

[54] METHOD AND APPARATUS FOR
CARBONIZING AND DEGASSING
WORKPIECES625,675 9/1961 Italy 432/128
878,743 10/1961 United Kingdom..... 432/128[75] Inventors: William W. Konas; Paul L. Day,
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266/5 A; 432/128; 75/224[51] Int. Cl.² C21D 9/00; C21D 1/74[58] Field of Search 266/5 R, 5 A, 5 C, 5 E,
266/5 EI; 13/26; 219/10.71, 10.73; 432/80,
81, 82, 83, 128; 165/65; 75/224, 227

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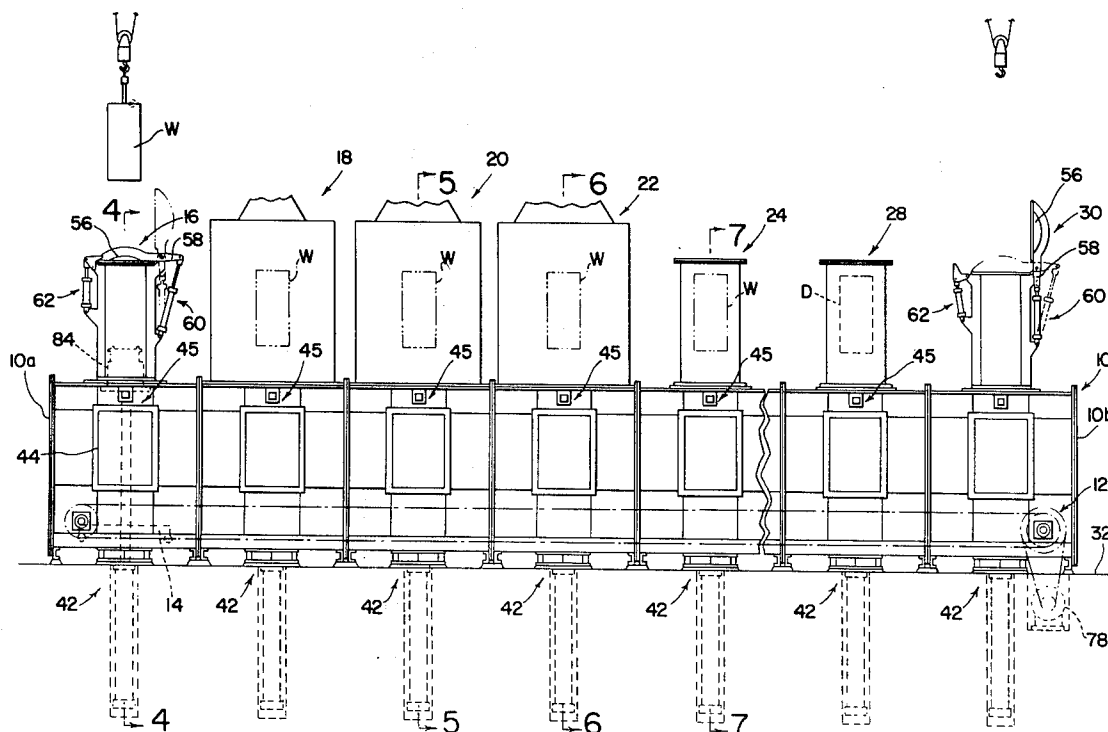
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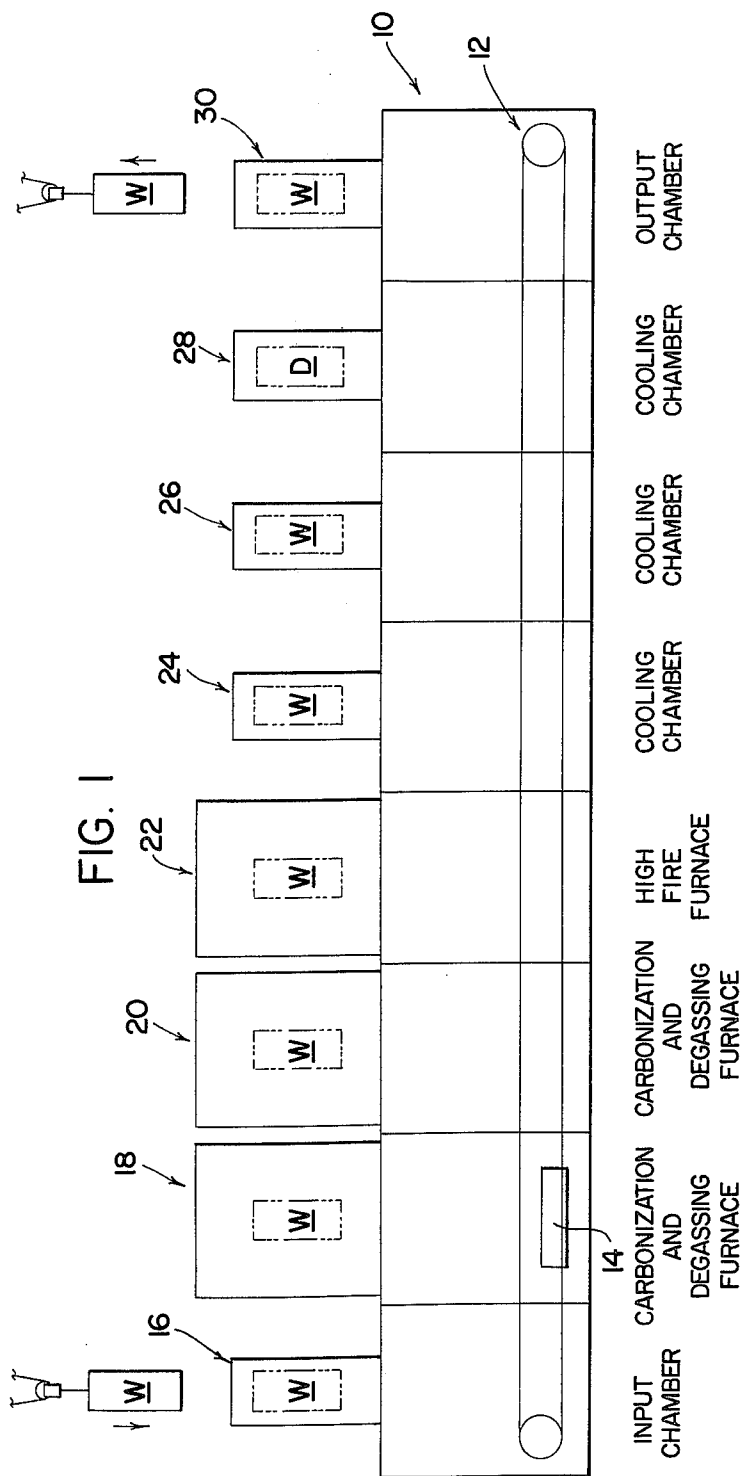
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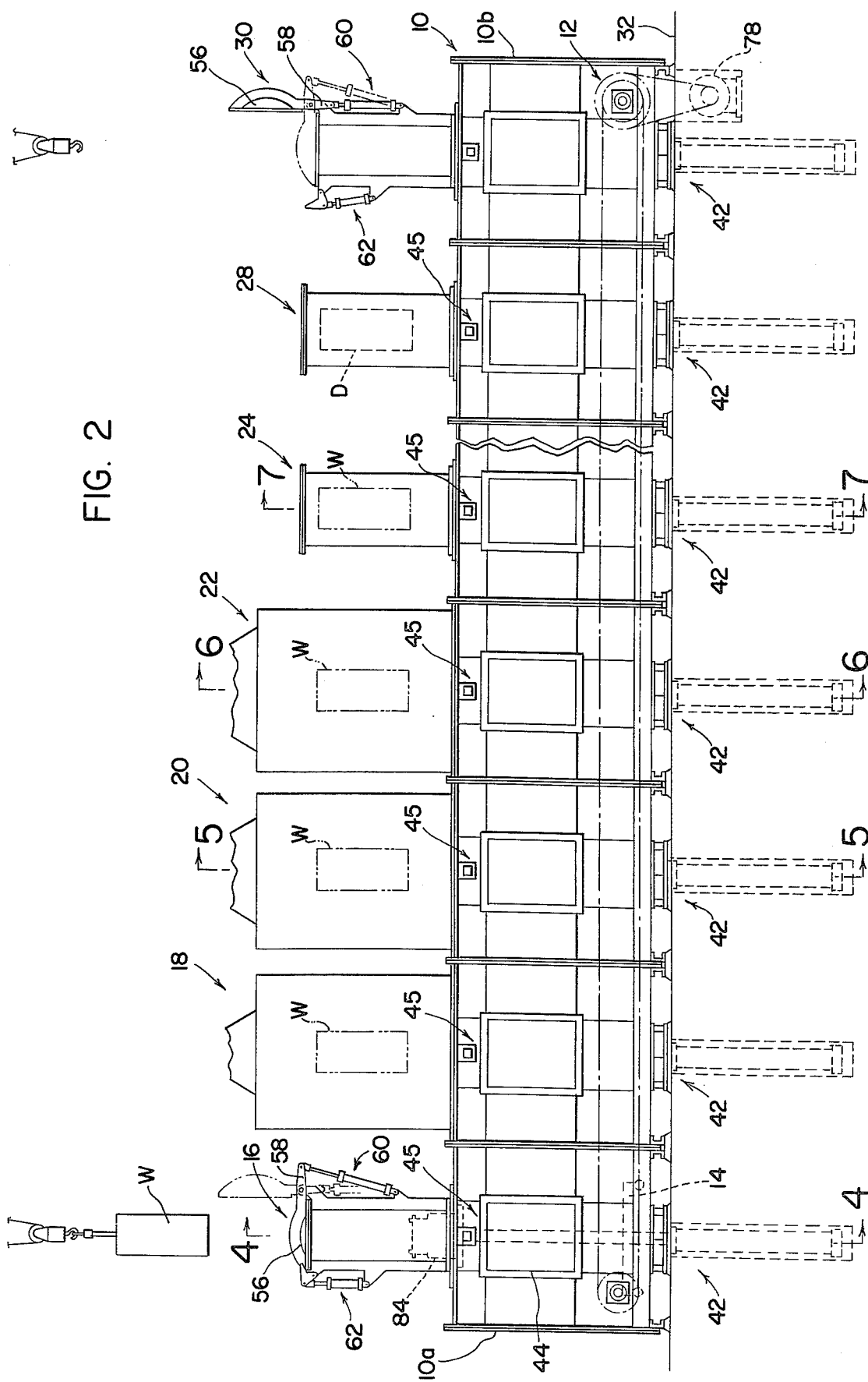
ABSTRACT

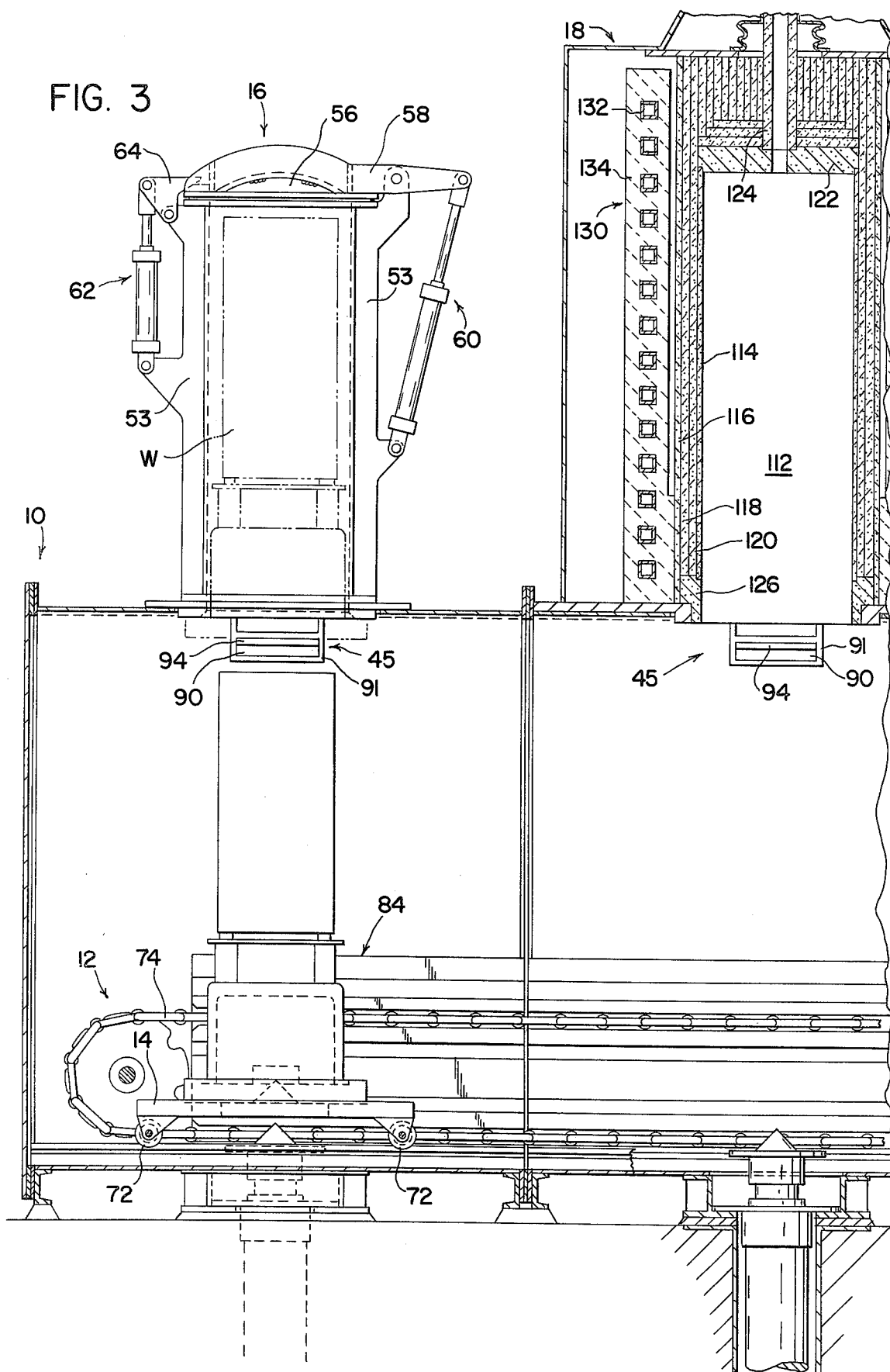
A method and apparatus is disclosed for carbonizing and degassing workpieces in a furnace including an enclosure in which a carriage is provided for transporting workpieces between the opposite ends of the enclosure. Workpiece input and output chambers are disposed on top of the enclosure, and a series of workpiece heating and cooling chambers are provided on top of the enclosure between the input and output chambers. All of the chambers open into the enclosure, and the input and output chambers have closures spaced from the transportation chamber to facilitate the insertion and removal of workpieces from the enclosure free of the ingress of ambient air into the furnace. Workpieces to be treated are inserted into the furnace by way of the inlet chamber, sequenced through the heating and cooling chambers and removed from the furnace through the output chamber. An auxiliary cooling chamber is provided for a dummy workpiece which is introduced into a heating chamber following a heating operation to facilitate cooling thereof.

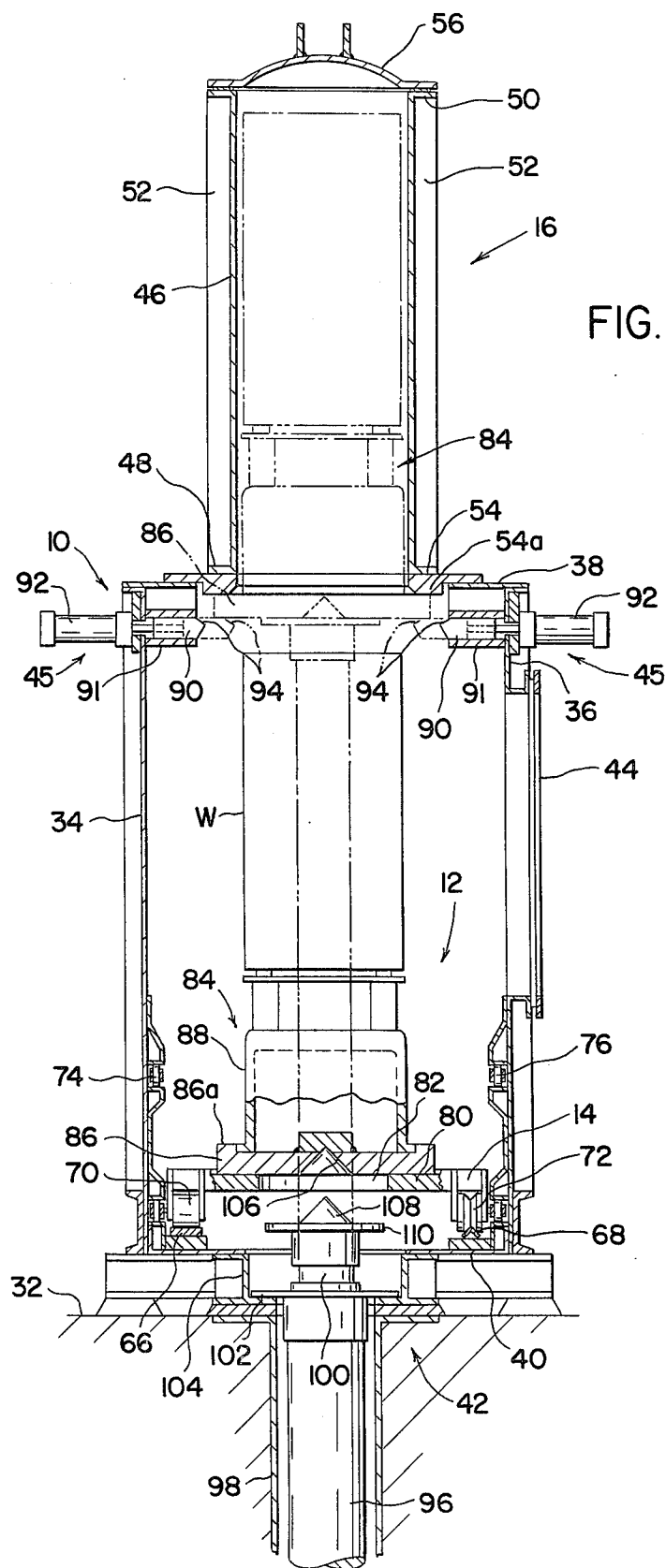
16 Claims, 7 Drawing Figures

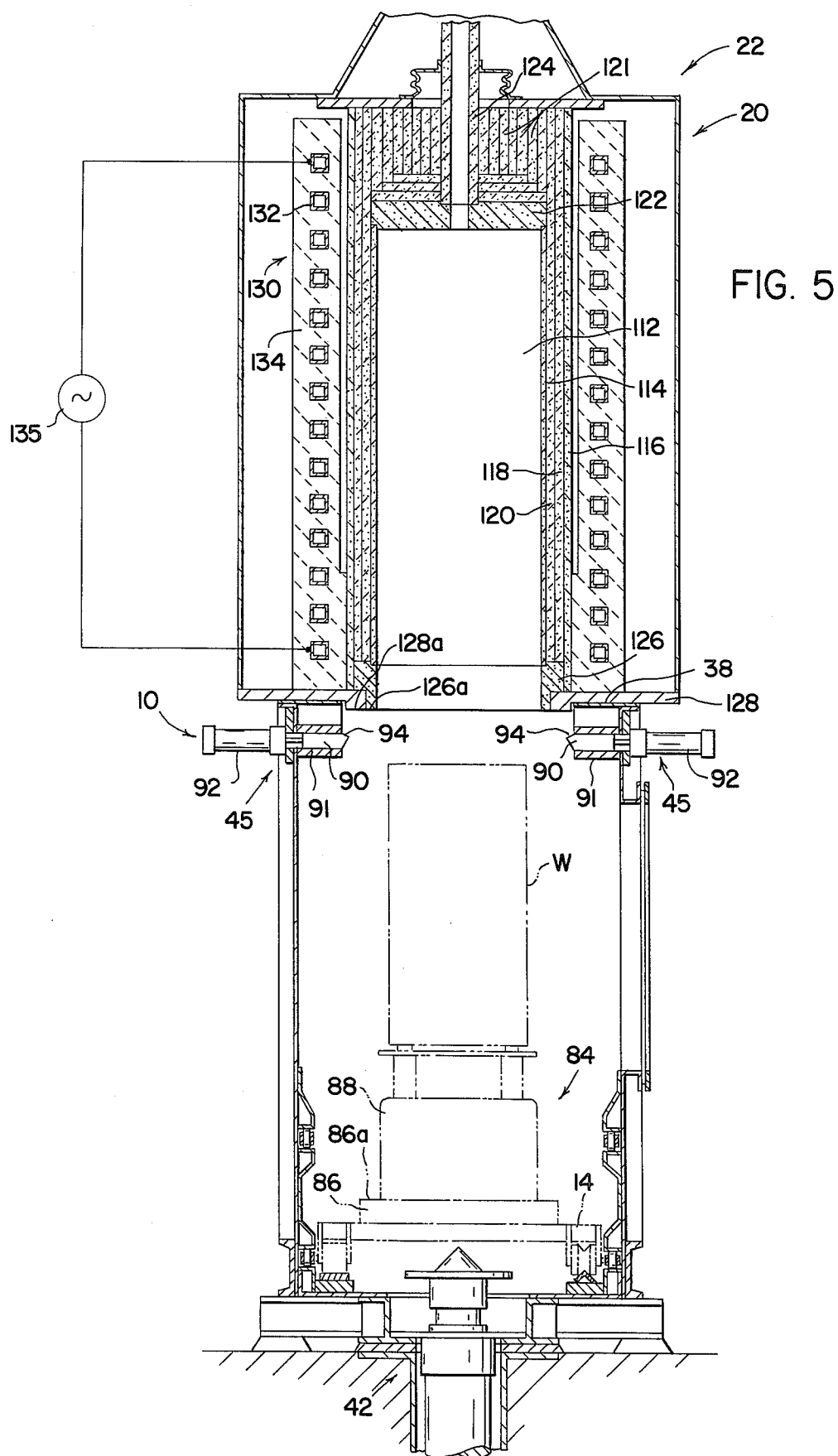


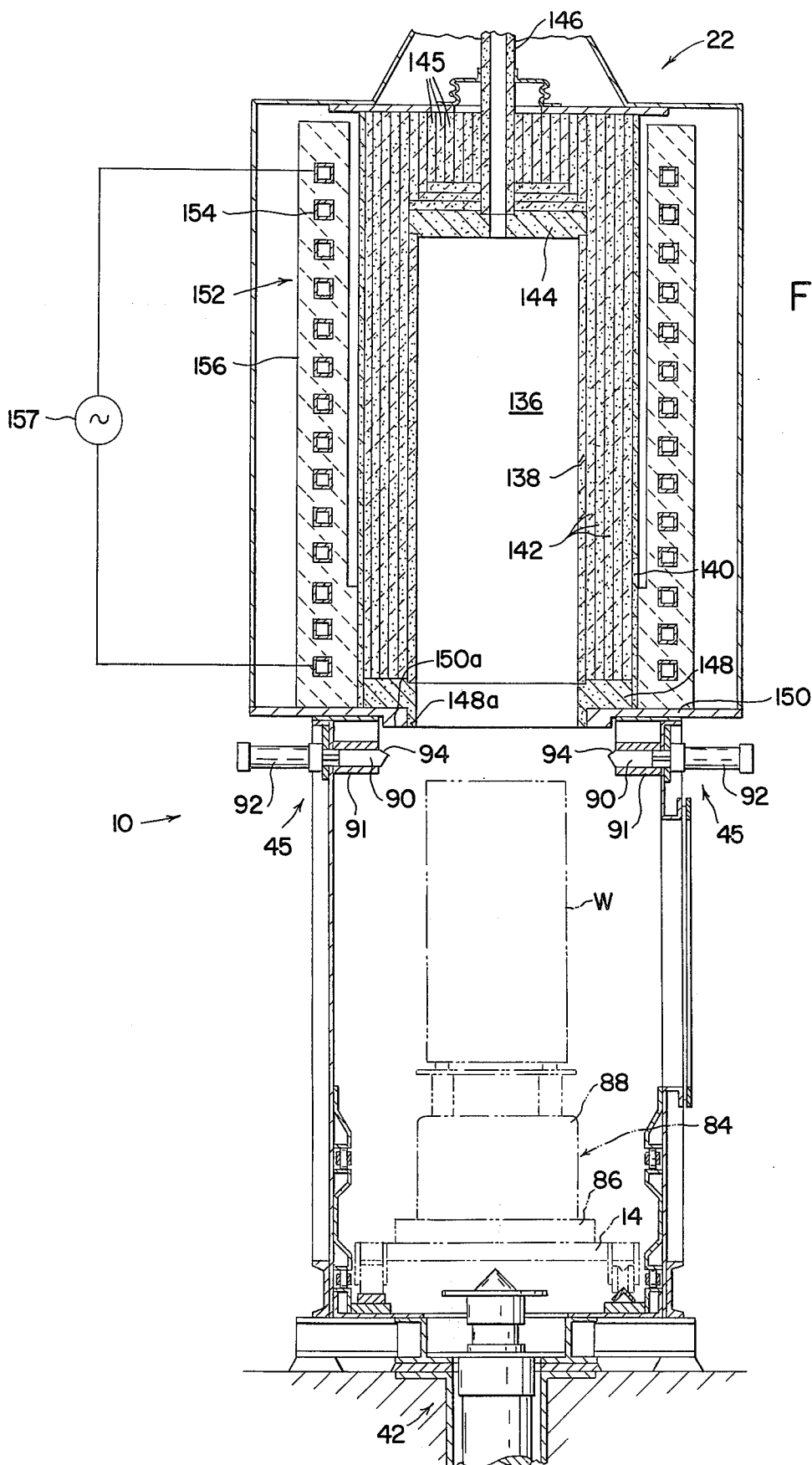


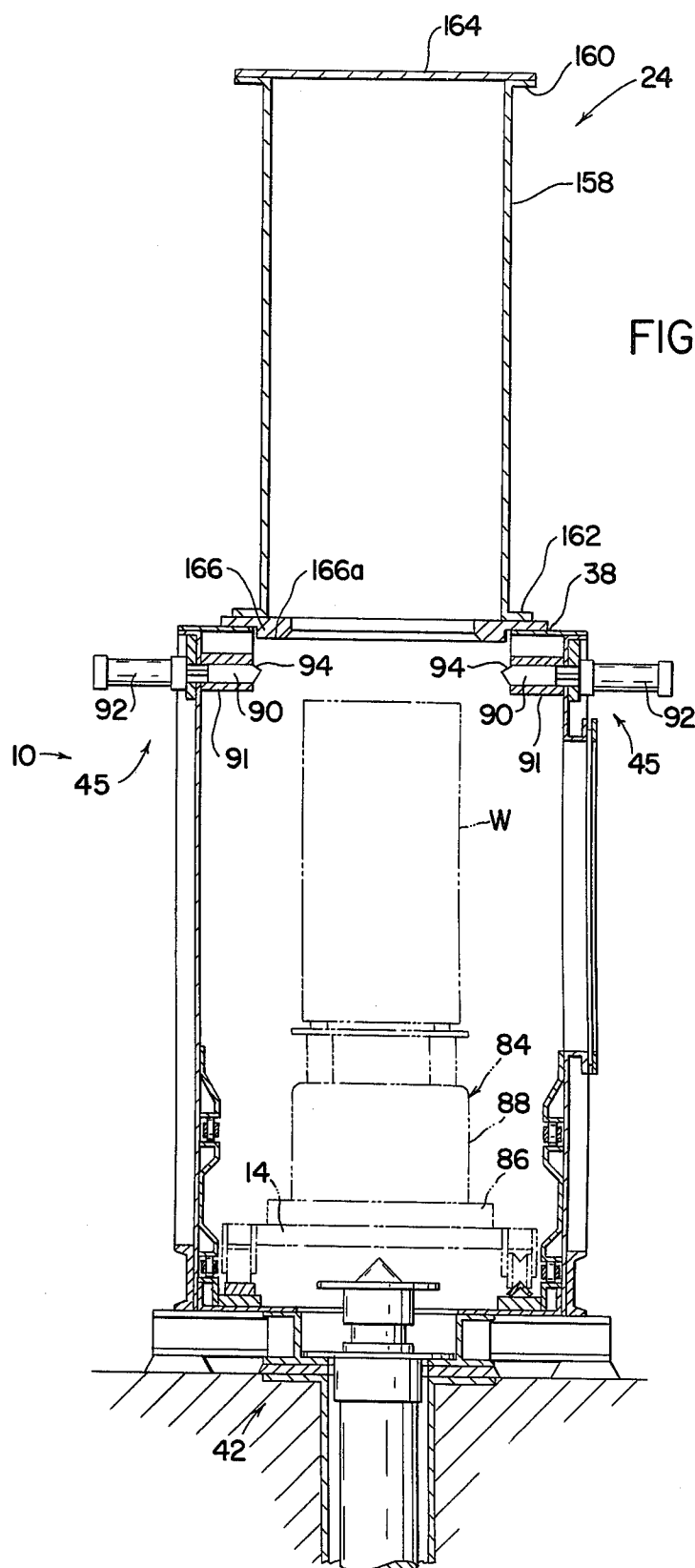












METHOD AND APPARATUS FOR CARBONIZING AND DEGASSING WORKPIECES

The present invention relates to the art of heat treating workpieces and, more particularly, to a method and apparatus including an inductively heated furnace operable to sequentially receive, heat, cool and discharge workpieces.

The present invention finds particular utility in conjunction with the heat treating of workpieces such as might be defined by a green billet of powdered metal which must be carbonized and degassed and then sintered. Accordingly, the invention will be disclosed and described with particular reference to such use. It will be appreciated, however, that the method and apparatus have utility in conjunction with other workpiece heat treating operations.

Method and apparatus have been provided heretofore for carbonizing and degassing green workpieces and then sintering the workpieces. Generally, such operations include sequentially heating the workpieces to a temperature to drive off gases therein, heating the degassed workpieces to a sintering temperature and then cooling the workpieces. Moreover, both the heating and cooling operations generally take place in a gaseous atmosphere devoid of ambient air. More particularly, a workpiece to be treated is introduced into an enclosed space in which the desired controlled atmosphere is maintained. The workpiece is then conveyed sequentially to one or more heating furnaces associated with the enclosed space and then to a cooling chamber associated with the enclosed space so that the workpiece is carbonized and degassed, sintered, and cooled prior to removal from the enclosed space and the consequent exposure of the workpiece to ambient air.

Methods and apparatus for achieving heat treatment in the foregoing manner should provide a high production rate with regard to the output of workpieces per hour for a given line of operation. Moreover, structural arrangements provided to achieve the transporting of workpieces between the working stations of the apparatus and the displacement of workpieces into the heating and cooling chambers should be efficient in operation and economical from the standpoint of production and maintenance costs. Similarly, arrangements for introducing and removing workpieces from the apparatus without materially affecting the controlled atmosphere within the enclosure should be structurally simple and economical. The workpiece heating and cooling times are generally preset, whereby the time required to achieve the feeding, conveying, displacing and discharging functions is directly related to production rate. Accordingly, it becomes desirable to minimize the time required to achieve the latter functions.

Still further, a cold workpiece introduced into a carbonizing and degassing furnace chamber must be heated at a predetermined heat rate in elevating the temperature thereof to the desired level. Following the heating of one workpiece the furnace chamber must be sufficiently cooled before the introduction of another workpiece thereinto to assure that the heat rate with respect to the second workpiece is not higher than acceptable. Accordingly, the furnace is shut down or de-energized following the removal of the first workpiece and is allowed to cool sufficiently prior to introduction of the second workpiece thereinto. It will be appreciated that production rate can be affected by the

time required for the furnace chamber to cool if such time exceeds the normal time required to achieve other conveying and displacing functions prior to insertion of the second workpiece into the chamber. Therefore, it becomes desirable to minimize the time required to cool the furnace chamber to the temperature necessary to avoid an undesirably high initial heat rate.

In accordance with the present invention, a method and apparatus is provided for achieving the foregoing desirable characteristics and functions with respect to the continuous sequential heating and cooling of workpieces in a heat treating system. In accordance with one aspect of the invention, heat treating apparatus is provided which is structurally compact and in which the components of the apparatus are structurally interrelated to enable economical use of floor space in a plant or the like. In this respect, input and discharge of workpieces from the apparatus is in a vertical direction, and the heating and cooling chambers for the workpieces are disposed above the path of movement thereof between the input and output ends of the apparatus. The workpieces are displaced upwardly into the heating and cooling chambers from a conveying mechanism which supports the workpieces for movement between the input and discharge ends of the apparatus. The vertical relationship between the components of the apparatus minimizes the floor space requirement for the apparatus laterally with respect to the path of movement of workpieces therethrough.

In accordance with another aspect of the present invention, the vertical input and discharge of workpieces and the vertical displacement thereof into the heating and cooling chambers is achieved by corresponding elevating mechanisms disposed beneath the conveying apparatus at spaced locations corresponding to the input, heating, cooling and output stations. The elevating mechanisms reciprocate along corresponding linear paths to displace a workpiece relative to the conveying device and workpiece chambers at the input, heating, cooling and discharge stations. The elevating mechanisms advantageously provide for the displacement operation to be efficient and provide for desired alignment between a workpiece and a chamber into which it is displaced. Moreover, the displacement mechanisms minimize transfer time of a workpiece to and from a chamber.

In accordance with yet another aspect of the present invention, the conveying device is adapted to support a pedestal member which is displaceable from the conveying device together with a workpiece supported by the pedestal. The pedestal is elevated from the conveying device to move the workpiece into a chamber, and the pedestal is adapted to be held in place with respect to the chamber and to seal the entrance through which the workpiece is inserted. Moreover, the input and discharge stations of the apparatus are provided with air lock chambers which permit a workpiece to be introduced and removed from the apparatus free of any undesirable effect on a controlled atmosphere within the apparatus. The pedestal member is operable at the input and output stations to seal the corresponding chambers to assure against the ingress of ambient air into the apparatus during the input and discharge operations.

In accordance with yet another aspect of the present invention, the apparatus is provided with an auxiliary cooling chamber adapted to receive a dummy workpiece which is cooled while in the auxiliary chamber.

Preferably, the workpiece heating chamber or chambers are inductively heated and, following removal of a heated workpiece from a heating chamber, the inductor for the chamber is de-energized so that the chamber can cool prior to the transfer of a green workpiece thereinto. During this time, the dummy workpiece is transferred from the auxiliary cooling chamber into the de-energized heating chamber to assure sufficient cooling of the chamber. Accordingly, the auxiliary cooling assures against a higher initial heat rate than desired for the green workpiece when the latter is introduced into the heating chamber. Additionally, the auxiliary cooling minimizes the cooling time and avoids the possibility of a time delay resulting from natural cooling and which would result in a decrease in production rate.

An outstanding object of the present invention is the provision of apparatus for sequentially heating and cooling workpieces transferred therethrough and by which a high production rate is achieved and transfer of workpieces through the apparatus and displacement of the workpieces relative to heating and cooling chambers of the apparatus is highly efficient.

Another object is the provision of apparatus of the foregoing character which is economical to produce and operate and occupies a minimum amount of floor space in a direction laterally with respect to movement of workpieces therethrough.

Still another object is the provision of apparatus of the foregoing character in which transfer of workpieces is along a horizontal path, and workpiece input, displacement and discharge operations are along vertical paths above the horizontal path, thus to minimize dimensions of the apparatus laterally of the horizontal path.

A further object is the provision of apparatus of the foregoing character in which the workpiece conveying device and the workpiece input, displacing and discharging devices are of simple construction and are structurally cooperable to achieve the workpiece input, displacing and discharging operations efficiently and in a minimum amount of time.

Still another object is the provision of apparatus of the foregoing character in which the vertically reciprocable displacing devices are operable to assure displacement of a workpiece and a support pedestal therefor into a chamber at the heating, cooling and discharge stations in properly aligned relationship with respect to the chamber.

Still a further object is the provision of apparatus of the foregoing character in which the support pedestal for a workpiece is cooperable with the chambers at the input, heating, cooling and discharge stations to seal the interiors of the chambers.

Yet another object is the provision of a method of heat treating workpieces by sequentially transferring a workpiece into a heating chamber which is inductively heated, transferring the heated workpiece to a cooling chamber, de-energizing the induction heating device, and artificially cooling the heating chamber prior to the introduction of another workpiece thereinto.

Another object is the provision of a method of the foregoing character in which artificial cooling is achieved by transferring a dummy workpiece from a corresponding cooling chamber into the heating chamber following removal of the heated workpiece therefrom.

The foregoing objects, and others, will in part be obvious and in part pointed out more fully hereinafter

in conjunction with the written description of a preferred embodiment of the present invention illustrated in the accompanying drawings in which:

FIG. 1 is a schematic representation of the components of carbonizing and degassing apparatus in accordance with the present invention;

FIG. 2 is a side elevational view showing a structural embodiment of the apparatus schematically illustrated in FIG. 1;

FIG. 3 is a detailed side elevation view, partially in section, of the workpiece input end of the apparatus illustrated in FIG. 2;

FIG. 4 is a sectional elevation view of the apparatus taken along line 4—4 in FIG. 2;

FIG. 5 is a sectional elevation view of the apparatus taken along line 5—5 in FIG. 2;

FIG. 6 is a sectional elevation view of the apparatus taken along line 6—6 in FIG. 2; and,

FIG. 7 is a sectional elevation view of the apparatus taken along line 7—7 in FIG. 2.

Referring now in greater detail to the drawings wherein the showings are for the purpose of illustrating a preferred embodiment of the present invention only and not for the purpose of limiting the invention, apparatus for carbonizing and degassing workpieces W is schematically illustrated in FIG. 1 of the drawing. The apparatus includes a gas tight enclosure 10 having closed opposite ends, and a workpiece conveyor mechanism 12 including a carriage 14 which is operable to transport workpieces between the opposite ends of enclosure 10, as set forth more fully hereinafter. The apparatus further includes an input or loading station at one end and including an input chamber 16, a first heating station including a carbonizing and degassing furnace 18, a second heating station including a carbonizing and degassing furnace 20, a third heating station including a high fire furnace 22, a first cooling station including a cooling chamber 24, a second cooling station including a cooling chamber 26, an auxiliary cooling station including a cooling chamber 28, and an output station including an output chamber 30.

A green workpiece to be treated is introduced into input chamber 16 at the input station. The workpiece, may for example, be a powdered metal workpiece, or a workpiece including powdered metal in its composition and which requires heating to remove gases therein and sintering to achieve a cohesive mass. The treating operation takes place in a controlled atmosphere of gas, such as nitrogen, and, accordingly, the green workpiece introduced into input chamber 16 is thereafter protected from exposure to ambient air until it is removed from output chamber 30. Enclosure 10 is adapted to contain the desired gas atmosphere and, as will become apparent hereinafter, input chamber 16 and output chamber 30 are air-lock chambers which are operable to provide for evacuation of air therefrom following insertion of a workpiece into chamber 16 and following removal of a workpiece from chamber 30. With regard in general to the functions of the components of apparatus schematically illustrated in FIG. 1 with regard to a simple workpiece, the green workpiece is introduced into input chamber 16, the opposite ends of the chamber are sealed, air is evacuated therefrom and nitrogen is introduced thereinto to neutralize the chamber with respect to enclosure 10. The workpiece is then introduced into enclosure 10 and is, sequentially, heated in one of the carbonizing and degassing furnaces, heated in the high fire furnace, cooled in one

of the cooling chambers other than the auxiliary chamber, and transferred to output chamber 30 for removal from the apparatus. The workpiece is heated in the carbonizing and degassing furnace for a predetermined period of time to elevate the temperature thereof to a desired level for achieving carbonizing and degassing. The workpiece is then heated in the high fire furnace at a desired temperature for a given period of time to achieve sintering. Sintering is achieved in about one-half the time required for degassing. The workpiece is then cooled in the cooling chamber for a period of time corresponding substantially to the period of time of heating in the carbonizing and degassing furnace.

It will be appreciated, therefore, that the provision of two carbonizing and degassing furnaces and the provision of two cooling chambers, other than the auxiliary cooling chamber, provides for the apparatus to be continuously operated at a higher production rate than would be possible if only one carbonizing and degassing furnace and one cooling chamber were provided. In this respect, the production rate is maximized by transferring a degassed workpiece to the high fire furnace each time a workpiece is removed therefrom, and this can be achieved in accordance with the embodiment disclosed by providing for a workpiece to be discharged alternately from the two carbonizing and degassing furnaces into the high fire furnace and by providing for the workpieces in the cooling chambers to be alternately transferred to the discharge station for removal from the apparatus. A more detailed description of a sequence of operation of the apparatus, including the use of the auxiliary cooling chamber, is set forth hereinafter.

The structure of the apparatus and the operation of components thereof will be best understood from the following description of the illustrations in FIGS. 2-7 of the drawing. Enclosure 10 is supported on a floor or the like 32 and, in the embodiment disclosed, is comprised of a plurality of flanged box-like sections of similar structure suitably interconnected in end-to-end relationship. The endmost sections are provided with end covers 10a and 10b, whereby the several sections define a tubular enclosure which is closed at its opposite ends. The several sections of the enclosure are of similar structure in cross section and, as illustrated in FIG. 4 for example, each section includes a pair of opposed parallel sidewalls 34 and 36, a top wall 38, and a bottom wall defined by a plate 40 together with components of a corresponding plunger mechanism 42 which is described more fully hereinafter. Side wall 36 of each section is provided with a suitable viewing window 44 which facilitates visual observance of the operations taking place within enclosure 10, and sidewalls 34 and 36 support holding devices 45 at each station for the purpose set forth hereinafter.

It will be seen in the embodiment disclosed that each of the sections of enclosure 10 is associated with one of the input, heating, cooling and discharge components of the apparatus. While this structure facilitates the manufacturing and assembly operation, it will be appreciated that other enclosure structures could readily be employed. Each of the chambers and heating furnaces along the length of enclosure 10 is supported on the top wall of the corresponding enclosure section and opens into the interior of enclosure 10. Input and output chambers 16 and 30 are of like structure, as are carbonizing furnaces 18 and 20, and cooling chambers 24, 26 and 28. Accordingly, the description hereinafter

of the chamber and furnace structures is with regard to one of each of the different structures.

Input chamber 16 is best illustrated in FIGS. 2-4 of the drawing. In this respect, chamber 16 is comprised of a cylindrical wall 46 having a peripheral flange 48 at its lower end, a peripheral flange 50 at its upper end, and pairs of diametrically opposed longitudinally extending reinforcing ribs 52 and 53 extending between flanges 48 and 50. Chamber 16 further includes an annular sealing member 54 interposed between flange 48 and top wall 38 of the corresponding enclosure section. Top wall 38 is apertured to receive sealing member 54 so that chamber 16 opens into enclosure 10. Sealing member 54 includes an annular sealing surface 54a facing the interior of enclosure 10 for the purpose set forth more fully hereinafter.

The outer end of chamber 16 is adapted to be selectively opened and closed by means of a cover 56 having an operating arm 58 pivotally interconnected with one of the opposed pairs of ribs 53. Cover 56 is adapted to be displaced between the open and closed positions thereof by means of a suitable pneumatic or hydraulic piston and cylinder assembly 60, and is adapted to be clamped in the closed position by means of a suitable pneumatic or hydraulic piston and cylinder assembly 62 which is operable to displace a pivotal clamping member 64 into clamping relationship with cover 56. It will be appreciated, of course, that suitable fluid connections are provided for actuating piston and cylinder assemblies 60 and 62, and that suitable controls are provided for controlling fluid flow to and from these units.

Conveyor mechanism 12 is operable to transfer carriage 14 between the opposite ends of enclosure 10 to facilitate the transportation of workpieces to the various stations between the input and discharge chambers. Any suitable conveyor mechanism can be employed for this purpose and, in the embodiment illustrated, as best seen in FIGS. 3 and 4, the conveyor mechanism includes a pair of guide tracks 66 and 68 extending longitudinally of enclosure 10 adjacent sidewalls 34 and 36, respectively, of the enclosure sections. Carriage 14 is provided with corresponding pairs of wheels 70 and 72 on opposite sides thereof which support the carriage on tracks 66 and 68 for guided movement longitudinally of enclosure 10. Sidewalls 34 and 36 of the enclosure sections support corresponding endless chain devices 74 and 76 which are adapted to be driven in opposite directions by a suitable motor 78 to impart movement to carriage 14 along the tracks. Chain devices 74 and 76 are, of course, suitably interconnected with carriage 14 to displace the carriage along the tracks and, in the embodiment illustrated, the axles of wheels 70 and 72 extend laterally outwardly of carriage 14 to define the pivot pins between an adjacent pair of links of chains 74 and 76 to provide the chain and carriage interconnection.

Carriage 14 further includes a platform or bottom wall 80 provided with an opening 82 extending vertically therethrough for the purpose set forth hereinafter. Carriage plate 80 is adapted to receive and support a pedestal assembly 84 which includes an annular sealing plate 86 at the lower end thereof and a workpiece supporting portion 88 extending upwardly from plate 86. Pedestal 84 is adapted to be transported along enclosure 10 by carriage 14, with or without a workpiece thereon, and is adapted to be elevated from carriage 14 as explained hereinafter to facilitate the dis-

placement of a workpiece into and/or from a chamber of the apparatus disposed above the position in which the carriage is stopped. With regard to the illustration in FIGS. 3 and 4 of input chamber 16, for example, pedestal 84 is adapted to be elevated for workpiece supporting portion 88 to enter chamber 16 and receive a workpiece, and for the pedestal to be lowered from chamber 16 for a workpiece thereon to be supported on carriage 14 for movement therewith. When pedestal 84 is elevated from carriage 14, the upper sealing face 86a of sealing portion 86 thereof engages the lower sealing face 54a of sealing member 54 to provide a contact seal therebetween, whereby chamber 16 is sealed from enclosure 10.

During the loading of a workpiece onto the pedestal disposed in chamber 16, carriage 14 is transferred to facilitate the achievement of other operations, as set forth more fully hereinafter. Accordingly, holding arrangements 45 are provided for holding pedestal 84 in sealed relationship with the lower end of chamber 16. More particularly, holding arrangements 45 are diametrically opposed and each includes a reciprocable cam plate 90 and a corresponding support member 91 suitably mounted on the corresponding one of the side walls 34 and 36 of the enclosure. Suitable hydraulic or pneumatic motors 92 are provided for reciprocating cam plates 90 horizontally relative to sealing plate portion 86 of pedestal 84. When sealing plate portion 86 of pedestal 84 is disposed in sealing engagement with sealing member 54 at the lower end of chamber 16, cam plates 90 are displaced inwardly to underlie sealing plate 86 and thus hold the pedestal in its upper position. Preferably, cam plates 90 have cam surfaces 94 operable to engage and press sealing plate portion 86 against sealing plate 54 to achieve tight sealing engagement therebetween.

When pedestal 84 is held in its uppermost position to seal chamber 16 from enclosure 10, cover 56 of chamber 16 can be opened so that a workpiece to be treated can be inserted into the chamber. This, of course, exposes chamber 16 to ambient air. Following insertion of the workpiece into chamber 16 and onto the workpiece supporting portion 88 of the pedestal, cover 56 is closed and sealed, whereby the opposite ends of chamber 16 are sealed. Chamber 16 is then evacuated of air, by means not illustrated, and nitrogen is introduced into the chamber to neutralize the chamber with respect to enclosure 10.

Any suitable mechanism integral with or separate from carriage 14 can be provided for elevating and lowering pedestal 84. Preferably, a plunger mechanism 42 separate from the carriage is provided at each of the stations along the length of enclosure 10 to facilitate the elevating and lowering operation. As best seen in FIG. 4, plunger mechanism 42 includes a cylinder 96 supported beneath conveyor mechanism 12 in a suitable housing 98 extending below floor 32. The plunger mechanism further includes a piston component 100 which is vertically reciprocable relative to cylinder 96 in a well known manner. In this respect, piston 100 and cylinder 96 may be defined by a suitable hydraulic or pneumatic piston and cylinder arrangement in which the feed and discharge of operating fluid into the cylinder provides for the vertical reciprocation of piston 100 relative thereto. The upper end of cylinder 96 is provided with a sealing flange 102 which cooperates with a cylinder support frame 104 and bottom wall plate 40

of the corresponding enclosure section to seal the bottom of the enclosure section.

The axis of piston 100 is aligned with the axis of the chamber thereabove. To assure proper alignment of pedestal 84 with the chamber, the underside of sealing plate 86 and the upper end of piston 100 are provided with a cooperatively contoured interengaging structure. In the embodiment disclosed, the latter structure includes a conical recess 106 in the underside of sealing plate 86 and a corresponding conical projection 108 on the upper end of piston 100. Thus, should pedestal 84 be positioned on carriage plate 80 in misaligned relationship with respect to piston 100, or should carriage 14 be stopped in misalignment with respect to piston 100, recess 106 and projection 108 interengage to shift pedestal 84 relative to the piston to assure that elevation of pedestal 84 is in proper alignment with chamber 16. Peripheral flange 110 surrounding projection 108 of piston 100 engages the flat underside of sealing plate 86 to support the pedestal against tilting movement during the elevating and descending movements thereof.

The structures of carbonizing and degassing furnaces 18 and 20 is illustrated in FIG. 5 with regard to carbonizing furnace 20. In this respect, carbonizing furnace 20 is supported on top wall 38 of the corresponding section of enclosure 10. The carbonizing furnace includes a chamber 112 adapted to receive a workpiece to be heated. In the embodiment disclosed, chamber 112 is cylindrical and is defined by coaxial, radially spaced apart inner and outer shells 114 and 116, respectively, of a suitable refractory material, such as silicon carbide. A pair of shells or sleeves 118 and 120 of non-magnetic material, such as carbon, are interposed between shells 114 and 116, and the top of chamber 112 is defined by an apertured end plate 122 of refractory material, such as silicon carbide. An exhaust tube 124 of such refractory material communicates with the interior of chamber 112 for exhausting gases within the chamber to atmosphere. A number of sleeves 121 of the material of sleeves 118 and 120 surround exhaust tube 124. The lower end of chamber 112 is defined by an annular ring of refractory material 126, such as silicon carbide, and an annular metal support plate 128 which rests on top wall 38 of the enclosure section. Ring 126 and annular support plate 128 have lower faces 126a and 128a, respectively, which face inwardly of the enclosure section and define a sealing surface for cooperation with sealing plate portion 86 of pedestal 84 in the manner described hereinabove with regard to inlet chamber 16.

An induction heating coil assembly 130 surrounds sleeve 116 and is comprised of a plurality of convolutions 132 of a tubular conductor of conductive material such as copper embedded in a sleeve of refractory insulating material 134. In a well known manner, the coiled conductor has opposite ends adapted to be connected across a source of alternating current 135 for energizing the conductor, and the tubular configuration of the conductor facilitates the circulation of cooling fluid therethrough to cool the conductor when the latter is energized. With an arrangement of the character described, energization of the induction heating coil induces current flow in nonmagnetic shells 118 and 120, whereby the latter are inductively heated. Accordingly, a workpiece disposed in chamber 112 is heated primarily by convection and radiation resulting from the heating of shells 118 and 120.

To achieve heating of a workpiece for carbonizing and degassing the workpiece in furnace 20, the workpiece is transported by carriage 14 to a position underlying furnace 20 and the corresponding plunger mechanism 42 is actuated to elevate the workpiece and pedestal 84 for the workpiece to enter chamber 112. The induction heating coil assembly is then energized and the workpiece is heated to elevate the latter to a desired temperature and the workpiece is soaked in the furnace to achieve the removal of volatiles therefrom, which are exhausted from the furnace through exhaust tube 124 in the form of exhaust gases. During the heating operation, sealing surface 86a of plate portion 86 of the pedestal sealingly engages the lower surfaces 126a and 128a at the entrance end of chamber 112 in the manner described hereinabove with regard to input chamber 16, and cam plates 90 of the corresponding holding arrangements 45 are actuated to support the pedestal and workpiece and to tightly seal the lower end of chamber 112 during the carbonizing operation.

High fire furnace 22 is illustrated in FIG. 6 of the drawing and, in many respects, is of a construction similar to that of the carbonizing and degassing furnaces 18 and 20. In this respect, the high fire furnace includes a chamber 136 defined by inner and outer sleeves 138 and 140, respectively, of a suitable insulating material, such as silicon carbide. A plurality of juxtaposed sleeves 142 of nonmagnetic material, such as carbon, are disposed between sleeves 138 and 140. The upper end of chamber 136 is defined by an apertured end plate 144 of refractory material, such as silicon carbide, and an exhaust tube 146 of the same material cooperates with end plate 144 to vent the interior of chamber 136 to atmosphere. A plurality of carbon sleeves 145 surround exhaust tube 146. The lower end of chamber 136 is defined by an annular ring 148 of refractory material, such as silicon carbide, and an annular metal support ring 150. Rings 148 and 150 have lower surfaces 148a and 150a, respectively, facing the interior of enclosure 10.

An induction heating coil assembly 152 surrounds insulating sleeve 140 and is comprised of a coil 154 of tubular conductive material, such as copper, embedded in a sleeve of insulating refractory material 156. Induction heating coil 154 is adapted to be energized by a corresponding alternating current power supply 157 to inductively heat nonmagnetic sleeves 142, whereby a workpiece disposed in chamber 136 is heated by convection and radiation to elevate the temperature thereof to a desired level. The high fire furnace is designed to elevate the workpiece to a sintering temperature therefor which, of course, is higher than the temperature reached in the carbonizing and degassing furnace. Movement of a workpiece into and out of chamber 136 is achieved, in the manner described hereinabove, by means of a corresponding plunger mechanism 42 disposed therebeneath. Further, it will be appreciated that sealing surface 86a of plate portion 86 of the pedestal supporting a workpiece for displacement into chamber 136 engages lower surfaces 148a and 150a at the open end of the chamber to close the latter, and that cam plates 90 of the corresponding holding arrangements 45 are actuated to hold the pedestal in its upper position and to tightly seal the opening between chamber 136 and enclosure 10.

The structure of cooling chambers 24 and 26 and auxiliary cooling chamber 28 is illustrated in FIG. 7 in conjunction with cooling chamber 24. In this respect,

the cooling chamber is comprised of a cylindrical wall 158 of suitable sheet metal having a peripheral flange 160 at the outer end thereof and a peripheral flange 162 at the inner end thereof. The outer end of the cooling chamber is closed by a corresponding end plate 164 suitably interconnected with flange 160 such as by welding. An annular sealing plate 166 is interposed between flange 162 and top wall 38 of the corresponding section of enclosure 10, and plate 166 includes a lower surface 166a facing inwardly of enclosure 10 for sealing engagement with upper surface 86a of sealing portion 86 of pedestal 84, as described hereinabove. Moreover, the opposed cam plates 90 of the corresponding holding arrangements 45 are positioned to engage beneath sealing plate portion 86 of the pedestal to support a workpiece within the cooling chamber and to seal the entrance between the cooling chamber and enclosure 10.

Cooling chambers 24 and 26 are each adapted to receive and hold a hot workpiece until the temperature thereof subsides sufficiently for the workpiece to be removed from the apparatus. Auxiliary cooling chamber 28 is adapted to serve the same function but with regard to a dummy workpiece D which is alternately cooled and then inserted into one of the carbonizing furnaces 18 and 20 to artificially cool the latter. In this respect, during the time between the displacement of a workpiece from one of the furnaces 18 and 20 into high fire furnace 22 and the introduction of a green workpiece into the empty carbonizing furnace, induction heating coil assembly 130 is deenergized to allow furnace chamber 112 to cool. To assure sufficient cooling of chamber 112, a cool dummy workpiece is introduced thereinto to absorb heat and thus artificially cool the chamber.

Normally, ambient air surrounding cooling chambers 24, 26 and 28 will be sufficient to lower the temperatures of heated workpieces of the dummy workpiece prior to removal of the workpieces from the apparatus or use of the dummy workpiece to artificially cool a carbonizing furnace chamber. However, it will be appreciated that external cooling in the form of liquid circulating coils or the like surrounding the cooling chambers can be employed if desired to assure sufficient cooling during the time in which a given workpiece is disposed therein.

In the following discussion of a preferred sequence of operation of the apparatus described, it will be presumed that the apparatus is fully loaded, whereby carbonizing furnaces 18 and 20, high fire furnace 22 and cooling chambers 24 and 26 contain workpieces, and auxiliary cooling chamber 28 contains the dummy workpiece. Further, it will be presumed that output chamber 30 is empty, that the corresponding closure 56 thereof is sealed in its closed position, and that the inner end of the chamber is open to enclosure 10. Still further, it will be presumed that input chamber 16 is empty, closure 56 thereof is sealed in its closed position, that an empty pedestal 84 has been transported to and elevated by the corresponding plunger mechanism 42 to close the lower end of the input chamber to enclosure 10, and that the pedestal is supported at the lower end of chamber 16 by the corresponding cam plates 90. At this time, carriage 14 is empty, and it will be appreciated that each of the workpieces in furnaces 18, 20 and 22 and in cooling chambers 24, 26 and 28 is supported therein by pedestal 84 and the corresponding cam plates 90.

Following movement of the pedestal into closing relationship with respect to chamber 16 and actuation of cam plates 90 to hold the pedestal, the corresponding plunger mechanism 42 is retracted to its position below carriage 14. The carriage is then driven by motor 78 to a position underlying cooling chamber 26. When the carriage is so positioned, it is stopped and the corresponding plunger mechanism 42 is elevated to engage the underside of the pedestal closing cooling chamber 26 and supporting a workpiece therein. Cam plates 90 are then withdrawn releasing the pedestal, and plunger mechanism 42 is retracted to lower the pedestal onto carriage 14. The conveyor mechanism is then driven to transport carriage 14 and the pedestal and workpiece thereon to a position underlying output chamber 30. The corresponding plunger mechanism 42 is then actuated to elevate the pedestal and workpiece into the output chamber. When the pedestal is positioned in closing relationship with respect to the opening into the output chamber, corresponding cam plates 90 are actuated to hold the pedestal in place, and plunger mechanism 42 is then retracted to its position beneath carriage 14. Cover 56 for discharge chamber 30 is then moved to the open position thereof, whereby the treated workpiece can be removed in any suitable manner such as by an overhead crane. Following removal of the workpiece, closure 56 is again moved to its closed position and sealed, air is evacuated from the interior of chamber 30 and nitrogen is introduced into the chamber to neutralize the interior thereof with that of enclosure 10. The pedestal closing the lower end of chamber 30 remains in place at this time.

During the workpiece discharge, chamber purging and neutralizing operations, carriage 14 is transported by the conveyor mechanism to a position underlying high fire furnace 22, and the corresponding plunger mechanism 42 is elevated to engage the pedestal supporting the workpiece therein. The pedestal is then released by withdrawal of cam plates 90, and the plunger mechanism is retracted to lower the pedestal and workpiece onto the carriage. The carriage is then transported by the conveyor mechanism to a position underlying the now empty cooling chamber 26, and the corresponding plunger mechanism 42 is elevated to displace the hot workpiece and pedestal into the cooling chamber. After the corresponding cam plates 90 are actuated to hold the pedestal in its upper position the plunger mechanism is retracted to its position below the carriage.

The carriage is then transported to a position underlying carbonizing and degassing furnace 20 and the corresponding plunger mechanism 42 is elevated to engage the pedestal closing chamber 112 and supporting the workpiece therein. The corresponding cam plates 90 are retracted to release the pedestal after which the plunger mechanism is retracted to lower the pedestal and workpiece onto carriage 14. The carriage and workpiece are then displaced to a position underlying high fire furnace 22 and the corresponding plunger mechanism 42 is actuated to elevate the workpiece into the high fire furnace chamber, and the pedestal is clamped in place with respect thereto by the corresponding cam plates 90. Following the clamping operation plunger mechanism 42 returns to its position beneath carriage 14 and the carriage is transported to a position underlying auxiliary cooling chamber 28. Corresponding plunger mechanism 42 is elevated to engage the pedestal closing the lower end of the auxiliary

cooling chamber, the pedestal is released, and the plunger mechanism is retracted to lower the pedestal and dummy workpiece onto carriage 14. The carriage is then transported to a position underlying the now empty carbonizing furnace 20, the dummy workpiece is introduced thereinto by the corresponding plunger mechanism 42, and the pedestal is locked in place by the corresponding cam plates 90.

During the artificial cooling operation, carriage 14 is maintained in its position underlying carbonizing furnace 20. Following cooling, the corresponding plunger mechanism is elevated to engage the pedestal supporting the dummy workpiece, the pedestal is released, and the plunger mechanism is retracted to lower the pedestal and dummy workpiece onto the carriage. The carriage is then transported to a position underlying the auxiliary cooling chamber, and the pedestal and dummy workpiece are elevated thereinto by the corresponding plunger mechanism and the pedestal is locked in place by the corresponding cam plates. Following retraction of the plunger mechanism carriage 14, which is now empty, is transported to a position underlying input chamber 16.

During the time between closing of the lower end of input chamber 16, as described hereinabove, and the return of carriage 14 to a position underlying the input chamber, a green workpiece has been introduced into the chamber. In this respect, the outer closure 56 thereof is opened following sealing of the inner end of the chamber, a green workpiece is lowered onto the pedestal such as by an overhead crane, and closure 56 is closed and sealed. Air is then evacuated from the chamber and nitrogen is introduced thereinto to neutralize the chamber with respect to enclosure 10.

When the carriage is positioned below chamber 16 following return of the dummy workpiece to its cooling chamber, plunger mechanism 42 at the input station is elevated to engage the pedestal covering the lower end of the input chamber. The pedestal is then released and lowered onto the carriage by retraction of the plunger mechanism, and the carriage is then moved to transport the cold workpiece to a position underlying the now empty and cooled chamber 112 of carbonizing furnace 20. The corresponding plunger mechanism is actuated to elevate the cold workpiece into the furnace chamber, the pedestal is locked in place with regard thereto and the plunger mechanism is withdrawn to its position below the carriage. Carriage 14 is then moved to a position underlying the now empty output chamber, plunger mechanism 42 is elevated to engage the pedestal closing the lower end thereof, the pedestal is released, and the plunger mechanism is retracted to lower the empty pedestal onto the carriage. The carriage is then moved to a position underlying input chamber 16, and the corresponding plunger mechanism is actuated to elevate the pedestal to close the lower end of the chamber. Cam plates 90 lock the pedestal in place after which the plunger mechanism is retracted.

Carriage 14 is then transported to a position underlying cooling chamber 24, and the preceding sequence is repeated to achieve displacement of the workpiece from chamber 24 to output chamber 30, the transfer of a heated workpiece from high fire furnace 22 to cooling chamber 24, the transfer of a heated workpiece from carbonizing furnace 18 to high fire furnace 22, the transfer of the dummy workpiece from auxiliary cooling chamber 28 to carbonizing furnace 18 and

back, the loading of a new workpiece into input chamber, and the transfer of the new workpiece into carbonizing furnace 18.

It will be appreciated that motor 78 for conveyor mechanism 12 is provided with suitable controls which are programmed to achieve displacement of carriage 14 to the several stations thereof in the desired sequence and in timed relationship with regard to the functions to be achieved. Moreover, it will be appreciated that such programming will include controls for actuating the plunger mechanisms 42 and pedestal holding cam plates 90 for these components to function as desired. Such controls do not form a part of the present invention and, accordingly, are not disclosed in detail. Moreover, it will be appreciated that while the specific steps in the sequencing operation described above are preferred, certain changes can be made therein without departing from the basic sequencing of a workpiece through the apparatus. For example, it may be that under certain operating conditions, the carbonizing and degassing furnaces will cool sufficiently when de-energized to negate the necessity of artificial cooling by the dummy workpiece, whereby the artificial cooling step can be eliminated.

While considerable emphasis has been placed herein on the specific structure of certain components of the apparatus illustrated in the drawings, it will be appreciated that many modifications may be made in the apparatus structure without departing from the principles of operation thereof. For example, pedestal clamping arrangements other than that defined by reciprocating cam plates 90 can be employed to releaseably hold the pedestals in place relative to the lower ends of the chambers and to seal the lower ends of the chambers with respect to the interior of enclosure 10. Similarly, pedestal and workpiece elevating mechanisms other than reciprocating fluid actuated plungers can be employed. In this respect, for example, cooperable rack and pinion mechanisms could be employed for reciprocating the plunger mechanisms, or a suitable elevator mechanism could be associated with carriage 14 for movement therewith and for achieving the elevating and lowering functions at each station of the apparatus. Still further, input, discharge, furnace and cooling chamber structures other than those specifically illustrated and described could readily be provided without departing from the principles of the present invention, as could conveyor arrangements for transporting the pedestal and workpiece components relative to the enclosure. Moreover, it will be readily appreciated that pedestal structures other than that specifically illustrated herein can be employed, and that the pedestals and plunger mechanisms can have interengaging contours to achieve alignment of the workpiece and pedestal relative to a chamber other than the conical projection and recess structure disclosed.

As many possible embodiments of the present invention may be made, and as many possible changes may be made in the embodiment herein illustrated and described, it is to be distinctly understood that the foregoing descriptive matter is to be interpreted merely as illustrative of the present invention and not as a limitation.

We claim:

1. A heat treating furnace comprising an input station, a heating station, a cooling station and an output station, a vertically fixed carriage movable along a horizontal path relative to said stations, enclosure

means for said carriage and including top wall means spaced above said carriage and overlying said path, chamber means at each of said stations supported on said top wall means and opening therethrough, means to heat said chamber means at said heating station, means to position said carriage along said path at each of said stations in alignment with the opening into the chamber means at the corresponding station, workpiece support and chamber closure means separate from and movable with said carriage and displaceable vertically from said carriage at each of said stations between a first position on said carriage and a second position spaced from said carriage and closing the opening into the chamber means at the corresponding station, means at each of said stations separate from said carriage and displaceable relative thereto to move said support and closure means relative to said carriage between said first and second positions, and means separate from said carriage to hold said support and closure means in said second position.

2. The furnace according to claim 1, wherein said chamber means at said input and output stations have corresponding closure members spaced from said top wall means, and means to move said closure members between open and closed positions relative to the corresponding chamber means.

3. The furnace according to claim 1, wherein said support and closure includes plate means adapted to overlie the peripheral edge of a chamber opening, and said means to hold said support and closure means in said second position includes extendable and retractable clamping means operable when extended to sealingly clamp said plate means against the peripheral edge of said opening.

4. The furnace according to claim 1, wherein said carriage means has a vertical opening therethrough, said means to move said support and closure means including vertically reciprocable plunger means at each station operable through said carriage opening to engage and move said support and closure means between said first and second positions.

5. The furnace according to claim 4, wherein said support and closure means and said plunger means have interengageable guide means for aligning said support and closure means relative to said plunger means.

6. The furnace according to claim 5, wherein said plunger means and the opening into said chamber means at the corresponding chamber are coaxial, and said interengageable guide means includes cooperatively contoured recess and projection means on said plunger means and support and closure means.

7. The furnace according to claim 4, wherein said support and closure means includes plate means adapted to overlie the peripheral edge of a chamber opening, and said means to hold said support and closure means in said second position includes extendable and retractable clamping means operable when extended to sealingly clamp said plate means against the peripheral edge of said opening.

8. The furnace according to claim 7, wherein said clamping means includes opposed horizontally reciprocable cam plates supported adjacent said peripheral edge and spaced apart when retracted for said means to pass therebetween, said cam plates when extended engaging under said plate means to cam said plate means against said peripheral edge, and drive means to displace said cam plates between the extended and

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retracted positions thereof.

9. The furnace according to claim 3, wherein each said chamber means at said input and output stations has an opening spaced from said enclosure means and a corresponding closure member for said opening, means to move said closure member between open and closed positions with respect to the opening, and means to sealingly clamp said closure member in the closed position thereof.

10. A heat treating furnace comprising, an elongate tubular housing closed at its opposite ends and of generally gas tight construction, said housing including top wall means, a tubular workpiece input chamber on said top wall means at one end of said housing and having an open first end facing said top wall means and a second end spaced from said top wall means, means to selectively open and sealingly close said second end of said input chamber, a tubular workpiece output chamber on said top wall means at the other end of said housing and having an open first end facing said top wall means and a second end spaced from said top wall means, means to selectively open and sealingly close said second end of said output chamber, a heating chamber on said top wall means between said input and output chambers and having an open first end facing said top wall means and a second end spaced from said top wall means and vented to atmosphere, said heating chamber including chamber wall means of nonmagnetic material and induction heating coil means surrounding said chamber wall means in inductive heating relationship therewith, a tubular cooling chamber on said top wall means between said heating chamber means and output chamber means, said cooling chamber having an open first end facing said top wall means and a closed second end spaced from said top wall means, said top wall means having openings there-through each communicating the interior of said housing with one of said chambers, peripheral seal means about the open first end of each of said chambers, pedestal means including workpiece supporting means and sealing flange means, carriage means in said housing for supporting and transporting said pedestal means along a path in said housing between said one and other ends thereof, means for moving said carriage means

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sequentially to positions underlying said chambers, means at each of said positions for elevating said pedestal means from said carriage means to position said workpiece supporting means in the corresponding chamber and to position said sealing flange means against the peripheral seal means for the corresponding chamber, and means independent of said elevating means to releasably hold said pedestal means in the elevated position thereof.

11. The furnace according to claim 10, wherein said means to selectively open and sealingly close said second ends of said input and output chambers includes corresponding cover members for said chambers, drive means for moving each cover member between open and closed positions relative to the corresponding chamber, and means to clamp the cover members in the closed positions thereof.

12. The furnace according to claim 10, wherein said carriage means includes a wheeled carriage and track means supporting said carriage for rolling movement along said path.

13. The furnace according to claim 12, wherein said carriage includes an apertured bottom wall and said elevating means includes vertically reciprocable plunger means movable through said aperture to engage and elevate said pedestal means.

14. The furnace according to claim 13, and interengaging positioning means on said plunger means and pedestal for positioning said pedestal relative to said plunger means upon engagement therebetween.

15. The furnace according to claim 10, wherein said means to releasably hold said pedestal means includes extendable and retractable clamping means supported adjacent said top wall means and engaging under said sealing flange means when in the extended position thereof, and means to move said clamping means between the extended and retracted positions thereof.

16. The furnace according to claim 15, wherein said clamping means includes opposed horizontally reciprocable cam plates having cam surfaces engaging beneath said sealing flange means when said cam plates are in the extended positions thereof.

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