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Hovis et al.

[11] **3,920,382**

[45] **Nov. 18, 1975**

[54] **METHOD AND APPARATUS FOR HEAT TREATING ARTICLES IN A RECIRCULATING TYPE FURNACE**

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[21] Appl. No.: **497,320**

[52] **U.S. Cl.** **432/209**; 432/21; 432/133; 432/136; 432/147; 432/152

[51] **Int. Cl.**[2] **F27B 5/14**; F27B 9/00

[58] **Field of Search** 432/19, 21, 133, 136, 144, 432/147, 152, 209

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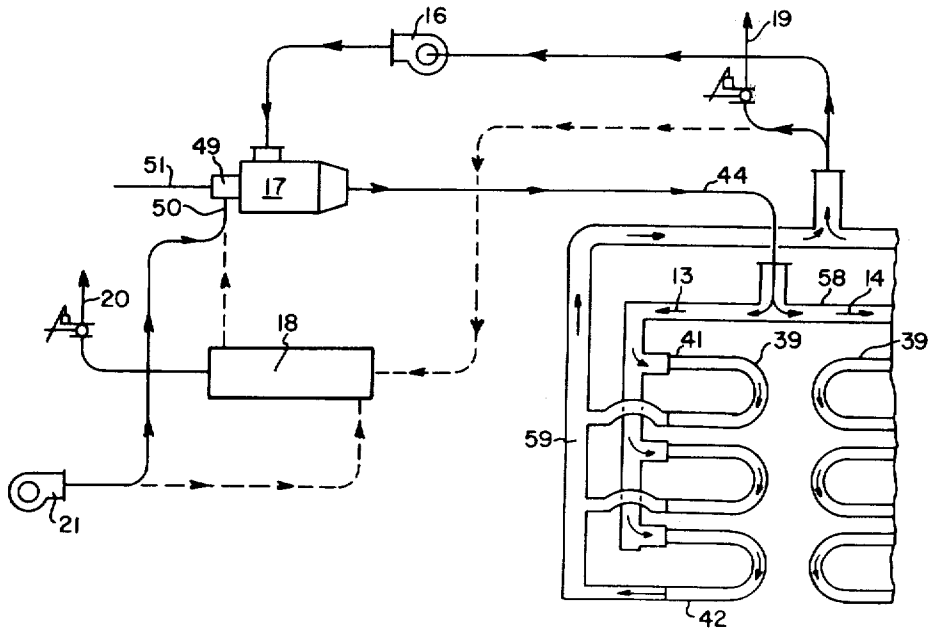
Primary Examiner—John J. Camby

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[57] **ABSTRACT**

A method and apparatus for heat treating articles in a recirculating type furnace in which hot gases and returned reheated products of combustion are injected into the furnace chamber from a pressurized feed system external to the furnace walls, through injection nozzles spaced along the walls which provide a velocity sufficient to create adequate forced recirculation to provide not only uniform heat distribution within the chamber, but rapid equalization of temperature. The invention is applicable to batch type and continuous heat treating or annealing processes and can be also applied to radiant tube fired furnaces such as protective, reductant, carburizing and the like atmosphere radiant tube fired batch or continuous heat treat furnaces or box annealers.

6 Claims, 7 Drawing Figures



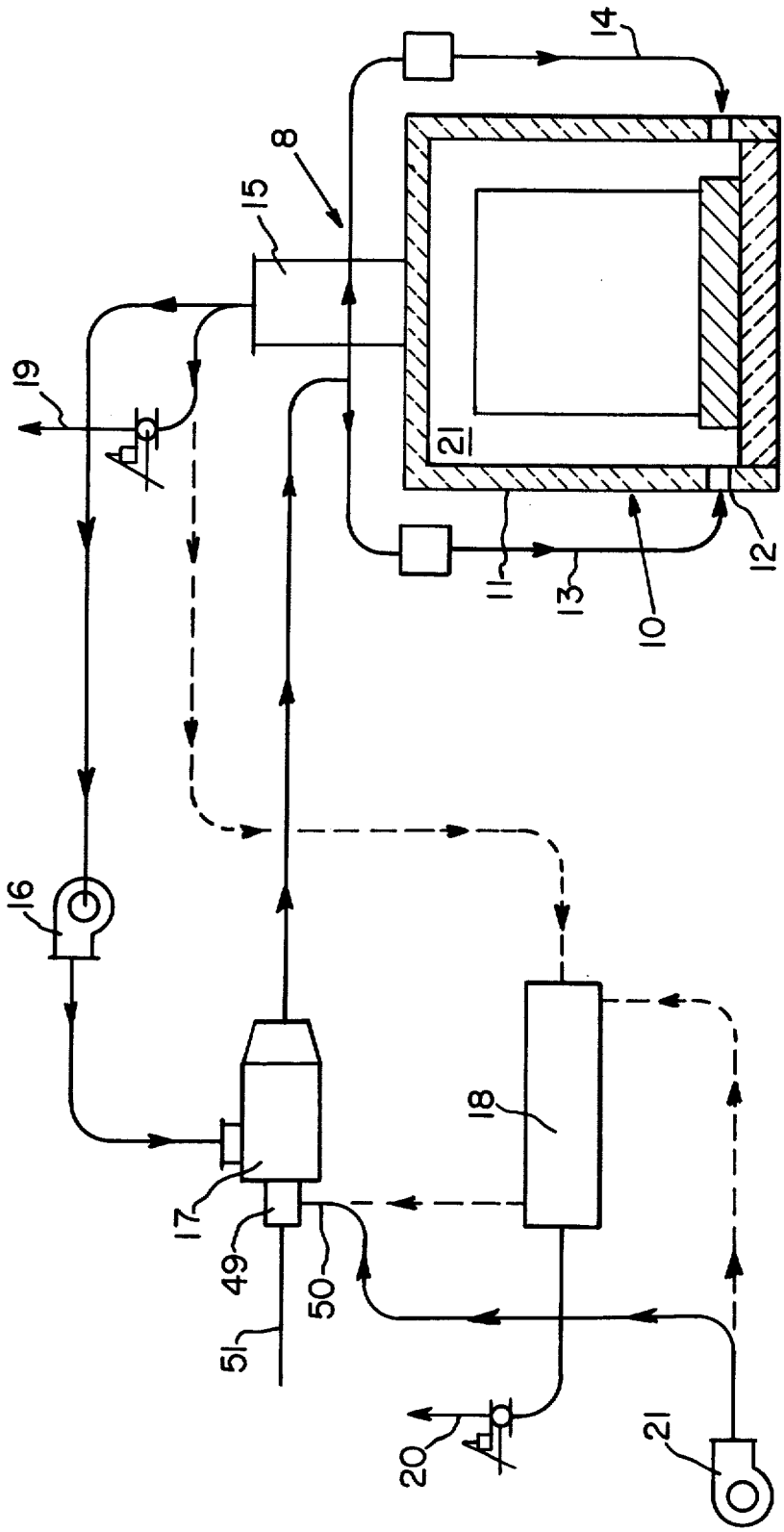


Fig.1

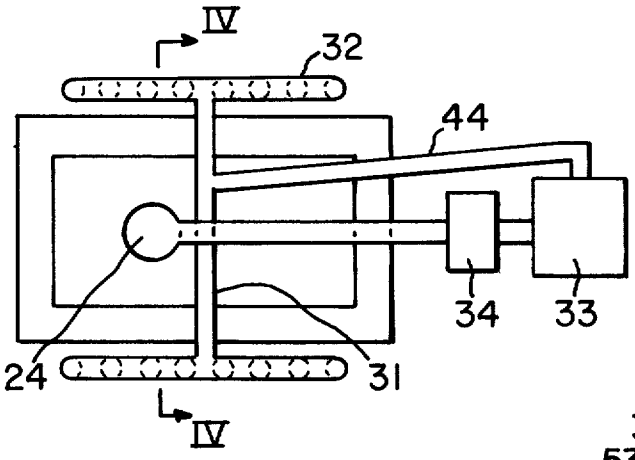


Fig. 2

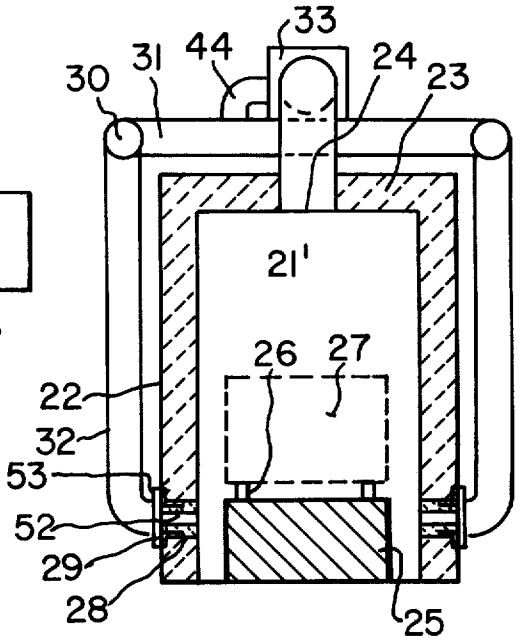


Fig. 4

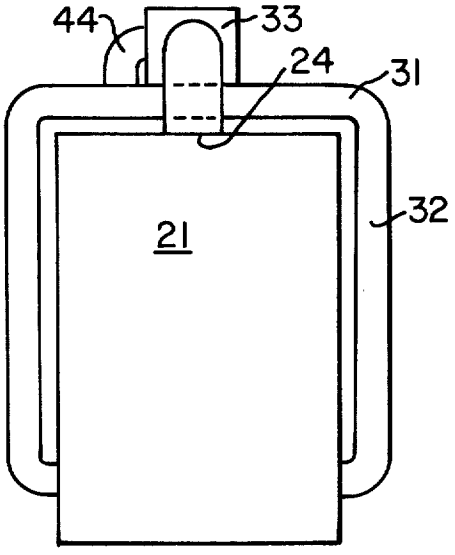


Fig. 3

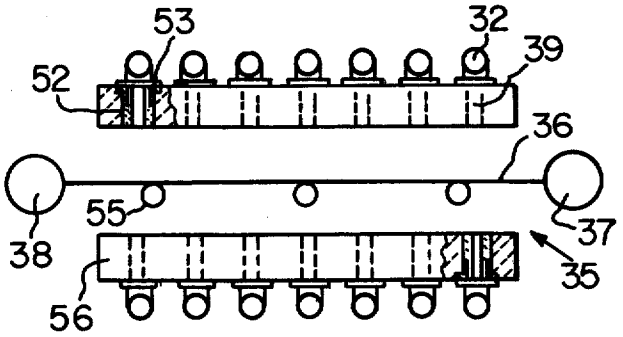


Fig. 5

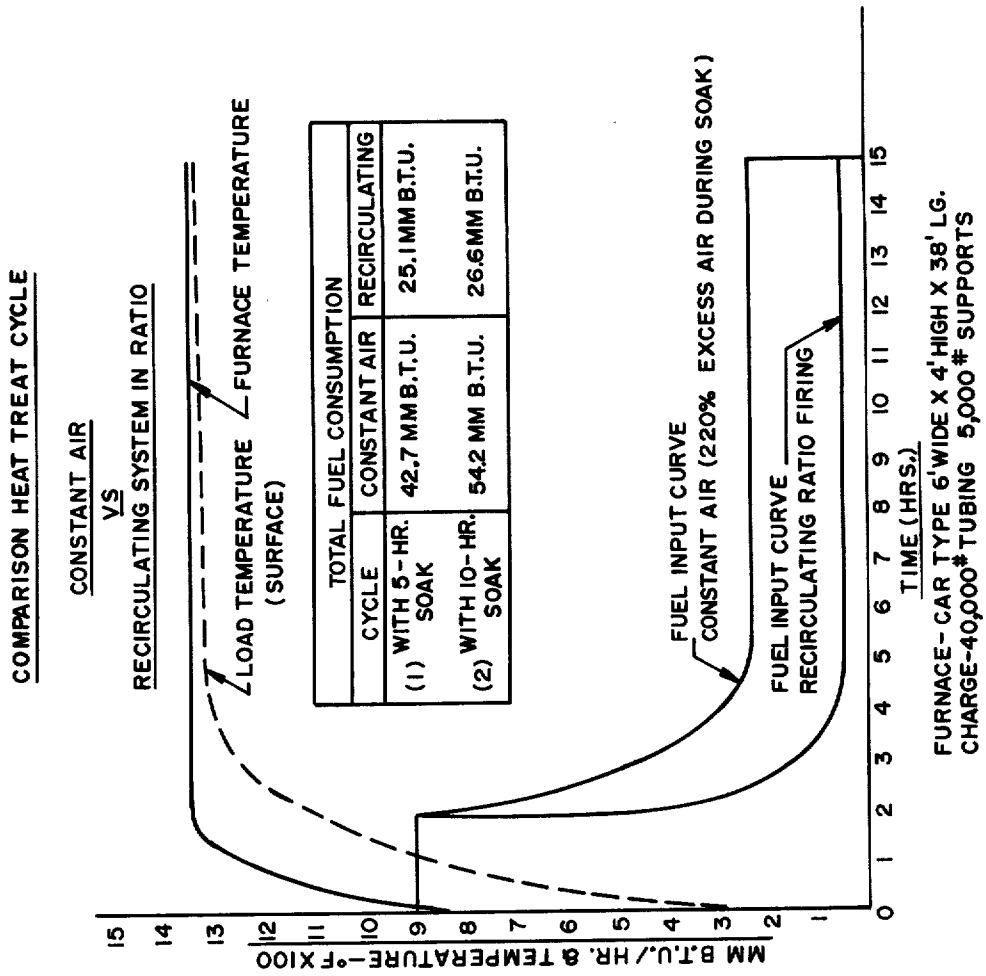

COMPARISON HEAT TREAT CYCLE
CONSTANT AIR
VS
RECIRCULATING SYSTEM IN RATIO
LOAD TEMPERATURE
FURNACE TEMPERATURE
(SURFACE)
TOTAL FUEL CONSUMPTION
CYCLE
CONSTANT AIR
RECIRCULATING
(1) WITH 5-HR. SOAK
42.7 MM B.T.U.
25.1 MM B.T.U.
(2) WITH 10-HR. SOAK
54.2 MM B.T.U.
26.6 MM B.T.U.
FUEL INPUT CURVE
CONSTANT AIR (220% EXCESS AIR DURING SOAK)
FUEL INPUT CURVE
RECIRCULATING RATIO FIRING
MM B.T.U./HR. & TEMPERATURE-°F X100
TIME (HRS.)
FURNACE-CAR TYPE 6'WIDE X 4'HIGH X 38' LG.
CHARGE-40,000# TUBING 5,000# SUPPORTS

Fig. 6

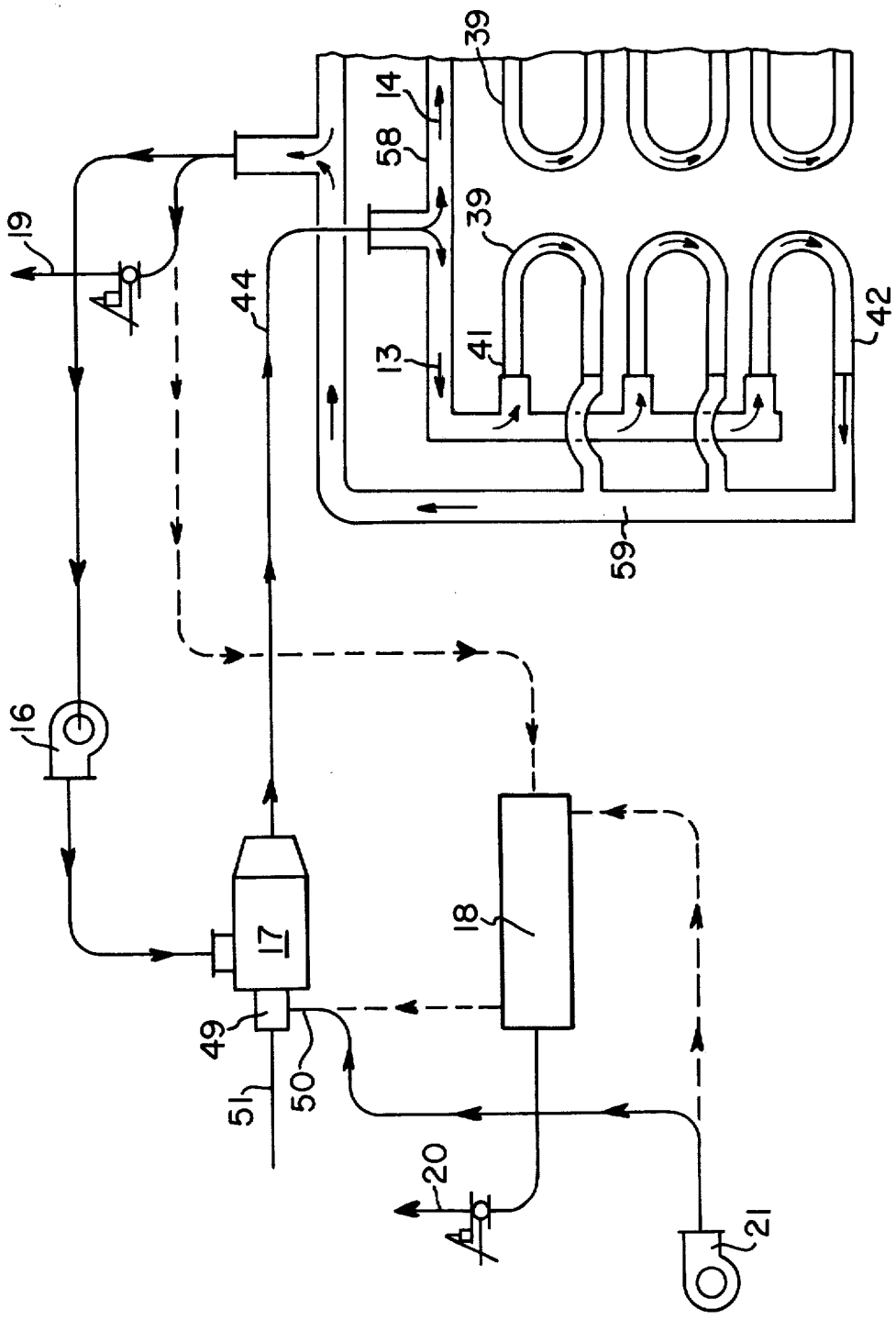


Fig. 7

METHOD AND APPARATUS FOR HEAT TREATING ARTICLES IN A RECIRCULATING TYPE FURNACE

FIELD OF THE INVENTION

This invention relates to heat treating or annealing and particularly to a method and apparatus for a furnace in which products of combustion are recirculated through a return gas reheater and directed through a pressurized system arranged external to the furnace chamber.

DESCRIPTION OF THE PRIOR ART

Recirculating type furnaces in which products of combustion are continuously circulated through the furnace chamber have been known and used for years since, in theory, the passage of a large quantity of gas through the chamber means minimum temperature difference on the articles being treated, particularly in the critical equalization stages of the heat treat cycle. However, the designs used consisted of recirculating gas heaters generally mounted on top of the furnace, a single or dual hot fan arrangement, refractory hot gas feed ducts built integral with the furnace structure and finally, feed ports in the refractory walls intended to direct the hot gas uniformly along the length of the furnace. This arrangement is not particularly successful because of the use of a refractory feed system which allows no appreciable static pressure to assure positive distribution of the hot gas in the proper quantity to assure uniform temperature along the furnace length. The result was localized hot or cold spots with wide temperature spreads, as much as 50° to 100°, irrespective of an overall average calculated 5° to 10° drop in gas temperature.

Another problem with this arrangement was the heater design itself where, in most cases, combustion took place in a combustion chamber with no heat load or heat loss from that chamber so that the refractory structure was exposed to flame temperature with rapid deterioration. As a result of these problems, the recirculating type furnace approach was substantially abandoned, particularly in the higher heat treat temperature ranges requiring refractory structures, and a simple multiple direct fired burner system utilizing constant air or substantial excess air throughout the cycle was adopted.

The advantage of the multiple burner system is the positive placement of heat in the required amount at the right location along the furnace length to assure uniform temperatures. This is accomplished by utilizing appreciable pressures to the burners which provide a substantially constant feed of the products of combustion throughout the entire heat treating cycle since the combustion air is held constant or at high levels of excess air. In turn, high circulation throughout the cycle is maintained and the flame temperature can be reduced to a level just above that required on the articles being heat treated so that hot spots at burner locations are eliminated. Another resultant advantage is that with essentially constant products of combustion, the furnace is maintained under pressure throughout the cycle thereby avoiding uncontrolled cold air leakage into the furnace in the soaking portion of the cycle where heat input levels are extremely low.

The multiple burner system provided excellent results from the standpoint of heat treating cycle time and temperature uniformity. However, it is extremely inefficient from the standpoint of fuel consumption since all of the extra air must be heated to furnace temperature. This fact coupled with the recent substantial increase in the cost of energy, makes the simple direct fired, multiple burner system completely unattractive from the standpoint of both economics and availability of energy.

Attempts have been made to modify the operation of the multiple burner system in the direction of decreasing the amount of excess air in order to reduce total fuel consumption; however, results are unsatisfactory from the standpoint of uniformity and, therefore, metallurgical quality.

Pressurized recirculating systems have been previously used in low temperature applications, but in such cases, the pressurized feed system is mounted inside the furnace chamber itself such as described in U.S. Pat. No. 3,186,694. The inherent disadvantage of the system is that there is a very limited temperature range allowable due to the use of metal components inside the furnace chamber, the increased furnace chamber size necessary to accommodate such a system, and to some extent, the increased furnace losses due to the required increase in chamber size. Further, the use of metal feed manifolds and ductwork inside the furnace chamber necessitates special attention to expansion problems and is costly, or conversely, leads to high maintenance.

SUMMARY OF THE INVENTION

Having recognized the shortcomings of the foregoing described methods and apparatus, we have concluded that the optimum situation is to use a hot gas recirculating system, fired in essentially theoretical fuel/air ratio, with the system constructed external to the furnace chamber itself, thereby increasing the allowable temperature range to the practical limit of a high temperature recirculating fan. The use of a pressurized feed system assures positive control of distribution of the correct amount of hot gases along the length of the furnace to assure temperature uniformity and in addition, gives high injection velocities which assure high forced recirculation within the furnace chamber itself. Such a system also maintains this constant recirculation throughout the entire heating cycle, and avoids the use of high temperature flames which create hot spots.

Firing in ratio insures theoretical minimum energy usage and maintenance of constant recirculation insures minimum cycle times and maximum degree of temperature uniformity. Additional advantages include flexibility relative to the type of fuel used since heavy residual fuel oil, or other types of fuels which cannot practically be applied in a multiple burner system directly fired into the furnace chamber can be utilized. The return gas can be used as a coolant to the combustion chamber, avoiding any unreasonable maintenance in this area, and the temperature drop in the hot gas feed system can be held minimal with reasonable line construction. The system also lends itself readily to a recuperator so that in the higher temperature heat treat ranges, energy usage is further reduced.

Specifically, our recirculating furnace comprises a main furnace structure including walls made of refractory material. External to the walls is a pressurized system for circulating hot products of combustion through the furnace. Means are provided to reheat recirculated products of combustion and to add additional hot gases required for optimum performance. The pressurized

system includes hot gas lines located adjacent the refractory walls and is provided with a plurality of injection nozzles which extend from the lines through the walls and into communication with the interior of the furnace structure. The nozzles can be placed along opposite walls of the furnace below the level of the articles to be treated or can be located for direct hot gas impingement. Likewise, the system can be utilized with radiant tubes. The articles may be treated in batch or in continuous processes utilizing the principles of the invention. Cover annealing is another application for which our invention can be employed.

In the accompanying drawings, we have illustrated a preferred embodiment of the invention together with various modifications which can be made without departing from the scope of the invention:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a preferred embodiment of the recirculating system;

FIG. 2 is a plan view of the system applied to a furnace and constructed in accordance with the invention;

FIG. 3 is an elevation of the system and furnace shown in FIG. 2;

FIG. 4 is a cross section taken along the lines IV—IV of FIG. 2;

FIG. 5 is a recirculating system applied to a continuous strip furnace having direct hot gas impingement;

FIG. 6 is a graph comparing fuel consumption for the subject invention and a multiple burner system; and

FIG. 7 is a modified system utilizing radiant tubes.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A preferred system is diagrammatically shown in FIG. 1. The furnace **10**, having a recirculating pressurized system, generally designated **8**, constructed in accordance with the principles of the invention, includes refractory walls **11** defining a heating chamber **21**. Nozzles (not shown) are provided in openings **12** in the walls **11** to permit products of combustion to enter the furnace chamber **21** from the pressurized system **8** (in the direction of arrows **13, 14**). The exhaust gases leave the furnace chamber **21** through port **15** for recycling either directly to a hot fan **16** and then to hot gas heater **17**, which includes at least one burner **49** having an air inlet **50** and a fuel inlet **51**, or indirectly to a recuperator **18** and then to the heater **17**. Waste exhaust gas may be exited from the furnace **10** as shown by arrow **19** or from the recuperator **18** as shown by arrow **20** or both. When exhaust gas is directed to a recuperator **18**, cold air is passed in heat exchange relationship with the hot gas by a fan **21** in the conventional manner well known in the art of recuperation.

Heat treating is accomplished by moving an article **27** to be processed into the furnace chamber **21** by some transfer means, such as a transfer car, conveyor or the like, depending upon whether it is a batch or continuous process. Hot gases are then circulated in the pressurized system through hot gas lines and then through nozzles extending into the interior of the furnace structure at such velocity as to cause sufficient turbulence of the hot gases to insure temperature uniformity within the furnace and, consequently, to obtain uniform heat treatment of the articles. We have found a practical minimum preferred velocity to be about 100 ft./sec.

A preferred embodiment of the furnace is shown in FIGS. **2, 3** and **4**. The main furnace chamber **21'** is defined by walls **22** made of refractory material. The top **23** of the furnace chamber **21'** is closed except for a port **24** through which exhaust gases can pass. The floor of the furnace chamber **21'** supports piers **25** which in turn support rails **26** to accommodate a transfer car **27** (shown in dashed lines), a conveyor or other means for carrying an article or articles into and out of the furnace.

There are a plurality of openings **28** in the walls **22** of the furnace located below the articles to be treated and spaced between the piers **25**. Nozzle means, such as nozzles or jets **29**, extend through the openings **28** and are in fluid communication with the hot gas lines comprising the pressurized system which are mounted external to the furnace walls **22** and adjacent to them. The system includes a main hot gas line **44** connected to a cross header **31**. The cross header **31** connects to two feed headers **30** positioned along opposite walls **22** of the furnace chamber **21**. Individual feed lines **32** connect the feed headers **30** with the nozzles **29** which extend through the walls **22** into the furnace chamber **21**.

The nozzle means must maintain the pressure tight seal. Nozzle **29** is illustrated as including a port block **52** extending through the opening **28**, a mounting flange **53** secured between the port block **52** and the furnace wall **22** and a flange **53** integral with the feed line **32** and sealably bolted to the mounting flange **53**. Port block **52** is normally a hard refractory, but it could also be metal.

A heater **33** for reheating the recirculating gases is located above the furnace chamber **21**. The heater **33** includes one but may include more than one conventional burner, normally capable of burning a variety of grades of fuel including the low grades such as bunker C oil.

Means, such as hot fan **34**, are provided for moving exhaust gases from the furnace **21** through the port **24** into the lines for recirculation to and through the heater **33**.

The hot gas lines are preferably metal and tubular in cross section, but may be of any suitable configuration and material capable of withstanding the necessary temperatures and pressures. They may be, for example, square or rectangular in cross section.

The pressurized system including the nozzle size is designed to provide a port velocity of the hot gas which will have sufficient turbulence within the furnace chamber to assure a uniform temperature throughout. The results of tests to date demonstrate that this port velocity should be at least 100 ft./sec.

FIG. **6** is a comparison of the fuel consumption between the recirculating concept described in FIGS. **2–4** and firing in ratio and a typical constant air multiple burner direct fired furnace for a specific cycle on a car type application. Maximum B.T.U. input in the case of the multiple burner furnace is 9 MM and in the case of the recirculating furnace is 9.2 MM which allows for the heat loss from the hot gas feed system. In other words, there is little difference at maximum input. A substantial savings in fuel is developed during the cutback section of the cycle and during the soak. Should the cycle be such that the charge was pulled after 10 hours, allowing a 5 hour soak, the recirculating furnace would use 41% less fuel than the direct fired constant air furnace. Should the soak cycle be 10 hours instead

of 5 hours, the recirculating furnace would use 49% less fuel than that required for the constant direct fired furnace.

In FIG. 5 we have shown an application of our invention to a furnace **35** for continuous strip annealing wherein flame impingement on the article to be treated is conventionally used. In the system illustrated, all of the elements are the same as earlier described except that the strip **36** to be heat treated is drawn through the furnace by tension rolls **37** and bridle rolls **55** as the strip is continuously drawn from payoff reels **38.** In our invention, there is no impingement of flame on the strip, but instead there is direct impingement of hot products of combustion or hot gases through the nozzles **39.** As shown in this embodiment, the nozzles **39** are constructed in the same manner as nozzles **29** of the earlier embodiment, i.e. a port block **52** and a mounting flange **53.** This construction permits a minimum amount of space between opposite walls **56** of the furnace. Of course, longer nozzles extending into the furnace may be used where required.

In a further embodiment of the invention, schematically shown in FIG. **7,** we have employed our external pressurized system utilizing radiant tubes **39** which may be in any conventional shape, i.e. "U," "W" or straight. Such a system provides the ability to use bunker C oil or other low grade liquid fuels which are not practical for the conventional radiant tube burner.

Typical of this application is protective, reductant, carburizing and the like atmosphere radiant tube fired batch or continuous heat treat furnaces and box or cover annealers. This general type of furnace normally includes a plurality of vertically and horizontally spaced radiant tubes along each of two opposing sides and this has been illustrated in FIG. **7** through the broken view for the one set of radiant tubes. The main feed line **44** from the heater **33** connects to a hot gas feed header **58** which is coupled into the input leg **41** of the radiant tube **39.** In a similar manner a return gas collector **59** is coupled into the exhaust leg **42** and the products of combustion are circulated through the radiant tubes **39** and through the entire external pressurized system as in the earlier embodiments.

Our invention is a signifcant improvement over prior methods and apparatus for recirculating systems. Our invention eliminates the need for excess or constant air inherent in direct fired furnaces with the resultant waste of energy. Our invention also allows the use of lower quality fuels without any sacrifice in the metallurgical characteristics obtained.

Having set forth preferred embodiments of the invention, it should be understood that it may otherwise be embodied within the scope of the appended claims.

We claim:

1. A recirculating system suitable for a furnace for heat treating articles comprising:

A. a closed furnace chamber defined by at least one wall of refractory material;

B. positioning means within the furnace to position articles to be treated;

C. a pressurized system comprising hot gas lines positioned external to the furnace and adjacent the wall;

D. a heater including a combustion source connected between the pressurized system and the furnace chamber for providing hot gases and reheating recirculated products of combustion from the furnace chamber, and

E. nozzles extending between the hot gas lines and the interior of the furnace for communicating the hot gases and products of combustion from the lines into the furnace for treating the articles, the hot gases and products of combustion entering the furnace chamber at a minimum velocity of about 100 ft./sec. which is sufficient to cause turbulence within the furnace to insure substantial uniformity in temperature within the furnace, said nozzles positioned away from and out of line with the positioning means so as to avoid direct hot gas impingement on said articles.

2. In a furnace having at least two oppositely disposed walls of refractory material between which articles are positioned by transfer means for heat treating and in which products of combustion are recirculated into the furnace, the improvement in a recirculation system comprising:

A. a pressurized system of hot gas lines positioned external of the walls of the furnace;

B. a heater including a combustion source connected between the hot gas lines and the furnace for providing hot gases and recirculated products of combustion within the lines;

C. nozzles extending from the lines through at least one wall for passing hot gases and recirculated products of combustion into the interior of the furnace, said nozzles positioned away from the out of line of the transfer means so as to avoid direct impingement of the entrants on the articles; and

D. fan means associated with the heater for forcing the hot gases and recirculated products of combustion through the lines such that the velocity of the entrants leaving the nozzles into the furnace is a minimum of about 100 ft./sec. which is sufficient to cause turbulence within the chamber to insure substantial uniformity of temperature within the furnace.

3. A recirculating system for a furnace having walls of refractory material within which articles to be treated are moved into and through the furnace by positioning means comprising a pressurized system including hot gas lines external of the walls through which heated products of combustion pass, nozzle means between the lines and the interior of the furnace and positioned in removed relationship from the positioning means for passing products of combustion into the furnace in avoidance of direct article impingement and at a velocity of at least 100 ft./sec. to cause turbulence of the products of combustion within the furnace, removal means connected to the furnace for removing the spent products of combustion and heater means including a combustion source and connected to the removal means and hot gas lines for reheating the spent products and recycling them through the system to the furnace for treating articles therein.

4. In combination, an external pressurized recirculating system connected to at least one radiant tube having an inlet leg and an exhaust leg, the recirculating system comprising a heater including a burner having an air inlet and a fuel inlet, a hot gas line placing the heater in communication with said inlet leg, an exhaust gas line communicating the exhaust leg with the heater for the recirculation of exhaust gases and circulation means associated with one of the hot gas or exhaust lines for causing circulation of the hot gases through the heater and the radiant tube.

5. The recirculating system of claim 1 wherein each of said nozzles terminates at the furnace wall adjacent the chamber.

6. The combination of claim 4 including a recuperator positioned between the air inlet of the burner and the exhaust gas line to preheat the air into the burner.

* * * * *