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KILN FOR HEAT-TREATING MATERIALS

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1 Claim. (Cl. 25--142)

This invention relates to improvements in kilns for heat treatment of materials such as clay, shales and the like and a kiln therefor.

Therefore in kilns for treating materials at very high temperatures wherein the kiln employs an endless conveyor for conveying the material to be treated through the kiln, it has been thought necessary to employ a conveyor surface composed of slabs of refractory material and usually a thin film of sand or other suitable granular material is spread over the refractory slabs to serve as a parting compound. These refractory slabs have not proven entirely satisfactory, but it has been thought necessary to use such materials because of the deleterious effect that high temperatures have upon metals. It has also been considered necessary in the past to pre-dry clays, shales, and the like at temperatures ranging up to 900° F. before subjecting the material to higher temperatures required in the treatment in order to prevent portions of the material from popping or exploding off the main body of the clays or shales. This pre-heating treatment is both expensive and time consuming. In addition when it has been desired to treat clay products, shales and the like to provide a bloated material, it has been deemed necessary to spread a thin layer of granulated clay or the like upon the conveyor and pass this thin layer of material through the kiln where it is subjected to bloating temperatures ranging from 1000° F. to 2200° F. This treatment is so slow that rotary kilns have been resorted to for the purpose of forming light weight or bloated materials and even then the results have not been satisfactory.

It is an object of this invention to provide a kiln for treating materials such as clay, shale, and the like at elevated temperatures in which a metal conveyor may be employed for conveying the material to be treated through the kiln.

Another object is to provide a kiln for treating materials at high temperatures wherein an endless metallic conveyor carries the material through the kiln and a means is provided for protecting the material of the conveyor from exposure to the temperature within the kiln.

Still another object is to provide a kiln with a conveyor material to be treated through the kiln in which a flat support surface is closely associated with the conveyor for supporting a layer of granular insulating material covering the portion of the conveyor which extends through the kiln and means is provided for continuously applying a layer of insulating material to the surface.

Other and further objects of this invention will appear from the following description.

The accompanying drawings, which form a part of the instant specification, are to be read in conjunction therewith, and wherein like reference numerals are employed to designate like parts in the various views:

Fig. 1 is a side elevational view of a kiln embodying this invention;

Fig. 2 is a cross-sectional view taken along the line 2—2 in Fig. 1 in the direction of the arrows;

Fig. 3 is a side elevation view mostly in plan but with parts broken away to illustrate the construction of a chain type conveyor in accordance with this invention;

Fig. 4 is a side elevation view along the line 4—4 in Fig. 1 in the direction of the arrows;

Fig. 5 is a side view of one of the links from which the chain shown in Figs. 3 and 4 is fabricated;

Fig. 6 is a detail or fragmentary view of the discharge end of the kiln shown in Fig. 1;

Fig. 7 is a side elevational view upon a fragmentary scale illustrating the stacked arrangement of material to be treated upon the insulation layer which covers the conveyor;

Fig. 8 is a plan view of the kiln shown in Fig. 1;

Fig. 9 is a view illustrating a modified form in which the material to be treated may assume;

Fig. 10 is an enlarged front elevational view of the shoe for regulating the thickness of the layer of granular insulation material covering the conveyor in the kiln of Fig. 1; and,

Fig. 11 is a graph of the curves of which may be employed to determine the required thickness of the layer of granular insulation material.

In general this invention is concerned with the heat treatment of materials, such as clays, shale or the like at elevated temperatures. The invention is especially adapted but not limited to the treatment of bloatable ceramic materials such as certain clays and shales or centered material to form light weight expanded objects. By way of illustration and not by way of limitation the invention will be described in conjunction with its application to the bloating of clay and the like. The material to be treated is preferably formed into objects having sufficient strength to support their own weight and having substantially uniform wall thicknesses. These objects are placed upon a moving hearth and pass through a kiln within which the temperature is maintained at bloating temperatures usually within the range of 1800° F. to 2200° F.

During this bloating period, the material as-
sumes a plastic state and upon discharge from the kiln the material is permitted to cool to the rigid state and then the forms of the material may be disposed of in the fashion desired. The conveyor for carrying the material through the kiln preferably is made of mild steel because of its cheapness and ruggedness. This material of the conveyor is deleteriously affected if its temperature is raised to the temperature existing within the kiln. For this reason a layer of granular or finely divided insulating material is placed over the conveyor and supported on a flat surface which is associated with the conveyor. Of course the insulating material should have a fusion point greater than the temperatures to which it will be exposed within the kiln. It has been found that the thickness of the layer of insulating material required for given conditions of time of treatment, permissible temperatures of the conveyor, and temperature within the kiln can be determined experimentally or a safe thickness may be determined by use of a mathematical expression hereinafter more fully developed.

It is well known that practically all clays or shales, under ordinary conditions, if rapidly heated to temperatures exceeding 900° F. will have fragments exploded off probably due to the formation of steam within the material itself. It has been found, however, that if the clay or shale is quite moist so as to contain free water that this spilling, exploding, or popping off of the material is eliminated. If the moisture content of the clay or shale is adjusted to permit forming of the material under pressure, such as is commonly known in the industry as pug mill where the material is extruded through dies, these forms or objects may be passed directly and quickly into a kiln at temperatures between 1000° F. and 2200° F. for the purpose of bloating the material. The customary pre-drying at relatively low temperatures may be dispensed with, thus eliminating the expense involved in the pre-heat treatment and also reducing the time of total treatment. Usually in the adjustment of the moisture content of the material, particularly where the material has been dug for several days and has lain exposed to the atmosphere, it is necessary to add water to the clay or shale in order to give it sufficient plasticity to be formed into self-supporting forms when subjected to pressure as in a pug mill. On the other hand, if the material is taken directly from marshy or swampy ground, the material may contain such a high degree of moisture as to require some drying before it is introduced into the forming machinery. In any event, the moisture must be adjusted and it has been found that when this relative moist material, as it is extruded from the pug mill, is subjected to the elevated temperatures even as high as bloating temperatures, that quite unexpectedly no explosion takes place. A great number of clays and shales have been treated in this fashion, including a shale obtained at Strawn, Texas, and several varieties of Beaumont clays and in no instance have these clays had a tendency to pop or explode when subjected in the moist state directly to the intense heat of the kiln for the purpose of causing the clays to bloat. These same materials, on the other hand, are very bad about spilling and exploding or popping-off unless this moisture content adjustment is first made or unless the clays are first subjected to a pre-heating treatment at temperatures preferably between 400° F. and 800° F. for some one to six hours.

Referring now to the details of the kiln shown generally at 10 in the drawings, the kiln proper is a furnace having walls made of refractory material 31 or having refractory material lining. The upper portion of the kiln may carry a layer of sand or the like 32 for added insulation. The kiln 10 has a fire box 11 with suitable openings 12 therein, communicating with pipes 13 for supplying fuel such as gas, powdered coal, oil, or the like. This fire box extends substantially the full length of the kiln and is separated from the heat treating chamber 14 by a perforate wall or partition 15. The heat treating chamber 14 has another wall or partition 16 also perforate, which communicates with the vent means or chimney 17. This arrangement provides a draft from the fire box through the chimney causing the heated gaseous medium from the fire box to pass through the heating chamber substantially normal to the direction of travel of the conveyor 18 through the heat chamber.

The structure just above described may be supported on suitable supports 19 which may carry a metallic plate or the like 20 upon which the kiln rests. Preferably the bottom of the heat treatment chamber is somewhat lower than the bottom of the fire box 11, as is shown at 21. This bottom may be formed of refractory material supported by plate 22 but this is not essential when the kiln is to be operated and constructed, in accordance with this invention, for the insulated material that protects the conveyor from the extreme temperatures of the kiln also will protect the bottom of the heat treating chamber and a metallic structure or surface may be employed alone.

Referring to the conveyor 18, it will be seen that the endless conveyor extends about sprockets 23 and 24 at opposite ends of the kiln. The sprocket 24 is the driven sprocket and has a drive connection with driven sprocket 25 including shaft 26 upon which both sprockets 24 and 25 are mounted. Sprocket 25 has a suitable drive connection through chain 27, sprocket 28 and gears not shown in the drawings with a suitable prime mover 29.

The chain conveyor 16 extends through the kiln at the entrance 14a of the heating chamber and the exit 14b of the heating chamber. The bottom of the heating chamber shown at 21 extends beyond the entrance of the kiln and has a flat top surface. This flat top surface extends substantially to the sprocket 23 and provides a support surface in close proximity to the conveyor and associated with the conveyor for supporting a layer of sand 33 or other suitable granular material above the conveyor. This insulating material has a fusion or melting point greater than the temperature to be encountered within the kiln. A trough is provided within the kiln and through the heat treating chamber thereof by the off-bottom portion, of the bottom 21, relative to the refractory bottom of the adjacent fire box and chimney. This trough is extended from the entrance 14a of the kiln toward sprocket 23 by providing side wall members 30 for the part of bottom 21 that extends from the kiln. These members are supported by plates 30a mounted on uprights 19. These plates also support the shaft for sprocket 23.

The layer 33 of granular insulating material, such as sand, diatomaceous earth, silicon carbide,
pulverized fire brick, is distributed upon the flat top surface 21 to cover the conveyor by hopper 34. The hopper is supported adjacent sprocket 23 by legs 34a footing on plates 38a. Hopper 34 has an adjustable shoe 35 which may have its vertical position adjusted to determine the thickness of the layer of insulating material to be deposited over the conveyor. This shoe is detailed in Fig. 10 and has slots to provide for bolting the shoe to the hopper in a selected position. The layer 33 of granular material is carried along by the conveyor. The conveyor chain shown in the drawings pulls the material through the heat treating chamber with practically no disturbance to the upper surface of the sand. The speed of the conveyor is relatively slow and depends upon the length of the heat treating chamber and the time of treatment required. At such slow conveyor speeds, the body 32 of insulating material behaves substantially as a continuous slab of material.

As the chain moves through the trough formed by bottom 21 the chain apparently floats in the sand and it has been found that there is extremely little or no practical wear either of the chain or the support surface provided by the top of bottom surface 21. Preferably the sprockets 23 and 24 which carry the conveyor should have their upper peripheries, at the valleys between the teeth, slightly above the end portions of the bottom member 21 and 1/4 inch has been found satisfactory. This allows the conveyor to sag down onto the support surface and materially reduces the wear.

It is contemplated that in lieu of the support surface 21 a conveyor may be employed of the type which carries its own support surface. It is difficult to provide a seal between the support surface carried by the conveyor and the side walls of the trough and for this reason the arrangement shown in the drawings is preferred. With this arrangement there is no possible way for the sand or other granular insulating material to leak from operative position. A means is provided for distributing the sand from the exit end of the conveyor adjacent sprocket 24 into hopper 34. This means includes chute 36, endless conveyor 37 supported on sprockets 38 and 40, and laterally extending chutes 41 and 42. A drive means such as prime mover 43 is associated with one of the sprockets as 39 in the drawings. By this arrangement the sand or other granular insulating material drops through the conveyor and from the support surface at the end of the bottom 21 adjacent the exit of the kiln, upon laterally extending chute 41. This chute distributes the sand into chute 36 where it is moved along by conveyor 37 and carried to the upper end of the chute. At this position it falls into the laterally extending chute 42 and drops into hopper 34. This means for moving the sand is external of the kiln and the heat accumulated by the sand in the kiln is dissipated to the atmosphere. Also associated with the conveyor 18 adjacent the exit of the kiln is a chute 44 residing just beyond sprocket 24 and communicating with a hopper 45. The material discharged from the kiln falls over the end of the conveyor at the discharge end and drops into the chute 44 and drops into receptacle 45 where it may be disposed of in the manner desired.

It is preferred to fabricate conveyor 18 from mild steel for the reason that the conveyor of this material has great strength, is economical, and when protected by the layer of granular insulating material from the extreme temperatures of the kiln may be maintained at a temperature below the temperature at which it would be deleteriously affected. It is contemplated that high temperature alloy steels may be employed for this purpose and that when so employed the thickness of the sand can be substantially reduced. Of course if the kiln is to be operated at relatively low temperatures, that is, temperatures at which the alloy steel conveyor is able to withstand, no sand need be used at all, as long as the character of the material to be treated would permit it to be placed directly upon the alloy steel conveyor. However, due to the great cost of these alloys it is not preferred at this time to use a conveyor fabricated of such alloys. Of course, alloy steels presently known may not be heated to the temperature range required for bloating ceramics.

The chain 18 is made up of a plurality of links 46 detailed in Fig. 5, having apertures 46a. These links are strung on rods 47 with spacer washers 48 holding the links in proper spaced relation upon the rods. This arrangement of parts for the conveyor has been found entirely satisfactory for advancing the bed of insulating material over the support surface 21. With this arrangement it has been found that the bed 33 moves substantially as a solid body with practically no vibration or movement of the surface of the insulating material other than in a forward direction.

It is contemplated that other forms of conveyor arrangement may be employed, such as wire meshes and the like.

In operation, the kiln is fired up until the desired temperature within the heat treatment chamber has been obtained. During the heating up operation or at least the last stages thereof, the chain or conveyor should be covered with the insulating material to protect it from overheating as the temperatures rise within the heat treating chamber. Preferably as the temperature within the chamber commences to rise the prime mover 29 is started in order to advance the conveyor through the heat treating chamber reducing any likelihood of over-heating the conveyor. The arrangement of the shoe 35 upon the hopper makes it possible to selectively gauge the thickness of the bed of granular insulating material to be deposited upon the conveyor. Prime mover 43 is started to drive sprocket 33 and thus drive conveyor chain 37 to distribute the sand from the discharge end of conveyor 18 to the hopper 34. The chain 37 carries the granular material along chute 36 and it falls into the lateral chute 42 and thence is deposited within the hopper 34.

When the proper treating temperature has been reached within the kiln, the material to be treated is deposited upon the upper surface of the insulating granular material or bed 33. In the operation to be carried out is to treat a bloatable ceramic material the material may be deposited upon the bed 33 of insulating material in the usual fashion in granular form in a thin layer, but due to the slowness of this operation it is much preferred to place pre-formed objects upon the bed of sand 33 in the manner shown in the drawings.

Fig. 7 shows the preferred open ended form of the material at 49 but it is to be understood that other forms may be employed. The thickness of the wall affects the time required to complete the treatment and in the interest of high
rate of production, a thickness of .75 inch is usually the thickest wall that should be used. A wall thickness of 3 of an inch is preferred. A tubular form with an internal diameter of one inch and an outside diameter of one and three-fourths inches has been found entirely satisfactory and such forms are capable of maintaining their shape when stacked eight high upon the moving hearth.

The forms should be distributed upon the bed of insulating material in such fashion as to provide passageways 50 and 51 through the stacked material. These passageways extend substantially normal to the direction of travel of the conveyor and are provided by the spaces between adjacent tubular objects 49 and by the openings through the objects 49 themselves. These objects 49 are open-ended hollow objects in the forms of tubes and may be formed by the usual pug mills well known to the art but not shown in the drawings. These tubes or pipes are placed by hand upon the bed of insulating sand but may be distributed thereon by machinery. The plasticity of the clay or shale is such that the objects are not only self-supporting but also will support the layer of several other such objects when in stacked relation.

The conveyor 18 with the superimposed cover of insulating granular material 33 provides in effect a moving hearth for carrying the material to be treated through the kiln. Material passes slowly through the heat treating chamber of the kiln and the heated gas or gaseous medium from the fire box circulates through and past the objects continuously passing through the passageways 50 and 51 subjecting the objects to be treated uniformly to the heat treatment. By this method the rate of production of the kiln is greatly increased over the method of depositing a thin layer of a granular material to be treated upon a moving hearth and carrying it through the kiln. This is true because the thickness of such a film of material to be treated preferably should not be greater than about three-eighths of an inch.

The rate of movement of conveyor 18 is adjusted to provide a proper length of heat treatment of the material so that it is discharged at the expiration of the proper heat treatment. The treated material is permitted to fall from the conveyor on to chutes 44 and into a suitable receptacle 46. However, before the treated material is discharged the granular insulating material is discharged into lateral chutes 41 and is conveyed back to the hopper 34 for re-use, cooling en route.

Where the material is bloated and is to be used for light weight aggregate in making light weight concrete and the like, the bloated objects 49 are removed from the container 45 and taken to a suitable mill for breaking into the proper size. It is contemplated that the forms of the material to be treated may be adjusted into any suitable shape or desired shape so long as the shapes may be arranged upon the moving hearth in such a manner as to provide for substantially even heat treatment. In other words, so as to provide passages for circulating a heated gas between surfaces of adjacent objects and if desired through passages formed in the objects themselves. Preferably these fluid passages for the gaseous medium should be in a direction substantially normal to the direction of travel of the conveyor.

A modified form in which the material to be treated may be shaped in a pug mill is shown in Fig. 10 at 52. In this form the material has a plurality of passages 53 therethrough and the wall thicknesses of the solid portion of the honeycomb as shown at 54 are substantially uniform. The advantage of this shape or form is in the handling and stacking of the material upon the hearth.

Referring to the layer of insulating material 33 the thickness of this layer must be selected to provide sufficient insulation to protect the conveyor from the extreme heat of the kiln and to prevent it from rising to such a temperature that it would be deleteriously affected. Of course, the temperature which the conveyor may be subjected to will depend upon the materials from which the conveyor is constructed. For most mild steel construction the conveyor may safely be subjected to temperatures in the order of 700°F, but in order to provide a safety factor it is preferred that the thickness of the layer of sand be sufficient to prevent the material of the conveyor from attaining a temperature greater than 500°F. Also, it is desirable to maintain the thickness of the layer of granular insulating material sufficiently great to protect the conveyor in the event of break-downs for a period of time at least as great as thirty minutes over the time of the pass through the kiln. This reduces the necessity of shutting off the heat in the fire box of the furnace which would otherwise be required by short interruptions of the heat treating operation.

Under some conditions it is contemplated that special alloy steels capable of withstanding relatively high temperatures may be employed. Alloy steels are now available which may be safely operated at temperatures up to 1700°F. However, these alloys are expensive and at the present time it is preferred to use the mild steel materials for the conveyor for this reason. For some operations it may be necessary to heat certain clays, shales or other ceramics at temperatures under 1700°F. If this is true, of course the layer of sand need not be employed and the formed objects of the material to be treated may be stacked directly upon the conveyor.

The thickness of the layer of insulating granular material may be determined by experimentation and has been experimentally determined for mild steel conveyors wherein the temperature to be encountered in the kiln is in the neighborhood of 2150°F. This temperature is preferred for most bloating operations. The initial temperature of the granular insulation material was 100°F, and the time within the furnace was one hour, the normal bloating operation requiring thirty minutes and thus providing for a thirty minute safety factor. The conveyor was fabricated of mild steel and the permissible temperature was considered to be 500°F to provide an additional safety factor. It was found that a sand layer 1.24 inches thick was sufficient under these conditions to maintain the temperature of the conveyor below 500°F. With these same conditions, but with the time within the kiln of only 30 minutes, the sand layer need be only .88 inch thick.

With the kiln temperature of 2200°F, which is the maximum bloating temperature usually encountered in a kiln, a sand layer 1.26 inches deep for 30 minutes with the conveyor was found satisfactory. It is preferred to use this thickness of sand in order to provide for a safety factor when materials are to be bloated.

A plot or graph has been prepared based upon experimental data for facilitating the calcula-
tion of the temperature at a point in a sand slab at inches below the surface of the slab after an elapsing time in a furnace maintained at a constant temperature or the thickness of a sand layer required for preventing the temperature of the conveyor from exceeding a predetermined temperature.

This graph is shown in Fig. 11 and the data upon which it is based was obtained by a plurality of test runs in a kiln employing a mild steel conveyor chain and employing sand as the granular insulating material. The curve 55 may be used to calculate the sand thickness required with close approximations for furnaces of this general type.

A second curve representing the temperature distribution, neglecting surface resistances to heat transfer and dissipation of heat from beneath the conveyor is given in dotted lines and indicated at 56. By the use of this curve the calculation of the desirable depth of the sand layer which will provide safety for the conveyor may be calculated and will fit any furnace conditions that are likely to be encountered. By experimentation thinner layers of sand or other insulating materials, than those indicated by the curve 56, usually may be found to be satisfactory. Also, by solving simultaneous partial differential equations, the depth of the insulating material may be more closely obtained or calculated. These heat transfer formulae are readily available to those skilled in the art, but their use is so cumbersome or tedious as not to be of practical application.

In using these curves 55 and 56, they should not be extrapolated to long periods of time or to very thin layers of granular insulating material, but these curves will give satisfactory results under average operating conditions.

In the graph the vertical co-ordinate is plotted in accordance with the mathematical expression

\[ T - T_0 = \frac{t}{T - T_s} \]

The horizontal co-ordinate is plotted on the mathematical expression

\[ t = \frac{T - T_s}{T - T_0} \]

In the above expressions, the reference letters have the following meaning:

- \( T \): temperature of furnace, °F.
- \( T_0 \): initial temperature of sand.
- \( T_s \): temperature of sand at position \( X \) at time \( T \).
- \( t \): time in furnace, minutes.
- \( x \): distance below surface, inches.

In the above graph the constant of the equipment, due primarily to the coefficient of distribution of heat of the particulate insulating material employed, is introduced into the curve. It is believed that examples will aid in the understanding of the application of the above curves.

Example 1

\[ T_i = 2100\,^\circ\, F.;\, T_0 = 100\,^\circ\, F.;\, T_s = 400\,^\circ\, F.;\, t = 60\, \text{minutes};\, x = \text{the layer of sand or insulating material above the conveyor.} \]

The expression

\[ T - T_0 = \frac{t}{T - T_s} = .80 \]

Reading on curve 55 it is seen that the horizontal co-ordinate corresponding with this value is 39. Solving the expression

\[ t = \frac{T - T_s}{T - T_0} \]

for \( x \), \( x \) is found to equal 1.23 inches.

Example 2

Assuming that in the Example 1 conditions, the character and coefficient of distribution of heat of the granular insulating material was unknown, the value of \( t/x^2 \) should be obtained from curve 56. In accordance with this, the value of the expression as taken from curve 56 is 11 and solving for \( x \), \( x \) is equal to 2.33 inches.

By calculations based on curves 55 and 56, thickness of the insulating material may be obtained that will provide adequate protection for the conveyor. This thickness may be adjusted, based upon experience of operation if desired.

It will be seen that the objects of this invention have been accomplished. There has been provided a kiln having insulating means for protecting the conveyor for moving material to be treated through the kiln from the excessive temperatures encountered in the kiln. The arrangement is such that this means for supplying the insulating material to the conveyor may be readily varied to provide proper protection for varied conditions of operation in a kiln.

There has been provided a method for treating material in a kiln by which the rate of treatment of the material may be greatly increased in a given kiln over what has gone before. In accordance with this method all clays, shales and other ceramic materials to be treated may be treated without an expensive pre-heating operation, to prevent spoiling, exploding, or popping off.

From the foregoing it will be seen that this invention is one well adapted to attain all the ends and objects hereinabove set forth together with other advantages which are obvious and which are inherent to the structure and process.

It will be understood that certain features and sub-combinations are of utility and may be employed without reference to other features and sub-combinations. This is contemplated by and is within the scope of the claims.

As many possible embodiments may be made of the invention without departing from the scope thereof, it is to be understood that all matter herein set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

Having described the invention, what is claimed is:

In a kiln a furnace with entrance and exit openings, a substantially flat support surface extending through the furnace entrance and exit, a metal chain type continuous conveyor operably mounted with its portion to be loaded extending through the furnace and disposed in close overlying proximity to said surface, and means for distributing at a point exterior of the furnace and adjacent its entrance a finely divided granular insulating material upon the surface in a selected thickness to encompass the conveyor for protecting the conveyor against the high temperature encountered within the furnace.

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