Nov. 5, 1946. W. R. CLIFFE 2,410,598

ROTARY KILN

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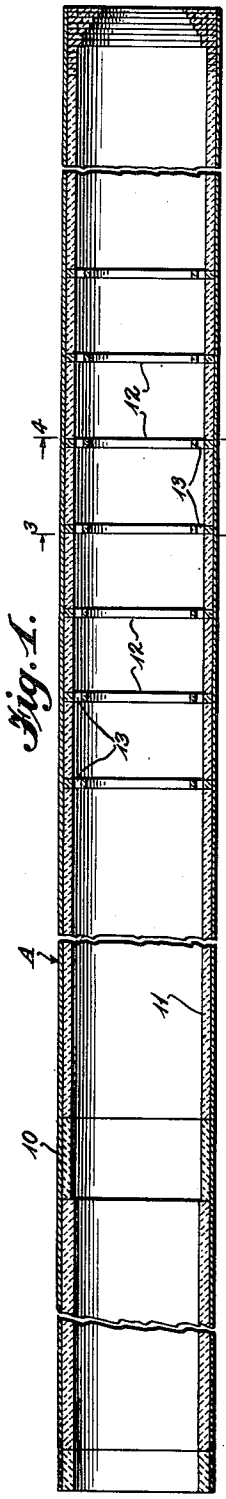



Fig. 1.

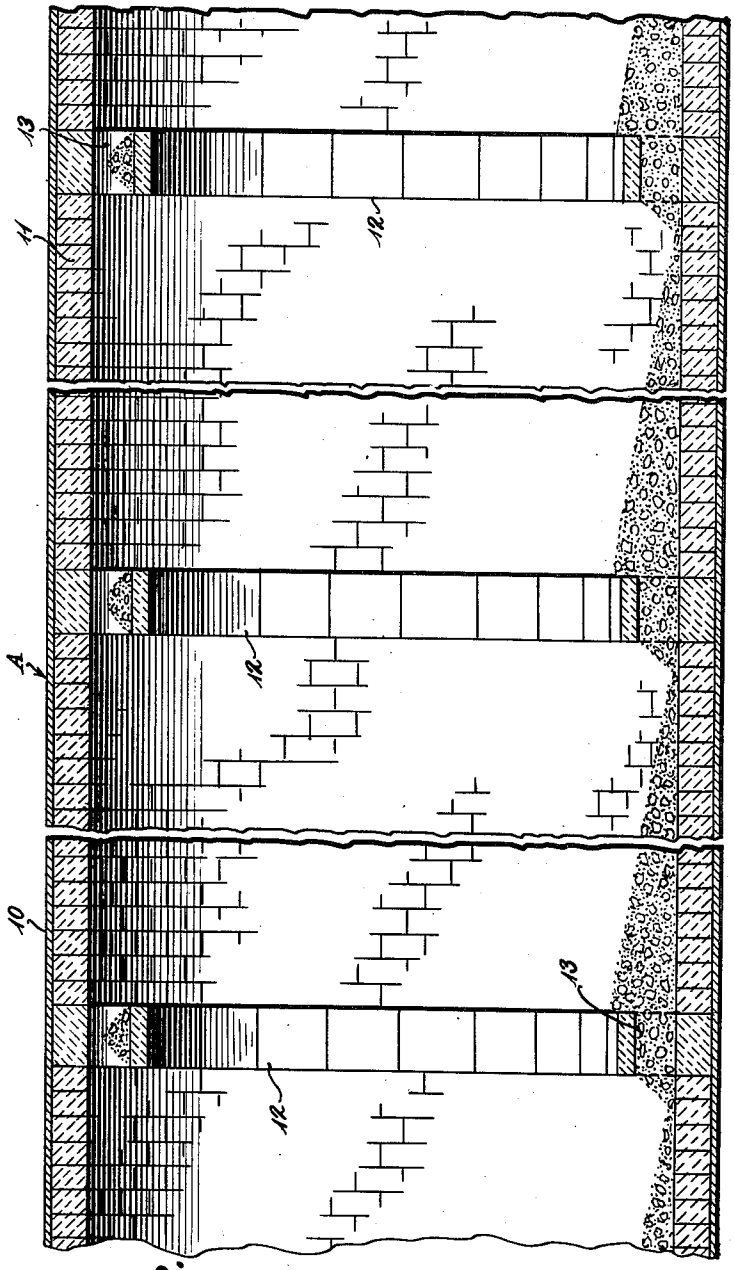



Fig. 2.

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Fig. 3.

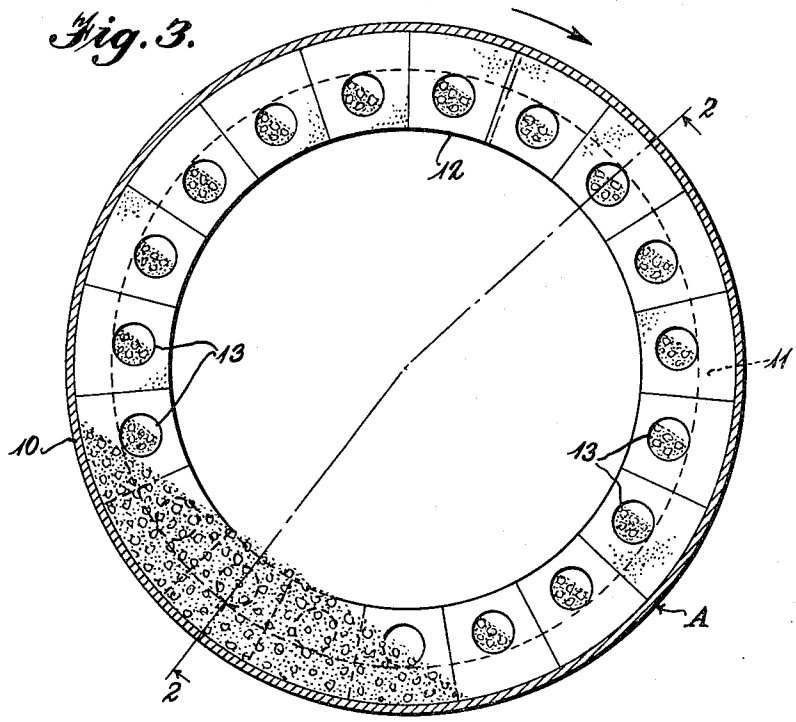
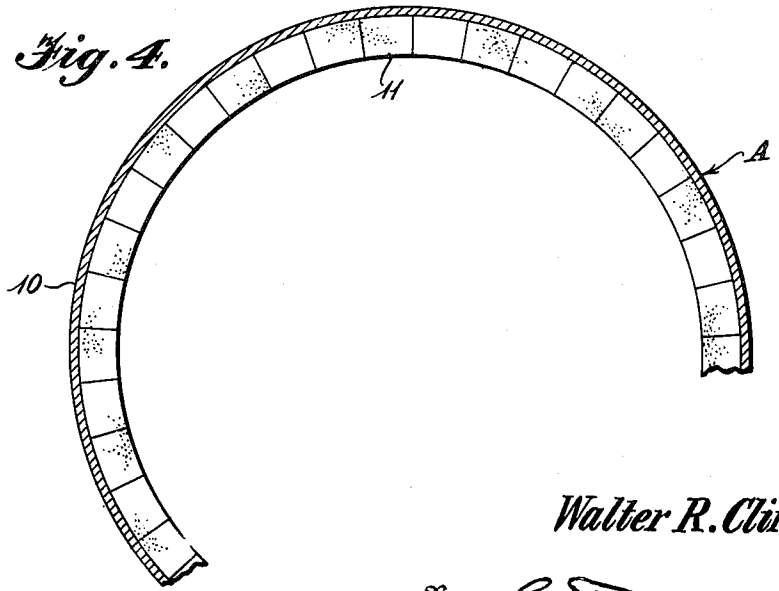



Fig. 4.




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# UNITED STATES PATENT OFFICE

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## ROTARY KILN

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Application April 24, 1943, Serial No. 484,420

8 Claims. (Cl. 263—32)

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This invention relates to rotary kilns, and has particular reference to improvements in rotary kilns of the type comprising a rotary drum into one end of which the material to be treated is introduced for travel through the drum in one direction, and into the other end of which the hot gas or other medium for treating the material is introduced for travel through the drum in the opposite direction in heat exchange relationship to the material.

In such kilns high temperatures usually are employed, and in order to derive the greatest benefit from the fuel consumed in supplying the heat to treat the material, it has been the prevailing prior practice to employ drums of great length. The longer the drums may be, however, the more expensive they are to install, maintain and operate. Therefore, there has always existed the problem of minimizing the length of the drums consistent with deriving maximum benefit from the fuel consumed.

One outstanding development in rotary kiln practice directed toward the end of minimizing drum length and obtaining high efficiency from the fuel consumed was to provide the drums with metal heat exchangers. This was sound practice because the transfer of the heat to the material was accomplished much more readily through the metal heat exchangers than directly from the gas to the material. There then were developed various different types of metal heat exchangers of greater or lesser efficiency certain of which now are in common use. All have the disadvantage, however, that they cannot withstand temperatures in excess of approximately 1500° F. which is the approximate working limit of the best known alloy steel from which they are made. Therefore, their use necessarily has been confined to those portions of the drums wherein the working temperatures do not appreciably exceed 1500° F., which means, of course, that in some kilns employing temperatures considerably higher than 1500° F. at their hot gas inlet ends, it may not be possible to employ metal heat exchangers except throughout relatively short-length portions of the drums near their gas outlet ends where the temperature of the gases is considerably lower due to heat losses therefrom during their travel through the drums. Therefore, in order to obtain the benefit of more effective heat transfer resulting from the employment of alloy steel heat exchangers, kilns have been lengthened far beyond the practical necessity.

Another disadvantage of certain types of metal heat exchangers is that, if one requires replacement or repair, it may be necessary to remove another, or perhaps many others, to gain access to or to enable removal of the one requiring replacement or repair, in which event high maintenance costs are involved.

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Another disadvantage of practically all prior types of rotary kilns is that all of the material being treated remains in the bottom of the drum, where the heat is at a lower temperature, never reaching the top of the drum where the heat is greatest.

Certain rotary kilns are provided with means to carry some of the material being treated upwardly with the drums as the drums rotate, but in most such kilns the elevated material is disadvantageously cascaded with damaging effect upon the refractory linings of the drums and to the material itself when soft in character before it reaches the tops of the drums.

Accordingly, one special and important object of the present invention is to provide a rotary kiln with means which may be located within the drum at any point, or points, along the length thereof, regardless of the temperature therein; which is effective to elevate the major amount of the material being treated to the highest temperature top portion of the drum without any appreciable dropping of the elevated material, and which, at the same time, is effective to cause tumbling of the elevated material, whereby the greatest benefit is derived from the fuel consumed in supplying the heat for operating the kiln and whereby the kiln may be of minimum length.

Another special and important object of the invention is to provide a rotary kiln with means as stated which is of comparatively low installation cost, which is readily accessible for replacement and repair purposes and which, therefore, is of comparatively low maintenance cost.

With the foregoing and other objects in view, which will become more fully apparent as the nature of the invention is better understood, the same consists in a rotary kiln embodying the novel features of construction, combination and arrangement of parts as will be hereinafter more fully described, illustrated in the accompanying drawings and defined in the appended claims.

In the accompanying drawings, wherein like characters of reference denote corresponding parts in the different views:

Figure 1 is a longitudinal section through a rotary kiln constructed in accordance with one practical embodiment of the invention,

Figure 2 is a longitudinal section on an enlarged scale through a portion of the kiln, and

Figures 3 and 4 are cross sections on the lines 3—3 and 4—4, respectively, of Fig. 1.

Referring to the drawings in detail, it will be observed that the present rotary kiln is generally similar to prior rotary kilns in that it comprises a cylindrical, or substantially cylindrical, drum, designated generally as A, which is composed of a metallic shell 10 and a refractory lining 11.

As will be understood, suitable means are provided to mount the drum A for rotation and to effect its rotation. It will also be understood that said drum is slightly inclined to the horizontal in accordance with known practice so that the material to be treated, which is introduced into the drum at its higher end, slowly gravitates therethrough to its lower end. It will further be understood that the hot gases for treating the material are introduced into the drum at its lower end, likewise in accordance with known practice, and flow therethrough in a direction counter to the direction of flow therethrough of the material to be treated, and are discharged therefrom at its other or higher, material inlet end.

The refractory lining 11 may be of monolithic molded type as it may be composed of bricks, as shown. In any event, a plurality of rings 12, constituting, preferably, parts of said lining 11, are located at points spaced along any desired portion of the length of the drum A, or throughout the length of said drum, and project suitable distances inwardly beyond the inner face of the main body of said lining 11.

Preferably the rings 12 are disposed concentrically with respect to the drum A and in planes at right angles to the longitudinal axis of said drum, although these are not essential requirements. Preferably, too, said rings 12 are composed of duplicate bricks for purposes of their practical and economical production, installation, replacement and repair. Preferably, also, said ring portions extend outwardly to the shell 10 between sections of the main body of the lining 11 so that they constitute parts of said lining. They may, however, be separate from the lining 11, in which event they may extend outwardly only as far as the inner face of said lining. In addition, they preferably are composed of refractory material so that they may be located at any points along the length of the drum A regardless of high working temperatures which may be employed in said drum. They may, however, be composed of other materials, particularly in instances where they are not subjected to damaging high temperatures. In any event, the portion of each ring which projects inwardly beyond the inner face of the main body of the lining 11, has formed therethrough an annular series of openings 13 which are continuously closed at their sides and which are of such form otherwise as to receive portions of the material advancing along the drum at the bottom thereof and to be capable of carrying the material which they receive around with the drum as the latter rotates.

The rings 12 are of appreciable thickness so that the openings 13 are of appreciable length. Moreover, said openings 13 have appreciable cross sectional areas. Therefore, they are capable of receiving and retaining appreciable amounts of the material being treated. Appropriately, said openings 13 may be of circular shape in cross section, and may be disposed parallel to the longitudinal axis of the drum 10, as shown, so as to be capable of performing their function of carrying portions of the material entirely around with the drum as the same rotates. Moreover, if the



openings 13 are of circular, or substantially circular, shape in cross section, the material contained therein is continuously tumbled as it is carried around with the drum; whereas, if said openings were of rectangular or similar shape in cross section, advantageous continuous tumbling of the material therein might not occur. However, the invention contemplates openings 13 of any appropriate shape in cross section, cross sectional area and length, but continuously closed at their sides so that the material may not fall therefrom through the inner sides of the rings 13.

The distances that the rings 13 project into the drum beyond the inner face of the lining 11 is arbitrary. Preferably, however, these distances are approximately equal to the normal depth of the material in the bottom of the drum. Said rings thus act as dams to retard flow of the material through the drum and to prolong its period of heat treatment in the drum, thereby contributing to lower temperature requirements in the drum. However, should the rate of feed of the material exceed the normal rate of feed at any given time, with consequent rise in the level of the material in the bottom of the drum, the amount of material above normal that is fed to the drum may readily spill over the rings 12. This may result in more or less decrease in the efficiency of the kiln, but the feeding of a greater than normal amount of the material to the kiln does not result in any undesirable and disadvantageous congestion of the kiln such as occurs in certain prior types of kilns due to above normal rates of feed of the material thereto.

As the drum A rotates, the openings 13 obviously planetate, each moving in a circular path directly adjacent to the inner face of the lining 11, and as the material in the bottom of the drum advances through the drum it enters the openings 13 as said openings move successively across the bottom portion of the drum. As the openings 13 move upwardly at one side of the drum A above the level of the material in the bottom of said drum they carry with them the charges of material they received at the bottom of the drum, and any spilling of said charges from the ends of said openings progressively diminishes and practically ceases before said charges have reached a height such that falling of the material upon the lining 11 would cause any serious harm to said lining. Moreover, as the openings 13 planetate they rotate, each describing one complete revolution about its own axis for each cycle of planetation thereof. Therefore, the material in each opening 13, in constantly seeking its angle of repose, is constantly tumbled as it is carried upwardly at one side of the drum, across the upper part of the drum and downwardly at the other side thereof. As each opening enters the material at the bottom of the drum a new charge of the material enters the same and causes the prior charge to be advanced therethrough.

Due to the material being carried upwardly to and across the upper part of the drum, and to being simultaneously tumbled, it is most effectively subjected to the maximum temperature in the drum. Therefore, the greatest benefit is derived from the fuel consumed with consequent high efficiency of the kiln, particularly since the rings 12 serve to prevent stratification of the hot gases and cause them to flow more or less turbulently through the drum and to thereby most completely and effectively impart their heat to the material. The drum, therefore, may be

shorter than comparable drums employing metal heat exchangers. Moreover, the rings 12 afford ready access to any part of the drum and any ring may, therefore, be replaced or repaired without disturbing any other ring. In addition, the rings themselves are of comparatively low installation and replacement cost. Accordingly, the present kiln not only is highly efficient in operation, but is of low maintenance cost.

From the foregoing description considered in connection with the accompanying drawings, it is believed that the construction, operation and the many advantages of the present rotary kiln will be readily understood and appreciated. It is desired to point out, however, that while only a single specific structural embodiment of the invention has been illustrated and described, the same is readily capable of embodiment in specifically different structures within its spirit and scope as defined in the appended claims.

Having thus described the invention, I claim:

1. A rotary kiln comprising a lined rotary drum, a plurality of axially spaced, annular members of appreciable width positioned in said drum in contact with its lining and rotatable with the drum, said members each projecting radially into the drum beyond its lining a distance which approximately equals the depth of the material moving through the drum, whereby the hot treatment gases will be permitted to partake of a substantially normal longitudinal flow through the drum and the flow of the material through the drum will be retarded by the members to prolong the transfer of heat to the material from the flowing gases and from the portions of the drum lining located between the spaced members, each of said members having a circular series of openings extending axially therethrough, each of said openings being continuously closed throughout its circumference and adapted to receive and retain a small charge of the material advancing through the drum for carrying the charge in heat transfer relation with the high level gases passing through the drum as the latter rotates.

2. A rotary kiln comprising a lined rotary drum, a plurality of axially spaced refractory rings of appreciable width positioned in said drum in contact with its lining and rotatable with the drum, said rings each projecting radially into the drum beyond its lining a distance which approximately equals the depth of the material moving through the drum, whereby the hot treatment gases will be permitted to partake of a substantially normal longitudinal flow through the drum and the flow of the material through the drum will be retarded by the rings to prolong the transfer of heat to the material from the flowing gases and from the portions of the drum lining located between the spaced rings, each of said rings having a circular series of openings extending axially therethrough, each of said openings being continuously closed throughout its circumference and adapted to receive and retain a small charge of the material advancing through the drum for carrying said charge in heat transfer relation with the high level gases passing through the drum as the latter rotates.

3. A rotary kiln comprising a rotary drum, a refractory lining for the drum, said refractory lining, at points spaced longitudinally of the drum, being formed of greater radial depth than the remainder of the lining so as to form an annular projection of appreciable width that extends into the drum beyond the remainder of the lining a distance which approximately equals the depth of the material moving through the drum, whereby the hot treatment gases will be permitted to flow substantially normally through the drum and the flow of the material through the drum will be retarded by the annular projections to prolong the transfer of heat to the material from the flowing gases and from the drum lining, each of said annular projections having a circular series of openings extending axially therethrough, each of said openings being continuously closed throughout its circumference and adapted to receive and retain a small charge of the material advancing through the drum for carrying said charge in heat transfer relation with the high level gases passing through the drum as the latter rotates.



4. A rotary kiln comprising a rotary drum, a refractory lining for the drum, said refractory lining, at points spaced longitudinally of the drum, being formed of a circular course of bricks of appreciable width and of greater radial depth than the remainder of the lining so as to form an annular projection that extends into the drum beyond the remainder of the lining a distance which approximately equals the depth of the material moving through the drum, whereby the hot treatment gases will be permitted to flow substantially normally through the drum and the flow of the material through the drum will be retarded by the annular projections to prolong the transfer of heat to the material from the flowing gases and from the drum lining, the inwardly projecting portion of each one of the bricks of said circular courses having an opening extending therethrough from side to side and adapted to receive and retain a small charge of the material advancing through the drum for carrying said charge in heat transfer relation with the high level gases passing through the drum as the latter rotates.

5. A rotary kiln comprising a lined rotary drum, a plurality of axially spaced circular courses of refractory bricks positioned in said drum in contact with its lining and rotatable with the drum, each of said courses of bricks being of appreciable width and projecting radially into the drum beyond its lining a distance which approximately equals the depth of the material moving through the drum, whereby the hot treatment gases will be permitted to partake of a substantially normal longitudinal flow through the drum and the flow of the material through the drum will be retarded by the inwardly projecting courses of bricks to prolong the transfer of heat to the material from the flowing gases and from the portions of the drum lining located between the said courses of bricks, each of said courses of bricks having a circular series of openings extending axially therethrough, each of said openings being continuously closed throughout its circumference and adapted to receive and retain a small charge of the material advancing through the drum for carrying said charge in heat transfer relation with the high level gases passing through the drum as the latter rotates.

6. A rotary kiln comprising a rotary drum, a lining for the drum formed of refractory bricks, a limited number of the bricks forming the lining of a given longitudinal zone of the drum being of greater radial depth than the remaining lining bricks of said zone so they will project into the drum beyond the remainder of the lining a distance which approximately equals the depth

of the material moving through the drum whereby the hot treatment gases will be permitted to flow substantially normally through the drum and the flow of the material through the drum will be retarded by the inwardly projecting bricks to prolong the transfer of heat to the material from the flowing gases and from the lining bricks of the drum which do not project into the drum, said bricks of greater depth being of appreciable width and having formed therein openings extending axially of the drum, each of said openings being continuously closed throughout its circumference and adapted to receive and retain a small charge of the material advancing through the drum for carrying said charge in heat transfer relation with the high level gases passing through the drum as the latter rotates.

7. A rotary kiln comprising a rotary drum, a lining for the drum formed of refractory brick, a limited number of the bricks forming the lining of a given longitudinal zone of the drum being of greater radial depth than the remaining lining bricks of said zone so they will project into the drum beyond the remainder of the lining a distance which approximately equals the depth of the material moving through the drum, each one of the said bricks of greater depth being arranged in said drum zone so that it will be in longitudinal alignment with and longitudinally spaced from others of the bricks of greater depth, whereby the hot treatment gases will be permitted to flow substantially normally through the drum and the flow of the material through the drum will be retarded by the inwardly projecting bricks to prolong the transfer of heat to the material from the flowing gases and from the portions of the lining located between the said longitudinally aligned and spaced bricks, said bricks of greater depth being of appreciable



width and having formed therein openings extending axially of the drum, each one of said openings being adapted to receive and retain a small charge of the material advancing through the drum for carrying said charge in heat transfer relation with the high level gases passing through the drum as the latter rotates.

8. A rotary kiln comprising a rotary drum, a lining for the drum formed of refractory bricks, a limited number of the bricks forming the lining of a given longitudinal zone of the drum being of greater radial depth than the remaining lining bricks of said zone so they will project into the drum beyond the remainder of the lining a distance which approximately equals the depth of the material moving through the drum, each one of the said bricks of greater depth being arranged in said drum zone so that it will be in longitudinal alignment with and longitudinally spaced from other bricks of greater depth, whereby the hot treatment gases will be permitted to flow substantially normally through the drum and the flow of the material through the drum will be retarded by the inwardly projecting bricks to prolong the transfer of heat to the material from the flowing gases and from the lining, said bricks of greater depth being of appreciable width and each having formed therein a circular opening which extends entirely therethrough axially of the drum, each of said openings being continuously closed throughout its circumference and being adapted to receive and retain a small charge of the material advancing through the drum for carrying said charge in heat transfer relation with the high level gases passing through the drum as the latter rotates.

WALTER R. CLIFFE.