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ORIGINAL PAPERS

DATA ON THE OPERATION OF A CONTINUOUS TUNNEL KILN AT THE PLANT OF THE A. C. SPARK PLUG COMPANY¹

By SAMUEL J. McDOWELL AND PERRY D. HELSER

ABSTRACT

This kiln has total length of 75 feet and interior width of 2 feet 8 inches. Design is based upon the idea of firing small thin mass at a rapid rate, only 12 hours being required for the burning operation. The ware, spark plug porcelain insulators, is passed through in a single, unprotected, horizontal tier, being subjected to direct fire. The kiln is operated at cone 18 half down. City gas is used, with burner equipment which is a modified form of Surface Combustion.

The initial cost is low. The kiln is of simple construction, permitting rapid heating and cooling. Output depends upon ability of individual pieces of ware to safely absorb heat necessary for their vitrification. The process is patented.

Introduction

The data given in this paper has been obtained from tests and observations on the tunnel kiln installed at the plant of the A. C. Spark Plug Co., Flint, Michigan. It covers a period of over two years' successful operation, first at cone 16 and later at cone 18.

This kiln is used for firing spark plug porcelain insulators. It is probably unique for several reasons:

1. The kiln proper is but 60 feet long, with an additional wind tunnel of 15 feet, making a total length of 75 feet. The interior width is 2 feet 8 inches.
2. A high temperature is obtained for a kiln of such length.
3. The kiln is open or direct fired.

¹ White Wares Division, St. Louis Meeting, Feb. 28, 1922.

4. The ware is passed through in a single horizontal tier subjected to direct fire, that is, not protected by saggars.

5. The ware is advanced continuously, in contrast to the type in which the ware progresses more or less intermittently.

6. The construction is simple. The cost of installation is, therefore, comparatively low. This simple construction allows the kiln to be brought to a maximum temperature in a minimum length of time without detrimental effects to the structure.

7. It is possible to closely control the composition of the kiln atmosphere, maintaining either oxidizing or reducing conditions.

8. The kiln, throughout its length, is supported on concrete arch construction. This permits access to the space under the cars at all times. It also prevents possible overheating of the steel framework of the cars.

Description of Kiln

Preheating Zone.—The preheating zone is lined entirely with high grade fire brick. The walls are built of fire-brick and Nonpareil insulating brick. The arch is built of a double rowlock of fire-brick with a covering of insulation brick.

Drop arches of fire-clay shapes act as baffles to force the hot combustion gases down around the ware as the preheating progresses.

Hot Zone.—The hot zone walls are built of silicon carbide brick, high grade fire brick, and Nonpareil insulating brick. The arch is similarly built of carborundum brick, high grade fire brick and insulating brick.

There are nine burner openings in each side. The burner orifices open into the kiln slightly above the level of the ware and at such an angle as to allow the flame to impinge upon the arch.

At the end of the hot zone is a soaking or retarding zone of similar side wall construction, but with hollow arch construction of carborundum blocks filled with Kieselguhr. These blocks form a drop arch immediately over the ware to prevent the hot gases from escaping toward the cooling end of the kiln.

Cooling Zone.—The cooling zone is composed of three sub zones:

(1) *Muffle Cooling.*—The top of the muffle cooling zone is built of fire-clay shapes and corundum slabs, so arranged as to give a continuous air duct leading back and forth over the ware from an opening in the cool end of this sub zone to a stack in the hot end, where the hot air escapes.

(2) *Water Cooling.*—The walls and arch of the water cooling zone are built of second grade fire brick. Coils are placed immediately above the ware and water passes through them continuously.

(3) *Direct Air Cooling.*—This was not a part of the kiln as originally designed. However, the cars and ware came out too hot to comfortably

handle and a wind tunnel of 15 feet was added. The walls are built of brick and the top is constructed of sheet metal.

An air duct leads from a fan to two openings through the sheet metal top of the wind tunnel and near the exit end of the kiln. The air from this fan is prevented from entering the kiln proper by a flap which brushes on top of the ware.

A sand trough runs the entire length of the kiln on either side. It is built of angle iron and is bolted to the concrete through slotted holes to allow expansion.

Pusher.—The pushing mechanism consists of an endless chain extending six feet into the kiln under the center of the cars. The chain carries dogs four feet apart. Each of these dogs in turn engages the rear axle of the last car and pushes forward the entire train. The chain is propelled through various speed reducing mechanisms by a continuously operating 3 H.P. motor. The power actually required is 1 H.P. The speed reducing mechanism is so arranged as to permit control of the rate of travel through the kiln. This rate may be varied from a minimum of five hours to a maximum of thirty hours elapsed time for travel through the kiln.

Burner Equipment.—The burner equipment used is a modified application of the Surface Combustion low pressure system. In this system the air is supplied by a Root's positive pressure blower. The gas is reduced to atmospheric pressure by means of a regulator. The air and gas are then automatically mixed in any desired proportion. This explosive mixture is forced through the burner orifices and impinged upon the arch of the kiln.

Fuel.—The fuel used is artificial city gas. This is a mixture of coal gas and water gas enriched with oil to insure a product having a heating value of approximately 550 B.t.u. per cubic foot.

Burner equipment is on hand for the application of fuel oil, the possibilities of which we plan to thoroughly investigate.

Pyrometer Equipment.—The pyrometer equipment consists of two base metal couples in the preheating zone, three in the cooling zone, and three platinum couples in the hot zone. These couples are connected to an indicating pyrometer which is read and recorded every thirty minutes.

Figure 1 shows a car of ware entering the kiln.

Cars.—The cars are 4 feet in length and 2 feet 6 inches in width. Steel aprons attached to either side of the cars drag through the sand in the sand-seal trough and prevent the hot gases from coming into contact with the wheels and rails.

Refractory blocks are placed along the edges of the steel car frame, while in the center insulating brick are used. Additional refractory blocks cover the entire car.

The trays are 15" x 16" x 2" outside dimensions and are approximately 1" thick. They are composed of fire-clays and grog and are formed on a

sagger press. The life of the trays is lengthened because of the fact that they carry only the weight of the ware in them.

In the event of firing ceramic ware of sufficient base area to stand unsupported, the trays might be dispensed with and the ware placed directly upon the car, thus eliminating the use of saggers or the like.

FIG. 1.

Ware.—The ware consists of one-fire, glazed porcelain spark plug insulators approximately $2\frac{1}{2}$ " in length by $\frac{3}{4}$ " in diameter. They are placed in the trays with unglazed shoulders touching.

Standard Conditions of Operation.—The kiln was put into operation in November, 1919, at a temperature of cone 16 touch. Later a change in body composition necessitated a temperature of cone 18 half down, and since that time the kiln has been operated at this latter temperature.

The kiln is operated on a twelve-hour schedule, that is, twelve hours are required for a car to pass from the entrance to the end of the kiln proper (60 feet), at which location access is gained to the ware. This speed means that the car advances through the kiln at the rate of one inch per minute.

Figure 2 shows a car of ware emerging from the wind tunnel.

FIG. 2.

Figure 3 shows the temperature curve throughout the length of the kiln. These temperatures were obtained by means of a thermo-couple projecting up through the bottom of a car to the level of the ware. This car was passed through the kiln in the usual manner to a maximum temperature of cone 18 half down. Temperatures were recorded every twelve minutes, or every foot of travel. This curve, therefore, shows the actual continuous heat change to which a piece of ware is subjected.

FIG. 3.

Cones show practically no variation from side to side of the car top. Cones 17 and 18 are placed on cars where they may be seen from the entrance opening of the kiln in order to serve as a check on firing. The operator watches the cones as closely as he does the pyrometer.

The burner equipment is adjusted to maintain a desirable kiln atmosphere. The combustion gases pass over and around the ware as it advances through the preheating zone and are finally carried off by a stack at the entrance of the kiln. No serious attempt has been made to utilize the waste heat.

The temperature of the gases in the stack is approximately 100°C, the gases being diluted with air from the entrance of the kiln, which accounts for their low exit temperature.

The absence of a complicated construction in the kiln permits a more rapid elevation of the temperature upon lighting than is usually the case with tunnel kilns. Approximately 36 hours elapse from the time of lighting until the ware is started in.

The idea in designing a continuous tunnel kiln of such small dimensions was based upon firing a small mass at a rapid rate. Attempts have been made to fire comparatively large masses of ware at a rapid rate, but with disastrous results.

The benefits of this kiln are limited to the firing of ceramic wares composed of such materials and of such dimensions or so grouped as to

be capable of absorbing sufficient heat to produce vitrification in a comparatively short length of time.

It is a very desirable type of kiln in which to fire bodies containing those synthetic fluxes, which are susceptible to objectionable crystalline growths unless properly cooled.

The flexibility of control of the kiln atmosphere enables the maintenance of oxidizing, neutral or reducing conditions as the ware may demand.

This kiln was originally built more or less as an experimental unit, but its operation was so successful that it has been used in production almost continuously since its installation.

With gas at 87 cents per thousand cubic feet, the cost of the burning operation is slightly less than the cost of burning in coal fired periodic kilns. And greater uniformity of product is obtained due to uniform heat treatment.

A new kiln of similar design has been constructed and has just recently been put into operation. This kiln is 87 feet in length and has an interior width of 5 feet 2 inches, or twice the width of the original kiln. Uniform temperatures are also obtained over this greater width. This kiln only requires approximately one-third more fuel to operate than the original kiln and yet has more than twice the capacity.

Protection on both design and process has been allowed by the U. S. Patent Office.

In conclusion, the writers wish to express their appreciation to Mr. Taine G. McDougal for his assistance in the preparation of this paper.

Discussions

BY C. B. HARROP:—For the firing of a shallow layer of small size ware, made from a body mix that will stand rapid heating and cooling, the above-described kiln is undoubtedly a real success. However, for capacities such as are being secured from some of the other tunnel kilns firing sanitary ware, general ware and electric porcelain, this type of kiln would undoubtedly be out of the question.

The writer has been much interested in this kiln and in reports that have filtered in concerning it, ever since it was put into operation, although for some reason the construction and operation of the kiln have always been kept close secrets by the owners.

The *surface combustion* firing equipment is probably responsible to a large extent for the success of the kiln. Any other system of fuel application would undoubtedly result in so much greater volumes of combustion gases that the temperature at the charging end of the kiln would be excessive and serious damage would occur to the entering ware. The *surface combustion* principle of firing gives an intense temperature in a restricted space which is absolutely necessary in a kiln of this length.

If the authors had given more real operating data their paper would be of far greater practical value. It would be very interesting to know:

- (a) Tonnage or number of pieces fired per 24 hours.
- (b) Cubic feet of gas required per 24 hours.
- (c) Total power required to operate kiln.
- (d) Labor required to operate kiln.
- (e) Cost of repairs—average over a long period.
- (f) Approximate total cost of kiln.

BY A. W. BUCKINGHAM:—The following discussion consists mainly of questions on points which should be emphasized in view of the fact that this kiln differs in a number of respects from the other makes.

Two features of this kiln illustrate a tendency in present day kiln construction which make for better control: First, the cross-section of this kiln is as small as possible, consistent with the production required.

Second, the large number of burners in the firing zone undoubtedly permits considerable flexibility in "soaking" time.

Other points have occurred in reading this paper which we believe the author should have brought out:

1. What is the approximate cost of the different kilns?
2. It is natural to suppose that heating up and cooling down a tunnel kiln would cause more or less wear and tear on the structure. The author states that after two years of operation there has been very little damage to the kiln on account of this intermittent operation. To what particular features of the construction or operation does he attribute this?
3. The width of the kiln is given in the paper but not the height of the crown of the arch above the deck of the kiln car. It would be interesting to know how much air space there is above the material being fired.
4. Drop arches in the preheating zone should serve as an effective baffle provided they extend down fairly close to the deck of the kiln car. How much below the crown of the main arch do these baffles extend?
5. Manufacturers of this grade of ware would be interested in learning what the unit fuel consumption is, that is, cubic feet of gas per ton of ware, etc.
6. The method of taking temperature for the full length of the kiln at 12 minute periods is a novel one and certainly should be very accurate. Does the author suggest this as being a practical method of taking temperatures at frequent intervals throughout the day?
7. The second installation is described as being about twice the width of the smaller one. What is the total burning time in the longer kiln as compared to the 12 hours for the first installation?

BY A. F. GREAVES-WALKER:—The kiln described is what would be termed a "Sport" in botany. It will do excellent work on such wares as

spark plug porcelains which are very small or on wares of thin section, or it could be used for decorating on some classes of ware.

It is an unqualified success; is cheap to construct and easy and cheap to operate. Furthermore, it is the ultimate in quick results.

It is out of the question, of course, to consider the use of this type of kiln for the vast bulk of ceramic products. The further development of its limited use is a question of the future.