HEAT TREATMENT FURNACE AND METHOD

Inventor: Philip John Griffiths, Sutton Coldfield, England
Assignee: Actric Limited, Bromwich, Staffordshire, England
Filed: Oct. 24, 1972
Appl. No.: 300,356

Foreign Application Priority Data
Oct. 27, 1971 Great Britain 49856/71

U.S. Cl................. 266/5 R, 432/128, 432/133, 266/4 B
Int. Cl......................... C21d 9/00
Field of Search............. 432/121, 128, 130, 133; 266/5 R, 5 H; 148/13, 13.1, 134, 16.7

References Cited
UNITED STATES PATENTS
2,233,474 3/1941 Dreffein .................. 266/5 R X
2,799,491 7/1957 Rusciano .................. 266/5 R
2,845,260 7/1958 Rusciano .................. 266/5 R

3,304,210 2/1967 Lofstrom.......................... 266/5 R

Primary Examiner—Roy Lake
Assistant Examiner—Paul A. Bell
Attorney, Agent, or Firm—Holman & Stern

ABSTRACT
A heat treatment furnace is sub-divided by an internal wall into an ante-chamber and a treatment chamber arranged so that workpieces pass through an entry of the furnace into the ante-chamber, and thence through the treatment chamber to an exit of the furnace. Fuel-fired heating tubes are provided in the treatment chamber to radiate heat to workpieces therein and the tubes are arranged to discharge into the ante-chamber so that the hot products of combustion contact the workpieces in the ante-chamber. The ante-chamber itself is sub-divided into front and rear parts, and the front part is provided with a gas outlet through which the products of combustion from the heating tubes can leave the furnace. Air may be drawn through the entry into the front part of the ante-chamber to burn off oil from the workpieces therein.

7 Claims, 2 Drawing Figures
HEAT TREATMENT FURNACE AND METHOD

SUMMARY OF THE INVENTION

This invention relates to a furnace and method for the continuous heat treatment of workpieces in a non-oxidising atmosphere, which furnace comprises an entry through which workpieces are conveyed into the furnace, an exit through which workpieces leave the furnace, and a treatment chamber through which the workpieces are conveyed between the entry and exit and in which the workpieces are heated to the required treatment temperature.

The term "heat treatment" embraces tempering, hardening, normalizing, annealing, carburising, carbo-nitriding, sintering and brazing. Thus, in certain cases the furnace exit would be a chute leading in a quench tank.

When such heat treatment operations are carried out it is generally necessary to avoid contact between the workpieces and oxygen, and in many cases the presence in the treatment chamber atmosphere of other gases, for example water vapour, carbon-dioxide and hydrogen, must be avoided, or the concentrations of such gases must be carefully controlled. Thus in a case where heat is supplied by combustion of a fuel, the furnace is so arranged that the mixture of fuel and air and the products of combustion thereof are separated from the workpieces. In many furnaces combustion of the fuel occurs in heating tubes which extend through one or more walls of the furnace into the treatment chamber, the interior of the tubes being sealed from the interior of the treatment chamber.

Heat released by combustion of the fuel is radiated from the tubes to the workpieces and to the walls of the treatment chamber. Since the rate of radiation of heat from a body decreases rapidly with decreasing temperature of that body, the heating tubes must be maintained at a high temperature, e.g. 1,000°C or more, to enable heat energy to be radiated to the workpieces at the required rate. Since heat is transferred to the tubes from the gases passing therethrough, the gases exhausted from the heating tubes will be at an even higher temperature, and accordingly these gases carry away from the furnace to the ambient atmosphere a considerable proportion of the heat energy released by combustion of the fuel.

It has previously been proposed that, in order to increase the overall efficiency of a furnace of the kind specified wherein heat is supplied by combustion of a fuel, heat should be exchanged between gases exhausted from the heating tubes and the incoming air supply. However, the amount of heat which can thus be transferred is relatively small, and the overall efficiency of the furnace is not much improved.

In order to achieve a sufficiently high rate of heat transfer to the workpieces a fairly large number of heating tubes is normally provided and a consequence of this is that the heating tubes must normally be arranged transversely of the length of the furnace. It is thus generally necessary to leave a fairly wide unobstructed space along one or each side of the furnace to enable the heating tubes to be withdrawn for replacement or maintenance. This is generally inconvenient and wasteful of floor space. The provision of a relatively large number of heating tubes also contributes significantly to the capital cost of the furnace.

Alternatively, furnaces of the kind specified are provided with electrical heating elements. However, in order to attain the required rate of radiation of heat to the workpieces, a fairly large number of electrical heating elements must be provided and these contribute significantly to the capital cost of the furnace. Furthermore, electrical energy is more expensive than heat energy derived directly from the combustion of a fuel, and the running costs of an electrically-heated furnace are correspondingly high.

In known furnaces of the kind specified, whether heated electrically or by combustion of fuel, elaborate precautions are taken to reduce the ingress of air into the treatment chamber. Thus the furnace is normally operated with a protective atmosphere in the treatment chamber at a pressure slightly above that of the ambient atmosphere so that the protective atmosphere continuously flows through the furnace entry to the outside of the furnace. The protective atmosphere normally comprises combustible gases and these gases burn on reaching the outside of the furnace when the protective atmosphere mixes with ambient air. Such combustion occurring outside the furnace is wasteful of heat energy, is inconvenient in that it leads to uncomfortable working conditions near to the furnace, and also causes a pollution problem since the combustible gases burn in an uncontrolled manner and frequently with a smoky flame.

Notwithstanding the elaborate precautions taken in known furnaces of the kind specified to avoid ingress of air to the treatment chamber, air does pass through the furnace entry and thus contaminates the protective atmosphere within the treatment chamber.

A further problem which arises in connection with known furnaces of the kind specified is that the atmosphere within the treatment chamber does not support combustion of oils and grease commonly present on workpieces which are to be subjected to heat treatment. If the surface layer of oil or grease is not removed before a workpiece enters the treatment chamber, the treated workpiece will at best be coated with a layer of carbon, and in many cases surface properties of the workpiece would be substantially modified. Thus it is generally necessary to degrease workpieces by washing in a solvent before the workpieces enter the furnace.

It is an object of the present invention to reduce or overcome one or more of the problems hereinafter referred to.

According to one aspect of the present invention there is provided a furnace of the kind specified comprising an ante-chamber in addition to the treatment chamber, these chambers being arranged to communicate through an opening so that workpieces entering the furnace can pass through the ante-chamber and then through the treatment chamber, at least one heating tube disposed at least partly within the treatment chamber, means for supplying fuel and air to the interior of the heating tube to burn therein so that the heating tube radiates heat to the contents of the treatment chamber, said heating tube being so arranged that gases are exhausted therefrom into the ante-chamber to contact any workpieces therein, and the ante-chamber being provided with a gas outlet so that gases can leave the ante-chamber other than through the furnace entry or the opening into the treatment chamber.

In a furnace according to the invention direct contact between workpieces in the ante-chamber and gases ex-
hausted from the heating tube is permitted so that the temperature of these gases when they leave the furnace is much lower than the temperature of the exhaust gases leaving the known type of furnace hereinbefore described. A larger proportion of the heat released by combustion is transferred to the workpieces, and the running costs of the furnace are reduced accordingly. Furthermore, the workpieces are heated before they enter the treatment chamber to a temperature between that within the treatment chamber and the ambient temperature. Accordingly, the amount of heat which is required to be imparted to the workpieces within the treatment chamber is reduced and a smaller number of heating tubes can be employed, as compared with the known type of furnace. Thus, the capital costs of the furnace are reduced. Also the smaller number of heating tubes can be arranged more conveniently for maintenance.

A furnace according to the present invention also provides that contamination of the treatment chamber atmosphere can be avoided without losing protective atmosphere from within such chamber at a high rate. Furthermore, it is not necessary to cause hot or combustible gases to flow out of the furnace entry. Any air passing into the furnace through the entry mixes with the exhaust gases delivered into the ante-chamber from the heating tube. Normally all of such exhaust gases would pass through the gas outlet and thus carry through the gas outlet any air which enters the ante-chamber. Any moderate leakage of gas which occurs from the ante-chamber into the treatment chamber does not result in a significant increase in the concentration of oxygen in the treatment chamber, since the concentration of oxygen in the ante-chamber is much smaller than in the ambient atmosphere.

A further advantage provided by a furnace according to the present invention is that it is unnecessary to degrease workpieces before they enter the furnace. Air can be admitted to the ante-chamber through the furnace entry to burn oil and grease from the workpieces whilst in the ante-chamber. Conditions in the ante-chamber can readily be so controlled that oxidation is substantially complete and the production of smoke is negligible. In this way not only is the cost of degreasing by means of a solvent avoided, but at least some of the heat released by combustion of the oil or grease will be absorbed by the workpiece and will therefore contribute to lower fuel requirements of the furnace.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows in horizontal cross-section a heat treatment furnace according to the invention, and FIG. 2 shows the furnace of FIG. 1 in vertical cross-section.

DETAILED DESCRIPTION

The exterior walls of the furnace shown in the accompanying drawings may be constructed in a conventional manner, for example they may consist of a sheet metal outer skin lined with refractory material. A front wall 10 is formed with an entry opening 11 through which workpieces can be conveyed into the furnace. The conveying means would be supported on a bottom wall 12 of the furnace and may be of any known form, for example a shaker or roller hearth, a walking beam conveyor, or a mesh belt or cast link conveyor. The conveying means (not shown) would extend from a position in front of the furnace through the furnace to an exit of the latter, and possibly beyond the exit. In the particular example shown in the accompanying drawings the exit is in the form of a chute 13 which extends downwardly through the bottom wall 12 for delivering workpieces to a quench tank (not shown) situated beneath the furnace. Alternatively, the exit opening could be formed in a rear wall 14 of the furnace. The dimensions of the entry opening 11 are such that clearances will always exist between the boundaries of the entry on the one hand, and the conveying means and workpieces carried thereon on the other hand. It is not necessary for such clearances to be small since ingress of air through the entry 11 is not disadvantageous. The entry is made no larger than necessary in order to avoid excessive loss of heat from the interior of the furnace through the entry, since such loss of heat would reduce the overall efficiency and would contribute to inconvenient or uncomfortable working conditions in the vicinity of the front end of the furnace.

The furnace is divided by an internal wall 15 into an ante-chamber 16 and a treatment chamber 17. The conveying means extends through an opening 18 at the bottom of the internal wall. Again, the clearances between the conveying means and workpieces on the one hand, and the boundaries of the opening 18 on the other hand are not critical, but the opening is made no larger than necessary. With certain kinds of conveying means it would be possible to provide a door to close the opening 18 when no workpiece is moving therethrough but such a door is not considered necessary in a furnace in accordance with the present invention.

The ante-chamber 16 is sub-divided by a wall 19 into front and rear parts 20 and 21 respectively. At the bottom of the wall 19 is an opening 22 through which the conveying means extends, this opening being similar to the opening 18. A pair of heating tubes 23 and 24 extend longitudinally of the furnace through the treatment chamber 17. An end portion of each heating tube is disposed within and sealed within a respective aperture in the rear wall 14. An opposite end portion of each heating tube is disposed within a respective aperture in the internal wall 15, which wall supports this end of the heating tube. The heating tubes would not normally be tightly sealed within their respective openings in the internal wall although a packing would normally be provided to prevent free flow of gases through these openings. A burner 25 is provided for each of the heating tubes, these burners being disposed outside the rear wall 14 and communicating with the ducts defined by the heating tubes. When the furnace is operating, fuel and air are supplied to the burners and a burning mixture of fuel and air is directed along the duct defined by each of the heating tubes, thereby raising the temperature of the latter so that they radiate heat to the interior of the treatment chamber and to workpieces disposed therein.

At their ends remote from the burners 25, each of the heating tubes 23 and 24 communicates directly with a respective extension tube 26. One end portion of each extension tube lies within the opening in the internal wall 15 into which the associated heating tube extends. The extension tubes extend from the wall 15 horizontally through the rear part 21 of the ante-chamber, through respective openings in the internal wall 19, through the front part 20 of the ante-chamber to the
3,857,553

front wall 10. End portions of the extension tubes are received in respective sockets formed in the internal face of the front wall 10.

The heating tubes 23 and 24 and the extension tubes 26 are each fixed at their respective end portions which engage external walls of the furnace, and the thermal expansion and contraction of the tubes is accommodated by movement of adjacent end portions situated within the openings of the internal wall 15. The adjacent end portions of each heating tube and its associated extension tube are arranged telescopically so that relative longitudinal movement of these end portions can occur without impairing the substantially gas-tight character of the junction between the extension tube and heating tube. The relative diameters of these tubes would be selected to provide a substantially gas-tight junction at the normal operating temperature which, nevertheless, permits of relative longitudinal movement without the tubes being subjected to large stresses.

As shown, the openings in the wall 15 may taper towards the treatment chamber, in a case where end portions of the heating tubes are received within end portions of the extension tubes. A packing (not shown) may be provided in each of these openings, which packing will be compressed when the extension tubes expand longitudinally.

Each of the extension tubes 26 is formed with two upwardly presented openings, one of which, 27, is disposed within the rear part 21 of the ante-chamber, and the other of which, 28, is disposed in the front part 20 of the ante-chamber. Thus, hot gases can be discharged from the heating tube 24 through the associated extension tube 26 into both parts of the ante-chamber.

Discharge control means is provided for controlling the relative rates of discharge from each heating tube into the front and rear parts 20 and 21 respectively of the ante-chamber. This discharge control means comprises control tubes 29 disposed one either on or, as shown, within each of the extension tubes 26 and slidably therealong. The control tubes fit within the extension tubes with sliding clearance and each have a length such that in one extreme position, shown in FIG. 1, the associated opening 28 is closed and the associated opening 27 is completely unobscured. Each control tube can be moved along the associated extension tube by settable adjustment means to partly open the opening 28 and partly obscure the opening 27, and eventually into a further extreme position in which the opening 28 is completely unobscured and the opening 27 is closed. In this further extreme position, a machined end face of the extension tube abuts a machined end face of the associated heating tube and forms a fairly gas tight junction which is made even more gas tight by the extension tube which embraces adjacent end portions of the control and heating tubes.

The settable adjustment means comprises a rod 30 which is secured to and projects forwardly from the control tube through an aperture in the front wall 10. The rod 30 may be displaced longitudinally by an operator pushing or pulling the rod as appropriate. Alternatively, a portion of the rod which lies outside the front wall 10 may be formed with a screw thread engaged with a screw-threaded bush fixedly mounted outside the front wall. A hand wheel may be rigidly secured to the front end of the rod 30 to enable the latter to be rotated and thereby screwed through the bush to slide the control tube in an appropriate direction.

In a further alternative arrangement, automatically operated drive means may be provided for controlling the settable adjustment means. Such drive means may comprise a motor, operation of which is controlled by a signal derived from a temperature-sensing means situated at the bottom of the ante-chamber 16, preferably in the rear part 21 thereof. The motor may be an electric motor in a case where the settable adjustment means comprises a screw-threaded rod co-operating with a screw-threaded bush as aforementioned. Alternatively, the motor may be a pneumatic or hydraulic piston and cylinder unit in a case where the settable adjustment means comprises a longitudinally slidable rod secured to the control tube. The arrangement would be such that when the temperature at the bottom of the ante-chamber reaches a predetermined value, which may be varied in accordance with the nature of the workpieces being treated, the control tubes 29 are displaced towards the internal wall 15 to further obscure the openings 27 and thereby divert a greater proportion of the hot gases exhausted from the heating tubes to flow directly to the gas outlet 31, instead of flowing through the rear and front parts of the ante-chamber. This would have the effect of reducing the amount of heat imparted to the ante-chamber and workpieces therein, thus lowering the temperature therein. In this way, the temperature within the ante-chamber can be controlled automatically to ensure that the temperature does not rise to a value at which the workpieces would be adversely affected by free oxygen or other gases present in the ante-chamber.

A gas outlet 31 leads upwardly from the front part 20 of the ante-chamber. Control means is provided for controlling the rate of gas flow through the outlet 31, this control means being in the form of a damper 32 which is slidable between a position shown in FIG. 2 in which it closes the outlet 31 and a further position in which the outlet is fully open. The damper is displaceable by means of a rod 33 attached to the damper and projecting therefrom through an aperture in the front wall 10. The damper 32 may be adjusted by an operator pushing or pulling the rod 33, or screw means as hereinbefore described in connection with the rod 30 may be provided.

A protective atmosphere for the treatment chamber 17 is produced from gases exhausted from the heating tube 24. An outlet duct 34 is provided to convey some of the gases leaving this heating tube from a position within the extension tube 26 to a heat exchanger (not shown) outside the furnace. Such cooling causes the precipitation of water and the de-watered gases thus produced are pumped through an inlet 36 into an annular passageway 37 which surrounds the heating tube 24. If required, additional fuel gas may be introduced into the de-watered gases before the latter are passed into the passageway 37, such addition being made according to the nature of the atmosphere required in the treatment chamber.

The passageway 37 is conveniently defined by a further tube 38 arranged concentrically with the tube 24 and extending along a part of the length of the latter. The heating tube 24 will thus radiate heat to the further Tube 38 when the furnace is operating. The gaseous mixture introduced into the passageway 37 will thus pass over the external surface of the heating tube 24 and the internal surface of the further tube 38 so that the gases will be heated and, in a case where additional
fuel gas has been introduced, will undergo further reaction which may be exothermic if any free oxygen is present or may be endothermic. The hot protective atmosphere thus produced issues from the end of the further tube 38 which is remote from the burner 25 into the interior of the treatment chamber.

When the furnace is operating the damper 32 would normally be so positioned that all of the gases exhauster from the heating tubes 23 and 24 into the ante-chamber 16 pass through the gas outlet 31 to a flue. It will be noted that hot or burning gases do not normally arise from the entry 11, and therefore working conditions adjacent to the furnace will be significantly improved, as compared with known furnaces of the kind specified.

If there is present on the surface of workpieces to be treated in the furnace grease, oil or other combustible material which is required to be removed preparatory to treatment in the treatment chamber 17, the damper 32 would be so positioned that ambient air is drawn into the ante-chamber 16 through the entry 11. The atmosphere within the ante-chamber, at least in a zone adjacent to the entry 11, would thus include a small proportion of oxygen. Workpieces entering the ante-chamber would be heated by radiation from the walls of this chamber and by direct contact with hot or burning gases issuing from the heating tubes 23 and 24. Thus any combustible material on the surface of the workpieces would be burnt therefrom. Conditions within the ante-chamber can readily be controlled so that such combustion is complete and little or no smoke is produced.

The temperature to which workpieces are heated within the ante-chamber 16 is such that the properties of the workpieces are not affected adversely, notwithstanding that the atmosphere within the ante-chamber will include considerable proportions of water vapour, carbon-dioxide, and possibly oxygen. Thus, for example, workpieces passing from the ante-chamber into the treatment chamber 17 may be at a temperature of approximately 500°C. Whilst travelling through the treatment chamber, the workpieces are heated further by heat energy radiated from the heating tubes 23 and 24. As a result of the preheating carried out in the ante-chamber, the required treatment temperature can readily be reached with a moderate rate of radiation of heat from the tubes 23 and 24. Thus a smaller number of heating tubes can be provided than would be provided in a furnace of known design intended for the same duty. It will be noted that it is not necessary to place heating elements beneath the conveying means in the furnace shown in the accompanying drawings.

The respective pressures within the ante-chamber 16 and treatment chamber 17 would normally be maintained at values such that the protective atmosphere tends to migrate from the treatment chamber into the ante-chamber. However, it would not be necessary to maintain a rapid flow of atmosphere in this direction, since some migration of atmosphere from the rear part 21 of the ante-chamber into the treatment chamber can be tolerated. Although ambient air may be permitted to enter the front part 20 of the ante-chamber through the entry 11, all or almost all of such ambient air will be carried upwards from the entry 11 through the gas outlet 31. Thus the concentration of oxygen in the atmosphere of the rear part of the ante-chamber adjacent to the internal wall 15 will be very low. Accordingly migration of a small quantity of this atmosphere into the treatment chamber will result in an exceedingly low concentration of oxygen within that chamber.

The heating tubes 23 and 24 may be withdrawn from the furnace, for maintenance or renewal, in a direction longitudinally of the furnace. Alternatively, provision may be made for withdrawing these tubes upwardly, the roof of the furnace first having been removed. The accessibility of the heating tubes is good, as compared with known designs of furnace of the kind specified. A small number of heating tubes of simple form is sufficient to provide the required amount of heat in the treatment chamber 17.

The arrangement illustrated in the accompanying drawings provides for a better heat process pattern compatible with metallurgical requirements in all zones of the furnace, as compared with the process pattern achieved with known furnaces of the kind specified. Furthermore, we have found that with the furnace illustrated in the accompanying drawings we can achieve better control over the composition of the protective atmosphere within the treatment chamber than is possible with known furnaces of the kind specified. Thus the treatment such as carbo-nitriding and carburising where the avoidance of contamination of the atmosphere is critical, can readily be carried out without the use of means such as a fan for establishing a predetermined circulation of atmosphere within the treatment chamber. Furthermore, carbo-nitriding can be carried out at a similar rate to that at which simple hardening can be effected.

In certain cases the relative amounts of heat required to be imparted to the workpieces in the ante-chamber and in the treatment chamber may be such that the gases which are exhausted from the heating tube or tubes which extend through the treatment chamber do not carry sufficient heat into the ante-chamber. In such cases further heating elements may be provided in the ante-chamber. Such further heating elements could be electrical heating elements, radiant fuel burning tubes or fuel burners delivering burning fuel directly into the ante-chamber to contact the workpieces.

In some applications, for example in furnaces having relatively long treatment chambers to provide for a long residence time of workpieces therein, the heating tubes may be arranged to extend transversely of the length of the treatment chamber. Conveniently in such cases the treatment chamber and ante-chamber would extend side-by-side, a number of heating tubes extending across an outer wall of the treatment chamber, across such chamber and through a wall dividing the treatment chamber from the ante-chamber so that hot gases will be exhausted from these tubes into the ante-chamber. A transfer chamber would be provided across the ends of both the ante-chamber and the treatment chamber, the conveying means being arranged to convey workpieces along the ante-chamber and into the transfer chamber, across the transfer chamber to a position adjacent the treatment chamber and then through the treatment chamber. The conveying means may conveniently include three hydraulically-operated pushers, one to push workpieces through the ante-chamber into the transfer chamber, a second pusher to push workpieces across the transfer chamber and a third pusher to push workpieces into and through the treatment chamber.

I claim:
1. In a furnace of the kind used for heat treatment of workpieces and comprising an entry through which the workpieces enter the furnace, an exit through which workpieces leave the furnace and a treatment chamber through which the workpieces are conveyed between the entry and exit and in which the workpieces are heated to the required treatment temperature, the improvement wherein the furnace comprises:

   an ante-chamber adjacent to the treatment chamber
   and into which ante-chamber the furnace entry leads;
   means defining an opening affording communication
   between the ante-chamber and the treatment chamber;
   at least one heating tube disposed at least partly
   within the treatment chamber and communicating
   with the ante-chamber;
   means for supplying fuel and air to the heating tube;
   and a gas outlet leading out of the ante-chamber;

   whereby fuel can be burned inside the heating tube
   to cause the tube to radiate heat to the contents of
   the treatment chamber, and the products of combus-
   tion pass from the heating tube into the ante-
   chamber and thence through the gas outlet.

2. The improvement according to claim 1 wherein:
   the ante-chamber is sub-divided into front and rear
   parts,
   the gas outlet and furnace entry communicate di-
   rectly with the front part,
   and said opening communicates directly with the rear
   part.

3. The improvement according to claim 2 wherein:
   the heating tube communicates with the ante-
   chamber through means defining first and second
   discharge apertures,

   said first discharge aperture is situated in the front
   part of the ante-chamber,
   said second discharge aperture is situated in the rear
   part of the ante-chamber,
   and discharge control means is provided for adjusting
   the relative rates of discharge from the heating tube
   through the first and second discharge apertures
   respectively.

4. The improvement according to claim 3 wherein:
   the ante-chamber is divided from the treatment
   chamber by a first internal wall,
   the rear part of the ante-chamber is divided from the
   front part thereof by a second internal wall,
   the heating tube is supported at one end in an exter-
   nal wall of the furnace and at the other end in said
   first internal wall,

   there is further provided an extension tube which ex-
   tends from that end of the heating tube supported
   in said first internal wall through the rear part of
   the ante-chamber, through the second internal wall
   and into the front part of the ante-chamber,

   and said first and second aperture means are formed
   in the extension tube.

5. The improvement according to claim 4 wherein;
   said discharge control means comprises a control
   tube slidable along the extension tube between po-
   sitions in which it obscures one or other of said first
   and second aperture means.

6. The improvement according to claim 3 wherein:
   said first aperture means faces towards the gas outlet.

7. The improvement according to claim 1 wherein:
   control means is provided for controlling the rate of
   flow through the gas outlet.

* * * * *