Jan. 6, 1953 J. J. CRAIG ET AL 2,624,560

SHAFT FURNACE

Filed Jan. 18, 1949 8 Sheets-Sheet 1

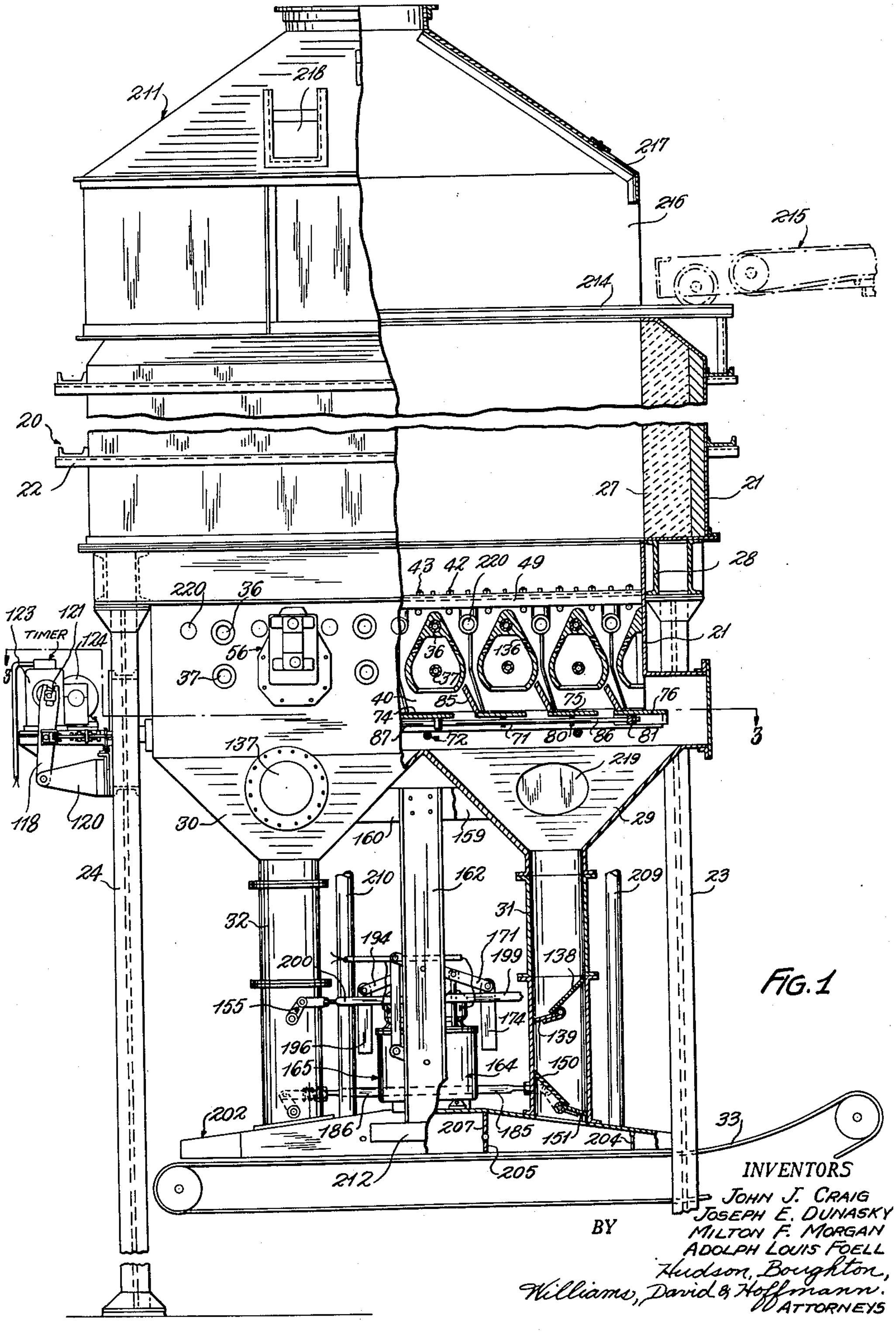

FIG. 1

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SHAFT FURNACE

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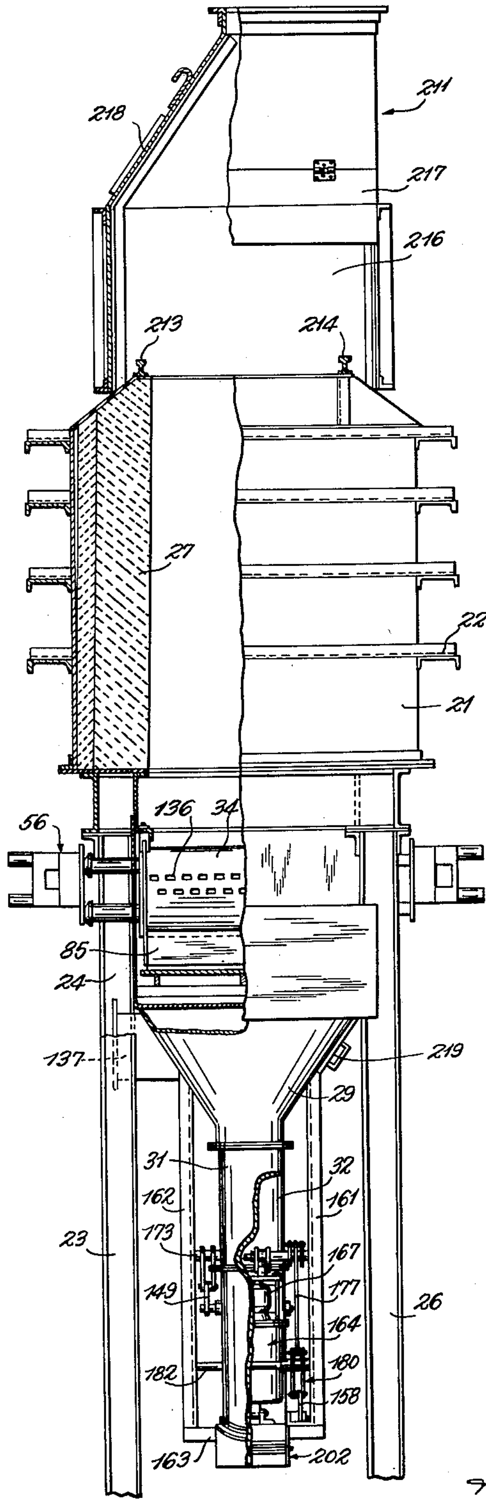

FIG. 2

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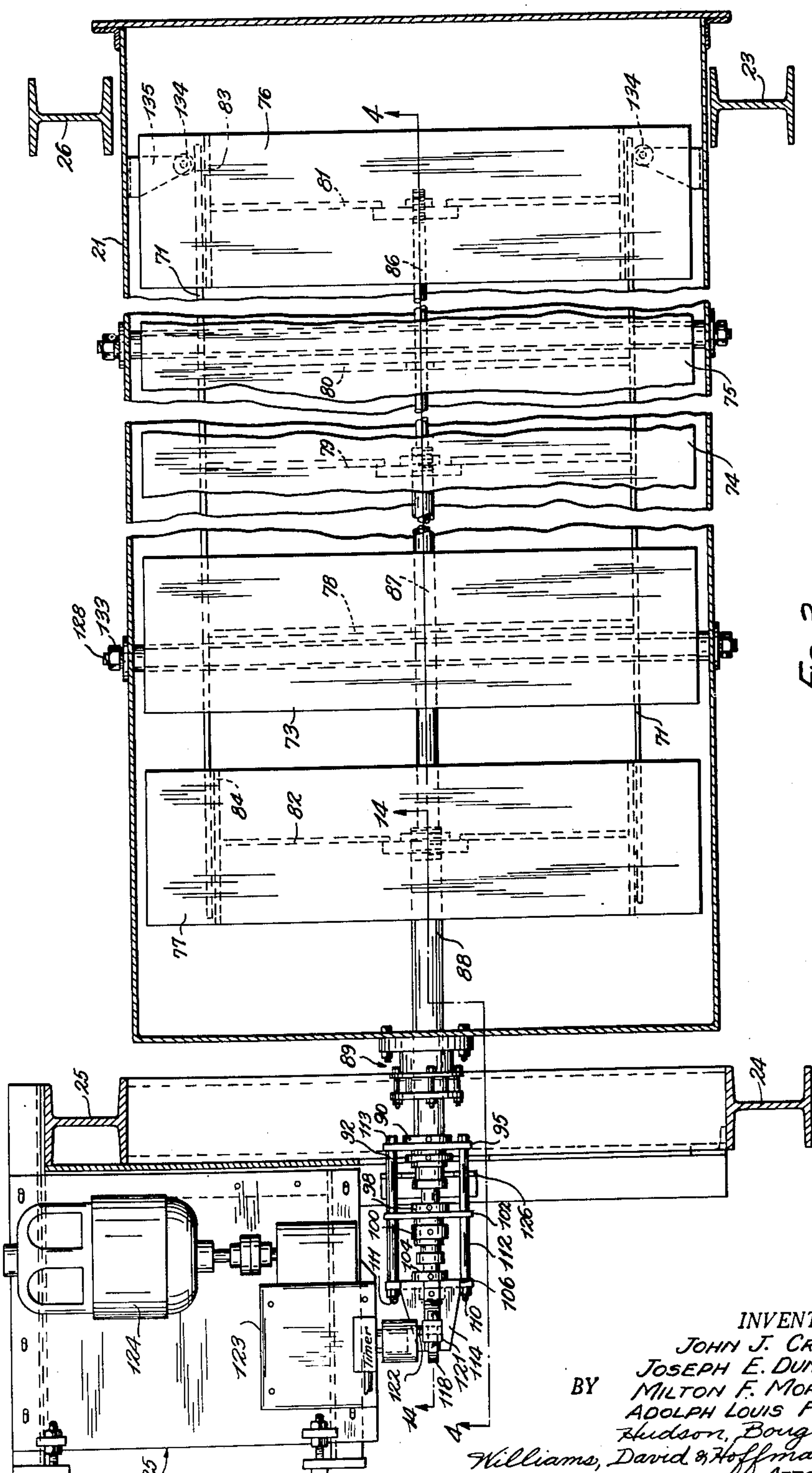

FIG. 3

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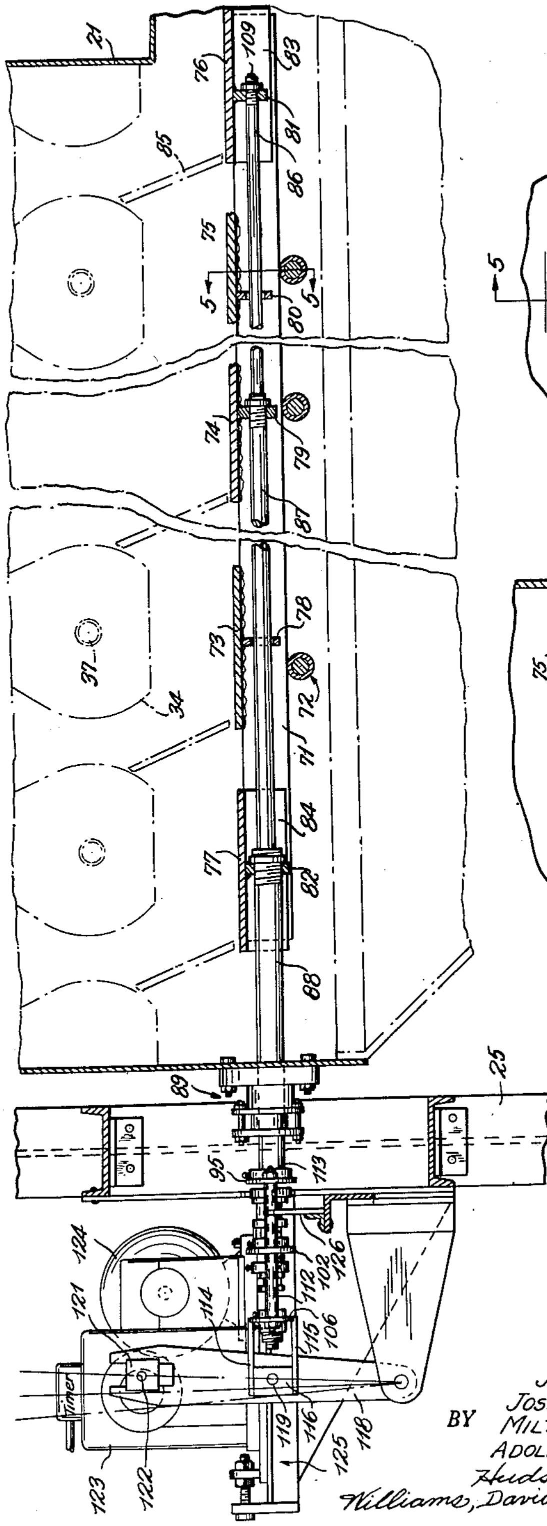

FIG. 4

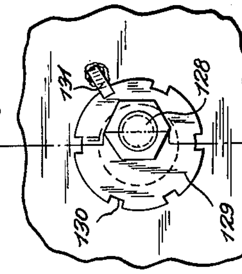

FIG. 6

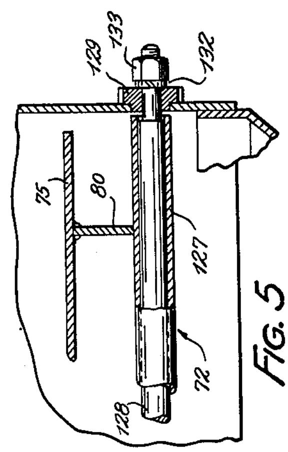

FIG. 5

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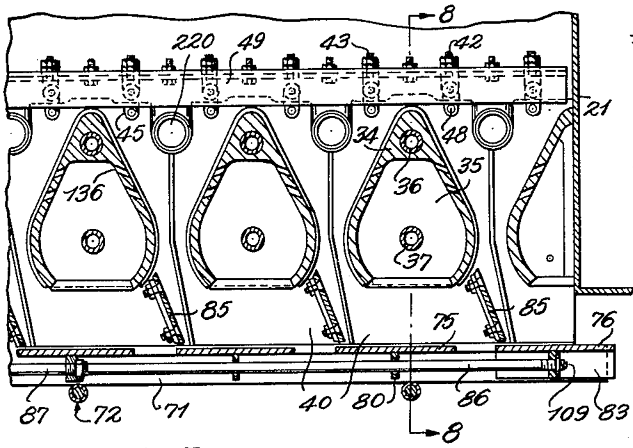

FIG. 7

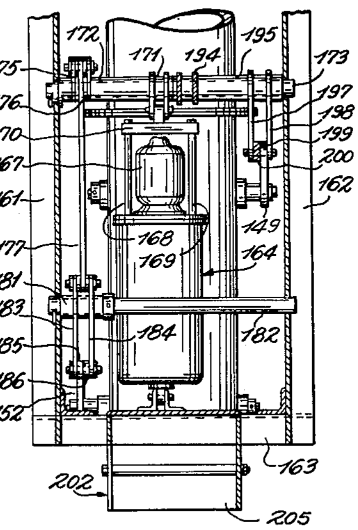

FIG. 11

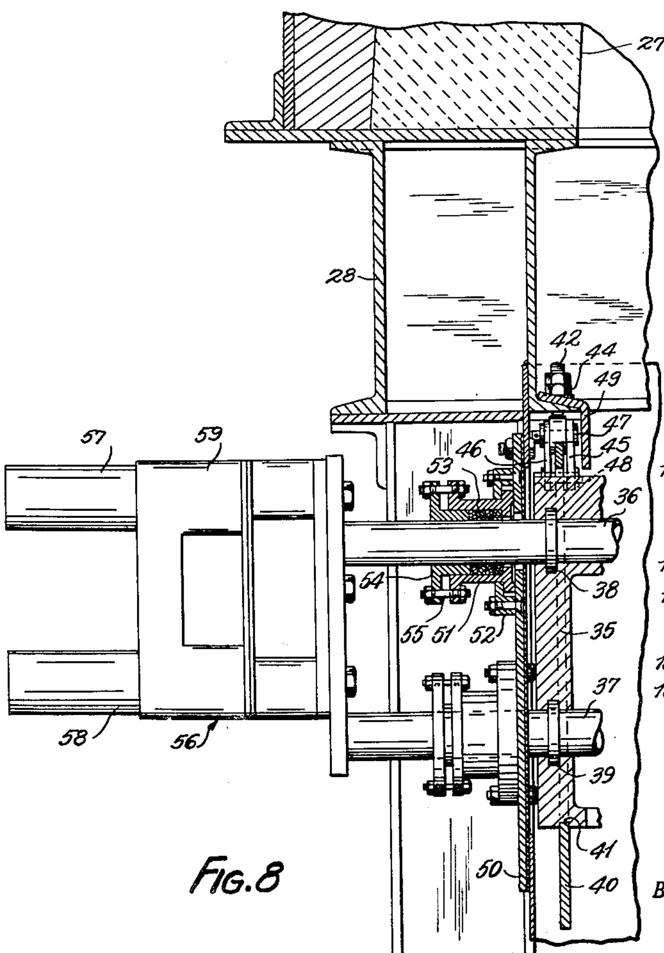

FIG. 8

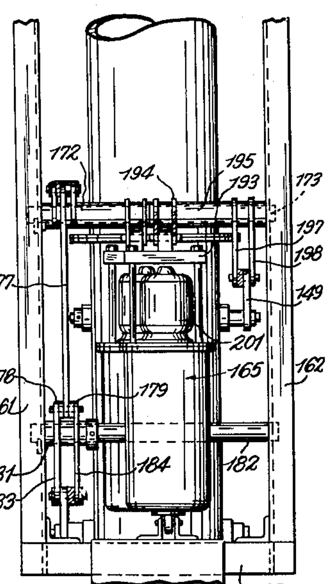

FIG. 12

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Filed Jan. 18, 1949 8 Sheets-Sheet 6

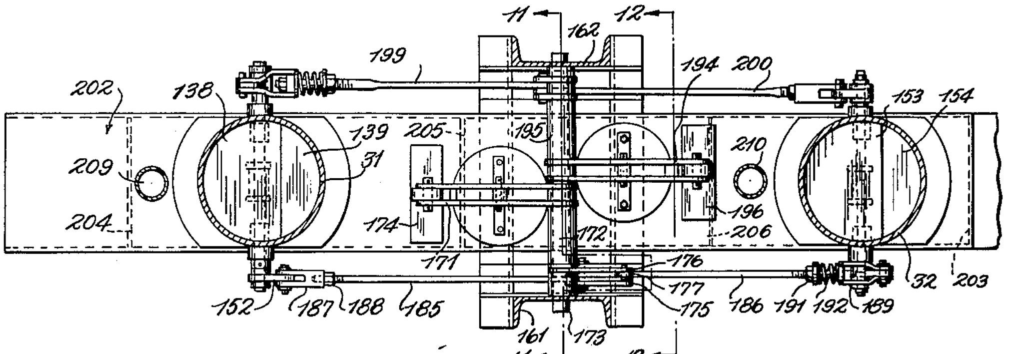

FIG. 10

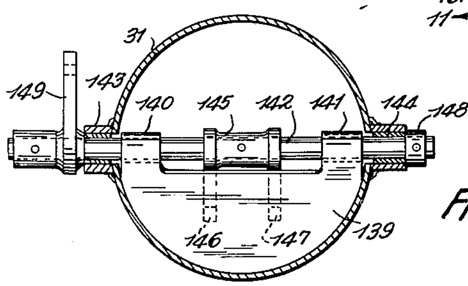

FIG. 13

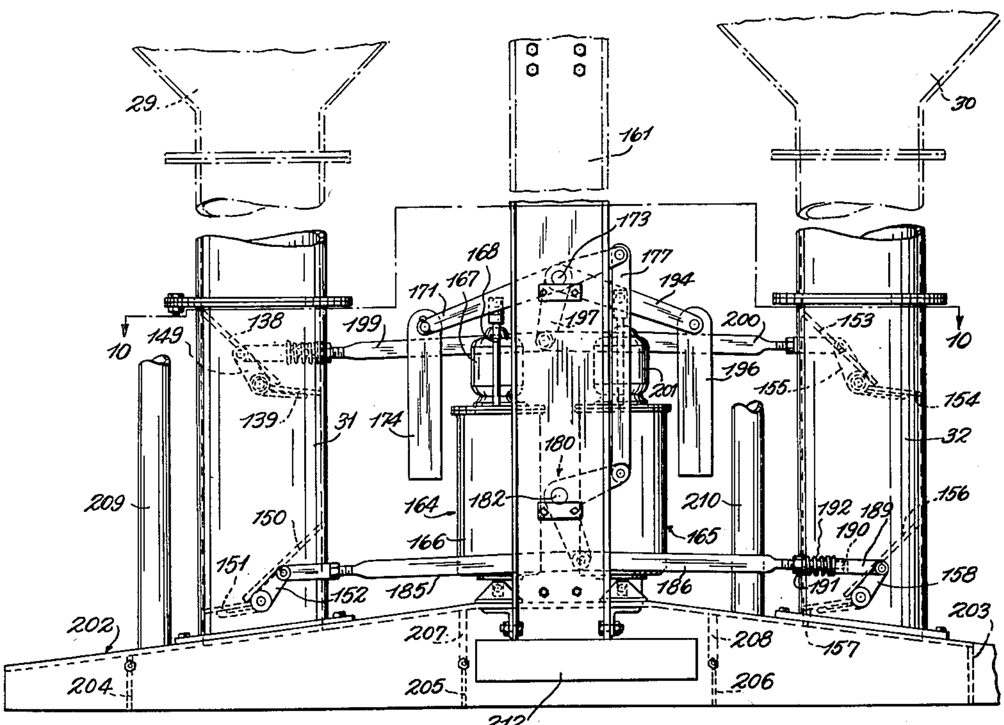

FIG. 9

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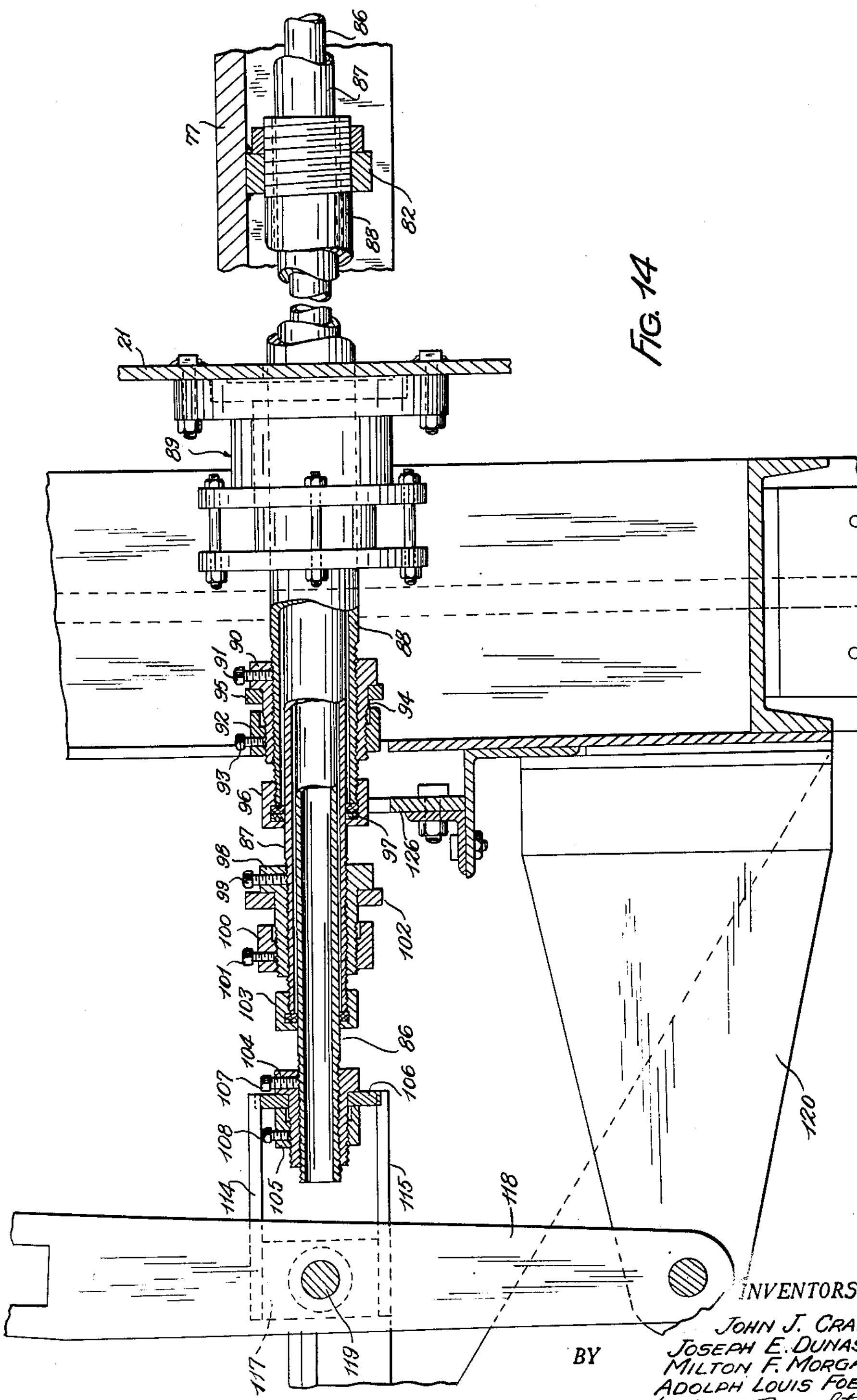

FIG. 14

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Filed Jan. 18, 1949 8 Sheets-Sheet 8

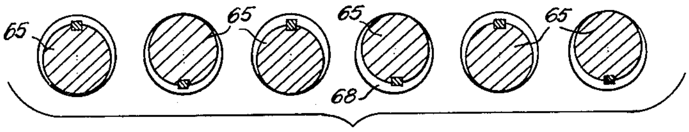

FIG. 17

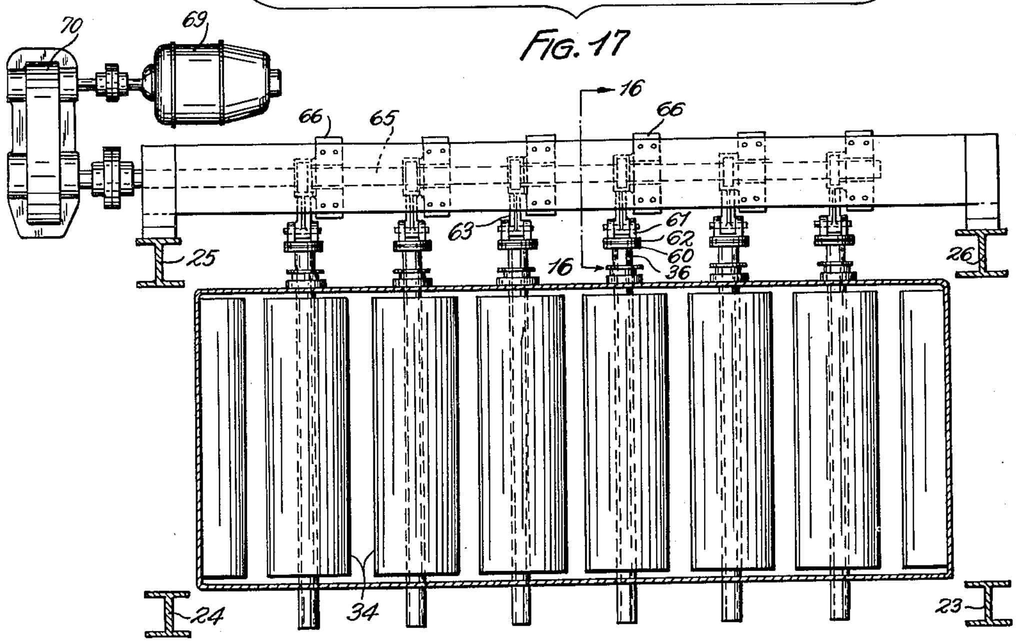

FIG. 15

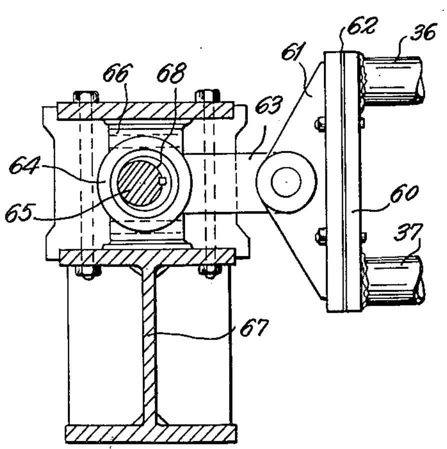

FIG. 16

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Patented Jan. 6, 1953 2,624,560

UNITED STATES PATENT OFFICE

2,624,560

SHAFT FURNACE

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Application January 18, 1949, Serial No. 71,512

11 Claims. (Cl. 263—29)

1

This invention relates to shaft furnaces and, more particularly, to a novel construction of the grates and discharging mechanism for such a furnace which, while not limited thereto, is especially useful for heating pellets of fine particle, metalliferous material.

In certain metallurgical processes, it is often necessary to crush metalliferous materials to substantially fine particle size in order to remove the gangue therefrom. Since it is usually desirable to obtain metalliferous material in suitable sizes for practical utilization, the relatively fine-sized material must be agglomerated.

By way of example, but without limitation thereby, attention is directed to the fact that the rapid depletion of high-grade iron ore deposits in the Mesabi Range has caused increasing interest to be directed to both its lower-grade ores and iron-bearing rocks, there being immense deposits of each. One of these rocks, taconite, is available in enormous quantities and while taconite is not practical as a charge for a blast furnace, it may be conditioned through the removal of a percentage of its gangue to so increase the percentage of iron, as iron oxide, and through agglomeration thereafter, so as to be commercially acceptable as a burden for conventional blast furnaces.

The above-mentioned and other metalliferous materials of fine particle size, after concentration, have been agglomerated into bodies of suitable size by compacting the particles into substantially symmetrical pellets. This may be effected by a procedure such as disclosed by Firth in Patent No. 2,411,873, which produces substantially ball-like bodies, or by other known procedures. For the purpose of simplicity, fine particles of metalliferous material which have been agglomerated into larger bodies by balling or other known procedures will be hereinafter referred to as pellets, it being understood that this term is used in a generic sense, and is not intended to be limited to substantially spherical agglomerates formed from iron ore concentrates by the procedure disclosed by Firth but is intended to include all agglomerates formed from fine particles of metalliferous material.

Pellets as formed by the Firth and other known procedures are generally somewhat moist and upon drying are relatively fragile but may be sufficiently hardened by heating to permit handling thereof by conventional ore-handling equipment. This heating of the pellets should be substantially uniform to effect the desired degree of hardening in all the pellets but must not be such as to cause incipient fusion resulting in the formation of large clusters of the pellets. Moreover, since the pellets are relatively fragile before they have been heated, they must not be subjected to forces resulting in substantial breakage or abrasion during the heating. While batch procedures may be employed, the production of pellets is rendered more economically feasible through the use of continuous methods.

2

The principal object of this invention is, therefore, the provision of an improved shaft furnace which is so constructed and arranged that it will satisfactorily effect heating of pellets, formed from fine particles of metalliferous material, which are substantially continuously charged into the top and removed from the bottom of the furnace whereby the heating is effected as a continuous operation without breaking of the pellets or the formation of excessively large clusters.

Another object of the invention is to provide an improved shaft furnace in which the movement of the burden therethrough is accurately controlled and the burden is discharged substantially without crushing.

A further object of the invention is to provide an improved shaft furnace for hardening pellets of fine metalliferous material, the grates and discharge mechanism of the furnace being so constructed and arranged that the pellets in any horizontal plane move downwardly through the furnace at a substantially uniform rate, and the pellets may be subjected to sufficient agitation, adjacent the grate bars, to break up any large clusters of pellets that may form thereby facilitating discharge from the furnace.

A further object of the invention is the provision of a shaft furnace of the type mentioned in the preceding object and wherein the grate bars thereof are individually supported elongated members extending transversely of the furnace and the breaking of clusters is effected by means for vibrating or moving the grate bars.

A still further object of the invention is the provision of a shaft furnace of the type mentioned and wherein the rate of movement of the burden through the furnace is controlled by a plurality of spaced, substantially horizontally disposed plates extending transversely of the furnace below the openings between the grate bars, the said plates being repeatedly moved to discharge a predetermined portion of the burden resting thereon in a manner such that the individual pellets of the burden in any horizontal plane within the furnace move downwardly at a substantially uniform rate.

A more specific object of the invention is the provision of a shaft furnace for hardening pellets of iron ore concentrates or the like, by heating, which furnace has a plurality of spaced, inverted substantially V-shaped grate bars extending transversely of the shaft of the furnace adjacent the bottom thereof and supported for limited movement relative to the shell of the furnace, there also being a plurality of substantially horizontally disposed plates extending transversely of the furnace below the openings between the grate bars, the said plates being reciprocated in a manner to discharge a portion of the pellets resting thereon with the extents of movement of the several plates being so regulated that the pellets in any horizontal plane within the furnace move downwardly at a substantially uniform rate.

The invention further resides in certain novel features of construction and combination and arrangement of parts, and further objects and advantages thereof will be apparent to those skilled in the art to which it pertains from the following description of the present preferred embodiment, and a modification of a portion thereof, described with reference to the accompanying drawings in which similar reference characters represent corresponding parts in the several views and in which:

Fig. 1 is a view, partly in front elevation and partly in vertical section, of a furnace constructed in accordance with this invention with certain parts omitted and others broken away;

Fig. 2 is a side view, partly in section and partly in side elevation of the furnace illustrated in Fig. 1, the view being taken from the right-hand side of Fig. 1 with certain parts broken away and others omitted;

Fig. 3 is a transverse sectional view taken substantially on the section indicating line **3—3** of Fig. 1 and looking in the direction indicated by the arrows, the view being to an enlarged scale with respect to Fig. 1 with portions intermediate the end walls of the furnace broken away;

Fig. 4 is a sectional view taken substantially on the section indicating line **4—4** of Fig. 3 and looking in the direction indicated by the arrows, portions being broken away and the grate bars and associated inclined plates being indicated in broken lines;

Fig. 5 is a fragmentary sectional view to an enlarged scale showing the manner in which the rollers for supporting the discharge plates are mounted, the section being taken substantially on the section indicating line **5—5** of Figs. 4 and 6;

Fig. 6 is a fragmentary elevational view to an enlarged scale of the eccentric mounting for the end of a roller as seen from the right-hand side of Fig. 5;

Fig. 7 is a fragmentary sectional view to an enlarged scale of the grate bars, inclined plates, and discharge plates illustrated in Fig. 1;

Fig. 8 is an enlarged sectional view illustrating the manner in which the grate bars are supported and the present preferred means for vibrating these bars, the view being taken substantially on line **8—8** of Fig. 7;

Fig. 9 is an enlarged fragmentary rear elevational view of the mechanism associated with the bottom of the furnace to control the delivery of the material therefrom;

Fig. 10 is a sectional view taken substantially on the section indicating line **10—10** of Fig. 9 and looking in the direction indicated by the arrows;

Fig. 11 is a fragmentary sectional view taken substantially on the section indicating line **11—11** of Fig. 10 and looking in the direction indicated by the arrows;

Fig. 12 is a fragmentary sectional view taken substantially on the section indicating line **12—12** of Fig. 10 and looking in the direction indicated by the arrows;

Fig. 13 is an enlarged detached view, partly in section and partly in plan, illustrating one of the pivoted valves for controlling the discharge of material, the associated inclined plate being omitted;

Fig. 14 is an enlarged fragmentary view, partly in side elevation and partly in section, the view being taken substantially on the line **14—14** of Fig. 3 and illustrating the operative connections for reciprocating the sliding discharge plates;

Fig. 15 is a fragmentary view, partially in plan and partially in section, illustrating another means for vibrating the grate bars;

Fig. 16 is an enlarged sectional view taken substantially on the section indicating line **16—16** of Fig. 15 and looking in the directions indicated by the arrows; and

Fig. 17 is a schematic showing of the cam means for vibrating the grate bars in the manner shown in Figs. 15 and 16 and illustrating the relative positions of the several cams at a given time.

It will be appreciated that the furnace of this invention may be utilized for operations other than hardening pellets of metalliferous material by heating but because its novel construction renders it especially useful for this purpose the description will, for simplicity, be restricted to such a use. It is to be understood, however, that this restriction is only for the purpose of clarity and is not to be considered as a limitation of the invention.

Referring now in detail to the drawings, it will be seen that the invention is embodied in a shaft furnace, designated generally **20**, which is preferably of rectangular cross section. The furnace comprises a shell **21** formed of steel plates suitably secured together and reinforced by channel members **22**, the furnace being supported at the desired elevation by vertically extending standards or legs **23**, **24**, **25** and **26**. As will be seen from Figs. 1 and 2, the upper portion of the shell **21** is provided with a suitably refractory type lining **27** thereby forming the shaft proper of the furnace, a portion of the shell **21** extending inwardly beneath the lining **27** to retain the latter in place. Suitable reinforcements are provided beneath the lining by channel members such as **28** which form a rectangular frame secured to the tops of the aforementioned legs **23**, **24**, **25** and **26**.

The shell **21** is continued downwardly below the lining **27**, substantially in alignment with the inner surface of the latter, and this portion of the shell is provided with grate bars and reciprocating discharge plates. The lower part of this portion of the shell merges into two downwardly converging hopper-shaped portions **29** and **30** constituting a plenum and discharge chambers for the furnace. The lower portions of the hopper-like portions **29**, **30** respectively converge to, and communicate with, vertically extending discharge conduits or spouts **31** and **32** through which the material from the shaft furnace is discharged to, and removed by, a conveyor **33**. As will be hereinafter described, the discharge of material is controlled by the novel grate bars and discharge plates, intermediate the shaft and the plenum of the furnace, acting in conjunction with gas sealing valves in the discharge spouts.

As shown in Figs 1, 2, 7 and 8, the grate bars **34** extend transversely of the furnace shaft, adjacent the bottom thereof, in parallel spaced relationship and are supported from the shell of the furnace in a manner such that they may receive limited movement or vibrations without transmission of such vibrations to the lining of the furnace. These grate bars **34** are preferably shaped substantially as shown in the drawings from which it will be seen that the bars are substantially inverted V-shaped in cross section and have integral closed ends such as **35**, see Fig. 8. The two end bars, however, are only half the width of the other bars, these end bars each having one inclined side thereof omitted to provide perpendicular surfaces for cooperation with the adjacent side walls of the furnace and thereby prevent the lodging of material between these bars and the side walls. The grate bars are preferably formed of cast metal and all but the two end bars are provided with two vertically-spaced pipes, such as **36** and **37**, which extend longitudinally through the bars and are preferably embedded therein at the time the bars are cast. While the pipes have been shown, the members **36** and **37** may be shafts or bars. For simplicity, however, only the term "pipe" will be used hereinafter in referring to the members **36** and **37**.

Each pipe **36** extends through the integral, solid apex of its grate bar and is provided with a collar or flange **38** adjacent either end of the bar and embedded within the material of the latter to prevent longitudinal displacement of the pipe with respect thereto. The pipe **37** extends parallel with, but vertically spaced below the pipe **36**, and is likewise provided with a collar or flange such as **39**, adjacent either end of the grate bar, which collars are embedded within the closed end walls **35** of the latter to securely retain the pipe **37** and prevent its longitudinal displacement relative to the grate bar. These pipes provide a means for imparting vibrations to the grate bars as will hereinafter appear.

Each grate bar is supported by hangers connected with the shell of the furnace and engaging the grate bars adjacent their ends. As shown most clearly in Figs. 7 and 8, these hangers each comprise a plate **40** having an aperture therethrough substantially the same shape as that of the grate bar **34** but slightly larger so that the grate bar may extend freely therethrough. The bottoms of the end walls **35** of the grate bars **34** are each provided with a transversely extending notch or recess **41**, and each notch or recess **41** is adapted to fit over the lower edge of the opening in the corresponding hanger plate **40** so that the grate bars are suspended by the hanger plates **40** and may move therewith.

Each hanger plate **40** is supported, adjacent its upper edge, from a longitudinally extending flange of a channel member, such as **28**, by pairs of spaced links, there being two pairs of such links for each plate **40** except those which support the two end bars. This is effected by employing a pair of spaced eye bolts such as **42**, **43** for each plate **40** which supports one of the intermediate grate bars, the shanks of which bolts pass through the lower flange of the channel member **28** and are secured thereto by suitable nuts **44**. The eye of each of the bolts, such as **42** and **43**, extends between the upper ends of one pair of links such as **45**, **46** and the latter are supported by a pin **47** extending therethrough and through the eye of the bolt. The lower ends of the links **45** and **46** extend downwardly below the upper edge of the corresponding plate **40**, on either side thereof, and spaced therefrom, and are provided with a transversely extending pin **48** which passes through a hole in the plate **40**, this hole preferably being of larger diameter than the pin. It will be seen that the relative dimensions of the eye bolts and of the plates **40** are such that the links **45**, **46** straddle the upper portions of the plates **40** with a clearance so that the plates **40** may move relative to links such as **45**, **46** in directions extending parallel with the grate bars **34**, the link construction, however, preventing any substantial vibrations from being transmitted to the furnace lining **27**. Since there are two eye bolts and two pairs of spaced links for each hanger plate **40** of each intermediate grate bar, the grate bars are maintained parallel with each other at all times.

The two half or end grate bars are shown as supported at either end by a single eye bolt and pair of spaced links since their hanger plates are but half the width of the plates **40** which support the intermediate bars. These half or end bars are not vibrated and hence are not provided with spaced pipes such as **36**, **37**. Since the two end bars are not vibrated, they may be rigidly supported in the furnace, if desired.

Each of the channel members **28**, to which the eye bolts are connected, has a shield member **49** secured to its lower flange. These shields are angular in cross section and each has a downwardly directed portion which extends substantially parallel with, but spaced inwardly from, the supporting links for the grate bars so that the material within the furnace cannot enter into the spaces between the links and interfere with the vibration of the grate bars.

The pipes such as **36** and **37**, which are united with each of the grate bars **34**, other than the two end bars, extend outwardly therefrom beyond the side walls of the furnace through suitable openings in the shell of the latter, suitable packing or sealing means being provided to prevent the escape of gases at these points while permitting longitudinal movement of the pipes. For this purpose, the shell of the furnace is provided with the plates, such as **50**, which cover the openings in the shell of the furnace through which the grate bars are initially inserted, these plates **50** being provided with holes therethrough for accommodating the pipes **36** and **37**. Surrounding each pipe **36**, **37**, and the holes therefor through the plates **50**, is an annular member **51** which is secured to the plate **50** by a flanged ring **52**. Each annular member **51** has a sleeve-like portion spaced outwardly from the pipe which extends therethrough thereby providing an annular chamber about the pipe in which chamber packing material **53** is disposed. This packing material is retained in place by a sleeve-like portion of a gland member **54** which is slidably fitted within the outer end of the member **51**, the members **51** and **54** being secured together by bolts such as **55** which extend through outwardly directed flanges of the members.

The grate bars **34** may be vibrated by any suitable means which will impart relatively high frequency, short stroke, movement thereto. This vibration of the grate bars tends to break up any relatively large clusters that may form without, however, effecting an appreciable grinding action upon the material passing between the grate bars. One suitable means for effecting this vibration is illustrated in Figs. 1, 2, and 8 as comprising electromagnetic vibrators, generally designated 56, there being one such vibrator attached to the adjacent ends of each pair of pipes 36 and 37 externally of the shell of the furnace. These vibrators are of well-known construction and hence need not be illustrated or described in detail but may be briefly characterized by mentioning each contains coil springs disposed within housings 57, 58 and cooperating with a suitable inertia member within a housing 59, the inertia member being actuated by an electromagnet to thereby impart vibration to the pipes 36, 37 and hence to the corresponding grate bar 34.

Preferably, the vibrators for alternate grate bars are arranged on opposite sides of the furnace as shown in Fig. 2, these vibrators being capable of individual or simultaneous actuation so that one or any desired number of the grate bars may be vibrated. It should be particularly noted that the vibration thus imparted to the grate bars is of exceedingly short stroke and therefore is not equivalent to the usual transverse movement of grate bars for discharging material therebetween. It should also be noted that adjacent grate bars are vibrated in a manner to move them in opposite directions relative to each other.

Instead of individual electromagnetic vibrators for vibrating the grate bars other mechanisms may be employed for imparting the desired vibratory motion. For example, there is illustrated in Figs. 15, 16 and 17 a somewhat diagrammatic representation of a mechanism for effecting relatively short-stroke movement of the grate bars simultaneously in opposite directions by means of a single electric motor. In this construction the adjacent ends of the pipes 36, 37 of each of the movable grate bars are joined together as by welding to separate plates such as 60. These plates are bolted or otherwise adjustably secured to flanges of members 61 which have spaced outwardly extending portions or ears, a shim or shims 62 being placed between the members 60 and 61 to provide for an adjustment of the members 61 relative to the actuating mechanism about to be described. The ear portions of each member 61 are pivotally connected to a link 63 which extends therebetween and outwardly therefrom, the outer ends of the links being provided with enlarged circular bosses 64. Extending through the central openings of the several bosses 64 is a common drive shaft 65 which is mounted in suitable bearings such as 66 supported by structural iron members 67 which are in turn connected with the legs or with reinforcing portions of the furnace

The shaft 65 is disposed eccentrically within the openings of the bosses 64 and the shaft is surrounded by and keyed or otherwise connected with disk or collar-like members 68 rotatably fitted within the openings of each of the enlarged bosses 64. The collars or disks 68, in effect, provide cams upon the shaft 65 and are so positioned that the lobes of adjacent cams extend in diametrically opposite directions. This will be apparent from the schematic representation in Fig. 17 which illustrates the relative angular positions of the disks or collars forming the cam lobes.

The shaft 65 is rotated by a motor 69 through a change-speed mechanism 70, the motor and change-speed mechanisms being suitably mounted upon the furnace supports by means not shown. It will be apparent, therefore, that when the motor 69 is rotated, the resulting rotation of the shaft 65, and of the attached disks or cams, results in movement of the grate bars, adjacent grate bars moving in opposite directions with respect to each other. As in the preferred form of vibrating mechanism, the length of stroke of the grate bars in this movement is relatively short, the length of the stroke resulting from the mechanism shown in Figs. 16 and 17 being, however, greater than that resulting from the use of electromagnetic vibrators such as shown in Fig. 8. Also, while the frequency of the movement of the grate bars is relatively low the motion is vibratory in nature and hence reference hereinafter and in the subjoined claims to vibration of the grate bars is intended to cover the mechanism illustrated in Figs. 15, 16 and 17 unless excluded by recitation of features not present therein.

A discharge controlling mechanism is supported in spaced relationship below the grate bars and moves in a substantially horizontal direction for controlling the discharge of the material from the shaft of the furnace. This mechanism comprises a plurality of plate-like members, equal in number to the number of spaces between the grate bars, and mounted to extend transversely of the furnace substantially below the said spaces between the grate bars, the plates being movable transversely of the grate bars in a manner hereinafter described. The lower surfaces of these plate members are each supported adjacent their ends upon longitudinally extending bars 71 which are in turn supported upon rollers such as 72 extending transversely of the furnace and rotatably supported from the side walls thereof, see Figs. 4 and 5. The intermediate discharge plate members, such as 73, 74, and 75, that is all but the two end plates of the discharge mechanism, are welded to the previously mentioned bars 71 while the two end plates 76 and 77 are not welded to the bars 71 but are slidable thereon.

The intermediate plates, such as 73, 74, and 75, are each provided with a downwardly extending, substantially centrally located bar 78, 79, and 80, respectively, extending between the bars 71 and secured to the latter and to the corresponding plates 73, 74, 75 as by welding. The end plates 76 and 77 are provided with similar downwardly extending bars 81 and 82, respectively, which are welded to the lower surface of the plates 76 and 77. The ends of these bars 76 and 77 are not welded to the bars 71 but instead are welded to separate bars such as 83, 84 which extend parallel with, and spaced slightly inwardly from the bars 71, these bars 83 and 84 having their upper edges welded to the corresponding plates 76 and 77, as will be seen from Figs. 3 and 4.

Inclined plates, such as 85, are mounted below and at one side of the spaces between the grate bars 34. These plates are substantially parallel, extend transversely of the furnace, and have their ends secured to the hanger plates 40 for the adjacent grate bars. The upper edges of these plates 85 are adjacent the lower right-hand portions of the grate bars, as seen in Figs. 1, 4 and 7 and the lower edges of these inclined plates are disposed slightly above the upper surfaces of the reciprocating plates, such as 73 to 77, and adjacent the left-hand edges thereof when the plates are in the positions shown in the drawings. Consequently, the pellets or other material falling between the grate bars 34 are guided by the plates 85 onto the reciprocating plates 73 and 77, the dimensions of the parts being such that the angle of repose of the material, with the mechanism positioned as shown in the drawings, causes the material to be retained upon the horizontal discharge plates such as 73 to 77. When the latter plates are moved to the left, as viewed in the drawings, a layer of the pellets or other material supported thereon is caused to move outwardly over the right-hand edges of these plates due to the relative motion between the latter and the inclined plates 85, the material thus discharged dropping downward into the funnel-shaped portions 29, 30 of the furnace and being discharged therefrom as hereinafter described. In view of the tendency of the side walls of the furnace to partially support the material therein, which tendency is especially noticeable adjacent the end walls probably due to the transverse arrangement of the grates, the end plates 76 and 77 are preferably moved greater distances than are the intermediate plates, such as 73, 74 and 75, during each stroke of the plates. As shown in Figs. 3 and 4, the downwardly extending bar 81, which is connected with the plate 76, is connected substantially centrally thereof to a pipe or rod 86. This pipe or rod slidably extends through the downwardly extending member 80 of plate 75 and slidably through a larger diameter pipe or tube 87 which is connected to one or more of the downwardly extending bars, such as 79, of the intermediate discharge plates 73 to 75. The tube or pipe 87 in turn is slidably passed through a third pipe or tube 88 which is connected to the downwardly extending bar 82 secured to the plate 77. These pipes or tubes extend through the side wall of the furnace, which is provided at this point with a substantial stuffing box or sealing gland, generally designated 89, which may be simillar to the previously described sealing means provided for the outwardly extending tubes of the grate bars and which is illustrated in detail in Fig. 8.

The outer surface of the pipe 88 is threaded adjacent its end, see Fig. 14, and an internally threaded sleeve 90 is screwed thereon and retained in adjusted position by a set screw, or the like 91. The forward end portion of the sleeve 90 is of reduced diameter and is provided with an external screw thread on which is screwed a collar 92 which is retained in adjusted position by a set screw or the like 93. The sleeve 90 has an upstanding flange portion providing an integral shoulder and between the shoulder and the external threaded portion is a cylindrical surface 94 on which a yoke member 95 is slidably positioned. The inner face of the collar 92 provides a second abutment for this yoke member and the extent of its sliding movement upon the cylindrical surface 94 is adjustable by varying the position of the collar 92.

The tube 87 extends outwardly beyond the outer end of the tube 88 and a gas seal 96 is provided on the outer end of the latter tube for cooperation with the former. This gas seal may be of any suitable construction, but is here shown as a sleeve member threaded upon the end of the tube 88 and having an inwardly directed flange between which and the outer end of the tube 88 is provided a suitable packing material 97.

The tube 87 is threaded adjacent its outer end and is provided with a sleeve member 98 adjustably secured in position by a set screw or the like 99, these parts being substantially identical with those provided upon the tube 88 and designated 90, 91, respectively. The sleeve 98 is likewise provided with an adjustable collar 100 which is held in adjusted position by a set screw, or the like, 101 thereby providing an adjustable abutment for a yoke member 102 which is slidable between the integral flange portion of the sleeve member 98 and the collar 100 in a similar manner to the previously described yoke member 95. The outer end of the tube 87 is likewise provided with a gas seal or packing gland 103 coperating with the outer surface of the tube or rod 86 in the same manner that the seal 96 cooperates with the tube 87.

The outer extending end of the tube or rod 86 is likewise screw-threaded and provided with a sleeve and collar organization 104, 105 for receiving therebetween a third yoke member 106, the sleeve 104 and the collar 105 being held in adjusted positions by set screws 107 and 108 as in the previously described similar organizations attached to the tubes 88 and 87. If the member 86 be a tube, as shown, the outer end thereof may be provided with a suitable cap or plug to prevent the escape of gases therethrough. Preferably, however, this sealing is effected by a plug or cap 109 provided upon the inner end of the tube, as shown in Fig. 4.

The yoke members 95, 102, and 106 are connected together and maintained in predetermined spaced relationship by a pair of spaced rods 110 and 111 passing through apertured ends of the yoke members and provided with tubular spacers 112, intermediate the yoke members, to maintain predetermined distances between the latter, the ends of the rods being threaded and provided with suitable nuts 113, see Fig. 3. Secured to the upper and lower surfaces, respectively, of the yoke member 106 are pairs of spaced, forwardly-extending plate members 114 and 115, the forward ends of the plates 114 being connected to the corresponding plates 115 by spaced blocks 116 and 117. A lever 118 has an intermediate portion positioned between the blocks 116 and 117 and is pivotally connected with the blocks by a pivot pin or shaft 119, the ends of which are supported in the spacer blocks. The lower end of the lever 118 is pivotally supported between spaced bracket members 120 which are secured to a portion of a framework extending between the legs of the furnace. The upper end of the lever 118 is bifurcated and the bifurcation thereof is provided with a connection member 121 which is pivoted on a pin 122 mounted eccentrically upon the output shaft of a gear reduction unit 123 driven by an electric motor 124. The motor 124 and gear reduction unit 123 are adjustably supported upon a platform, generally designated 125, which is attached to the legs of the furnace. Connected with a part of the supports for this platform and the brackets 120 is an upstanding guide plate 126 which has semi-circular recesses in its upper edge in which the spacer tubes 112 of the yoke mechanism are received thereby guiding and supporting the latter in its reciprocating movements.

The construction just described is such that, when the motor 124 is energized, the lever 118 is rocked about its pivotal support in the brackets 120 thereby imparting reciprocating movement to the discharge plates, such as 73 to 77, through the yoke members 95, 102, and 106 which, it will be remembered, are connected together by the rods 110 and 111. The resulting extents of movements of the end plates 76 and 77 relative to the intermediate plates, such as 73, 74 and 75, is determined by the adjustments of the collar members, such as 92, 100, 105 which are capable of providing a desired amount of lost motion between the correpsonding yoke members and the tubes actuated thereby. For example, as shown in Fig. 14, the collar 105 is so positioned that it holds the yoke member 106 firmly against the integral flange on the sleeve member 104 so there is no lost motion at this point. Consequently, the tube 86 and the plate 76 connected therewith are reciprocated the maximum extent by the movement of the lever 118. The collar 100 is, however, position in spaced relationship to the integral flange of the sleeve member 98 so that the yoke member 102 has a lost motion between the collar and the flange of the sleeve and, consequently, the tube 87 has a stroke of lesser length than that of the tube 86 due to this lost motion travel of the yoke 102 between the sleeve and collar members. Therefore, the intermediate plates, such as 73, 74 and 75, move together butt through a lesser distance than the end plate 76. The intermediate plate 73, 74 and 75 all move as a unit since it will be remembered that they are each connected to the bar members 71 which are in turn connected to the bar member 79 with which the tube 87 is connected. The collar 92 is shown as positioned to provide a lost motion for the yoke member 95 between the collar and the flange of the sleeve member 90, this lost motion, however, being less than that of the yoke member 102. Consequently, the tube 88, and hence the plate 77 which is connected therewith, is reciprocated through a distance which is greater than that of the intermediate plates but less than that of the end plate 76.

The amount of adjustment of the collars, such as 92, 100, and 105, here shown is to be understood as illustrative only since the extents of movements of the several plates may be varied as is necessary or desired in accordance with the characteristics of the material in the furnace, the extents of movements of the discharge plates being selected to provide a substantially uniform discharge of the material for the entire cross sectional area of the shaft of the furnace. That is to say, the plates, such as 73 to 77, should be given reciprocating movements of such extent that the material in any horizontal layer through the shaft of the furnace moves substantially uniformly downwardly as the plates are reciprocated.

The rollers, such as 72, which support the discharge plate mechanism preferably comprise pipes or tubes 127 which extend substantially the entire width of the furnace and are rotatably supported upon shafts or rods 128, the ends of the latter extending through the side walls of the furnace and being adjustably mounted therein. As shown in Figs. 5 and 6, this adjustable mounting is effected by providing bearing members 129 for the ends of the shafts, each of which bearing members has the opening for the shaft 128 eccentrically disposed. The bearing members 129 each have an outwardly extending flange portion provided with a plurality of spaced notches 130 by which the bearing members may be rotated thereby changing the elevation of the shafts 128 and the tubes 127 to provide the desired elevation and alignment of the bars 71 of the discharge mechanism. When the bearing members 129 have been properly positioned, they may be secured in this position by inserting a lug-like member 131 into one of the notches and welding the latter to the side wall of the furnace. While the members 129 have been described as bearing members, it will be understood that the shafts 128 do not rotate therein during the reciprocation of the grate bars, but instead the tubes or pipes 127 rotate with respect thereto. Consequently, the ends of the shafts or rods 128 are secured by means of lock washers 132 and nuts 133, the latter being secured upon the threaded outer ends of the shafts.

The bars 71, and hence the discharge plates, are laterally guided and constrained to straight line motion by means of rollers 134, see Fig. 3. These rollers have their axes disposed vertically and are supported upon opposite side walls of the furnace by brackets 135 in positions such that the rollers engage the outer sides of the bars 71 and are at all times shielded by the discharge plate 76.

It will be understood that the furnace is operated under pressure. That is to say, gas such as air, gaseous fuel, or mixtures thereof will be introduced into the plenum of the furnace below the grate bars and ascend therebetween and through openings such as 136 in the grate bars to effect heating of the pellets or other burden in the furnace. Therefore, each hopper-like portion 29, 30 of the plenum is provided with an inlet opening 137 to which a suitable conduit is attached for conducting such gas or gases into the furnace. Consequently, the discharge of material from the furnace must be effected through a gas seal to prevent interference with the pressure conditions in the furnace and prevent loss of the gas or gases. To effect the discharge and provide such a gas seal each discharge spout or conduit 31, 32 of the furnace is provided with valve mechanisms operated in timed relationship with the reciprocation of the discharge plates, such as 73 to 77.

As will be seen from Figs. 1 and 9 of the drawings, the discharge valves are provided in vertically spaced pairs in each conduit, the upper valves in each conduit operating together and sequentially with respect to the lower valves in each conduit, which likewise operate together. As illustrated in Figs. 9 and 10, the conduit 31 is provided, intermediate its top and bottom, with an inclined plate 138 which is permanently attached to a portion of the side wall of the conduit and extends at an angle downwardly therein, the lower edge of the plate terminating short of the portion of the conduit side wall which is diametrically opposite the top of the plate so that the latter extends approximately two-thirds of the way across the conduit. The inclination of the plate is such that its highest portion is adjacent that side of the conduit which receives the impact of the majority of the pellets moving downwardly therein; that is to say, the relative position of the inclined plate with respect to the discharge plates, such as 73 to 77, should preferably be as shown in Fig. 1.

The opening through the conduit between the lower edge of the inclined plate 138 and the adjacent portion of the conduit side wall is adapted to be opened and closed by a pivoted valve 139. The details of this valve are shown to an enlarged scale in Fig. 13 from which it will be seen that the valve comprises a substantially semicircular plate-like member having spaced integral or rigidly attached bosses 140, 141 provided along the chordal portion which corresponds with its rear edge. These bosses have openings therethrough to receive a mounting shaft 142 which is journalled in bearings 143 and 144 provided at diametrically opposite points in the side wall of the conduit 31, to the rear and adjacent the lower edge of the incline plate 138. The openings through the bosses 140, 141 are somewhat larger than the external diameter of the shaft 142 so that the valve plate 139 is freely pivoted upon the shaft and may partake of some radial movement with respect thereto. Intermediate the bosses 140, 141 the shaft 142 has a collar member 145 attached thereto by any suitable means and this collar has spaced arms 146 and 147 which extend forwardly under the valve plate 139 with upwardly extending projections which engage the under surface of the latter. The shaft 142 extends beyond the bearings 143, 144 and is provided at one end with a retaining collar 148, the other end of the shaft being provided with an actuating arm 149 which is attached to the shaft 142 in any suitable manner to effect movement of the latter by rocking of the former.

Vertically spaced below the inclined plate 138 and valve 139, the conduit 31 is provided with a second permanently secured inclined plate 150 similar to the plate 138 but extending in the opposite direction so that its lower edge, which is spaced from the side wall of the conduit, is beneath the portion of the plate 138 which is attached to the conduit, see Figs. 1 and 9. Beneath the plate 150 and cooperating therewith, to selectively open and close the space between the conduit and the lower edge of the plate, is a pivoted valve 151. This valve is constructed in the same manner as is the valve 139 but is oppositely disposed within the conduit. The valve 151 is supported in a similar manner to the valve 139 and is actuated by an arm 152.

The conduit 32 is provided with an upper rigidly mounted inclined plate 153 and cooperating pivoted valve 154 corresponding in construction and position with the plate 138 and valve 139, the valve 154 being provided with an actuating arm 155 for effecting movement thereof. Vertically spaced below the plate 153 and valve 154, the conduit 32 is provided with a second inclined plate 156 and pivoted valve 157, which are constructed in the same manner as the previously described plates and valves and are mounted in the same horizontal plane and the same relative positions as the inclined plate 150 and valve 151 in the conduit 31. The valve 157 is provided with an actuating arm 158 corresponding with previously-mentioned actuating arms, such as 149, 152 and 155.

The actuating mechanism for the discharge valves is supported in a suitable framework, which is here shown as comprising a pair of spaced channel members 159 and 160 which extend horizontally between the hopper-like portions 29, 30 of the furnace plenum on opposite sides of the downwardly extending conduits or pipes 31, 32. Intermediate the conduits, the channels 159 and 160 are each provided with a downward extending channel member 161 and 162, respectively, the lower ends of which are connected together by a transversely extending member 163. Supported upon this framework are the actuators, generally designated 164 and 165, for operating the lower valves 151, 157 and the upper valves 139, 154, respectively.

These actuators are identical and are of the type well known to the trade as a "Thrustor" and hence need not be described in detail. Suffice it to note that such a device essentially comprises a hydraulic cylinder 166 in which fluid pressure is developed by an electric motor 167 so that a piston in the cylinder is moved therethrough to effect a thrust upon a pair of spaced rods 168 and 169 connected to the piston, the upper ends of the rods being joined by a cross member 170. As is well known, when the motor 167 of such a device is energized, the cross member 170 is moved relatively slowly outwardly with respect to the cylinder and attains its extreme position after a time interval of several seconds, this position being maintained so long as the motor is energized. Upon deenergization of the motor, the rods 168 and 169, together with the cross member 170, return to their initial position, the time interval of this movement being substantially the same as that required for their outward movement.

The actuator 164 has its cross member 170 connected to a composite lever 171 formed by a pair of spaced bars connected together as is shown in Figs. 10, 11, and 12, the member 170 being pivotally connected to the lever intermediate the ends of the latter. One end of the lever 171 is connected to a sleeve 172 which is rotatably supported upon a shaft 173 extending transversely between the channel members 161, 162, the other end of the level being provided with a pivotally mounted counterweight 174. The sleeve 172 is provided, adjacent the inner face of the channel 161 with a pair of spaced arms 175, 176 which are connected to rock with the sleeve 172. The outer ends of the arms 175 and 176 have a downwardly extending link 177 received therebetween, the upper end of the link being pivotally connected with the arms 175, 176. The lower end of the link 177 is received between, and pivoted to, the outer ends of a pair of spaced arms 178 and 179 of a composite bell crank lever, designated generally as 180. This lever is fixed, intermediate its end to a sleeve 181 which is rockable upon a shaft 182 extending transversely between and mounted in the channel members 161 and 162. The second pair of spaced arms 183 and 184 of the bell crank lever 180 straddle and are pivotally connected to adjacent ends of substantially horizontally extending links 185 and 186 the outer ends of which are connected, respectively, with the actuating arms 152 and 158 for the valves 151 and 157.

As shown in Figs. 9 and 10, the outer end of the link 185 is adjustably connected with a clevis 187 which straddles the arm 152 and is pivoted thereto, adjustment being effected by a threaded portion upon the rod 185 engaging in a threaded opening of the clevis 187 with the parts being maintained in adjusted position by a jam or lock nut 188. The outer end of the link 186 is likewise screw-threaded but this threaded end does not threadably engage the clevis 189 which is pivotally connected to the rock arm 158. Instead, the outer end of the link 186 slidably extends through an opening in the clevis, the outer end of the link 186 being provided with a nut 190 which is adapted to engage the portion of the clevis adjacent the opening therethrough when a pull is exerted on the link 186. Interposed between the end of the clevis 189 and a nut 191 upon the inner threaded portion of the link 186 is a compression spring 192 the compression of which may be adjusted by adjustment of the nut 191. There is thus provided a yieldable connection in the actuating mechanism for the valves 151, 157 to prevent injury to the parts if a pellet should be lodged between the end of one of the valve plates and the side wall of a conduit such as 31, 32 when the valves are operated to closed position.

The mechanism just described operates, when the motor 167 is energized, to rock the lever 171 in a clockwise direction, as viewed in Fig. 9. This rocks the arms 175, 176 moving the link 177 downwardly thereby rocking the bell crank lever 180 in a clockwise direction so that the links 185, 186 are moved to the left actuating the valves 151, 157 to open position. When the motor 167 is deenergized the counterweight 174 returns the actuating mechanism to its initial position. That is, the lever 171 is now rocked counter-clockwise, thus elevating the link 177 and rocking the bell crank lever 180 in a counter-clockwise direction so that the links 185, 186 move to the right, as viewed in Figs. 9 and 10, thereby closing the valves 151 and 157. In the event a pellet or other particle should have lodged between the edge of one or both of the valves 151, 157, the actuating mechanism may return to its initial position without effecting undue strains thereon or damage to the parts. This is due, in part, to the fact that the spring 192 provides a yieldable connection between the actuating mechanism and the valve plates. Moreover, it will be remembered that the valves are not directly moved by the actuating arms 152, 158 but freely rest upon the members or arms, such as 146, 147, which are connected to move with the arms 152, 158. It will also be remembered that there is radial play between the shaft and the bearing bosses of each of the valve plates. Consequently, the valve plates 151 and 157 may be displaced sufficiently to clear an obstruction such as a pellet, or a fragment thereof, and then continue to its closed position under the action of the spring 190 which is compressed if such an obstruction is encountered during the closing operation.

The actuator 165 is connected for operation of the valves 139 and 154 in a somewhat similar manner to that just described for the connection of the actuator 164 to the valves 151 and 157. Thus, the cross member 193 of the actuator 165, which corresponds with the member 170 of the actuator 164, is pivotally connected to a composite lever 194 intermediate the ends of the latter. One end of the lever 194 is connected to a sleeve 195, which is rockably mounted on the shaft 173, the other end of the lever 194 being pivotally connected to a counterweight 196. The sleeve 195 has the ends of a pair of spaced arms 197, 198 fixed thereto, the arms extending downwardly therefrom with their lower ends straddling and pivotally connected to substantially horizontally extending links 199 and 200. These links are connected with the rock arms 149 and 155 for the valves 139 and 154, respectively, by means of clevises providing adjustable and yieldable connections, as previously described with respect to the links 185 and 186, so that the valves 139 and 154 operate in substantially the same manner as the valves 151, 157. Therefore, when the actuator 165 has its motor 201 energized, the lever 194 is rocked in a counter-clockwise direction, as viewed in Fig. 9, thus moving the valves 139 and 154 to open positions. Likewise, deenergization of the motor 201 causes the counterweight 196 to rock the lever 194 back to its initial position thereby closing the valves 139, 154, this being effected without damage to the parts even though a particle or particles might have temporarily lodged adjacent their edges.

As mentioned heretofore, the discharge valves operate in timed relationship with the actuation of the discharge plates, such as 73 to 77. This is accomplished by controlling the energization of the motors 167, 201 by means of cam-actuated switches contained within a housing identified in the drawings as a "Timer" which is mounted upon the gear reduction unit 123 so that the cam-actuated switches are operated by the output shaft of the unit. The electric circuit thus controlled may be conventional and hence is not illustrated in detail. Suffice it to note that the cam switches are so disposed that both motors 167 and 201 are deenergized when the discharge plates 72 to 77 are positioned as shown in the drawings. As the motor moves these plates in a direction to discharge a portion of the material thereon, i. e., to the left as viewed in Figs. 1, 3 and 4, the motor 167 is energized thus opening the valves 151 and 157. Near the end of the stroke of the discharge plates in this direction the motor 167 is deenergized so that the valves 151 and 157 are again closed. During the return stroke of the discharge plates, the motor 201 is energized thus opening the valves 139 and 154. By the time the discharge plates have returned to their initial positions the motor 201 is deenergized so that the valves 139 and 154 are again closed.

For example, when the discharge plates require an interval of approximately twenty-two seconds for one complete reciprocation, all the valves 139, 151, 154 and 157 are closed during the initial two seconds of the movement of the discharge plates in direction which effects displacement of agglomerates or other material thereon. At the end of this interval of two seconds, the motor 167 is energized and during the next two seconds of operation the discharge plates are further moved in the direction for effecting discharge of the agglomerates and the lower valve plates 151, 157 move to open positions and remain open during the following three seconds of the cycle, thus allowing discharge of any material that may be present between the valve plates 139, 151 and 154, 157, respectively. During the next two seconds of discharging movement of the plates, such as 73 to 77, the motor 167 is deenergized and the valves 151, 157 move to closed positions, approximately two seconds being required for this operation. All of the valves then remain closed for the remaining two seconds of the discharging movement of the plates 73 to 77.

During the above-mentioned eleven seconds of operation of the plates 73 to 77 in the discharging direction, the pellets or other material discharged thereby will have dropped into the conduits 31, 32 and come to rest upon the valve plates 139 and 154 so that a gas seal is maintained while the lower valves 151 and 157 are open. In the initial two seconds of the interval of return movement of the plates 73 to 77, all valves remain closed and thereafter the motor 201 is energized. Hence, the valves 139, 154 move to open positions during the next two seconds and remain open for three additional seconds due to the continued energization of the motor 201. The pellets or other material that have accumulated above the valves 139 and 154 drop into the space between these valves and the lower valves 151 and 157 while further discharge of material is being gradually reduced by the return movement of the discharge plates 73 to 77. During the next succeeding two seconds of this return movement, the motor 201 is deenergized so that the valve plates 139 and 154 return to closed positions and remain closed during the final two seconds required to complete the return stroke of the discharge plates which terminates further fall of material into the conduits 31, 32.

This cycle is then repeated so that the pellets that have accumulated between the upper and lower valves in the conduits 31, 32 are discharged as a new quantity of the pellets drops from the discharge plates onto the upper valves 139, 157. Consequently, an effective gas seal is maintained so that free communication of the plenum of the furnace through the discharge conduits 31, 32 is never possible, these openings being sealed at all times by one or more of the valves together with the agglomerates accumulating thereon. It is to be understood that the time intervals just given are by way of illustration only and are not intended as a limitation, since the time cycle may be varied for any given furnace in accordance with the type of material treated therein, the operating characteristics of the furnace, and the like, and moreover, the length of time interval will vary in accordance with the size of the furnace. Furthermore, the energization of the motors 167, 201 may, if desired, be controlled by a suitable timing or sequencing device not actuated from the gear reduction unit 123. For example, a suitable clockwork mechanism or the like may be employed to effect the sequential energization and deenergization.

The pellets discharged from the lower ends of the conduits 31, 32 pass into a hood 202 which is connected with the lower ends of the conduits and is further supported by the channel members 161, 162 and the transverse member 163. This hood extends closely adjacent the previously-mentioned conveyor 33 which carries the discharged pellets to a point of further treatment or utilization, the hood being provided as a means to withdraw and prevent the spread of dust or the like at this point. Therefore, the hood 202 has one end closed, as indicated in 203, and adjacent the other end is provided with a transversely extending pivoted wall or flap 204, the pivoted wall or flap being disposed adjacent that end of the hood through which the discharge particles move upon the conveyor 33. Intermediate the wall 201 and pivoted flap 202, and between the conduits 31, 32, are provided one or more additional pivoted walls or flaps. In the present construction two such additional pivoted walls or flaps 205 and 206 are shown, these being illustrated as provided at the lower ends of relatively rigid upper wall portions 207 and 208, respectively. The pivoted walls or flaps allow the free passage of the pellets or other particles upon the conveyor, but substantially prevent the passage of dust or the like resulting from the impact of the pellets upon the conveyor 33 when the valves 151, 157 are initially opened.

In order to remove dust from the hood, the latter is provided with exhaust pipes or stacks 209, 210 which communicate with the hood intermediate the walls or flaps 204, 205 and 203, 206, respectively. These exhaust conduits or stacks are connected with a suitable exhaust and dust collecting means, not shown, to which is also connected the hood 211 provided at the upper end of the shaft of the furnace. Preferably a sight opening 212 is provided in one or more of the side walls of the lower hood 202 intermediate the pivoted walls or flaps 205, 206 to enable the operator to determine if pellets or other particles are being discharged from the conduit 32, which may be determined by the presence of such pellets or particles moving along the belt 33 towards the wall 205.

Proper heating of pellets, or similar particles, is greatly facilitated by charging the pellets, or the like, into the shaft of the furnace in substantially uniform layers. Therefore, the top of the furnace is provided with a pair of spaced rails 213, 214 extending transversely with respect to the grate bars and discharge plates. These rails serve to support and guide a movable conveyor, designated generally 215, which is adapted to move across the top of the furnace and deposit the pellets or other particles therein, the width of the conveyor 215 being substantially equal to the width of the shaft of the furnace. In order to accommodate the conveyor 215, the hood 211 is shown as having an opening 216 at one side thereof. This opening may be partially closed, if desired, by a pivoted wall or the like, not shown, which would extend closely adjacent the top of the conveyor and yet allow movement of the latter therethrough, such a wall or flap being similar to the wall or flap 204. To facilitate access to the furnace, a portion of the hood 211 adjacent the opening 216 may be hinged, as indicated at 217, and in addition suitable access openings, such as 218, may be provided.

Access to the plenum of the furnace, for cleaning or repair operations is afforded by manhole openings provided with suitable covers, such as 219, as is well known in the art. In addition, the opposite side walls of the furnace shell are provided with pokehole openings, such as 220 adjacent the upper edges of the grate bars and intermediate the latter. These latter openings are normally closed by suitable plugs which may be removed for the insertion of a poker or the like if at any time it be necessary to break up clusters or remove obstructions from between the grate bars.

It is believed that the operation of a shaft furnace constructed as described will be apparent from the above detailed description of the several parts thereof. However, in order to facilitate an understanding, the operation may be briefly summarized as follows:

The furnace is charged by employing the conveyor 215 to lay down successive layers of green pellets within the shaft of the furnace. Since these pellets may contain a certain amount of solid fuel therein, they may be satisfactorily heated by simply introducing heated air through the openings, such as 137, which air ascends between the grate bars and through the openings 136 therein to effect combustion of the solid fuel in the pellets thereby heating the latter to the desired temperature. If, however, solid fuel be not employed, in the pellets, or if solid fuel be thus used but in less quantity than the amount necessary to provide the desired heat, a gaseous fuel may be introduced along with the air through the openings 137, or through separate openings, the fuel burning between and among the pellets to heat, or assist in heating, the latter. The operation of the furnace is so controlled that the highest temperature zone therein is preferably within the shaft of the furnace and above the grate bars. Consequently, the incoming air and/or other gas passing over the lowermost pellets, which are below the highest temperature zone, cool these pellets while the ascending hot gases above the combustion zone tend to dry and preheat the green pellets moving downwardly within the furnace from the top thereof. It will be understood that the lower pellets which have been heated to the desired extent and are then somewhat cooled by the ascending gases will rest upon and between the grate bars **34**, a portion of the pellets moving downwardly therebetween and coming to rest upon the upper surface of the discharge plates **73** to **77** which have sufficient width to extend beyond the pellets thereon when the latter have reached their angle of repose.

Assuming that the furnace is in continuous operation with pellets being charged at the top of the furnace, the motor **124** will be in continuous operation. Hence, a portion of the pellets which have been sufficiently heated and have come to rest upon the discharge plates **73** to **77** are discharged as the latter plates are moved relative to the inclined plates **85**. The extents of movements of the two end discharge plates **76** and **77** are so adjusted relative to that of the intermediate plates such as **73** to **75**, by means of the mechanism shown in detail in Figs. 3, 4, and 14, that the discharge of material is substantially uniform throughout the entire cross-sectional area of the furnace. Hence, the separate pellets in any horizontal layer of material within the furnace move downwardly at substantially the same rate so that all the pellets within such a hypothetical layer are subjected to substantially the same temperatures for the same periods of time.

The pellets discharged upon reciprocation of the discharge plates, **73** to **77**, accumulate upon the upper valves **139** and **154** within the conduits **31**, **32** while the discharge plates are moving to the left, as viewed in Fig. 1. During this same interval, the timer, which is preferably operated by the gear reduction unit **123**, energizes the motor **167** to move the lower discharge valves **151** and **157** to open positions thus discharging any material that has accumulated between the upper and lower valve plates in the conduits **31**, **32**, the lower valves being again closed shortly prior to the time that the discharge plates, **73** to **77**, reach their extreme left positions. As the motor **124** continues to rotate and moves the discharge plates, **73** to **77**, back to their initial positions, the lower valves **151** and **157** remain closed while the timer now energizes the motor **201** to open the upper valves **139** and **154** thus allowing the material which has accumulated thereon to move downwardly and come to rest upon the valves **151** and **157**. The upper valves **139** and **154** are returned to their closed positions, due to deenergization of the motor **201**, by the time that the reciprocating plates, **73** to **77**, have returned to their initial positions. Upon the next cycle of movement of the discharge plates, **73** to **77**, the previously described operations are repeated, this continuing so long as the motor **124** is in operation and the furnace is charged with material.

The length of time required for the pellets to pass from the top of the shaft of the furnace through the grate bars and be discharged therefrom, and hence the extent of their heating, may be controlled by regulating the speed of operation of the motor **124** and the extents of movements of the discharge plates. It will be apparent, however, that the rate of movement of the pellets through the furnace is relatively slow and that these pellets are not subjected to any appreciable grinding or breaking forces since the grate bars and discharge mechanism so function that the pellets move in relatively uniform layers downwardly through the shaft of the furnace. Moreover, the pellets are not subjected to any appreciable grinding forces in passing between the grate bars or by action of the discharge plates.

The grate bars **34** may be vibrated either continuously, or intermittently, or not at all, during the operation of the furnace and, when individual vibrators such as shown in Figs. 1, 2, and 8 are employed, any desired number of the grate bars may be vibrated at a given time. This vibration is, as noted above, preferably of relatively high frequency, short stroke type but may be of relatively low frequency when the mechanism illustrated in Figs. 15, 16 and 17 is used, the vibration being used to break up large clusters of pellets, if formed. The vibratory motion is, however, insufficient in extent of movement to effect appreciable abrasive action between the pellets and the grate bars or between adjacent pellets. It should be further noted that this vibration of the grate bars is not injurious to the lining of the furnace due to the novel manner in which the grate bars are mounted so that the vibrations are not transmitted to the furnace walls.

While the invention has been illustrated and described in considerable detail as embodied in a rectangular shaft furnace for hardening pellets of iron ore, it will be readily understood that the furnace is not limited to such a use, but may be employed for other purposes where similar problems are encountered. Furthermore, variations may be effected in the details of construction of the device and, while the invention is especially useful when embodied as a shaft furnace of rectangular cross-section, many, if not all, of the features herein disclosed may be employed without material change in shaft furnaces of circular or elliptical cross-section. Consequently, the construction described above and illustrated in the accompanying drawings is simply illustrative of a practical embodiment of the invention and, therefore, the invention is not to be considered as limited to the exact details shown and described.

Having thus described the invention, we claim:

1. A grate construction for a shaft furnace comprising a plurality of spaced substantially parallel grate bars extending transversely of the shaft of said furnace adjacent the bottom thereof, means connected with each of said grate bars and slidably extending through corresponding openings in the shell of said furnace, sealing means surrounding a portion of said means adjacent the shell of the furnace to prevent the escape of gas thereabout, the said sealing means being so constructed and arranged as to allow at least limited longitudinal movement of the said means extending therethrough, and means for applying longitudinally directed forces to the said extending means to vibrate the latter and the attached grate bars.

2. A grate construction as defined in claim 1 and further comprising means individually supporting the grate bars including a separate plate-like member attached to each grate bar adjacent each end thereof and means suspending said plate-like members from the shell of said furnace in a manner permitting limited movement of the said plate-like members relative to the furnace shell.

3. A combined grate and discharge mechanism for a shaft furnace comprising a plurality of spaced substantially parallel grate bars extending transversely of the shaft of said furnace adjacent the bottom thereof, a plurality of plate-like members horizontally spaced from each

other and supported for transverse reciprocation in a horizontal plane and in vertically spaced relationship below said grate bars, the upper surfaces of said plate-like members being adapted to receive and retain material moving downwardly between said grate bars, a common power means for transversely reciprocating all of said plate-like members, separate means connecting each end member of said plurality of members to said power means, and means interconnecting the others of said members together and to said power means, the several said connecting means including adjustable means for providing an adjustable lost-motion therebetween and said power means whereby the length of the stroke of said end plate-like members and of said other plate-like members may be adjusted to effect substantially uniform discharge of the material throughout the entire cross-sectional area of said furnace.

4. A combined grate and discharge mechanism for a shaft furnace comprising a plurality of spaced substantially parallel grate bars extending transversely of the shaft of said furnace adjacent the bottom thereof, a plurality of members horizontally spaced from each other and supported in vertically spaced relationship below said grate bars with their upper surfaces substantially horizontal and positioned to receive and retain material moving downwardly between said grate bars, means to vibrate said grate bars to disrupt large clusters that may have formed in said material, means to transversely reciprocate said members to displace a portion of the material resting thereon, and means to adjust the extent of reciprocating movement of at least some of said members relative to that of the others to thereby effect substantially uniform discharge of the material throughout the entire cross sectional area of said furnace so that the material in any horizontal plane within the furnace moves downwardly at a substantially uniform rate.

5. A combined grate and discharge mechanism for a shaft furnace comprising a plurality of spaced substantially parallel grate bars extending transversely of the shaft of said furnace adjacent the bottom thereof, means individually supporting the ends of each grate bar on the shell of the furnace for limited movement relative thereto, a plurality of members horizontally spaced from each other and supported in vertically spaced relationship below said grate bars with their upper surfaces substantially horizontal and positioned to receive and retain material moving downwardly between said grate bars, means mounted adjacent corresponding lower longitudinal edges of each of said grate bars providing inclined surfaces extending from the said grate bars to points closely adjacent one side edge of the corresponding members to guide material onto the latter as the said material moves downwardly between said grate bars, means to vibrate said grate bars to disrupt large clusters that may have formed in said material, means to transversely reciprocate said members to displace a portion of the material resting thereon, and means to adjust the extent of reciprocating movement of at least some of said members relative to that of the others to thereby effect substantially uniform discharge of the material throughout the entire cross-sectional area of said furnace so that the material in any horizontal plane within the furnace moves downwardly at a substantially uniform rate.

6. A combined grate and discharge mechanism for a shaft furnace comprising a plurality of spaced substantially parallel grate bars extending transversely of the shaft of said furnace adjacent the bottom thereof, means for imparting oscillatory impulses to said grate bars, a plurality of members horizontally spaced from each other and supported in vertically spaced relationship below said grate bars with their upper surfaces substantially parallel and positioned to receive and retain material moving downwardly between said grate bars, means to transversely reciprocate said members to displace a portion of the material resting thereon, and means to control the discharge from said furnace of the material displaced from said members in predetermined timed relationship with the reciprocation of said members.

7. The combination as defined in claim 6, and in which said last-mentioned means includes a pair of vertically spaced valves and means to operate said valves alternately to open and closed positions in timed relationship with the reciprocation of said members.

8. A shaft furnace comprising a shell, a portion of which is provided with a lining forming a shaft-like material treating chamber, a plurality of spaced grate bars extending substantially parallel with each other and transversely of said chamber adjacent the bottom thereof, the said shell of the furnace extending below said grate bars to provide a plenum portion having openings for introduction of gas under pressure and also having a material discharge opening, a plurality of members horizontally spaced from each other and arranged in vertically spaced relationship below said grate bars with their upper surfaces substantially horizontal and positioned to receive and retain material moving downwardly between said grate bars, means to transversely reciprocate said members to displace a portion of the material resting thereon, means controlling the passage of material through said discharge opening and forming a gas seal for the latter, and means to operate the last-mentioned means in a predetermined timed relationship with the reciprocation of said members whereby material discharged from the latter is removed from said plenum substantially without loss of the gas pressure therein.

9. The combination as defined in claim 8 and in which said grate bars are individually supported for limited movement, and means for vibrating said grate bars to break large clusters that may have formed in the material.

10. A shaft furnace comprising a shell, a portion of which is provided with a lining forming a shaft-like material treating chamber, a plurality of spaced grate bars extending substantially parallel with each other and transversely of said chamber adjacent the bottom thereof, the said shell of the furnace extending below said grate bars to provide a plenum portion having openings for introduction of gas under pressure and also having a material discharge opening, a plurality of members horizontally spaced from each other and arranged in horizontally spaced relationship below said grate bars with their upper surfaces substantially horizontal and positioned to receive and retain material moving downwardly between said grate bars, means to transversely reciprocate said members to displace a portion of the material resting thereon, a pair of spaced valves controlling the passage of material through said discharge opening and form-

ing a gas seal for the latter, means to operate the said valves between open and closed positions in alternation so that one valve is closed when the other is open, and means to control the operation of said valves in a predetermined timed relationship with the reciprocation of said members whereby material discharged from the latter is removed from said plenum substantially without loss of the gas pressure therein.

11. A shaft furnace comprising a shell a portion of which is provided with a lining forming a shaft-like material treating chamber, a plurality of spaced grate bars extending substantially parallel with each other and transversely of said chamber adjacent the bottom thereof, the said shell of the furnace extending below said grate bars to provide a plenum portion having openings for the introduction of gas under pressure and also having a material discharge opening, a plurality of members horizontally spaced from each other and arranged in vertically spaced relationship below said grate bars with their upper surfaces substantially horizontal and positioned to receive and retain material moving downwardly between said grate bars, means to transversely reciprocate said members to displace a portion of the material resting thereon, means to adjust the extent of reciprocating movement of at least some of said members relative to that of others of said members to thereby effect substantially uniform discharge of the material through the entire cross-sectional area of said furnace so that the material in any horizontal plane within the shaft thereof moves downwardly at a substantially uniform rate, means controlling the passage of material through said discharge opening and forming a gas seal for the latter and means to operate the last-mentioned means in a predetermined timed relationship with the reciprocation of said members whereby material discharged from the latter is removed from said plenum substantially without loss of the gas pressure therein.

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