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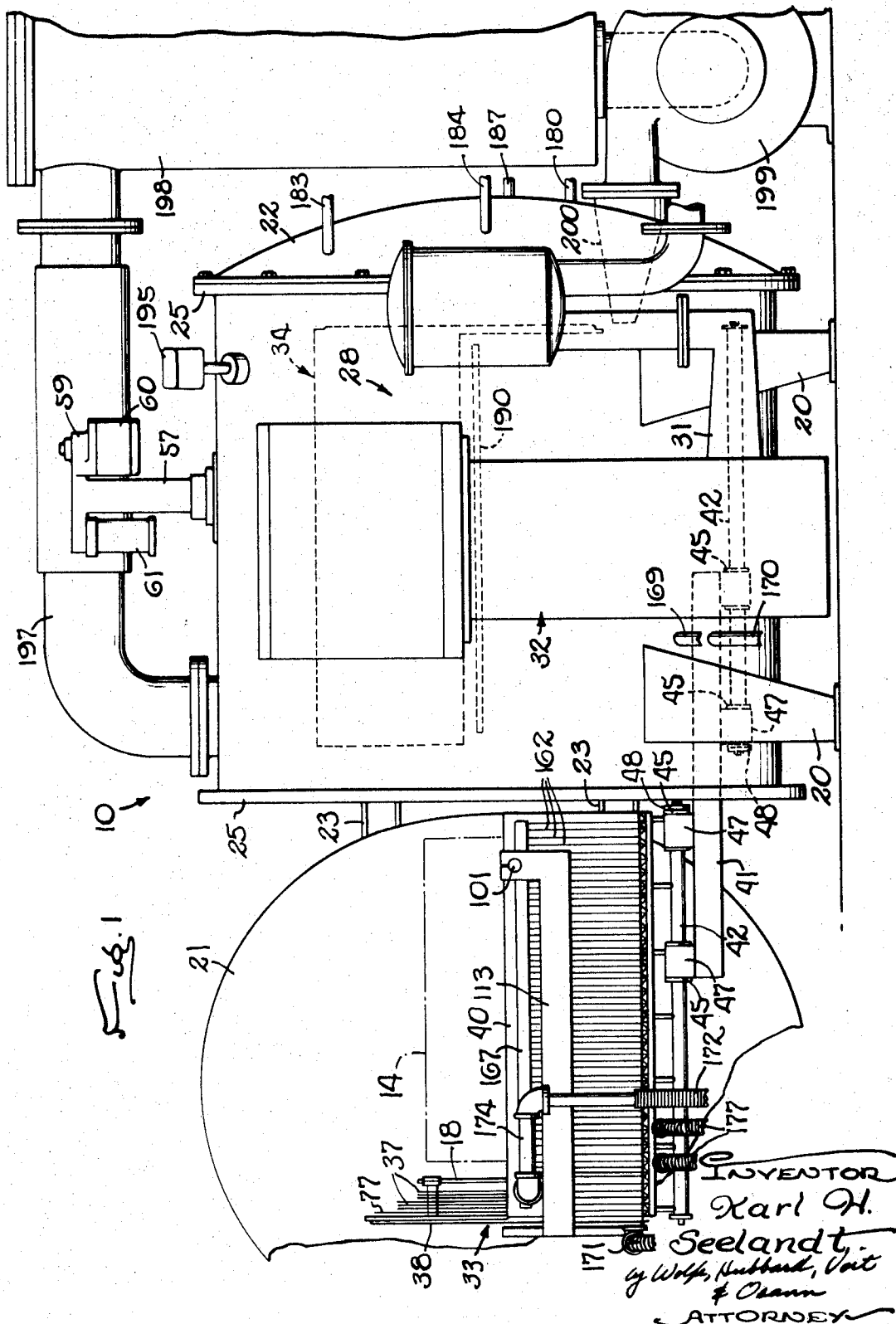
K. H. SEELANDT

3,438,618

VACUUM HEAT TREATING FURNACE

Filed Sept. 8, 1966

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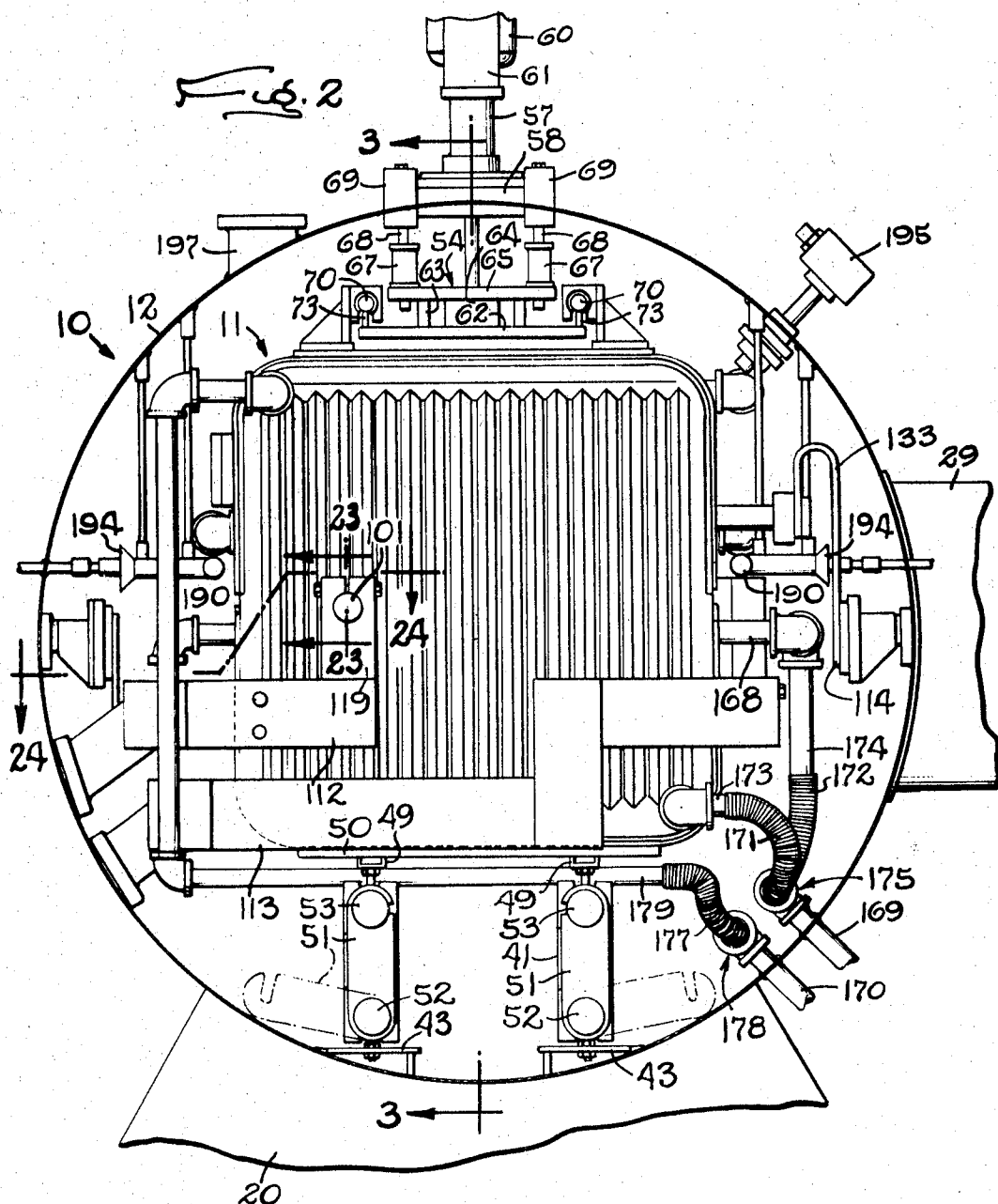
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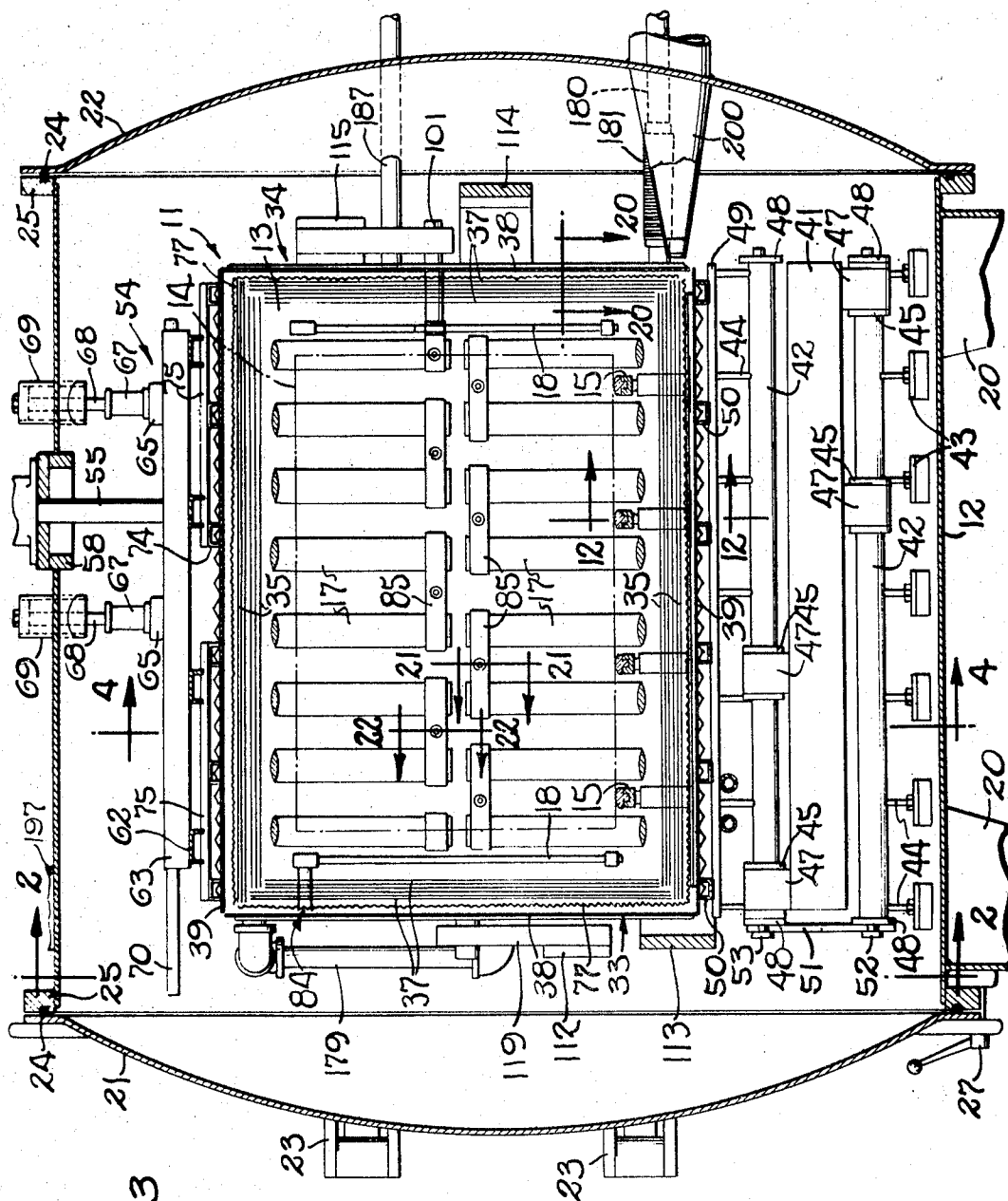
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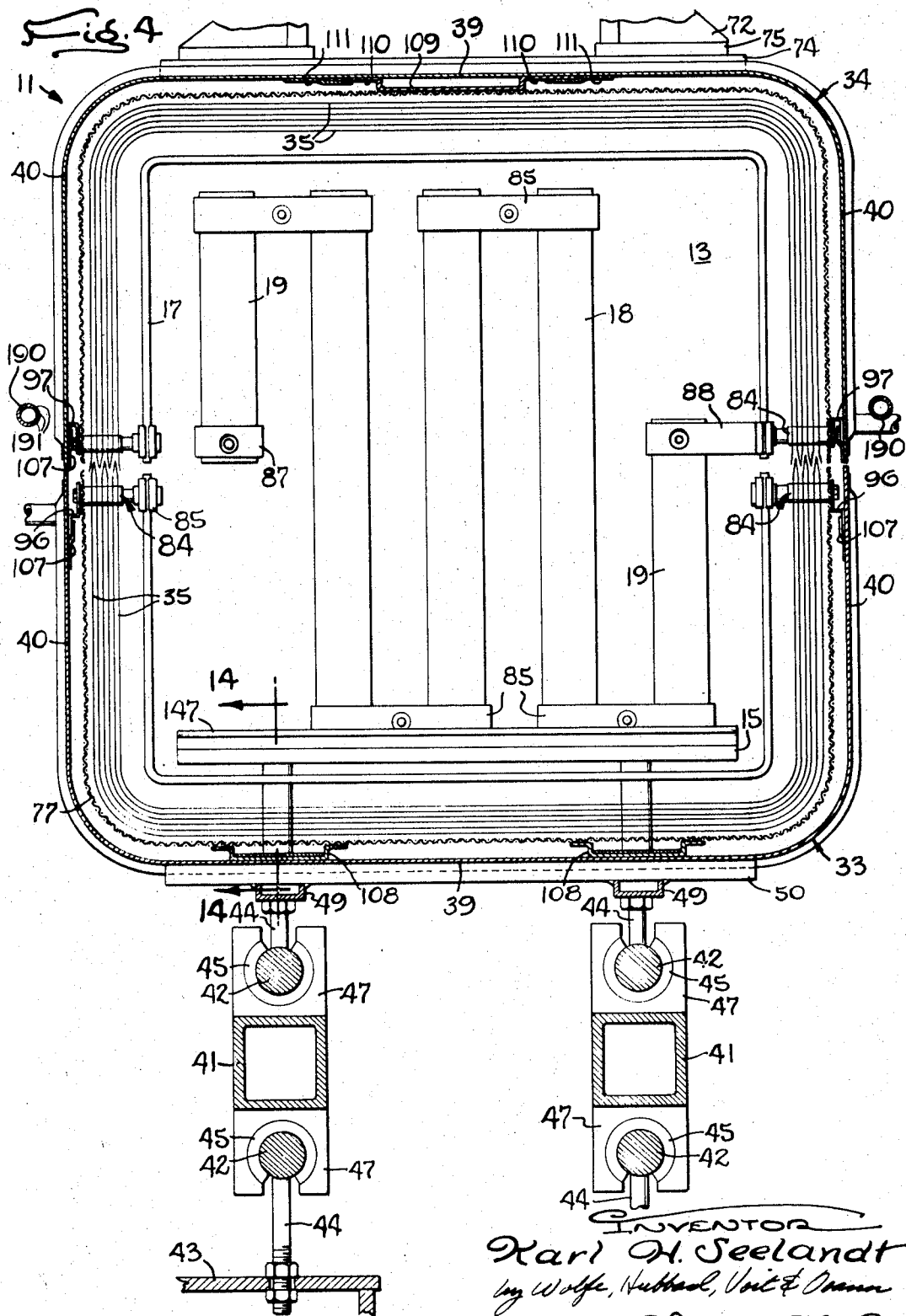
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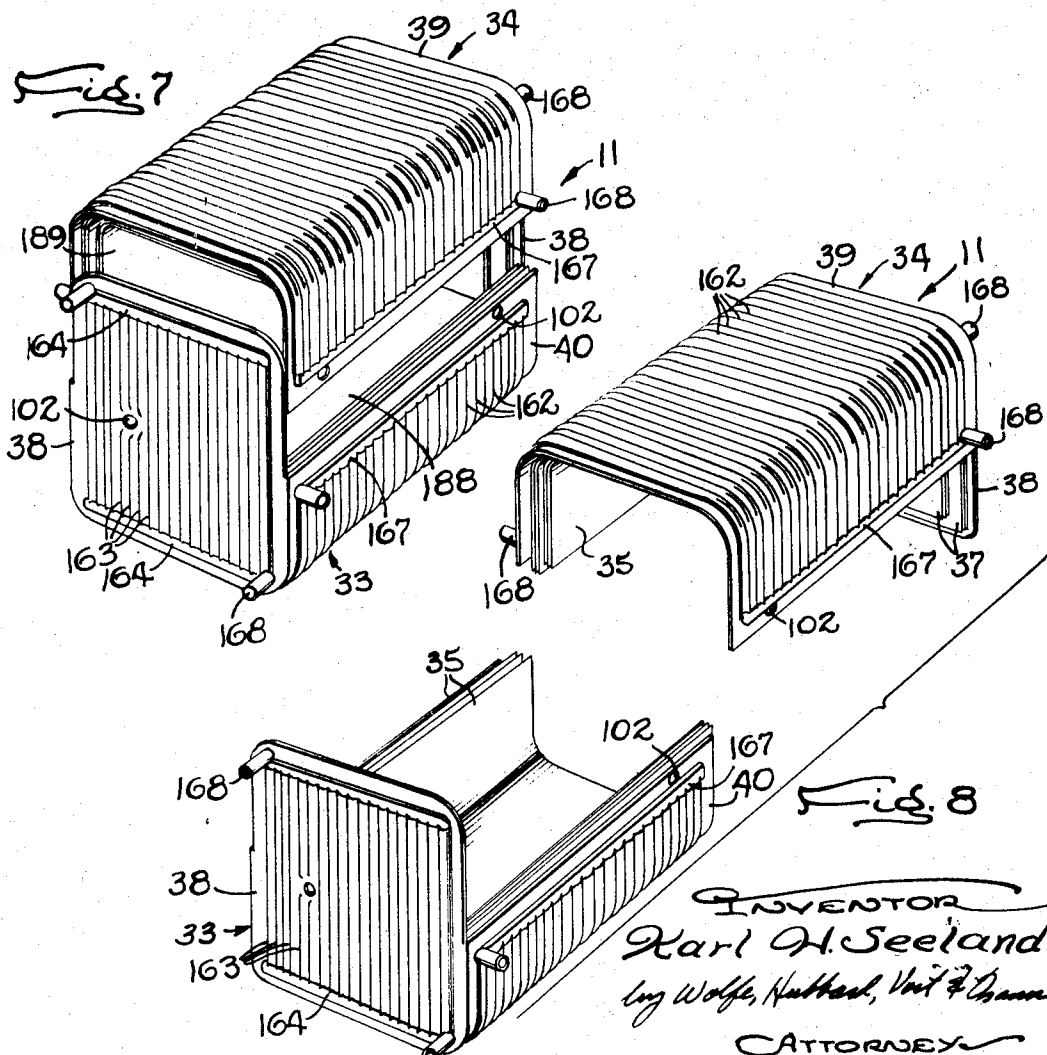
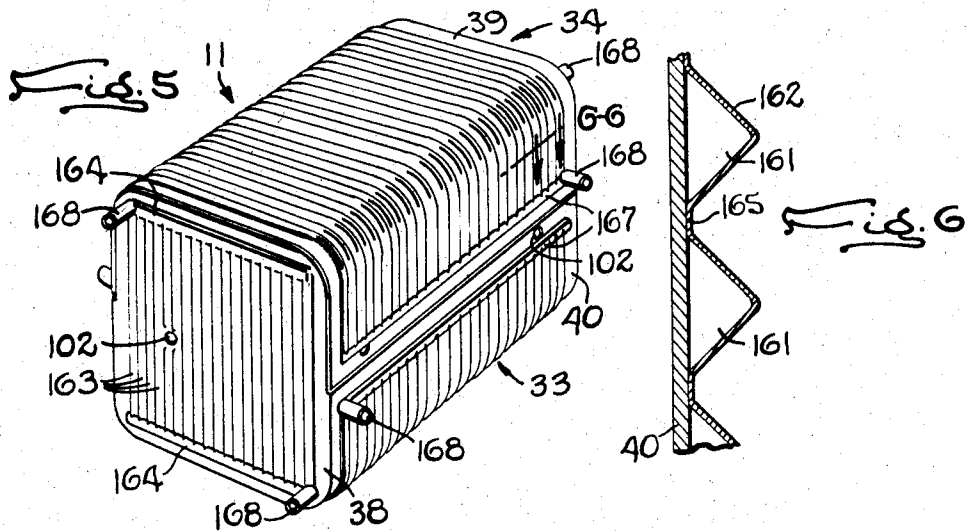
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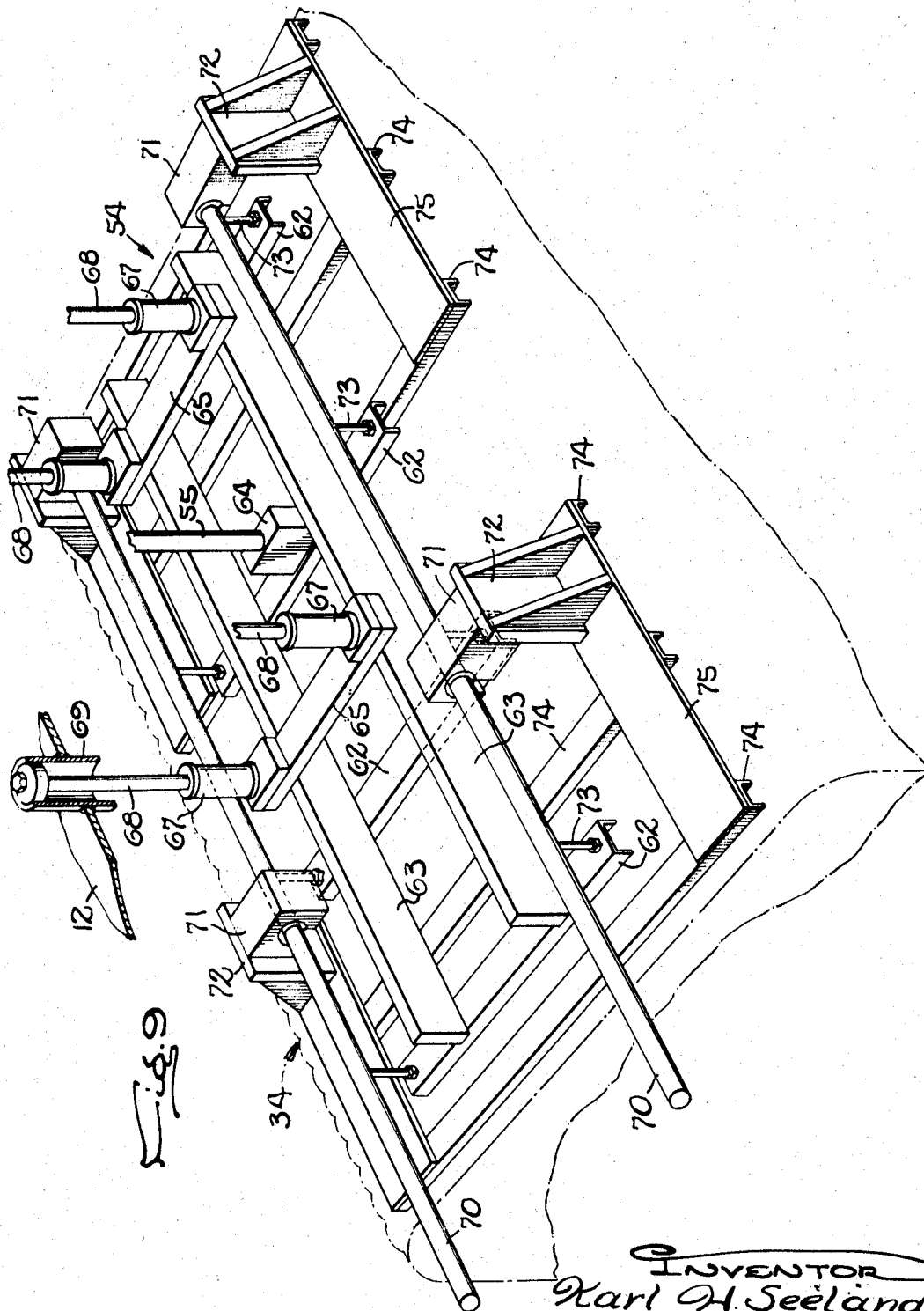
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Fig. 10

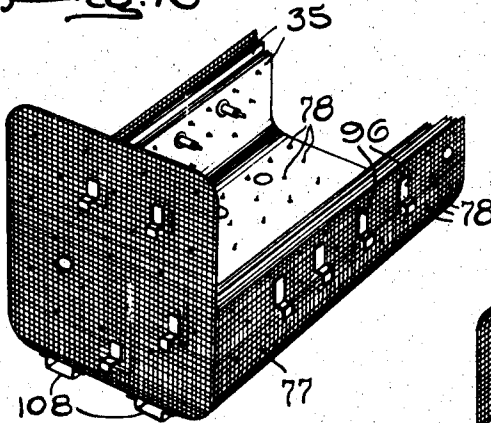
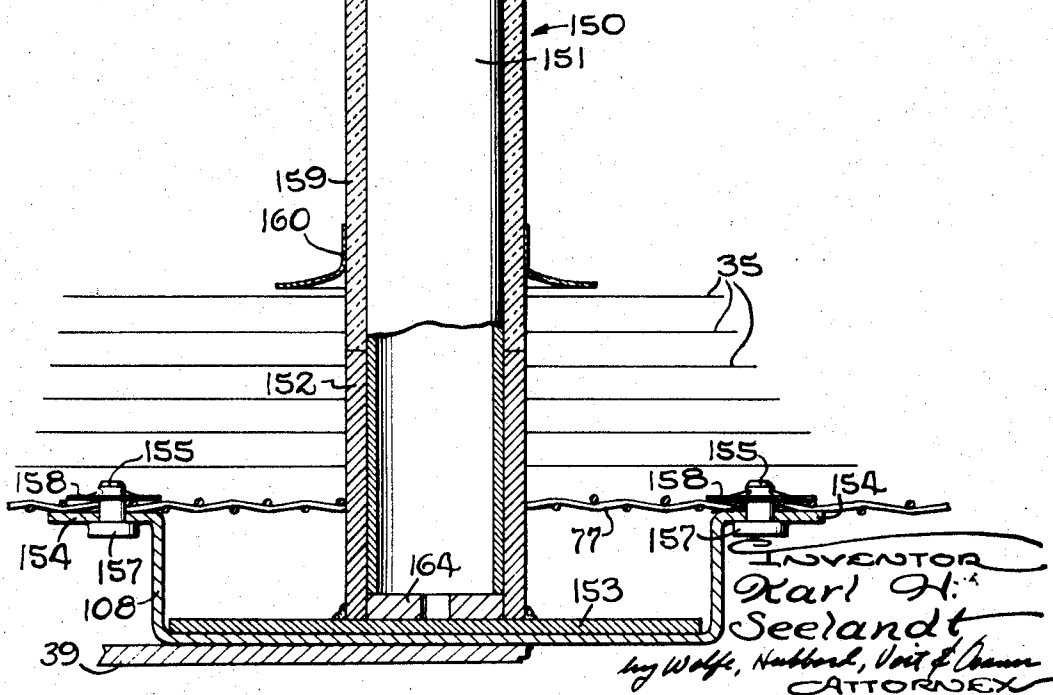
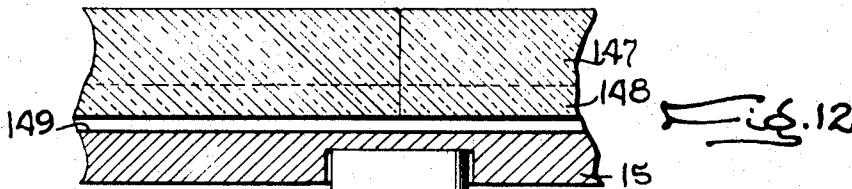
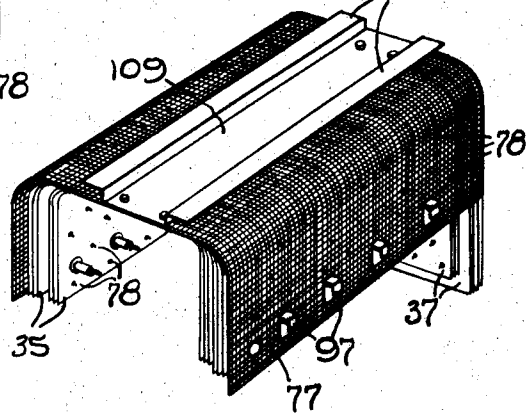


Fig. 11



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Fig. 13

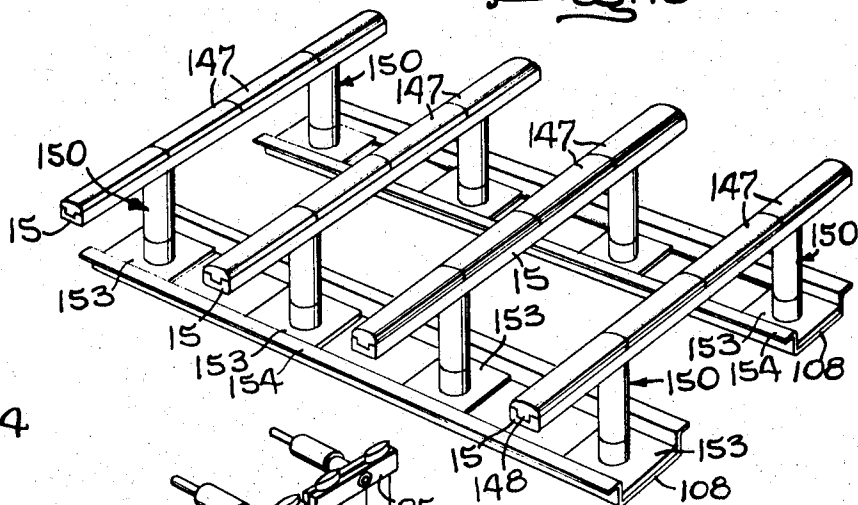


Fig. 14

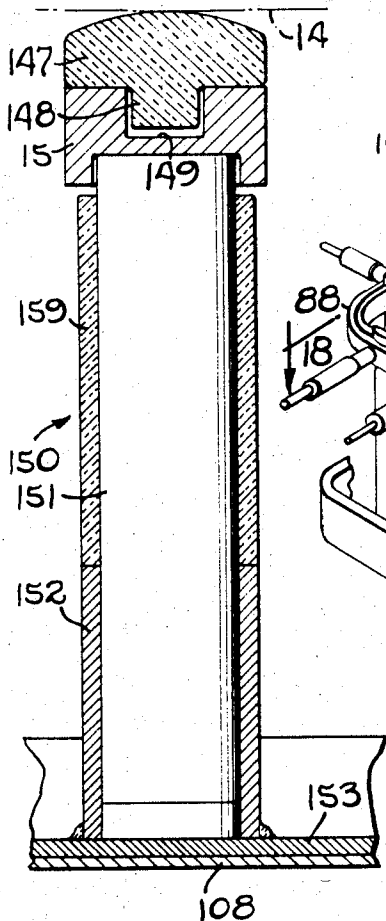
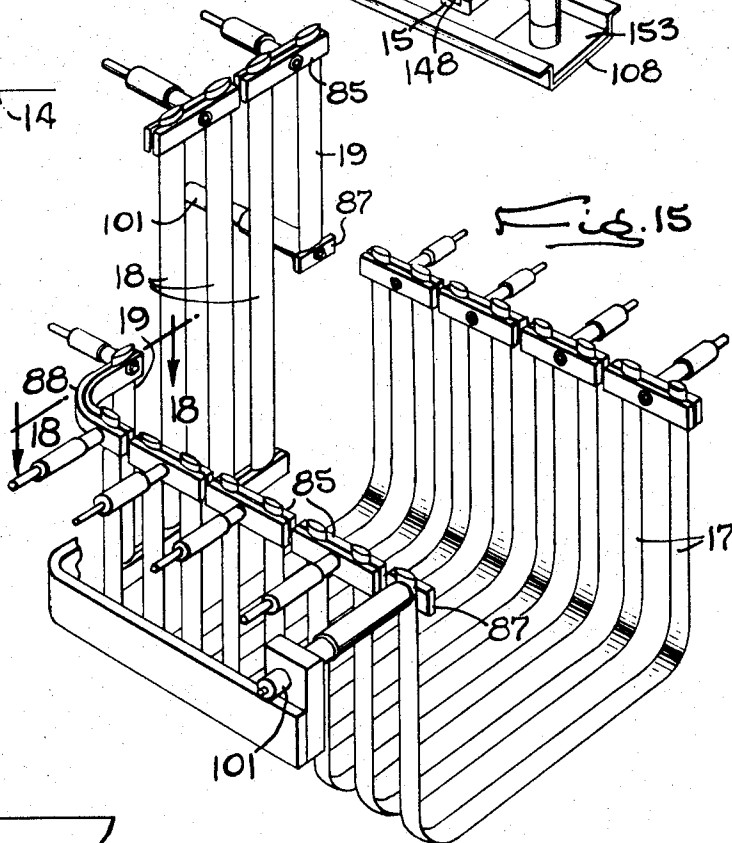


Fig. 15



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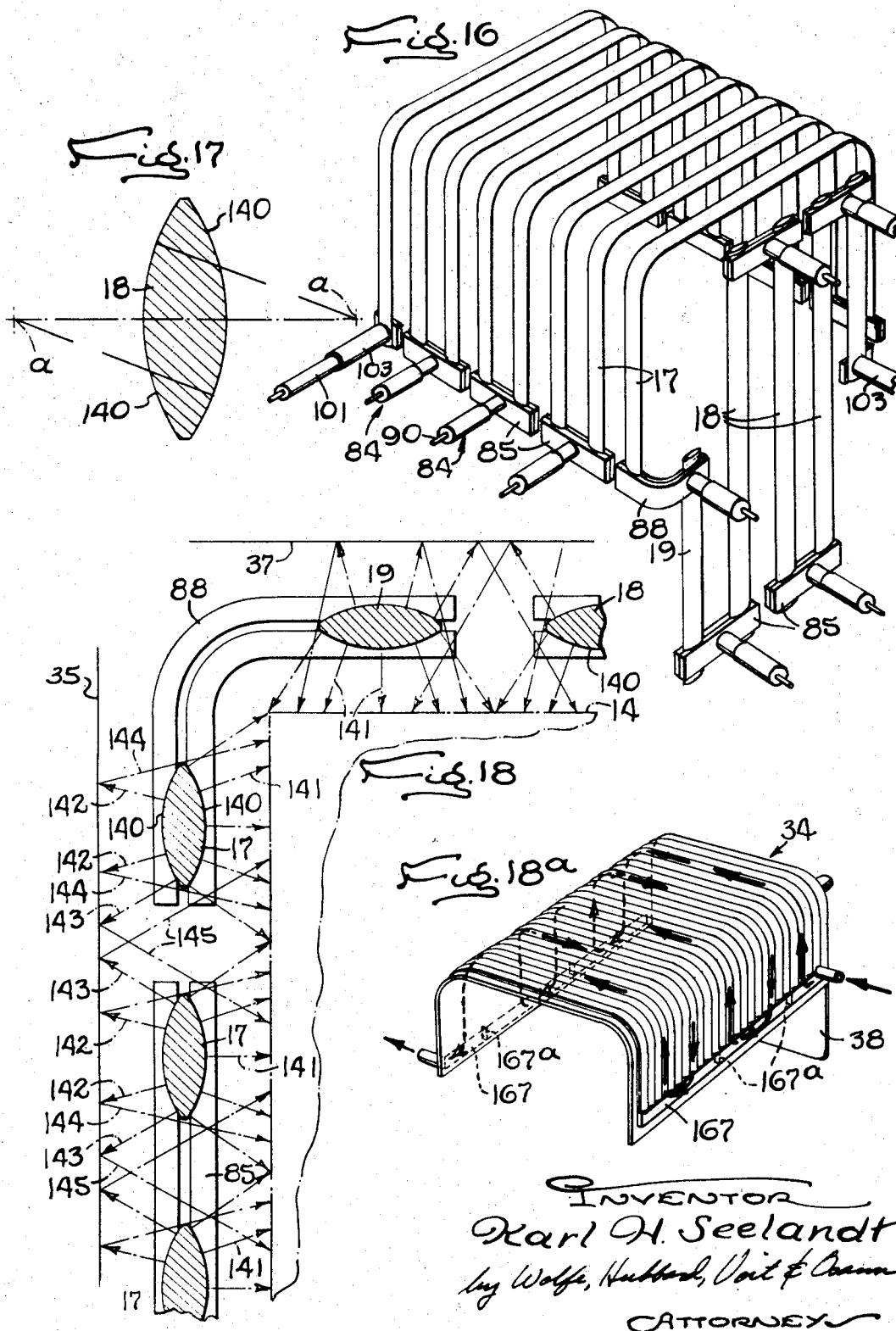
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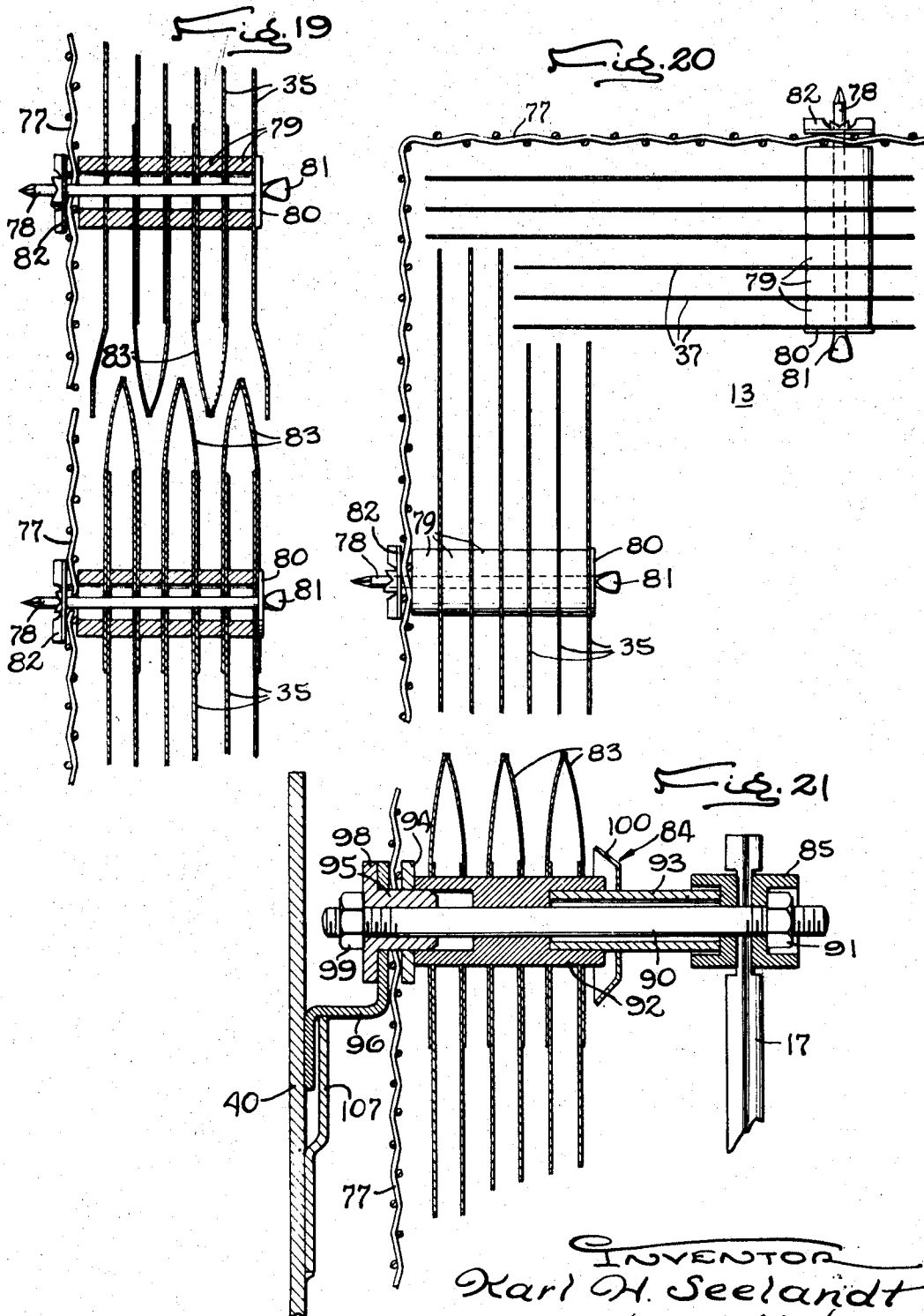
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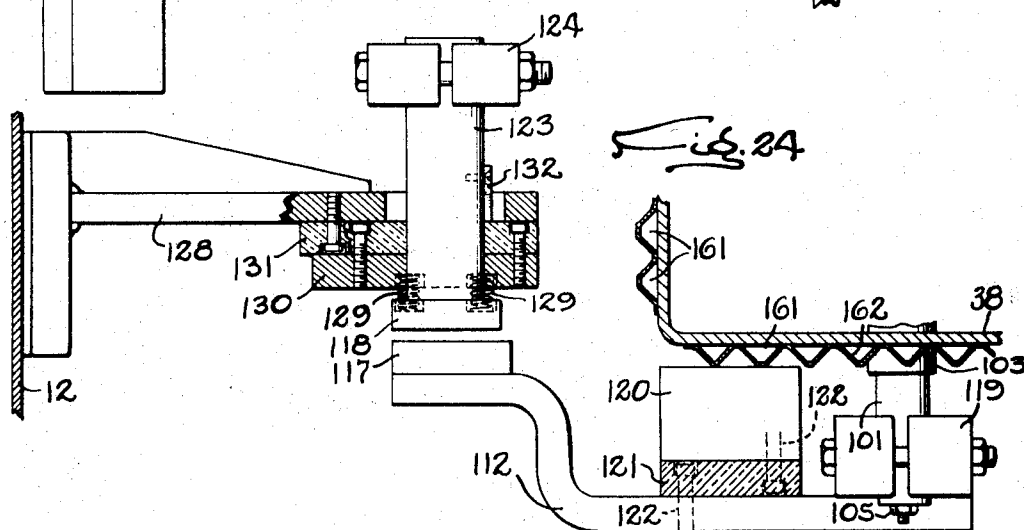
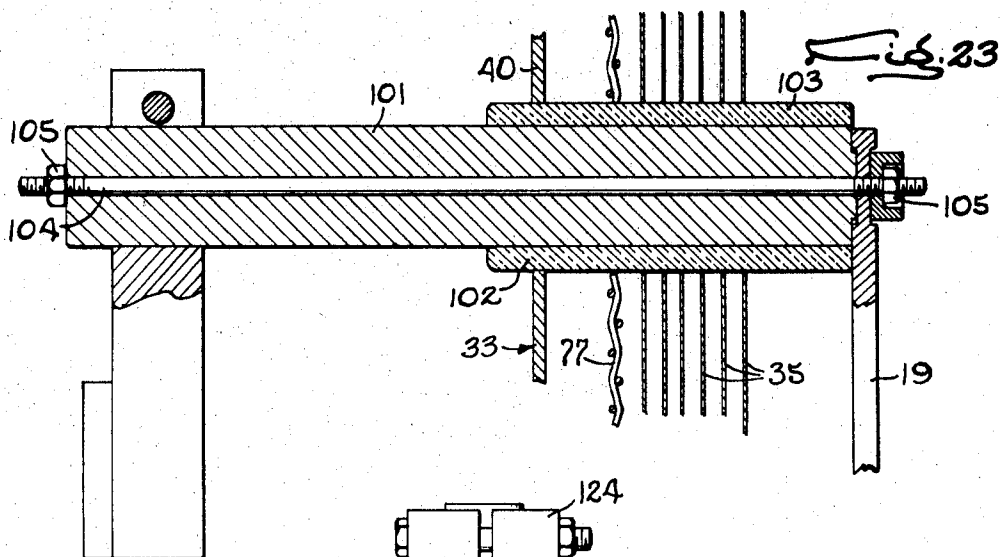
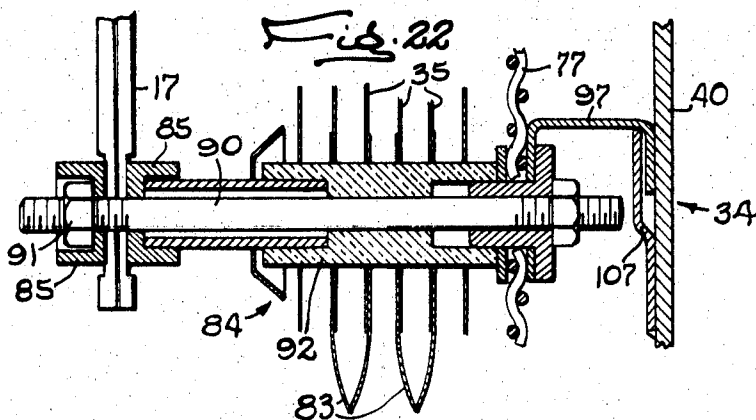
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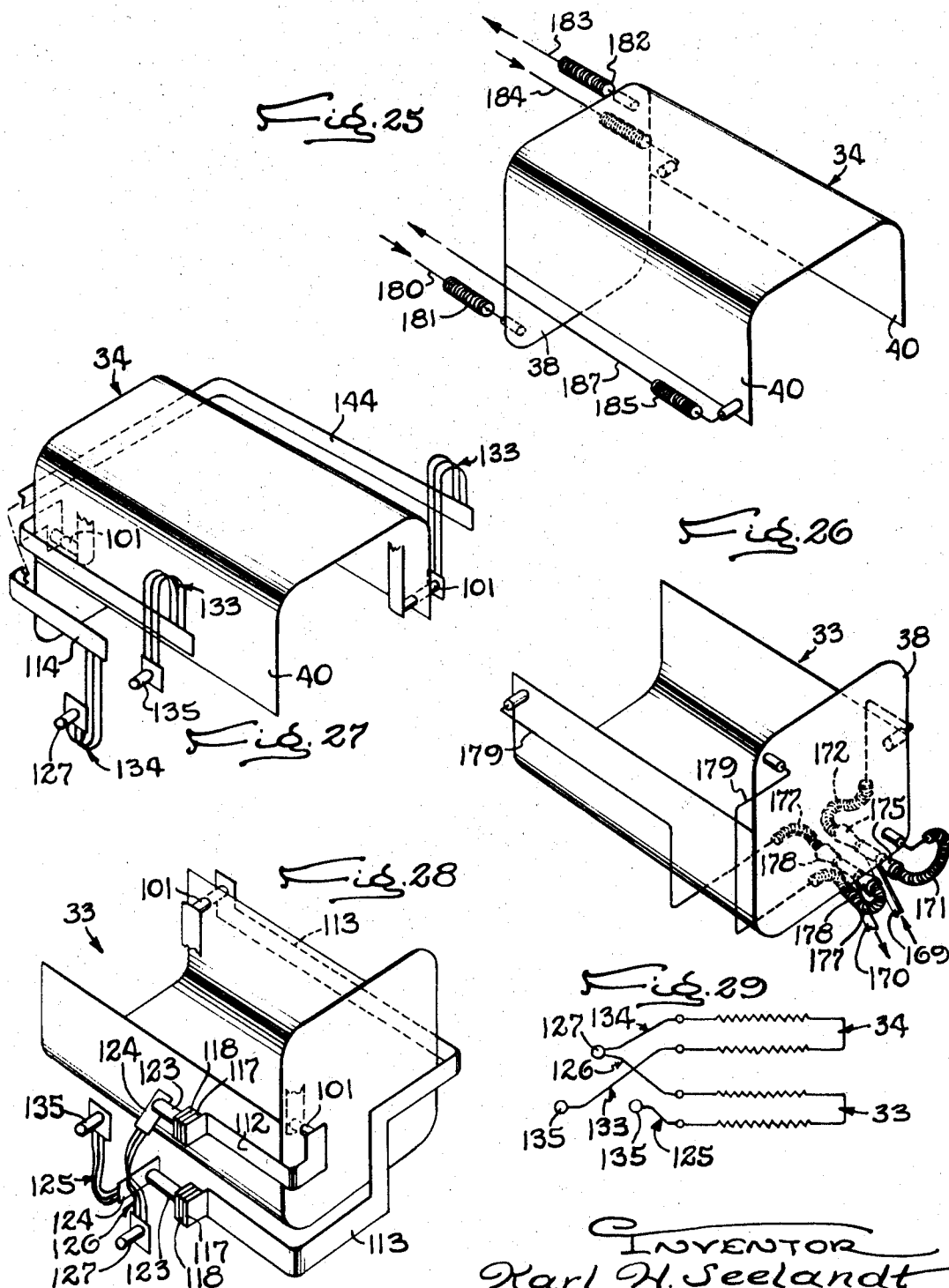
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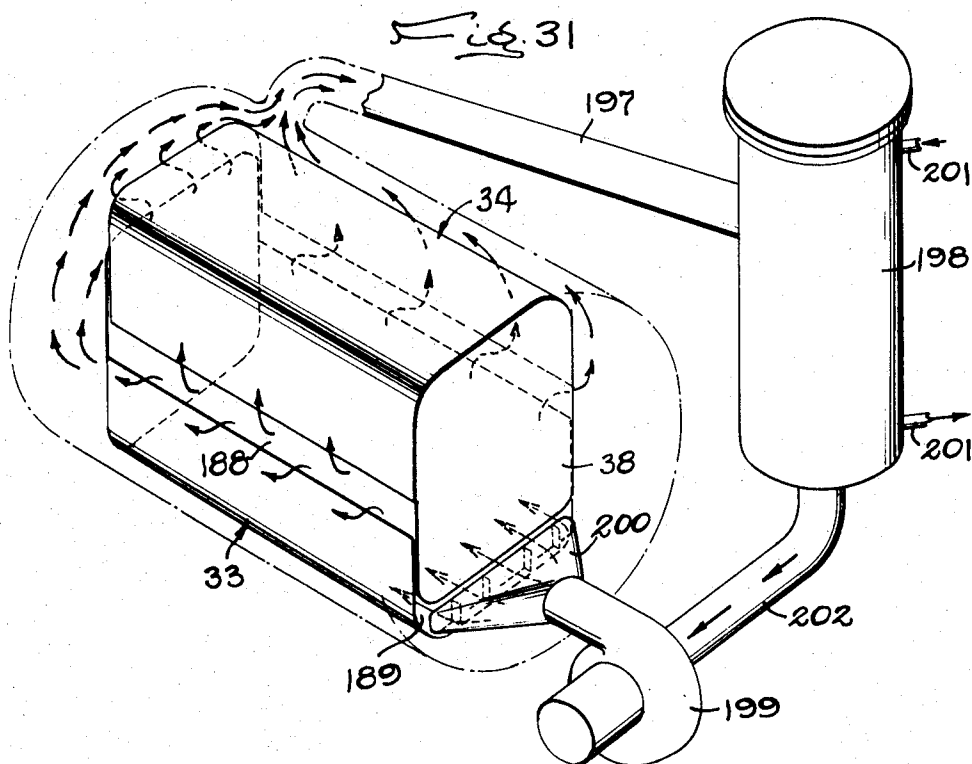
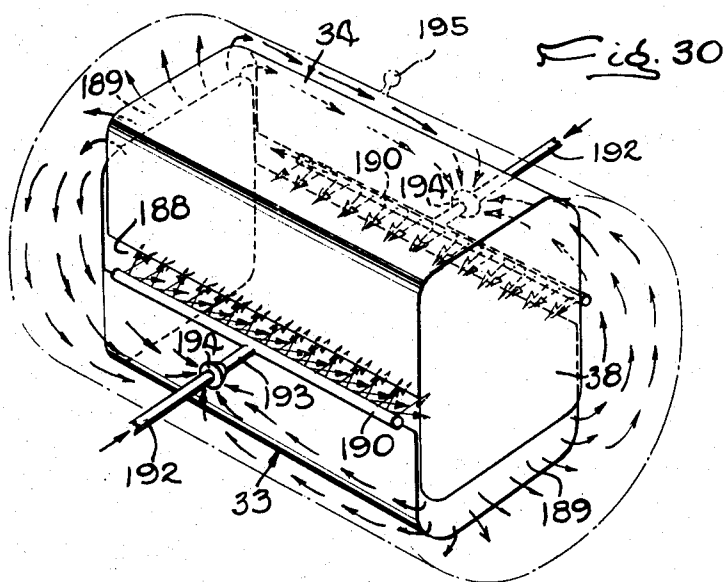
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VACUUM HEAT TREATING FURNACE

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U.S. Cl. 266—5

29 Claims

ABSTRACT OF THE DISCLOSURE

The retort of a vacuum heat treating furnace is formed by two side-by-side and oppositely concave shells which are separable sideways from one another to exposed workpieces in the chamber to quenching fluid and which are separable endwise from one another to facilitate loading of the workpieces into the chamber. Correspondingly concave heating elements and reflecting shields are nested compactly within shells and are movable with the latter, the heating elements being formed by bars with an elliptical cross section and being located to radiate heat of high and substantially uniform intensity. Cooling jackets surround each shell and insure positive circulation of cooling fluid around and in direct contact with the shell while providing reinforcing cold support for the shell.

This invention relates to heat treating furnaces and, more particularly, to furnaces of the type in which the treating chamber is defined in an enclosure or retort disposed within an outer vessel that may be evacuated to provide an artificial nonoxidizing atmosphere. The retort is lined with a heat barrier such as a series of spaced reflecting shields for blocking the escape of heat as the work is heated in the retort by radiant elements distributed around the walls of the chamber, and the work subsequently is quenched by cooling fluid circulated through the chamber and around the work.

A general object of the present invention is to heat work loads rapidly with greater uniformity and to quench the heated work in the retort more effectively than has been possible with prior furnaces of the foregoing character.

Another object is to facilitate the loading and unloading of the retort in such a furnace, particularly of delicate parts that require careful handling and placement.

A more specific object is to form the retort with two side-by-side and relatively movable shells fitted together to enclose the heating chamber and surround the work during heating, and separable from each other within the vacuum-tight vessel for the free circulation of gas through the retort during quenching.

Another object is to surround the work during heating with a compact array of closely and uniformly spaced heating elements on all sides of the work and to separate the heating elements along with the shells to expose the work for quenching.

A further object is to form both shells of the retort and the components therein with concave or U-shaped sides fitting together and closely around the work.

Still another object is to obtain greater uniformity of radiation intensity close to the heating elements where the intensity is greatest, in order to heat the work both rapidly and uniformly.

A related object is to provide a novel arrangement of spaced radiating surfaces and reflectors positioned outside the heating elements to obtain substantial uniformity of radiation intensity adjacent the inner sides of the elements.

A further object is to quench the work with cooling fluid injected into the open retort and directly against the

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work without prior contact with heated components of the furnace.

An additional object is to recirculate the quenching fluid after contact with the work as an incident to continued charging of the furnace with cold fluid or, alternatively, to recirculate and recool the quenching fluid on completion of such charging.

Another object is to simplify the mass production and servicing of such furnaces by making the two shells identical in shape for ready interchangeability of the shells and the parts therein.

Still another object is to support the components in each shell for quick and easy insertion and removal for repair and replacement of parts.

An additional object is to use thin and freely flexible sheet material as reflectors to reduce the mass of the shields, and to support the reflectors in a novel manner in the desired shape within the shells.

A further object is to cool the outer side of the retort more effectively than has been accomplished in prior furnaces, thereby positively preventing the escape of heat to the vessel, and to accomplish such cooling in a novel and relatively simple manner that insures the positive circulation of cooling fluid around and in direct contact with the shell while providing reinforcing cold support for the shell.

The invention also resides in the novel manner of nesting the reflecting shields and the heating elements compactly within each shell, and supporting the shields for movement relative to each other and to the shells during heating and cooling of the furnace.

Other objects and advantages of the invention will become apparent from the following detailed description taken in connection with the accompanying drawings, in which

FIG. 1 is a fragmentary side elevational view of a heat treating furnace embodying the novel features of the present invention.

FIG. 2 is an enlarged fragmentary cross sectional view taken substantially along line 2—2 of FIG. 3.

FIG. 3 is a fragmentary cross sectional view taken substantially along line 3—3 of FIG. 2.

FIG. 4 is an enlarged fragmentary cross sectional view taken substantially along line 4—4 of FIG. 3.

FIG. 5 is a perspective view of the retort.

FIG. 6 is an enlarged fragmentary cross sectional view taken along line 6—6 of FIG. 5.

FIGS. 7 and 8 are perspective views similar to FIG. 5 but showing the shells forming the retort in different moved positions.

FIG. 9 is an enlarged perspective view, partially in cross section, showing the supporting structure for one part of the retort, the retort being indicated in dot-dash lines.

FIGS. 10 and 11 are perspective views showing the internal construction of the two shells.

FIG. 12 is an enlarged fragmentary cross sectional view taken substantially along line 12—12 of FIG. 3 and showing the construction of the hearth.

FIG. 13 is a perspective view of the hearth and its supporting structure.

FIG. 14 is an enlarged fragmentary cross sectional view taken through the hearth substantially along line 14—14 of FIG. 4.

FIG. 15 is a perspective view of the heating elements of one of the shells, the lower shell herein.

FIG. 16 is a perspective view of the heating elements of the upper shell.

FIG. 17 is an enlarged cross sectional view of one of the heating elements.

FIG. 18 is an enlarged fragmentary cross sectional view taken along line 18—18 of FIG. 15 and showing

the relationship of the heating elements to the innermost reflector and to the preferred position of the work load.

FIG. 18^a is a perspective view of one of the shells illustrating the flow path of coolant therein.

FIG. 19 is an enlarged fragmentary view of part of FIG. 4 showing the interfitting relationship of the shells along one edge thereof and the manner of supporting the reflecting shields relative to each other.

FIG. 20 is an enlarged fragmentary cross sectional view taken along line 20—20 of FIG. 3 and showing a corner of the internal retort construction.

FIG. 21 is an enlarged view similar to another portion of FIG. 4 with additional parts shown in cross section and illustrating the support of the heating elements and reflecting shields of the lower shell.

FIG. 22 is a view similar to FIG. 21 but showing the manner of support in the upper shell.

FIG. 23 is an enlarged fragmentary cross sectional view taken substantially along line 23—23 of FIG. 2 with additional parts broken away and shown in cross-section for clarity of illustration.

FIG. 24 is an enlarged fragmentary cross sectional view taken substantially along line 24—24 of FIG. 2 with additional parts broken away and shown in cross-section.

FIGS. 25 and 26 are schematic perspective views of the two shells illustrating the flow paths of the coolant to and from the shells.

FIGS. 27 and 28 are views similar to FIGS. 25 and 26 but showing the conductors for carrying current to and from the shells.

FIG. 29 is a diagram showing the manner of connecting the different sets of heating elements.

FIG. 30 is a schematic perspective view of the retort with the shells thereof separated from each other, and illustrating the manner of charging and recirculating quenching fluid within the vessel.

FIG. 31 is a schematic perspective view of the retort and apparatus for recirculating and recooling the quenching fluid after the vessel has been charged.

As shown in the drawings for purposes of illustration, the invention is embodied in a heat treating furnace 10 of the type having a retort 11 (see FIGS. 2-5) enclosed in an outer vessel 12 and defining a heating chamber 13 in which a work load 14 is supported on a hearth 15 and heated by radiant heating elements 17-19 in the chamber. In this instance, the outer vessel is an open-ended cylinder supported on legs 20 adjacent its opposite ends and having outwardly dished circular heads 21 and 22 which close the ends of the vessel. The head 21 at the front end is hinged at 23 on one side of the vessel to form a door for access to the interior of the vessel during loading and unloading of the retort and servicing of the furnace. Suitable seals 24 (FIG. 3) are provided between the heads and the flanges 25 on the vessel ends to insure that the vessel is vacuum-tight when closed, and several clamps 27 hold the door tightly in place when it is closed.

With a work load 14 in place in the retort 11 and the outer vessel 12 sealed, the furnace 10 is evacuated by vacuum pumping apparatus 28 (FIG. 1) which herein is disposed along one side of the vessel and opens into the latter through a pipe 29 (FIG. 2) sealed to the vessel around an opening therein. Various types of pumping apparatus may be used such as the combined arrangement shown in Patent No. 3,144,199 and comprising a mechanical pump connected by piping 31 to the lower, outlet end of an oil diffusion pump 32 communicating with the outlet pipe. The operation of such apparatus is well known to those skilled in the art and need not be described in detail herein. When the desired vacuum level has been obtained, the heating elements are energized to heat the work in the retort to a preselected temperature determined by the composition of the metal of the work and by the particular treatment to be performed. Then, after the work has been heated uniformly to the selected

temperature, it is cooled in quenching fluid such as an inert gas at a rate selected to obtain the physical properties desired in the finished product, the gas being circulated through the heating chamber 13 and around the work therein.

The present invention contemplates a new and improved furnace 10 of the foregoing character for heating work loads 14 rapidly with greater uniformity than has been possible with prior furnaces and quenching the heated work rapidly at closely controlled rates, and in which the work is loaded into and out of the retort 11 in a novel manner facilitating the handling and placement of the work, particularly delicate parts such as brazing assemblies, without need for special handling equipment. To these ends, the retort comprises generally a pair of relatively movable shells 33 and 34 fitted together in side-by-side relation to define the enclosed heating chamber 13, and a unitary assembly is nested in each shell to provide an effective heat barrier between the shell and the chamber, including inner reflecting shields 35 and 37 lining the chamber, and also to provide an array of heating elements 17-19 uniformly spaced around the chamber and cooperating with the shields to produce substantially uniform radiation intensity on all sides of the work.

For rapid and controlled quenching of the heated work 14, the shells 33 and 34 are separated to open the sides of the retort 11 and a charge of quenching fluid is injected into the chamber and directly against the work therein to reduce the temperature of the work quickly below the critical temperature. To facilitate loading and unloading, one of the shells is supported on the vessel for endwise movement away from the other shell and out through the door 21 into an extended position in which the work may be placed directly on the hearth 15. Then, as the shell is shifted back into the vessel, the work is carried into the heating chamber for the treating cycle.

In this instance, the retort 11 is in the shape of an elongated box having six generally rectangular walls. The shell 33 is disposed beneath the shell 34 and is formed by an upright wall 38 constituting the front of the retort, a horizontal lower wall 39 (see FIG. 4), and elongated rectangular lower sidewalls 40 extending upwardly from the sides of the lower wall half way to the top of the retort. For purpose of manufacturing economy and interchangeability of parts, the upper shell is the same shape as the lower shell but is inverted and fitted over the latter with the depending end wall 38 closing the open rear end of lower shell and the depending sidewalls 40 extending downwardly from the sides of the upper wall 39 and cooperating with the lower sidewalls to close the sides of the retort. Each shell is composed of suitable sheet material such as stainless steel, the end walls being welded to a one-piece U-shaped section forming the primary part of each shell.

The lower shell 33 is supported in the vessel 12 for horizontal movement relative to the upper shell 34 on a telescoping horizontal frame 41 (FIGS. 1-4) which is slidably mounted on the bottom of the vessel on two parallel rods 42. The latter extend from front to rear in the vessel along the tops of two spaced rows of pads or brackets 43 fastened to the bottom of the furnace. Each slide rod 42 is supported on the associated row of pads by studs 44 threaded upwardly into the underside of the rod and extending downwardly through holes in the aligned pads. Lock nuts (see FIG. 4) threaded on each stud on opposite sides of the pad hold the stud in place. It will be seen that this arrangement makes it possible to adjust the level of the rods relative to the pads and lock the rod in the selected position.

Telescoped onto each slide rod 42 are two bearing sleeves 45 (FIGS. 1, 3 and 4) which are fast in bores in blocks 47 fast on the underside of the telescoping frame 41 thereby supporting the frame for free in-and-out sliding along the rods. The blocks and the bearing sleeves are split (see FIG. 4) to form clearance slots in their under-

sides for passing the studs 44 as the sleeves move along the rods. It will be seen in FIGS. 1 and 3 that the two sleeves on each rod are secured to the rear portion of the telescoping frame which thus projects outwardly or forwardly, cantilever fashion, beyond the ends of the slide rods when the two forward sleeves are at the front ends of the rods. End flanges 48 on the rods abut against the sleeves to prevent the latter from riding off the rods.

To increase the distance the lower shell may be shifted forwardly from the operating position, two additional sets of bearing sleeves 45 are mounted in bores in blocks 47 fast on top of the telescoping frame 41 adjacent the forward end thereof, with two upper slide rods 42 slidably supported in these sleeves in parallel relation with the lower rods 42. Studs 44 threaded into the tops of the upper rods extend upwardly through aligned holes in two channel-shaped supports 49 paralleling the rods, and are fastened to the supports. The upper sides of the upper sleeves and blocks also are split to form slots permitting movement of the studs past the sleeves. Above the studs, the channel-shaped supports are welded to a series of parallel transverse channels 50 which, in turn, are welded to the underside of the lower shell 33. Thus, the upper slide rods slide through the upper bearing sleeves as the shell is pulled outwardly toward the door until the rear sleeve on each rod abuts against an end flange 48 on the rear end of the rod. Then the continued outward motion of the shell pulls the telescoping frame outwardly along the lower slide rods to the position shown in FIG. 1. Accordingly, the shell may be pulled completely out of the vessel 12 for loading and unloading. Even in the fully extended position, however, the telescoping cantilever support holds the shell firmly in place.

End flanges 48 on the front ends of the upper slide rods limit inward motion of the latter through the upper bearings and similar end flanges on the lower slide rods limit inward motion of the lower bearings. To hold the lower shell positively in place in the furnace 10 during the treating operation, latch arms 51 are pivoted on headed pins 52 projecting forwardly from the lower slide rods and are swingable upwardly from the broken-line positions in FIG. 2 into the positions shown in full in which the notched free end portions of the arms interlock with headed pins 53 on the upper slide rods. This latches both the upper rods and the telescoping frame to the fixed lower rods.

As shown most clearly in FIGS. 2, 3 and 9, the upper shell 34 is supported in the vessel 12 on a horizontal frame 54 which is suspended on the lower end of an elevator rod 55 extending downwardly from a vertical elevator cylinder 57 mounted on a ring 58 sealed in an opening (see FIG. 3) in the top of the vessel. On the upper end of the rod is a piston (not shown) guided in the cylinder for vertical movement in response to the admission of pressure fluid into the opposite ends of the cylinder. To supply the pressure fluid for operation of the elevator mechanism, a pump 59 is mounted on top of the vessel beside the cylinder and is driven by a selectively operable motor 60, the pump delivering pressure fluid to the cylinder through a control valve 61 which directs the pump output to the appropriate end of the cylinder. Thus, the elevator mechanism raises and lowers the upper shell to open and close the retort when the lower shell is in place within the furnace.

Herein, the horizontal frame 54 connected to the elevator rod 55 is formed by a series of parallel transverse channels 62 (see FIG. 9) joined together by two elongated, front-to-rear rails 63, one of the channels being fastened to a block 64 on the lower end of the rod to fasten the frame to the elevator mechanism. It will be seen in the drawings that two cross-bars 65 on the upper sides of the frame rails support sleeves 67 having center bores receiving vertical guides 68 depending from the top of the vessel through the sleeves and on through aligned holes in the cross-bars beneath the sleeves. Thus, the guides and the sleeves cooperate to maintain the frame horizontal at

all times. The upper ends of these guides are fastened to the upper end walls of tubular fittings 69 sealed in the top of the furnace.

For convenient access during servicing of the furnace, the upper shell 34 also is supported for sliding out of the vessel 12 through the open door 21. For this purpose, two parallel slide rods 70 are mounted on the frame and the shell is slidably supported on the rods by bearing sleeve carried in bars 71 projecting horizontally from brackets 72 upstanding from the top of the shell. Specifically, the rods extend from front to rear along the top of the shell and are adjustably secured to the frame 54 by two rows of studs 73 similar to the lower studs 44, the sleeves and the supporting bars having split lower sides to move along the rods past the studs. Welded to the top of the upper shell adjacent the front and rear ends thereof are two sets of three parallel channels 74 extending transversely of the furnace with two plates 75 spanning and fastened to the opposite ends of each set. These plates support the brackets which are rectangular plates securely braced in upright positions with the bars 71 projecting across the top of the shell and across the slide rods 70. If desired, means (not shown) may be provided for latching the upper shell in place relative to the elevator frame and releasing the shell only when it is necessary to pull it out of the furnace.

While the illustrative embodiment of the invention comprises two shells forming a box with rectangular sides, it will be evident to those skilled in the art that the U-shaped sections can be semicylindrical rather than semi-rectangular, particularly if the work load is to be cylindrical, and that the shells may be of other shapes that fit together to form an enclosure within the vacuum vessel. Moreover, the concept may be applied to vertically loaded furnaces with modifications to suit this type of furnace.

As shown in FIGS. 3 and 4, the heat barrier within each shell 33, 34 is formed by a set of reflecting shields 35 and 37 that are formed in the same shape as the shells and nested therein in spaced relation with the shells and with each other to reflect radiation from the heating elements 17-19 back into the heating chamber 13, the shields 35 being U-shaped in cross section to cover the U-shaped portions of the shells and the shields 37 being flat. Both types of shields are composed of suitable high-temperature metal such as molybdenum, tungsten or tantalum, depending upon the temperature levels to be developed in the furnace, and are made as thin as is practical to minimize the mass of the shielding and reduce the heat stored therein during the heating operation. Herein, thin and flexible molybdenum sheet material on the order of .003 of an inch thick is used, several strips of such foil being disposed in side-by-side overlapping relation to form each shield. Molybdenum parts, including the heating elements, may be used in a vacuum where the work is to be heated to about 2400 degrees F. From 2400 to somewhat above 3000 degrees, tantalum parts are used, and tungsten parts are used in temperatures up to about 4000 degrees.

Supporting the shields in each shell is a basket 77 (see FIGS. 10 and 11) composed of relatively heavy screen material such as No. 4 mesh Inconel which is stiff enough to be formed into the shape of the shells and thereafter retain its shape as the shields and associated parts are assembled into the baskets. The baskets comprise generally rectangular end walls and shallow sections of U-shaped cross-section for fitting into the U-shaped portions of the shells, and are sufficiently smaller than the shells to leave a small clearance space inside the shells. The shields are supported on the baskets primarily by a plurality of pin 78 (see FIGS. 19 and 20) inserted through sets of aligned holes in the shields and through the screen, and are held in spaced relation with each other by spacers 79 in the form of rings or washers telescoped onto each pin between each pair of adjacent shields. The spacers may be on the order of 1/4 inch wide. On the inner end of each pin is a washer 80 abutting against the exposed surface of the innermost shield and held on the pin by a head

81. On the outer end of the pin, which preferably is pointed as shown in FIGS. 19 and 20, is a washer 82 which frictionally grips the pin to tie the assembly together. The spacer rings are telescoped loosely onto the pins and the holes in the shields around the pins are made substantially larger than the thickness of the pins themselves, thereby permitting the shields and the rings to move relative to the pins during heating and cooling of the furnace. The spacer rings, the pins and the washers on the pins all are composed of high-temperature metal selected for the temperatures to be attained in the furnace, molybdenum in this instance.

As indicated generally in FIGS. 10 and 11, the supporting pins 78 are distributed liberally around the basket to hold the shields in the desired shape and in properly spaced relation. To assemble the U-shaped shields with the pins and spacers after the strips have been pre-punched at the locations where pins are to be inserted, the strips of the innermost shield are laid out and the pins are inserted through the inner washers 80 and upwardly through the strips. Then a spacer 79 is dropped onto each pin and the strips of the next shield are laid over the inner shield so that the pins pass through the pre-punched holes and the second shield comes to rest against the spacers. Successive shields are placed in this manner until the pre-selected number of shields are in place. Herein, six shields are used.

It will be appreciated that the shields become progressively smaller from the outer shield inwardly, and that the strips are sized and the pin holes are positioned to provide the appropriate radius at the junctions of the upright sidewalls with the horizontal walls. After the shields have been laid out on the pins and the spacers, the sidewalls may be brought into their proper positions simply by raising the horizontal walls and allowing the sidewalls to hang downwardly therefrom. For this purpose, a suitable frame (not shown) may be disposed beneath the central portion of the shields during assembly and then lifted upwardly to raise the central portion.

With a set of shields 35 assembled in the proper inverted U shape, a basket 77 is fitted over the assembly and the pins 78 are passed through the screen material to mount the shields in the basket. Additional spacers 79 on the pins between each basket and the outer shield space the latter from the basket. It is possible to spring the basket walls outwardly sufficiently to pass over the shields and then release them to close around the shields. After the lock washers 82 have been slipped onto the pins, the flexible shields are held in shape by the pins which are held in place by the basket.

The sets of flat shields 37 for the end walls 28 of the shells are held together in the same manner (see FIG. 20) by pins 78, spacers 79 and washers 80 and 82. To avoid the formation of straight-line paths at the corners of the shells, the ends of the shields are stepped as shown in FIG. 20 with the outer three flat shields overlying the ends of the outer three U-shaped shields and with the inner three shields of each type foreshortened so that the inner three flat shields overlie the ends of the inner three U-shaped shields. Along the side edges of the U-shaped shields, where the two sets of shields fit together when the retort 11 is closed, three elongated caps 83 of V-shaped cross section are fitted over the edges of the lower shields on each side as shown in FIGS. 19 and 21 and two similar caps are fitted over the edges of the four central upper shields on each side to overlap vertically with the lower caps when the shells are together. This eliminates straight-through radiation paths between the shells.

To support the heating elements 17-19 inside the shields 35 and 37 and also to assist in supporting the shields on the baskets 77, hanger pins 84 (FIGS. 4 and 21) are secured to each basket in two rows adjacent the free edges of the U-shaped portion and to the end wall in selected locations, each pin extending inwardly through a series of alined holes in the shields and supporting on

its inner end a heating element clamp 85. Each such clamp comprises a pair of bars (see FIGS. 15 and 16) disposed in side-by-side relation on opposite sides of two heating elements which are notched to receive the clamp bars. Herein, the heating elements are elongated solid bars forming electrical resistors and are composed of molybdenum. As shown most clearly in FIGS. 4, 15 and 16, the elements are bent into a U shape and arranged in parallel planes to form a U-shaped grid with each bar closely following the innermost U-shaped shield 35 of each shell, the straight portions of the resistor bars generally paralleling the corresponding flat portions of the inner shield in closely spaced relation therewith. The end elements 18 and 19 are straight resistor bars arranged in parallel in flat grids that overlie and substantially cover the inner flat shields 37. Herein, each such grid comprises three long bars 18 covering the central portion of the shield and two shorter bars 19, approximately half as long as the central bars, positioned along opposite sides of the shield. One short bar extends downwardly from the upper end of grid while the other extends upwardly from the bottom of the grid.

The heating element clamps 85 in each shell 33, 34 are electrical conductors and cooperate with the bars 17-19 and with additional clamps 87 and 88, to define a single series path for the flow of electricity in the two grids. For this purpose, the clamps 85 extend in opposite directions from the opposite ends of each bar to connect the bar electrically to the two adjacent bars. As will be seen in FIG. 15, the U-shaped bar at the right or inner end of the lower shell is supported at one end by a single-bar clamp 87 and at the other end by a double-bar clamp 85 that also supports the second heating bar. The other end of the second bar is held by a double-bar clamp that also holds the third bar. This alternating arrangement of clamps continues to the left end of the grid where the last U-shaped bar is held by a curved clamp 88 that turns the corner and also holds the upper end of the lower short bar 19, thereby electrically connecting the two grids. The lower end of the short bar shares a double-bar clamp 85 with the lower end of the adjacent long bar 18, and the series connections continue across the flat grid to the lower end of the upper short bar 19 which is held in a single-bar clamp 87. The arrangement for the upper grids is similar, as shown in FIG. 16, the U-shaped bar 17 at the left and the lower end of the upper short bar 19 being held in single-bar clamps 87 at the opposite ends of the series.

Since the clamps 85 are conductors, the hanger pins 84 supporting the clamps on the baskets 77 are designed to insulate the clamps from the shields 33, 34 and the wire of the baskets. For this purpose, each pin comprises an elongated stud 90 (See FIGS. 21 and 22) extending at its inner end through alined holes formed in the clamp bars between the two heating bars held thereby, and a nut 91 is threaded onto the inner end and tightened against the inner clamp bar. Telescoped snugly over the intermediate portion of the stud is a ceramic sleeve 92 which extends loosely through the six shields and projects somewhat beyond the inner and outer shields. Between the outer clamp bar and the sleeve is a tube 93 which fits snugly into a counterbore in the inner end of the sleeve and is held by the counterbore in co-axial relation with the stud. The inner end of this tube, which herein is composed of molybdenum, is seated in a counterbore in the clamp bar and thus cooperates with the nut 91 in holding the clamp together.

At the outer end of the insulating sleeve 92, a washer 94 is telescoped loosely over the stud 90 inside the screen 77 and an insulating plug 95 is slipped onto the stud through a clip or bracket 96, 97 which is used to support the basket on the shell. A flange 98 on the insulating plug is pressed tightly against the clip by a nut 99 that is threaded onto the outer end of the stud to draw the entire hanger assembly together, clamping the clip against

the screen and securing the hanger both to the clip and to the screen. Preferably, a dished washer **100** is telescoped snugly on the tube **93** adjacent the inner end of the ceramic sleeve to prevent coating of the sleeve by metallic vapor that could conduct current to the shields, and also to cover the clearance between the sleeve and the shields against the escape of radiation.

At the ends of the series flow paths formed through the two pairs of grids, the single-bar clamps **87** are supported on lead-in bars **101** which extend out of the shells through holes **102** (FIGS. 5, 7 and 8) for connection to the leads from an outside source (not shown) providing power for the furnace. As shown in FIGS. 15, 16 and 23, each lead-in bar is an elongated and relatively heavy rod that may be composed of molybdenum, abutting at its inner end against the heating element and extending outwardly through an insulating ceramic sleeve **103** which extends through the shell **33** or **34**, the reflecting shields **35** or **37**, and the basket **77**. A stud **104** extending through the lead-in bar has nuts **105** threaded on its opposite ends to hold the heating bar firmly against the lead-in bar.

To support the baskets **77** within the upper and lower shells, the clips **96** and **97** spaced along the edges of the U-shaped portions engage elongated rails **107** (FIGS. 4, 21 and 22) fastened to the sidewalls of the shells, the rails and clips being arranged to permit the baskets to be slipped quickly into and out of the shells. For these purposes, the clips **97** on the upper basket (See FIGS. 4, 11 and 22) are inverted U-shaped pieces each having a depending leg or tab hooked over and into an upwardly opening groove defined between an inwardly offset upper portion of the adjacent upper rail **107**. The latter is welded to the upper shell and preferably extends along substantially the full length of the shell. The lower rails are the same as the upper rails and receive downwardly extending legs or tabs of the lower clips **96** which are Z-shaped as shown in FIGS. 4, 10 and 21.

With the foregoing arrangements, the upper basket may be slid endwise into the upper shell through the open front end of the latter, and the lower basket may be lowered into the lower shell through the top, both sets of clips and rails becoming engaged during such assembly. For additional support of the horizontal walls of the two baskets, two channels **108** are fastened to the underside of the lower basket to rest on the bottom of the lower shell, and a similar channel **109** (FIGS. 4 and 11) is fastened to the top of the upper basket and formed with oppositely projecting flanges **110** fitting over the downwardly offset portions of two spaced parallel rails **111** fastened to the upper wall of the shell. This forms a dovetail connection between the basket and the upper shell parallel to the sliding connections along the sidewalls of the shell and engageable as an incident to sliding of the basket into the shell. The end walls of the basket preferably are supported independently of the U-shaped portions by elements (See FIG. 10) similar to the clips **96**.

Outside the shells **33** and **34**, the lead-in bars **101** are fastened to bus bars **112-115** (FIGS. 1-3, 27 and 28) which extend around the shells to suitable electrical connections as shown most clearly in FIGS. 27 and 28. In FIGS. 24 and 28, it will be seen that the lead-in bar projecting through the front end wall **38** of the lower shell is fastened to the bus bar **112** which bends around the shell to the left side and carries a rearwardly facing contact plate **117** engageable with a similar forwardly facing plate **118** that is supported on the adjacent side of the vessel **12**. The lead-in bar exiting through the rear portion of the lower shell is fastened to the bus bar **113** which extends forwardly along the right side of the shell, then across the front and downwardly to a level below the bus bar **112**, and finally rearwardly beneath the other bar, terminating in another rearwardly facing contact plate **117** engageable with a similar forwardly

wardly facing plate **118** supported on the vessel beside the left side of the retort.

As shown in FIGS. 2 and 24, the outer end portion of the front lead-in bar **101** is clamped between the legs of a split conductor **119** upstanding from the bus bar **112**, the latter being fastened to the front of the shell by means of a block **120** welded to the shell and carrying an insulating plate **121** which is fastened separately to the bus bar and to the supporting block by bolts **122**. The contact plates **117** are fastened to the out-turned ends of the bus bars to face rearwardly along the side of the shell and toward the plates **118** which are carried on the front ends of two rods **123** connected at **124** to cables **125** and **126** fastened to connectors **135** and **127**, respectively, passing through the vessel wall, the rods being supported for limited front-to-rear sliding on brackets **128** (See FIG. 24) welded to the inside of the vessel. The rods and plates are urged forwardly by springs **129** acting between the plates and backing plates **130** bolted to ceramic insulating blocks **131** bolted, in turn, to the supporting brackets. One or more stops **132** on each rod **123** abut against the insulating plate **131** to limit forward movement of the plate. It will be seen that the two sets of contact plates form switches that are closed when the lower shell is in its normal position in the vessel, but are opened when the plates separate as the shell is moved out of the vessel, thus positively breaking the lead-in circuits for the heating elements in the lower shell. The plates **118** yield to cushion to impact with the plates **117** as the lower shell slides in, and the springs **129** hold the plates in firm face-to-face contact while the lower shell is in place beneath the upper shell.

On the upper shell **34**, the lead-in bars **101** are connected to the bus bars **114** and **115** (FIGS. 2 and 27) which extend around the back of the shell to the left side where cables **133** and **134** connect the bars to another set of connectors **135** and **127**, respectively, passing through the vessel. The cables accommodate up-and-down movement of the shell during normal furnace operation, and may be disconnected when the upper shell is to be slide out through the front door during servicing. Herein, the cables **125** and **133** are hot lines and the cables **126** and **134** are grounded. This is indicated in FIG. 29 wherein the four heating grids are shown schematically as resistors connected through the cables **125** and **133** to hot terminals **135** and through cables **126** and **134** to a common ground terminal **127**.

From the foregoing, it will be seen that the internal components of the retort **11**, including the shields **35** and **37** and the heating elements **17-19** are mounted compactly within the baskets **77** for quick and easy removal from the associated shells for servicing or for replacement by other assemblies. Moreover, the two heating grids in each shell are replaceable as units without disturbing the shields. For manufacturing economy, the two shells, the shields therein, and the heating grids are made identical in size and shape thereby reducing the number of different fabrication parts and facilitating mass production, and also simplifying the servicing of the furnace.

For optimum uniformity of heating of the work **14** at rapid rates, the invention contemplates a novel configuration of the heating elements **17-19** and arrangement of the elements relative to the innermost reflecting shields **35** and **37** to produce substantially uniform radiation intensity close to the elements. For this purpose, each of the heating bars is elliptical in cross-section to provide oppositely facing convex side surfaces **140** (FIGS. 17 and 18) facing inwardly toward the work and outwardly toward the shield, and the elements are spaced preselected distances from each other and from the shields to heat spaced areas of the work primarily by direct radiation and heat the intervening areas at substantially the same rate with the assistance of reflected radiation.

The optimum elliptical shape is shown in FIGS. 17 and 18 wherein it will be seen that the width of the bars is substantially greater than twice the thickness, and that the center of curvature *a* (FIG. 17) of each bar side surface **140** is spaced a substantial distance beyond the opposite side of the bar. In FIGURE 18, it will be seen that the shields are placed close to the lines defined by the centers of curvature of the inwardly facing sides **140** of each row of bars, about one-half the bar width from the outwardly facing side, and that adjacent bars of each grid are spaced apart a distance the same as the bar width. Moreover, the heaters are centered between the shields and the work load **14**. According to the well known laws regarding radiation intensity, the intensity drops sharply as the distance from the source increases (specifically, in accordance with the square of the distance), and also decreases as the angle of incidence of the radiation is reduced. Consequently, the area of the work beside the central portion of each bar, and closest to the bar as indicated by the length of the arrows **141** in FIG. 18, will be heated directly to the greatest extent as a result of both the close spacing and the angle of incidence. The areas of the work opposite the side portions of the bar will be heated directly to a lesser extent due to the increasing distance from the convex radiating surface **140**, and also due to the decreasing angle of incidence. By making the radiating surface relatively flat (as compared to a cylindrical surface of equal thickness), this variation in direct radiation, in areas opposite the bars, is minimized.

In addition, however, the combination of the substantially flat shields with the convex outside radiating surfaces **140** results in the heating of the intermediate areas of the work by reflected heat that combines with the direct radiation to bring these intermediate areas quickly up to substantially the same temperature as the areas directly opposite the bars. The radiation from the outer surfaces, considered as traveling along straight lines from point sources on the surfaces, is dispersed in the manner indicated by the arrows **142** and **143** in FIG. 18 and reflected back between the bars as at **144** and **145** to cover the intermediate areas of the work. The result is greater uniformity close to the grids where the intensity is greatest and where the work may be heated rapidly to the desired temperature, this arrangement thus approximating the heating effect of a solid-sheet resistor. At the same time, the heating bars **17-19** are of substantial thickness for durability and long life in service use. It should be understood that FIGS. 17 and 18 illustrate the optimum configuration and spacing of the bars, and that it is possible to obtain improved heating uniformity with elliptical bars of somewhat different curvature—for example, with sides formed with a larger radius of curvature—and also with bars spaced somewhat farther apart and from the shields. Of course, as the distance between the work and the elements increases, intensity falls off sharply so that more time must be spent in heating.

In view of the relatively large cross-sectional area of the heating bars, the resistance is relatively low, and a low-voltage source is used to produce a high rate of current flow and generate heat at the desired rate. For example, the input voltage may be on the order of 60 volts derived through a step-down transformer (not shown) from the usual 220 volt supply. Moreover, the large radiating surface area provided by the grids in each shell maintains a low power density at the surfaces of the elements.

The hearth **15** (See FIGS. 3, 4 and 13) for supporting the work in the heating chamber **13** comprises a series of elongated hearth bars that are spaced above the level of the horizontal portions of the lower U-shaped heating bars **17** and have upper surfaces disposed in a common horizontal plane. The hearth bars are composed of high-temperature metal, herein molybdenum, and are provided with ceramic caps **147** for applications in which there is a danger of damage as a result of placement of metal work-

baskets directly on the metal bars. As shown in the drawings, such caps may take the form of elongated blocks of the same width as the hearth bars, and formed with rounded upper surfaces for engaging the workbasket and depending longitudinal ribs **148** (FIGS. 12, 13 and 14) fitting loosely into longitudinal grooves **149** in the tops of the hearth bars to hold the blocks removably in place. Herein, there are four such blocks arranged end-to-end on each bar. Under appropriate circumstances, the blocks are removed so that the work rests directly on the bars **15**.

Supporting the bars **15** above the lower heating bars **17** are a plurality of upright posts **150** which extend downwardly through the heating grid, the several shields **35** and the basket **77** and are supported on the lower wall **39** of the shell. As shown most clearly in FIGS. 12-14, the posts comprise central molybdenum tubes **151** fitting at their upper ends into recesses in the undersides of the hearth bars adjacent the ends thereof and telescoped at their lower ends into upright sleeves **152** of suitable high-temperature metal. Each such sleeve is welded to a square plate **153** that is fitted into one of the elongated upwardly opening channels **108** fastened to the underside of the basket. As shown in FIG. 12, each channel is formed with flanges **154** that abut against the bottom of the basket **77**, and pins **155** having heads **157** below the flanges extend upwardly therethrough with washers **158** locked on the pins above the screen. The two channels support two rows of hearth posts beneath the opposite end portions of the hearth bars, the supporting plates **153** being spot-welded to the channels to hold each post in a centered position between two heating bars **17**.

To protect the metal tubes **151** against exposure to direct radiation from the heating bars **17**, an insulating ceramic sleeve **159** is telescoped onto the upper portion of each tube and covers the latter between the hearth bars **15** and the supporting sleeves **152**, the ceramic sleeves extending through the innermost shield **35** and preferably somewhat farther into the shielding. A washer **160** on the insulating sleeve above the inner shield covers the clearance left between the shields and the post to permit shifting of the shields during heating and cooling, and a ceramic washer **164** in the bottom of the supporting sleeve prevents metal-to-metal contact between the tube and the plate **153**, thereby spreading and distributing the heat conducted through the tube and the plate to the shell **33**.

The escape of heat from the retort **11** to the vessel **12** is prevented by novel water jackets which cover the shells **33** and **34** and form a plurality of elongated conduits **161** (FIG. 6) having open, relatively wide sides facing toward and covered by the shells whereby the conduits carry separated flows of cooling fluid around the shells in direct contact with a major portion of each shell. As shown most clearly in FIGS. 5-8, the conduits are V-shaped grooves formed by corrugations **162**, **163**, in a sheet of impermeable material laid over the outer sides of the shell and substantially coextensive with the shell sides with one generally rectangular sheet covering each end wall of the retort and one U-shaped sheet covering the remainder of the shell. The corrugations **163** in the end sheets are vertical and have open upper and lower ends communicating with headers **164** formed by transverse horizontal ridges in the corrugated sheet extending across the upper and lower edge portions of the sheet, which is sealed to the end wall by continuous, fluid-tight marginal welds and also is sealed around the lead-in holes **102** and spot-welded to the sheet at spaced points along the inner ridges **165** abutting against the shell between adjacent conduits, as illustrated in FIG. 6. These ridges need not be perfectly sealed to the shell. Similarly, the corrugations **162** in the U-shaped sheet define conduits extending along U-shaped paths from near one side edge around the shell to the other side edge and having open ends opening into headers **167** formed by transverse or horizontal ridges extending along the side edges, this sheet also being sealed to the shell

around its edges and around the holes 102 and spot-welded along the inner ridges 165 abutting against the shell.

Each header 164 and 167 is provided with a flow pipe 168 for connection to an outside circulation system for forcing a suitable coolant, usually water, through the jackets at a relatively high rate to cool the shells during heat treating. For example, 30-40 gallons per minute may be forced through each shell. In FIG. 2, the circulation system is shown as including supply and return pipes 169 and 170, respectively, for the lower shell 33 entering the vessel 12 on the lower right side. The supply pipe feeds two flexible hoses 171 and 172 carrying water to the inlet headers which are at the lower edge of the front end wall and at the right side of the U-shaped section. The flexible supply hoses lead into pipes 173 and 174 leading to the flow pipes on the headers, and are connected to the supply pipe by joints at 175 (see FIG. 26) which enable the operator to disconnect the hoses manually in a simple and rapid operation preparatory to sliding of the lower shell out of the furnace. The return pipe 170 receives water from two flexible return hoses 177 fastened to the pipe at quick-disconnect joints 178 and communicating through piping 179 with the flow pipes of the outlet headers, the upper header on the end wall and the left header on the U-shaped section. Thus, water forced into the vessel through the supply pipe 169 fills the two inlet headers and flows through the conduits to the outlet pipes thereon.

Water for cooling the upper shell 34 enters and leaves the vessel 12 through pipes passing through the rear head 22. One pipe 180 (FIGS. 3 and 25) feeds water into a flexible and extensible hose 181 fastened to the lower flow pipe 168 on the rear wall 38 of the retort 11 to flow upwardly to the upper header 164 from which it exits into a hose 182 and a pipe 183. Another supply pipe 184 feeds the header 167 on the right, as viewed in FIG. 2, with water that flows around the U-shaped section and out of the other header through a hose 185 at the front of the header and a return pipe 187 extending to the rear and out through the head 22.

To insure that the coolant circulates in the water jackets over all of the cooled areas of the shells, the conduits are divided into banks of several conduits each and means are provided for directing the coolant from one bank to the next to flow back and forth along zigzag paths from one header to the other while progressing from the inlet pipe to the outlet pipe, this being indicated by the arrows in FIG. 18^a. Herein, this is accomplished by dams or weirs 167^a partially or fully closing the headers between adjacent banks of conduits and staggered longitudinally of the shell in a manner similar to the arrangement of the heating bar clamps 85. Thus, the flow from the inlet pipe on the right in FIG. 18^a fills the first bank of conduits with water which crosses the shell to the other header and then flows into the next bank to recross the shell, continuing in this manner to the opposite end of the shell and the flow pipe communicating with the header on the left side.

It will be evident that the flow path may be designed for the entry and exit of coolant on the same side of the shell, if desired, and that other variations are possible. With similar weirs or complete blocks (not shown), an up-and-down zigzag flow is provided in each end wall jacket. With the foregoing arrangement, the corrugated sheets reinforce and provide cold support for the entire shell structure, and distribute the flows of coolant over virtually all of the outer surface of each shell for a positive cooling action. Accordingly, the shells are effectively maintained at low temperatures during heating, and this facilitates the rapid cooling of the work during quenching. Moreover, it will be seen that the effective internal cooling eliminates the need for direct cooling of the vessel and its heads.

To quench the work after it has been heated to the desired temperature, the retort 11 is opened by raising the

upper shell 34 away from the lower shell 33 and thereby forming elongated circulation ports 188 (FIGS. 7, 30 and 31) along both sidewalls and ports 189 across both end walls, and quenching fluid is injected into the retort and directly against the work therein. For this purpose, an elongated spray pipe 190 is disposed along each side of the retort as shown in FIGS. 2, 4 and 30 and centered on the spaces between the shells when the retort is open, each pipe being formed with longitudinally spaced nozzles 191 (see FIG. 4) for directing jets of fluid into the chamber 13 and against the work 14. Herein, three rows of nozzle holes are drilled through the pipe, one row of holes opening horizontally toward the retort and the other two rows being angularly spaced from the first row to incline quenching jets into the chamber at angles of approximately thirty degrees above and below horizontal as indicated by the arrows in FIG. 30. The quenching fluid, argon for example, is stored under pressure in a bottle or tank (not shown) outside the furnace and preferably is maintained in liquid state for delivery to the spray pipes 190 through inlet pipes 192 extending through the opposite sides of the vessel. The inlet pipes deliver the fluid to the spray pipes at the longitudinal midpoints thereof, and suitable valving (not shown) controls the flow from the source into the inlet pipes.

When quenching gas in the liquid state is directed into the evacuated furnace 10 through the spray pipes 190, the liquid immediately vaporizes as it enters the retort 11 and circulates around the work 14. In changing phase from liquid to gas, of course, the quenching fluid becomes substantially cooler than its storage temperature. Thus, even if the liquid is stored at room temperature, the temperature of the expanding gas as it is about to impinge against the work may be as low as -80 degrees F. For an even lower initial quenching temperature, the liquid may be refrigerated in storage and delivered to the retort at a temperature considerably below room temperature. In this manner, the temperature of the work is reduced rapidly below the critical range by cold gas impinging against and circulating around the work in the retort. It will be seen that the gas is not brought into contact with any heated parts of the furnace but, instead, is injected directly into the retort and against the work for optimum results. After taking on heat from the work, the gas escapes from the retort through the ports 188 and 189 and fills the vessel. Preferably, a flanged tube 193 (FIGS. 2 and 30) is disposed between the inner end portion of each inlet pipe and the associated spray pipe to receive the flow of coolant from the inlet pipe and guide the liquid into the spray pipe. At the same time, the action of the liquid entering the flanged and flared end 194 of the tube draws or aspirates gas from outside the retort back into the latter through the tube. This recirculates a substantial portion of the gas through the retort as long as liquid is supplied to the nozzles. A pressure relief valve 195 is mounted on the vessel to release gas to the outside when the pressure attains a level on the order of 2-5 p.s.i.

For operating economy, particularly when the quenching fluid is relatively expensive, the furnace may be charged with gas in the manner described above to cool the work quickly below the critical range as the vaporizing fluid is sprayed on the work, and the gas leaving the retort is collected in an outlet duct 197 (FIGS. 1, 2 and 31), cooled in a heat exchanger 198 outside the vessel 12 and then returned to the retort by an outside blower 199 through a diffuser 200 for directing the cooled gas through the rear port 189 and against the work. The outlet duct opens into the top of the vessel adjacent the front end thereof (see FIG. 1) and leads rearwardly to the upper end of the heat exchanger which is housed in a vertical cylindrical case at the rear end of the furnace. In passing through the exchanger, the gas flows over suitable heat transfer components (not shown) such as water-cooled fin tubing, and also over the inner wall of the cylindrical case which is formed as a water jacket.

Coolant enters and leaves the exchanger through pipes 201 as indicated in FIG. 31.

At the lower end of the heat exchanger 198 is the blower 199 which draws gas from the exchanger through a duct 202 (FIG. 31) and then redirects the gas into the retort through the diffuser 200 and the rear head 22. In the diffuser, the cool gas expands and is directed into the open rear end of the retort to flow through the latter, around the work, and then back into the duct 197 for recirculation. A selectively operable gas supply also may be provided between the blower and the diffuser.

All of the components of the recirculation system are open continuously to the inside of the furnace and are vacuum-tight so as to be evacuated with the furnace at the beginning of the treating operation. This insures that there is no oxygen in the system to be directed against hot work, which could be ruined by oxygen in the initial charge of recirculated gas. If any leak develops in the system, it prevents the attainment or maintenance of the desired vacuum level and thus will be detected by the usual instruments provided on such furnaces.

The furnace 10 is provided with suitable automatic controls for the operation of the vacuum pumping apparatus 28, the energization of the heating elements 17-19, the flow of coolant, and the quenching of the work, all in accordance with a preselected program providing the desired sequence of operations. In a typical sequence, starting with the furnace deenergized for loading, the water supply for the water jackets of the two shells 33 and 34 and the vacuum pumps are shut off and the heating elements are deenergized. The furnace door 21 is opened by releasing the clamps 27 and swinging it away from the vessel 12, and the water hoses 171, 172 and 177 are disconnected manually at the joints 175 and 178 to free the lower shell for movement out of the vessel. If the upper shell is in its lowered position, it may be raised away from the lower shell by activating the pump 59 to deliver pressure fluid through the control valve 61 to the lower or rod end of the cylinder 57.

To load the retort 11, the lower shell 33 is released by disengaging the latch arms 51 from the pins 53 and is pulled out of the vessel as permitted by the sliding connection with the telescoping frame 41 and the sliding support of the frame on the lower wall of the vessel. As shown in FIG. 1, the shell slides completely out of the furnace for quick and easy top-loading of the shell. Even very delicate assemblies may be carefully positioned in the shell without need for special handling equipment. With the work in place, the shell is pushed back into place beneath the upper shell and is latched in place. Then the water hoses are reconnected, the door 21 is closed and sealed, and the retort is closed by returning the upper shell to its lowered position, preferably with a control which initiates the automatic cycle.

Evacuation of the vessel 12 by the vacuum pumps 30 and 32 may be completely automatic, starting with the activation of the mechanical pump to reduce the pressure to a low level such as 100 microns of mercury or less. Then the diffusion pump reduces the pressure to the level required during heating, for example, 1-10 microns. In some instances, a partial pressure of treating gas will be admitted into the furnace to reduce the vapor pressure of the work. When the required artificial atmosphere has been attained, the heating elements 17-19 are energized to begin heating the work to the desired temperature. The power input to the heaters also may be varied automatically in a manner well known in the art.

As the heating elements begin to generate heat, the convex side surfaces 140 radiate heat both inwardly toward the work 14 and outwardly toward the shields 35 and 37 which reflect most of the heat back toward the work. The inner shield also is heated, however, by the portion of the radiation that is absorbed and thus, in turn, becomes a source of radiant energy for heating the work.

By using very thin shields, the time lag before such secondary radiation becomes effective is reduced. In addition to radiating toward the work, each inner shield also radiates outwardly toward the second shield which reflects most of the radiation and becomes heated by that which is absorbed. This process continues outwardly through the shielding to the shell wall which is cooled by the jacket surrounding it.

When an equilibrium condition is established, there is a progressive temperature drop through the successive shields to the shell so that the shields form a heat barrier and the coolant in the water jackets carry away the heat that escapes. The circulation of water through the jackets may be initiated automatically in response to the attainment of a predetermined temperature such as 150 degrees F.

When the work has been heated uniformly to the required temperature, the heating elements 17-19 are deenergized to terminate heating. Then the work 14 may be cooled slowly in the furnace 10 in some instances, or may be quenched rapidly with quenching fluid injected through the spray pipes 190. For the rapid quench, the retort is opened by raising the upper shell 34 away from the lower shell 33, and delivering fluid to the spray pipe through the valving previously mentioned for injection into the retort to impinge directly against the work. Both the opening of the retort and the supply of quenching fluid preferably are controlled automatically as part of the preselected sequence of operations.

If the recirculation system is to be used, the gas supply is terminated when the internal pressure attains a preselected level, and the blower 199 is energized to begin drawing gas from the vessel 12 through the duct 197 and the heat exchanger 198 and forcing the gas back into the retort 11 through the port 189 in the rear end thereof. The flow of coolant through the exchanger is initiated along with operation of the blower.

Upon completion of the quenching operation, the door 21 is opened for removal of the completed work load and insertion of another load to be treated. Again, the lower shell 33 is released, the water hoses 171, 172 and 177 are disconnected and the shell is pulled out of the furnace for convenient handling of the work.

I claim as my invention:

1. In a heat treating furnace, the combination of, a vacuum-tight vessel having a loading door at its front end; selectively operable means for evacuating said vessel; a box-like retort disposed within said vessel and comprising upper and lower shells composed of heat-conducting sheet material and cooperating to define an enclosed heating chamber; said lower shell having an upright front wall adjacent said door, a generally horizontal lower wall forming the bottom of said retort, lower sidewalls extending upwardly from the sides of said lower wall part way to the top of said retort, and an open rear end; said upper shell having a generally horizontal upper wall spaced above and overlying said lower shell to form the top of said retort, an upright rear wall depending from the rear end of said upper wall and closing the rear end of the retort, upper sidewalls depending from the sides of said upper wall and cooperating with said lower sidewalls to close the sides of the retort, and an open front end covered by said front wall; means supporting said shells in said vessel for relative vertical movement to separate the shells and open ports into said chamber for circulation of quenching fluid therethrough; means supporting said lower shell on said vessel for generally horizontal movement from beneath said upper shell and through said door when the latter is open into a forwardly extended position to receive work to be treated, and then back beneath the upper shell to carry the work into the chamber; jackets surrounding the outer sides of said upper and lower shells and each comprising a series of elongated open-sided conduits fastened to said shells with the open sides of the conduits closed by said sheet material whereby the conduits conduct

cooling fluid around the sheet material in direct contact with the latter, said conduits being arranged in closely spaced side-by-side relation to cover substantially all of said sheet material with cooling fluid; a first series of spaced U-shaped radiation shields nested within each of said shells, each shield having three generally flat sides covering the horizontal and side walls of the shell; a second series of flat radiation shields in each shell spaced apart and covering the end wall thereof and cooperating with the associated U-shaped shields to block direct radiation of heat from said chamber to said sheet material; a first series of heating elements in the form of U-shaped bars nested within each of said shells, each element having a central horizontal portion and upright end portions spaced inwardly from and generally paralleling the flat sides of the innermost U-shaped shield in the shell; a second series of heating elements in each shell in the form of substantially straight bars spaced inwardly from and extending along the innermost shield of each series of flat shields; means supporting said shields and said heating elements on the respective retort shells for movement therewith relative to the other shell whereby each shell and its associated parts constitute a unitary assembly; a generally horizontal hearth spaced above the horizontal portions of the U-shaped heating elements of said lower shell for holding the work within said chamber; supports for said hearth fastened to said lower shell and extending through the shields therein to said hearth; a set of electrical conductors extending through each shell and the shields therein to said heating elements; and means disposed alongside said retort for injecting quenching fluid into said chamber and directly against the work therein when said shells are separated.

2. The combination defined in claim 1 in which said bars are of generally elliptical cross section with convex sides facing toward said shields and into said chamber, and are spaced apart along each shield distances approximately equal to the width of the bars.

3. A heat treating furnace as defined in claim 2 in which said innermost shields are spaced a preselected distance from the outer sides of said bars to lie approximately on the centers of curvatures of the inner sides of said bars, and said hearth is positioned to support the work with the surfaces thereof approximately said preselected distance from said inner sides of the bars.

4. A heat treating furnace as defined in claim 1 in which said supporting means for said shields and said heating elements include a basket composed of screen material shaped to fit closely within each shell, fasteners supporting the baskets on the shells, hangers on said baskets extending through said shields to said elements, clamps fixing said elements to said hangers, pins distributed around each basket and extending loosely through the latter and the shields, and spacers on said pins holding the shields and the baskets in spaced relation with each other.

5. A heat treating furnace as defined in claim 1 in which said injecting means are elongated spray pipes on opposite sides of said retort level with the ports between said side-walls when the shells are separated and each formed with longitudinally spaced nozzles for directing quenching fluid into the retort and against the work therein.

6. A heat treating furnace as defined in claim 1 in which said means supporting said shells for relative vertical movement comprise a frame disposed above said upper shell, an elevator mechanism for raising and lowering said frame, and means supporting said upper shell on said frame for vertical movement with the frame and also for horizontal sliding thereon toward and away from said door.

7. A heat treating furnace as defined in claim 1 in which said supporting means for said lower shell comprise a frame disposed beneath said retort and slidably supported on said vessel for front-to-rear movement toward and away from said door between extended and retracted positions, and means slidably supporting said lower shell on said

frame for movement relative thereto into an extended position projecting forwardly beyond the extended position of said frame.

8. In a heat treating furnace, the combination of, a vacuum-tight vessel, a retort disposed within said vessel and comprising upper and lower shells cooperating to define an enclosed heating chamber, said lower shell having an upright wall closing one end of said retort and having a first section of upwardly facing concave cross section extending horizontally inwardly therefrom, and said upper shell having a second section of downwardly facing concave cross section overlying said first section and having an upright wall closing the other end of said retort, means supporting said shells in said vessel for relative vertical movement to separate the shells, means outside said retort for directing quenching fluid into said chamber when said shells are separated, a first series of spaced radiation shields of corresponding concave cross section nested within the concave section of each shell and covering the inner surfaces thereof, a second series of spaced radiation shields covering the upright wall of each section and cooperating with the shields of said first series and the shields in the other shell to block direct heat radiation from said chamber to said shells, a first series of correspondingly concave heating elements nested within the concave shields of each section and spaced inwardly from the innermost shield thereof, a second series of heating elements in each shell overlying and spaced inwardly from the innermost shield of said second series, and means supporting said shield and said heating element on the associated shells for movement therewith relative to the other shell.

9. In a heat treating furnace, the combination of, a vacuum-tight vessel having a loading door at its front end, a retort disposed within said vessel and comprising upper and lower shells cooperating to define an enclosed heating chamber, said lower shell having an upright front wall adjacent said door closing the front end of said retort and having a first section of upwardly facing concave cross-section extending horizontally rearwardly therefrom, and said upper shell having a second section of downwardly facing concave cross section overlying said first section and having an upright rear wall closing the rear end of said retort, means on said lower shell defining a hearth within said first section, means supporting said lower shell on said vessel for movement from beneath said upper shell and out through said door when the latter is open into an outwardly extended loading position and then back beneath said upper shell, a first series of spaced radiation shields of corresponding concave cross section nested within the concave section of each shell and covering the inner surfaces thereof, a second series of spaced radiation shields covering the upright wall of each section and cooperating with the shields of said first series and the shields in the other shell to block direct heat radiation from said chamber to said shells, a first series of correspondingly concave heating elements nested within the concave shields of each section and spaced inwardly from the innermost shield thereof, a second series of heating elements in each shell overlying and spaced inwardly from the innermost shield of said second series, and means supporting said shields and said heating elements on the associated shells for movement therewith relative to the other shell.

10. In a heat treating furnace, the combination of, an outer vessel having a loading door, a retort disposed within said vessel and comprising two shells each having a portion of generally U-shaped cross section, said shells being fitted together in side-by-side relation and opening toward each other to form the sides of a heating chamber, end walls on said shells closing the ends of said heating chamber, and means supporting said shells in said vessel for relative movement away from each other to open said chamber for circulation of quenching fluid therethrough and also supporting one of said shells for endwise move-

ment away from the other and toward said door to facilitate the insertion of work into said chamber.

11. The combination defined in claim 10 further including a series of spaced, generally U-shaped reflecting shields nested in each of said U-shaped portions and conforming to the shape thereof, said shields being supported on the associated shell for movement therewith relative to the other shell.

12. The combination defined in claim 11 further including a grid of elongated U-shaped heating bars disposed in generally parallel planes and nested in the innermost shield of each series, said bars being spaced inwardly from said innermost shield and supported on the associated shell for movement therewith relative to the other shell.

13. The combination defined in claim 12 further including an additional series of spaced reflecting shields covering each of said end walls, and a grid of side-by-side heating bars spaced inwardly from the innermost shield of each additional series whereby all of the walls of said retort are lined with shields and covered by grids of heating bars.

14. The combination defined in claim 13 in which said bars are of elliptical cross section providing oppositely facing convex sides facing outwardly toward said shields and inwardly into said chamber, adjacent bars of each grid being spaced apart a distance approximately equal to the width of the bars and being spaced from said innermost shields a distance substantially less than said width.

15. The combination defined in claim 10 further including a generally U-shaped jacket mounted on and surrounding each of said shells and having means thereon for carrying cooling fluid in direct contact with a major portion of the outer side of the shell.

16. The combination defined in claim 15 further including a jacket mounted on the outer side of each of said end walls and having means thereon for carrying cooling fluid in direct contact with a major portion of the end wall.

17. In a heat treating furnace, the combination of, a vacuum-tight vessel having a loading door at one end, a retort disposed within said vessel and comprising first and second relatively movable shells defining an enclosed heating chamber, said shells having sections of generally U-shaped cross section disposed in opposed side-by-side relation and said retort having end walls cooperating with said U-shaped sections to enclose said chamber, means supporting said shells in said vessel for relative sidewise movement away from each other to open said chamber for circulation of quenching fluid therethrough, means supporting said first shell for endwise movement out of side-by-side relation with said second shell and out of said vessel through said door when the latter is open and into an outwardly extended loading position, means on said first shell for holding work to be treated and carrying the work into said chamber as the first shell moves back into said vessel, spaced radiation shields nested within each of said shell sections and covering the inner surfaces and said end walls, heating elements within each shell spaced inwardly from the shields thereof, and means supporting said shields and said heating elements on the associated shells for movement therewith relative to the other shell.

18. In a heat treating furnace, the combination of, a vacuum-tight vessel having a loading door, a retort disposed within said vessel and comprising first and second relatively movable shells defining an enclosed heating chamber, means supporting said first shell in said vessel for endwise movement out of side-by-side relation with said second shell and toward said door into an extended loading position, means on said first shell for holding work to be treated and carrying the work into said chamber as the first shell moves back into side-by-side relation with said second shell, means lining said shells and forming a heat barrier and covering the inner surfaces thereof, heating elements within each shell spaced inwardly from the

heat barrier means thereof, and means supporting said heat barrier and said heating elements on the associated shells for movement therewith relative to the other shell.

19. In a heat treating furnace, the combination of, an outer vessel having a loading door, a retort disposed within said vessel and comprising first and second relatively movable shells fitted together in side-by-side relation to define a heating chamber, means supporting said shells in said vessel for relative sidewise movement along one path away from each other to open said chamber for circulation of quenching fluid therethrough and supporting said first shell for endwise movement along a different path and away from said second shell into a loading position spaced from said second shell, means lining said shell sections and forming a heat barrier along the walls thereof, heating elements within each shell and spaced inwardly from said heat barrier, and means supporting said heat barrier and said heating elements on the associated shells for movement therewith relative to the other shell.

20. In a heat treating furnace, the combination of, a retort comprising a pair of relatively movable shells of oppositely facing concave cross section fitted together in side-by-side relation to define an enclosed heating chamber, correspondingly concave means lining each of said shells and forming a heat barrier therein, a set of correspondingly concave heating elements in each shell inside said lining means for heating work in said chamber, and means on each of said shells securing said elements and said lining means to the associated shell for movement therewith relative to the other shell.

21. In a heat treating furnace, the combination of, a retort defining a heating chamber, a series of elongated generally parallel heating elements of preselected width in said heating chamber spaced inwardly from a wall of said retort, and a reflecting shield disposed between said wall and said heating elements to reflect radiation from said elements back into said chamber, said elements being of generally elliptical cross section, with convex sides facing outwardly toward said shield and inwardly toward said chamber, and said elements being spaced apart a distance approximately equal to the width of the elements.

22. The combination as defined in claim 21 in which said elements are spaced inwardly from said shield a distance equal to approximately one-half the width of the elements.

23. The combination as defined in claim 21 in which the inner sides of said elements are curved about centers disposed adjacent said shield.

24. In a heat treating furnace, the combination of, a retort defining an enclosed heating chamber, substantially flat reflecting shields lining said chamber and covering the walls thereof, and a plurality of elongated heating bars in said chamber arranged in parallel in grid-like groups spaced inwardly from said shields, said bars being of generally elliptical cross section with a width substantially greater than the thickness of the bar and having outer convex sides facing toward the associated shield and inner convex sides facing inwardly into said chamber, and the width of the spaces between said bars being approximately equal to the width of the bars, and the spacing of each bar from the associated shield being less than the width of the bars.

25. The combination defined in claim 24 in which said inner convex sides have centers of curvature disposed adjacent said shields.

26. For use in a heat treating furnace having a retort with a reflective lining, a radiant heating element in the form of an elongated bar having a generally elliptical cross section substantially wider than its thickness and providing oppositely facing convex side surfaces.

27. For use in a heat treating furnace as part of a retort defining a heating chamber, the combination of, an upwardly concave outer shell having a bottom wall, an open top and one open end, up-turned sidewalls at-

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tached to the edges of said bottom wall, and an end wall attached to and closing the other end of the shell, a series of reflecting shields composed of thin and flexible sheet material formed into a concave shape and nested within said shell to cover said bottom and sidewalls, additional reflecting shields covering said end walls, concave heating elements arranged side-by-side in generally parallel planes and nested inside the innermost shield of said series in closed spaced relation therewith, additional heating elements disposed adjacent the innermost end shield; means supporting said shields and said heating elements on said shell, and means on said shell for supporting work to be treated.

28. The combination defined in claim 27 in which said supporting means include a shape-retaining basket of the same shape as said shell between the latter and said shields, means securing said basket to said shell, fasteners on said basket extending through said shields to support the latter on the basket, spacers on said fasteners holding the shields apart, and hangers extending through said shields from said basket and secured to said heating elements to hold the latter in place.

29. The combination defined in claim 28 in which said

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securing means are clips on said basket, and interfitting rails on the inside of said shell for receiving said clips with a slip fit as said basket is slipped into the shell.

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