March 18, 1969 R. A. SCHOENLAUB 3,433,468

FURNACE APPARATUS WITH A SERIES OF HEARTHS

Original Filed Oct. 25, 1965 Sheet 1 of 3

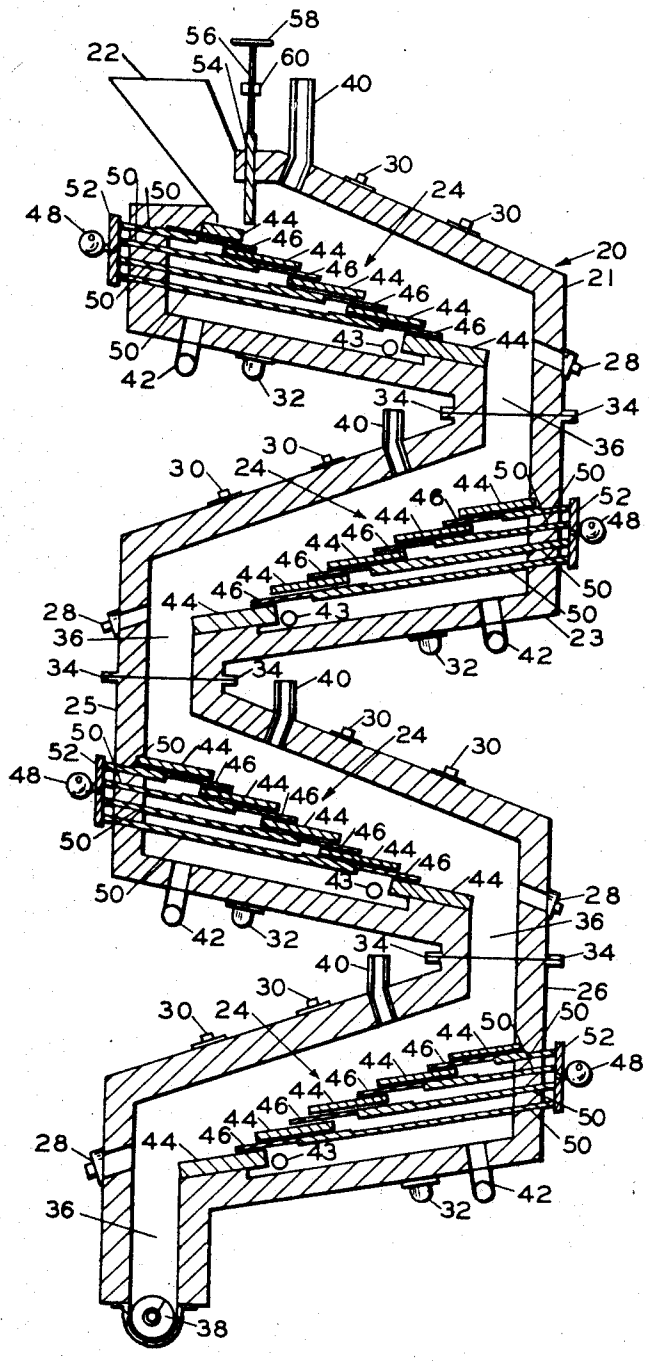

FIG. 1

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FURNACE APPARATUS WITH A SERIES OF HEARTHS

Original Filed Oct. 25, 1965 Sheet 2 of 5

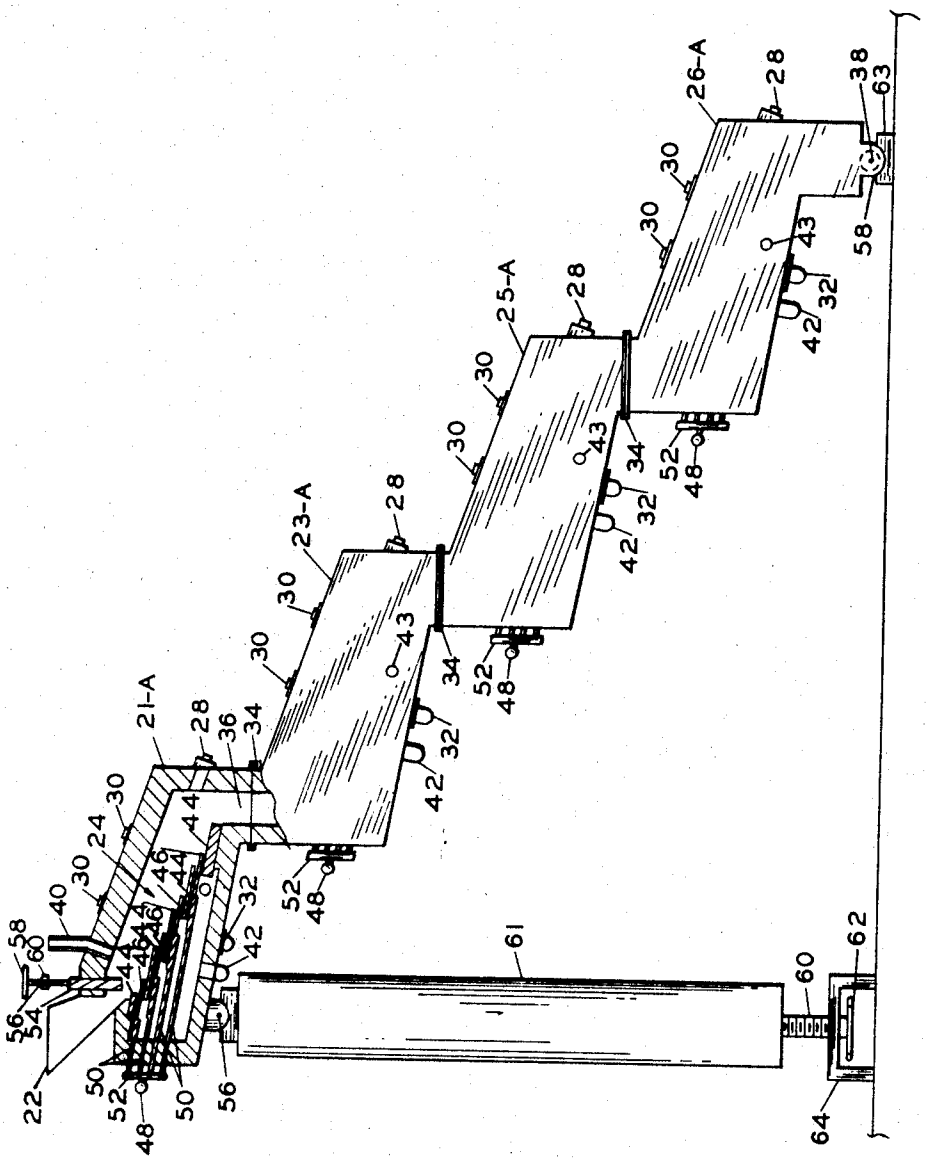

FIG. 2

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FURNACE APPARATUS WITH A SERIES OF HEARTHS

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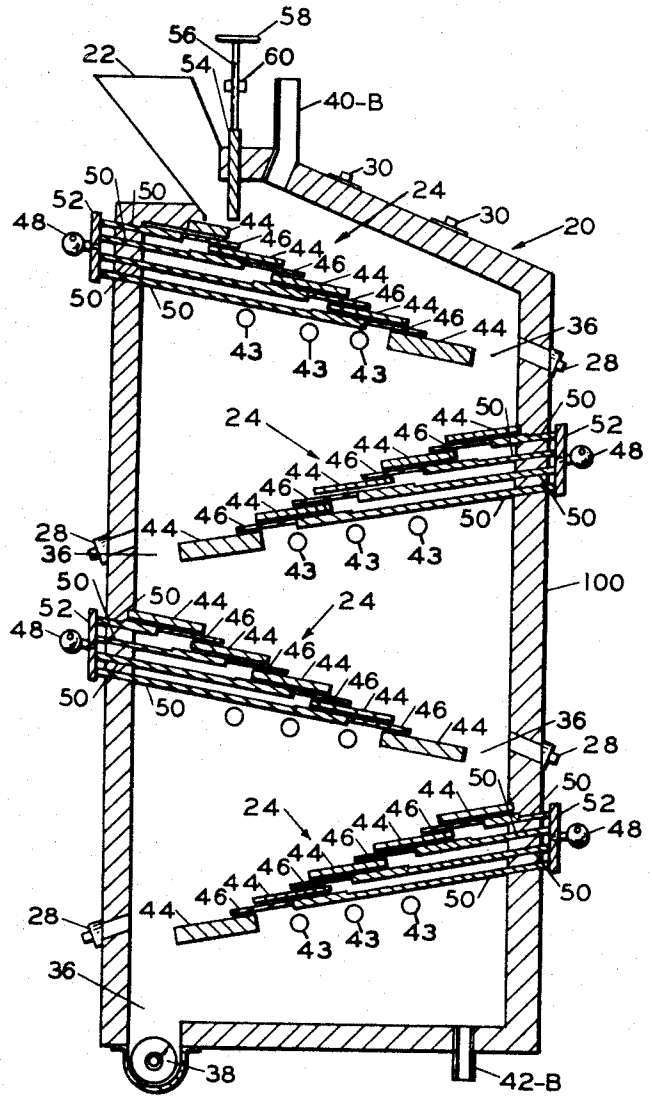

FIG. 3

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3,433,468

FURNACE APPARATUS WITH A SERIES OF HEARTHS

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Continuation of application Ser. No. 504,283, Oct. 25, 1965. This application Apr. 9, 1968, Ser. No. 726,272
U.S. Cl. 263—21 19 Claims
Int. Cl. F27d 3/04; F27b 9/22; F26b 9/00

ABSTRACT OF THE DISCLOSURE

An apparatus for calcining ores that includes a housing for a series of hearths. Each hearth includes a plurality of hearth plates disposed in vertically spaced overlapping relationship. Between each adjacent pair of hearth plates, a reciprocating plate is movably mounted to push the load from one hearth plate to the next. The reciprocating plates are preferably formed of metal, such as stainless steel and when retracted each is covered by the hearth plate, composed of a refractory material, immediately above. In one preferred embodiment of the invention the hearth plates and reciprocating plates are inclined with respect to the horizontal such that the angle formed by the edges of the hearth plates and the horizontal is bebetween minus fifteen degrees to the horizontal with an optimum angle for most materials being approximately plus fifteen degrees to the horizontal. In addition the hearth means are preferably disposed in separate housings joined to one another by appropriate passages and each housing includes separately controlled burners and flues.

This application is a continuation of Ser. No. 504,283, filed Oct. 25, 1965, now abandoned.

The present invention relates generally to industrial furnaces and aprticularly to a novel furnace apparatus for calcining ores, chemicals, ceramic raw materials and the like.

In general, the novel furnace of the present invention comprises a housing forming a suitable refractory in which are mounted a plurality of inclined hearth means. Each hearth means includes a plurality of inclined hearth plates disposed in a decending step-like manner. The load material to be calcined passes over the hearths, dropping from one hearth to another. A plurality of oscillating plates driven by an eccentric driving means are also mounted in the housing. One oscillating plate is mounted in parallel extending relationship between adjacently disposed hearth plates and moves the load material over the hearths. Suitable heating means are disposed in the housing to fire the load material as it passes over each hearth means.

In accordance with the present invention, the novel construction of the furnace apparatus, wherein the load material passes over a series of inclined hearth means and is moved by a plurality of oscillating plates disposed between individual hearth plates, provides the following advantages:

(1) The rate of passage of the load material through the furnace may be closely controlled and varied according to the type of material being processed.

(2) The load material is gently agitated as it passes from one hearth means to another to provide a more uniform calcine between load particles of different sizes.

(3) Load materials can be flashed by reducing gases or bloated to expanded aggregate if desired with no major change in design.

(4) Thermal efficiency is high as the load material on the hearths may be exposed to preheated air or hot gases

may be drawn from the upper hearths down through the load.

(5) The temperatures and furnace atmosphere may be closely controlled in relatively simple manner, and the temperatures are not limited by the exposed metal within the furnace.

As another aspect of the present invention, the novel construction of the furnace apparatus in one of its embodiments permits the angle of inclination of the hearth means to be varied thereby permitting a wide variety of different materials to be more efficiently processed in the same furnace.

As still another aspect of the present invention, the novel construction of the furnace permits the load material to be fired by any of the conventional fuels in present use.

As a further aspect of the present invention the novel construction of the furnace in one of its embodiments permits the housing to be conveniently sealed by conventional techniques to isolate the interior of the furnace from the atmosphere. This sometimes is very desirable for particular calcining operations.

As still a further aspect of the present invention the novel construction of the furnace permits lower construction and maintenance costs as compared to prior art furnaces.

It is therefore an object of the present invention to provide a furnace apparatus of the type described which permits a greater variety of materials to be calcined in the same type of furnace.

It is another object of the present invention to provide an apparatus of the type described which permits nonuniform particle sizes to be calcined in a more uniform manner thereby eliminating the necessity of close particle size control.

It is another object of the present invention to provide an apparatus of the type described in which not only may the furnace temperatures and atmosphere be closely controlled but further provides a high thermal efficiency.

It is another object of the present invention to provide an apparatus of the type described in which materials may be flashed by reducing gases or bloated to expanded aggregate in the same furnace in a simple manner.

It is another object of the present invention to provide an apparatus of the type described which permits a variety of fuels to be used, such as for example, admixed solid fuel, gas, oil, or electrical power.

It is still another object of the present invention to provide an apparatus of the type described which is not limited in operating temperature by exposed metal.

It is a further object of the present invention to provide an apparatus of the type described which is less costly to construct and fabricate and which requires a minimum of maintenance and repairs.

Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawings wherein preferred forms of embodiments of the invention are clearly shown.

In the drawings:

FIG. 1 is a side elevational sectional view of a furnace apparatus constructed in accordance with the present invention the section being taken along a vertical plane through the centerline of the apparatus;

FIG. 2 is a side elevational view partially in section of a modified furnace apparatus constructed in accordance with the present invention, the section being taken along a vertical plane through the centerline of that portion shown in section; and

FIG. 3 is a side elevational sectional view of still another modified furnace apparatus constructed in accordance with the present invention, the section being taken

along a vertical plane through the centerline of the apparatus.

Referring in detail to the drawing, a calcining furnace constructed in accordance with the present invention is illustrated in FIG. 1 and includes a shell or housing, indicated generally at **20**. Housing **20** is fabricated with conventional refractory materials and includes a load inlet in the form of a hopper **22**.

Preferably a plurality of hearth means, indicated generally at **24**, are mounted within a respective oppositely inclined subhousing **21**, **23**, **25**, and **26**. Said subhousing may be interconnected at confronting flanges **34** in any conventional manner, such as suitable bolts or the like, not shown, and each subhousing is provided with heating means preferably in the form of counter-flow burners **28**, impingement burners **30** and under hearth excess air burners **32**.

Each subhousing further includes a passage **36** which guides the load material from each hearth means **24** to the next lowest and eventually to discharge mechanism **38**, as will be described later herein.

An upper flue **40** and a lower flue **42** are provided in each subhousing to remove exhaust gases. In this manner exhaust gases may be removed from the top of the subhousing through flue **40** or drawn down below the hearth means **24** through flue **42**. Air ducts **43** are provided in each subhousing to permit the injection of oxidizing or reducing gases into the subhousing or to inject a flow of air to cool the hearth means **24**. Still referring to FIG. 1, each hearth means **24** include a plurality of inclined hearth plates **44** rigidly fastened to the side walls of subhousings **21** through **26**.

The angle of inclination of each hearth plate **44** formed by the edge of said plates and the horizontal, hereafter referred to as the slant angle, must be kept between the angle of repose and approximately minus five degrees.

If the slant angle is at or close to the angle of repose, the load material will avalanche through the furnace and if the slant angle is too low, fine material will work back into the sub-hearth plenum which then requires more frequent clean out.

The calcinating furnace of the present invention works well when the previously defined slant angle is between five degrees less than the angle of repose and a minus five degrees of the horizontal. However, the furnace is most efficient for most materials when the slant angle is between fifteen degrees less than the angle of repose plus or minus ten degrees to the horizontal with an optimum angle of approximately plus fifteen degrees to the horizontal.

In between the vertically spaced hearth plates **44** are mounted push plates **46** which are driven back and forth by an eccentric **48** which in turn may be driven in any conventional manner, such as for example, a sprocket and chain drive, not shown.

Plates **46** are connected to push rods **50** which in turn are mounted to a bar **52** which is pivotally connected to eccentric **48**.

In the embodiment of FIG. 1, each hearth means **24** is constructed in identical manner except that the hearths are inclined in an opposite direction from the adjacent hearth means disposed above or below it.

The oppositely inclined hearth means permit a plurality of hearths to be vertically stacked and yet minimize the total width of the apparatus.

A control gate **54** is movably mounted in subhousing **21** and is disposed between inlet hopper **22** and hearth means **24**. A conventional screw thread is provided on a shaft **56**. Shaft **56** is connected to a manually operated wheel **58** and to gate **54** and is mounted through a threaded hole in a bracket **60**.

Raising or lowering control gate **54** by rotating wheel **58** controls the depth of the load material on first hearth means **24**. The depth of the load material on the remaining hearth means **24** may be controlled by the rate of reciprocation of push plates **46**.

In operation, the load material to be calcined enters the upper subhousing **21** through inlet hopper **22**, the depth of the material disposed on first hearth means **24** being controlled by the distance between the uppermost hearth plate **44** and the lower edge of gate **54**.

It is important to point out that the depth of the load material on hearth means **24** is important as the amount of material that can be calcined is, of course, directly proportional to the depth of said load. However, temperature differentials between the top and bottom of the load increase with the depth of the load which result in less uniform calcination of the material. The selection of the depth of the load therefore is a compromise between production rates and temperature uniformity and a depth of four to six inches is preferred for most materials.

As the load material falls through inlet **22**, push plates **46** are activated to slide back and forth in a reciprocating manner and push the load material down one inclined hearth plate **44** to the next until the last hearth plate **44** in the descending series is reached. Then the material falls through the passage **36** and onto the first hearth plate **44** of the next hearth means **24** in subhousing **23**. In the same manner, the load material is moved through the subhousings **25** and **26** and into discharge mechanism **38**. Discharge mechanism **38** may be in the form of any conventional collecting means and may feed the calcined material to various loading locations if desired by means of a conveyor or the like.

It should be pointed out that having separate subhousings for each hearth means **24** disposed in vertical alignment permits convenient control of both furnace temperatures and atmosphere.

The rate of flow of material over each hearth means **24** may be varied as well as the temperature in each subhousing. The separate burners for each subhousing permit much more precise temperature control than prior furnace devices. Further, preheated air, reducing or oxidizing gas may be injected in a selective manner in individual subhousing are desired.

The frequency of reciprocating push plates **46** is a compromise between production rates and wear on the moving parts. The normal cycles which seem to suit most materials are between one-half and two cycles per minute although the frequency may be as high as ten cycles per minute or as low as one cycle every twenty minutes.

The amplitude of the stroke of push plates may be from two inches up to mechanical limitations. Strokes shorter than two inches become less effective due to the capacity of most materials to absorb some thrust before they move. If the strokes become too long then push plates **46** become exposed to high operating temperatures and such long strokes should be avoided especially with light loads.

It is important to point out that push plates **46** are preferably made of stainless steel and will withstand temperatures of up to 2000 degrees F. The temperature of push plates **46** is much lower than the load and air may be blown over the bottom surface of hearth plates **44** and push plates **46** to cool them if desired. This permits less expensive metals to be used even with the calcining temperatures reaching as high as 2600 degrees F. If even higher temperatures are to be attained, then push plates **46** are preferably formed of a refractory material such as silicon carbide, which is also the preferred material for hearth plates **44**.

It is also important to point out that in the flow of material from one hearth means **24** to another, there is a natural tendency for the material to be mixed. Further, as the load material moves along an individual hearth means **24** from one hearth plate **44** to another, the larger sizes of particles which require more exposure than the

finer particles will work upward in the load and so will have greater exposure to heat. The above factors create a more uniform calcine between nonuniform particle sizes thereby permitting a wider tolerance of particle size in the load material.

Now referring to FIG. 2, another embodiment of a furnace apparatus constructed in accordance with the present invention is illustrated.

The essential difference between the embodiment shown in FIG. 1 and the one shown in FIG. 2 is that the subhousings **21**–A, **23**–A, **25**–A and **26**–A are inclined in the same direction and provision is made for changing the slant angle of the hearth means **24**–A.

Those portions of the embodiments of FIGS. 1 and 2 which are of identical construction are indicated by the same reference numerals.

Referring to FIG. 2, the uppermost subhousing **21**–A is rotatably mounted as at **56** to a supporting column **61** and the lowermost subhousing **26**–A is rotatably mounted to a supporting structure **63** as at **58**. A power screw **60** is connected to the underside of column **61** and is mounted through an appropriate threaded bore, not shown, in support **64**. Upon rotation of a manually actuated wheel **62** which is connected to screw **60**, the column **61** is mover vertically which rotates the subhousings **21**–A through **26**–A to change the slant angle of the respective hearth means **24**–A.

It therefore will be understood that in the embodiment illustrated in FIG. 2, a greater variety of load materials may be calcined with the slant angle being varied according to a predetermined optimum slant angle for a given material or given particle size.

Other than the adjustable feature the operation of the embodiment shown in FIG. 2 is essentially identical to the operation of the embodiment shown in FIG. 1.

Referring now to FIG. 3, another modification of the present invention is illustrated and differs from the embodiment shown in FIG. 1 in that a single refractory housing **100** is employed with the oppositely inclined hearth means **24** all disposed therein.

Those portions of the embodiment of FIGS. 1 and 3 which are of identical construction are indicated by the same reference numerals.

One of the major advantages of the embodiment shown in FIG. 3 is that the single housing **100** lends itself to convenient sealing from the atmosphere using conventional techniques. For purposes of simplification, the means for sealing the housing are not illustrated as in themselves they form no part of the present invention. Further, the simplified housing **100** is quite suitable for relatively low temperature applications.

If the calcining operation is to be isolated from the atmosphere wherein a partial vacuum is desired inside the housing **100**, the single housing permits more convenient adaptation to provide for sealing all openings including the feed hopper **22** and the discharge mechanism **38** than either of the embodiments shown in FIGS. 1 and 2.

The operation of the embodiment of FIG. 3 is essentially identical to the operation of the preceding embodiment described as the hearth means **24** and push plates **46** are of identical construction.

It is important to note that high thermal efficiency is comparatively easy to obtain in the furnace apparatus of the present invention as such efficiency is greatest when the ratio of fuel to air shows no excess or deficiency of oxygen. This is true even in a conflicting situation such as when the load must be exposed to excess oxidizing gases as is necessary when organic matter and sulphur must be removed from the load.

The conflict may be solved by injecting air or preheated air beneath hearth means **24** and running the burners with a deficiency of air. The end result is a balanced composition of flue gases and proper exposure of the load to oxidizing gases.

It is further important to note that the thermal efficiency may be increased by drawing hot gases from the upper preheating hearths down through the load and out of flues **42**.

While the forms of embodiments of the present invention as herein disclosed constitute preferred forms, it is to be understood that other forms might be adopted, all coming within the scope of the claims which follow.

I claim:

1. A furnace apparatus adapted for calcining or pyrolyzing materials comprising, in combination, housing means including a load inlet and a load outlet; hearth means mounted in said housing and including a plurality of fixed hearth plates vertically spaced from one another and including end portions extending in overlapping parallel relationship with the next adjacent hearth plate; first passage means connecting one end of said hearth means to said load inlet; second passage means connecting the other end of said hearth means to said load outlet; a plurality of plates slidably mounted for reciprocation in said housin, a respective one of said plates being disposed between each adjacent pair of hearth plates in parallel relationship therewith; driving means operatively connected to said slidably mounted plates; and heating means disposed in said housing for firing a load of materials disposed on said hearth means.

2. A furnace apparatus adapted for calcining or pyrolyzing materials comprising, in combination, a housing including a load inlet and a load outlet; hearth means including a plurality of hearth plates inclined at a predetermined angle and mounted in said housing in parallel vertically spaced relationship from one another, adjacent hearth plates including end portions extending in overlapping relationship with the next adjacent plates, the uppermost hearth plate being disposed below said load inlet and lowermost hearth plate being disposed above said load outlet; a slideably mounted plate means disposed adjacent to each of said hearth plates in parallel extending relationship, each of said plate means including a forward edge movable beyond the vertically overlapping edge portion of the hearth plate disposed immediately above; driving means operatively connected to a respective one of said plate means for imparting reciprocal motion to said plate means; and heating means disposed in said housing for firing a load material disposed on said hearth means.

3. The apparatus defined in claim **1** including a plurality of hearth means disposed in a vertically spaced relationship, each of said hearth means being oppositely inclined from the next adjacent hearth means; and third passage means for conducting the flow of material from one of said hearth means to another.

4. The apparatus defined in claim **1** including a plurality of hearth means, each being mounted in a separate housing, each of said housings disposed in vertically spaced parallel relationship with one another; and third passage means for conducting the flow of material from one of said housings to another.

5. The apparatus defined in claim **1** wherein said hearth plates are inclined at an angle between fifteen degrees less than the angle of repose of the material disposed on said hearth plates and plus ten degrees to the horizontal.

6. The apparatus defined in claim **2** including a plurality of hearth means each mounted in a separate housing and each housing disposed in a vertically spaced relationship with a respective one of said hearth means being oppositely inclined from the next adjacent hearth means; and passage means for conducting the flow of material from one of said housings to another.

7. The apparatus defined in claim **2** wherein a plurality of hearth means are disposed in vertically spaced relationship with one another; and passage means for conducting the flow of material from one of said hearth means to another.

8. The apparatus defined in claim 2 wherein said housing is sealed from the surrounding atmosphere.

9. The apparatus defined in claim 2 wherein said hearth plates are inclined at an angle between fifteen degrees less than the angle of repose of the material disposed on said hearth plates and plus ten degrees to the horizontal.

10. The apparatus defined in claim 1 including means for varying the inclination of said hearth means.

11. The apparatus defined in claim 2 including means for varying the inclination of said hearth means.

12. The apparatus defined in claim 1 including adjustable gate means disposed between said load inlet and said hearth means for varying the depth of the load material disposed on said hearth means.

13. The apparatus defined in claim 2 including adjustable gate means disposed between said load inlet and said hearth means for varying the depth of the material disposed on said hearth means.

14. In a furnace apparatus for calcining or pyrolyzing materials the combination of a housing; hearth means for supporting a load of material mounted in said housing and including a plurality of plate means inclined at a predetermined angle and disposed in parallel extending and overlapping relationship, certain of said plate means being mounted for reciprocal sliding movement; drive means operatively connected to said slideable plate means; and heating means for firing the load of material disposed on said hearth means.

15. A furnace apparatus adapted for calcining or pyrolyzing material comprising, in combination, housing means provided with a load inlet and a load outlet and including a plurality of subhousings connected to one another; hearth means mounted in each of said subhousings and including a plurality of fixed hearth plates vertically spaced from one another and including end portions in overlapping parallel relationship with the next adjacent hearth plate; first passage means connecting the uppermost hearth means to said load inlet; second passage means connecting the lower most hearth means to said load outlet; third passage means in each of said subhousing connecting the lower end of each hearth means with the upper end of the hearth means disposed immediately below; a plurality of plates slideably mounted for reciprocation in each of said subhousing, a respective one of said plates being disposed in parallel extending relationship with a respective one of said hearth plates; driving means operatively connected to said slideably mounted plate means; and heating means and flue means disposed in each of said subhousings.

16. A furnace apparatus for calcining or pyrolzing a load of materials comprising, in combination, a plurality of separate housings connected to one another in a vertically spaced relationship; hearth means mounted in each of said housing for supporting said load; reciprocating plate means slideably mounted in each of said housings for moving said load along a respective one of said hearth means; passage means in each of said housing for conducting the load from one hearth means to the next lower adjacent hearth means; individual heating means and flue means mounted in each of said housings; and driving means operatively connected to each of said reciprocating plates.

17. A furnace apparatus for calcining or pyrolyzing a load of materials comprising, in combination, a plurality of separate housings connected to one another in a vertically spaced relationship; hearth means mounted in each of said housings and including a plurality of fixed hearth plates vertically spaced from one another in substantially parallel relationship; a plurality of slidable plates mounted in each of said housings for reciprocating movement, a respective one of said plates being disposed in adjacent parallel extending relationship with a respective one of said hearth plates; passage means in each of said housings for conducting the load from one hearth means to the next lower adjacent hearth means; individual heating means and flue means mounted in each of said housings; and driving means operatively connected to each of said reciprocating plates.

18. The apparatus defined in claim 16 wherein said heating means includes an upper burner disposed above said hearth means, a lower burner disposed under said hearth means and a counter-flow burner disposed substantially opposite to one end of said hearth means.

19. The apparatus defined in claim 16 including duct means for injecting gases into each of said housings.

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U.S. Cl. X.R.

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