

Aug. 12, 1969

M. J. GREAVES ET AL
APPARATUS FOR TREATMENT OF PARTICULATE MATERIAL
ON MOVING SUPPORT

3,460,818

Filed May 31, 1966

10 Sheets-Sheet 1

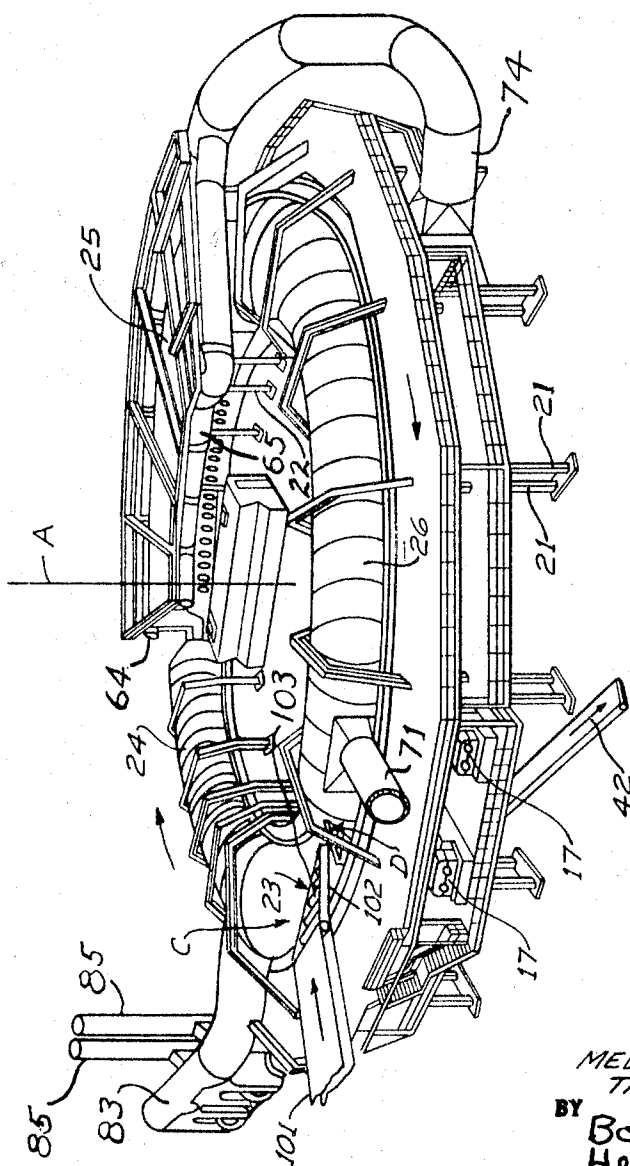


Fig. 1

INVENTORS.
MELVIN J. GREAVES
TAGE WERNER
BY *Booworth, Sessions,
Herrington & Knowles*
ATTORNEYS.

Aug. 12, 1969

M. J. GREAVES ET AL
APPARATUS FOR TREATMENT OF PARTICULATE MATERIAL
ON MOVING SUPPORT

3,460,818

Filed May 31, 1966

10 Sheets-Sheet 2

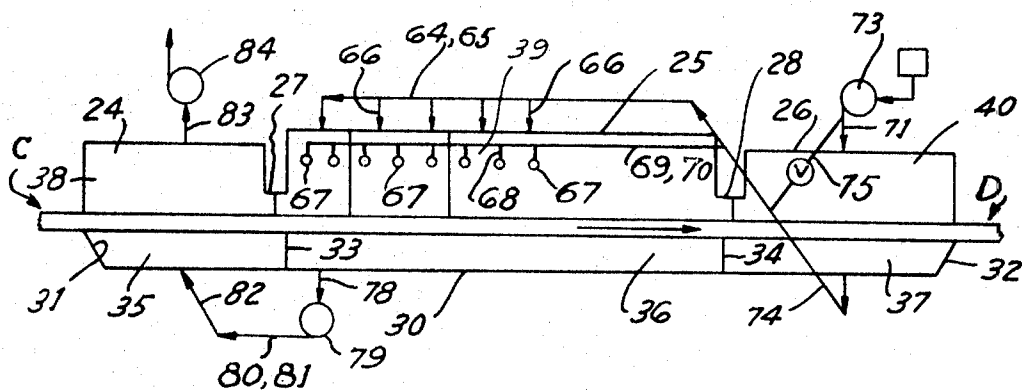


Fig. 3.

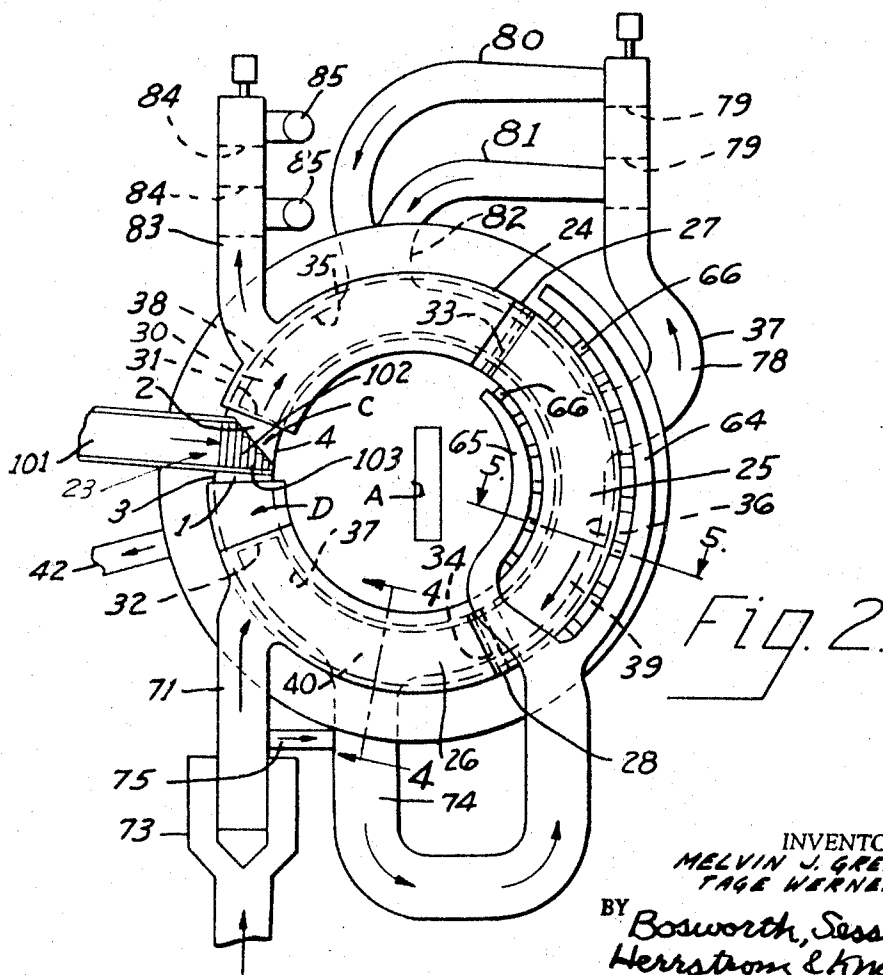


Fig. 2.

INVENTORS.
MELVIN J. GREAVES
TAGE WERNER
BY Bosworth, Sessions,
Herrstrom & Knowles
ATTORNEYS.

Aug. 12, 1969

M. J. GREAVES ET AL
APPARATUS FOR TREATMENT OF PARTICULATE MATERIAL
ON MOVING SUPPORT

3,460,818

Filed May 31, 1966

10 Sheets-Sheet 3

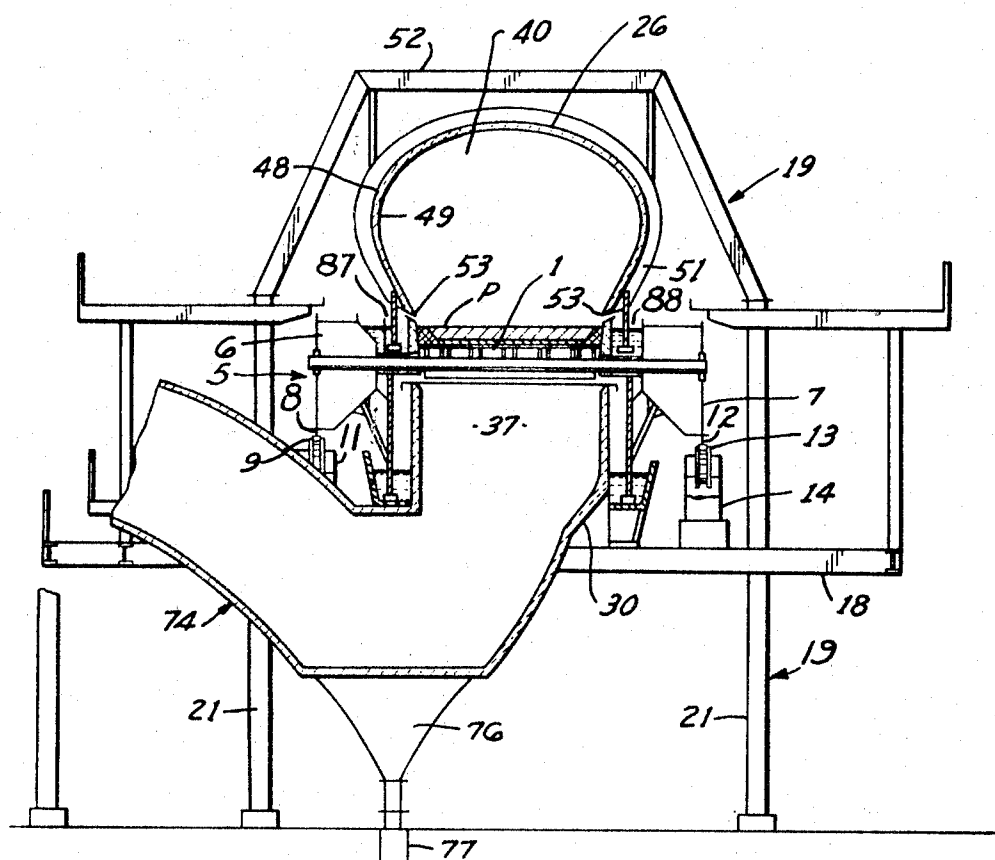


Fig. 4.

INVENTORS:
MELVIN J. GREAVES
TAGE WERNER
BY Bosworth, Sessions,
Heerstrom & Knowles
ATTORNEYS

Aug. 12, 1969

M. J. GREAVES ET AL
APPARATUS FOR TREATMENT OF PARTICULATE MATERIAL
ON MOVING SUPPORT

3,460,818

Filed May 31, 1966

10 Sheets-Sheet 4

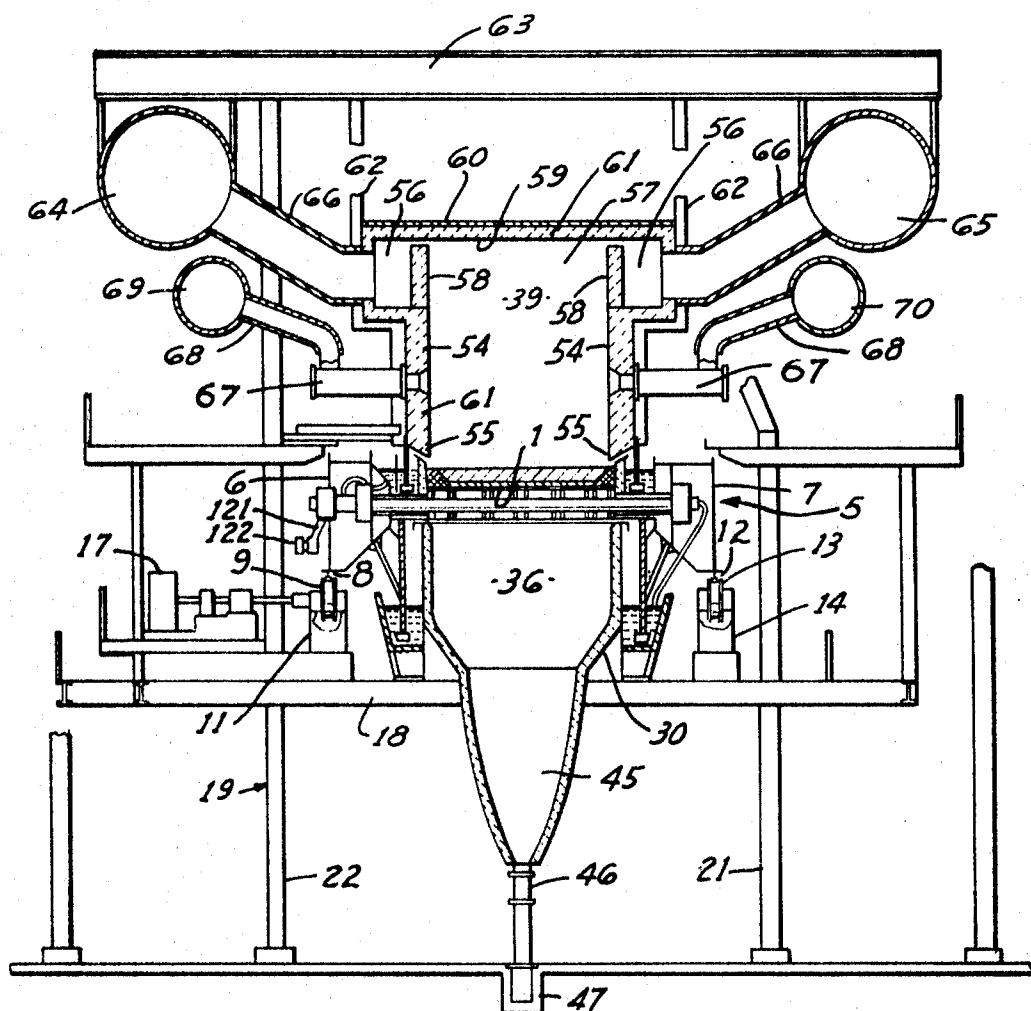


Fig. 5.

INVENTORS:
MELVIN J. GREAVES
TAGE WERNER
BY Bosworth, Sessions
Herrstrom & Knowles
ATTORNEYS.

Aug. 12, 1969

M. J. GREAVES ET AL
APPARATUS FOR TREATMENT OF PARTICULATE MATERIAL
ON MOVING SUPPORT

3,460,818

Filed May 31, 1966

10 Sheets-Sheet 5

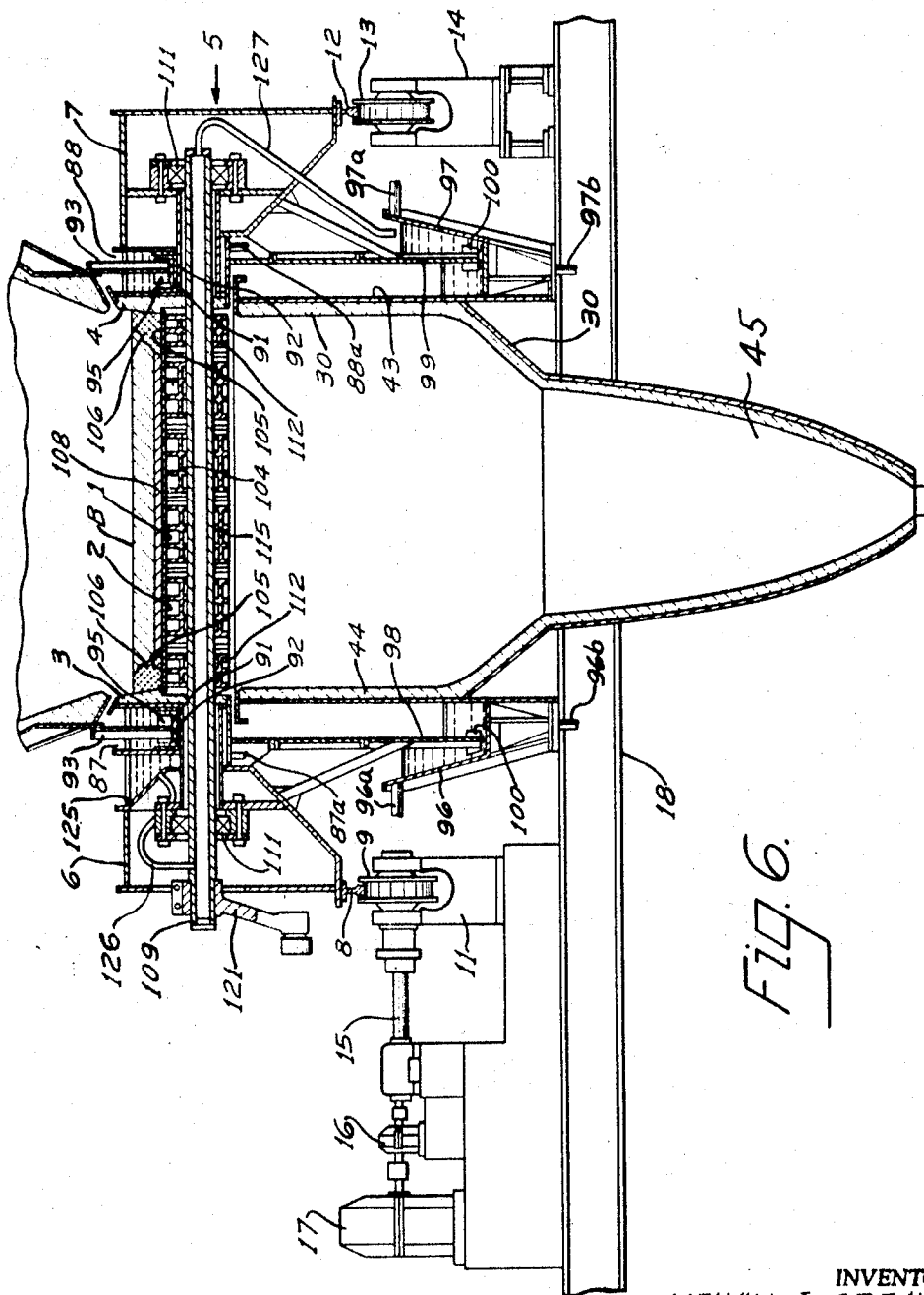


Fig. 6.

INVENTORS.
MELVIN J. GREAVES
TAGE WERNER
BY
Bosworth, Sessions,
Herstrom & Knowles
ATTORNEYS.

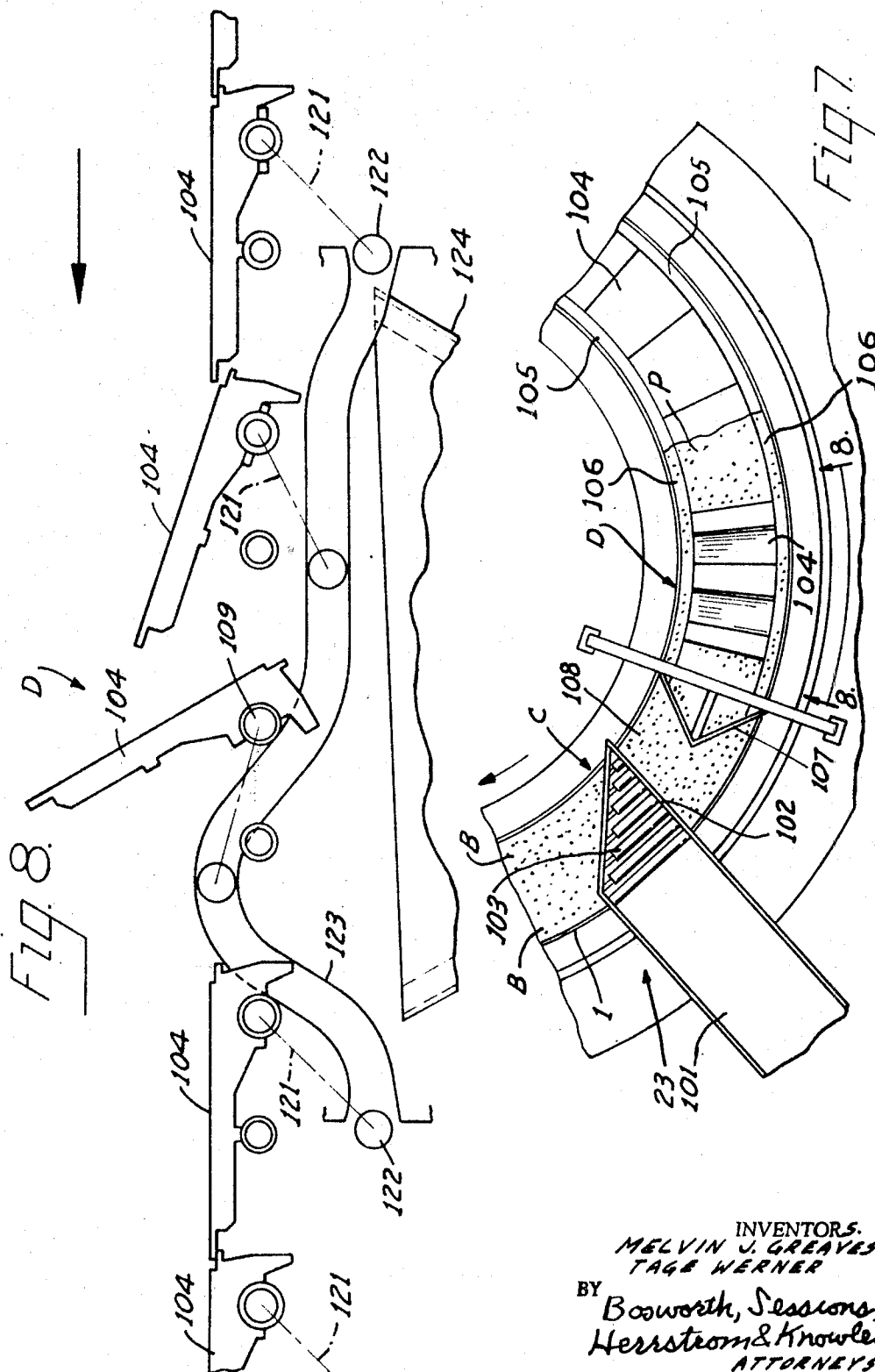
Aug. 12, 1969

M. J. GREAVES ET AL
APPARATUS FOR TREATMENT OF PARTICULATE MATERIAL
ON MOVING SUPPORT

3,460,818

Filed May 31, 1966

10 Sheets-Sheet 6



INVENTORS.
MELVIN J. GREAVES
TAGE WERNER
BY Boosworth, Sessions,
Herrstrom & Knowles
ATTORNEYS.

Aug. 12, 1969

M. J. GREAVES ET AL
APPARATUS FOR TREATMENT OF PARTICULATE MATERIAL
ON MOVING SUPPORT

3,460,818

Filed May 31, 1966

10 Sheets-Sheet 7

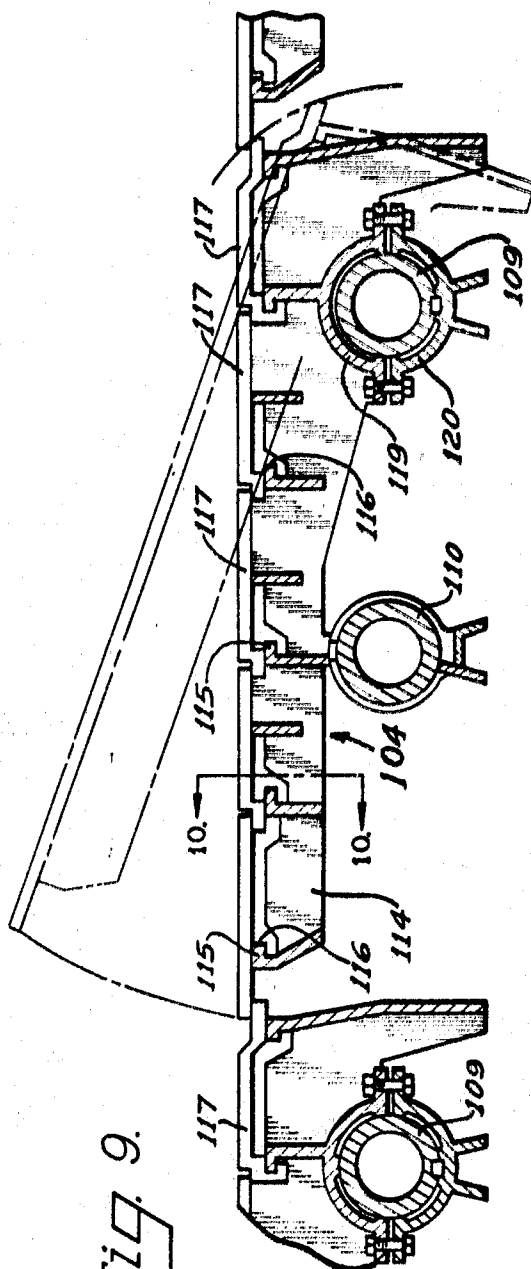
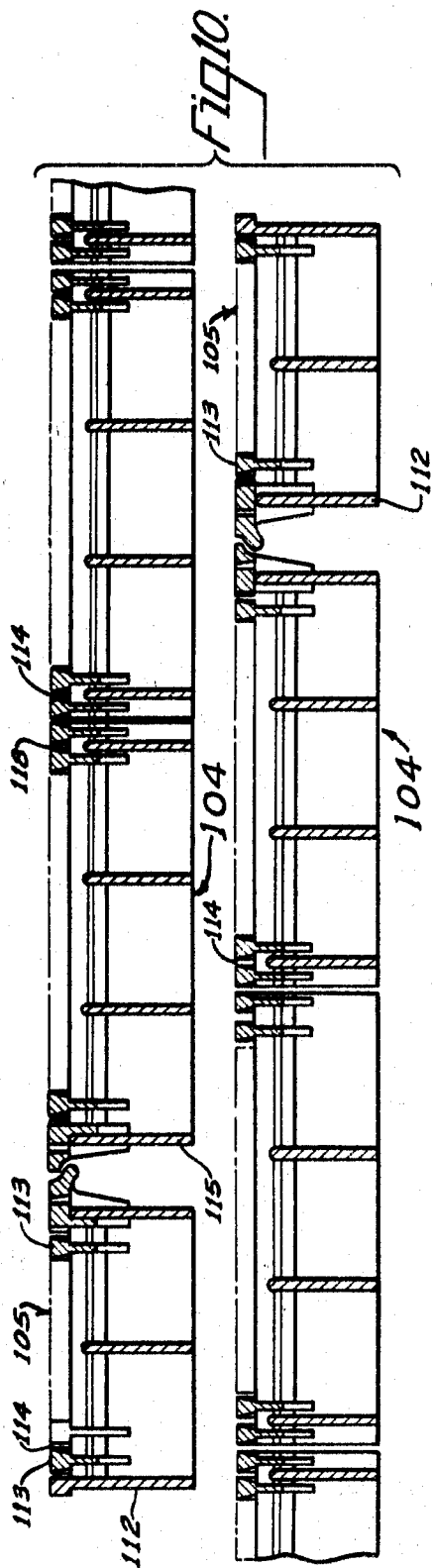


Fig. 9.

INVENTORS
MELVIN J. GREAVES
TAGE WERNER
BY Bosworth, Sessions,
Herstrom & Knowles
ATTORNEYS.

Aug. 12, 1969

M. J. GREAVES ETAL
APPARATUS FOR TREATMENT OF PARTICULATE MATERIAL
ON MOVING SUPPORT

3,460,818

Filed May 31, 1966

10 Sheets-Sheet 8

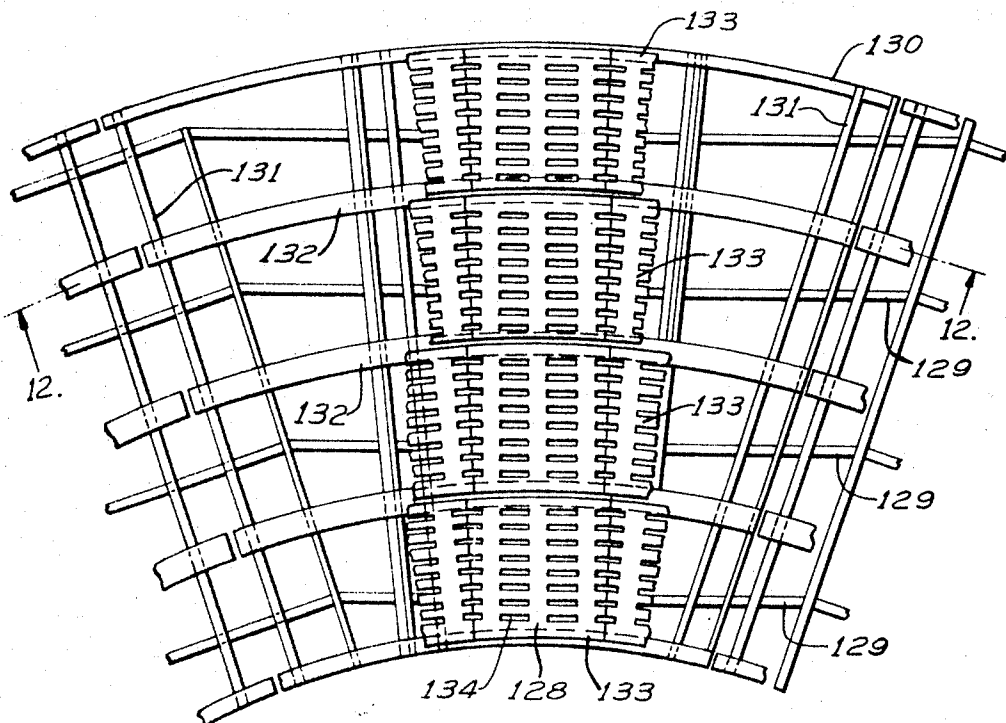


Fig. 11.

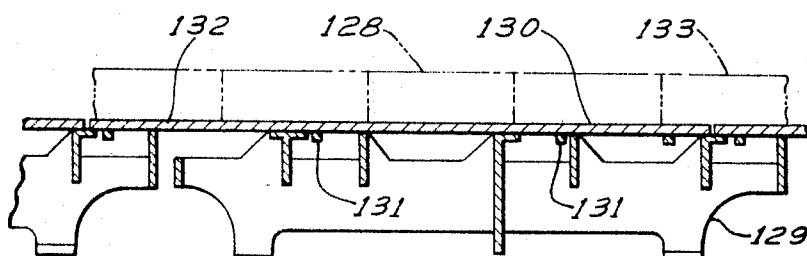


Fig. 12.

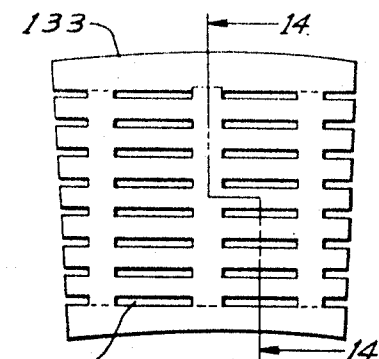


Fig. 13.

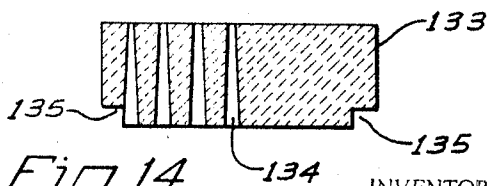


Fig. 14.

INVENTORS.
MELVIN J. GREAVES
TAGE WERNER
BY
Boosworth, Sessions,
Herrstrom & Knowles
ATTORNEYS.

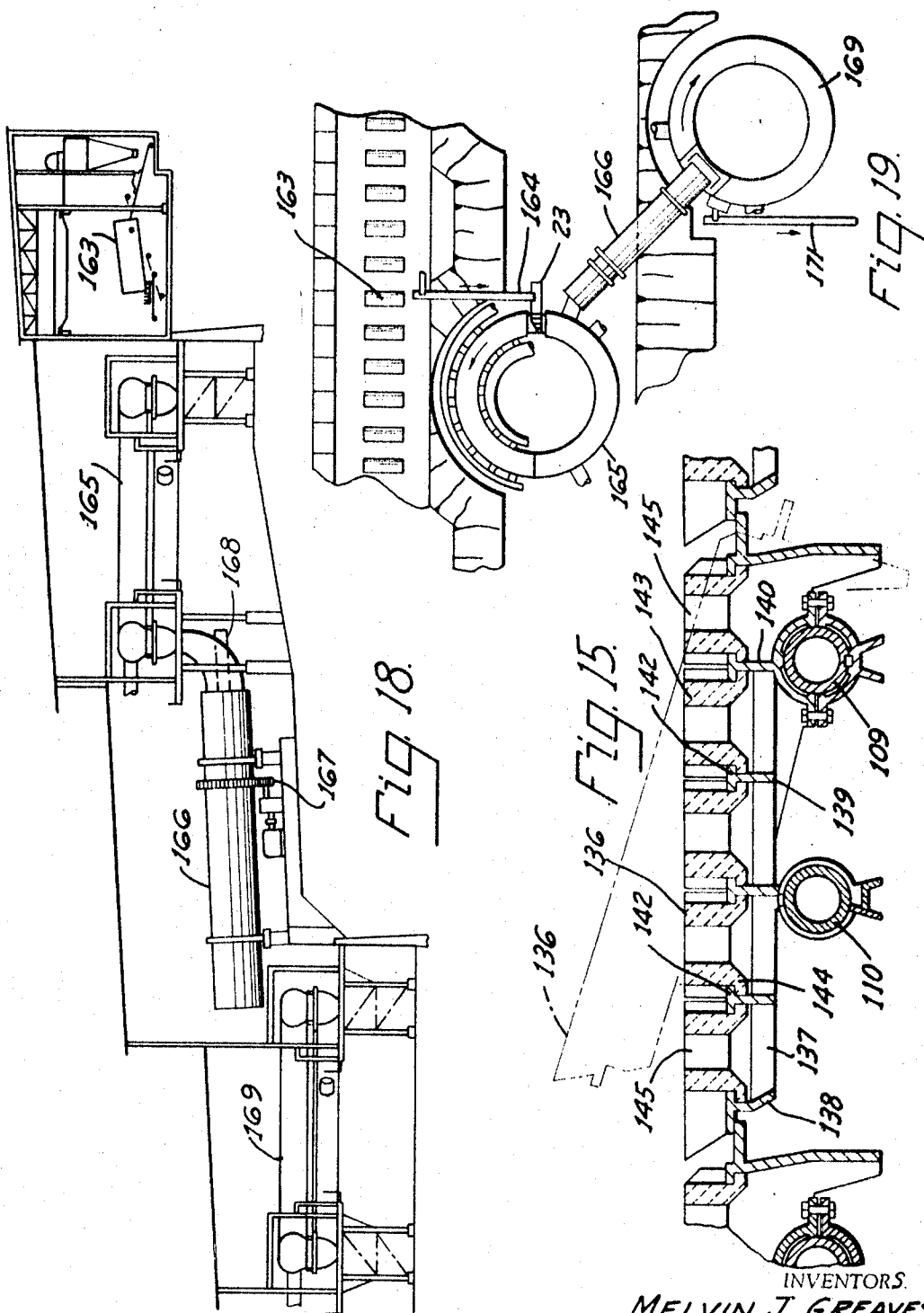
Aug. 12, 1969

M. J. GREAVES ET AL
APPARATUS FOR TREATMENT OF PARTICULATE MATERIAL
ON MOVING SUPPORT

3,460,818

Filed May 31, 1966

10 Sheets-Sheet 2



INVENTORS.
MELVIN J. GREAVES
TAGE WERNER
BY *Bosworth, Sessions,
Herrstrom & Knowles*
ATTORNEYS.

Aug. 12, 1969

M. J. GREAVES ET AL
APPARATUS FOR TREATMENT OF PARTICULATE MATERIAL
ON MOVING SUPPORT

3,460,818

Filed May 31, 1966

10 Sheets-Sheet 10

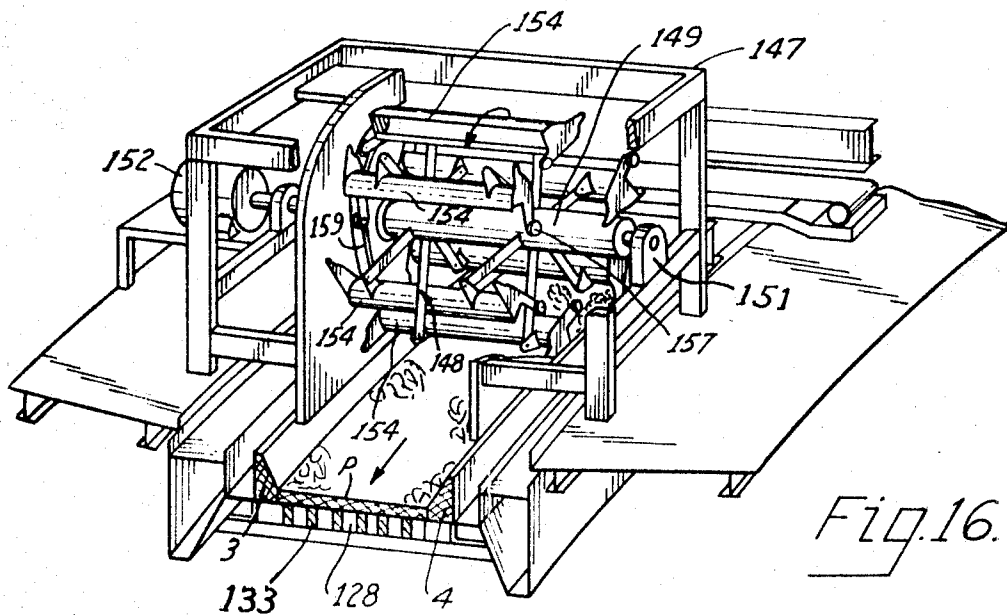


Fig. 16.

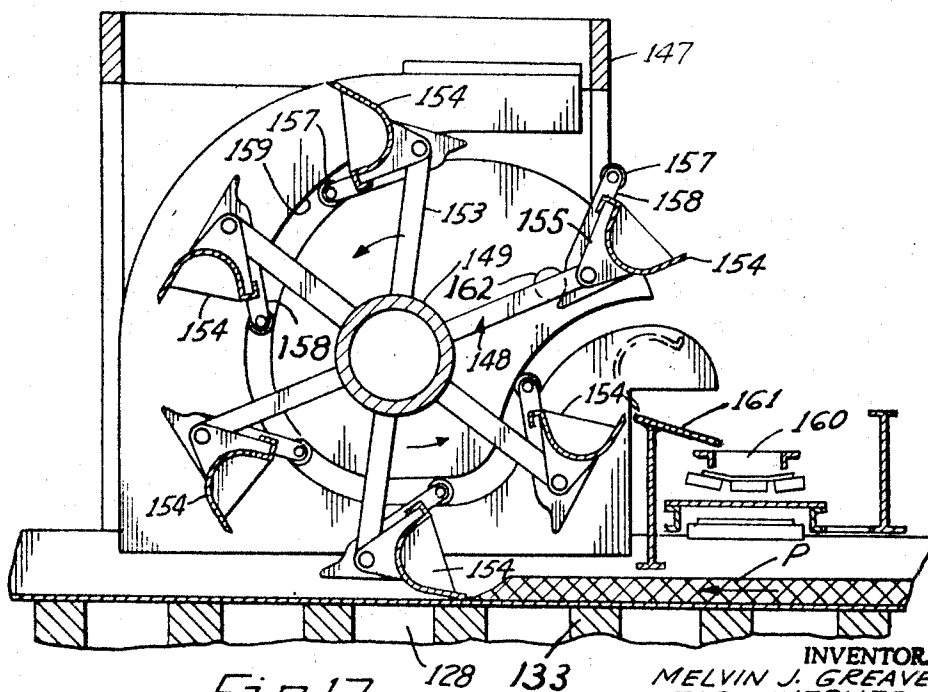


Fig. 17.

INVENTORS:
MELVIN J. GREAVES
TAGE WERNER
BY *Bosworth, Sessions,
Herrold & Knowles*
ATTORNEYS.

1

3,460,818

APPARATUS FOR TREATMENT OF PARTICULATE MATERIAL ON MOVING SUPPORT

Melvin J. Greaves, Cleveland, and Tage Werner, Rocky River, Ohio, assignors to Arthur G. McKee & Company, Cleveland, Ohio, a corporation of Delaware

Filed May 31, 1966, Ser. No. 553,939

Int. Cl. F27b 21/02; C21b 1/16; C22b 1/08

U.S. Cl. 266—21

30 Claims

ABSTRACT OF THE DISCLOSURE

Apparatus and process for treating particulate material that is carried by a support traveling in a generally circular path, such as a circular grate for heat hardening balls of iron ore. One form of the apparatus includes means for removing particulate material from only a portion of the width of the support as the support passes a discharge location, and means for spreading across the support the particulate material that has not been removed to form a layer on which other material is subsequently deposited. Another form of the disclosed apparatus includes a gas permeable circular grate having gas enclosing means above or below the grate and liquid seals at the sides of the grate sealing the grate to the gas enclosing means. The process includes the steps of passing the material on the grate through several zones and maintaining at each zone a superatmospheric pressure on the higher pressure side of the grate from which the gas is passed through the grate to the other side of the grate in said zone.

This invention relates to the treating of particulate materials, such as ores or other metal compounds, as by heating, and more particularly to method and apparatus for handling such materials.

While the invention may be advantageously used in treating various types of particulate materials, it will be discussed below primarily in connection with agglomerating particulate iron oxide material to form heat hardened pellets having sufficient strength and hardness to permit them to be handled, shipped, stored and charged into blast furnaces or other smelting apparatus. The invention provides particular advantages in such uses.

In the production of such heat hardened iron ore pellets, finely divided ore, beneficiated ore concentrate, flue dust, or other iron-bearing material, either alone or with particles of solid fuel, flux materials or other substances, are mixed together with water to form a moist, mud-like mass that is then formed into green balls by any suitable known means. When the balls are generally spherical, as is common practice, to as great an extent as possible they are of a uniform desired size, usually between about 1/4" to 1" in diameter, and preferably between about 3/8" and about 1/2" in diameter. Pelletizing, involving heating of these balls under temperature and other conditions to dry and harden them, will remove moisture from and strengthen the balls by heat hardening so that they may thereafter be handled, shipped, stored and charged by conventional apparatus. Horizontal traveling straight grate machines, certain grate-kiln machines, and shaft furnaces have been the most widely used types of pelletizing machines.

In the shaft furnace, green balls while in a deep body are caused to move downwardly through a vertical furnace while heating gases are passed upwardly through the body of balls. This type of machine has not been used as widely as other types because of the relatively low upper limit on productive capacity of such machine and because it has been difficult to achieve desired uniformity of pellet quality due to difficulties of insuring uniform gas

2

flow across the cross section of the body of pellets in the furnace. Furthermore, other limitations on the usage of these machines have arisen because it is difficult, if not impossible, to achieve in them the high temperatures necessary for pelletizing of hematite materials.

The typical horizontal traveling straight grate pelletizing machine heretofore used comprises a number of wheeled pallets that travel in an endless strand having upper and lower paths. The grate is formed by pallets traveling in the upper path along a straight horizontal track while in abutting relation to define a straight channel cross-sectioned material-carrying grate having a permeable bottom and upwardly-extending confronting side-walls; the pallets return in the lower path to the end of the machine at which the green balls are charged onto the grate. In a typical pelletizing operation on such a machine, the green balls are deposited in a layer of predetermined thickness at the charging end of the grate. The balls on the grate are subjected to drying, high temperature indurating heating that heat hardens the balls, and cooling as the grate moves through the several stages of the pelletizing machine, the balls being completely heat hardened and cooled substantially to handling temperatures before being discharged from the grate as product. Heat treatments involve passing air in the cooling zone and hot gases in the other zones through the bed of balls on the grate, either downdraft or updraft, or in a combination of downdraft and updraft gas flows. The product pellets are discharged from the pallets at the discharge end of the grate when the pallets tilt as they pass from the upper to the lower paths.

The typical grate-kiln type of pelletizing machine heretofore used has a short straight traveling grate having a permeable bottom hearth and upwardly-extending confronting sidewalls, the grate usually being a chain grate. The grate-forming parts also travel in upper and lower paths, the upper run of the path constituting the grate and the lower run being the return run. Green balls are deposited on the grate and travel on the grate through drying and preheating zones which partially harden the balls; the partially hardened balls are then discharged from the grate into a kiln, rotating about an axis inclined downwardly from the receiving end to the discharge end of the kiln, hot combustion gases being introduced into the kiln at its discharge end for completing heat hardening of the balls into pellets as they tumble in the kiln; the resulting pellets are then discharged from the kiln. To conserve heat the gases leaving the kiln pass one or more times through the balls on the grate to perform heating operations on the grate.

Each of these prior types of machines utilizing grates has been susceptible of certain disadvantages that have been difficult to overcome.

Thus, in the above described grate-kiln apparatus difficulties arise because of grinding or breakage of the incompletely hardened balls as they are tumbled in the kiln, which results in degradation of pellet quality and undesirable formation in the kiln of rings formed of materials resulting from grinding or breakage of the tumbling incompletely hardened pellets. Such ringing adversely affects the flow, tumbling and heat treatment of pellets in the kiln. Since the kiln is long, removal of the rings while the kiln is operating requires shooting of projectiles into the kiln to knock off the rings, which requires careful aim and nevertheless often damages refractory material. When the kiln is shut down to remove rings and repair lining damage, costly loss of production time results. These factors adversely affect pellet quality. The kiln must be long to permit completion of the heat hardening in the kiln; this adds to the cost of the kiln and the plant space to house it. Moreover, large quantities of fuel must be burned in

the kiln in order to effect desired completion of heat hardening, and large volumes of hot gases must be moved through and out of the kiln. In order to prevent undue loss of heat in these cases, it has been the practice to pass the gases, after they leave the kiln, one or more times through the balls on the grate in order to transfer to the balls some of the heat that would otherwise be wasted; this requires movement of large volumes of gases to and through the grate, with consequent high cost of construction for large refractory lined or exteriorly insulated ducts. Consequently, the operational efficiencies of such prior grate-kiln apparatus have not been as good as desired.

In the prior horizontal traveling straight grate machines and in the grate-kiln machines, there have also been disadvantages, arising out of the grate itself, apparent from the following discussion.

The present invention provides apparatus in which a grate formed of a permeable bottom hearth and upstanding sidewalls travels in a circular path. At a charging location on the grate, means are provided to spread the balls on the grate in a layer of essentially uniform thickness extending on the hearth between the sidewalls. Hoods and gas conduit means, and sealing means, are arranged above and below the grate to provide various treatment zones, such as drying, high temperature indurating heating to harden the pellets, and cooling zones as the grate moves the green balls through the several zones; air may be passed through the layer of balls on the grate in the cooling zone, and hot gases in the other zones, downdraft or updraft as desired. When the balls reach the discharge location on the grate, usually in the vicinity of the charging location, they are discharged from the grate, preferably according to the present invention, without tilting the sidewalls of the grate. The grate is preferably supported by fluid cooled supports, and the apparatus of the invention preferably embodies liquid seals to prevent undesired passage of gases into or out of the side portions of the junctures of the moving grate and the hoods above the grate and the conduit means below the grate. These factors make possible substantial improvements in product quality.

In prior conventional straight grate machines, it is difficult to maintain absolutely uniform processing conditions laterally across all cross sections of the grate in each treating zone, because of the effects of the sidewalls in changing gas flows and modifying transfer of heat to or from balls or pellets near the sidewalls. Similarly, the bottom of the grate affects the processing of those balls or pellets near the bottom differently from those more remote from the bottom. These factors tend to cause the pellets discharged from the grate, particularly those near the sidewalls, to be of non-uniform quality, unless special precautions are taken such as the provision of sidelayers and hearth layers of preburned pellets or reject pellets that must be separated from product pellets. Such precautions add complexity and expense to construction and operation of straight grate apparatus. According to the present invention, due to the fluid-cooled pallet supports, it is practical to build a circular grate machine considerably wider than a conventional straight grate machine, twice as wide or even wider. Therefore, the relative effects of the sides on the product material is proportionately reduced.

In prior straight grate apparatus, it is necessary to use mechanical seals for sealing the sidewalls of the pallets forming the grate to the hoods above the grate to the windboxes below the grate, since the pallets and their sidewalls tilt as the pallets move between the upper and lower runs of the strand. Such seals generally are not as effective as desired since they permit leakage that tends to chill pellets located next to the sidewalls. Furthermore, although attempts have been made to maintain a slight super-atmospheric pressure in the hoods of zones having downdraft gas flows on straight grate apparatus, this has not always been successful because ineffective sealing can cause pressure within the hood to vary along the hood

length, so that at one or more locations negative pressures may exist that can permit infiltration of cold air, resulting in off grade products. The present invention makes possible the use of liquid, such as water, seals above and below the grate because the grate sidewalls need not tilt. These seals can virtually eliminate gas leakage at the sidewalls of the grate, thus eliminating chilling of pellets near the walls and permitting pressurizing of the hood. In particular, the hood in the cooling zone can be maintained at super-atmospheric pressures with cold air, thereby making downdraft cooling practical and causing uniform heating of the pellets at pelletizing temperatures by preventing interruptions of the indurating process that can occur if updraft cooling air reaches the lower stratum of pellets prior to their complete treatment.

In conventional straight grate machines, it has been necessary to use metal sidewalls because refractories have not proven sufficiently durable to withstand the mechanical shocks to which the tilting pallets are subjected as they pass between the upper and lower runs of the strand and as they dump pellets at the discharge end of the apparatus. However, such metal sidewalls constitute heat sinks that absorb heat from the process gases and reduce their temperatures below those necessary properly to treat the pellets. In the circular apparatus of the present invention, the grate sidewalls need not be subjected to shocks and can be made of non-metallic refractory materials rather than metal, which because of their low heat conductivities or insulating qualities will absorb substantially less heat from the process gases and make it possible for gases flowing through the pellets in contact with sideplates to be at proper temperatures to permit adequate treatment of the pellets adjacent the sidewalls.

However, if it is desirable to use hearth layers and sidelayers of pellets, as is desirable in pelletizing hematite ores, the invention provides an arrangement that can be provided to recycle the sidelayers as a hearth layer.

In the circular grate apparatus of the present invention, the exposed surface areas of gas-containing chambers and duct work can be greatly reduced, even to about one-half that of a straight grate machine of the same capacity. This occurs largely because the means for conducting gases to or from the underside of the grate can be located directly under the grate, since there is no lower strand to interfere with such means in such location; therefore, there is no need for the complicated arrangements of wind-boxes and downcomers necessary in conventional apparatus embodying straight grates to connect the grate to a collector main that must be located alongside the lower strand. Furthermore, since the waterseals virtually eliminate side leakage, no fuel is required to replace heat losses through escape of hot gases from the sides of the machine or to reheat gases which have been tempered by infiltration of cold air. Consequently, fuel required to compensate for heat radiation and leakage losses from these causes may be reduced substantially, even by as much as 50% or more. If the side-layer is recircled as a hearth layer, as is possible according to the invention, sensible heat in the sidelayer material is recovered.

Furthermore, since in this circular grate apparatus there is no return strand that carries no pellets, there are no heat losses corresponding to the large amounts of heat normally lost by radiation from the hot pallets in the return strand of the conventional grate-kiln machine. In a circular grate machine embodying the invention, about 85% of the grate may be effective for heating as compared with about half of that in a straight grate or grate-kiln machine.

Since there can be leakproof seals both above and below the grate, the fans for moving gases can be located to handle gases on the cooler and cleaner side of the layer of pellets, eliminating or reducing the need for addition of cold tempering gases to hot gases for fan protection, as is necessary in conventional pelletizing ma-

chines using straight grates. Hot gases that have been tempered may require additional fuel to restore them to processing temperature and additional power is required for moving tempering gases alone or admixed with hot gases. When the fans are located on the cooler side of each gas pass, substantial savings can be effected in fan power because smaller volumes of cool gases are handled and because it is not necessary to handle substantial volumes of tempering gases.

Since according to the present invention, it is possible to use a much wider grate than in a straight grate machine, a thinner bed of balls may be used on the grate, with less pressure drop of gases passing through the bed of balls on the grate; this is extremely important because the power required to pump gases is approximately proportional to the cube of the bed depth. Power savings also result because gas leakage is essentially completely eliminated. Furthermore, location of the collector main directly beneath the grate and consequent elimination of downcomers and windboxes eliminates the largest single cause of pressure drop, apart from the drop across the bed itself, in conventional apparatus, with consequent power savings.

Maintenance costs may also be substantially reduced by the apparatus of the present invention. Use of refractory sidewalls eliminates one of the largest maintenance cost items in conventional straight grate machines, that of frequent replacement of metal pallet sidewalls. Since the circular grate always moves in a single generally planar path, it need not be made up of wheeled pallets, as is necessary in straight grate machines in which the pallets move in upper and lower paths. Therefore, there is eliminated the costly maintenance required on the several hundred wheels supporting the pallets arising from the need for lubrication, for replacement of wheels that become distorted from heat or wear, and for replacement of parts such as bearings or axles deteriorated from heat. Use of fluidcooled supports for carrying the grate greatly reduces deterioration of these supports from heat, correspondingly decreasing another item of high maintenance cost in conventional apparatus using straight grates in which the grate-supporting members deteriorate due to thermal fatigue. Use of liquid seals according to the invention eliminates conventionally used mechanical seals which require considerable maintenance. Fan deterioration is reduced by location of the fan on the cooler side of each gas pass. The simple means provided by the invention for forming hearth layers out of sidelayers eliminates coolers, feeders and conveyors required in conventional straight grate apparatus for forming hearth layers and sidelayers. On apparatus embodying straight grates, alignment problems are frequently the cause of operating difficulties; these can be eliminated in apparatus of the invention because alignment need not depend on members that are subject to expansion and distortion by heat. There need be only about one-half as many grate bars in apparatus of the above invention as in conventional straight grate apparatus of the same capacity; grate bars in general are the most expensive items of initial and maintenance costs.

By use of apparatus embodying the invention it is possible to build a larger product capacity into a single unit than with any other apparatus heretofore known, thus making considerable cost advantages for large annual capacity. The compact design, in which all the equipment is arranged in a compact fashion in comparison with conventional straight grate and grate-kiln apparatus, which require long length apparatus, permits lower initial costs and lower plant housing costs. It also makes it possible for each circular machine to be operated in service by a minimum number of people. Because of the watercooled construction and possibilities of using refractory materials in the grate, apparatus embodying the invention can be used for processes requiring several hundred degrees

higher temperatures than apparatus embodying straight grates.

It is an object of the present invention to provide apparatus which can overcome all or as many as desired of the above indicated disadvantages of prior pelletizing methods and apparatus. A further object is the provision of apparatus embodying a circular traveling grate for producing high quality, heat hardened pellets of exceptional high quality and exceptional high uniformity of quality. A further object is the provision of apparatus that has substantially improved durability over and can be operated for longer periods without shutdown than prior apparatus embodying straight grates. Another object is the provision of apparatus that can be built to have larger production capacities and lower per-ton product costs of installation and operation than prior apparatus embodying straight grates.

These and other objects of the invention will become apparent from the following description of a preferred embodiment of the invention in connection with the accompanying drawings in which:

FIGURE 1 is a perspective of one embodiment of a circular grate pelletizing machine of the invention;

FIGURE 2 is a somewhat diagrammatic plan of the machine of FIGURE 1;

FIGURE 3 is a diagrammatic view of the grate as extended illustrating the gas flow;

FIGURE 4 is a section along line 4—4 of FIGURE 2;

FIGURE 5 is a section along line 5—5 of FIGURE 2;

FIGURE 6 is an enlargement of the lower portion of FIGURE 5, showing in particular the water seals and means for driving the grate;

FIGURE 7 is a plan view of a portion of the grate and adjacent apparatus, particularly showing the ball feeding and pellet discharging locations on the grate;

FIGURE 8 is a somewhat diagrammatic side elevation of the dumping portion of the grate of the apparatus of FIGURE 1, illustrating how the center sections of the grate are caused to dump, this figure generally corresponding to line 8—8 of FIGURE 7;

FIGURE 9 is a longitudinal section through one of the dumping sections of the grate;

FIGURE 10 is a section along line 10—10 of FIGURE 9, showing across section of the grate, FIGURE 10 being drawn in two portions to permit showing of the grate structure in a sufficiently large scale;

FIGURE 11 is a plan of a portion of another type of grate, having a refractory hearth that does not dump, parts being broken away to show the construction;

FIGURE 12 is a view generally along line 12—12 of FIGURE 11 showing a section through a portion of the grate and its supporting structure;

FIGURE 13 is a plan of one of the refractory members forming the hearth of the grate of FIGURE 11;

FIGURE 14 is a section along line 14—14 of FIGURE 13;

FIGURE 15 is a section, generally corresponding to FIGURE 9, showing an alternative type of grate with a hearth formed of refractory non-metallic material in which the central portion of the hearth can dump as in FIGURE 9;

FIGURE 16 is a perspective of a type of means for removing pellets at the discharge location for use in conjunction with a grate that does not discharge pellets by dumping;

FIGURE 17 is a section of the apparatus of FIGURE 16 generally along a vertical plane normal to its axis of rotation;

FIGURE 18 is a side elevation of another form of apparatus embodying circular grate apparatus according to the invention, this apparatus comprising a circular grate on which green balls are indurated, a kiln in which the balls are tumbled for further treatment, and a circular grate cooler; and

FIGURE 19 is a plan of the apparatus of FIGURE 18 to a smaller scale.

The apparatus of FIGURES 1-10 embodying the present invention comprises (FIGURES 1, 2, 4-6) a grate 1 that is circular in plan and designed to travel in a circular path in the direction indicated by the arrows in FIGURES 1, 2 and others. This grate 1 comprises a gas-permeable hearth 2 and upstanding gas-impermeable sidewalls 3 and 4. The sidewalls 3 and 4 extend entirely around the outer and inner circumferences of the grate, and, with the hearth, define a grate of generally channel-shaped cross section.

The grate is supported on a rigid frame 5 rotatable about vertical axis A and comprising a fabricated outer member 6 that extends around the outer circumference of the apparatus adjacent the outer sidewall 3 of the grate and a fabricated inner member 7 that extends around the inner circumference of the apparatus adjacent the inner sidewall 4 of the grate. The lower portion of outer frame member 6 carries a circular rail 8 that rides on and is supported by rotatable rollers 9 mounted in supports 11 spaced around the outer periphery of the apparatus. The lower portion of inner frame member 7 carries a circular rail 12 that rides on rollers 13 mounted in supports 14 spaced around the inner periphery of the apparatus. At least some of outer rollers 9 are driven by shafts 15 through speed reducers 16 from motors 17 (FIGURES 1 and 6).

Supports 11 and 14 for the rollers are carried by horizontal members 18 of a stationary supporting frame 19 having vertical supporting columns 21 and 22. Suitable green balls, such as those previously mentioned, are deposited on the grate by charging means 23 at a charging location C, and travel on the grate around the circumference of the apparatus in the direction indicated by the arrows in FIGURE 1 and other figures to a discharge location D immediately adjacent but upstream of charging location C, where they are discharged from the grate by means to be described later.

Supported by stationary frame 19 over the grate 1 are stationary hoods 24, 25 and 26, interconnected by intermediate hood portion 27 between hoods 24 and 25 and intermediate hood portion 28 between hoods 25 and 26. These hood portions, and the ends of the hoods separate the interiors of the hoods from each other so little if any gas can pass above the layer of pellets from one hood to an adjacent hood. A fixed gas collector main 30 extends directly under the grate through the portion of the circumference of the apparatus covered by the hoods, being closed at its ends 31 and 32 and subdivided by partitions 33 and 34 into sections 35, 36 and 37. Hood 24 and its associated collector main section 35 define a drying zone 38, in which the green balls are subjected to drying and preheating by hot gases passing updraft through the layer of balls on the grate; they are carried through this zone by the moving circular grate. Hood 25 and its associated collector main section 36 define an indurating zone 39, in which the preheated and predried green balls are subjected to high temperatures to indurate or heat harden them by means of oxide conversions, recrystallizations and grain growth, in manners known to the art, by hot gases passing downdraft through the layer of balls on the grate as it travels through the zone; hood section 26 together with its associated collector main section 37 defines a cooling zone 40 in which the hot heat hardened pellets are cooled by passage of ambient air passed downdraft through the layer of hot pellets on the grate traveling through the zone. The hot pellets are discharged in discharging section D, and are conveyed away from the apparatus on suitable conveyor 42.

As is apparent from FIGURE 6, the collector main 30 is formed of a metal shell 43 and an inner heat-resistant, heat-insulating refractory lining 44. At spaced locations thereunder, the collector main has downwardly-depending portions 45, also formed of a metal shell and a similar lining, for accumulating dust from the gases and dis-

charging it through a trap 46 into a flume 47 in the floor from which it may be removed by a stream of water.

The hoods 24 and 26 in the drying and cooling zones have the cross sectional shape shown in FIGURE 4; each includes an outer metal shell 48 lined with heat-resistant, heat-insulating refractory material 49 in the usual manner, the metal shell having lateral reinforcing strips 51. The hood is suspended from framing members 52 from columns 21 of the main frame 19. The lower edges 53 of the hood sidewalls closely approach the upper edges of the sidewalls of grate 1.

The cross sectional shape of hood 25 in the indurating zone is shown in FIGURE 5. This hood has sidewalls 54 the lower edges 55 of which closely approach the upper edges of the grate sidewalls. The upper portion of the hood is widened to provide chambers 56 extending lengthwise of the hood and separated from the furnace portion 57 of the interior of the hood by baffle walls 58 that stop short of the ceiling 59 of the hood. The hood itself has an outer shell 60 and is lined with a layer of heat-insulating, heat-refractory material 61; walls 58 are of similar material. The hood itself is carried by members 62 from cross members 63 supported from posts 22 of the main frame.

Air supply mains 64 and 65 extend adjacent to and above each side of hood 25, being supported by cross members 63. Spaced branch conduits 66 conduct air from mains 64 and 65 to the interiors of the side chambers 56 of the hood 25 to supply secondary combustion air, which enters the furnace chamber 57 over the tops of walls 58.

As in conventional practice, each side of the induration hood 25 has several fuel burners 67, such as burners capable of burning gas or oil, supplied with fuel by conventional means not shown. Each of these burners is also supplied with primary combustion air by a branch conduit 68 communicating with one of the conduits 69, 70. The air conduits are preferably insulated to conserve heat in the heated air that is preferably used.

FIGURES 1, 2, 3-6 illustrate the means for handling gases and the pattern of gas flows in the illustrated apparatus. Ambient air is introduced into the hood 26 of the cooling zone 40 through conduit 71 by conventional fan apparatus 73 that maintains a substantial super-atmospheric pressure of air in the hood 26, such as about 22 inches of water at standard conditions. The air passes downwardly through the layer of hot pellets on the grate into the collector main section 37 in which a lower but appreciable super-atmospheric pressure, as about 10 inches of water, is maintained. From main section 37 the heated air, normally at a temperature of between about 800° F. and 1600° F., passes laterally to the outside of the apparatus through a duct 74 that is preferably heat-insulated to conserve heat and for safety. This heated air, still at super-atmospheric pressure, passes from duct 74 to ducts 64, 65, 69 and 70 for supplying combustion air to the hood 25 of the indurating zone; if desired, but not necessarily, tempering or cooling air at ambient temperatures can also be introduced into duct 74 by cross duct 75 connected to ducts 71 and 74. This lateral duct 74 (FIGURE 4) preferably communicates with a dust collection portion 76 discharging into another flume 77.

The fuel burned by burners 67 in such combustion air produces in conventional manner hot gases at temperatures ranging from about 2350° F. to about 2500° F. and preferably about 2400° F., and these gases pass downdraft through the layer of balls on the grate, causing the oxide conversions, recrystallizations, and grain growth that produce the desired heat hardening resulting in pellet formation. After passing through the balls on the grate and the hearth, the gases pass into the collector main section 36 in the induration zone and from such section pass through lateral conduit 78, similar to conduit 74, to fans 79. The downdraft gas flow through the grate and balls in the induration zone arises from a super-atmospheric atmosphere, such as about 10 inches of water, maintained

above the layer of balls by conduit 74, and from a suitable subatmospheric pressure maintained below the layer of balls in the indurating zone by suction of fans 79.

The gases discharged from the fans 79 pass through conduits 80 and 81 to a lateral conduit 82, similar to conduit 74, opening into collector main section 35 of the drying zone, the gases being at super-atmospheric pressure, as about 12 inches of water. These gases, which are at temperatures between about 500° F. and 800° F., pass upwardly through the grate into the hood 24 of the drying zone, to dry the green balls traveling through such zone; the gases are drawn from the hood through conduit 83 communicating with fans 84 that discharge the gases, which are now at temperatures of between about 250° F. and 400° F., to the stacks 85.

The illustrated apparatus (FIGURES 4, 5 and 6) embodies water sealing means for preventing leakage of gases at the sides of the grate into or out of the hoods and into or out of the collector main sections. The water sealing means for preventing passage of gases between the grate and the hoods comprises annular channel-shaped movable troughs 87 and 88 fixed in gas-leakproof relation immediately adjacent the outer and inner walls 3 and 4 of the grate 1 and carried by the frame members 6 and 7 of the traveling frame 5 that carries the grate. These troughs both carry water supplied and removed as described below. In each trough there is a removable tray 91 for collecting sediment, that rests on the watertight housing 92. Shield walls 93 and 94 extend downwardly from the lower edge portions of the sidewalls of the hoods into the water in the troughs 87 and 88. Preferably these walls also extend continuously throughout the lengths of all hoods from the beginning of the drying section to the end of the cooling section and near trays 91, preferably being connected at the ends of the hoods to transverse baffle members that prevent escape of gases past the ends of the hoods over the water surface. The walls preferably have transverse members 95 located close to trays 91, to inhibit deposit of sediment. Thus it can be seen that as the grate rotates about its axis A, the troughs 87 and 88 travel with it, while walls 93 and 94 remain stationary and by their projection into the water effectively seal the hoods against escape of hot gases or ingress of ambient air.

There are also stationary troughs 96 and 97 located on the inside and outside borders of collector main 30 in gas-leakproof relation and extending entirely around the circumference of the apparatus, in each of which troughs water is maintained at a suitable level. Downwardly-extending shield walls 98 and 99 fixed in gas-tight relation to the bottoms of upper troughs 87 and 88 have their lower ends immersed in the water in their associated channels 96 and 97; these walls therefore move with the grate. These walls also have spaced transverse members 100 inhibiting deposition of sediment in troughs 96 and 97.

Undesirable boiling of water in these seals that may be subjected to high temperatures can be prevented or inhibited by known expedients, such as mixing in large proportions of cold water, maintaining a high velocity of water flow in the trough, and inducing substantial water turbulence.

Charging means 23 for depositing green balls B on the moving grate may be any one of various types, such as that diagrammatically shown in FIGURES 1 and 7 corresponding to FIGURE 1 of U.S. Patent 3,160,402; it comprises a conveyor 101 having an upper run that continuously travels and carries green balls toward the grate from a suitable source, such as a conventional balling drum or disk, and discharges the balls onto a conveyor 102 comprising positively rotated ball-carrying rollers 103. The lengths of the rollers uniformly vary across the width of the grate, being related in proportion to the circumference of the grate beneath each dumping edge of each roller, so a bed of green balls of essentially uniform thickness is deposited across the width of the grate between its sidewalls 3 and 4 despite the increasing lengths

of circumferences from the inner to the outer edges of the grate.

The apparatus of FIGURES 1-10 also includes a hearth 1 that provides unique advantages in that only its central portion or segments 104 (FIGURES 6-10) tilt at the discharge location D to discharge heat hardened pellets, and narrow shelf portions 105 on either side of central portions 104 do not dump but carry the pellets in side-layers 106 adjacent the sidewalls past the discharge location to spreading means such as a plow 107 (FIGURE 7) that spreads the pellets P from the sidelayers into a hearth layer 108 on which the green balls B are deposited by the charging means 23. Thus, even if the pellets of the side-layers may not have been as completely treated as the pellets in the central portion of the grate due to the side-layer effects previously alluded to, they are twice treated as they pass twice through the zones of the pelletizing machine, once as side-layer and once as hearth layer; consequently the pellets discharged from the grate have a high degree of uniformity of characteristics and hence are of exceptionally high quality.

The structure of the grate of FIGURES 1-10 is shown in more detail in FIGURES 6, 8-10. Each of sidewalls 3 and 4 of the grate is preferably formed of heat resistant lining material having heat-insulating properties, such as ceramic or refractory material, fixed to supporting metal sheathing which can as shown form a wall of one of troughs 87 or 88, mounted on frame members 6 and 7. The side shelf portions 105 and the dumping portions 104 of the hearth are supported by watercooled tubular rotatable shafts 109 and watercooled tubular shafts 110 stationary relative to rotatable frame 5. Both of these shafts are supported by the frame members 6 and 7 of frame 5, the former by bearings 111.

The side portions 105 comprise frames 112 that are supported by and fixedly engage shafts 110; these frames removably carry bar members 113 extending generally parallel to the direction of grate movement.

Each dumping portion 104 comprises a frame 114 that has key portions 115 that engage laterally-extending slotted portions 116 of removable bar members 117 generally parallel to grate movement. The bar members 113 and 117 are shaped so abutting members define between them slots 118 large enough to permit desired gas passage but small enough to prevent passage of green balls or pellets.

Each frame 114 of each movable portion 104 is rigidly fixed to its rotatable shaft 109 by a clamping portion 119 bolted to a clamp member 120 keyed to shaft 109. Frame 114 also is shaped to rest on one of the members 110 near its central portion, as shown in FIGURE 9.

Each shaft 109 is caused partially to rotate as required to tilt its affixed portion 104 of the hearth to dump pellets thereon, by an arm 121 (FIGURES 5, 6 and 8) rigidly clamped at one end to the shaft and at its other end carrying a roller 122 that engages and travels in a track 123 fixed to the stationary frame 19 adjacent the discharge location D of the grate and shaped so that as the traveling frame rotates and carries the arms 121 with it the arms successively engage the track 123 and causes their associated shafts 109 partially to rotate about their axes and successively tilt the movable hearth portions 104 to cause the pellets on portion 104 to dump into the discharge chute 124 that extends under the entire length and width through which the pallet portions 104 tilt, and that carries the pellets to conveyor 42 (FIGURE 1). Preferably, as shown in FIGURE 8, portions 104 of the hearth tilt away from their direction of movement so their pellet-carrying top surfaces face opposite to the direction of movement. The reverse tilting of portions 104, as well as the location and extent of the chute 124, insure that all pellets discharged in discharge location D will pass into the chute 124; FIGURE 8 shows that all pellets carried by a tilting hearth portion 104 necessarily will discharge into the chute 124 and that any pellets that may spill from the portion 104 immediately before the one

titling will also spill into chute 124. Consequently, there is little if any possibility of having pellets drop into portions of the apparatus where they can cause harm, damage or be wasted.

The water cooling system for each of shafts 109 and 110 can be understood by reference to FIGURE 6, showing shaft 109 only. There is a trough 125, separate from trough 87, supported from frame member 6 at the outer side of rotatable frame 5. This trough extends entirely around the apparatus, and is supplied and kept filled with water by suitable conventional means not shown. A flexible tube 126 connects the lower portion of this trough with the interior of rotatable shaft 109, outside of associated bearing 111. Another flexible tube 127 is connected to the outer end of the shaft and discharges into lower trough 97. Water thus flows by gravity from trough 125 through tube 126 to and through shaft 109, and through tube 127 to lower trough 97. The water cooling system for each nonrotatable shaft 110 is similar.

Water from each of the upper throughs 125, 87 and 88 overflows through pipes 87a and 88a into the lower troughs 96 and 97. Water in the lower troughs overflows through drainpipes 96a, 97a; pipes 96b, 97b are provided to drain sludge.

Alternatively, the hearth of the grate can be made of refractory material, as shown in FIGURES 11-14. These figures depict a non-dumping grate hearth 128 comprising a rigid supporting structure 129 that is generally circular about the axis of rotation A of the grate and forms part of rotatable frame 5, and a number of rigid auxiliary frame segments 130 carried on structure 129 and having radially-extending members 131 supporting curved top members 132. The frame 129 may be designed to support metal bars, if desired, and the segments 130 make possible a simple conversion to means for supporting refractory blocks 133, of which one is shown in FIGURES 13 and 14, fitted between these top members 132 to form a hearth extending between the sidewalls 3 and 4 of the grate entirely around the grate. Each block has through slots 134 extending from top to bottom, the slots being spaced and large enough to provide the desired gas flow, but small enough to prevent passage of green balls or pellets. These blocks abut and have shoulders 135 that fit between members 132; for convenience in manufacture and inventory, these blocks are all identical, being of such dimensions that they fit to form a substantially continuous hearth despite the changes in the radius of curvature of the hearth from its inner to its outer edge; there is some clearance between adjacent blocks to permit the desired fit. Preferably, these blocks are formed of silicon carbide that has long life even when exposed to high temperatures, although other refractory, preferably non-metallic, materials can be used.

If desired, a hearth having refractory surfaced portions 136 that dump, can be made from similar slotted refractory blocks. As shown in FIGURE 15, a grate frame 137 similar to frame 114 of the embodiment of FIGURES 1-10, is rigidly mounted on a rotatable shaft 109. This frame has transversely-extending bar portions 138, 139 and 140, having keying portions 142. The refractory blocks 143 formed of silicon carbide or other suitable material, have bottom-slotted portions 144 that lock on keying portions 142. Vertical slots 145 in the blocks make possible gas flow through the grate. Each dumping segment 136 can be tilted as required by the means previously described. The dumping portion can be made to extend entirely across the grate, or to extend between non-dumping shelf portions adjacent the grate sidewalls. Such shelf portions may also have refractory surfaces formed of blocks similar to blocks 133 or 143 and held in place as illustrated in FIGURES 11-13 or 15. With such a hearth having side shell portions and central dumping portions it is possible to recirculate side layer pellets into a hearth layer, as previously described.

If it is not desired or feasible to discharge the pellets by dumping, it is possible to discharge the pellets from

the grate by lifting them by apparatus like that of FIGURES 16 and 17. This apparatus is mounted at the discharge location above a non-dumping circular grate embodying the invention. The illustrated grate has a refractory non-dumping hearth 128 like that of FIGURES 11-14, and refractory sidewalls 3 and 4 as in FIGURE 6. The apparatus comprises a stationary frame 147 supported from the stationary frame of the circular grate apparatus, and carrying a rotatable frame 148 having an axle 149 mounted in bearings 151 and driven by power source 152 for rotation about a generally horizontal axis that is radial to the traveling grate and to axis A of the grate. This rotatable frame has spaced aligned spokes 153 rigidly mounted on the axle 149. A scoop member 154 is pivotally mounted by lugs 155 on each pair of corresponding spokes. Each scoop member 154, of which six are shown, has a generally concave surface, terminating in a leading edge. The scoop members are mounted so that as the frame 148 is rotated each scoop member 154 in its lowermost position faces with its concave surface the approaching pellets on the grate, engages the pellets on the hearth and scoops them off the hearth.

If all of the pellets are to be removed from the grate, then each scoop member extends from sidewall to sidewall of the grate and to the hearth of the grate; if the sidelay pellets are not to be removed, as because they are to be spread into a hearth layer by a following spreader 107 as previously described, then the scoop members are shorter to permit the pellets adjacent the sidewalls to remain. If a hearth layer is not to be removed by the scoop members, then the scoop members, are mounted to clear the grate by an appropriate distance.

The means for actuating the scoops comprises rollers 157 mounted on each end portion of each scoop by suitable lugs 158. The rollers travel in a stationary cam-shaped track 159 shaped so that it causes the leading edge of each scoop member in the lowermost position to engage the pellets on the grate at the desired location, and then when such scoop member is raised to a position where its axis is approximately horizontally disposed with respect to the axis of the rotatable frame, allows such scoop member to tilt and discharge the pellets it carries into a suitable conveyor 160 that extends above the grate and conducts the pellets laterally away. The relationship of the center of gravity of each scoop member, whether loaded or not, to the axis about which it is pivotally supported on frame 148 is such that the member tilts to dumping position by gravity as allowed by the cam track 159. If desired, shielding means 161 may be provided to guide the pellets onto the conveyor. As the scoop member progresses upwardly after dumping, fixedly located members 162 engage its lugs 158 to move the scoop member to a position where its rollers 157 can re-enter cam track 159.

FIGURES 18 and 19 illustrate apparatus embodying the invention in which green balls produced by conventional balling apparatus 163 travel by conveyor system 164 and are deposited by charging means 23 on a circular grate apparatus 165 that can be similar to any of the circular grate apparatuses previously described, except that in this case it has no cooling section. While carried around the circumference of this apparatus, the balls are subjected to appropriate updraft or drowndraft drying, preheating, and indurating temperatures sufficient to harden them at least partially, or preferably completely, before they are discharged by perivously described means into an elongated kiln 166 rotated about an inclined axis by power means 167. In the kiln, the pellets are subjected to additional heat either for the purpose of completing their heat hardening or, if they have been completely heat hardened on the apparatus 165, for polishing of the heat hardened pellets and rendering more uniform the temperatures and quality of all of the balls. If desired, hot gases may be introduced by conventional burner means 168 into the kiln at one of its ends to provide such additional heat hardening. The completed pellets dis-

charging from the kiln 166 then pass to and on another circular grate apparatus 169 on which they are cooled by means of air passing through the pellets either updraft or downdraft as the pellets are carried around the grate apparatus. The pellets are then discharged from the grate, as by any of the discharging means previously described, and are deposited on a conveyor 171 which conducts them away.

The processes and apparatuses of the invention make possible important and unique advantages in providing increased thermal efficiency and more effective and uniform treatment of particulate material on the grate. The essentially gas-tight sealing means containing water or other suitable liquid make possible the successful maintenance on the higher pressure side of the grate in a treating zone of a gas pressure that is considerably higher than heretofore possible. According to the invention, super-atmospheric gas pressures of at least about 8 inches of water to as much as about 60 inches of water or more above atmospheric pressure may be maintained on the higher pressure side of the grate in one or more, or in all, zones. Therefore, by subjecting gas to a single pumping action developing such a pressure, it is possible to cause the gas to pass through the grate a plurality of times in a plurality of zones. For example, as illustrated by FIGURE 3, cool ambient air may be supplied by pumping means, fan 73, to the cooling zone, and the hot air that has passed through the grate and the material on the grate in the cooling zone is passed to the heating zone without the action of additional pumping means.

Furthermore, in most if not all cases the pumping means used to cause flow of gases through a treating zone may be advantageously located in the gas flow system to handle the cooler, and preferably cleaner, gases rather than the hotter and dirtier gases. Referring to FIGURE 3 again, it is apparent that the pumping means, fan 73, blows clean cool air into the cooling zone, and clean cool tempering air through pipe 75 into the conduit 74 to mix with the hot air leaving the cooling zone; the next pumping means, fan 79, is on the cooler side of the grate in the heating zone and handles gases that have passed through the grate in the heating zone and have been cooled by transfer of their heat to the balls on the grate; the next pumping means, fan 84, handles the air that has been cooled by passage through the bed of moist balls on the grate in the drying zone. If desired, the gas passing into fan 79 or 84 can be cleaned conventionally, which will benefit the fan; such cleaning is facilitated by the lower temperature of the gas. Consequently, according to the invention, it is possible to pass gases through a plurality of zones on the grate without exposing fans or other gas pumping means to gases that are at such high temperatures or that are so dustladen that they could deteriorate or damage the pumping means. Also, it is possible to pass gases through a plurality of zones on the grate by using pumping means to pump only the cooler gases at each side of the grate.

Various other modifications may be made in the embodiments illustrated, including that of FIGURES 18 and 19. Modifications may be made to overcome difficulties that may arise if the circular grate apparatus is used to heat materials containing compounds, such as sulfur compounds, that upon heating produce gases which when dissolved in the liquid of the liquid sealing means might form corrosive compounds that could attack the metal in contact with the liquid in the sealing means if the liquid is water or another material that could react with such gases. In such a case it is desirable to provide on the surface of the bodies of liquid in the liquid sealing means a compound, preferably a liquid, that has a lower specific gravity than the liquid of the body so it can float thereon and form a top layer that can prevent passage into the body of gases that could penetrate into the liquid in the sealing means to cause such difficulties. If, for example,

the liquid in the sealing means is water, a liquid for forming such a layer should be one that will float on water and form an essentially homogeneous layer that will prevent passage of undesired gases into the water; that is essentially immiscible with water; that has low evaporability; that will itself not react with the metals of the apparatus or with the water to form corrosive compounds; that will not decompose under the temperatures that it will reach; and that has a high flash point of at least 300° F. Examples of liquids suitable for the layers are Dow Corning silicon oils F-6-7024 and F-6-7039 which meet the above requirements and have flash points of essentially 600° F.

Of course solid materials may be used, such as particulate materials that will float on the liquid of the sealing means and be of sufficient small cross section to form an essentially fluidized layer that is sufficiently homogeneous to prevent passage into the liquid on which the particles float of gases that could react with the liquid to form corrosive or other undesirable compounds; these materials themselves should not react with the gases or liquid to form undesirable compounds, or decompose under heat in service. Examples of suitable particulate materials are hollow beads of glass or certain plastics, or expanded mineral materials.

It is thus apparent that the apparatuses and processes provided above can produce all of the previously described advantages and overcome the previously described deficiencies of prior apparatuses and processes, and can also provide other advantages. It is also apparent that modifications other than those discussed above may be made in the apparatuses and processes described as embodying the invention without departing from the spirit of the invention. It is intended that the patent shall cover, by suitable expression in the appended claims, whatever features of patentable novelty reside in the invention.

What is claimed is:

1. Apparatus for treating particulate material comprising an elongated traveling support of substantial width; means for depositing particulate material at a charging location to form on said support a layer extending across said support; means for removing particulate material from only a portion of the width of said support as said support passes a discharge location; means for treating said particulate material in said layer as it travels between said charging and discharge locations; and means for spreading across said support, in a lower layer of substantially uniform thickness adapted to lie below the layer deposited in said charging location, particulate material that is not removed from said support as it passes said discharge location.

2. Apparatus according to claim 1 in which said traveling support is of generally circular configuration in plan and travels in a generally circular path.

3. Apparatus according to claim 1 in which said spreading means comprises plow means that engages particulate material that has not been removed from said support as it passes through said discharge location, said plow means acting to spread said particulate material across said support in said lower layer of substantially uniform thickness.

4. Apparatus according to claim 1 in which said movable support is supported by shaft means through which cooling fluid is passed.

5. Apparatus according to claim 1 in which said means for removing particulate material comprises tiltable segments included in said elongated traveling support and extending across only part of the width of said support, and means for tilting said segments to discharge particulate material from each tilted segment as said support passes said discharge location.

6. Apparatus according to claim 5 in which said tiltable segments of said traveling support while tilting face away from the direction in which said traveling support travels.

15

7. Apparatus according to claim 5 in which each tilt-able segment of said support is rotatably supported by shaft means through which cooling fluid is passed.

8. Apparatus according to claim 5 in which said traveling support is of generally circular configuration in plan and travels in a generally circular path.

9. Apparatus according to claim 1 in which said means for removing particulate material comprises means for lifting particulate material from only a portion of the width of said support at said discharge location.

10. Apparatus according to claim 9 in which said traveling support is of generally circular configuration in plan and travels in a generally circular path.

11. Apparatus according to claim 1 in which said traveling support comprises a bottom portion and up-standing sidewalls defining a channel-shaped cross section transverse to the direction of travel of said support, in which said means for removing said particulate material removes particulate material from the central portion of said support and leaves particulate material adjacent said sidewalls, and in which said spreading means acts to spread particulate material from said portions adjacent said sidewalls substantially entirely across said bottom portion of said support beyond said discharge location.

12. Apparatus according to claim 11 in which said means for removing particulate material comprises tilt-able segments comprising only the central portion of said bottom portion of said traveling support, there being generally horizontal portions of said bottom portion adjacent said sidewalls that do not tilt with said adjacent tilt-able segments, and means for tilting said tilt-able segments to discharge particulate material from each tilted segment as said support passes said discharge location.

13. Apparatus according to claim 12 in which said spreading means comprises means that engages particulate material on said nontilting portions of said bottom portion of said support adjacent said sidewalls after they have traveled beyond said discharge location and spreads said particulate material into a layer extending across said bottom portion after said tilt-able segments have been restored to their untilted positions, and in which apparatus said means for depositing particulate material deposits additional particulate material on said layer.

14. Apparatus according to claim 11 in which said means for removing particulate material from said support comprises means for lifting particulate material from only the central portion of said support while not removing material from adjacent the sidewalls of said support.

15. Apparatus according to claim 14 in which said spreading means comprises means that engages particulate material adjacent said sidewalls after they have traveled beyond said discharge location, and spread said particulate material into a layer extending across said bottom portion of said support, and in which apparatus said means for depositing particulate material deposits additional particulate material on said layer.

16. Apparatus for treating particulate material comprising a rigid generally circular frame comprising an outer generally circular frame member and an inner generally circular frame member spaced radially inwardly of said outer frame member; a grate having at least a portion mounted in fixed relation on said frame between said outer and inner generally circular members, said grate having a gas permeable bottom adapted to carry particulate material to be treated; means for supporting said rigid generally circular frame for rotational movement so said grate travels in a generally circular path about a generally vertical axis; stationary gas enclosing means adjacent said permeable bottom of said grate and adapted to contain gas that passes through said grate; and gas sealing means between said gas enclosing means and each side of said grate comprising, at least side of said grate between said grate and the adjacent generally circular frame member, a trough fixed with relation to one of said adjacent frame members and said gas enclosing means, which

16

trough is adapted to contain a liquid, and shield means extending from the other of said adjacent frame member and said gas enclosing means into said liquid to form an essentially gas impervious seal.

17. The apparatus of claim 16 in which said liquid in said trough means is a body of liquid that is covered with a layer of protective liquid that prevents the ingress into said body of liquid of gaseous materials that could combine with said liquid in said body to cause corrosive effects upon metal parts contacted by said liquid.

18. The apparatus of claim 16 in which said generally circular grate first travels past a charging location in which particulate material is deposited on said grate and then past a discharge location in which said particulate material is removed from said grate, said gas enclosing means being located adjacent the bottom of said grate between said two locations.

19. The apparatus of claim 18 in which said grate has a gas permeable bottom hearth portion and upstanding side walls, said hearth portion and side walls that contact said particulate material being formed of non-metallic refractory material.

20. The apparatus of claim 16 in which said gas enclosing means is located below said grate, said trough at each side of said grate is stationary and disposed adjacent said gas enclosing means in essentially gas-tight relation thereto, and said shield means at each side of said grate is carried by and movable with said rigid generally circular frame in essentially gas-tight relation to said grate and extends into liquid contained in the adjacent trough to seal against passage of gas between said gas enclosing means and the side of said grate.

21. The apparatus of claim 16 in which the gas enclosing means is stationary and extends over said grate, said trough at each side of said grate is movable and carried by said rigid generally circular traveling frame in essentially gas-tight relation to said grate so it travels with said grate, and said shield means at each side of said grate is stationary and disposed adjacent said gas enclosing means in essentially gas-tight relation thereto and extends into the liquid contained in the adjacent trough to seal against passage of gas between said gas enclosing means and the side of said grate.

22. The apparatus of claim 16 which comprises first gas enclosing means that is stationary and disposed below said grate; a stationary trough disposed at each side of said grate adjacent said first gas enclosing means in essentially gas-tight relation to said gas enclosing means; movable shield means disposed at each side of said grate in essentially gas-tight relation thereto and carried by and movable with said generally circular frame, to extend into liquid carried by said trough at said side of the grate to seal against passage of gas between said first gas enclosing means and said side of said grate; second gas enclosing means that is stationary and disposed above said grate; a movable trough carried by said rigid generally circular frame at each side of said grate in essentially gas-tight relation thereto, between the grate and the adjacent generally circular frame member; and stationary shield means disposed at each side of said grate adjacent to said second gas enclosing means and in essentially gas tight relation thereto, to extend into liquid carried by the adjacent movable trough to seal against passage of gas between said second gas enclosing means and the side of said grate.

23. The apparatus of claim 16 in which said means for supporting said rigid generally circular frame for rotational movement so said grate travels in a generally circular path on a generally vertical axis comprises track means carried by at least one of said generally circular frame members, said track means having a substantially continuous downwardly facing bearing surface, and means at fixed locations that contact said bearing surface of said track means to support said frame.

24. Apparatus for treating particulate material com-

17

prising a generally circular traveling grate having a gas permeable bottom hearth portion and upstanding side walls, said hearth portion and said side walls that contact the particulate material being formed of non-metallic refractory material, said grate including portions of said hearth portion of said grate that tilt to discharge particulate material therefrom; and means for supporting said traveling grate for movement in a generally circular path about a fixed axis.

25. The apparatus of claim 24 in which said hearth portion of said grate is formed of tiltable segments each of which extends across only a portion of the width of the grate, said tiltable segments acting to discharge material therefrom, and a portion of said hearth portion adjacent each sidewall that does not tilt.

26. Apparatus for treating particulate material comprising a generally circular traveling grate having a gas permeable bottom hearth portion and upstanding side walls, said hearth portion at said walls in contact in particulate material being formed of non-metallic refractory material; means for movably supporting said traveling grate for movement in a generally circular path about a fixed axis; stationary gas enclosing means above said grate; stationary gas enclosing means below said grate; means for causing a flow of gas from one gas enclosing means to the other gas enclosing means through said grate; and sealing means at the sides of said grate sealing and grate to said gas enclosing means to prevent escape of gas out of the sides of said grate between said grate and said gas enclosing means.

27. Apparatus according to claim 26 in which said hearth portion of said grate is immovable with respect to said sidewalls.

28. Apparatus for removing particulate material from a traveling moving support comprising a frame rotatable about a generally horizontal axis past which said support travels, a plurality of scoop means carried by said frame for pivotal motion thereon about axes generally parallel to said axis of rotation, each of said scoop means being adapted to pivot on said frame from a position in which, when in a location near to said traveling support, it can scoop particulate material from said support, to a position in which, when at a predetermined location above said support, it can tilt relative to said frame to dump material from said scoop means; and means for moving each of said scoop means between material-receiving position and material-dumping position relative to said frame as said frame rotates.

29. Apparatus for treating particulate material com-

18

prising a traveling gas-permeable grate, means for depositing particulate material on said grate in a bed, means providing drying, heating and cooling zones sequentially disposed on said grate in the direction of grate travel; means through which air can pass to the space on the higher pressure side of said grate at the heating zone, from said cooling zone after said air passes through the grate at the cooling zone; means for supplying cooling air to said cooling zone under super-atmospheric pressure sufficient to cause the air to pass through said grate at said cooling zone and to maintain the air at super-atmospheric pressure at said higher pressure side of said grate at said heating zone; means for withdrawing gases from said heating zone after they have passed through said grate at said heating zone; and means for removing gases from said drying zone after they have passed through said grate at said drying zone.

30. Apparatus according to claim 29 in which said grate is a generally circular grate that travels in a generally circular path, said grate having a location at which particulate material is charged onto said grate, a discharge location at which particulate material is discharged from said grate, and said drying, heating and cooling zones being disposed along said grate between said charging and discharging locations, and in which apparatus there are sealing means capable of sealing the grate and the higher pressure side of each zone against substantial escape of gases at pressures of at least 8 inches of water above atmospheric pressure.

References Cited

UNITED STATES PATENTS

1,038,408	9/1912	Meigs	263—28 X
1,069,191	8/1913	Van Schlippenbach	266—21 X
1,433,354	10/1922	Dwight	266—21
1,634,027	6/1927	Honigmann et al.	266—21 X
1,940,935	12/1933	Bennett	266—21 X
2,095,567	10/1937	McGee	263—28 X
3,302,936	2/1967	Ban	266—21 X
3,322,414	5/1967	Boron	266—21 X
3,370,937	2/1968	Tsujihata et al.	266—20

J. SPENCER OVERHOLSER, Primary Examiner

R. S. AUNEAR, Assistant Examiner

U.S. Cl. X.R.

75—3