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[54] **MOVABLE HEARTH FURNACE**
3 Claims, 4 Drawing Figs.

[52] **U.S. Cl.** ..... **263/6 A**
[51] **Int. Cl.** **F27b 9/14**
[50] **Field of Search** ..... 263/6, 6 A

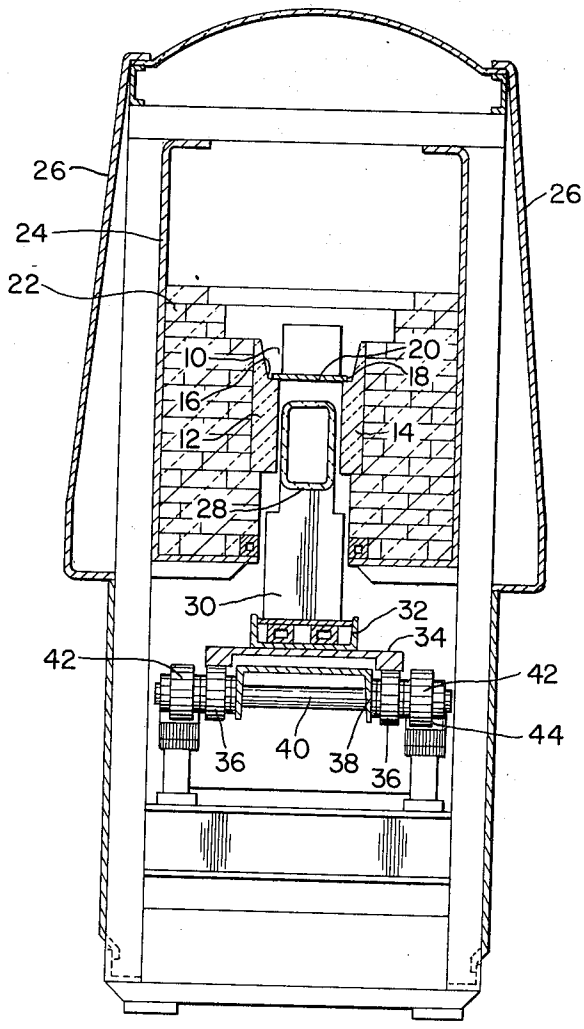
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ABSTRACT: A furnace especially adapted for high-temperature heat processing in which a work product is efficiently conveyed through the furnace without any conveyance structure within the furnace and without material affect on the cleanliness of the furnace environment. An elongated ceramic member forms part of the furnace hearth and is movable in a cyclic manner to cause stepwise movement of product carriers thereon through the furnace.



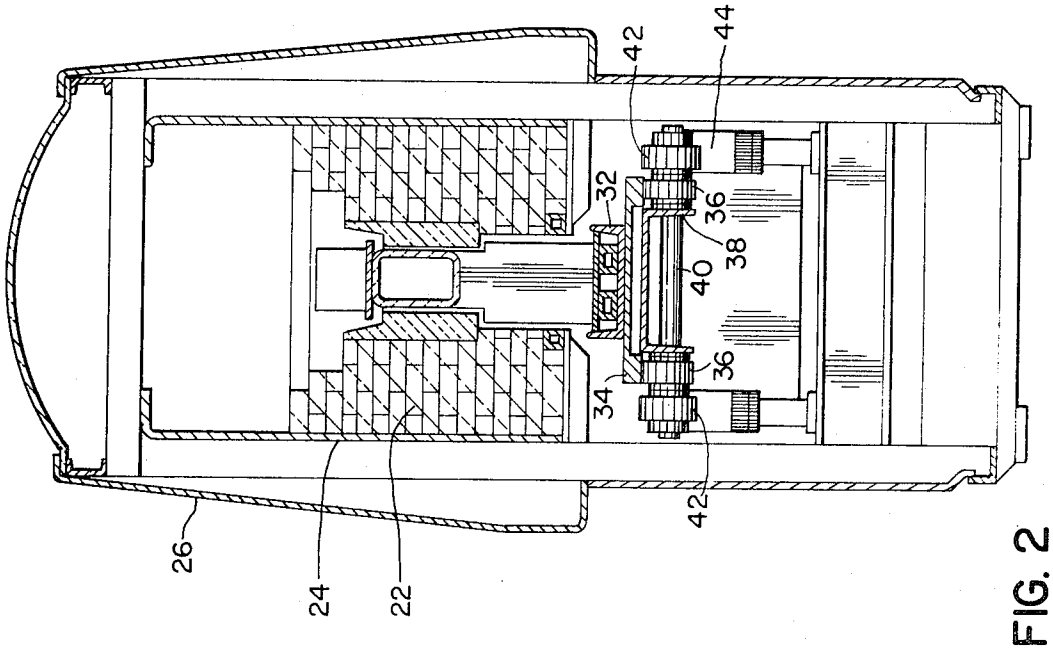


FIG. 2

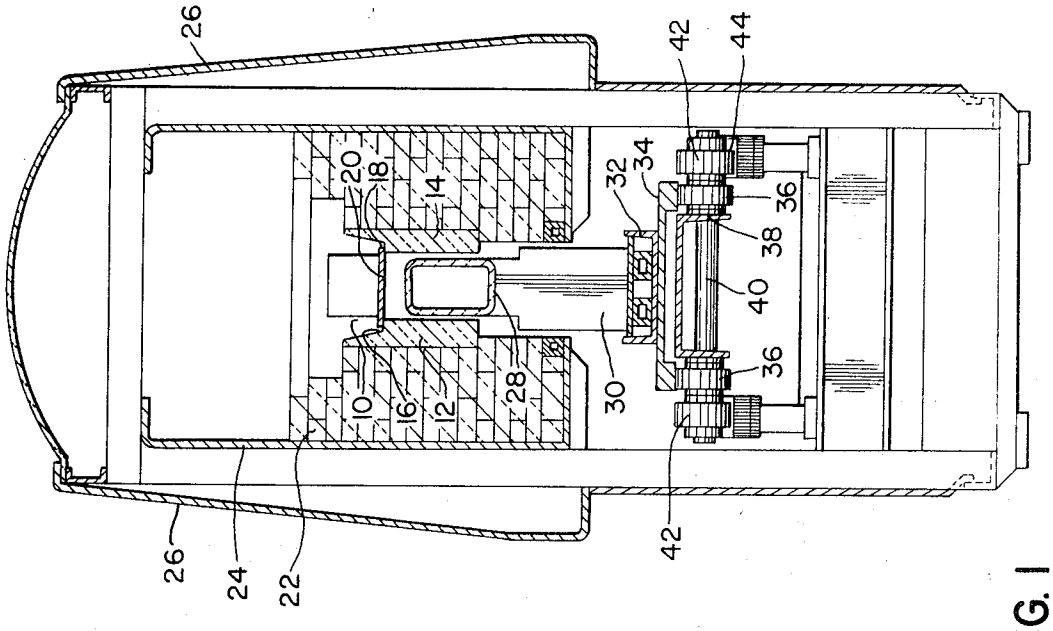


FIG. 1

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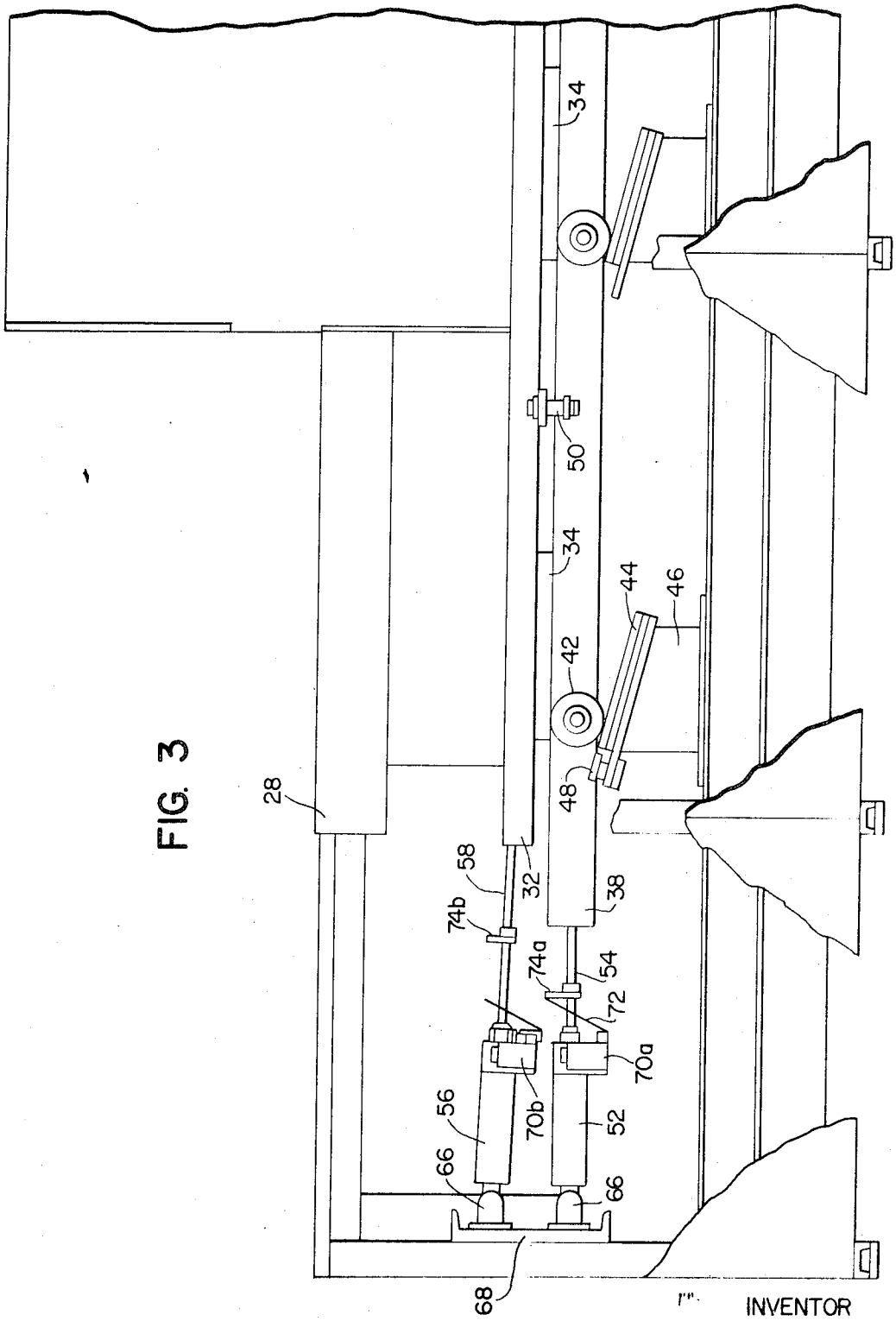
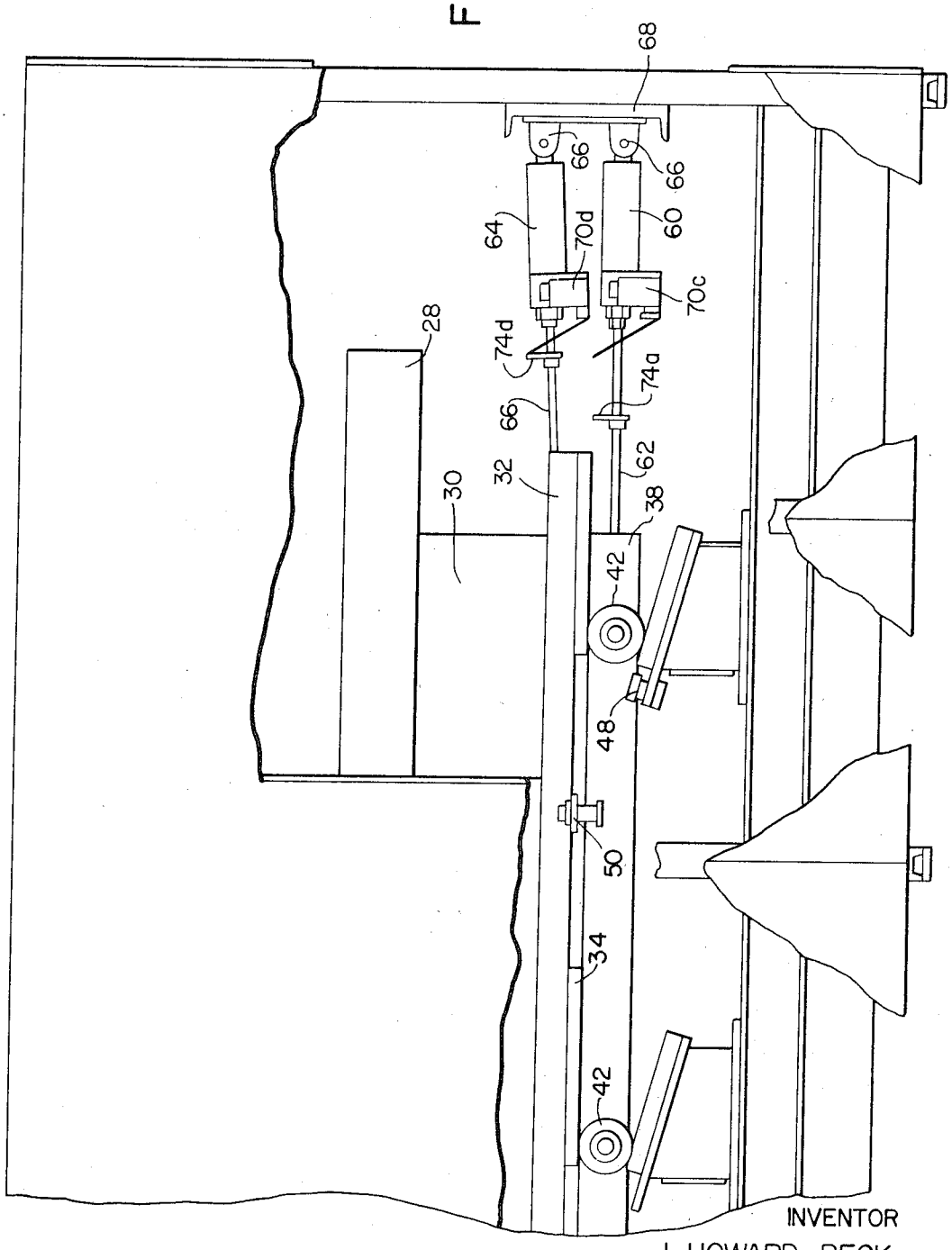


FIG. 3

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FIG. 4



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MOVABLE HEARTH FURNACE

FIELD OF THE INVENTION

This invention relates to furnaces and more particularly to precision furnaces for the heat processing of products and materials.

BACKGROUND OF THE INVENTION

In the heat processing of materials, the work product is usually conveyed through an elongated furnace which can be divided into respective zones each of which may have its own temperature and gaseous environment. The work product is often conveyed through the furnace by means of a woven metal belt which is moved along the furnace hearth. At elevated temperatures, generally above 1,110° C., such as required for the firing of ferrites and titinates and for the sintering of powder metals and nuclear fuel elements, such metal conveyor belts cannot be employed since the metal will soften or melt at these elevated temperatures. In addition, even at temperatures at which the metal retains its structural integrity, such belts are often a source of contamination.

In order to accomplish heat processing at temperatures at which metal conveyor belts are unuseable, furnaces have utilized push-rod systems in which a row of product carriers are conveyed through a furnace by means of a reciprocating push rod located at the entrance end of the furnace. The product carriers in such pusher systems must be sufficiently strong to transmit the compressional force applied by the push rod, resulting in a relatively thermally massive carrier sensitive to thermal shock and of sufficient mass to require a considerable heating and cooling period. Additionally, in such push-rod systems, the product carriers are usually in sliding contact with the muffle hearth, giving rise to abrasion which can cause contamination and consequent degradation of the furnace environment.

To overcome the limitations of push-rod conveyor systems, furnaces have been developed which include a furnace hearth movable with cyclic vertical and horizontal motion to transport product carriers supported thereon in stepwise fashion through the furnace. The movable hearth is usually supported for vertical and horizontal motion by respective pluralities of hydraulic cylinders disposed below the furnace chamber to provide lifting and lowering motion and at each end of the furnace for providing lateral movement of the hearth. These driving elements must be operated in a timed sequential manner to provide intended conveyor motion, and in practice, sequential operation of the plurality of driving elements is difficult to maintain. As a result, precise and consistent transport of a work product through a furnace is not easily achieved and the accuracy of the thermal processing can consequently be impaired. Nonsynchronous operation of the plurality of driving elements can also cause bending moments to be applied to the furnace hearth, which can result in damage to the hearth. In addition, the driving elements below the furnace can be damaged by the high furnace temperature and are not easily accessible for maintenance.

SUMMARY OF THE INVENTION

In accordance with the present invention, an improved movable hearth furnace is provided which is especially adapted for operation at extremely high temperatures and which allows transport of a work product therethrough in an efficient and consistent manner. An elongated structural member is provided within the furnace and includes a high-temperature ceramic hearth adapted to support a plurality of product carriers. The furnace hearth and its supporting structural member are movably supported by a relatively simple assembly which provides consistent and precise cyclic movement of the furnace hearth to achieve stepwise transport of a work product through the furnace.

In brief, the invention includes a first structural assembly having a plurality of inclined planes and associated rollers coupled to the furnace hearth and operative to provide elevating and lowering motion to the hearth. A second assembly is coupled to the first assembly and to the hearth and is operative to provide lateral hearth movement. Cyclic motion is imparted to the hearth by hydraulic cylinders or other motive means disposed at one or both ends of the furnace and only two or four cylinders are required to achieve intended conveyor action. The invention offers major advantages over furnaces of conventional design. Sequential movement of the hearth is easily maintained and the hearth is supported such that no bending moments or other spurious forces are applied during operation. Moreover, the driving means are at the furnace ends, in a position for easy maintenance and in a position away from the high furnace heat.

DESCRIPTION OF THE DRAWINGS

The invention will be more fully understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a sectional end elevation view of a furnace embodying the present invention, with the movable beam in its lowermost position;

FIG. 2 is a sectional end elevation view of a furnace embodying the invention, with the movable beam in its uppermost position;

FIG. 3 is a cutaway side elevation view of the entrance end of a furnace according to the invention; and

FIG. 4 is a cutaway side elevation view of the exit end of a furnace according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring to the drawing there is shown a furnace embodying the novel stepwise conveying mechanism and including a furnace chamber **10** defined by elongated side members **12** and **14** which typically are formed of a high-temperature ceramic such as alumina and which extend along the active length of the furnace. Each side member **12** and **14** has a respective shoulder portion **16** and **18** adapted to support a suitable sized substrate or product carrier **20**. This product carrier is conveyed through the furnace in stepwise fashion in a manner to be described in detail hereinbelow.

Appropriate heating elements (not shown) are arranged within the furnace chamber to provide requisite heating, and as is known, the heating elements and the furnace chamber itself can be divided into respective zones which may contain respective gas atmospheres, and heat or heat and gas barriers can be provided between adjacent zones to maintain insulation therebetween. The furnace chamber is insulated by firebrick **22** built-up around the chamber in the manner indicated and contained within a jacket **24**, while the entire furnace can be suitably encased such as by a housing **26**.

An elongated hollow member **28**, typically formed of a high temperature ceramic such as alumina, is supported between side members **12** and **14** and is movably disposed to provide transport of the product carriers **20** through the furnace. Member **28** includes an upper surface which forms part of the furnace hearth and is generally longer than the active length of the furnace chamber in order to provide access portions for loading and unloading of a work product.

Member **28** is supported by an insulating refractory **30** which in turn is supported by an elongated structural channel **32** horizontally disposed along the length of the furnace and below the furnace chamber. Channel **32** is secured to a plurality of support plates **34** which are spaced along the length thereof. Each of the plates **32**, which are also of channel shape, are supported by respective rollers **36** each of which is rotatably disposed on a shaft **40** attached to a channel **38**. Rollers **42** are attached to shaft **40** and cooperate with respective inclined planes **44** disposed along the length of the furnace on respective opposite sides of channel **38**. Channel **38** is movable by means of rollers **42** upon inclined planes **44**, causing corresponding movement of member **28**. Channel **32** is movable by means of rollers **36** to provide lateral movement of

member 28. The vertical and horizontal motion of the hearth member is employed to achieve stepwise movement of product carriers 20 through the furnace, as will be described.

In its uppermost position, member 28 is disposed with its upper surface above shoulders 16 and 18 to raise product carriers 20 supported thereon off of the shoulders. The carriers are laterally moved in this raised position to a position forwardly in the furnace. In its lowermost position, member 28 is disposed with its upper surface below shoulders 16 and 18 to replace carriers 20 onto the shoulders. In this lower position, member 28 is laterally moved to its initial position for commencement of another cycle of operation.

As seen more clearly in FIGS. 3 and 4, the inclined planes 44 are disposed in pairs along the length of the furnace in operative association with rollers 42, each inclined plane being disposed in its predetermined disposition by a suitable support 46. The pair of inclined planes adjacent to the entrance end of the furnace and the pair of planes adjacent to the exit end of the furnace include rollers 48 which are in rolling contact with the respective side surfaces of channel 38 and which are operative to maintain horizontal alignment of channel 38 and the associated conveyor structure during movement upon the inclined planes. A plurality of rollers 50 are also provided along the length of channel 38 to maintain horizontal alignment of channel 32.

Movement of hearth member 28 is accomplished in the illustrated embodiment by hydraulic cylinders coupled to channels 32 and 38 and located at the furnace ends. As seen in FIGS. 3 and 4, a hydraulic cylinder 52 is coupled to the entrance end of channel 38 by means of a rod 54, while a hydraulic cylinder 56 is coupled to the entrance end of channel 32 by means of a rod 58. At the exit end of the furnace (FIG. 4) a hydraulic cylinder 60 is coupled to channel 38 by means of a rod 62, while a cylinder 64 is coupled to channel 32 by means of rod 66. The hydraulic cylinders 52 and 60 are operative to provide movement of channel 38 and the associated conveyor structure upward and downward on inclined planes 44, while cylinders 56 and 64 provide lateral movement of channel 32 to advance the product carriers 20 along the length of the furnace. The hydraulic cylinders are attached to mounting plates 68 by means of swivel connections 66 in order to accommodate the vertical movement of the conveyor structure during operation. Each of the cylinders has associated with it a respective electrical switch 70*a*–70*d* which includes an angularly disposed arm 72 actuated by a respective contact element 74*a*–74*d* connected to the respective rods of a cylinders. The switches are connected to suitable control circuitry which is well known and which governs cyclic operation.

Cyclic operation of the furnace hearth is accomplished by means of sequential actuation of cylinders 52, 56, 60 and 64 and it should be evident that motive force is applied only at the furnace ends and essentially along a single axis. In order to elevate member 28 from its lowermost position, as shown in FIG. 1, to the uppermost position shown in FIG. 2, cylinder 52 is energized to draw channel 38 and its associated structure up the inclined planes 44 until switch 70 is actuated to cause deenergization of the power applied to cylinder 52. Cylinder 64 is next energized to cause movement of channel 32 and member 28 to a forward position in the furnace, in a direction to the right in the illustrated embodiment. Lateral movement of member 28 continues until switch 70*d* is actuated. Member 28 is lowered by energization of cylinder 60 which draws channel 38 down the inclined planes to a position determined by switch 70*c*. Channel 32 and the associated hearth member is then moved by cylinder 56 laterally toward the entrance end of the furnace, to the left in the illustrated embodiment, to a position determined by switch 70*b*. The conveyor system is now in condition for another cycle, and operation continues in like manner to cause stepwise movement of product carriers through the furnace. The channel 32 and its associated member 28 is maintained in a fixed lateral position during elevation or lowering of the hearth such that member 28 is caused to move in a rectangular path.

Alternatively, cyclic operation of the hearth can be accomplished with only two motive elements. For example, a double-acting hydraulic cylinder can be coupled to channel 32 to provide forward and reverse lateral movement, while a double-acting cylinder coupled to channel 38 provides movement up and down the inclined planes. In some instances, member 28 can be lowered by gravity, with a single-acting cylinder provided to raise the beam on the inclined planes.

It will be appreciated that the work product is conveyed through the furnace in a cyclic stepwise manner with no sliding contact between the product carriers and any furnace surfaces. The invention thus affords a clean furnace environment, which is particularly important at the extremely high temperatures at which the furnace is usually employed. The invention also provides a furnace chamber which is free of any ancillary hardware such as required for the support of a conveyor belt.

The product carriers employed by the invention can be relatively lightweight as compared to those employed in conventional push-rod furnaces since the carrier need only support the product and need not transmit any compressional pushing forces. As a result, the product carriers are of lower thermal mass and are not as sensitive to thermal shock. Moreover, these carriers permit faster heating and cooling times, which in turn permit more rapid adjustment of furnace temperature to accommodate particular heating processes. The lower thermal mass of the product carriers also results in more efficient furnace operation by reason of the shorter heating and cooling times of the carriers themselves.

During furnace operation, the work product is supplied to the furnace at the entrance end (FIG. 3) by a suitable transport mechanism (not shown) which feeds product carriers serially onto the entrance end of the movable hearth member 28. The product carriers thus supplied are moved in cyclic fashion as previously described through the active length of the furnace to the exit end thereof (FIG. 4). At the exit end of the furnace, the product carriers are removed from the movable member 28 by another transport mechanism (not shown), which may be for example an inclined array of rollers or a chute. The rate of travel of the product carriers, the length of the lateral movement during each cycle and the time of dwell of the carriers during each cycle can be determined to suit particular process requirements.

It will be appreciated that the invention provides a furnace in which the hearth is movably supported in a relatively simple and positive manner and in a manner which affords consistent, reliable and precise stepwise movement of product carriers through the furnace. The hearth movable upon the supporting inclined planes remains level during its cyclic operation, and timed sequential operation of the hearth is readily achieved by driving elements disposed at the furnace ends. A work product being processed in a furnace embodying the invention is conveyed through the furnace in an accurately timed and repeatable manner to assure uniform and precise heat treating.

Various modifications and alternative implementations will occur to those versed in the art without departing from the true spirit and scope of the invention. Accordingly, it is not intended to limit the invention by what has been particularly shown and described except as indicated in the appended claims.

What is claimed is:

1. A heat-treating furnace comprising:

an elongated furnace chamber formed of a high-temperature material and having a hearth which includes shoulder portions disposed along the length thereof and adapted to support product carriers thereon;

an elongated member at least coextensive with the active length of said furnace chamber, said member being formed of a high-temperature material and having an upper surface confronting said chamber and serving as part of the furnace hearth, said member being adapted for cyclic vertical and horizontal movement;

first means coupled to said member and operative to elevate said member to a position above the plane of said shoulder portions to raise product carriers off of said

shoulder portions, and to lower said member to a position below the plane of said shoulder portions to replace product carriers onto said shoulder portions;

second means coupled to said member and to said first means and operative to provide lateral movement of said member along the axis of said furnace in a first direction when said beam is in its uppermost position and in an opposite direction when said beam is in its lowermost position; and

means for providing cyclic operation of said beam to transport product carriers in stepwise fashion through said furnace chamber;

wherein said first means includes

a first elongated structural member disposed below and supporting said elongated hearth member;

a plurality of inclined planes disposed in pairs below said furnace chamber along the length thereof on respective opposite sides of said first structural member, each having a like inclined surface confronting said furnace chamber;

a plurality of rollers attached to said first structural member each roller being rotatably supported on a respective inclined plane to maintain said elongated hearth member in level disposition within said furnace chamber;

said second means including a second elongated structural member attached to and supporting said elongated hearth member and slidably attached to said first structural member;

said rollers cooperative with each pair of inclined planes being rotatably attached to a shaft which also rotatably supports rollers arranged for slidable movement of said second structural member;

said cyclic-operating means including

a first driving element disposed at an end of said furnace and coupled to said first structural member and operative to raise and lower said first structural member on said inclined planes; and

a second driving element disposed on an end of said furnace and coupled to said second structural member to provide lateral movement thereof in a first direction along the axis of said furnace and in an opposite direction.

2. A heat-treating furnace comprising:

an elongated furnace chamber formed of a high-temperature material and having a hearth which includes shoulder portions disposed along the length thereof and adapted to support product carriers thereon;

an elongated member at least coextensive with the active length of said furnace chamber, said member being formed of a high-temperature material and having an upper surface confronting said chamber and serving as part of the furnace hearth, said member being adapted for cyclic vertical and horizontal movement;

first means coupled to said member and operative to elevate said member to a position above the plane of said shoulder portions to raise product carriers off of said shoulder portions, and to lower said member to a position below the plane of said shoulder portions to replace product carriers onto said shoulder portions;

second means coupled to said member and to said first means and operative to provide lateral movement of said member along the axis of said furnace in a first direction when said beam is in its uppermost position and in an opposite direction when said beam is in its lowermost position; and

means for providing cyclic operation of said beam to transport product carriers in stepwise fashion through said furnace chamber;

wherein said first means includes

a first elongated structural member disposed below said elongated hearth member;

a plurality of stationary inclined planes disposed below said furnace chamber and along the length thereof and each having a like inclined surface confronting said furnace chamber;

a first plurality of rollers attached to said first structural member, each roller being rotatably supported on a respective inclined plane to maintain said elongated hearth member in level disposition within said furnace chamber;

a second plurality of rollers attached to said first structural member and rotatable independently of said first plurality of rollers;

said second means including

a second elongated structural member attached to and supporting said elongated hearth member and supported by said second plurality of rollers for slidable motion with respect to said first structural member;

said cyclic-operating means including

a first driving means disposed at an end of said furnace and coupled to said first structural member and operative to raise and lower said first structural member, said second structural member and said elongated member on said inclined planes; and

a second driving means disposed at an end of said furnace and coupled to said second structural member and operative to provide longitudinal movement thereof in a first direction and in an opposite direction along the axis of said furnace with respect to said first structural member.

3. A heat-treating furnace comprising:

an elongated furnace chamber formed of a high-temperature material and having a hearth which includes shoulder portions disposed along the length thereof and adapted to support product carriers thereon;

an elongated member at least coextensive with the active length of said furnace chamber, said member being formed of a high-temperature material and having an upper surface confronting said chamber and serving as part of the furnace hearth, said member being adapted for cyclic vertical and horizontal movement;

first means coupled to said member and operative to elevate said member to a position above the plane of said shoulder portions to raise product carriers off of said shoulder portions, and to lower said member to a position below the plane of said shoulder portions to replace product carriers onto said shoulder portions;

second means coupled to said member and to said first means and operative to provide lateral movement of said member along the axis of said furnace in a first direction when said beam is in its uppermost position and in an opposite direction when said beam is in its lowermost position; and

means for providing cyclic operation of said beam to transport product carriers in stepwise fashion through said furnace chamber;

wherein said first means includes

a first elongated structural member disposed below and supporting said elongated hearth member;

a plurality of stationary inclined planes disposed in pairs below said furnace chamber along the length thereof on respective opposite sides of said first structural member and each having a like inclined surface confronting said furnace chamber;

a first plurality of rollers attached to said first structural member, each roller being rotatably supported on a respective inclined plane to maintain said elongated hearth member in level disposition within said furnace chamber;

a second plurality of rollers attached to said first structural member each roller being independently rotatable with respect to said first plurality of rollers;

wherein said second means includes

a second elongated structural member attached to and supporting said elongated hearth member and disposed adjacent and coextensive with said first structural member; and

a plurality of support members each attached to said second structural member along the length thereof and sup-

ported on said second plurality of rollers for slidable movement thereon with respect to said first structural member.

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