# United States Patent

[11] **3,565,409**


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## [54] HEAT-TREATING APPARATUS

**9 Claims, 3 Drawing Figs.**


[52] **U.S. Cl.** .......... **266/4,** 134/134

[51] **Int. Cl.** .......... **C21d 1/62**

[50] **Field of Search** .......... 266/4, 4 (A), 6; 148/153; 134/75, 133, 134


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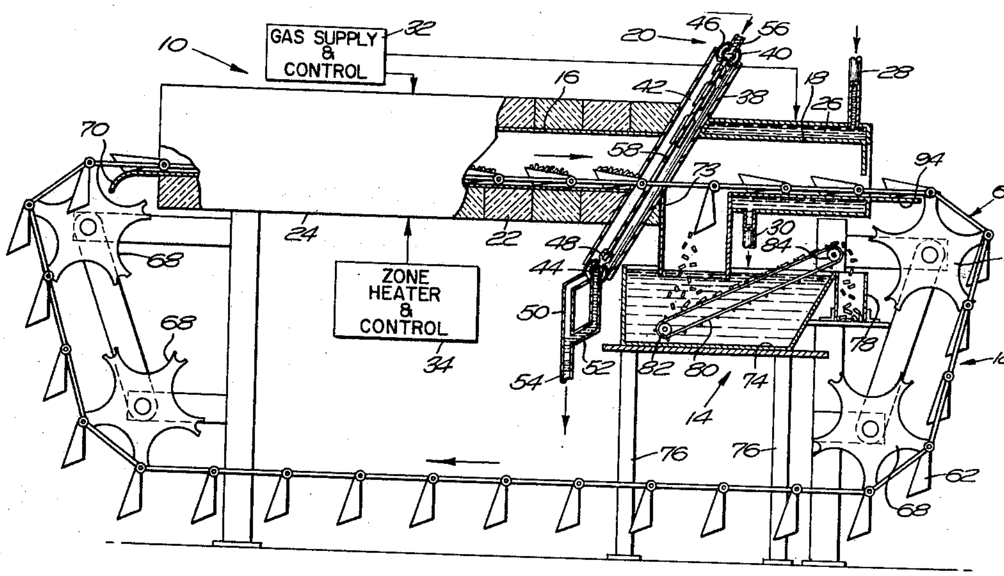
**ABSTRACT:** A furnace for precision heat treatment of materials which permits selective liquid or gas quenching and substantially prevents undesired transitional cooling between heating and quenching phases. The furnace includes a muffle having adjacent zones of individually controllable temperature and gas environments, adjacent zones being separated by a barrier operative to maintain effective temperature and gas isolation as required. Transported by an endless conveyor, the materials being heat treated remain at elevated furnace temperatures for a preselected time, thereafter, depending on the presence or absence of a removable furnace section, the materials enter a chilled continuation of the furnace muffle or are dropped instantaneously into an appropriate liquid quench.

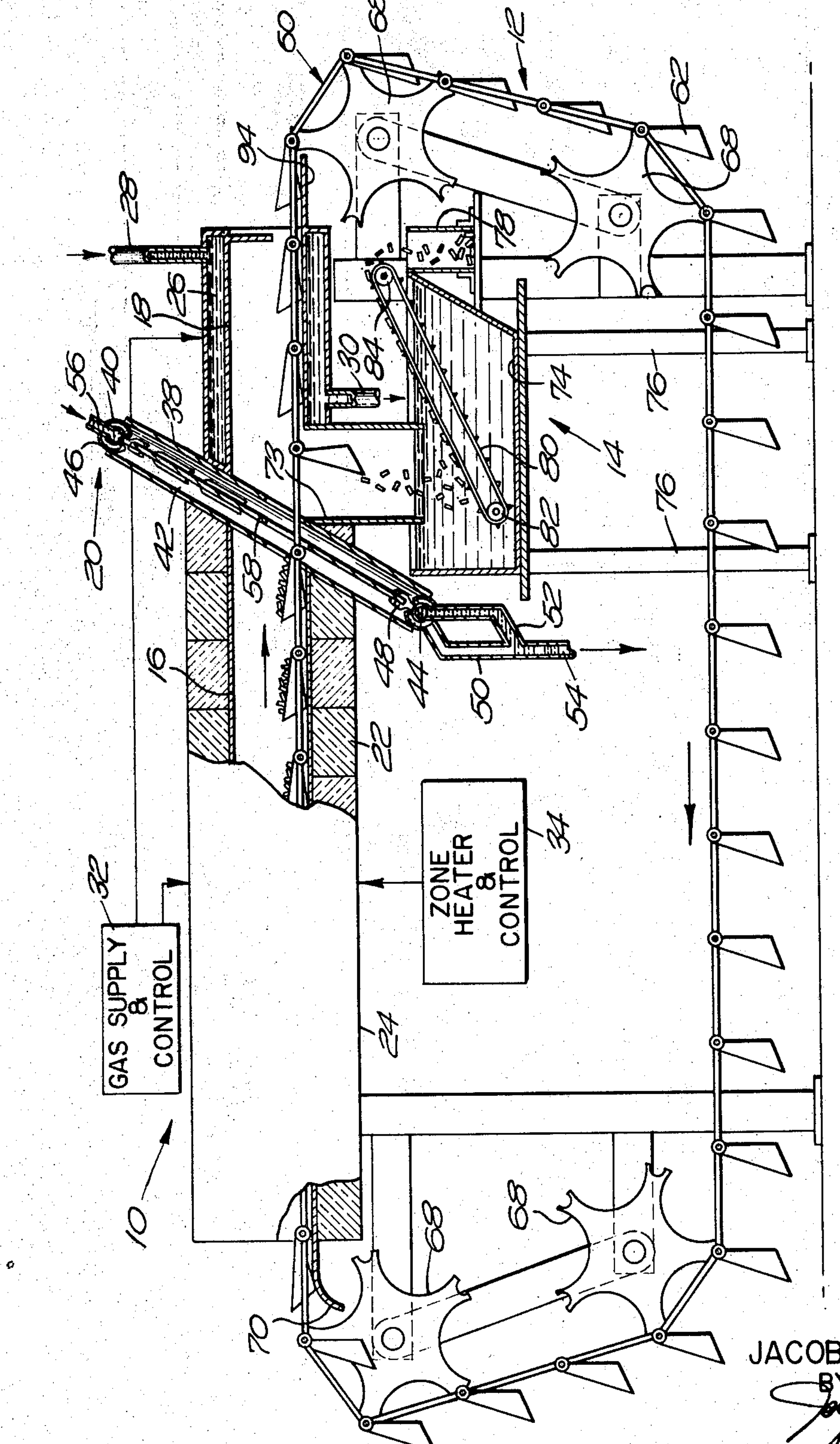



FIG. 1

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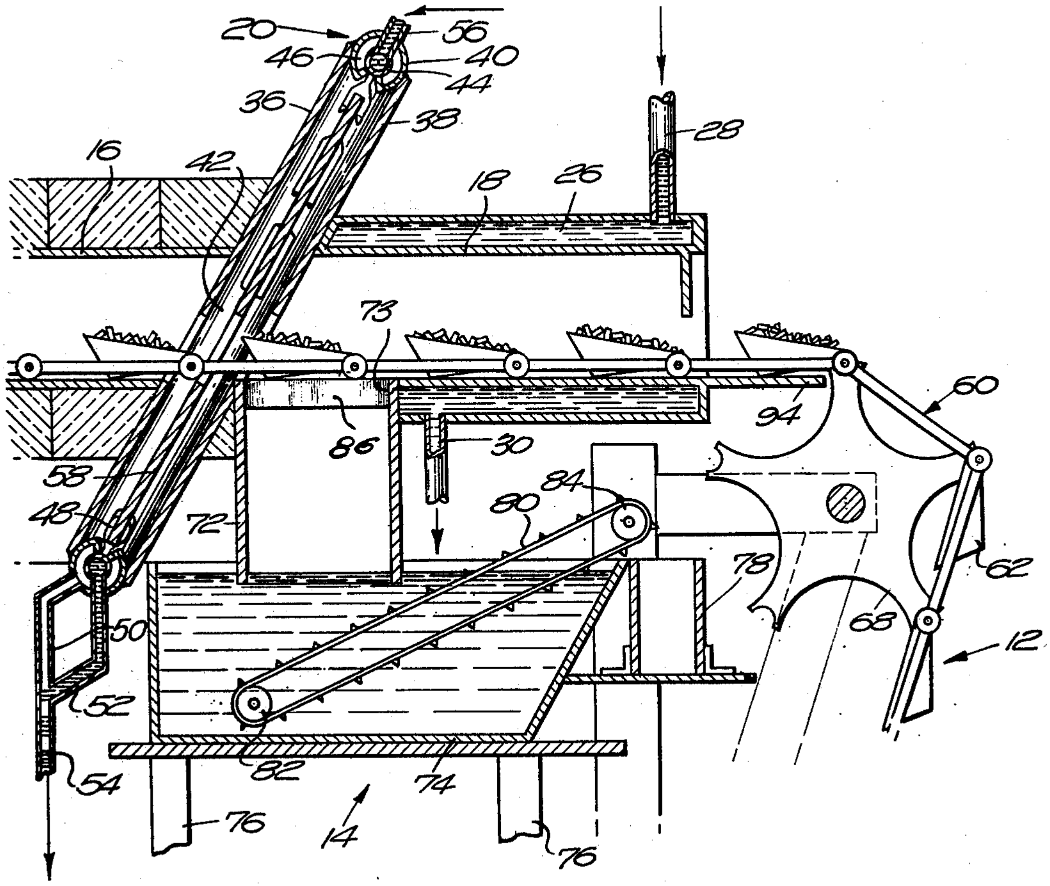


FIG. 2

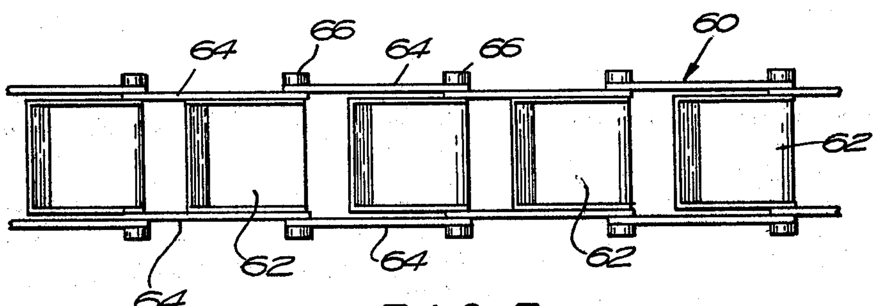


FIG. 3

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# HEAT-TREATING APPARATUS

## FIELD OF THE INVENTION

This invention relates to furnaces for heat treating materials under precisely controlled conditions.

## BACKGROUND OF THE INVENTION

In the heat treatment of various metals it is customary to subject the materials in process to a controlled temperature for a predetermined period of time, followed by a rapid quench in a liquid or gaseous atmosphere. A vast art of empirical data has been developed covering temperature cycling, quench environment, time, atmosphere control and other parameters for each material depending on the properties and characteristics desired. With this has come the development of furnaces for automatic heat treatment to avoid the need for costly batch handling, and as an example, a device known in the art as the shaker-hearth furnace is useful for production heat treatment of small steel parts. This furnace includes a vibratory or oscillatory conveyor which transports the materials being treated through a zone maintained at a predetermined temperature and then deposits the heated materials in a quenching bath. While conventional furnaces are entirely acceptable for the treatment of metal components such as nuts and bolts where critical values and exact reproducibility are unessential, they are generally unsatisfactory in those instances where precise heat treatment is required time after time, for example, in the preparation of precision magnetic metal components or in the hardening of small steel parts to exacting specifications.

The limitations of conventional heat-treating systems can usually be traced to the relatively uncontrolled transitional cooling which occurs in the interval that materials being treated are moved from the heated zone to the quench region. Preferably, the quenching of the materials should occur substantially instantaneously; thus, transitional cooling which is not an intended part of the preset temperature cycle reduces not only the effectiveness of the treating process, but also the high degree of control which is so essential to exact reproducibility.

Furnaces are available for providing a controlled temperature in a defined zone through which materials can be transported for precise heating. However, such furnaces do not provide means for rapidly quenching the heated materials as they leave the heating zone to achieve the intended metallurgical effect. In conventional furnaces, the cooling effect from the time the materials leave the controlled heating zone to the time that the materials are effectively quenched is unduly long, and thus largely unpredictable. As a result of these deficiencies, desired metallurgical characteristics are not easily obtained, and even if an intended result is obtained in a particular instance, this result is often not repeatable by reason of the relatively variable cooling cycle. It is, therefore, a principal object of this invention to provide an automatic production heat-treating furnace wherein materials can be heated to a precise degree and for a precise period of time and then substantially instantaneously quenched under continuous, exact control to achieve a desired metallurgical result.

## SUMMARY OF THE INVENTION

In accordance with the present invention, a furnace is provided having an elongated muffle divided into one or more heated zones of separately controlled temperatures and gaseous environments, followed by a cooled quench zone of separately controlled gaseous environment, adjacent zones being separated by extremely effective heat and/or gas barriers which maintain exact temperature profiles while preventing the transfer of gas from one zone to the other. Transit through the heated muffle zone raises the temperature of the materials under treatment to the desired temperature under a known, preselected atmosphere, while in the quenching zone, novel means are provided for substantially instantaneously transferring the materials being treated to a cooled environment, thereby substantially preventing the occurrence of undesired transitional cooling, as aforesaid.

The novel arrangement for transferring materials from the heated zone to the quench zone includes a conveyor system and a removable bridge section disposed in the floor of that part of the muffle which constitutes the quench zone adjacent the heat barrier, these being cooperative to transfer materials being treated rapidly to either a liquid or gas quench environment, as desired. Although the term "gas quench" is generic to the technique of rapidly cooling a heated metal element in a gaseous atmosphere, the term "air quench" is often used in this art as an equivalent. Thus the term "air quench" will be used herein to denote the quenching of heated materials in any chilled gaseous atmosphere, which may be, for example, air, inert gases such as nitrogen or argon, or reducing gases such as hydrogen, or gases such as ammonia, or a mixture of gases. "Liquid quench" will be used herein to cover the rapid chilling of heated elements in water, oil or the like.

With the aforesaid removable bridge section in place in the muffle floor, the conveyor system transports the heated materials through the heat barrier from the heated zone to the chilled air quench section of the muffle. With the bridge removed, the conveyor discharges the heated elements through the opening in the muffle floor into an appropriate liquid quench.

The conveyor system itself is arranged to transport materials being treated through the several zones of the furnace muffle. The conveyor includes a plurality of hinged trays attached to a movable chain, the trays being arranged to either drop their contents into the quench bath or to convey their contents to the air quench atmosphere, depending upon the presence or absence of the removable bridge section.

The transition from the heated zone to the quench zone in the furnace muffle is achieved by use of an effective heat and gas barrier which defines and preserves a very sharp temperature gradient between zones, and simultaneously prevents comingling of the two gaseous environments in the muffle sections. This barrier generally comprises a short transition muffle section between adjacent furnace zones and may in one form include two large plates respectively welded to the adjacent ends of the muffle sections of each zone. Each plate is provided with an opening which essentially matches the interior cross-sectional configuration of the muffle. The plates are spaced from each other by a closed ring of pipe welded to the peripheral edges of the plates, the plates and the pipe thereby defining an annular chamber. A second pipe is disposed coaxially within the outer pipe and openings are formed in the outer pipe which communicate with the aforesaid annular chamber. The inner pipe functions to carry coolant around the interior of the pipe and is operative to remove heat flowing outwardly through the plates. The flow of the coolant may be also arranged to provide an aspirator effect and exhaust gases within the annular chamber. Finally, a shield is provided to minimize longitudinal heat transfer by radiation, with the result that the heat and gas barrier maintains a sharp temperature gradient between adjacent muffle zones and simultaneously acts to prevent the flow of gas from one muffle zone to the other.

The heat-treating furnace according to the invention employs a barrier of the type generally described above to separate the zones, and the barrier may be disposed at an angle to maintain a desired temperature of the materials to the very point where it is dropped into the liquid quench. Such control of the heating and quenching environments, together with the novel means for rapidly transferring materials from the heat zone to the quench zone, yield a desired, readily reproducible metallurgical result on a volume production basis.

## DESCRIPTION OF THE DRAWINGS

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

FIG. 1 is an elevation view, partly in section, of a heat-treating furnace according to the invention, arranged for liquid quenching;

FIG. 2 is a partial elevation view, partly in section of the heat-treating furnace according to the invention, arranged for air quenching; and

FIG. 3 is a top view of a conveyor useful in the invention.

## DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. 1, there is shown a heat-treating furnace according to the invention adapted to selectively provide rapid liquid or air quenching of heated metals. The illustrated apparatus includes a two zone muffle furnace shown generally at **10**, a conveyor assembly **12**, and a liquid quenching apparatus **14**. The furnace itself is comprised of a first heated muffle zone **16** communicating with and joined to a second or quench muffle zone **18** through a heat and gas barrier **20**. Suitable refractory material **22** is built up around the muffle zone **16** to provide necessary heat insulation, and the muffle and the associated insulation are enclosed within a metal housing **24**.

A liquid cooling jacket **26** is formed around quench muffle zone **18** to provide a predetermined quench temperature. Cold water or other suitable coolant enters jacket **26** through an inlet pipe **28** and exits via an outlet pipe **30** connected to an opposite end of the jacket. The degree of cooling can be controlled by adjusting the rate of coolant flow and the temperature thereof to provide the intended temperature in the quench zone **18**.

The two muffle zones may be of the same cross section, as illustrated, or may be of different cross sections. In the illustrated embodiment, the muffle sections are of generally rectangular cross section.

Each of the zones is provided with means for maintaining a selected atmosphere during the time that materials are being treated within the furnace. The atmosphere in the heating zone may consist of one or more gases, the term gases being used broadly to include substances such as oxygen, nitrogen, hydrogen, ammonia and the like, or suitable vapors as dictated by the heat treatment being performed. The gas supply and control apparatus is denoted diagrammatically by block **32**; specific details are not shown since such apparatus is well known in the art. For example, U.S. Pat. No. 3,086,764, entitled Tandem Furnace, and assigned to the assignee of the present invention, describes details as to how gases are introduced and removed from different stages of a muffle.

The muffle section **16** is heated and maintained at a precisely controlled temperature by means of, for example, conventional electric heating coils or rods (not shown) surrounding the muffle. Alternatively, gas heaters and gas heater controls may be used under certain circumstances. The zone heater and control are denoted by block **34** and are not shown in detail, as these too are well known to the art.

The heat and gas barrier **20** which separates the adjacent muffle zones **16** and **18** comprises two circular plates **36** and **38**, plate **36** being welded to muffle section **16** and plate **38** being welded to muffle section **18**. The plates are provided with central openings which essentially match the interior configurations of the muffle, and are spaced from each other by a circular ring of pipe **40** which is welded to the peripheral edges of the two plates, with approximately half of the exterior surface of the pipe being exposed to the space enclosed between plates **36** and **38**. It will be appreciated that plates **36** and **38** cooperate with pipe **40** to define a chamber **42** between the two plates. A second ring of pipe **44** is disposed coaxially within outer pipe **40**, pipes **40** and **44** defining a chamber **46** therebetween. The inner pipe ring **44** is maintained in fixed relation to the outer pipe ring **40** by means of appropriate spacers welded to pipe ring **40**.

Chamber **46**, which is formed between pipes **40** and **44**, communicates with chamber **42** by means of ports **48** formed in pipe **40**. A pipe **50** is attached to and communicates with chamber **46**, while a second pipe **52** communicates with the interior of pipe **44**, pipes **50** and **52** being connected to a single pipe **54**. The inner pipe **46** is employed to carry a coolant flowing therethrough. The coolant enters pipe **44** via an inlet pipe **56** and exits via pipe **52**. As the coolant exits from pipe **52**, it may be arranged, as in FIG. **1**, to produce an aspirator effect on pipe **50** connected to chamber **46** thereby exhausting gases contained within this chamber and within chamber **42** communicating therewith. Full details of this barrier construction are disclosed in U.S. Pat. No. 3,138,372 entitled Heat-Treating Apparatus, and an alternative arrangement is shown in U.S. Pat. No. 3,179,392, both assigned to the assignee of the present invention.

A circular metal plate **58** is interposed between plates **36** and **38** and is welded on its outer peripheral edge to pipe **40**. Plate **58** has a central opening sized to accommodate the conveyor and to permit passage therethrough of materials supported on the conveyor. This plate is made of metal and functions as a radiation shield, as will be explained hereinafter.

The barrier assembly **20** is tilted as shown with respect to the longitudinal axis of the furnace, as illustrated, and this in effect lengthens the upper and sidewalls of the heated muffle zone **16** and thereby provides requisite heating of materials up to the point of liquid quenching, as will be described. It will be evident, however, that the barrier can also be disposed orthogonal to the axis of the muffle between the heat zone and the quench zone.

The barrier described hereinabove is operative to isolate both the temperatures and the gases in adjacent muffle zones **16** and **18**. In some instances, however, it is only necessary to maintain a selected temperature gradient between zones. For example, in certain heat-treating processes, the gaseous environment in a muffle zone may not be critical, or the same gaseous atmosphere may be employed in all sections of the muffle. In these instances it is not necessary to provide gas isolation and the barrier described herein can be operated to provide only heat isolation by not utilizing the aspirator apparatus associated therewith. Alternatively, a simpler barrier can be employed which provides only temperature isolation. An effective heat barrier which is useful in the present invention is described in U.S. Pat. No. 3,041,056, entitled Heat-Treating Apparatus, and assigned to the assignee of this invention.

Materials to be treated are moved through the furnace by means of conveyor assembly **12** which includes a link chain **60** having trays **62** pivotally mounted thereon, the chain passing through the furnace muffle with the trays **62** being supported in a horizontal material-retaining position by the floor of the muffle. The link chain is shown more clearly in FIG. **3** and includes spaced-apart link members **64**, each pair of link members being pivotally connected to a like pair of adjacent members by pivot rods **66**. Pivotally mounted on each pivot rod **66** is a generally rectangularly shaped tray **62** for retaining the materials to be treated.

The chain link conveyor is driven by suitable motive means (not shown) coupled to one or more of the drive wheels **68**, these drive wheels also serving to retain the chain link for endless movement through the furnace. The chain link and the associated materials contained in the trays may be moved continuously through the furnace or alternatively by an intermittent motion depending upon the requirements of the particular heating operation, as will be discussed.

As seen in FIG. **1**, the trays **62** hang vertically from their mounting pivots **66** as the chain moves externally of the furnace. However, as a particular tray enters the furnace muffle on the left side of FIG. **1**, the tray is cammed to a horizontal position by an extension **70** of the floor of the muffle and is supported in this horizontal position by the muffle floor as the tray moves to the right through the length of the furnace. Materials to be treated are placed in each tray at the entrance end of the furnace after each tray is cammed into its horizontal position by muffle floor extension **70**.

The liquid quench assembly **14**, as shown in FIGS. **1** and **2**, includes a rectangular chute **72** which extends downwardly from and communicates with a generally rectangular opening **73** provided in the floor of muffle zone **18** adjacent barrier **20**. The lower end of chute **72** terminates below the liquid level in a quench bath **74** which is supported in the requisite position by legs **76**. Quenched materials are removed from the quenching bath and deposited in a receptacle **78** by a conveyor mechanism, diagrammatically shown in the form of an endless belt **80** movably supported by rollers **82** and **84**. One end of the conveyor is located well under the surface of the quenching bath while the other end of the conveyor is located above the surface of the quenching liquid and is operative to discharge materials carried from the bath into receptacle **78**. The quenching bath as noted earlier may be oil or water or other suitable quenching liquid useful in a particular heat-treating process.

With reference to FIG. **2**, a removable bridge section **86** is shown as inserted within the rectangular opening **73** provided in muffle zone **18** adjacent barrier **20**. Bridge section **86** conforms closely to the configuration of opening **73** and thus closes off the upper end of chute **72**. Also, as shown, the upper surface of bridge **86** lies in the plane of the upper surface of the floor of muffle section **18**, thus providing a continuous and uninterrupted muffle floor surface throughout the length of the furnace. The means for supporting bridge section **86** have not been shows but any suitable arrangement may be used. This element may be inserted, for example, through a drawer-like support compartment (not shown) at the side of the furnace. As shown in FIG. **2**, the bridge section **86** defines a continuation of the floor of the muffle in the quench zone **18**, and thus the bridge section itself may be hollow and liquid cooled. By suitable piping, not shown, the bridge section may be cooled independently or may be placed in series with the coolant flowing through the water jacket **26**.

FIGS. **1** and **2** serve to illustrate the manner in which removable bridge section **86** may be used to convert the novel furnace from the liquid quench mode shown in FIG. **1** to the air quench mode shown in FIG. **2**. With reference to FIG. **1**, the operation of the invention in providing effective liquid quench of precisely heated materials will now be described in detail. In this mode of operation, bridge **86** is absent; and the opening in muffle zone **18** communicates with liquid quenching bath **74** via chute **72**. Materials to be heat treated are deposited into trays **62** as they enter the left side of the furnace, and these materials are subjected to a prescribed gaseous environment and elevated temperature for a precisely controlled period of time determined by the conveyor rate as the materials pass through muffle zone **16**. Materials reaching barrier **20** pass into muffle zone **18**, and each tray **62** on entering muffle zone **18** passes over the opening **73** provided in the floor of muffle **18**, thereby tipping downwardly into chute **72** and discharging its contents into quenching bath **74**. The drop of the materials into the quenching bath is substantially instantaneous and the transitional cooling effects in zone **18** are therefore absolutely minimal. Furthermore, the operation is easily repeatable since the apparatus functions from tray to tray in precisely the intended manner without change in the process variables encountered in conventional techniques. Conveyor belt **80** is actuated to remove the quenched materials from the quenching bath and to deposit them into receptacle **78**.

Most rapid liquid quenching is achieved when the conveyor is moved through the furnace in an intermittent fashion (by the source of motive power, not shown). The indexing distance is chosen such that a tray **62** in muffle zone **16** adjacent barrier **20** is moved in one indexing motion to a position in zone **18** over the opening **73** associated with chute **72**. In this position, the tray pivots to discharge its contents via chute **72** into quenching bath **74**, and it will be appreciated that the materials being treated are thereby even more rapidly transferred from the heated muffle zone **16** to the quenching bath **74** in one efficient motion which can readily be arranged to occur in an extremely short period. Transitional cooling is thereby minimized by the prompt transfer of materials from the heat zone to the quenching bath. Certain other advantages of the novel furnace operating in the liquid quench mode should immediately be apparent. As is evident from FIG. **1**, tilting the gas and heat barrier extends muffle section **16** to the right to retain the materials in each tray **62** at elevated temperature up to the very point where the intermittent motion, if used, results in discharge of the materials into the quench bath. The various components which are being quenched thus arrive at the surface of the quench liquid at virtually the elevated temperature of the muffle zone **16**. Gas barrier **20** in operation exhausts the fumes which are generated at the surface of the quench bath, thus preventing the passage of such fumes either into muffle zone **16** or into the atmosphere at the right hand side of the furnace.

With reference to FIG. **2**, to operate in the air quench mode, bridge section **86** is secured within the muffle opening **73** as shown and previously described, thereby permitting each tray **62** to move through muffle zone **18** for cooling. In the air quench mode, the conveyor is moved continuously at a uniform rate of speed. The requisite air quench atmosphere is provided within muffle zone **18** by gas supply and control **32**, and the cooling temperature is controlled by suitably adjusting the flow of coolant within chamber **26** to achieve the quenching environment needed in a particular process. As discussed hereinabove, bridge **86** may also be liquid cooled if desired. Thus, for air quenching purposes, the materials being treated are appropriately heated within muffle zone **16**, from which they are conveyed to zone **18** having an abruptly lower temperature and isolated gaseous atmosphere. The trays **62** and the materials contained therein are conveyed through muffle zone **18** and, after leaving the furnace, the materials can be deposited from the dropped tray into a suitable receptacle, not shown, which may be located for example beneath the muffle floor extension **94** on the discharge end of the furnace.

From the foregoing, it is evident that the heat-treating furnace according to the invention provides precise heating of materials and substantially instantaneous liquid or air quench of these materials in a controllable manner to achieve a desired and easily repeatable metallurgical result. The furnace shown is an extremely useful arrangement in precision heat-treating covering in one unit the entire range of alloys from plain carbon steels requiring water quench, through oil quench and alloys requiring air quench. When used in the liquid quench mode, the materials being heat treated are at all times exposed to the gaseous atmosphere of the quench zone **18**, that is, until they fall beneath the surface of the liquid quench. Thus, the transitional cooling period is exceedingly brief, but to the extent that the materials do cool, they do so in a controlled gaseous atmosphere of the quench zone.

The various elements of the muffle may be made of the same type of material to avoid problems of bonding and danger of rupture due to different coefficients of expansion. Typically, the muffle and the heat and gas barrier are made of high temperature stainless steel, which is particularly resistant to gaseous atmospheres which are conventionally employed in muffle-type furnaces. It will be appreciated that various modifications and alternative implementations of the invention may occur to those versed in the art. Accordingly, it is not intended to limit the invention by what has been particularly shown and described, except as indicated in the appended claims.

I claim:

1. A heat-treating furnace comprising:
   - a muffle having an elongated heated zone and a cooled longitudinally adjacent elongated quench zone disposed therein;
   - means for establishing a predetermined elevated temperature and gaseous environment within said heated zone of said muffle;

means for establishing a predetermined cooling temperature and gaseous environment within said quench zone of said muffle;

a barrier disposed between said adjacent zones of said muffle and operative to maintain an abrupt temperature gradient therebetween and to prevent migration of gas from one to the other of said zones;

a conveyor extending through said muffle and adapted to transport materials being treated through said furnace from said heated zone to said quench zone;

a bath of quench fluid disposed beneath the quench zone of said muffle and adapted to receive materials dispensed from said conveyor; and

a removable bridge section adapted to be disposed over an opening in the quench zone of said muffle adjacent said barrier, said conveyor being operative selectively to dispense materials being treated into said quench bath in the absence of said bridge section and to transport materials for a predetermined time through said quench zone of said muffle in the presence of said bridge section over said opening.

**2**. A heat-treating furnace in accordance with claim **1**, wherein said barrier is inclined thereby extending said heated zone over said bridge section.

**3**. A heat-treating furnace in accordance with claim **1**, including a chute extending from said opening in said quench zone into and beneath the surface of said quench bath.

**4**. A heat-treating furnace in accordance with claim **3** and including:

a plurality of trays for said materials being heat treated, said trays being spaced along the length of said conveyor and pivotally attached thereto;

said trays being adapted to pivot into said opening in said quench zone in the absence of said bridge section to dispense said materials through said chute into said quench bath; and

said trays being further adapted to pass into said quench zone with said materials therein in the presence of said bridge section.

**5**. A heat-treating furnace in accordance with claim **4** wherein:

said conveyor is adapted to transport said materials being heat-treated in said trays by intermittent movement through said furnace from said heated zone to said quench zone;

said intermittent movement being arranged to convey each of said trays in succession from a stationary position rapidly through said barrier to a position over said opening in said quench zone;

each of said trays in said last position being thereby adapted to pivot into said chute and dispense said materials therein into said quench bath in the absence of said bridge section.

**6**. A heat-treating furnace as in claim **1** wherein said bridge section may be cooled when disposed over said opening in said quench zone.

7. A heat-treating furnace comprising:

a muffle having an elongated heated zone and a cooled longitudinally adjacent elongated quench zone disposed therein;

means for establishing a predetermined elevated temperature within said heated zone of said muffle;

means for establishing a predetermined cooling temperature within said quench zone of said muffle;

conveyor means adapted to transport materials being treated through said furnace from said heated zone to said quench zone;

a bath for quench fluid disposed beneath the quench zone of said muffle and adapted to receive materials dispensed from said conveyor means; and

a removable bridge section adapted to be disposed over an opening in the quench zone of said muffle, said conveyor means being operative selectively to dispense materials being treated into said quench bath in the absence of said bridge section and to transport materials for a predetermined time through said quench zone of said muffle in the presence of said bridge section over said opening.

**8**. A heat-treating furnace in accordance with claim **7** wherein said conveyor means includes:

a plurality of trays for said materials being heat treated, said trays being spaced along the length of said conveyor means and pivotally attached thereto;

said trays being adapted to pivot into said opening in said quench zone in the absence of said bridge section to dispense said materials into said quench bath; and

said trays being further adapted to pass into said quench zone with said materials therein in the presence of said bridge section.

**9**. A heat-treating furnace in accordance with claim **7** including a barrier disposed between said adjacent zones of said muffle and operative to maintain an abrupt temperature gradient therebetween and to prevent migration of gas from one to the other of said zones.