No. 829,957. PATENTED SEPT. 4, 1906.

B. E. ELDRED.

APPARATUS FOR MAKING CEMENT CLINKER.

APPLICATION FILED AUG. 9, 1905.

7 SHEETS—SHEET 1.

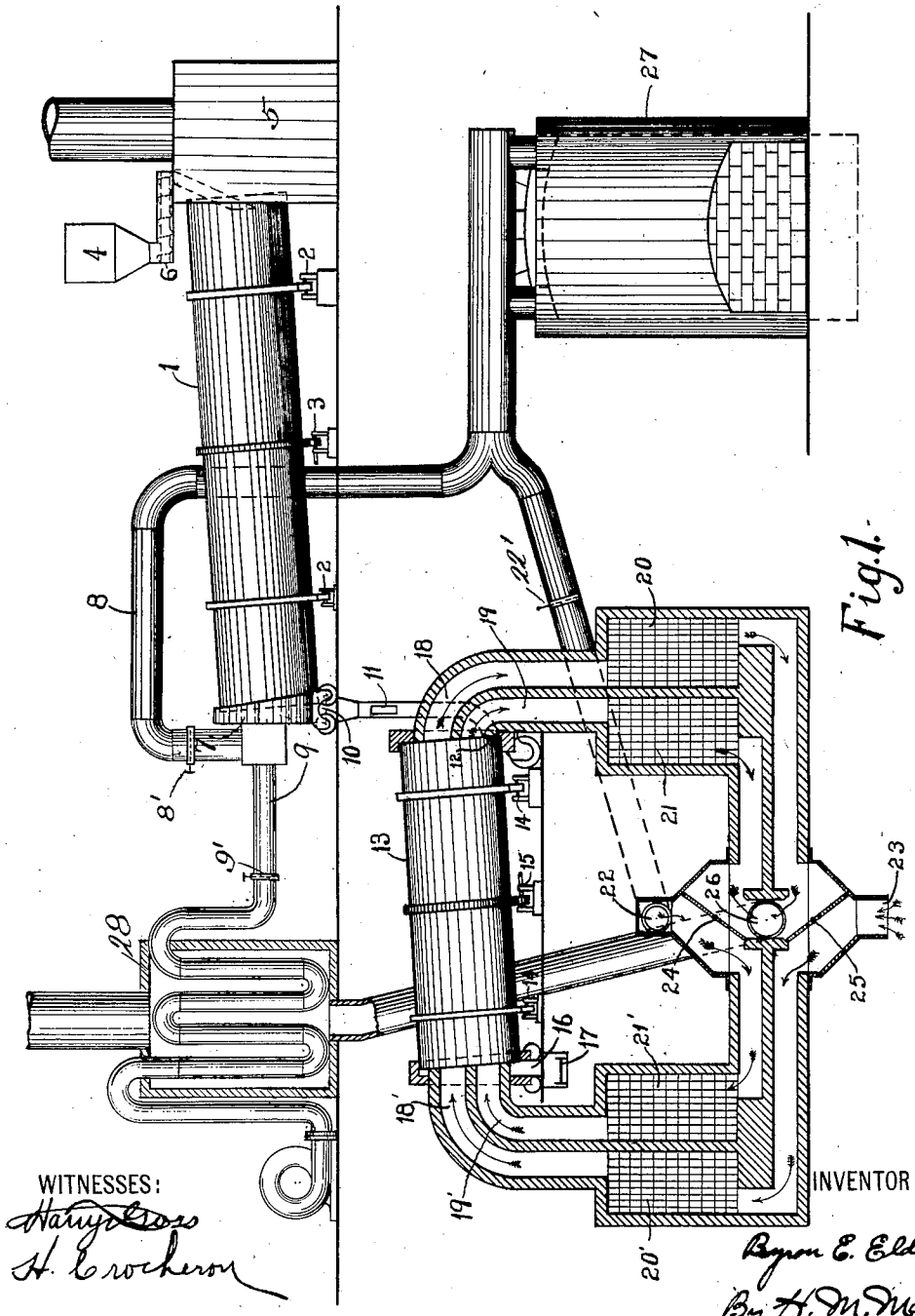

Fig. 1.

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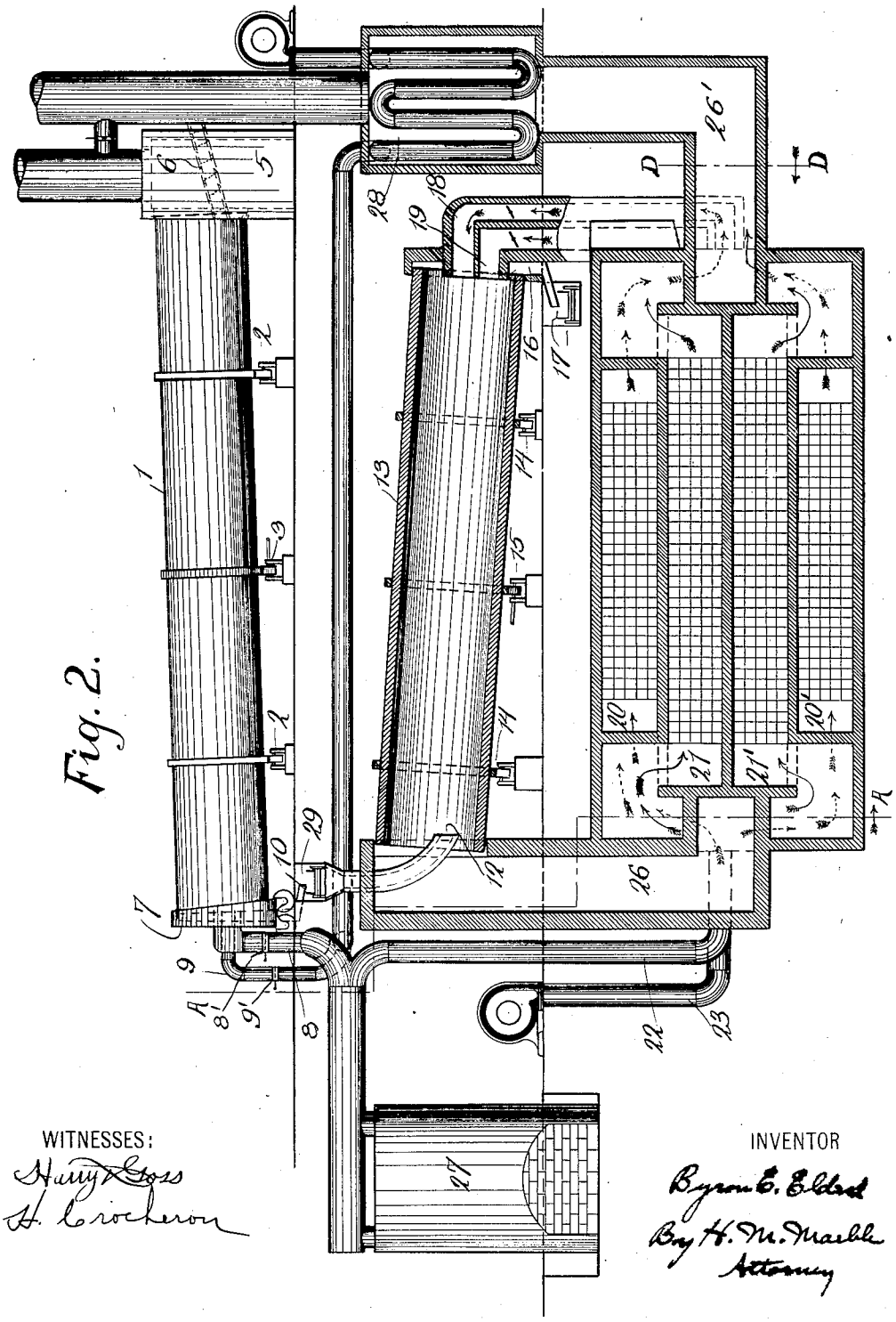

Fig. 2.

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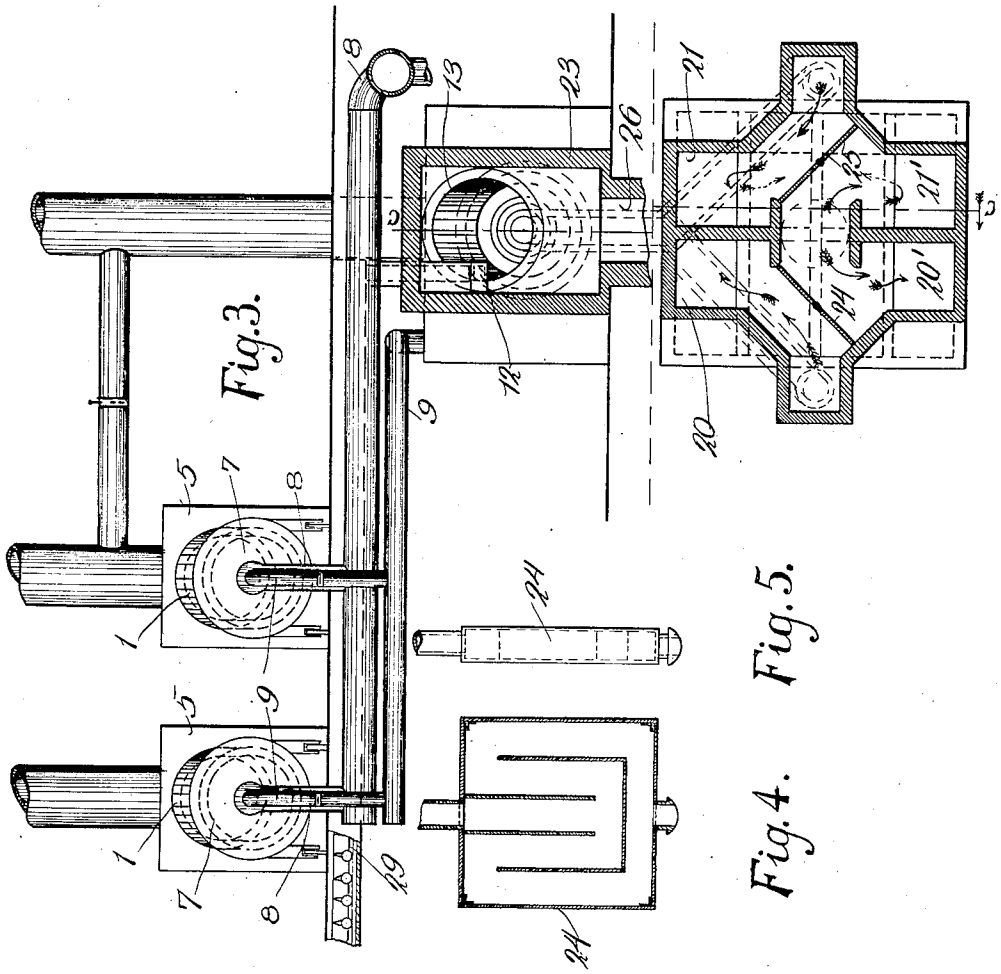

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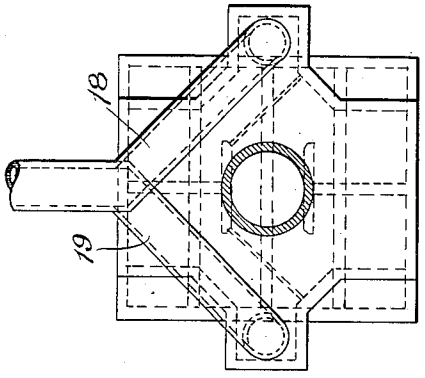

Fig. 8.

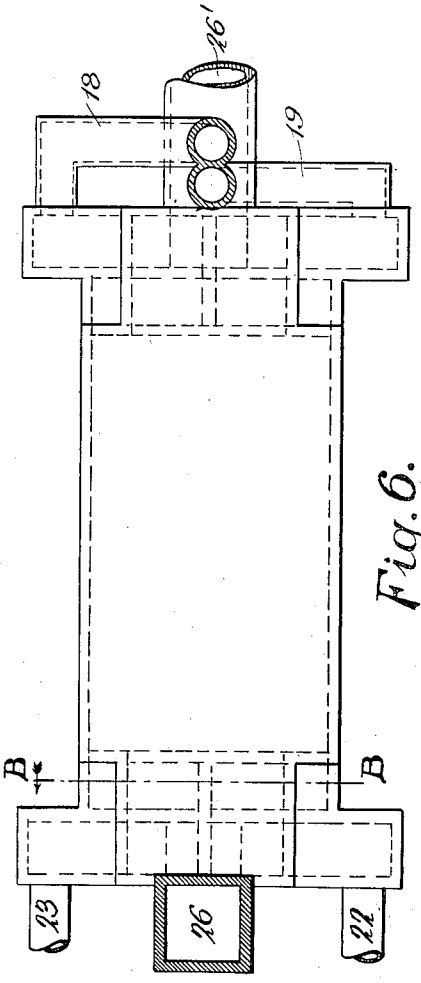

Fig. 6.

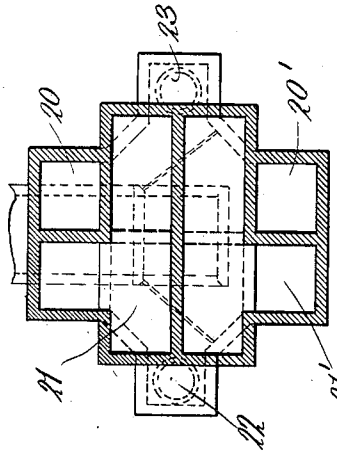

Fig. 7.

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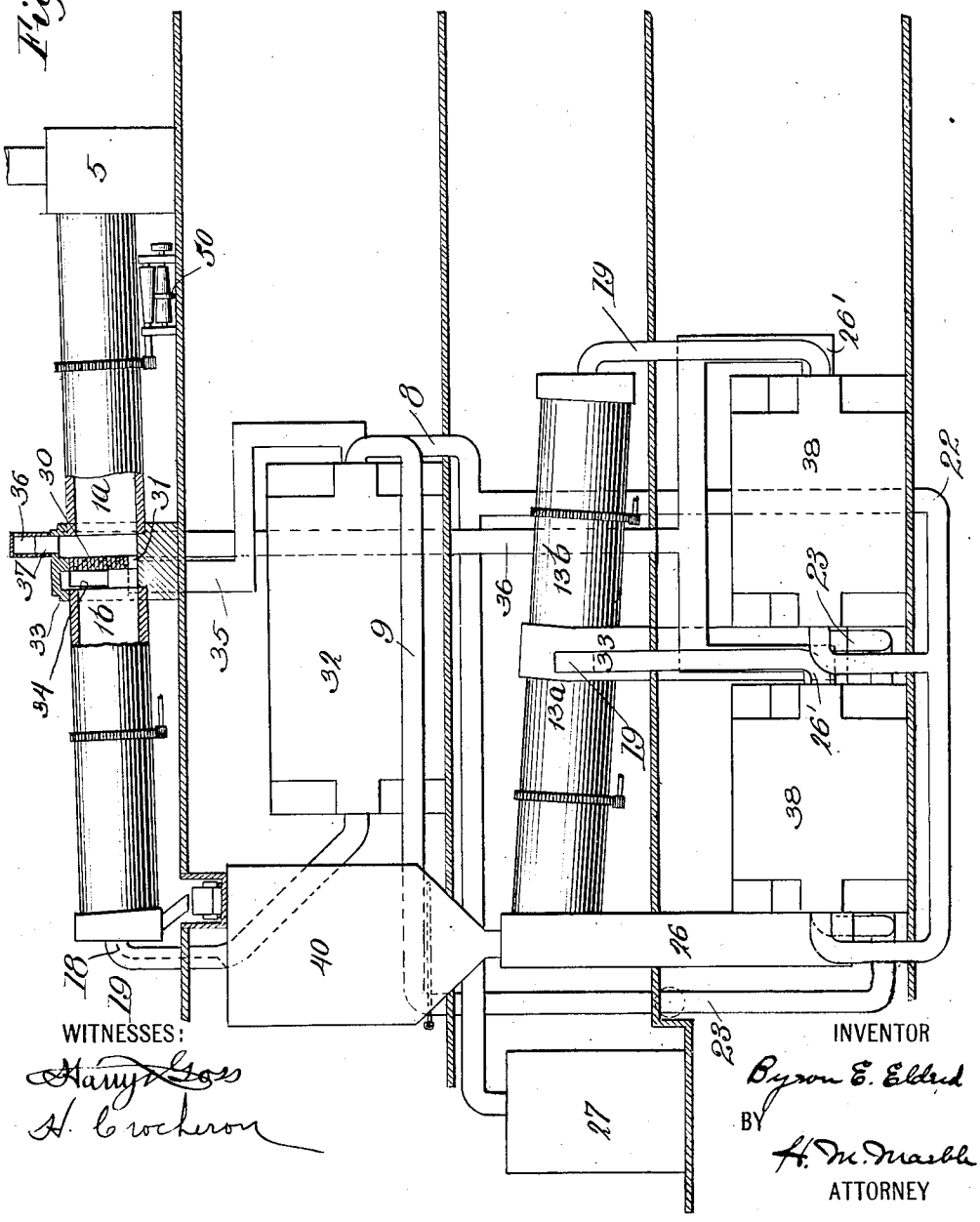
7 SHEETS—SHEET 5.

Fig. 9.



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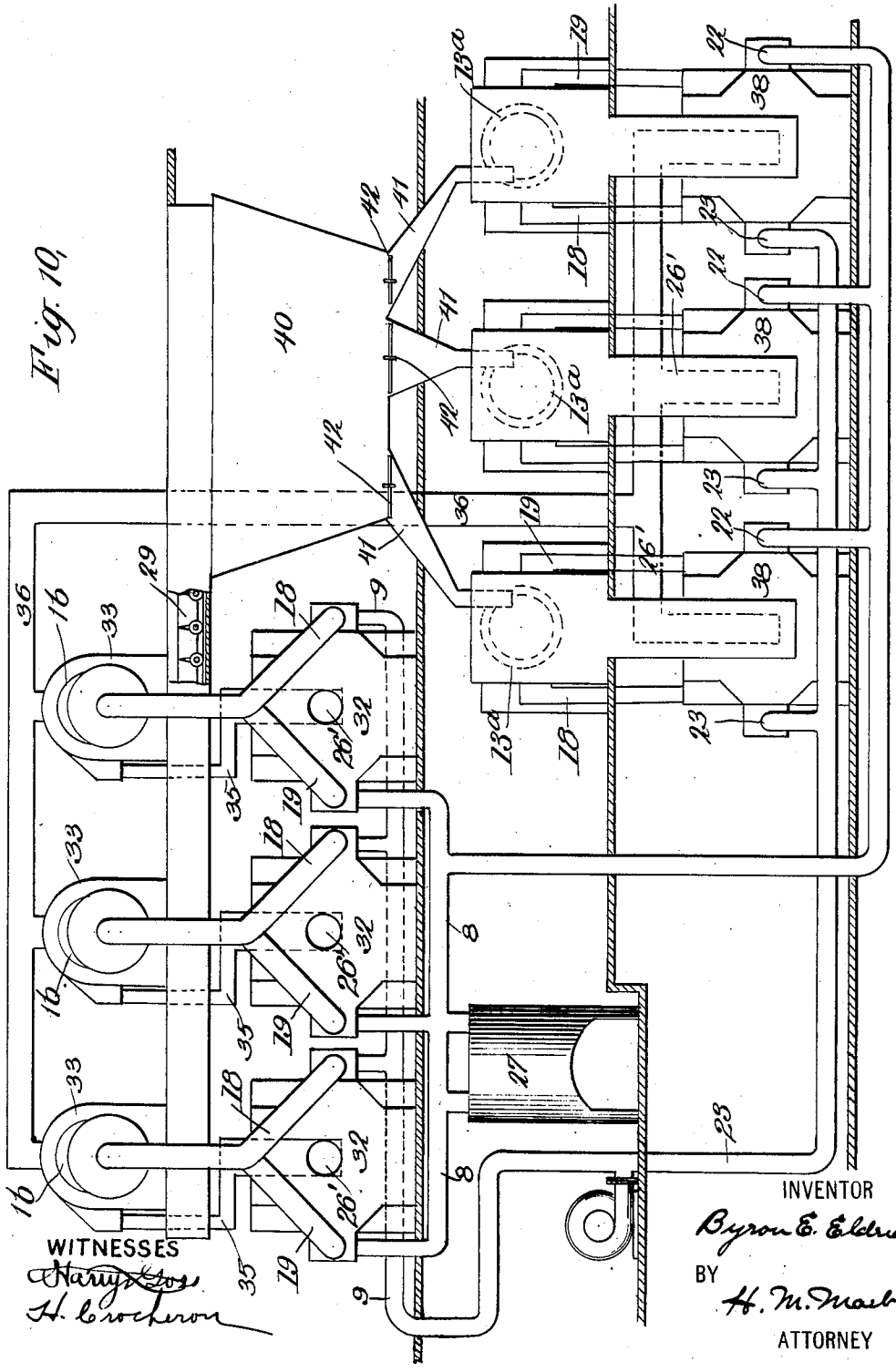
7 SHEETS—SHEET 6.

Fig. 10.



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APPARATUS FOR MAKING CEMENT CLINKER.

APPLICATION FILED AUG. 9, 1905.

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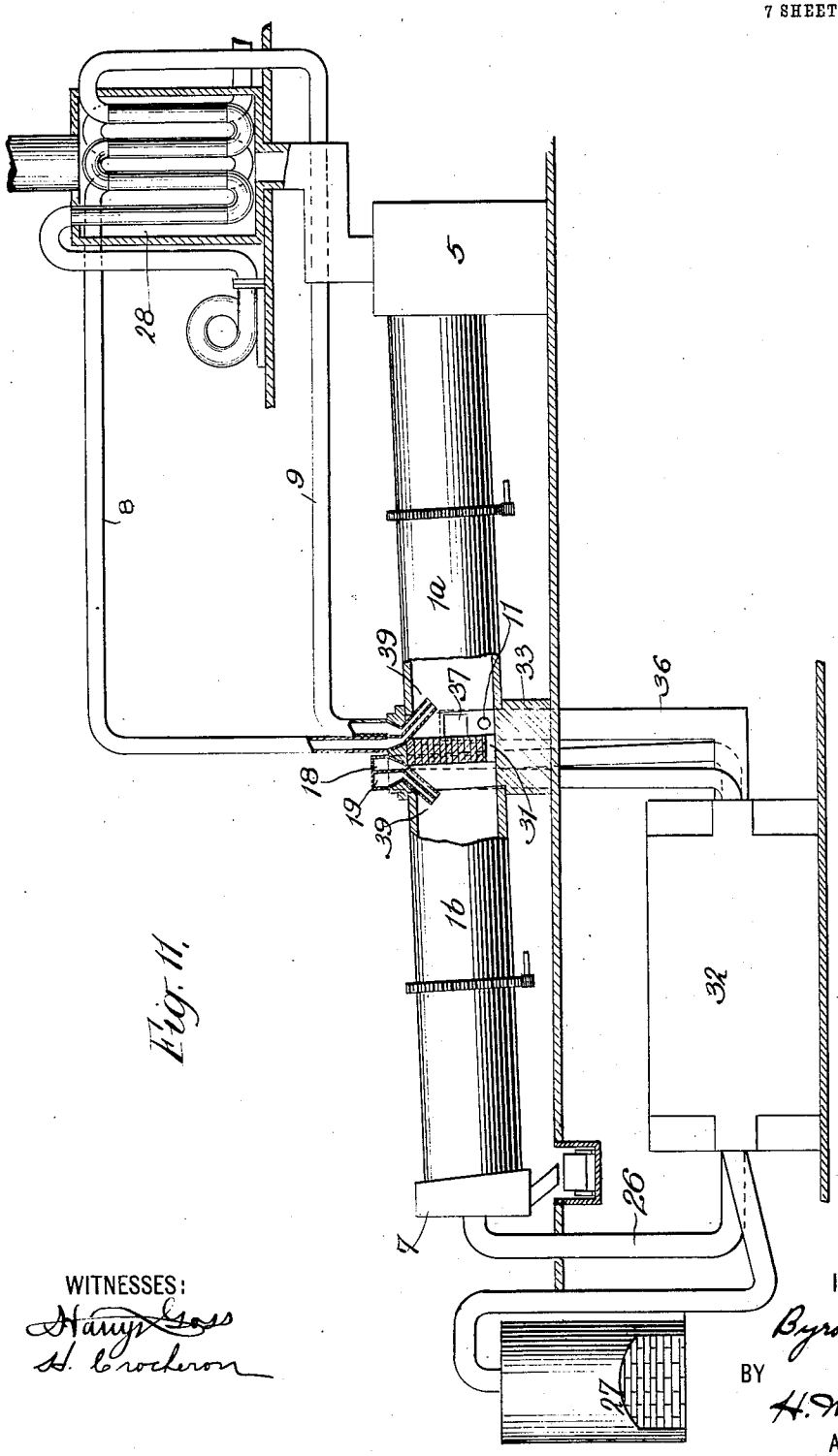

Fig. 11.

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UNITED STATES PATENT OFFICE.

BYRON E. ELDRED, OF BRONXVILLE, NEW YORK.

APPARATUS FOR MAKING CEMENT CLINKER.

No. 829,957. Specification of Letters Patent. Patented Sept. 4, 1906.

Application filed August 9, 1905. Serial No. 273,454.

To all whom it may concern:

Be it known that I, BYRON E. ELDRED, a citizen of the United States, residing in Bronxville, Westchester county, State of New York, have invented certain new and useful Improvements in Apparatus for Making Cement Clinker, of which the following is a specification.

This invention relates to apparatus for making cement clinker.

Said apparatus constructed in accordance with my invention comprises a plurality of heating-chambers or kilns arranged in series and arranged to perform separately and independently discrete stages of the clinker-making process, calcining and clinkering being performed each in a separate heating-chamber, the calcining-chamber provided with means for conducting the calcining in the immediate presence of large volumes of flame-gases and products of combustion, the clinkering-chamber comprising heating means independent of that of the calcining-chamber and each chamber arranged to perform its appropriate operation under such conditions of rate of feed, temperature, and other physical conditions as are best adapted for the operation.

Said apparatus also comprises, preferably, means for supplying producer-gas as fuel to the calcining-chamber or to the clinkering-chamber, or both, and heat-regenerating or heat-exchanging means, whereby the entering combustible, the entering air, or both, may be heated initially by waste heat.

Other features of the apparatus will be pointed out hereinafter.

In another application for Letters Patent, filed May 1, 1905, and serially numbered 258,414, in the Patent Office, I have described and claimed a process of burning cement material to form clinker wherein the preliminary heating, calcining, or causticizing is performed at one temperature and in one operation and the final heating or clinkering proper is performed at another temperature and as another operation. The invention herein illustrated, described, and claimed resides in apparatus for carrying out such a process and for carrying out other like processes to which it may be adapted.

In the manufacture of cement clinker the raw materials, usually clay and calcium carbonate, (limestone, chalk, marl, shells, &c.,) either naturally or artificially mixed, are furnaced together until the mixture becomes more or less homogeneous and frits or sinters—*i. e.*, enters into a state of "semifusion," as it is sometimes expressed. This final product in the art is termed "clinker," irrespective of whether it is in masses or is more or less pulverulent, and the word "clinker" is hereinafter used in that sense to express the finished material delivered by the kilns and ready for grinding into cement, irrespective of its particular physical shape.

The reactions active in the making of clinker are many and diverse, depending largely upon the character of the particular mixture employed; but two among them are always predominant. The first in the order of time is the causticizing of the lime and other strong bases—that is, the expulsion of the carbon dioxid of the calcium carbonate, as well as of other carbonates, such as that of magnesium. At the same time the water of the silicates, &c., chemically and mechanically bound, is also expelled. For brevity this stage may be called "calcining."

In the second main reaction in point of time the free bases formed in the calcining stage are presented to the action of the acidic components of the mixture being treated—*i. e.*, to the silica and silicates, as well as to the alumina, ferric oxid, &c., of the clay—and a number of complex compounds are formed, these being the substances which later confer the setting qualities on the finished cement. At the high temperature necessary for this stage, which may be called the "clinkering" operation, the silica, alumina, ferric oxid, &c., and the bases enter into reaction in a way not yet well understood and probably different with each special mixture of raw materials employed and the new compounds interpenetrate each other. Although the clinker is not completely fused, it is softened by the heat and the said new compounds probably form a series of "solid solutions" with each other.

The calcining reaction is endothermic and also dependent to a great degree on the principles of mass action, large quantities of heat being absorbed in the evolution of the carbon dioxid and in the other reactions, the evolution of the carbon dioxid being influenced by the character of the surrounding atmosphere. A great volume of heated gases is necessary to furnish the relatively great amount of heat required and also to furnish a diluting medium by which the carbon dioxid may be swept away as fast as formed and at the

point of formation, or, in other words, to form a preponderating mass of gas into which the carbon dioxid will diffuse as fast as liberated and by which its liberation will be facilitated; but since these reactions take place under these conditions at relatively low heats it is not necessary that the temperature of the gas mass be particularly high. What is required is a large mass of gases brought into close proximity to all particles of the material treated and containing in the aggregate a great amount of heat, but not necessarily at a very elevated temperature. These conditions I find to be best furnished in practice by supplying producer-gas and air to the calcining kiln or chamber, such gases and the products of combustion thereof passing in contact with and bathing all portions of the material treated. On the other hand, in the clinkering stage there is little or no gaseous product to consider; neither is there here any great absorption of heat; but a high temperature is necessary in order that the clinker-forming reactions, chemical and physical, may take place.

Comparing the heating conditions which are best adapted for carrying on the two operations, we may say, borrowing terms from another art, that in the calcining operation great amperage rather than high voltage is desirable, whereas in the clinkering operation high voltage rather than great amperage is wanted. It is apparent, therefore, that the conditions of temperature, combustion, &c., best adapted for clinkering are vastly different from those conditions best adapted for calcining and that it is difficult to obtain in a single kiln the diverse conditions required. Nevertheless, heretofore both operations have been conducted, customarily, in a single kiln, chamber, or furnace, the apparatus heretofore employed comprising a great variety ranging from the ordinary limekilns to the more modern rotary clinker-kilns, but the whole operation from the feeding in of the raw material to the delivery of the finished clinker being conducted in a single heating-chamber. In contradistinction to this former practice I employ separate heating-chambers, usually contained in separate kilns, for the calcining and for the clinkering, and may even subdivide the calcining stage or the clinkering stage, or both, by providing a plurality of heating-chambers for the stage so subdivided, performing a portion of the operation in one such chamber and then transferring the material treated to another chamber.

It will be appreciated readily, and practice shows it to be a fact, that when performing both calcining and clinkering in a single chamber or kiln, according to former practice, a delicate balance between the calcining and clinkering stages exists and must be maintained. A single flame must have its action so divided as to produce a relatively low temperature in the calcining zone and a relatively high temperature in the clinkering zone, and the operation of the kiln must be so regulated that just so much calcined material will be produced as can be completely sintered without overburning and with an approximation to maximum capacity of the kiln. If the action of the flame is exerted in too great measure during the calcining stage, too little of the flame remains for sintering, and vice versa. If the cement material passes from the calcining zone into the clinkering zone before it is sufficiently calcined, there may be such absorption of heat in the clinkering zone as to prevent attainment of a proper temperature for clinkering and the material discharged from the kiln will be improperly or insufficiently burned, while if the material is subjected too long to the clinkering heat the capacity of the kiln is reduced unnecessarily and the material may be overburned. The flow of the material through the clinkering zone can be regulated only by varying the flow of the material through the calcining zone. It will be obvious, therefore, that much skill is required of the attendant and that there is much probability that the product will often be uneven.

When the clinkering and the calcining are conducted in separate chambers or kilns in which the temperature, conditions of combustion, and, preferably, the rate of feed may be regulated independently, this delicate balance between the two operations no longer exists and the necessity for great skill in the handling of the apparatus no longer exists, it being easy to regulate the calcining so that the material treated is calcined to just the proper amount. It is also possible to regulate the clinkering with great nicety and to force the operation of the clinkering kiln—as, for example, by increasing its speed of rotation in the case of a rotary kiln—so that the material may be rushed through the clinkering-kiln, and thus a relatively small clinkering-kiln may be caused to perform efficiently a relatively large amount of work and a single clinkering-kiln may handle the product of a number of calcining-kilns of the same size. In fact, the calcining operation is one requiring considerable time as compared with the clinkering operation, which latter may be conducted very quickly with proper conditions of temperature.

By employing separate kilns or heating-chambers for the calcining and for the clinkering a great economy in the consumption of fuel is rendered possible, and it becomes practicable to use producer-gas as fuel in either or both kilns, and this is desirable, since producer-gas is, I believe, the cheapest and most satisfactory fuel for the purpose. By employing separate kilns or heating-chambers for calcining and for clinkering it further becomes

practicable to employ regenerators, and thus to economize greatly in the consumption of fuel.

Obviously, when both calcining and clinkering are performed in a single kiln, as has been the case heretofore, there is an enormous waste of heat, for it is obviously impossible with a single flame to produce a high temperature at one end of an ordinary large rotary kiln and a low-temperature large-volume flame extending from the central portion to the other end of the kiln without great waste of fuel. The conditions are contradictory. The heat which does the clinkering is of such character that it does but little calcining. I have found that carbon dioxid is given off most readily by a flame such that combustion takes place practically in contact with the material to be calcined. The producer-gas flame supplies this condition admirably, the gas burning somewhat slowly, so that the flame fills practically the entire length of the kiln, producing a flame of moderate temperature, such as is best adapted for calcining, the flame sweeping along the material being calcined.

A further advantage of the use of separate calcining and clinkering kilns, particularly when said kilns are of the ordinary nearly horizontal rotary type, is that kilns of moderate length may be used, and the use of powdered coal as a fuel may be avoided. When both calcining and clinkering are done in a single kiln, said kiln must be of excessive length, and because of its length and of the necessity of having a large volume of burning gases at its upper end it has been customary to use powdered coal as a fuel, notwithstanding the many disadvantages of such a fuel, among which may be mentioned the danger of explosion, the cost of pulverizing coal, and the contamination of the clinker with ash.

A further advantage of the use of separate calcining and clinkering kilns is that means for transferring waste heat from the outgoing gases to the incoming air and gas—such, for example, as regenerators—may be used in connection with the clinkering-kiln, and even in connection with the calcining-kiln, and thereby much heat is saved and the use of producer-gas of relatively low thermal value is rendered possible. When performing both calcining and clinkering in a single kiln, it is not practicable or advantageous to employ regenerators, both because the temperature of the gases discharged from the kiln is too low to raise a regenerator to a high enough temperature to aid materially in the production of the high temperature required for clinkering and because of the rapid choking of the regenerator by dust carried away from the material being calcined, and owing to the large volume of gases required for and produced in the process of calcination a regenerator, if used, would have to be of great size; but these difficulties disappear when the calcining and clinkering are performed separately. The gases discharged from the clinkering-kiln are then of relatively small volume, but are of very high temperature, and, moreover, since the cement-forming material is softened and agglutinated somewhat by the heat of the calcining-kiln before it is discharged into the clinkering-kiln there is practically no dust produced in the latter kiln, and hence little or no clogging of the regenerator. It is important to be able to use a regenerator in connection with the clinkering-kiln in order that fuel-gas of low thermal value may be employed, such gas—as, for example, what is termed "producer-gas"—being relatively cheap. To obtain a high temperature, such as required for clinkering when using for fuel gas of low thermal value, it is desirable, if not necessary, to raise its temperature considerably before combustion takes place and also to heat similarly the air supplied for combustion. The temperature of the gas and air being so raised, a very high temperature may be produced, for since the reaction of clinkering is not endothermic, to any material extent at least, the main heat losses encountered in the clinkering-kiln are occasioned by radiation, leakage, and the carrying away of heat by the material treated as it is discharged. These losses are not excessive, and so a very high temperature may be reached. The gases as discharged impart much of their heat to the regenerator, thus permitting high economy of operation.

The use of separate calcining and clinkering kilns also makes practicable the use of regenerators in connection with the calcining-kiln, for the gases discharged from this kiln, although relatively cold as compared with those discharged from the clinkering-kiln, nevertheless have a temperature approximating that required for calcining, and hence much of their heat may with advantage be imparted to the incoming gas and air. Furthermore, since the temperature in the separate calcining-kiln is relatively low it is not necessary to use as high blast-pressure as when both calcining and clinkering are conducted in a single kiln, and hence there is less dust produced in the separate calcining-kiln and relatively little clogging of the regenerator.

Instead of using a regenerator I may use a heat-exchanger or "recuperator"—such, for example, as the "stove" hereinafter mentioned—in connection with the calcining-kiln.

As the clinkering reactions are between basic and acidic components, there may be some heat evolved in the clinkering stage, so that the clinkering-kiln has often merely to raise the material treated to the proper temperature and possibly to supply a portion of the heat required to compensate for leakage, radiation, and other losses.

The temperatures for the calcining reaction range with some common mixtures between 1,200° and 2,000° Fahrenheit, and the temperatures for the clinkering reaction range with such mixtures from 2,500° to 3,000° Fahrenheit.

Broadly, therefore, my invention consists in an apparatus for producing cement clinker comprising a series of kilns or heating-chambers, preferably of the nearly-horizontal rotary type, through which the material treated passes successively, said kilns provided with means for regulating independently the temperature and other conditions affecting the operations, and the calcining-kiln provided with means for passing large masses of gases of suitable temperature and character over and through the material being treated.

I believe that I am the first to appreciate the difference in character and requirements of the several stages of the process and to devise an apparatus in which these several stages may be performed separately and independently and each under the conditions most favorable to it.

In its simplest form my apparatus comprises two heating-chambers which usually are rotary, are structurally separate, and are therefore termed "separate" kilns. In the first in point of use of these chambers the operation conducted is mainly that of calcination, while in the second chamber the operation conducted is mainly that of clinkering. The two operations—calcining and clinkering—will intermingle to some extent, however, some calcining taking place in the clinkering-kiln or some clinkering taking place in the calcining-kiln. The capacity of my apparatus to work with high efficiency notwithstanding this intermingling of the two steps of calcining and clinkering and the possible shifting of the transition-point from one kiln to the other and back again from time to time is indeed one of the great advantages of my apparatus, for it is this capacity of the apparatus which does away with the delicate balance between calcining and clinkering heretofore necessary to maintain and which does away with the necessity of great skill of the attendant. I do not limit myself, however, to the use of a first kiln capable of performing all of the calcination. On the contrary, the calcination may be divided between a plurality of kilns or chambers, and this will often be exceedingly desirable, as affording means for utilizing what is otherwise waste heat in the gases discharged from the clinkering-kiln or the regenerator thereof or for utilizing waste heat of any other portion of the apparatus or other apparatus in connection with which the clinker-making apparatus may be used. Similarly, the operation of clinkering may be divided between a plurality of heating chambers or kilns. Further, a plurality of calcining kilns or chambers may be arranged in parallel to discharge their product into a common clinkering-kiln, and said latter kiln may with great advantage be made of such size and proportions as to retain within it a dominant mass of the material treated, insuring a thorough averaging of the material and insuring a uniform product, and, similarly, a plurality of clinkering-kilns may be arranged in parallel to receive the calcines from a single calcining-kiln or series or group of such kilns. This arrangement of clinkering-kilns will be especially desirable in large plants, as one or more of the clinkering-kilns may be laid up for repairs at any time, the remaining clinkering-kilns being operated somewhat faster, so as to be able to treat the entire product of the calcining-kilns, and while ordinarily the product of the calcining kiln or kilns will be passed directly into the clinkering kiln or kilns it may at times be stored and subsequently charged into the clinkering-kiln. The main purpose of passing the calcines directly into the clinkering-kiln is to conserve the heat in such calcines, also to avoid re-handling.

Any of the ordinary types of kiln or furnace may be employed so long as it is adapted to furnish the conditions necessary to the particular stage of working for which it is used. For the calcining-kiln I may use any type of lime-kiln, an ordinary rotary kiln, (such as illustrated and described herein,) or a straight-line or circular or turret furnace, direct-fired and equipped with rabbles, and the calcined product may be discharged upon the shaking or rocking hearth of a high-temperature furnace to perform the clinkering proper.

Instead of employing separate kilns for the several stages of the operation a single kiln may be divided into a plurality of different chambers through which the material passes successively, such separate chambers constituting for many purposes the substantial equivalent of separate kilns. Any fuel suited to the particular type of furnace, kiln, or heating-chamber may be employed with either calcining or clinkering kiln, such as coal, coke, gas, oil, powdered fuel, &c. I may even employ electric heating, particularly for the clinkering-kiln. In fact, my invention is independent, broadly, of any particular method of heating either kiln. I believe, however, that producer-gas is most suitable and most economical as a fuel, and hence in the drawings have shown the apparatus equipped for using such gas.

A further important advantage of the use of separate kilns for performing different portions of the work of forming the clinker is that it is then practicable to have the material treated accessible for analysis during its passage from one kiln to the other and to treat the material as it passes into the second

kiln in any desired manner. Thus, for example, if the calcines show free lime to an undue amount silicia, clay, &c., may be added to the calcines before they enter the clinkering-kiln in proportion sufficient to satisfy the free lime found present. Vice versa, if the calcines appear too acid lime may be added to them before they pass into the clinkering-kiln. For this purpose I prefer to provide the conduit connecting the calcining and clinkering kilns with means for withdrawing samples and for adding qualifying substances.

To recapitulate, the advantages of my invention over the prior art are: (*a*) the delicate balance between calcining and clinkering heretofore existing is done away with and with it the necessity of great skill on the part of the attendant, and each stage of the operation is rendered independent of the other and may be carried on separately and, if desired, at different periods of time—*i. e.*, not continuously; (*b*) the operation may be conducted with much greater economy as to the consumption of fuel, less heat being required and the use of an exceedingly cheap and convenient fuel—*i. e.*, producer-gas—being practicable; (*c*) the use of regenerators is rendered practicable, and thereby much heat otherwise wasted may be saved; (*d*) each portion of the plant may be operated under the particular conditions of temperature, draft, and gaseous conditions most favorable to the operation carried on in it—a great advantage in calcining particularly; (*e*) shorter and less cumbersome kilns may be used, and a single clinkering-kiln may be used in connection with a plurality of calcining-kilns, or vice versa, and the clinkering and calcining kilns may be operated at different rates of speed, thus making it possible to force the operation of either one or the other, as may be desirable; (*f*) wear and tear on the kilns, due to sudden changes of temperature and to different temperatures in different parts, is greatly reduced; (*g*) ashless fuel may be used, thereby avoiding contamination of the clinker and avoiding also the risk and expense of using powdered fuel; (*h*) clinkering is under better control, and in cases where one clinkering-kiln is used in connection with several calcining-kilns a dominant mass of material may be maintained in the clinkering kiln to average up differences in the material entering it; (*i*) the material, while in an intermediate stage, may be analyzed and modified as desired; (*j*) because of the possibility of forcing either part of the apparatus as required, to compensate for breakdowns or the laying up of kilns for repairs, &c., the plant may be kept in operation to, or nearly to, full capacity to a much greater extent than is possible with other apparatus; (*k*) because of the relatively moderate temperature in the calcining-kiln and the high temperature in the clinkering-kiln without intermediate temperatures the formation of rings in the kilns, due to adhesion of partly-softened material thereto, will be avoided; (*l*) the waste heat of the clinkering operation may be used for drying the material treated and for initiating the calcination thereof. Still other advantages might be pointed out.

I will now proceed to describe certain specific forms of apparatus embodying my invention as above outlined, it being understood that the apparatus illustrated are only a few of the many different forms of apparatus that may be devised to carry out the basic ideas of my invention, all of which I regard as within the scope of the following claims.

In said drawings, Figure 1 shows diagrammatically a side view and partial section of a simple form of clinker-making apparatus embodying my invention. Fig. 2 shows diagrammatically a side view and partial section of a somewhat more elaborate apparatus constructed on the same principle. Fig. 3 shows an end view and partial section of the apparatus shown in Fig. 2, the view being taken on the line A A of Fig. 2. Figs. 4 and 5 are respectively a longitudinal section and a side view of a water-cooled valve such as may be employed in the regenerator shown in Figs. 2 and 3. Fig. 6 shows a top view of this regenerator. Fig. 7 shows a vertical transverse section thereof on the line B B of Fig. 6 looking in the direction of the arrow. Fig. 8 shows an end view of the regenerator and shows particularly the passages by which the heated gas and air are conveyed to the kiln. Figs. 9 and 10 are corresponding diagrammatic views of a plant comprising a plurality of calcining and clinkering kilns, Fig. 9 showing a side view, and Fig. 10 an end view, of the kilns. Both the calcining and the clinkering kilns shown in these two views are subdivided into a plurality of separate kilns or heating-chambers, a regenerator being employed in connection with one section of each calcining-kiln and the other section of each such kiln being heated by the hot gases discharged from the regenerators of the clinkering-kilns. These said views further show a plurality of calcining-kilns, a plurality of clinkering-kilns, and means whereby the product of the several calcining-kilns may be discharged into all or any part of the clinkering-kilns at will. Fig. 11 is a detail view illustrating how in a divided kiln, such as shown in Figs. 9 and 10, gas and air may be admitted to one chamber through the central belt and how products of combustion may be withdrawn from another chamber through such belt.

Referring first to the apparatus shown diagrammatically in Fig. 1, said apparatus comprises a calcining-kiln 1, a clinkering-kiln 13, a gas-producer 27, a regenerator for

the clinkering-kiln, and suitable piping, &c. The two kilns illustrated are substantially ordinary rotary inclined kilns. Kiln 1 is an inclined cylinder mounted upon roller-bearings 2 and arranged to be rotated by suitable gearing 3. The cement material is fed into this kiln from a hopper 4 by means of an automatic feeding device 6, indicated in the drawing as a screw conveyer. The ends of the kiln are closed by housings 5 and 7, of which 5 customarily contains devices for intercepting dust and delivers the gases discharged from the kiln into a suitable chimney. Pipe 8 supplies gas from producer 27, and pipe 9 supplies air, both pipes being provided with suitable regulating-valves 8′ and 9′, as shown.

The calcines pass from kiln 1 into a conduit 10, by which they are conveyed to the clinkering-kiln. In this conduit is an opening 11, normally closed, whereby samples of the calcines as discharged from kiln 1 may be obtained and whereby modifying materials may be introduced into said calcines, as previously mentioned.

Kiln 13 is similar in general construction to kiln 1, being an inclined cylinder having roller-bearings 14 and provided with driving-gearing 15. Conduit 10 discharges into this kiln at 12, and the finished clinker passes out at 16 into a conveyer 17. The regenerator for this kiln comprises, as is customary, twin sections, and in the construction shown each such section comprises two chambers 20 and 21 or 20′ and 21′, the former two chambers connected to the kiln by passages 18 and 19, respectively, the latter two chambers connected to the opposite end of the kiln by similar passages 18′ and 19′, respectively. The chambers 20, 21, 20′, and 21′ are filled with heat-absorbing material—such as what is commonly termed "checker-work," for example. Suitable valves 24 and 25 regulate the flow of gas and air into the kiln through the chambers of one section of the regenerator and the flow of the gases discharged from the kiln through the chambers of the other section of the regenerator. A pipe 22, provided with a regulating-valve 22′, supplies gas. Air enters through an opening 23, and the discharge-gases escape through an opening 26 and flow through a so-called "stove" 28, by which the air for the kiln 1 is heated, and thence into a suitable stack.

In the drawings valves 24 and 25 are set to cause the entering gas and air to flow through chambers 21′ and 20′, respectively, of the regenerator and to cause the gases discharged from the kiln to pass through chambers 20 and 21 of the regenerator. As is commonly the case in the operation of regenerators, these valves will be reversed from time to time, so that that side of the regenerator which has been heated up by the outflowing gases may be caused to impart heat to the incoming gas and air and so that the other side of the regenerator which has been so imparting stored heat to the entering gas and air may be heated up again by the discharged gases.

The operation of this apparatus is as follows: The material from which the clinker is to be formed is delivered from hopper 4 by feeding device 6 into kiln 1. In this kiln a relatively moderate temperature suitable for the calcining of the particular material treated is maintained by the combustion of the gas supplied by pipe 8. The kiln 1 is caused to rotate slowly, and thereby the cement material is caused to pass slowly down the length of the kiln, being constantly turned over as it does so, so that all particles of the material are subjected to the action of the heat. By this heat the carbon dioxid and moisture will be driven off, and customarily the material treated will have been softened somewhat by the time it reaches the lower end of the kiln, so that it tends to agglutinate into masses. This obviates trouble from dust in the regenerator of the second kiln. The material discharged from kiln 1 passes through conduit 10 into kiln 13, where it is subjected to the much higher temperature produced therein, owing to the fact that there is little or no heat absorption in this second kiln and owing to the initial heating up of the gas and air during their passage through the regenerator before combustion begins. In this second kiln sintering occurs, and as the material passes down through the kiln it is turned into finished clinker and falls into the conveyer 17, by which it is carried off to be cooled and ground in the ordinary way.

Since the two kilns are driven independently and are provided with independent means for regulating temperature and other conditions of combustion, each kiln may be operated at such temperature and rate of speed and with such other conditious affecting the reaction going on within it as are best suited for the material being treated. In general substantially all of the calcining will be done within kiln 1 and substantially all of the clinkering or sintering will be done within the kiln 13; but these two operations may interlace or overlap somewhat, or the sintering may begin within the kiln 1 or the calcining may be completed within the kiln 13. There is no necessity for great care to confine the two operations each to its appropriate kiln, and this absence of a delicate balance between the two operations avoids the necessity of placing the kilns in the charge of an attendant having great skill and good judgment. If no more than moderate intelligence and judgment is exercised by the attendant, the operations cannot go wrong. Notwithstanding the use of a fluel of low thermal value the high temperature desired in the clinkering-kiln will be attained be-

cause of the regenerator, and much of the heat contained in the gases discharged from the kiln will be absorbed in the regenerator to be imparted to the incoming gases when the valves of the regenerator are reversed.

From time to time samples may be withdrawn at 11 and if analysis shows it to be necessary modifying materials may be introduced at this point.

While no blower is shown for the supply of air to the second kiln, it will be understood that, as is ordinarily the case, the air admitted at 23 comes from a suitable blower or air-forcing device. While I have shown means for supplying the first kiln with hot air, it will be understood that the air may be supplied cold, if desired.

When both calcining and clinkering are done in a single kiln, trouble is occasionally experienced from the formation of "rings," due to adhesion of the softened material to the walls of the kiln. In this apparatus no such trouble is experienced, because the material as discharged from the calcining-kiln is not sufficiently softened to adhere and the temperature in the clinkering-kiln is so high that adhesion to the walls will not occur. In my apparatus there is no point of intermediate temperature at which adhesion and the formation of rings may take place as there is in single kilns in which both calcining and clinkering is done.

In the apparatus shown in Fig. 1 the direction of flow of the products of combustion through the clinkering-kiln is at times the same as the direction of flow of the material treated therethrough and at times in the opposite direction. For some purposes it is desirable that the flow of gases through the kiln shall be always in the same direction. The apparatus illustrated diagrammatically in Figs. 2 to 8, inclusive, is such an apparatus, the regenerator being provided with suitable valves, so that the direction of flow of gases through the kiln is always the same.

The kilns shown in Figs. 2 and 3 are substantially like those shown in Fig. 1 and no further description of them is required. As shown in Fig. 3, however, a plurality of calcining-kilns (two in the instance shown) discharge into the single clinkering-kiln shown. Each such calcining-kiln discharges it calcines into a conveyer 29, operating, preferably, in a closed conduit, as shown, by which means the heat of the calcines is conserved, and this conveyer discharges the calcines into the common clinkering-kiln 13. As in the apparatus shown in Fig. 1, the regenerator comprises four chambers—viz., 20, 21, 20′, and 21′; but for convenience these chambers are placed close together, as shown, and valves 24 and 25, arranged as shown in Fig. 5, are placed at each end of the regenerator, so that air from pipe 23 and gas from pipe 22 may be directed into chambers 20 and 21 and thence through passages 18 and 19 into the kiln, and discharge-gases from flue 26 may be directed through chambers 20′ and 21′ into the offtake 26′, or vice versa. The operation of this second form of apparatus is in every respect the same as of the apparatus shown in Fig. 1, and hence it is unnecessary to repeat the description thereof. Obviously the same clinkering-kiln may handle the product of a greater number of calcining-kilns than the two shown in Fig. 3, and the number of such calcining-kilns may be increased at will up to the maximum capacity of the clinkering-kiln when operated at the highest desirable speed.

Since the valves of the apparatus shown in Figs. 2 and 3 are exposed to the gases discharged from the kiln and from the regenerator to such an extent as may lead to overheating of said valves unless the latter be cooled positively, I may make said valves hollow, as shown in Figs. 4 and 5, and circulate air or water therethrough to keep them cool.

The clinkering-kiln of the apparatus shown in Fig. 2 may be made of such size that it will retain within it a dominant mass of the material being treated, so as to average the product of the different calcining-kilns, avoiding sudden changes in the composition of the clinker and insuring a product which shall be substantially uniform in composition.

In the apparatus shown in Figs. 2 and 3 the conveyer 29 forms a convenient means for withdrawing samples of the calcines for analysis or test from time to time and for adding modifying substances when necessary.

Inasmuch as when separate calcining and clinkering kilns are employed the calcining-kiln may be operated with less blast-pressure than the single long combined calcining and clinkering kilns heretofore employed, less trouble from dust will be experienced in the calcining-kilns of my apparatus, thus rendering practicable and economically desirable the use of regenerators or recuperators in connection with the calcining-kilns. Heretofore when using a single kiln both for calcining and for clinkering there has been little advantage in using a regenerator, for so much heat is absorbed in calcining that notwithstanding the high temperature at the clinkering end of the kiln the gases discharged are of too low temperature to heat a regenerator to a high enough temperature to justify the use of the regenerator in seeking to attain the high temperature required for clinkering; but the temperature desired for calcining being so much lower when only this lower temperature is desired the regenerator becomes practicable and economical.

In Fig. 9 I have shown a calcining-kiln divided into separate chambers 1^a and 1^b by a wall 30, the material treated being admitted

first to chamber 1^a and thence passing through an opening 31 in the bottom of wall 30 into chamber 1^b. Chamber 1^a is heated by waste gases discharged from the regenerators of the clinkering-kilns, and chamber 1^b is heated by a gas-flame, the gas and air for which are preheated by a regenerator 32.

Most of the dusting will be found to occur in 1^a, where the heat first meets the calcining mass, and the use of a regenerator with 1^b is therefore practicable.

In the particular construction of kiln 1^a 1^b shown each of the two chambers of the kiln has a separate rotating cylinder, the adjacent ends of these cylinders fitting into a central belt or housing 33, containing the dividing-wall 30, above mentioned. Each of these cylinders may and customarily will be provided with its own driving mechanism, so that the two cylinders may be rotated at different speeds as desired. Such a construction may be regarded as a single kiln divided into separate heating-chambers or as two kilns arranged in series with respect to each other, and obviously there may be a greater number than two of such heating chambers or kilns arranged in series, if desired.

The products of combustion from chamber 1^b pass into a port 34 of housing 33 and thence through a flue 35 to the regenerator 32. This regenerator may be understood to be similar in construction to the regenerator illustrated in detail in Figs. 2 to 8, inclusive. The waste gases discharged by the regenerators of the clinkering-kilns are collected by a flue 36 and thence are delivered to the chamber 1^a of the calcining-kiln through a port 37 of housing 33.

In Fig. 9 I have also shown the clinkering-kiln divided into separate sections, chambers, or kilns arranged in series, these chambers being designated 13^a and 13^b, respectively. The material discharged from the calcining-kiln passes first into chamber 13^a of the clinkering-kiln and thence into chamber 13^b. I have shown each chamber of the clinkering-kiln as provided with its own regenerator 38. These chambers being therefore relatively short and having independent flames, a very high temperature may be obtained in either, or both, if desired, or the temperature in the two chambers varied as desired.

Numeral 50 designates a simple speed-changing device consisting of a pair of coned pulleys and belt applied to the driving-shaft of kiln 1^a, which may be used to control the speed of rotation of the kiln, and hence the rate of feed of material therethrough. Such speed-changing devices, either of the type shown or of any other, may be applied to the other kilns shown.

In Fig. 11 I show how gas and air may be admitted to the chambers of a double kiln, like that shown in Fig. 9, through the central housing 33. Said housing is provided with nozzles 39, having separate passages for the air and gas, which nozzles direct the flame as desired. Such a double kiln may be used as a complete clinker-making kiln, one chamber forming the calcining-chamber, the other the clinkering-chamber. Obviously the chamber 1^a of the kiln shown in Fig. 9 may have the action of the gases from the clinkering-kilns or regenerators supplemented by combustion of gases supplied by nozzles 39, such as shown in Fig. 11.

In the operation of apparatus such as shown in Figs. 9 and 10 the action going on in the first chamber 1^a will be mainly a drying action, the moisture being driven off. Nevertheless some calcining may be done in this chamber. In the second chamber 1^b the remainder of the calcining will be done, and some of the clinkering may even be done here. The material discharged from kiln 1^a 1^b passes into conveyer 29 and thence passes into the clinkering kiln or kilns.

It will often be desirable to employ a plurality of clinkering-kilns arranged in parallel. This is illustrated particularly in Fig. 10, a bank of three such kilns (designated by numerals 13^a) being shown, together with means for discharging the calcines into all or any less number of the clinkering-kilns. The conveyer 29 discharges into a hopper 40, and chutes 41 lead from this hopper to the several clinkering-kilns. Each of these chutes is provided with a suitable shut-off device 42, by which the proportion of the calcines going to the corresponding kiln may be regulated or the supply of calcines to such kiln stopped entirely.

Obviously the number of calcining-kilns and the number of clinkering-kilns may be as great as desired. In the event of the shutting down of any one or more of the clinkering-kilns the remainder may be operated at greater speed to take care of the calcines, and thus it is practicable to keep a plant operating constantly at full or nearly full capacity.

It will be obvious that the above are but a few of many forms of apparatus that may be devised for carrying out the basic principles of my invention and that I do not limit myself to the particular constructions illustrated and described.

While I have shown all of the various kilns or heating chambers as heated with gas-flames, I may use instead any other method of heating—as, for example, electric heating.

It will be obvious to those skilled in the art that owing to the fact that in my apparatus the temperature in each kiln or heating-chamber is nearly uniform throughout and there are no great extremes of temperature in different parts of the same kiln or chamber the wear and tear on the kilns is relatively small. The clinkering-kiln being sub-

ject to a constant high heat without sudden severe diminution of temperature, is better adapted to stand up under the severe work it is required to perform. The flexibility of the entire apparatus permits the forcing of any part of it and the "rushing" of any part of the operation, making the cement manufacturer independent whenever repair of one or more of the kilns is necessary.

I employ the term "regenerator" herein in a generic sense to include all forms of apparatus for transferring waste heat from outgoing to incoming gases.

What I claim is—

1. In a clinker-making plant, the combination of an internally-fired calcining-kiln provided with regulable means for controlling the rate of feed of material therethrough, and separately-heated clinkering means.

2. In a clinker-making plant, the combination of an internally-fired rotary calcining-kiln and separate independently-heated clinkering means.

3. Clinker-making apparatus comprising a plurality of independent internally-fired rotary chambers arranged successively to receive the material treated one from the other and provided with independent flame-producing means.

4. Clinker-making apparatus comprising an internally-gas-fired rotary calcining-chamber and an internally-fired clinkering-chamber connected thereto and receiving the clinker-forming material therefrom, said chambers having individual burners.

5. In clinker-making apparatus, a calcining-chamber provided with means for passing clinker-forming material past an internal flame sufficient to calcine the same, said means being regulable to control the speed of passage, a separately-heated clinkering-chamber receiving calcines therefrom and means for transferring the calcines from the calcining-chamber to the clinkering-chamber.

6. In a clinker-making plant, the combination of separate rotary calcining and clinkering kilns, independently heated, the former internally fired.

7. In a clinker-making plant, the combination with a source of gas-supply, of separate calcining and clinkering chambers independently connected to said source of supply, the former internally fired and means for conveying the calcines from the calcining to the clinkering chamber.

8. Clinker-making apparatus comprising a plurality of calcining-chambers and a common clinkering-chamber arranged to receive calcined material from all said calcining-chambers.

9. Clinker-making apparatus comprising a plurality of calcining-chambers and a common clinkering-chamber adapted to receive calcined material from all said calcining-chambers, and of such size and proportions as to maintain a dominant mass of material therein.

10. In a clinker-making apparatus, the combination of a calcining-chamber, a separate clinkering-chamber with independent heating means and provided with a heat-regenerator, and means for conveying calcines from the calcining-chamber to the clinkering-chamber.

11. In a clinker-making apparatus, the combination of a calcining-chamber, an independent gas-fired clinkering-chamber provided with a heat-regenerator, and means for conveying calcines from the calcining-chamber to the clinkering-chamber.

12. In a clinker-making apparatus, the combination of a calcining-chamber provided with air-heating means, a separate, independently-heated clinkering-chamber receiving calcines therefrom and means conveying calcines from the calcining-chamber to the clinkering-chamber.

13. In a clinker-making apparatus, the combination of an internally-fired calcining-chamber, means for introducing air heated by waste gases thereinto, a separate, independently-heated clinkering-chamber and means for conveying calcines from the calcining to the clinkering chamber.

14. In a clinker-making apparatus, the combination of a gas-fired calcining-chamber, means for feeding heated air to the gas-firing means, a gas-fired clinkering-chamber provided with a heat-regenerator and means for conveying the calcines from the calcining-chamber to the clinkering-chamber.

15. In a clinker-making apparatus, the combination of a calcining-chamber provided with heating means including a heat-regenerator, a clinkering-chamber provided with independent heating means, and means for conveying calcines from the calcining-chamber to the clinkering-chamber.

16. In a clinker-making apparatus, the combination of a gas-fired calcining-chamber provided with a heat-regenerator, an independently-heated separate clinkering-chamber and means for conveying calcines from the calcining-chamber to the clinkering-chamber.

17. In calcining means, the combination of a plurality of calcining-chambers provided with independent heating means, said chambers arranged in series and connected to treat successively the material to be calcined.

18. In calcining means, the combination of a plurality of chambers provided with independent heating means, one of said chambers being gas-fired, said chambers arranged in series and connected to treat successively the material to be calcined.

19. In clinker-making apparatus, the combination with calcining means comprising a plurality of chambers arranged in series, of a clinkering-chamber provided with heating means, and means for conveying hot gases from said clinkering-chamber to one of said calcining-chambers.

20. In clinker-making apparatus, the combination with calcining means comprising a plurality of chambers arranged in series, of a clinkering-chamber provided with heating means, means for conveying hot gases from said clinkering-chamber to one of said calcining-chambers, and means for heating the remainder of said calcining means.

21. In clinker-making apparatus, the combination with calcining means comprising a plurality of chambers arranged in series, of a clinkering-chamber provided with means for heating it and with a heat-regenerator, means for conveying hot gases from said heat-regenerator to one of said calcining-chambers, and means for heating the remainder of said calcining means.

22. In clinker-making apparatus, the combination with calcining means, of a clinkering-chamber provided with heating means, and regenerative means for conveying waste heat from said clinkering-chamber to said calcining means.

23. In clinker-making apparatus, the combination with a clinkering-chamber provided with heating means, of calcining means provided with independent means for producing combustion therein, and means for conveying hot gases from said clinkering-chamber into said calcining means.

24. A heating-kiln comprising a plurality of rotary chambers arranged in series and having independent heating means, and means dividing said chambers from one another, provided with means for permitting passage of the material treated from one chamber to another.

25. A heating-kiln comprising a plurality of rotary chambers arranged in series and having adjacent ends fitting into a housing, said housing provided with flues for the escape of products of combustion, means separating said chambers but permitting passage of the material treated from one chamber to another, and means for heating said chambers.

26. In clinker-making apparatus, the combination with calcining means, of clinkering means comprising a plurality of chambers arranged in series and connected to treat successively the material to be clinkered, and means for heating said chambers independently.

27. In clinker-making apparatus, the combination with calcining means, of clinkering means comprising a plurality of gas-fired heating-chambers arranged in series and connected to treat successively the material to be clinkered, and heat-regenerating means.

28. In clinker-making apparatus, the combination with a plurality of calcining means and a common clinkering means therefor, of means for conveying the calcines to said clinkering means.

29. In clinker-making apparatus, the combination with a plurality of calcining means, of a conveyer arranged to receive calcines therefrom, and clinkering means to which the conveyer delivers said calcines.

30. In clinker-making apparatus, the combination with calcining means, of a plurality of clinkering means, and distributing means for distributing calcines thereto, and provided with means for cutting off the supply of calcines to one of said clinkering means.

31. In a clinker-making apparatus, the combination of calcining means, means for controlling the rate of feed of material therethrough, separate clinkering means, a gas-producer connected to supply gas to both calcining and clinkering means, said calcining and clinkering means having separate, individually-regulable gas-burning means, and means to convey calcines from the calcining means to the clinkering means.

32. In clinker-making apparatus, the combination of calcining means, independent clinkering means provided with a heat-regenerator, a gas-producer connected to supply gas to both calcining and clinkering means, said calcining and clinkering means having separate, individually-regulable gas-burning means, and means to convey calcines from the calcining to the clinkering means.

33. In a clinker-making apparatus, the combination of calcining means, means for controlling the rate of feed of material therethrough, separate clinkering means, a gas-producer supplying gas to said calcining means, and means for conveying calcines from the calcining means to the clinkering means.

34. In a clinker-making apparatus, the combination of gas-fired clinkering means, gas-fired calcining means separate therefrom and provided with a heat-regenerator, a gas-producer connected to supply gas to burning means in the clinkering means and to burning means in the calcining means, and means for conveying calcines from the calcining means to the clinkering means.

35. In cement apparatus, a kiln composed of a plurality of successive chambers, each provided with individual heating means, and adjacent chambers being divided by partitions constructed to allow the transit of solid material therethrough while thermally isolating said chambers.

36. In an inclined horizontal kiln, the combination of a plurality of successive rotatable chamber-forming sections, stationary partition-walls between adjacent sections provided with passage-ways permitting transit of solid material from chamber to chamber, end walls for the sections at either end of the series, and individual heating means for the chamber formed by each section.

In testimony whereof I hereunto affix my signature in the presence of two witnesses.

BYRON E. ELDRED.

Witnesses:
H. M. MARBLE,
JAS. K. CLARK.