Aug. 12, 1958 H. A. MARKLE, JR 2,846,778

HORIZONTAL HEAT-EXCHANGE APPARATUS

Filed April 9, 1957 4 Sheets-Sheet 1

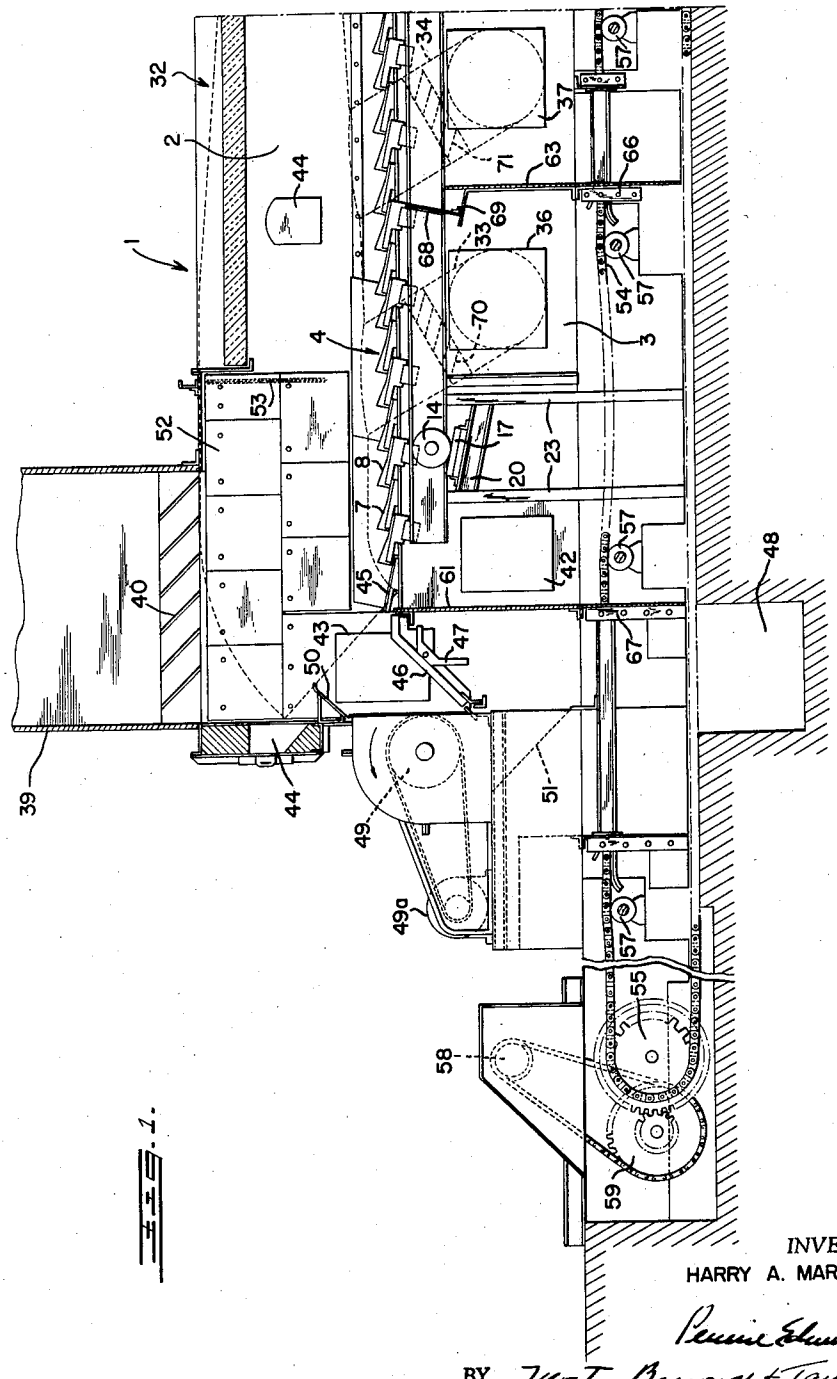


FIG. 1.

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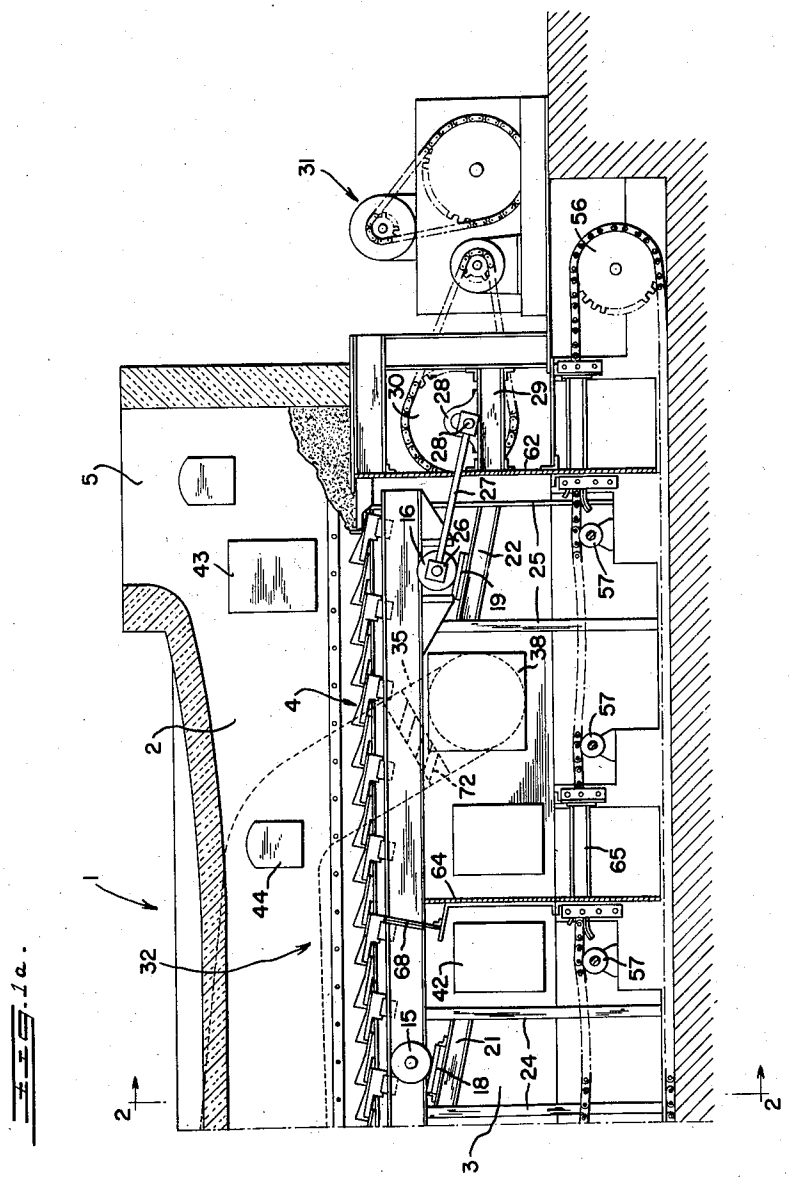


FIG. 1a.

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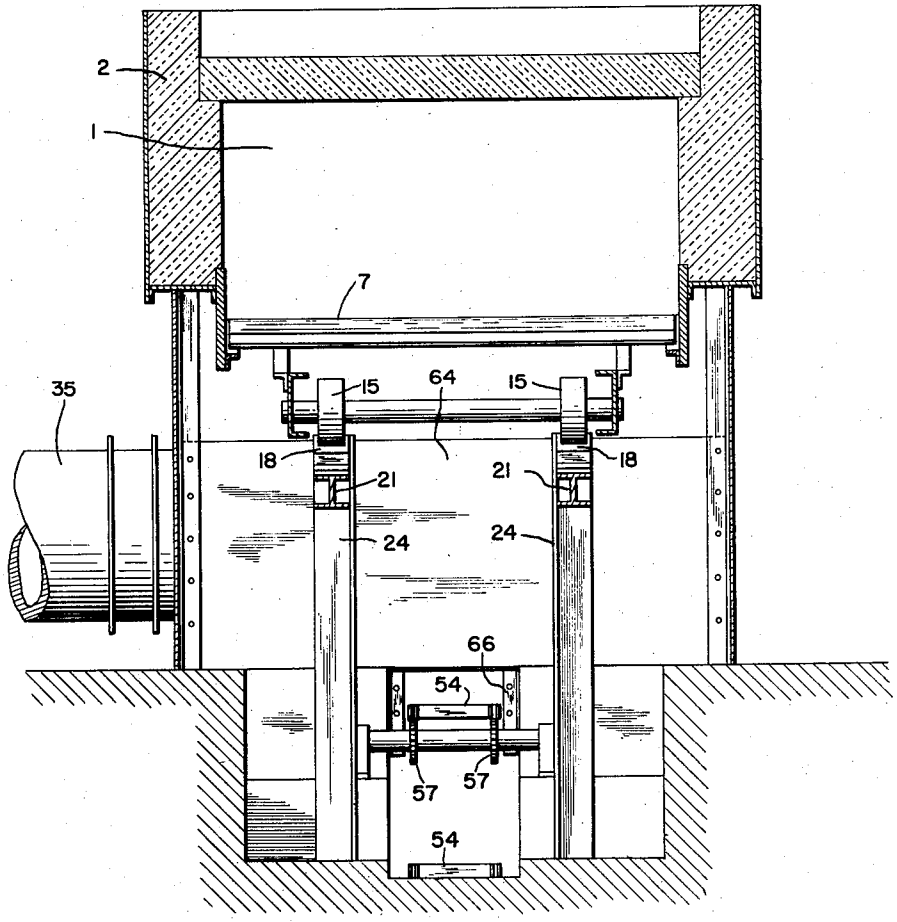
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HORIZONTAL HEAT-EXCHANGE APPARATUS

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FIG. 2.



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HORIZONTAL HEAT-EXCHANGE APPARATUS

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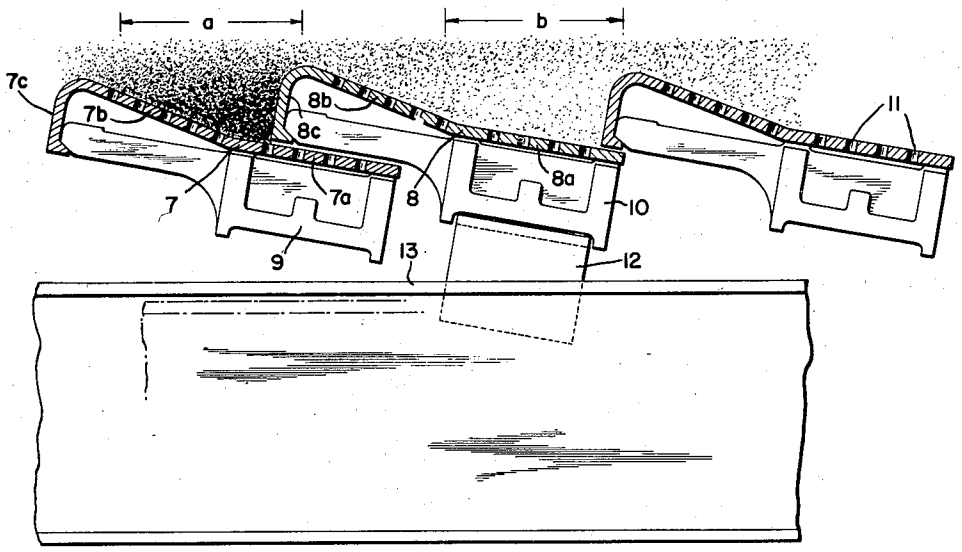


FIG. 3.

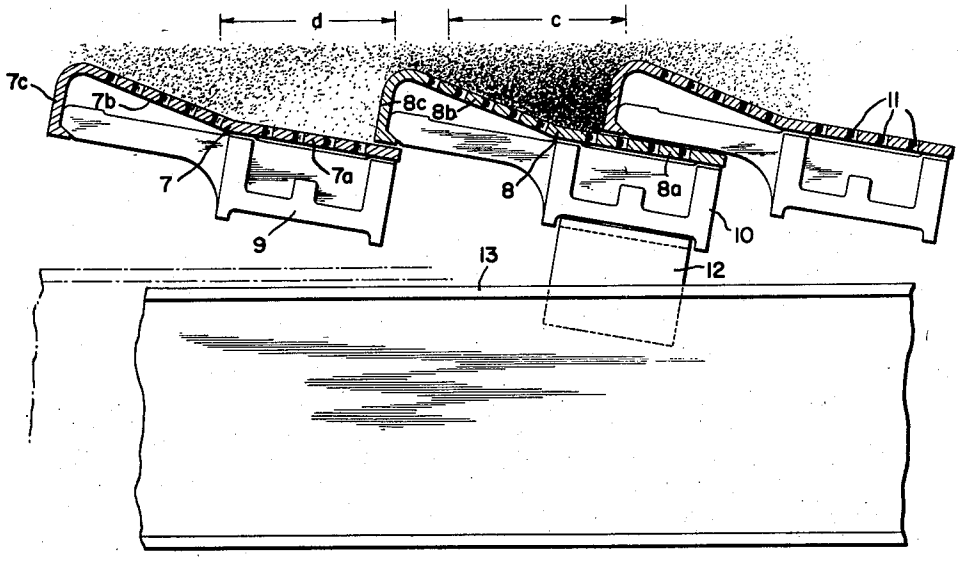


FIG. 4.

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HORIZONTAL HEAT-EXCHANGE APPARATUS

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Application April 9, 1957, Serial No. 651,676

4 Claims. (Cl. 34—164)

This invention relates to a heat-exchange apparatus and particularly to such an apparatus for the cooling of discrete particles of material by the rapid air quenching of materials discharged at a high temperature from kilns and the like, such as hot Portland cement clinker.

The patent to Douglas No. 2,137,158 discloses a cement clinker cooler in which the hot cement clinker is caused to flow downwardly over a series of stepped and perforated, alternately positioned, stationary and movable grates through which cooling air from an underlying plenum chamber is forced upwardly into and through the moving material. In such a cooler each movable grate, during its forward movement, forces the hot material along the surface and over the nose of the stationary grate over which it moves and onto the next lower movable grate. On its rearward movement, the toe of the next overlying grate acts as an abutment or stationary pusher to push the material along the surface of rearwardly-moving grates and over the noses thereof onto the next lower stationary grate. In this manner the hot cement clinker is progressively moved downwardly over the inclined stepped grates while simultaneously being subjected to the cooling effect of the air passing therethrough.

Cement clinker coolers of the type disclosed in the foresaid patent have been used extensively and have proved quite effective in the rapid cooling of cement clinker. However, the downwardly-sloping arrangement of the stepped grates has necessitated either that the discharge end of the kiln be substantially elevated or that the cooler be located in a relatively deep pit, from which the cooled material subsequently must be lifted. The downward sloping of the grates also occasionally permitted the cascading or avalanching of some types of material, especially when in large lumps or particles, over the bed of material. Since such large lumps or particles required a greater cooling effect than the finer particles, it sometimes was necessary to provide special means for breaking up such avalanching large lumps and returning the broken particles for further cooling.

The present invention contemplates the cooling of material in a cooler of the general type of that disclosed in the foresaid Douglas patent, but in which the alternating stationary and movable grates are arranged in a horizontal series.

The reduction in unit height afforded by arranging the alternating stationary and movable grates in a horizontal series provides a saving in space and structural materials, and particularly in the amount of firebrick required for the casing above the grates. It also precludes the cascading or avalanching of some types of material, and especially the large lumps or particles over the bed surface of the discharge, thereby assuring a more complete and effective cooling of the entire material forming the bed.

More specifically, the cooler of the present invention comprises a series of perforated, alternately positioned

stationary and movable grates through which cooling air is forced to cool the material thereon. These grates are arranged in a horizontal, overlapping series, and the upper surfaces of each set of grates are upwardly inclined in a forward direction. When cement clinker or other material is placed on such an arrangement of the grates, it will be formed into a horizontal bed, and as the movable grates move forwardly over the stationary grates, each movable grate will push the material on the next forward stationary grate over which it moves upwardly along the inclined surface thereof and over its nose onto the next forward movable grate. Thus, even though the material to be cooled is maintained in a horizontal bed, it is progressively moved forward until it reaches the discharge end of the series of grates.

For a better and more complete understanding of the invention, reference is made to the following drawings, in which:

Fig. 1 is a vertical cross-sectional view, partly in elevation, of one end of a material cooler of a type adapted for cooling cement clinker;

Fig. 1*a* is a similar view of the other end of the cooler;

Fig. 2 is a vertical cross-sectional view, on an enlarged scale, of the cooler shown in Figs. 1 and 1*a*, taken on line 2—2 of Fig. 1*a*;

Fig. 3 is a detail view on an enlarged scale, showing the arrangement of the overlapping stationary and movable grates at the end of the forward stroke of the movable grates, and illustrating the compaction of the material in different portions of the bed; and

Fig. 4 is a view similar to Fig. 3, with the movable grates at the end of their rearward stroke.

Referring to the drawings, reference character 1 designates a cooling chamber. This chamber comprises an upper casing 2 formed of firebrick through which the material to be cooled is passed and a lower portion 3 in the form of a plenum chamber. The upper and lower portions of the cooler are separated by a cooling grate structure 4, hereinafter more particularly described.

One end of the upper casing 2 (Fig. 1*a*) has an inlet 5 for material to be cooled. This inlet opening may be placed below the discharge end of a cement kiln to receive the hot clinker directly from the kiln. Directly beneath the inlet opening 5 is a material-receiving shelf 6 onto which the hot clinker drops. After the clinker particles have accumulated upon the shelf 6, and have formed a natural angle of repose thereon, succeeding clinker particles falling onto the pile will flow therefrom onto the adjacent end of the cooling grate 4.

The cooling grate comprises overlapping, alternating stationary grates 7 and movable grates 8, arranged in a horizontal series. The stationary grates are each mounted upon and supported by fixed, inclined grate plate supports 9, while each of the movable grates are mounted upon and supported by movable, inclined grate plate supports 10. The stationary and movable grates each include rear portions 7^a and 8^a, respectively, and forward portions 7^b and 8^b, respectively, which are upwardly inclined in a forward direction to a greater extent than the portions 7^a and 8^a. The forward portions 7^b and 8^b terminate in downwardly-extending toe portions 7^c and 8^c, respectively. These toe portions are upwardly and rearwardly inclined with respect to the direction of movement of the bed of material along the grate structure. The reason for this will be brought out later.

Both the rear portions 7^a and 8^a of the grates and the forward portions 7^b and 8^b thereof are provided with perforations 11 for the passage of air from the plenum chamber 2 into the overlying bed of hot cement clinker.

Each of the movable grate plate supports 10 is secured by members 12, at each side of the cooler, to movable

frames 13. These frames may be in the form of I-beams and carry flanged wheels 14, 15 and 16. Each of the wheels is mounted for rolling movement along inclined rails 17, 18 and 19, supported by horizontally-inclined frame members 20, 21 and 22 and vertical frame members 23, 24 and 25.

The wheels 16 are mounted on a shaft 26 which is connected through a crank and crankshaft 27 to shaft 28 mounted in bearings 28' secured to one of the frame members 29. The shaft 28 is driven through chain and sprocket gearing 30 from a conventional variable speed driving unit and transmission 31.

Rotation of shaft 28 results in a reciprocating motion being imparted to the crankshaft 27, which in turn imparts a reciprocating motion to the movable frame 13, causing the wheels 14, 15 and 16 to ride up and down along their inclined supporting rails. As the frame 13 moves forwardly and upwardly, the forward portions of 8^c the movable grates 8 will move forwardly over the rear portions 7^a of the stationary grates and push the hot clinker on the stationary grates forward. The hot clinker on the most forward portion of the stationary grates will be spilled over the noses of these grates onto the forwardly moving, next movable grate. The continued reciprocation of the movable grate sections thus causes a progressive forward movement of the material in the bed. The angle of forward inclination of the rails 18, 19 and 20 is the same as the angle of forward inclination of the rear portions of the grates 7 and 8, so that the forward portions of movable grates always maintain their parallel and spaced position with respect to the rear portions of the stationary grates.

Air under pressure from any suitable source is introduced into the plenum chamber 3 through an air manifold 32, offtakes 33, 34 and 35 and air inlets 36, 37 and 38. The size of the air manifold may be progressively decreased in diameter in the direction of offtake 35.

Air from the plenum chamber passes upwardly through the perforations 11 of the grates into the overlying bed of hot cement clinker to exert a cooling effect thereon. Some air will also pass into the bed of overlying hot clinker through the space between the toes of the removable grates and the rear portion of the underlying stationary grates.

The air after passing through the bed of hot clinker and cooling it is passed off through a stack 39. The flow of the air through the stack may be controlled by stack baffles or dampers 40.

The casing 2 and plenum chamber 3 may have the usual access doors 42 and 43 and the casing may have inspection ports 44.

The cooled clinker leaving the end of the cooling grate passes over a plate 45 and then downwardly over a grizzly 46, having a grizzly cleaner 47. The fines pass through the grizzly and drop into a pit 48 from which they may be removed in any manner. The oversize particles which do not pass through the grizzly, pass to a clinker breaker 49 driven by a motor 49^a. The clinker breaker is of a conventional design and has hammers secured to a rotor which rotates in a counterclockwise direction. These hammers on striking the large particles, shatter them and throw the fragments back into the cooler section for further cooling. Such fragments which may be knocked upwardly are deflected onto the cooling grate by a deflector 50. Fines from the clinker breaker pass down the incline 51 and fall into the pit 48.

The roof and sides of the forward end of the casing 2 are lined with steel plates 52 to protect against clinker fragments which may be thrown against that portion of the casing. To further protect the firebrick roof of the main portion of the casing 2, a chain curtain 53 is hung across the casing just in front of them.

A certain amount of the fines from the bed of material undergoing cooling will pass the grates and fall into the plenum chamber 2. These fall onto a drag chain conveyor 54 and are carried by it to a point above the pit 48 where they are freed to drop into the pit for removal with the main portion of the cooled material.

The drag chain conveyor passes over pulleys 55 and 56 and the upper flight thereof is supported by idler wheels 57. The pulley 55 is driven from a motor 58 through suitable gearing 59.

For more effective use of the air in the cooling of the hot clinker, the plenum chamber is divided into three compartments by means of end walls 61 and 62 and partitions 63 and 64. The air is introduced into these compartments through the inlets 36, 37 and 38, respectively. Special air seals 65, 66 and 67 are provided where the drag conveyor passes through the lower portions of the partitions 63 and 64 and end walls 61 and 62. To seal off the compartments at the upper end of the partitions 63 and 64, where the movable member 13 passes through them, a sealing plate 68 is secured to each of the movable members 13. These plates extend the full width of the plenum chamber and are provided with I-shape openings so as to closely conform to the contour of the members 13. The lower ends of the plates 68 ride along the upper surface of plates 69. The plates 69 are forwardly and upwardly inclined at the same angle as the rails 18, 19 and 20 so that the plates 68 and 69 always are in contact to provide a sliding seal.

The air off-take pipes 33, 34 and 35 may be provided with dampers 70, 71 and 72, respectively, so that the amount of air introduced into the several compartments of the plenum chamber for passage through the grates and into the overlying material may be individually controlled. By properly adjusting the respective dampers the amount of air to obtain optimum cooling or aeration of the material, or both, overlying each compartment may be obtained.

The hot material supplied to the cooler is progressively moved forward by the reciprocating motion of the movable grates 8 over the stationary grates 7. As the movable grates move forward on the forward stroke of the member 13, their toes 8^c act as rams to force the material on the forward portions 7^b of the stationary grates along those surfaces and over the noses of the stationary grates onto the next forward and underlying movable grate. On the return, or rearward movement of the movable grates, the toes of the stationary grates act as fixed abutments to prevent the material on the movable grates from moving back with them, resulting in the material on each movable grate being forced over its nose onto the next forward and underlying stationary grate.

The forward and upward inclination of the grates causes the material, as it is being progressively moved along the grate structure, to be pushed upwardly relative to the bed. During this movement, the particles tend to move laterally away from the resistance of the incline until it meets an equal or greater force. This produces an almost immediate lateral distribution of the material over the cooler width until confined by the side walls of the cooler, and results in uniform longitudinal movement of material throughout the width of the cooler. By thus distributing the hot material uniformly over the surface of the cooler, any hot spots in the grate assembly are avoided since no local area is overloaded with a deep pile of clinker, and simultaneously robbed of its cooling air by the increased resistance offered by a thicker pile of the material.

The forward inclination or negative slope of the grate surfaces also provides less opportunity for local static areas of the material to form above the stationary grates during the rearward movement of the movable grates. As the movable grates move backward, the forward face of the toes of the respective next rearmost stationary grates prevent any substantial rearward movement of the material on the surfaces of the movable grates, as

previously indicated, so that the moving grates slide under the material lying on their upper surfaces. This withdrawal of the moving grates progressively uncovers the upper surfaces of the rear portions of the stationary grates. This surface, as it is uncovered, is immediately recovered, partially by the material on the forward sloping surface of those grates sliding back down onto it, but principally by the material spilling over the noses of the receding movable grates, thereby resulting in a forward motion of the material with respect to the movable grates. Some of the material is partially reversed in direction between forward strokes of the movable grates and is, therefore, in motion substantially all the time.

Since the perforations 11 extend through the grate surfaces at right angles thereto, and the grate surfaces are inclined forwardly and upwardly, the cooling air passing through those perforations will be directed backwardly into the advancing material, thereby further agitating the bed without tending to blow or lift the material toward the discharge.

By reference to Figs. 3 and 4, it will be noted that the toes of the respective grates are inclined rearwardly with respect to the vertical. This prevents the air from short-circuiting upwardly along a vertical wall and assures better permeation of the air through the deeper body of hot material at that point and, consequently, a more effective cooling of it.

During operation of the grate, the bed of material is constantly undergoing relative compaction and expansion. On the forward movement of the movable grates, the material is pushed ahead against the resistance of gravity and the upward slope of the next forward stationary grates. This produces a degree of local compaction of the material in front of the forwardly moving toes of the movable grates, such as in the areas or bands *a* in Fig. 3. Such compaction increases the resistance of the affected material to air flow therethrough and, being progressive, progressively reduces the rate of air flow past the toes of the movable grates until the air flow rate reaches its minimum at the extreme of the forward travel of the movable grates.

Simultaneously with the forward movement of the movable grates and the progressive reduction of the air flow ahead of their toes, the movable grates are carrying material away from the toes of the adjacent rearward stationary grates, and the rear portions of the movable grates, which previously had been underlying the forward portion of the stationary grates are progressively exposed. The exposed area caused by the movement of the material away from the toes of the stationary grates is loosely covered by material spilling over the noses of the stationary grates onto the exposed rear portions of the movable grates. This repeated loosening of material forwardly of the toes of the stationary grates and the filling of the intervening space loosely with material, progressively decreases the air flow resistance of the material in that area, thereby resulting in large volumes of air being delivered through the rear portions of the movable grates and from beneath the toes of the stationary grates, between the toes of those grates and the upper surfaces of the adjacent forward movable grates, while a lesser amount of air is concurrently delivered between the toes of the movable grates and their adjacent forward stationary grates. This causes an intense aeration of a band of material in front of each of the stationary grates. This band is indicated at *b* in Fig. 3 and is approximately one-half a grate length from front to back of the grates and extends the full width of the cooler.

On the rearward movement of the movable grates, part of the looser material adjacent their upper surfaces is progressively compacted by the toes of the next rearmost stationary grates acting as fixed abutments, preventing appreciable rearward movement of the material

along with the movable grates. In this manner air flow through that area of the overlying material is reduced and elimination of the extreme aeration of the band *b* is obtained.

Simultaneously with the return or rearward stroke of the movable grates, material is spilled over the noses of the movable grates and falls loosely onto the rear portions of the stationary grates in front of the toes of the movable grates. This loosening of the bed progressively allows an increase in the airflow rate through the material just forwardly of the toes of the movable grates and completes the cycle of operation.

Fig. 4 shows the compaction and loosening of the material at the end of the rearward stroke of the movable grates. In this figure, the area or band *c* indicates the compaction of the material against the toes of the stationary grates, while *d* indicates the area or band in which the material is loosened as a result of the retraction of the forward portion of the movable grates along the rear portion of the stationary grates.

The foresaid progressive transition of airflow rates from one group of areas or bands to another prevents extreme pressure variations in the plenum chamber, since the overall airflow resistance for the total bed is not substantially altered by the transition.

The period or duration of a given band of extremely aerated material is dependent upon the length of time that the corresponding loose arrangement of particles is allowed to exist in that region, and partly on the physical characteristics of the material. The bands considered are not static but are constantly being either created or destroyed as the grate motion either loosens or compacts, respectively, the material in that region. An extremely aerated band begins to form when grate motion starts loosening the material in the region, and forms progressively until the end of the immediate grate stroke. The band is then progressively destroyed as the grates pass the extreme of linear travel and begin a reverse stroke. A certain amount of lag may be present in the aeration and de-aeration, by reason of the aeration and de-aeration characteristics of the material, and the deceleration and linear dwell of the crankshaft drive when near its linear extremes.

In cases in which a generally fine clinker is handled, or in which an advantageous size distribution is encountered, the extreme aeration of bands of the bed may take the form of fluidization. In cases in which particles of other than fluidizable ranges are handled, the extreme aeration is not as spectacular and does not impart the full hydraulic characteristics usually found in fluidized beds. When a material fluidizes on the cooler, it is in a relatively violent state as opposed to what may be referred to as a quiescent bed.

In the case of either a fluidized or non-fluidized material, the mobility of the particles among themselves, within an extremely aerated band, is so increased that said particles are segregated according to their size, with the larger particles either falling through or sliding in from the edge over the plate surfaces, until they are generally immediately adjacent the lower boundaries of the bed. Since the larger particles are the slower cooling, the most difficult particles, in terms of cooling, are supplied with the coolest air while in said band area of extreme aeration.

As the segregated band material is displaced forward away from the extreme air, it retains a large part of its segregated character while it passes the multiple air holes of the upper grate surfaces, thereby partially prolonging the differential cooling of the particle sizes in favor of the larger particles.

This aforesaid differential cooling, while facilitating the cooling of larger particles, does not jeopardize the cooling rate of the fine particles. The fines have smaller diameters through which heat must be transmitted from the core and, therefore, will cool more quickly than

large particles at the same temperature differential. As the thermal differential between the fine particle and the cooling gas is reduced, the rate of transfer from the fine particle surface will be reduced. Therefor, air heated by prior contact with large particles will not cool the fines surfaces as fast as it would if it were at inlet temperature, but the lesser radii of the fines more than adequately compensate for the difference.

As the material of the displaced band is spilled over the subsequent grate noses, the segregation is largely eliminated but is again established within one-half of a full reciprocation, or one single directional stroke of of the movable grates. This spilling over of the material further insures a thorough mixing and agitation of the bed so that incomplete segregation, occurring for any reason in one band, is not necessarily maintained throughout the cooler length or a large part thereof.

It has been observed in operation of the cooler that extremely large particles which require greater retention periods in the cooling zone by reason of less efficient heat transfer between their surface and their core than exists between their surface and a surrounding gas, are retained in the area of the cooling gases for longer periods than are the smaller particles introduced simultaneously therewith. This is believed to be due to the creation of the extremely aerated areas or bands of material across the cooler width, since loose aerated material cannot exert adequate force on such larger particles to move them along until its particle-to-particle friction is sufficiently increased by compaction. Also, during compaction, part of the material may escape laterally from between the moving grate toes and the extremely large particles, in which case the stroke effect of a given movable grate may be largely dissipated in the compaction of the loose material, with only a fraction of the supplied force remaining to be exerted against the larger particles.

While the invention has been particularly described in connection with a cooler for cooling hot cement clinker, it is to be understood that such description is merely by way of exemplification, and the invention is applicable to the cooling of any material in the form of discrete particles; also, that various changes may be made in the details of construction of the apparatus and mode of operating the same without departing from the invention or sacrificing any of the advantages thereof.

I claim:

1. A heat-exchange apparatus comprising a longitudinal, substantially horizontally-disposed chamber, having an entrance for material at one end and a discharge port for material at the other end, a series of grates extending longitudinally of the chamber, said series of grates being substantially horizontally disposed and including fixed grates alternating with movable grates, the forward portion of each grate element overlapping the rear portion of the next forward grate element, the upper surfaces of the grates being adapted to support a substantially horizontally-disposed bed of discrete particles of material, the forward portion of each grate being upwardly and forwardly inclined relative to the rear portion, means for reciprocating the movable grates to cause the forward portion of each movable grate to move over the rear portion of the next forward stationary grate, the movable grates having a downwardly-extending forward face, means at each longitudinal side of the series of grates to confine material at such side to the space over the grates, whereby upon forward reciprocation of the movable grates material on each stationary grate will be engaged by the forward face of the next rearward movable grate and will be pushed forwardly and upwardly along the upwardly-inclined portion of the stationary grate and will spill over the forward end of the stationary grate onto the rear portion of the next forward movable grate, and material on the grates will be moved stepwise along the series of grates from the entrance end of the chamber to the discharge port from which it will be discharged, the grates of said series having openings extending therethrough, a chamber below the series of grates, and means for admitting air under pressure to the chamber below the grates to flow upwardly through the grates and into overlying material to effect heat exchange with respect to such material.

2. A heat-exchange apparatus as set forth in claim 1 in which the rear portion of each grate element is upwardly inclined in a forward direction and the movable grates are mounted to be advanced and retracted at an angle to the horizontal substantially equal to the angle of upward incline of the rear portions of the grates.

3. A heat-exchange apparatus as set forth in claim 2 in which the movable grates are mounted for reciprocation along rails which are inclined upwardly in a forward direction.

4. A heat-exchange apparatus as set forth in claim 1 in which the rear portion of the grates have openings for the passage of air and the forward faces of the grates are inclined backwardly in an upward direction at an agle to the vertical to prevent air passing through the rear portion of the grates from short-circuiting upwardly through the material along the forward sides of the faces.

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