are not easy to obtain and are expensive, but having one on the job *every minute* is as necessary as the brick and mortar. It is not so essential that such an inspector should have had previous kiln experience, altho this is an advantage, but he must know what constitutes good brickwork and must be able to straighten out the difficulties which are certain to arise even when the most complete plans and specifications are furnished. An engineer often draws a few lines on paper which appear to offer no difficulties but are extremely difficult to execute in practice. Lack of attention to business, slow thinking and poor judgment on the part of incompetent inspectors has cost many clayworkers large financial loss and has resulted in many kilns being partial or complete failures. The clayworker should move slowly in this matter and should be extremely careful about *accepting, without thoro investigation,* the men recommended by kiln builders.

The foregoing specifications for the construction of continuous kilns are not intended for the exclusive use of the man who wants a *good* kiln, but represent what *must be done* by anybody if a kiln that will *stand up to its work and pay dividends* is to result. A more severe set of specifications may be followed, but if any attempt is made to "get by" with anything less rigid, nothing but regret will follow.

THE RESULT OF POOR CONSTRUCTION

An example of what poor continuous kiln construction can do is illustrated in the following. A large concern which operates a battery of down-draft kilns and a large continuous kiln unit on the same plant, found that the latter saved them two-thirds of the fuel and one-half of the labor as compared with the down-drafts. However, after the continuous kiln had been in operation a few years the repairs had become so heavy that it was necessary to make a new comparison of costs. It was then found that in spite of the saving in fuel and labor which the continuous kiln effected, it had cost *twenty-three cents per thousand brick more to operate it than the down-draft kilns.* Not only had the saving, made by cutting off two-thirds of the fuel cost and half the labor cost, been utterly wiped out, but twenty-three cents per thousand had been added. By what? *Repairs.* And this is the tale the cost sheets of many continuous kiln users would tell if they could but be consulted. As has been already stated, the men who have built continuous kilns heretofore have been the pioneers, it is they who have been paying for the experience which can only be bought in this way, and if the builder of the future will not benefit by the lessons learned by those who have gone before, he is simply courting disaster.

It is well to beware of the man who offers to build a *cheap* kiln and also it is well to consider carefully the "estimates" usually presented by kiln builders. When reliable information is wanted go privately to the men who have been operating kilns for several years, and as a general rule, it will be found that they are only too glad to help others avoid the pitfalls into which they themselves unwittingly fell.

CHAPTER XIV

Operating a Coal-Fired Continuous Kiln

ANY DESCRIPTION of the operation of a continuous kiln of any type can only cover the subject in a general way. Continuous kilns of the same type, as is the case with down-draft kilns, differ radically in action, each kiln having its own peculiarities. Continuous kiln operators have worked for months with a kiln, every detail of which was familiar to them, without producing a single successful burn, yet men with no experience whatever have, by study and close attention to details, made the same kilns a decided success. The reason for this is that the men who are usually sent out to start a new kiln follow certain set rules and methods, while the man with only an elementary knowledge allows the kiln to make its own regulations—something it is bound to do in the end if it is to be successfully operated.

Naturally the "standard" rules of procedure must be followed in the beginning and the necessary changes worked out from them as they are found unsuitable. Radical changes should not be made, the better policy being to change gradually.

In dealing with a new kiln it must be borne in mind that it takes from five to seven and, in some cases, even more complete rounds before normal operating conditions are reached. This is due to the large body of masonry which must be thoroly dried out and heated up, together with the drying out and heating up of the ground under the kiln. The bottoms usually give the most trouble on a new kiln and this must be expected. It is far more economical to accept soft brick in the bottom courses for the first few rounds instead of holding up the kiln and using fuel in an attempt to make them hard for, as a rule, not only is the attempt unsuccessful but brick are overburned on the top, and the kiln acts badly because of the impossibility of holding the "backing" heat for a long period.

Slack is generally used on all types of coal-fired continuous kilns and by far the best results can be obtained from its use. It is not the best practice to have the coal too fine, much better results being had when it ranges from dust to almost a nut size. Such coal burns freely and is not so likely to cake at the bottom of the fire shafts.

BEST FUELS RECOMMENDED FOR KILNS

While the claim that a continuous kiln can be operated on very low grade fuels is true, nevertheless, the best and most economical results cannot be gotten from such fuels. The results obtained from slack, which is high in ash and low in volatile matter, are not to be compared with those from a high grade, clean slack and, as a general rule, it does not pay to use the former where the latter is obtainable. A high-grade fuel will not only give greater burning speed, but much less will be used per unit of ware. Thus a decided saving in the cost of burning is shown in nearly every case. Where high-grade ware is burned it is decidedly advantageous to use a fuel low in ash. The draft carries the ash and scatters it over the ware and, if there is a large quantity, much of the ware may be marred or spoiled.

The setting of the ware in a continuous tunnel kiln is, with little question, the most important point in the operation On it depends to a great extent, not only the speed, but the quality of the resulting ware, and the fuel consumption. Many kilns which would have given good results have been condemned as failures thru the ignorance shown in this department.

The setting in this type of kiln differs from all others because the fire and draft moves in the direction of the length of the kiln. In other words, the draft, instead of being up or down, is horizontal.

Being generated, to a great extent, on or near the floor, the heat has a natural tendency to rise to the crown and this tendency can only be overcome by so arranging the setting that freer flow is given near the floor, while at the same time the draft is baffled by tighter setting towards the top. These conditions, coupled with the necessity for providing firing or fuel shafts in the setting, and also the necessity for counteracting the pull of the draft connections on one side of the tunnel, make the setting a difficult and intricate problem. In fact, setting ware in a tunnel kiln is in a class by itself, and requires considerable skill and head work if the best results are to be obtained.

TUNNEL KILN BEST ADAPTED TO CRUDER WARES

The tunnel kiln is really best adapted to burning the commoner grades of ware, in which clear color and flame flash are of little importance. However, it is successfully used

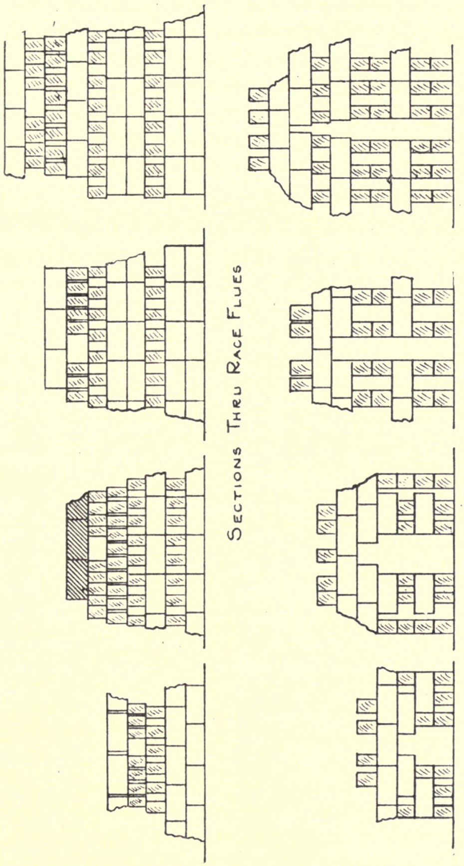


Fig. 72. Method of Setting Race Flues.

for high-grade products. In such cases, special care must be taken to protect the faces or sides to be exposed when in use, from the flame, flying ash and fuel.

Setting plans are usually furnished with a new kiln, and a skilled setter is often furnished to start the work off right, but as every kiln develops its own peculiarities, the standard setting plan is seldom followed, entirely, for any length of time.

THE MANNER OF SETTING RACE FLUES

The race flues or trace holes, as the flues running along the floor and parallel to the length of the kiln are called, are variously set from two to eight brick high and are from four to eight inches wide. Their number is governed by the number of feed holes across the tunnel. No standard size can be laid down for these flues, as they are governed by the amount of ash in the fuel, the draft, the kind of ware being burned, the setting above them, and the general conditions under which the kiln is operated. The low, wide flues are recommended, as they do not complicate the setting as much as the high, narrow ones.

As there is always a tendency for the heat to travel faster in the middle race flues, it is sometimes necessary to have the outside flues higher and sometimes wider than those in the center. In kilns with the tunnel continuing around the ends, it is necessary to vary tne size of these flues, making the one nearest the inner wall the smallest and gradually increasing the size towards the outer wall. This prevents the gases from short-cutting thru the shortest flues as they would do unless forced to take the longer route. Fig. 72 shows various methods of setting race flues.

Soft bottoms, one of the common difficulties of the tunnel kiln, are due in many cases to the size of the race flues. When too large, the cooler air has a tendency to run along the bottom thru these flues, thereby keeping the bottom courses chilled. This difficulty is often overcome by merely reducing the size of these flues. When using coals which are high in ash, care must be taken to provide sufficient height to prevent their becoming choked and thereby preventing sufficient air from reaching the fires ahead.

A GUIDE HELPS IN LOCATING THE FLUES

Unless the setters are skilled in continuous kiln work it is wise to provide a guide for locating the race flues in order to keep them straight. A guide consists of a board of a length equal to the width of the tunnel, with the correct location of the race flues marked upon it. It is quite important that the race flues be kept perfectly straight. Kinks and projecting brick interfere with the draft and make it impossible to standardize the kiln operation.

In determining the best type of fire shaft to use in a kiln, three factors must be taken into consideration: First, the size of the fuel to be used, whether very fine or very coarse slack; second, the quality of the fuel, whether high or low in ash and whether caking or non-caking; third, the kind of ware being burned, whether common and not effected by the flame flash and ash, or high grade and likely to be culled by flashing and ash.

The coarse grades of fuel usually burn faster than the finer grades (unless dust is used), and there is, therefore, less likelihood of their heaping up and caking and thereby choking the draft in the race flues. They also have a tendency to distribute themselves thru the length of the shaft better than the finer grades. For these reasons it is possible to set much simpler fire shafts when course fuels are used. See Fig. 73.

AN ADVANTAGE OF NON-CAKING FUEL

When non-caking fuel is used it is, of course, possible to allow more of it to drop to the bottom of the shaft without getting into difficulties with the draft, but when caking

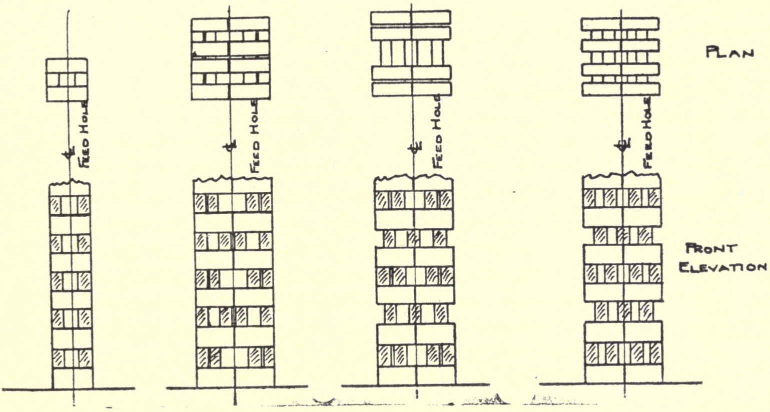


Fig. 73. Method of Setting Firing Shafts.

coal is used, whether fine or coarse, provision must be made to allow it to lodge at various points in the shaft. When fuels high in ash are used, and it is desired to have as few pieces of ware as possible spoiled by the ash, the shaft must be set so that as few lodging places as possible are provided, but at the same time enough so that the race flues will not become blocked up by the accumulation at the bottom.

When high-grade ware is being burned it is desirable to have as little contact between the ware and fuel as possible. This condition requires the fuel to be burned at the bottom. In cases where conditions prohibit such practice, common ware is set around the fire shafts or the ware which is set around the shafts is accepted as common or low-grade.

Combinations of the above conditions, of course, occur quite frequently, so that it is more often than not a case of experimenting until the most suitable method of setting the shafts is found.

Guides for setting the firing shafts are necessary if the best results are to be had. These guides are dropped thru the feed holes in the crown and extend to the floor. They are removed thru the holes when the shaft is completed. Shafts must always be set so that a clear view of the bottom can be had from the feed hole.

The setting of the benches depends to a considerable extent upon the draft used. The movement of the draft in a horizontal direction always has a tendency to overcome the disposition of the heat to rise from the bottom. Therefore, the stronger or higher the draft, the greater will be the concentration of heat near the bottom, and vice versa. This makes it necessary to set the ware tight at the botton and looser towards the top when high draft is used, in order to baffle the drift of the heat along the bottom and force it to the top. In case a low draft is used, the ware should be set looser at the bottom with a gradual tightening as it approaches the crown. There are, of course, many intermediate stages between the high and low extremes, but in each case the result to strive for is a heat balance over the entire cross-section of the tunnel, in order to get perfect heat distribution. Experiment alone will determine the best method for each kiln.

WARE SHOULD ALWAYS BE SET UP TO CROWN

In a tunnel kiln the ware should always be set up to the crown, otherwise much of the heat will travel along over the ware, with consequent loss of burning efficiency. The drop arches take care of this difficulty after the ware settles and for this reason they should be kept in good condition and the brick set tightly against them.

Two things to be constantly borne in mind are, that the heat must be kept ahead in the bottom; and that it does not pay to attempt to crowd the ware in a continuous kiln. Setting too close invariably increases the cost thru the slowing up of the fire travel. On the other hand, if the setting is too open, trouble will result from admission of too much air into the first zone, and thru the premature loss of "backing" heat.

PAPER PARTITIONS SHOULD BE PLACED WITH CARE

The lack of care in applying the paper partitions at the end of each section often results in poor operation. It is quite a difficult matter to put on a good air-tight partition, but it can be done. It is a good plan to train a careful man to do this work and put the responsibility on him. Ordinary flour paste will answer the purpose but it must be kept fairly thick. The paper must be of a kind that will not lose its strength when dampened by the moisture of the water-smoking period. In other words, it is best to use a paper that is as near waterproof as possible, but at the same time one that is not so heavy and stiff as to make it impossible to paste it to the brick.

Rats and mice are frequently numerous around a clay plant and these rodents are often the cause of considerable continuous kiln trouble. This is due to their eating the paper in order to get the flour paste, and in this way causing draft troubles which are hard to locate. Copper sulphate or other poisons should be dissolved in the paste, in such cases, or a cat trained to make its headquarters at the kiln.

Many tunnel kilns are not provided with water-smoking arrangements, the watersmoking being accomplished by drawing the combustion gases thru the last section set, before exhausting them into the draft flue. In such cases scumming trouble is practically a certainty. The combustion gases always contain considerable sulphur trioxide and sulphuric acid, and these, when they come into contact with the moist, cool ware, cause the formation of scum or "whitewash." It is for this reason that so much ware that is burned in this type of kiln is discolored and unsightly.

When the kiln has no special arrangement for water-smoking, the only precaution necessary at this period is to be sure that the temperature of the gases which are admitted into a freshly set section is not too high, or in other words, that the setters are not too close to the fire. With some clays it is possible to admit the gases at temperatures of 200 degrees Fahr. or over, but with others it is not safe to use them when over 100 degrees Fahr. at the beginning. This can be regulated by the number of sections ahead of the fire, as the greater the number of sections the gases travel thru, the cooler they become.

WATERSMOKING SIMPLE WITH SPECIAL FLUES

When watersmoking flues are provided, the operation of watersmoking is quite simple. It consists of connecting the flue to a section behind the fire which has still a temperature of from 200 degrees Fahr. to 500 degrees Fahr., and then making a connection with the section to be watersmoked. The connection with the main draft flue is then opened and the pure hot air is drawn thru the ware. Naturally the paper partitions at each end of the watersmoking section are kept intact until the period is completed. In this way the draft is controlled independently of the sections under fire. In order to control the temperature of the hot air entering the section, provision is made for the admission of cold air into the watersmoking flue in any desired quantity.

As kilns are generally designed so as to provide for an advance of one section per day, it is usual to complete the watersmoking in twenty-four hours. It is seldom *possible* and often difficult in this length of time to get the ware to a temperature much above 200 degrees Fahr. or 225 degrees Fahr. thruout, but whatever the temperature may be when the period is up, the partition nearest the fire is broken and the section thus connected up with the burning section. The watersmoking flue connections are then advanced one section at each end.

SUCCESSFUL WATERSMOKING DEPENDS UPON DESIGN

Successful watersmoking in a tunnel kiln depends very largely on the design. Some kilns are designed in such a way as to make it almost impossible to get the proper distribution of heat in this period. Often too, the construction of the watersmoking flues is so bad that sufficient heat cannot be drawn thru them because of air leaks, and the result is that the section has to be taken into the circuit before the period is complete, with the result that the ware is always "scummed."

The use of wicket fires (temporary fire-boxes built in the wickets) is sometimes resorted to in the watersmoking period. These fires are fed with wood, coke or coal, and are made to carry the section as far along as possible, or to augment the heat from the watersmoking flue.

When connecting up a section that has been watersmoking to the sections under fire, it is best to split the draft for a certain period. Instead of closing the connection between the section behind the watersmoked section and the draft flue, and drawing all of the gases thru the watersmoked section, the draft connections of both sections are partially opened, thus splitting the draft. If the gases in the burning section are very hot, this method reduces the shock to the ware in the new section. As the temperature is raised in this section, however, its draft connection is gradually opened wider while the one in the section behind is gradually closed. This operation is continued until all of the draft is taken thru the new section. With some clays such precautions are unnecessary and in such cases the change may be made abruptly.

PAPER PARTITION SHOULD NOT BURN PREMATURELY

The gases of the burning sections should *never be hot enough to burn the paper partition* of the watersmoking section until after the watersmoking is completed. If such is the case, the kiln is not being operated economically, the waste gases being discharged at too high a temperature. When the setting is held up for any reason, the burning must also be slowed, and if necessary, stopped completely. A continuous kiln loses heat very slowly and firing may be stopped for from two to five weeks and there will still remain enough heat to ignite fuel when operations recommence.

There is always considerable discussion as to the number of sections of a kiln that should be kept under fire, and as to the number of sections the draft should be pulled thru before being exhausted. It is small wonder that no agreement can be reached on these questions, and small wonder also that one who attempts to give advice on the subject can seldom be of very much service. As has been said before, it is seldom that two kilns are found that work alike, and when the difference in construction, clays, ware, setting, size of fans or stacks, condition of the kilns, and operators are considered, it is not to be expected. It is possible, therefore, to cover the subject of burning in a general way only, taking a sort of average of general existing conditions.

NUMBER OF SECTIONS TO KEEP UNDER FIRE

Fuel should be fed to from three to five sections. The high fire section naturally consumes the greatest quantity, and as a rule, light charges should be fed every ten to twenty minutes. The feed holes ahead and behind the high fire are fed lighter charges and at wider intervals, according to their distance from the high fire and according to the speed with which the fuel is consumed, and the sort of clay used. Usually a section is under high fire until the finishing heat is reached, top and bottom, and then a soaking heat is maintained for a certain period until the ware is finished. During this period the finishing heat is advanced. The whole operation, of course, is a continuous one, the peak of the temperature curve slowly advancing all the time.

As the fire advances, fuel is fed to fresh rows of feed holes, but this should never be done until a red heat shows in the bottom, and fuel should only be fed at such times and in such quantities as can be entirely consumed. Premature firing or feeding in too large quantities will result in an accumulation of fuel in the race flues, with consequent checking of the draft, and the possibility of too much local heat when the accumulated fuel does ignite. It is always best to defer feeding fresh feed holes until a red heat is visible, at the bottom, in daylight.

THE IMPORTANT MATTER OF "BACKING" HEAT

It is sometimes necessary to feed fuel to several rows of feed holes behind those which are at finishing heat, in order to maintain what is known as the "backing." A continuous kiln, in order to work efficiently, must have preheated air for combustion. This preheated air is furnished by passing the air required for combustion thru the ware that has been burned. In this way, not only is a large percentage of the heat recovered and reused, but the air reaches the high fire section at a temperature only a little below the temperature required to finish. It is for this reason principally, that a continuous kiln uses only from twenty-five to thirty-five per cent. of the fuel required on a periodic kiln.

The amount of fuel required to maintain the proper "backing" depends largely upon how close to the fire the unloaders work. If they are very close, thru a desire to rush ware out of the kiln, a larger number of rows will have to be kept under fire than if a good distance is kept. Of course, there is a limit. The result of working too close is that the cold air rushes along the floor thru the race flues and makes it almost impossible to get the bottom in the high fire section up to the finishing point, thus checking the advance. When the proper number of sections are kept behind the fire it is often possible to stop feeding fuel as soon as the ware has received the proper amount of "soaking," there being no necessity for maintaining a "backing" fire on account of the amount of hot ware thru which the air must pass.

Wicket fires are used in some kilns to assist the top firing in the high temperature zones. Not only do they increase the burning speed to some extent, but they insure a well burned wicket, a point usually hard to finish properly in the average continuous kiln. Wicket fires are usually started in the section ahead of the one showing red heat in the bottom. The fires are started slowly and gradually brought up as the ware will stand it. They are maintained until after the section has passed the finishing point, when the grates are withdrawn and the opening bricked up.

ECONOMY OF WICKET FIRES QUESTIONED

There is considerable question as to the economy of wicket fires, in spite of the aid they give locally to the ware in the wicket, and the section in general. As is the case with up and down-draft kilns, a considerable excess of air is certain to pass over the fires. The air is not preheated, as is the case with the air fed to the inside fires, and consequently, there is a loss in efficiency. Consideration must also be given to the ware damaged by contact with the flame and ash of these fires, there being no bag wall to protect it. Added to this is the cost of constructing these wicket fireboxes and cleaning up the ash and spoiled ware after them. These last two items are rather surprising when put down on a cost sheet.

DRAFT

It is practically impossible to designate the number of sections thru which the draft should be pulled to get the best results. Kilns equipped with stacks are definitely limited because the stack can only pull thru a certain number of sections and maintain any kind of speed. In this case experiments must be carried on to determine the maximum number for best results, and the standard thus determined upon, should be maintained. When fans are used, the size of the fan is one of the determining factors. Often fan units are far too small for obtaining the best results, but in such cases it is not so difficult to rectify matters as is the case where an undersized stack has been built. An oversize fan is a splendid investment, for it is an easy matter to cut the draft when it is too high.

The question of draft in continuous kiln operation is one of the greatest importance. The speed of the kiln is dependent to a large extent upon it. There is a surprising difference in the rate of advance of kilns of the same type and size which are burning practically the same class of ware. This advance ranges all the way from 100 to 250 feet per week. Some of this difference is due to the material, but most of it to methods of operation.

It will be plain to anyone that fire will travel at a greater rate thru a tunnel under a high draft than under a low one. It will be just as plain that fire will travel faster thru loose setting than thru tight setting, and that the gases can be pulled thru the former at a higher velocity than thru the latter.

However, there is a definite limit to the velocity that may be given to the gases in a kiln by the fan or stack. Kiln operators have all noticed that at a certain point, slightly in advance of the row of feed holes receiving the finishing heat, there seems to be no draft. When the caps are lifted over this point there seems to be neither suction nor pressure, while ahead there is suction, and behind, over the high fire, there is pressure or "kick." Some operators have also noticed that the best results can be obtained from the kiln when this point of "no draft" is kept at a certain determined distance ahead of the feed holes receiving the finishing heat. If the draft is increased or decreased, this point will move from its proper place almost immediately the rate of progress seems to be arrested.

William A. Butler, a ceramic engineer, who has given some good advice to continuous kiln operators, called attention to this point of "no draft," several years ago. He had found by experimenting that if air was forced by means of a fan, thru the cooling ware behind the fires, the draft could be increased and the point of "no draft" still maintained in its proper position. Such a condition allowed of a greater fuel consumption together with a more rapid advance of the fires. There is not the slightest question about the soundness of this idea. The draft unit is constantly attempting to create a vacuum in the kiln, while nature is attempting to fill this vacuum by supplying air from behind. Unless some mechanical assistance is given to this flow of air in order to push it to its destination (the fires) in larger quantities, the kiln speed will be governed by the speed with which the air can naturally work its way thru the closely set ware.

NOT HARD TO DETERMINE POINT OF "NO DRAFT"

Many operators pay little attention to this important point of "no draft," with the result that it wanders over a considerable area. Close observation for a few rounds of the kiln will determine its proper location (which will vary in each kiln), and when it is once found it should be maintained. Draft gauges are a valuable aid to the burner, but when not provided, he can soon learn to control the draft to a great extent by noting with his hand the distance above the feed holes, in the finishing zone, to which the hot air is forced.

After the finishing heat has been reached in a section it is the general rule to maintain the fires for a sufficient time to give the ware a "soaking." This "soaking" fire is usually maintained over an entire section at least, the fuel being fed in such quantities and at such intervals as will maintain a fairly constant temperature. The heat generated in this section not only improves the ware, but it furnishes "backing" for the high fire section by increasing the temperature of the air of combustion. There is no waste of fuel in this practice because the amount used on the fires ahead is decreased in proportion.

UNLOADERS SHOULD NOT BE TOO NEAR FIRE

Every effort should be made to keep a red heat in at least three sections behind the finishing fire. This is not difficult if the unloading section is kept far enough behind the fire. Opening sections too close to the fire greatly decreases the efficiency of the kiln and results in numerous troubles. Sometimes the ware is cooled too rapidly, resulting in cracked, checked, or brittle products.

No rule can be made regarding the number of sections to be carried in a circuit, but roughly it should be as many as can be handled and still get the proper draft. It is useless to connect more sections than the fan or stack can handle properly, for under such conditions the capacity is bound to be reduced.

After all, the continuous kiln is a very simple proposition. It is the clayworker himself who makes it otherwise. It is quite safe to say that a well designed continuous kiln is far simpler to operate than a battery of down-draft kilns, and requires a far smaller knowledge of the scientific side of ceramics. The greatest surprise most successful continuous kiln operators have had, is the discovery, after a more or less lengthy period of disappointment and dissatisfaction, that about all that is necessary to make their kilns work properly, is an ordinary amount of common-sense and good judgment.

CHAPTER XV

Operating a Gas-Fired Chamber Kiln

TO THE UNINITIATED, who have merely observed a producer-gas-fired continuous kiln during operation, it seems to be the most simple and easily operated kiln in existence. There can be little doubt but that such is the case when once the operator grasps the basic principles of operation and gets thoroly acquainted with his kiln. Until a certain degree of experience has been reached, however, especially in regard to the handling of the draft, the number of chambers to carry in the circuit and the manufacture of efficient producer gas, the operator is very likely to come to the conclusion that instead of being the easiest, it is the most difficult of all kilns to handle. The fact is, it is practically impossible for green, untrained men to take hold of this kiln and make a success of it. After being taught the elementary principles, however, any man who will use his brains can become a successful operator. The gas kiln is really the most scientific of all kilns in its operation and, this being the case, it can be brought to a point where its handling becomes almost automatic. This fact often leads an operator into careless ways with the result that a few poor chambers will follow a string of good ones.

There is no question but that the gas-fired kiln has a poor reputation in some parts of the country, even to the extent of being looked upon as a failure. There are many reasons for this, but none of them have to do with the principle of using producer gas in connection with a continuous kiln.

EARLY TROUBLE DUE TO LACK OF KNOWLEDGE

Producer-gas-fired continuous kilns have been in use in this country only a comparatively short time. The first of these were decidedly experimental and naturally the results were not at all satisfactory to the clayworker. Much of the trouble was due to a lack of knowledge concerning the proper methods of construction, the lack of trained operators and a very great deal to the old type of suction producers.

With the increased knowledge that has come in the past few years, the constructional faults are being rapidly overcome, trained operators are now available and the newer types of gas producers have made it possible to produce a high grade, efficient gas.

As in the case of the coal-fired continuous kiln there are certain "standard" burning rules which must be used as a basis for starting a new kiln, but as each kiln develops its own peculiarities these rules must be changed to meet the conditions.

Gas kilns probably take longer to get into normal working order than do other types, altho this is not a general rule. Besides the heating up of the masonry and ground under the kiln, which takes several rounds, there is the necessity of training men for the work on the producers. The difficulty involved in accomplishing this latter end depends to a large extent on the fuel used and the intelligence of the men.

GAS MANUFACTURE

The success of the gas kiln depends largely upon the operation of the producers. The pressure producer is not ordinarily difficult to handle, but this depends largely on the kind of coal available.

Unless the producers are especially designed for the use of slack, this type of fuel cannot be used. Nut, run-of-mine and lump coal are satisfactory, the nut giving the best results when it can be obtained. When run-of-mine or lump are used the large lumps must be broken up, while run-of-mine containing much slack must be avoided.

The principal requirements of a coal for producer work are that it be high in volatile matter and low in ash and sulphur, which means that it should be non-clinkering. To be high in volatile matter, however, is not enough. Many coals have a fairly high volatility but give it off with a rush, thus flooding the kiln with gas for a few minutes, following which the supply is poor. The ideal coal is one that gives off its volatile matter slowly, keeping up a steady supply from this source while the CO is coming from the fixed carbon. Coals high in fixed carbon and low in volatility can be used successfully, but such coals are consumed slowly or, in other words, give off their gas slowly. The result is that greater producer capacity is required in order to keep up the gas supply.

Clinker is the greatest enemy of gas producers and, if there is any possibility whatever of avoiding a clinkering coal, it should be done. If it is not possible to avoid its use, success can only be had with producers designed by experts expressly for the fuel in hand.

DETERMINING TYPE OF COAL TO USE

There are a great number of ideal producer coals in different parts of the country and experiments should be made until the best one has been located. The analysis of a coal will tell very little about its adaptability, but it will, of course, give an idea as to whether it is worth trying or not. Experiments have shown conclusively that with two coals having very nearly the same analysis, one will be almost twice as efficient as the other. One of the very safest plans to follow when looking for a good producer coal is to consult the manager of the nearest domestic gas plant. Such a plant uses the highest grades of gas coal, as a general rule, and information as to its source of supply will be valuable. Usually, it will be a good investment to pay from twenty-five to thirty-five per cent. more than the local market price in order to obtain a high-grade coal, as the difference is easily saved in the added efficiency of the gas and the lowered cost of the labor required to handle the producers.

Special producers are designed for use with peat, lignite, anthracite and low-grade bituminous coals. In fact, any sort of fuel can be used in a gas producer, providing the latter is of the proper design.

RATE AT WHICH PRODUCER SHOULD BE FED

The rate of feeding coal into the producer depends upon its size or capacity, and the fuel. A six-foot producer working under easy conditions with a good coal will consume from 160 to 200 pounds per hour. There is a certain height in each producer at which the top of the fuel bed should be kept. This is usually slightly below the outlet flue. Naturally, fuel cannot be fed faster than it is consumed or it will rise above its proper level, which is the gauge that regulates the rate of feeding.

Pokering is a very important part of producer operation. This consists of dropping a long poker thru the poke holes in the top of the producer and practically "stirring" the fuel bed. The pokers should reach to the grates and the pokering should be done in such a way as to affect the entire bed from top to bottom. The idea is to break up any clinker over the grate that may prevent the proper distribution of the air blast and to loosen up the fuel so that the air distributes itself thru it evenly, thus preventing the formation of holes or channels thru it. The amount of pokering necessary depends entirely upon the kind of fuel used. Sometimes it must be done every hour. At other times, every three or four hours is sufficient. The producer man should constantly watch the surface of the fuel bed for "holes" or bright spots which show that the air is "channeling" and, when one is noted, the poker should be used at once to fill it up.

PRESSURE AT BLOWER SHOULD BE SIXTY POUNDS

The steam pressure at the blower should be kept at sixty pounds when the producer is operating normally. It is quite important that the pressure be kept constant under ordinary conditions and that it be not allowed to fluctuate with the boiler pressure. The only safe method of handling this problem is to install a regulating valve in the steam line between the boiler and the blowers. This will insure constant pressure.

The air blast from the blower should indicate from 1½ to 2 inches of water on a U-tube for best results, altho when an increased volume of gas is required it is necessary to run it higher.

The gas pressure in the producer necks should register about ¾-inch on the U-tube. Maintaining a much greater pressure than this is likely to result in the gas forcing its way out of the gas flues at every crack on its way from producers to kiln. When this pressure drops close to the zero mark a dangerous condition exists, especially if the gas is hot. Good producer gas is highly explosive when at certain temperatures and when mixed with air. As long as a pressure is kept on the gas, no air can be drawn into the flues. But when there is no pressure and the kiln is creating a suction, air may be drawn into the flues, and if the conditions are right, a serious explosion will result. Several kilns have been badly damaged thru explosions caused by such conditions.

GAS TEMPERATURE EXCEEDINGLY IMPORTANT

The temperature of the gas as it leaves the producers is most important. One of the greatest troubles producer gas users have had in the past is due to the fact that the gas "cracks" at certain temperatures and rapidly deposits either soot or tar in the gas conveyors or flues. This soot and tar chokes the flues and shuts off the supply at the burners, thus necessitating frequent "burn-outs," as the process of lighting up and burning out the deposit is called. The time consumed by these "burn-outs" is a dead loss, since the kiln has to be shut down during that period, which covers from twelve to twenty-four hours.

The conditions under which gas "cracks" are fairly definitely known and there is really no good reason why there should be so much trouble from this source. Of course, producers are designed which overcome the trouble, or scrubbers could be installed for the same purpose but, as only the simple forms of producer are used on clay plants, and since scrubbers are expensive and unnecessary, the only method left to the clayworker is temperature control.

Producer gas made in the type of producer generally used will deposit tar at temperatures below 800 degrees Fahr. and will deposit soot at temperatures above 900 degrees Fahr. These temperatures refer to the gas as it leaves the producers.

It will be seen that there is a neutral zone between 800 degrees and 900 degrees Fahr. and, when the gas is kept within this zone, the minimum amount of tar and soot will be deposited.

EVERY COAL HAS NO-DEPOSIT TEMPERATURE

Experiments made by the author seem to show that each coal has a definite temperature at which there is practically no deposit, altho all the coals experimented with remained within the above mentioned range. By closely watching pyrometers installed in the gas necks it has been possible to operate a kiln for fifty-nine days before being troubled with choked flues; and by the simple method of keeping the gas at the proper color, it was possible to run without interruption for from thirty to forty days. When it is taken into consideration that the average gas kiln requires burning out every seven to ten days it will be seen how important it is to watch the gas temperature.

It is much better to keep the gas too cool than too hot. Tar is troublesome at the valves, but it takes up very little space in the flues and accumulates slowly. On the other hand, soot accumulates very rapidly and soon causes trouble. It should also be borne in mind that a high producer temperature means a reduction in the quantity of gas, for it is the burning of the gas, or the ingredients which make up the gas, that produces the high temperature.

When the gas temperature is between 800 and 900 degrees Fahr. the gas has a rich yellow color, tinged with light green, and if it is held at this color it cannot be far from its most efficient state. Hot gas is nearly colorless except that some smoke is seen in it. When it is very hot, it appears as nearly all smoke. Such gas is almost worthless except for its sensible heat.

When gas is at its best it will not ignite at the poke holes when a match is applied to it. As the temperature increases however, it will ignite readily and will finally reach a stage where it will issue as flame instead of gas.

HOW TO CLEAN A PRODUCER

There are various methods of cleaning the producers. On some plants the clinker is removed each day; on others, only once each week. A great deal depends upon the amount of clinker or ash the coal produces, but in any case it is quite unnecessary to clean as often as every day. Cleaning, especially in hot weather, is a nasty job and as much of it as possible should be avoided. In some cases all of the clinker is pulled out from beneath the producers thru the water pans, but it is far easier and quicker to remove all possible thru the clean-out doors and then with a bar punch the remaining clinker to the bottom where it is then pulled out thru the pans. Two rows of sight holes are provided on most producers. Sufficient clinker should be removed so that the fire may be seen thru the lower row and, when the clinker bed grows sufficiently thick to cover the upper row, it is time to clean again.

When producers are started it is best to dump in enough ashes to cover the grates. A wood fire is then started and coal fed as rapidly as it will ignite, until the proper fuel bed level is reached. The blowers are then started and run for a few hours until the gas begins to have the proper appearance. During this time the products of combustion are let out thru the clean-out doors in the gas necks.

When feeding gas to a kiln which is just being started it is always best to have the gas quite hot, that is, from

1,100 to 1,200 degrees Fahr. Such gas will ignite readily, while cool, rich gas may cause an explosion, with serious consequences. It is never safe to attempt to light gas in a continuous kiln chamber unless red heat can be plainly seen. This can be done by one who has become expert in the handling of gas, but even under such circumstances, kilns have been badly damaged by explosions, the cause of which were unknown.

METHOD TO FOLLOW IN BURNING OUT FLUES

Burning out the deposit in the flues is a comparatively simple matter. The kilns of latest design are equipped with flues which connect the fan with the gas flues. The older kilns have stacks, called "burn-out" stacks, which provide draft for the same purpose. When the stacks are used the process is a slow one, consuming considerable time. When the flues can be connected with the fan, the soot and tar are consumed very quickly. To start the deposit burning it is only necessary to open the wicket in the main gas flue near the producers and start the draft. The temperature in the flues is sufficient to ignite the soot and tar. In order to burn out the distributing flues, the gas valves on the chambers that are still red are opened slightly as is also one or two of the gas ports. This pulls the heat from the chambers thru the distributing flues and burns the deposit. Care must be taken not to let the temperature in these flues become too high or the iron gas valves will be damaged. Simply closing the main gas valve stops the fire in these flues. If they are not burned clean at the first attempt, they should be allowed to cool somewhat and the operation then repeated. Of course, only those distributing flues on chambers which are at red heat can be burned out in this way, but as a different set of chambers are in this condition at each burn-out period, they all receive attention in time. The distributing flues do not accumulate much of a deposit as they are in use for only a short period at a time, and at that time are at a fairly high temperature on account of their proximity to the heated chambers on each side.

It is very easy to determine when the flues have been burned clean. While the deposit is burning a thick smoke issues from the fan stack. When this ceases the flues can be assumed to be clean.

SETTING

There is nothing complicated about the setting in a chamber kiln as each chamber is exactly like a rectangular down-draft. Any method of setting which is used in a down-draft kiln can be followed successfully. This applies to brick, hollow-ware or other ware. In the one side fire type there is sometimes a tendency on the part of the gas to pull to the side of the chamber opposite the flash wall, but more often the tendency is to short cut to the floor close to the flash wall. In the former case it is necessary to tighten the setting against the partition wall and open it somewhat toward the flash wall, while in the latter case the method is reversed and the setting made tight against the flash wall.

In most gas kilns it has been found best to allow plenty of room between setting and crown if speed is desired. Experiments will have to be made with each kiln to find out at what height the greatest kiln speed can be attained. Experiments carried on by the author seem to show that after passing a certain height it becomes difficult to reach the bottoms which, of course, slows the kiln on account of the extra time consumed in getting the bottom ware to the finishing point. On the other hand, it was found that to set below a certain level did not increase the kiln speed at all, taking about the same amount of time to finish the chamber properly. Naturally, the material used and the ware produced has a great deal to do with the results. When the raw material has a very wide burning range and there can be a wide difference between the temperature, top and bottom, without injury to the top, the ware can be set higher without decreasing the speed. Also when fairly soft ware can be disposed of, there is not the necessity of spending so much time in getting the bottom to somewhere near the same temperature as the tops.

WATERSMOKING

Chamber kilns are equipped with watersmoking flues and, on account of their down-draft design, watersmoking can be efficiently done. The chamber from which the heated air is to be drawn should be selected, not on account of its location behind the fire, but on account of its temperature. Generally, the connection to the watersmoking flue is made with the chamber ahead of the last one broken into. The heat from this is drawn into the chamber to be watersmoked until the temperature of the latter is as high as it is possible to get it. The connection with the warm chamber is then broken and advanced to the chamber ahead, the temperature of which, of course, is higher. The heat from this chamber brings the temperature of the watersmoker still higher and, as a rule, is sufficient to finish this period. This practice is hardly necessary except in cases of clays which scum

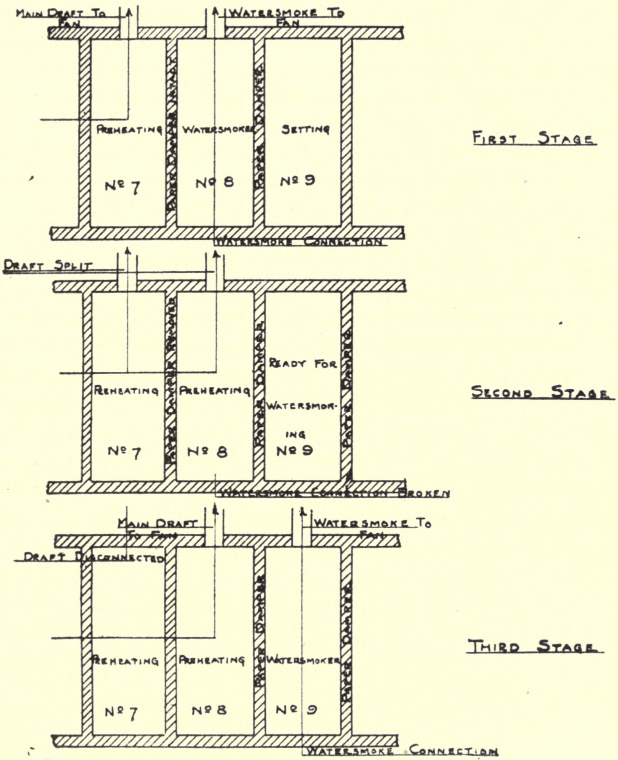


Fig. 74. Diagram Showing Method of Advancing the Heat.

easily. When efflorescence is not feared it is the usual practice to get what heat is possible from one chamber and then connect the watersmoker to the main burning circuit.

The watersmoker is isolated by means of paper partitions over its own bag wall openings and those of the chamber ahead, which is being set. Great care should be taken to have these partitions properly pasted on or draft troubles are sure to occur. When all of the connections are made with the watersmoking flue, the connection between the chamber to be watersmoked and main draft flue is made. This does not in any way interfere with the draft or operation of the burning section. The watersmoker is as independent as if it were a single down-draft kiln.

When the watersmoking is completed a hook is inserted thru the sight holes at each end of the chamber and the paper partitions torn. The draft is then "split," part of it being taken thru the watersmoker and part thru the chamber behind. This is accomplished by allowing both connections with the main draft flue to remain and partially closing the dampers on each one. The effect of this is to reduce the shock of the hot gases from the burning section on the watersmoked ware. As the temperature in the new unit increases, its damper is opened wider while the one behind is closed to the same extent. This is carried on until all of the draft is being taken thru the new unit, at which time the connection with the chamber behind is broken. This process of connecting up a new unit will take from four to twelve hours according to the raw material. Fig. 74 shows a diagram of this process.

It is only necessary to tear the paper partitions at each end of a chamber as the draft will then tear off the balance at once.

Starting a gas kiln is not a difficult matter. As soon as two or three chambers of ware have been set, about half of the floor openings in the chamber directly behind should be covered with brick. The wickets of this chamber should then be put up and mudded over. In the chamber behind this empty chamber, or the second behind the first chamber set, a few of the floor tile should be taken up so that fires may be started directly beneath the bags of the chamber ahead. Fires are then started beneath these bags with wood and coal, preferably slack. Connection is then made between the main draft flue and the last chamber set as shown in Fig. 75.

The fires are kept up until the bag-walls of the empty chamber and the crown just above are at a red heat, when the gas is turned into it. Burning gas in the empty chamber soon brings the walls and floor to a red heat and naturally very soon heats up the bag-walls of the chamber ahead, which is full of ware.

Considerable care is necessary during this period. The air control for the gas burning in the empty chamber, and later, in the chambers ahead, is thru the coal fires which are still kept burning in the under-flues. If these fires are allowed to get too low or are kept too open so that too much cold air is admitted to the gas, the flame will go out and the conditions may be right for an explosion. It is very easy to tell by the appearance of the gas when conditions are not right. It will burn brightly when the air control is right and become dark and smoky when it is wrong. It should be remembered too, that these coal fires must furnish the preheated air necessary for proper combustion until several chambers of ware have been finished. To let the fires out after the first chamber had been finished would mean that this chamber would lose its heat at once and this would prevent the proper finishing of the next chamber of ware. It is the best practice to wait until the fourth full chamber is ready to light before allowing the coal fires to die out.

The principal reasons for having an empty chamber between the coal fires and the first full chamber are, that the heat becomes somewhat tempered in passing thru the empty chamber and, therefore, does not shock the ware, and that it is much easier to keep the gas lit in the empty chamber than it would be in a full chamber, on account of the bulk of ware it is necessary to heat up before a dull red color is reached around the bags.

BURNING

As a rule gas is kept only on the high fire chamber, altho sometimes it is lit in the one ahead of the high fire chamber before the latter is finished. Very seldom is the gas kept on a chamber after it is finished for, in a properly operated kiln, it is absolutely unnecessary.

The conditions in a chamber when it is ready for the gas vary, of course, with the raw material, kind of ware and the kiln operation. When a chamber finishes at around 2,000 degrees Fahr. the chamber ahead will have a temperature of from 1,100 to 1,500 degrees Fahr. It is only necessary to open the valve connecting the main gas flue with the distributing flue and then the valves in the "down takes" leading to the gas ports. As soon as these valves are opened the gas ignites and the chamber is under fire. The main valve on the finished chamber is then closed.

In the gas kiln the center of the chamber has a great tendency to get ahead of the ends. It is possible to correct this by cutting down the gas supply at the middle ports, but this naturally slows up the burning. The best method of overcoming this difficulty and, at the same time maintaining or even increasing the burning speed, is to light up the two ports in each end of the chamber several hours before the high fire chamber is finished. This gives the ends a start over the center which will not be more than equalized until the chamber is about finished, even with the center ports going at top pressure.

"LEAD AHEAD" GAS TO INCREASE CAPACITY

When the kiln cannot be kept up to the capacity of the factory with only a single chamber on fire at a time, as is sometimes the case, the gas is often "led ahead." In this case the gas is lit in the chamber ahead of the high fire chamber, from six to twelve hours before the latter is finished. In other words, gas is kept on two chambers. In this way the chamber ahead of the high fire not only gets the waste heat from the high fire chamber, but also the heat from its own fires. In this way the burning speed can be materially increased. Of course, this can only be done when there is sufficient producer capacity to supply both chambers.

Perfect control can be had in a gas kiln thru the proper handling of the valves. There is not the slightest excuse for a fluctuation in the temperature of a chamber from one end to the other. The sight holes above the bags at each end of the chambers provide a means of detecting any variations in temperature almost instantly and the manipulation of the valve cords provides easy correction.

It is always necessary for the operator to give unceasing attention to the valves. Tar and soot are constantly accumulating between the valves and their seats, and the gas flow is thus diminished. This is especially true when the valves are only "cracked," as the slight opening is easily choked up. Sometimes only one or two of the valves "tar up" and the gas that cannot flow thru them is forced thru the other valves. This will cause local hot and cool spots in front of the affected ports. When valves choke it is only necessary to shake them slightly by pulling the cords to clear them.

NINE CHAMBERS FAIR AVERAGE TO CARRY

The number of chambers to be carried in a circuit varies with the size of the fan unit, the setting and the condition of the kiln. A fair average would be nine chambers. One of these would be on high fire, three ahead would be preheating with the waste gases from the fire, while the fourth ahead would be watersmoking. Three chambers behind the fire would be preheating the air for combustion, and the fourth behind would be supplying hot air for the chamber being watersmoked. The fifth behind the fire would be opened so as to admit the air to be preheated for combustion. The above might be varied by increasing the number of chambers ahead of and behind the fires, but it would be bad practice to carry less than three ahead and three behind, exclusive of the watersmoker and the chamber supplying the watersmoker with heat. See Fig. 76.

To a great extent the number of chambers ahead of the high fire should be regulated by the temperature of the waste gases as they are exhausted to the draft flue. On some kilns that are giving splendid results the temperature of the exhaust gases is seldom allowed to get above 80 or 100 degrees Fahr.

THE QUESTION OF DRAFT

It is extremely hard to say just how much draft should be carried on a gas kiln. Each kiln will vary somewhat according to the construction. Some kilns are so poorly built that it is impossible to get sufficient draft to insure a high burning speed, on account of the great number of air leaks between the fan and the fire. Up to a certain point the higher the draft used the greater the burning speed will be.

Under normal conditions a kiln which finishes a chamber every twenty-four to thirty-six hours should have one and one-half inches of draft on the chamber ahead of the high fire chamber, and two inches on the second chamber ahead of the high fire. These draft readings refer to conditions just after a fresh chamber has been lighted up. Normally, the draft will show a reduction of approximately one-half inch between the time a chamber is lighted up and finished. This means that on the chamber which has a two-inch reading when a fresh chamber is lighted, the reading will be one and one-half inches when the chamber is finished.

It is generally impossible to run around a big kiln with a "set" draft reading, as the amount of draft necessary is bound to vary in different chambers for several reasons, principally constructional. An expert burner, in addition to using his draft gauges, is governed by the sharpness of the flame as it leaves the ports. Under high draft the flame cuts sharply away from the ports, while under low draft it rolls slowly under the crown. A record should be kept on each chamber and, as soon as the best draft has been determined, it should be adhered to as closely as possible when that particular chamber is reached in the circuit.

FLASHED WARE EASILY OBTAINED IN GAS KILN

In ordinary burning the gas kiln will always produce oxidizing conditions, but reducing conditions can be easily obtained. It is extremely simple to get flashed ware if such is wanted, altho this result will not occur accidentally. However, as is the case with all continuous kilns, it is very

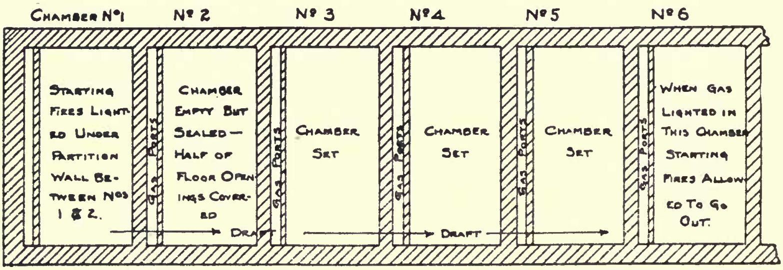


Fig. 75. Diagram Showing Method of Starting Gas Kiln.

hard to get any quantity of blacks or very dark colors. This is due to the fact that, while these colors can be easily given to the ware when it is under fire, as soon as it is off fire the ware is reoxidized by passing over it the air necessary for combustion in the chambers ahead. Under the continuous system it is impossible to avoid this. Some clays do not easily lose the flash and, of course, in such cases, the dark colors are obtainable. Ordinarily, the colors predominating where flashed ware is made, are browns, purples, dark reds and combination of these colors.

The method of flashing is extremely simple. When the finishing point of the ware is approached, the draft is cut very low. This causes the gas to smoke and the chamber is quickly filled. The chamber is allowed to remain in this condition for from fifteen to forty-five minutes and the draft is then raised and the chamber cleaned of smoke. The smoking is repeated with intervals of fifteen to thirty minutes and continued until the required colors are gotten from top to bottom. Some experimenting is necessary to determine just how long it is necessary to continue the smoking periods. Some clays take the required color in one period of forty-five minutes while others require the process to be kept up for ten or twelve hours.

Care must be taken during the reducing periods or the top

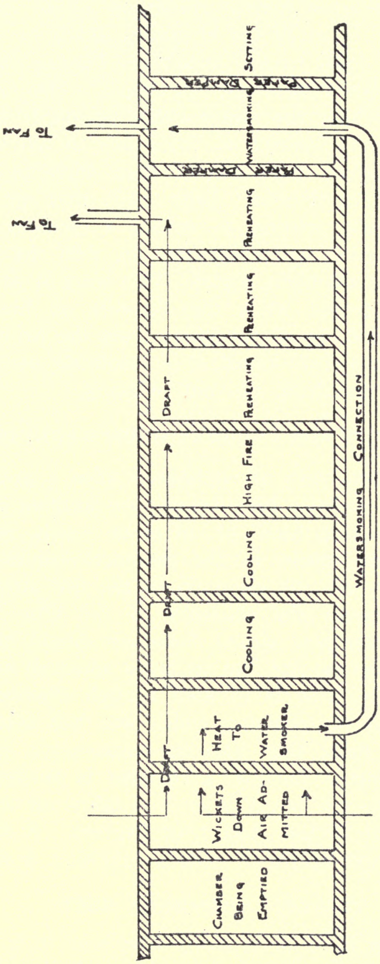


Fig. 76. Diagram Showing Burning Circuit of Gas Kiln.

course will get too hot and be deformed or melted. It is for this reason that the chamber is cleared occasionally. The draft being increased carries the heat from the top to the bottom and evens up the temperature of the chamber preparatory to another reducing period.

It must be remembered, when attempting to get flashed ware, that the conditions in a gas kiln differ from those occurring in other types. In order to get the chambers off quickly and preserve normal conditions ahead and behind, it is necessary to carry the chambers along to almost the finishing point under normal conditions, leaving the reducing periods to a few hours near the finish. Also, it must be borne in mind that the entire firing period is only about twenty-four hours instead of from five to ten days as is the case in a down-draft kiln or from three to four days in a coal-fired continuous. With clays that are likely to "black core," any attempt to reduce a chamber over the entire firing period will cause trouble, thru the effects on the ware in the chambers ahead. This ware is passing thru the oxidation period while the chamber on fire is being "brought up" and, as all the gases from the firing chamber pass thru the chambers ahead, it is absolutely necessary that these gases be oxidizing and not reducing.

SUCCESS DEPENDS LARGELY UPON BACKING HEAT

As in all other types of continuous kilns a great deal of the success of the gas kiln depends on keeping the proper amount of "backing heat" or, in other words, maintaining the proper temperature in the chambers behind the fire. Emptying chambers too close up to the fire always causes trouble and lowers the efficiency of the kiln. Generally speaking, *at least four closed chambers* should be kept behind the chamber on fire, the air being admitted at the fifth. Another working rule is to keep enough chambers behind the fire so that the chamber which was last taken off fire does not lose more than half its temperature in the first twenty-four hours. Thus, if a chamber is finished at 2,000 degrees, twenty-four hours after it is taken off its temperature should not be less than 1,000 degrees. A kiln should always give good results if such a condition is maintained

FIFTEEN CHAMBERS BEST

The question as to how many chambers it is absolutely necessary to have in order to get good results is an important one. Some kilns have been condemned as failures when the trouble was entirely due to the fact that there were too few chambers to maintain continuous operations. When a chamber holds a day's run and can be burned off in twenty-four hours the kilns should not have less than thirteen chambers. This allows for ten in the burning circuit, one setting and two being emptied. Such a kiln allows practically no leeway and, to be operated without interfering with the factory, it must run like clockwork. Sundays, holidays and factory delays would have to be taken full advantage of in operating such a kiln.

It is really best to provide at least fifteen chambers for good working conditions and to guard against emergencies.

CHAPTER XVI

Suggestions on Plant Location and Design

IT WOULD BE IMPOSSIBLE in a single chapter or even several chapters, to attempt to cover the subject thoroly of locating and designing a clay products plant. Each proposed plant should be handled as a separate engineering problem as conditions will vary greatly according to the ware to be made, the raw material used and the plant location.

This chapter will therefore treat only with the general principles governing the designing of all plants no matter what the type of ware produced.

It is presumed that in selecting a plant site the proper amount of consideration has been given to such important items as drainage, water supply, railroads, markets and freight rates.

Speaking of the industry at large, there are too many instances of lack of consideration on the future of the plant. This is often shown in purchasing the plant site proper. Only sufficient land or suitable land is acquired to build the original unit and consequently when the time for expansion arrives the company is in a quandary.

Every successful plant will grow and in acquiring a site, provision should be made for this growth. Land in the vicinity of a plant seldom depreciates and generally enhances in value so that even if too much is bought originally it can later be disposed of at a profit, if necessary.

WARE TO BE PRODUCED

This subject is generally given very early consideration, in fact, the product to be made is often decided upon before the deposit is located. There are two ways of approaching this subject—one to determine first the ware to be made and then to seek a suitable deposit of raw material and the other to determine by thoro tests what types of ware can be produced from the deposit after it is located.

Too often this most important item is approached in the wrong way. Either the product is determined upon without consideration being given to the raw material available or the raw material is determined upon without due consideration being given to the product it is intended to manufacture. Many plants have commenced operations before it has been discovered that the deposit is not suitable and in very many cases it has been the death knell of the plant, so far as its original owners were concerned at least.

CAPACITY OR OUTPUT

The original capacity of a plant is usually governed by the dryers or kilns. In considering the question of capacity of a new plant it is by far the wisest plan to figure under rather than over. If more ware can be produced than can be disposed of, part of the investment must stand idle, whereas, if the reverse is true it is always easy to make additions. Most plants, as originally designed, are poorly balanced, one or the other of the departments being unable to produce what the others can take care of.

Great care should be exercised in working out and balancing the various departments, this being especially true of the dryer and kiln departments.

Machine equipment whose capacity is considerably in excess of that required is not generally economical to operate. It is not good practice to put in a brick machine having 100,000 capacity per day if only 50,000 are to be made, with the idea of future development. It is far more sensible to put in a 60,000 capacity machine and when the increased demand comes install an additional unit. The large unit will produce the best product when operating at its normal capacity and would therefore produce the 50,000 required in half a day, leaving a problem of disposing of its crew for the balance of the day. In addition to this, a power plant sufficient to operate the large unit would be required and every machine from pan to pugmill would have to have the maximum rating or a great loss of efficiency would occur.

Dryers are very likely to be under the desired capacity and it is always wise to allow considerable leeway in this department, especially as the depreciation is very low. It is poor practice to provide more kilns than can be efficiently used, but this is seldom done. Very often it is the reverse. Kilns depreciate heavily when not in use, especially during winter weather.

CHOICE OF EQUIPMENT

Choosing the equipment for a plant is a very difficult job for the inexperienced and almost as difficult for a clayworker entering a new line.

The clay machinery manufacturers have greatly improved their equipment in the past few years and it is not now a question of getting good equipment so much as the proper selection.

Very often the prospective purchaser is forced to deal with men who have no engineering knowledge and who know as little about his requirements as he knows himself, sometimes less. The purchase of equipment on a purely price basis has also gotten many plants into difficulties at the very beginning.

When not thoroly familiar with the requirements, a clayworker or prospective clayworker should consult either an engineer or another clayworker who is familiar with the product, before reaching a decision. This is extremely important as it can safely be said that the great majority of new plants have in the past been greatly handicapped by purchasing unsuitable equipment. It is generally the one great desire of experienced clayworkers that they have the opportunity of rebuilding their plants in order that the original errors might be eliminated.

STORAGE OF RAW MATERIAL

Very seldom is a plant originally equipped with proper storage facilities. If a plant is to operate the entire year this is practically always essential. In cold climates frozen clay or shale is encountered during the winter and in warmer climates the winter season is generally wet. Rainy days will drive a clay or shale pit crew from their work and this compels a shutdown with attendant losses. Of course, where clay is mined underground a storage is not so essential.

It is not necessary to have an expensive storage shed or building as even an open building, simply roofed over, will serve the purpose.

As a rule, with good management, a clay or shale pit can be operated a great deal during the winter months and if only a storage building for minimum requirements can be afforded it is necessary only to figure on capacity sufficient to carry the plant over protracted cold or wet spells. As the men who usually handle the pit can be used in the shed when it is necessary to draw on the storage, equipment for mechanical handling is not necessary, altho when the situation warrants it, it is usually a good investment.

DRYING EQUIPMENT AND BURNING SYSTEM

There are four systems of drying available—mechanical, waste heat, direct fired and waste steam.

The mechanical dryer is an expensive installation and should be used in connection with the manufacture of high priced products such as refractories, in preference to all others.

The waste heat dryer, using heat from cooling kilns, is the most popular system and where heat can be drawn from a sufficient number of kilns, it is economical and generally successful. Where few kilns are available and it is necessary to resort to an auxiliary furnace for sufficient heat, the system becomes uneconomical and dirty. Practically any type of product can be dried by this system when it is intelligently handled and under proper control.

Direct heat dryers or those provided with a furnace under each tunnel are also popular and very successful with any type of product. The control of this type is almost perfect, but when a quantity of waste heat is available and is not used it is undoubtedly the more expensive to operate.

Waste steam dryers are not now used as much as formerly, due to the heavy upkeep and the fact that live steam has to be furnished during the hours when the plant is not producing ware, and the engine running. This makes the drying cost high.

The selection of one of the systems must be made after taking into consideration the raw material, the product, waste heat available and its source, and the price of fuel. Consultation on this matter with those having experience will also pay in the long run.

The selection of a burning system is so bound up with the product, location of plant, fuel available and size of plant that in this case also, it is a question that should be very thoroly investigated before a decision is reached. The systems available are the scove or open top, the down draft, the continuous and the railroad tunnel kiln.

It would require a chapter to go into the merits of these various types. It is sufficient to say, therefore, that the type in most successful and general use in the vicinity of the proposed plant, and in use on the same type of product, will usually be the safe type to select. This again is a question that should be referred to an authority before reaching a decision as each plant presents a problem in itself.

LAYING OUT THE PLANT

It is almost impossible to use standard plans in laying out a plant, but the method herewith presented will make it fairly easy for a man with very little mechanical ability to handle the planning successfully.

After the equipment, dryers and type and number of kilns has been fully decided upon a small drawing, absolutely to scale, should be made of the plan (floor area occupied) of each machine. The dimensions should be taken from blueprints furnished by the machinery companies. Similar drawings, always to the same scale, should be made of the motors, engines and boilers, in fact this must be done for each and every piece of equipment that goes into the factory. The dryers and kilns should be handled in the same manner, a separate drawing being made for each tunnel and kiln.

When these are completed, each drawing should be *cut out along the exterior lines.* With the aid of an architect's scale they can then be arranged on a large sheet of paper in any manner that suits the fancy and when finally a lay-out that appears to be the most compact and efficient has been arrived at, the outline of the buildings, tracks, switches, etc., can be sketched in around them. The beauty of this arrangement is that any number of different arrangements may be tried by merely shuffling the small drawing around and the defects in each arrangement studied. By this method also it is very easy to allow for the proper clearance around each piece of equipment, the proper pulley centers and to avoid crowding, as well as to tell at a glance whether or not the material is kept constantly flowing in one direction without any "back tracking."

By making an extra set of these small outline plans and using a surveyed plan of the property the proper provisions for future growth can be made.

This method will be found vastly superior to that of laying out a plant along the lines of another seen elsewhere or according to a single preconceived idea, as seldom, in such cases, does it happen that the mistakes are found until the plant is ready for operation.

BUILDINGS SHOULD ADMIT PLENTY LIGHT

During recent years the type of building erected by the clayworker has been a vast improvement over those of a few years ago.

There is really no reason why a clay products plant should not have buildings of a modern factory type. As the manufacturer of the best of structural products, the buildings should really be an advertisement. The elimination of fire risk is also an important item. Being almost always of the single story type there need be little lumber used and that only in the roof trusses.

Light buildings are almost essential if a good product is to be made, and as it is as cheap to put in sash and glass as to fill the same space with brick, plenty of light and air should be provided.

POWER CONSIDERATIONS

A few words on the subject of power may be of value. The time has arrived or is rapidly approaching when power can be purchased in almost any part of the country cheaper than it can be produced in a small factory steam plant.

In deciding the question as to the power that will be used a balance must be made between the individual plant and purchased power. On the individual plant the installation of boilers, engine, shafting, pulleys and feed water pumps are part of the original investment, with fixed charges for the services of engineers, fuel, fuel handling and boiler compounds additional. Against this there is the cost of purchased power and the motors. Installation expense and repairs are not taken into consideration, but they will be in favor of purchased power.

Aside from the above a great deal of consideration must be given to the flexibility of motor drives. A far more flexible and compact plant can be built and generally with a saving on building cost. In addition troublesome belts can be replaced by chain drives and line and counter shafting, which is always a nuisance, can be done away with. Before a decision is reached all these items should be carefully considered.

CONSTRUCTION OF PLANT

One of the peculiarities of the clay industry is that it is probably the only large industry known in which the plant operators attempt to do their own construction. This is stranger, too, when it is considered that so many clay plant managers and superintendents know absolutely nothing about building construction. Plenty of proof of this is seen in the many clumsy, dark, unhandy plants that are seen on every side.

Building construction is a business in itself, and in most cases should be left to those who know it. Why the clay-worker is unwilling to turn the construction of his plant over to a reliable contractor is hard to determine. The contractor will certainly make a profit on the job, but even allowing for this, it is safe to say that the job will cost less and be done better than if he attempts it himself. The larger and better managed companies are putting their construction work in the hands of reliable firms, but the smaller companies still seem to hesitate about doing so.

There can be no question about the advisability of letting plant construction out on contract, especially as the contracting business has reached a high plane. Very often the contractor, thru his experience, can point out various improvements that can be made in the plans, and if the contract is on a time and material basis plus a percentage, he can very often secure the materials cheaper than can an outsider.

While it is advisable to contract the construction of the buildings proper, it is always advisable for the clayworker to take charge of the setting of his equipment (providing he is capable of doing so), and the construction of the kilns. Kilns built on contract are usually unsatisfactory, and as they represent a large part of the investment and much depends on them, great care should always be exercised in their erection.

CHAPTER XVII

Caring for Equipment

CAPACITY IS THE TURNING POINT on which the success or failure of a clayworking plant depends. In this article "capacity" must not be confused with "output," but is to be defined as the maximum amount of material it is possible to put thru the weakest unit of a plant per day or per year. Very generally the weak units of a plant (or the units which have the smallest capacity) are either the dryers or the kilns, and in such cases these units regulate the capacity.

Most clayworkers realize that in order to be successful, or in other words, to pay dividends, it is absolutely necessary that the plant be *continuously* run to "capacity." However, from the annual record of failures in the clayworking industry it is quite plain that whether the importance of this fact is realized fully or not, the plant owners who are able to continuously get "capacity" are in the minority.

The writer could readily name a dozen men who stand head and shoulders above their fellows in the industry, and whose very names spell success; it takes but a moment to analyze the reason. In few words—it is because they can get "capacity"—every ounce of capacity out of their plants, day after day, month after month and year after year.

It goes almost without saying that men who can accomplish this result have very little trouble as regards quality, and very little trouble in the disposal of their products, the same rule being reversed and working the other way equally as well; men who handle a plant in such a way that breakdowns and shut-downs are the regular thing, cannot keep up the quality and cannot dispose of their products with the same ease as the men whose plants are run to "capacity" from one year's end to another.

In no other industry are excuses for failure so readily accepted; yet who can point to a leader in the field of clay-working who has not, at some time or other, taken hold of a plant which has been a financial failure in other hands and, by waving the magic wand of his efficiency, has brought it back to prosperity. Often this is done without the change or addition of a single piece of equipment. When investigation sought the reason for the financial reform, it found—it always finds—capacity.

What are the reasons for some plants running with a steady output, while others, equally well situated, are unable to do so? In the first place it is absolutely necessary that the machinery equipment be of the highest grade and suited to the materials and process; that the various units which make up the plant—mining, manufacturing, drying and burning—be well balanced; that there be harmony among the employes and that the man in charge be thoroly capable of keeping his equipment in first-class condition.

WELL BUILT MACHINERY A PRIME NECESSITY

The quality and type of the machinery is of prime importance. With weak, poorly designed and poorly built machinery, or machinery that is unsuitable for the work required, nothing but trouble can be expected. A plant is often doomed by the machinery salesman before it is built; and here our industry in unique, for in no other can equipment be found that is so totally unfit for the service required of it. It is useless to blame the machinery manufacturer altogether, for he is merely supplying the market with what it demands and at the price it is willing to pay.

Where it is practically impossible to get efficiency out of a plant because its equipment is not equal to the work required of it, there can be but one wise thing to do, and that is to eliminate the weak parts and replace them with units of sufficient strength. It is often a single machine that causes the trouble, a dry-pan, elevator, pug-mill, brick-machine or cutter, involving the expenditure of a thousand dollars or less, *an amount easily lost every month or two in a plant constantly bothered with break-downs.* As an illustration of this—the writer recently had occasion to go thru a very successful Ohio plant with a party of business men; pushed into an out-of-the-way corner was a complete and very fair looking hollow-ware machine. The president of the company was asked why the machine had been thrown out. His laconic reply was that "It was not a *dividend producer.*" It appeared that a smaller, but *better designed* machine which had taken its place, was producing fifty per cent more tonnage—not because the ware was pushed out faster but because the machine ran without constantly recurring mechanical troubles.

A plant to run efficiently should be well balanced. It is far easier to keep up a steady flow of ware if the dryer easily takes care of the machine, and the kilns easily take care of the driers. Moreover, a halting, unsteady flow of ware will demoralize the best gang of men that ever worked in a brick plant.

HARMONY AMONG EMPLOYES AN ESSENTIAL FEATURE

Harmony among the employes is a very important factor. This is especially true with regard to the foremen and mechanics. Foremen who work together and who constantly assist one another can do wonders toward getting capacity. One foreman or (to a lesser extent) one laborer who, either thru inefficiency or pure cussedness, is out of step with the organization, can do quite as much harm as a weak machine —probably more.

Granting that a plant is equipped with good machinery, is well balanced and has an efficient organization, what more is necessary to keep it running to capacity? The answer is—*the prevention of break-downs and the ability to make quick repairs.* Therein lies the secret of success. No machine is so strongly built that it will not wear out and break down —if allowed to do so.

The break-downs that are due to unpreventable accidents, can and should be reduced to a minimum. Preparedness will reduce the loss due to such accidents to a point where they are unimportant. It is with preparedness then that this article will principally deal, altho the prevention of break-downs and shut-downs will receive considerable attention.

FINDING THE WEAK POINTS

The first six months after a new plant has commenced operations will develop practically all of the weak points. One of the invariable rules a manager or superintendent should make on a new plant, or a new manager or superintendent on an old plant, is to *never allow any single part to break or cause trouble twice in the same place,* without making an effort to strengthen the part. A part may break once, and the break be due to flaws, carelessness, or other reasons over which there is little control and it may not be necessary to strengthen it—*but if the same thing hap-*

pens twice, there is seldom any other reason than inability to stand up to the work required. In the vast majority of cases, strengthening a part can be done without very much extra expense, and in any case with less expense than the loss incurred by constant shut-downs and consequent decreased output.

As an example of strengthening a piece of equipment, the following is cited. The pugging shaft on a long pug-mill broke where the hex portion was turned down to pass thru the marine thrust. A new shaft was ordered by express. During the interval of several days between the time of the break and the arrival of the new shaft, half of the plant was shut down. Within a week after the new shaft was put in, it broke in exactly the same place as the first. Such breakages might have kept up indefinitely, but when the second shaft broke, the hex portion of it was taken to a forge shop and a piece of ordinary cold rolled shafting, *one-half of an inch larger in diameter than the original,* was welded to it. The thrust rings were bored out to fit the new shaft and the bearings rebabbitted to take the larger diameter. There has not been a particle of trouble with that machine since.

In another instance the knife holders on a pug-mill shaft would break off near the hub, allowing a knife to drop to the bottom of the mill. This generally resulted in the breaking of several more, due to contact with the broken piece. A pattern was made, providing ¼ in. more metal all over, with a heavy fillet at the weak point. The trouble ceased at once.

In still another instance the cast-iron ring or front piece, to which the dies are fastened on a hollow-ware machine, broke. Another was procured and the same results followed, due to accidental stiffening of the clay. Instead of duplicating this front a third time, a steel one was made. *The trouble never occurred again.*

SOME PLANTS SEEM TO "GET TIRED"

These instances are cited merely to illustrate the point that if a weak point in the equipment is found, it is, as a general rule, a very easy and inexpensive matter to strengthen it. Time and again the author has come in contact with plants where no effort is made to overcome a weakness of this kind. Possibly a duplicate part is kept in stock and put in when necessary, or else the express company is called upon, *while the plant shuts down.*

The author has in mind a plant which is operating a very troublesome machine. All of the trouble is caused by the constant breaking of a very light shaft. This shaft has broken twice in a single day and seldom lasts more than a few weeks. Yet no effort has ever been made to *eliminate* the cause of the trouble, altho an extra shaft always lies beside the machine ready for instant use. In this day of special steels it would not even be necessary to increase the diameter of that particular shaft, altho it might be necessary to have one rolled to order. But special steel would eliminate the trouble.

Some clayworkers would do well to examine the gears and shafting of a fifty or sixty h. p. motor-truck, and then consider *that small as they are, they are called upon to convey as much power as the gears and shafts on some claywork-ing machines,* altho they are only from one-tenth to one-third the size. It is largely a question of special steel.

Lack of initiative on the part of the clayworker lies, at the bottom of a great deal of the trouble. If he cannot secure a stronger part from the maker of the machine, he simply "kicks" and—keeps on buying. The proper method, under the circumstances, would be to abandon the maker whose machine parts show such weakness and try elsewhere to have parts made that will give proper service.

A PROPER SUPPLY OF REPAIR PARTS

Next in importance to preventing the recurrence of an accident by increasing the strength or improving the design of the troublesome part, is the keeping of a supply of repair parts on hand. It is much easier and cheaper to do this, of course, when the plant has its own machine shop, *but it is far more important on the plant which has none,* especially if a custom repair shop is not easily accessible.

If a clayworker does not know what repair parts he should keep on hand, he soon learns thru "hard knocks." When once a part gives trouble, either thru breakage or wear, he should make it a rule to always have a duplicate within reach. This, of course, means an investment—probably a large one—but it is the best investment a clayworking plant can make. A few days shut down, with the attendant loss, more than offsets the "economy" that prevented a stocking up. Some plants follow this rule, and they generally arouse the envy of their competitors, who constantly wonder how those plants run with so little *apparent* trouble.

In the following, the author will attempt to itemize the troubles most generally encountered on any sort of a clay-working plant, and the remedies suggested.

SHALE OR CLAY PIT

In the average pit there is probably nothing that interferes with capacity so much as tracks. In the nature of things it is hard to keep tracks in good shape, as they are often damaged by shots. Dirt accumulates upon them and in the switches and frogs. Thru this, empty and loaded cars jump the tracks and, oftentimes, a machine is kept waiting or run under its capacity because of the derailed car or cars. In the author's opinion, *more pit foremen have "fallen down" on their jobs thru neglecting their tracks than thru all other reasons combined.*

The tracks should be kept clean enough to allow the flanges of the wheels to clear at all times. They should constantly be kept to gauge. Sharp curves should be avoided, for it is generally better to be without them than to put up with the trouble they give. The use of twelve and sixteen pound rails causes much trouble. *Rails under twenty-five pounds should never be used, except for the temporary jumpers,* and even there heavier rails save trouble in the end. Main lines, which need not be disturbed, should be laid with heavy rails and heavy ties. Even light standard rails and standard ties soon pay for themselves in such places.

The cars too, often give trouble thru wear, allowing the wheels to either jump or "drop in." This should be especially watched and the wheels bushed or washered so as to keep them to gauge.

When shovels are used, either steam or electric, a very complete set of repair parts should be kept on hand. The nature of shovel work causes constant repairs and attention, and unfortunately the men who handle them are too often of a careless sort. *Wearing parts should be examined daily, either by the superintendent, pit foreman or mechanic, unless a very reliable shovel man is in charge.* Chains, cables, bearings and teeth require particular attention. The pit foreman should watch the face in front of the shovel at all times to prevent "caves" that may bury or injure the shovel.

INCLINE

If an incline is used there are several things in connection with its maintenance and operation that require careful attention. In the first place the use of a standard sixty pound rail will do much to prevent trouble. Many plants operate a system in which the empties are drawn up by the descending loads. In most cases of this kind a hook on the ends of the cable is fastened to the couplings on the cars. The chief difficulty encountered in this system is that frequently the hooks or couplings break while they are on the incline, and the result is a "smash up" at the bottom. These breaks are

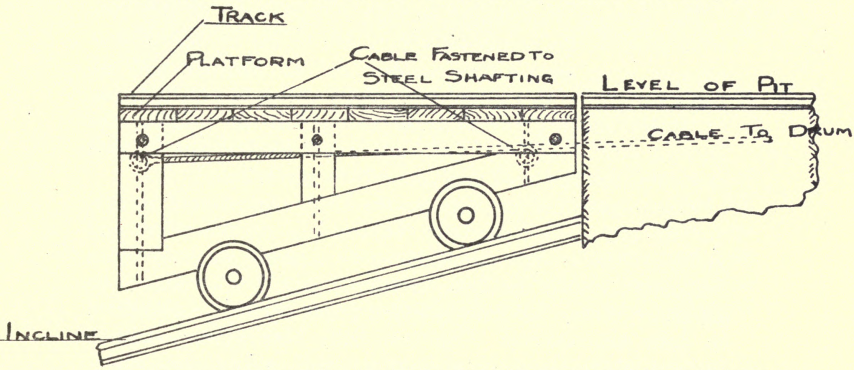


Fig. 77. Illustrating the Use of a "Cage" in the Haulage System.

caused by the crystallization of the iron hook or coupling. *If the hooks and couplings are taken from the rope and cars once a month, and put into a large wood bonfire which will heat them to a dull red, and are then allowed to remain in the ashes until cool, this trouble will be entirely eliminated.* It is preferable to put them in the fire on Saturday night and allow them to remain in the ashes until Monday morning.

Even at best, any haulage system where the cars run up and down an incline, is likely to be troublesome and cause delays. A great improvement is made by the use of a "cage" as shown in Figue 77. This may consist of a platform on wheels, to which the cable is permanently attached. The cars are run onto this platform at the top and off at the bottom, and vice versa.

The distinct advantage of this system over running the cars down the incline on their own wheels, is that the cable can be securely and permanently attached to the cage. An accident on this sort of an arrangement is practically unheard of, unless it be thru the breaking of a wornout cable.

The cable and drum should be thoroly examined by the foreman *each morning.* Too much care cannot be taken in this department, as accidents are generally serious enough to cause considerable damage or delay. A cable should never be allowed to "wear out." As soon as strands begin to break, it should be replaced, or cut and spliced.

STORAGE SHED

The storage shed should be kept full of clay. If this rule is adhered to, the source of supply can be cut off for several days or even weeks, thru accident or bad weather, and the plant can still run to capacity. Such things as the burying of steam shovels, the collapse of inclines or trestles, the burning out of dynamos and motors *will happen,* and in such cases the storage shed may be a "life saver."

When conveyors are used in the shed, they should be frequently examined—especially the bearings on the idlers and pulleys. The trough should be often cleaned, as the friction frequently causes the belts to tear if dirt is allowed to pile up under them. All conveyor belt joints should be submitted to daily examination. Conveyor belts have a way of tearing out at the fasteners without warning, and in some plants a break-down means a shut-down in the plant.

POWER PLANT

The power plant very seldom causes a shut-down, but that is no reason for its being neglected. Steam engines are easy to keep in first-class running order, principally because the parts are easy to see and easy to get at. It is an excellent rule to have the cylinder head occasionally taken off, in order to see that the large nut which holds the piston on is tight, and that the piston rings are intact. When an accident does happen to the engine it is serious, and attention given to prevention is well worth while.

Boilers are little likely to prove troublesome if intelligently handled. The accidents that generally happen to them are cracks in the sheets, blisters, open seams and leaky rivet holes. All of these things are due to carelessness. Plant operators are too much inclined to leave this department to take care of itself. A glance thru the boilers at the time of washing out takes but a moment and should always be done by the superintendent. *Intelligent firing avoids the other difficulties.*

THE CARE OF MOTORS

When electric current is used, the motors require careful attention. The motor is rather a new tool in the hands of the clayworker—something out of his line. He is inclined to look upon it as something with which he is anything but familiar—and therefore to be left strictly alone—or a contrivance so wonderfully self-contained that no particular attention need be given it. Seldom are experienced electricians employed on a clayworking plant, but it will pay to encourage someone to make a study of motors and then give him charge of that part of your equipment. The fact is, a motor does need intelligent care if it is not going to prove a big expense.

The bearings are the principal source of trouble. Bearing trouble leads to all of the other troubles, causing grounding of the field coils, charring of the insulation, etc.

The bearings should be emptied of oil at least once each month and then thoroly washed out with kerosene. The old oil should not be put back (unless it is filtered), but new oil used each time. The air gap between armature and field should be constantly examined, and as soon as it is seen to be closing on the bottom, the bearings should be adjusted or new ones put in.

It is the neglect of this air gap that causes nearly all "burn outs." As soon as the armature comes in contact with the field, the friction causes heat, which in turn burns the insulation and causes the machine to "ground."

On most motors, especially large ones, there are adjusting nuts on the under side of the frame. As the bearings wear and the armature drops, these nuts should be taken up. This increases the air gap at the bottom.

When all the adjustment is taken up (and it only amounts to about one-eighth of an inch) new bearings should be put in at once.

As clay-plant motors are generally in dusty places, they should be regularly blown out with a hand bellows. Dust accumulating in the coils and between the armature bars, especially if it gets damp after standing, will sometimes cause serious trouble. Motors when receiving regular attention *never give trouble.* It pays to look after them, for the burning out of a single motor often ties up a plant.

CHAPTER XVIII

Running a Plant to Capacity

THE TROUBLESOME POINTS about a pan are the scrapers, screen-plates, step and clutch. The scrapers are subjected to especially hard service, where hard, lumpy shales or damp sticky clay are used. Often in such cases, those which originally come with the pan are not strong enough, or are not set at the proper angle for the particular material. When necessary heavier ones should be put in. The "shoes" or replaceable, adjustable plates on the front of the scrapers should always be kept at a point where they *just clear the screen plates* (about one-quarter of an inch). More screen plates are broken and scrapers torn off by their being kept up too high than thru any other cause. Wedge shaped pieces of shale get between the plates and scrapers and *something must give away as the revolution of the pan drives the wedge further in.* It is generally the screen plates that are broken, altho sometimes the scraper is torn off. In one instance a large plant was known to have broken from three to ten screen plates per day for a considerable period before it was discovered that the scrapers were being carried too high. Aside from this, a "close" scraper keeps the pan bottom clean and gives maximum grinding capacity.

It is important that the scrapers have a long sweep from the muller to the rim. Short scrapers are subjected to a far greater strain, both from the friction of the bottom and the blows from lumps, than a long sweeping scraper, and the former give far greater trouble.

The underscrapers, or scrapers under the pan, should receive most careful attention. These are so situated that it is extremely hard to examine them without considerable trouble, and consequently they are neglected. When one of these is loosened up, thru nuts dropping off or bolts breaking, it generally means broken pan arms and screen plates, or torn up bottoms and chutes. The use of spring washers under every nut, and *regular inspection* will practically eliminate trouble from this source.

Screen plates are often a source of trouble and expense to a plant. Besides being careful to keep the scrapers down, great care should be taken to keep the mullers from running even a fraction of an inch over on the screen plates. If they are allowed to do so, and a piece of shale or other hard material happens to be even partly resting on a screen plate, the direct pressure transmitted to the screen plate will likely crack or break it.

In some cases, even the utmost care will not allow the use of cast-iron screens, on account of the excessive breakage. It is then wise to resort to malleable iron. These are expensive but they are practically unbreakable and give far better service than the alloy plates which cost about the same.

HOW TO CARE FOR PAN STEP

Some plants are greatly troubled with pan steps. Lack of proper attention has more to do with this, than has the type of the step. Besides being subjected to an excessively hard service, the step is located in a dusty place, and it is generally the dust and lack of proper lubrication that causes difficulties. Most steps are not properly protected from dust, i. e., are not tightly enclosed. At small expense the dust-cap can generally be fitted so that packing can be inserted around the shaft in the same manner as in the stuffing box of a pump or engine cylinder.

Another method is to fasten a flat or umbrella shaped circular plate tightly around the shaft, just above the dust-cap, as shown in Fig. 78.

Dust falling on this plate will be thrown clear by centrifugal force. It often happens that, when steps are sent out of the factory, they are not provided with proper lubricating facilities. Small pipes or grease cups are generally provided, but they soon become clogged at the inside end with dust, heavy oil or metal particles. In such cases, the man who oils may think he is feeding plenty of lubricant, or that the step is not using it very fast, whereas it is getting little or nothing. An inch-and-a-quarter or an inch-and-a half feed pipe, provided with a cap, will overcome this difficulty. If this pipe is brought up to the floor level of the factory or high enough to give it a "head," and the step housing made oil tight, the step can run on oil under a slight pressure.

An extra step should always be kept on hand, and the steps in use should be regularly examined—at least once each month.

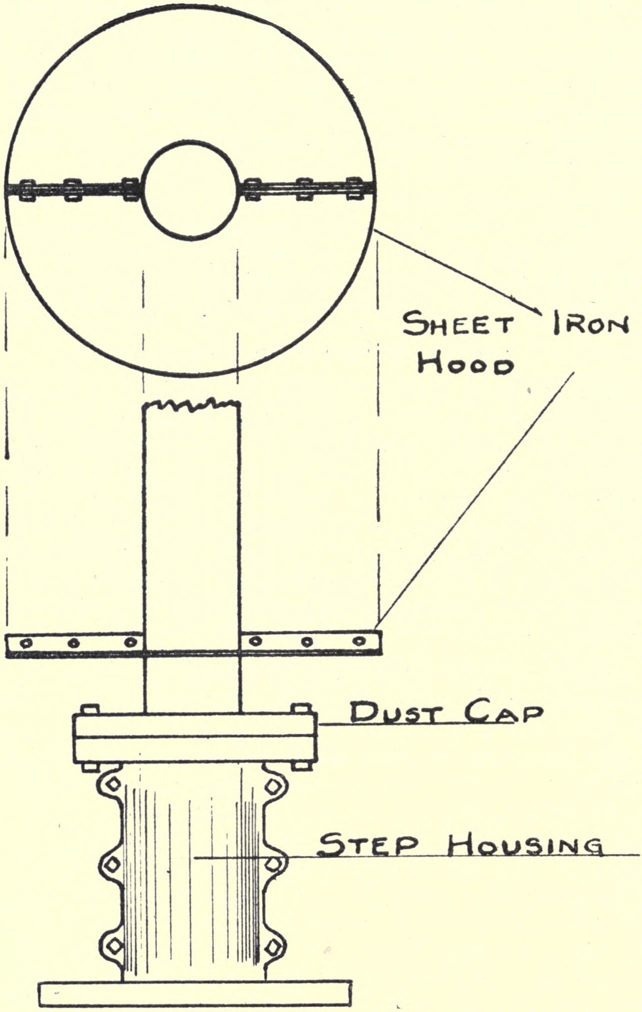


Fig. 78. Step Protector.

The clutch, always important on any machine should be particularly well looked after on the pans. Unless a pan can be stopped quickly, great damage may result from what otherwise would be a trifling accident. On many plants, any one who sees fit to do so can "monkey" with the clutches in an effort to "adjust" them. As a consequence they are constantly giving trouble and continually being "cussed." *The author has known a plant to be shut down for a week simply because a clutch would not "throw out."* Clutches are generally simple affairs and most of them will give efficient service if properly handled.

The superintendent should himself adjust the pan clutches and all other clutches about the plant, or should delegate his mechanic, a foreman or some other thoroly capable man to do so, *and should forbid others to touch them.* Such a rule may cause a few minutes delay at times, but will pay in the long run, and on any plant.

Bushings in the loose pulleys are likely to give trouble when not given sufficient lubrication. Careful attention should be given them and a duplicate for each pulley should be kept constantly ready for use.

Crown wheels and pinions seldom give trouble, but occasionally one will be broken by a sudden jar from a hard lump in the pan. It is a very good policy to have extras on hand.

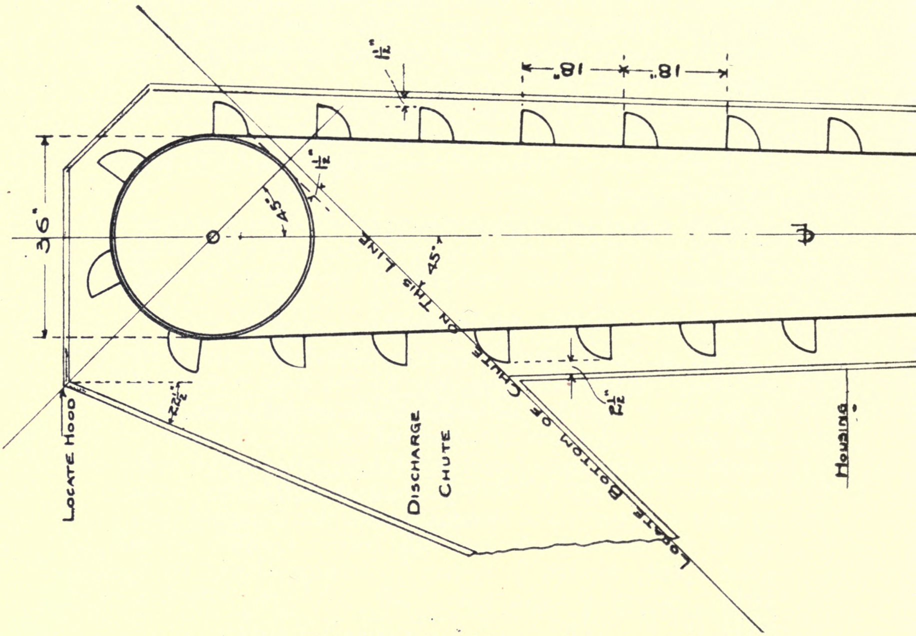
ELEVATORS

When an elevator causes constant shut-downs—and there are many such—the trouble may be due to a number of causes, all of which can be remedied. In the first place, most clay plant elevators are not designed correctly, consequently trouble is to be expected, and undoubtedly will continue until the proper remedy is applied, which is rebuilding. Some of the things that cause elevator trouble are: improper spacing of the buckets; undersized head pulley; too slow or too great speed; incorrectly designed discharge chute; incorrectly designed feeding chute; loose belts and failure to clean out the boots.

Buckets should be spaced on eighteen inch centers, and for a nine foot pan, should not be less than six inches by twelve inches in size.

Small head pulleys are often a most serious source of trouble. When the head pulley is too small, the ascending buckets will invariably throw part of their load into the air when they strike the pulley and start over. This is due to the abrupt change of direction, the dust being thrown upwards by centrifugal force. A large percentage of the material thus thrown out falls to the boot and requires re-hoisting, thereby at times overloading the elevator and choking it. Standard construction requires that the head pulley be thirty-six inches in diameter. Large pulleys, and belts traveling at the proper speed, absolutely insure the material remaining in the buckets until the proper point of discharge is reached.

The proper belt speed for an elevator of standard design is 325 feet per minute. This speed is taken from the average dry shale. It may vary as much as thirty feet either way



on some materials, but with this speed as a starting point, experiment will determine the proper speed for any particular material.

The discharge chute may be too high or too far away from the buckets. These defects result in material being thrown down again into the boot, thus necessitating rehoisting.

The feeding chute is almost always built too low. *It should be so located that the material will be fed into the third bucket from the bottom.* This allows the overflow to be caught by the two buckets below, and does away with the necessity of the buckets digging their load from the boot. Making the buckets dig their load from an enclosed boot should always be avoided, as it invariably results in an unnecessary consumption of power, the ripping off of buckets and torn belts. It is the author's opinion that more elevator trouble is due to this fault than any other. Fig. 79 shows an elevator of standard design.

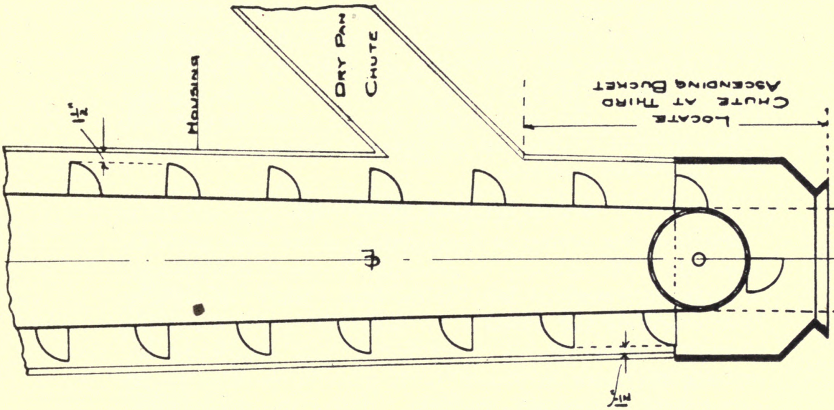


Fig. 79. Clay Plant Elevator.

The bucket belt should always be kept tight, and should run on a slatted pulley at the bottom. A slatted pulley will not allow clay to "build up" on it and therefore the belt will run true in the housing instead of scraping the sides and occasionally stopping thru friction.

"Digging out" the boots twice a day will eliminate a great deal of trouble, especially in wet weather or when using damp materials. The dust becomes packed very hard under the buckets and the friction on them gradually increases until they stop. On many plants the boot is never thought of until the elevator chokes and even then only enough is dug out to start up again. By having a man *thoroly clean* all the boots each noon and night, a vast amount of time and temper will be saved.

PUG-MILLS

Up to very recently these machines were built entirely too light for the heavy duty required of many of them. This has now been remedied, but hundreds of plants are equipped with pug-mills which are light and troublesome. As a general rule the trouble is to be found in the gears and intermediate shaft. Gear trouble can be remedied by replacing the much used cast-iron by either cast- or cut-steel. When the intermediate shaft often breaks, it should be replaced by one of larger diameter, or if that is impossible, by one made of special steel. In any case, it is well to have an extra one on hand with keyways cut and ready for an emergency. Most pug-mills, being set on a platform, *which at best is not a good machine foundation,* are subjected to considerable vibration. This has a tendency to loosen bolts and destroy bearings. The use of spring washers under the nuts will reduce the bolt trouble, but the pug-mill should be examined daily to prevent accidents.

BRICK OR TILE MACHINES

Machines are subject to break-downs in the same parts as pug-mills. The shafting is generally the most troublesome, with the intermediate easily in the lead. Many clayworkers have overcome the difficulty by installing larger shafts all around. Where this is impossible without practically rebuilding the machine, special steels must be resorted to, or extras kept in constant readiness. Where the intermediate shaft is the only one giving trouble it is a very good plan to have the extra equipped with a set of gears. It can then be put into place with little delay.

Machines should always be equipped with steel gears. A cast-iron gear will lose a tooth without giving a moment's warning, while a steel one will wear the teeth to a feather edge before breaking.

In going from one plant to another it is surprising to note the number of machines in use with cracked and patched barrels. In a case of this kind, when the conditions become so bad as to require a new barrel, it is poor practice to order a duplicate of the old one. If the maker will not make something stronger, call in a pattern maker who knows his business and have him make a pattern that will produce a casting which will stand up in spite of poor pugging.

CUTTING TABLES

There are many small parts about a cutting table which should always be kept on hand. Break-downs on a cutter are generally caused by wear, which should be readily caught before it gives serious trouble. As soon as a cutter begins to "act up," the trouble should be located and, *if the responsible part shows wear, it should be replaced.* Patching up does not pay, as a general rule, with automatic cutters.

KEY TROUBLES

One of the most annoying of the little troubles on a plant is caused by ill fitting keys. A pulley or a gear will constantly slip sideways, probably not causing any great loss of time, but helping to keep down "capacity." As a rule it does not require much time or work to correct this, but there can be no question that on some plants it is neglected. Day after day the plant is shut down for five or ten minutes at a time, while a pulley or gear is driven back to place, and still nothing is done to permanently correct the trouble.

A key once properly fitted is there, and it is worth while to see that this item is properly attended to.

BELT TROUBLES

When this subject is mentioned, the average clayworker is "right at home,"—and there's a reason. Briefly, it is *cheap belts.* The author has sometimes thot that if it were not for the clay plants and saw mills, most of the companies making cheap belts would either go out of business or improve their product. The amount of money clayworkers lose thru shut-downs to take up belts, repair broken lacings and thru "slipping," is appalling. In every instance where serious trouble of this kind is encountered it can be traced to low grade belts, or belts too light for the service. The trouble is always at its worst during a rainy spell, when the belts draw up or shrink, and tear out at the lacing. After a wet spell they stretch and require taking up.

To constantly go thru this annoying and costly experience is not at all necessary. It is not the intention of the writer to recommend any particular make of belts, but a plant *can* be equipped so that this trouble is reduced to a minimum or practically eliminated. The best of belts will stretch or occasionally break a fastening, but invariably they give sufficient warning to allow repairs to be made out of operating hours.

Machines are often equipped with belts that are too light (too few plies) or too narrow. Contact between the belt and the pulley is the all important factor in a belt drive and the greater the contact the better the drive. Naturally, drives should always be arranged so that the tight side of the belt is on the bottom. This gives a greater arc of contact and eliminates the necessity of keeping the belt too tight. This in turn eliminates stretching and torn joints. When the drive is wrong—the tight side on top—it is always a good plan to add at least two plies to the thickness, over and above what the tables call for.

When buying belts for a plant, the best—and in belts this means the highest priced—are none too good, no matter whether they be stitched canvas, woven canvas, rubber or balata. There are many plants which are only prevented from getting "capacity" thru belt troubles, and it would pay exceedingly well to re-equip thruout.

Belts should not be allowed to run until they slip, but as soon as they show signs of being too loose, should be taken up. When a joint shows signs of failing, repair it as soon as the plant shuts down.

DRYERS

On many plants the dryer controls the "capacity." Any interference in its operation, therefore, tends to reduce this capacity. Mechanical dryer troubles are generally limited to the tracks and cars, and in waste-heat dryers to the fan unit. Tracks should be so securely fastened that they cannot get out of gauge and *they should be kept clean.*

The bearings of the cars should be kept in good condition and should be oiled every time they come thru. The author has seen plants—several of them—where it was necessary to shut down the factory several times each day so that the hands could go into the tunnels to push the cars down. The trouble was wholly in the tracks and car bearings. The loss on these plants ran into a considerable amount in the course of a year, and there are many like them.

The fan unit, running as it does twenty-four hours a day and during the whole year or season, requires most careful attention. This is especially true of the engine and fan bearings.

KILNS

It is a very usual thing for plants to be short of kiln room. On such plants it is not unusual for the output to be interrupted thru a kiln running a day or two over the usual burning time. As a rule, there is little excuse for this. The trouble can generally be traced to sleepy firemen, unintelligent cleaning and firing, or dirty kilns.

It is necessary to closely watch the kiln department at all times. The coal should be closely watched to see that a bad car is not at times "slipped over," and if the firemen are likely to be lax it may be good policy to put them on a bonus system, whereby they get so much money for each day saved under a stated period, with certain deductions for spoiled ware.

Much kiln trouble is due to dirty bottoms. Sometimes a bottom is allowed to go until it takes from one to three days longer to make the burn, and unfortunately this extra time is on the hot end, when the kiln is simply "eating up" fuel. Even some very good plant operators do not seem to grasp the importance of clean flues and when designing the kiln make no allowance for the accumulation of some dirt in the kiln bottoms.

Keeping the temperature *constantly progressing* during a burn, and keeping the bottoms clean, will aid materially in getting capacity where "kiln room" is an important factor.

PLANT INSPECTION

Before closing the chapter the author wishes to make a suggestion to clayworkers which, if followed out regularly, will prove an almost certain "trouble preventive":

On a stated day each week while the plant is in full operation, have the superintendent, accompanied by the master mechanic, machinist, or "handy man," proceed to the clay bank or pit. There they pick up the bank foreman and together very minutely go over every piece of equipment that can in any way get out of order. Note is made by the superintendent of every defective or worn part and any other item that may need attention or is likely to interfere with operation.

The first two then proceed to the factory and with the factory foreman go thru the same process in this department. Each department is visited in the same way until the entire plant is gone over A copy of the notes taken is then made out for each foreman, detailing the defects found in his department, and a complete list is made out for the master mechanic or repair man. Instructions are given that repairs and changes be made before the next inspection.

The length of the list on the first inspection will be a surprise—even on the best of plants—but each week these lists will grow smaller and the number of jobs become fewer. The effects of such an inspection are several. The superintendent will come to know his plant as he never knew it before, and if the foremen are made of the right material, they will take pride in keeping their departments in such shape that no list is given them.

But most important is the fact that such inspections, if kept up regularly, will prevent dozens of break-downs, to say nothing of small repairs, by catching defects before they give trouble. Such inspections need not be confined to big plants, for even where the owner is superintendent, mechanic, head burner and all the rest, he will find them to be worth considerable money to him.

The mere fact that a man is "around" a plant continually is not enough. It requires a systematic search for *trouble causes* in order to systematically avoid trouble.

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