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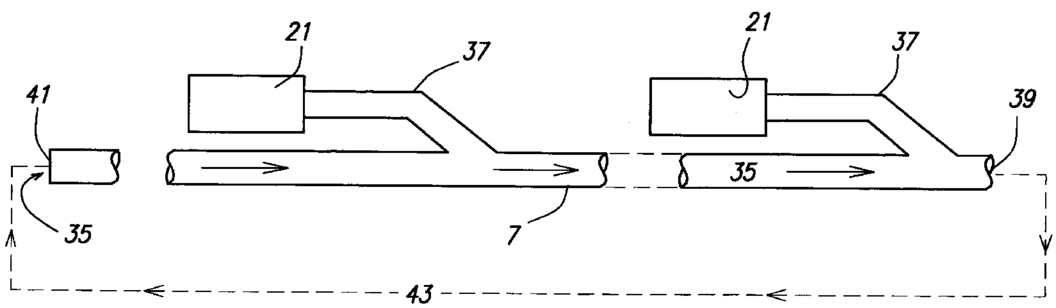
# (54) Improvements in and relating to radiant tube heaters

(57) A gas-fired radiant tube heater system comprises one or more pre-mix gas burners (21), a radiant carrier tube (35) and fan means for inducing a flow of carrier air into and along the carrier tube (35), wherein the or each gas burner (21) is located in a burner tube (34), an end of each burner tube being connected to the carrier tube (35) so that the hot combustion products from the burner(s) (21) are drawn from the burner tube(s) (37) into and along the carrier tube (35) by the flow of carrier air. The system promotes an even heat distribution by altering the carrier air flow rate and/or the gas mixture supplied to the burner(s) (21).

FIG. 5

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## Description

This invention relates to gas-fired radiant tube heater systems and to methods of use thereof.

Gas-fired radiant tube heaters are widely used to heat large internal areas, such as workshops, factories, warehouses and the like. They are normally located near the ceiling and are arranged to radiate heat downwardly, with reflectors provided to prevent heat being radiated other than downwardly.

One or more gas burners, depending on a particular heating requirement, are arranged so that the hot combustion products emitted therefrom are fed into and flow through a carrier tube, which may be of linear configuration or "U" shaped. Heat from the combustion products is transferred, by convection and conduction, to the carrier tube which then radiates the heat outwardly. Usually, fan means are provided to induce a flow of air along the carrier tube so as to draw the hot combustion products therealong and to exhaust the cooled combustion products out of the carrier tube and out of the building.

The simplest and cheapest form of heater comprises a single gas burner, which operates on a similar principle as a bunsen burner, feeding into a single radiant carrier tube. Gas is fed at a pressure of about 4 inches water gauge (W.G.) (10 mbar) to the burner and the necessary air for combustion is induced by the gas flow. The combustion products are removed by a fan at the distal end of the carrier tube. Sometimes the fan is located adjacent the burner and feeds the air past the burner at a pressure of about 1 inch W.G. (2.5 mbar) or less.

Often, two such burners are arranged in systems, feeding the hot combustion products therefrom into a common radiant carrier tube, often referred to as a flue duct.

In one such system, known as a double linear system, two burners are located at the ends of the radiant carrier tube and the fan is located towards the centre of the tube.

In other systems, where a greater heat output is required, multiple burners are arranged so that each burner feeds into a separate branch, or burner, tube, the burner tubes leading into a common carrier tube in a linked or a herringbone pattern. Such systems can also be operated in parallel or in series in order to give a greater heat output. In such systems, the fan operates at an increased rate, typically to give a suction of about 2 inch W.G. (5 mbar), to remove the combustion products.

Where more than two burners are required, such systems have the disadvantage that it is not possible evenly to distribute the heat to be radiated from the carrier tube, since the positions of the burners relative to the carrier tube are fixed. In particular, when it is desired to vary the total heat output of the system to take account of variations in ambient temperature, the heat distribution along the carrier tube is uneven, due to the fixed positions at which the hot combustion products are fed into the carrier tube, with the result that different portions of the carrier tube radiate different amounts of heat. Moreover, the type of burner hereinbefore described, which operates on the "bunsen burner principle", produces levels of oxides of Nitrogen ($NO_x$) and of Carbon (CO) which are increasingly environmentally unacceptable.

In an attempt to reduce $NO_x$ and CO emissions, pre-mix gas burners have been used. Such burners operate on the principle whereby a mix of gas and air sufficient for combustion to take place (usually a stoichiometric mixture) is fed, typically at a low pressure of 1 inch W.G. (2.5 mbar) or less, to a gas burner head comprising a plurality of burner "ports", usually holes of between about 1 mm and 2 mm diameter. The introduction of a mixture of gas and air to such a pre-mix burner has the effect of reducing $NO_x$ and CO emissions therefrom.

Systems have been produced incorporating several such pre-mix gas burners arranged inside a common radiant carrier tube. A fan is provided at the end of the carrier tube, which sucks or blows air at a pressure of about 6 inch W.G. (15 mbar) to draw the gas/air mix through the burner ports, to draw the hot combustion products along the carrier tube and to spread out the heat therealong.

The problem with such systems is that it is difficult to ensure even heat distribution along and radiation from the carrier tube, particularly when it is necessary to vary the total heat output of the system.

In order to vary the total heat output, the operation of the fan must be varied so as to draw a different amount of gas and air mixture from the separate pre-mix burners and this effectively alters the length of the combustion zone, or flame, from each burner.

The variation in length of the combustion zone leads to the length of the combustion zone being significantly less or greater than the distance between adjacent burners (which is fixed). In the former situation, alternate "hot" and "cold" zones are created, where the carrier tube radiates different amounts of heat i.e. the radiant heat distribution is uneven.

Where the length of the combustion zone exceeds the distance between adjacent burners, the hot combustion products from one burner interfere with the combustion process occurring at the subsequent burner, which leads both to uneven radiant heat distribution and also to an undesirable increase in $NO_x$ and CO emissions.

Prior art attempts to solve these problems have included varying the diameter of, or the material of, the carrier tube; these lead to unnecessarily complicated and expensive system design and manufacture.

Furthermore, in such "pre-mix gas burner" type radiant heater systems, because air at ambient temperature is induced to flow past each gas burner head, in order to draw out the gas/air mixture therefrom, this cooler air comes into contact with the combustion zone and the interaction between cool air and the hot combustion products in or adjacent the combustion zone produces $NO_x$ and CO emissions and these are increased when, in order to vary the heat output of the system, the ambient air flow rate is increased. Thus, although in principle a pre-mix gas burner reduces $NO_x$ and CO emissions, known pre-mix gas burner radiant heater systems do not effectively minimise these undesirable emissions.

In accordance with the present invention, a gas-fired radiant tube heater system comprises one or more pre-mix gas burners, a radiant carrier tube and fan means for inducing a flow of carrier air into and along the carrier tube, wherein the or each gas burner is located in a burner tube, an end of each burner tube being connected to the carrier tube so that the hot combustion products from the burner(s) are drawn from the burner tube(s) into and along the carrier tube by the flow of carrier air.

Such an arrangement enables the total heat radiated by the carrier tube to be easily varied and to be evenly distributed along the carrier tube, by varying the flow rate of the carrier air and/or the amount of gas/air mixture fed to the or each burner.

Preferably, the length of the or each burner tube is greater than or equal to the maximum length of the combustion zone from the gas burner associated therewith. This ensures that the cooler ambient air does not come into contact with the hot combustion products in the combustion zone until combustion is complete, thereby minimising $NO_x$ and CO emissions.

Preferably the or each burner is located at the end of the burner tube remote from the carrier tube, that end of the burner tube being closed so as to prevent any ingress of air thereinto, adjacent the burner and/or the combustion zone.

With systems in accordance with the invention comprising two or more burner tubes, the hot combustion products from each burner are fed separately into the carrier tube and mix evenly with the carrier air. It is therefore possible to ensure that the heat distribution within, and the consequent heat radiation from, the carrier tube is evenly distributed along the carrier tube by adjusting the flow rate of carrier air. Moreover, because the hot combustion products from one burner do not come into contact with the combustion zone of the adjacent burner, because combustion is completed in the burner tubes, $NO_x$ and CO emissions are minimised. These emissions are also minimised by preventing air from entering the burner tubes other than in the gas/air mix flowing through the pre-mix gas burner. Finally, for any system, the distance between adjacent burner tubes can be optimised, depending on such variables as the individual burner heat output, the size and material of the carrier tube and the carrier air flow rate so as to ensure an even radiant heat distribution along the carrier tube across the range of operating conditions for the system.

For a pre-mix gas burner having a heat output of between 10 kW and 60 kW, the length of the burner tube is preferably between 0.2 m and 1.5 m. Suitably, the burner tube has the same diameter on the carrier tube, usually between 50 and 200 mm, for ease of manufacture of the system and to reduce the cost thereof.

There may be a single gas burner in each burner tube, or each burner tube may contain several gas burners provided these are disposed relative to each other so that the combustion zones thereof do not interfere, such as by positioning the burners side-by-side and/or providing baffles between the burners, or by locating each burner in a separate tube leading into the burner tube.

In multiple burner systems, the burners and burner tubes may be parallel to the carrier tube, in a herringbone pattern, or they may be linked perpendicularly thereto, or disposed in any intermediate configuration.

As is known in the art, portions of the carrier tube may be formed of different materials and/or covered with a thermal insulation so as to vary the radiant emission of the carrier tube. These techniques may also be applied to the burner tubes in order to optimise the transfer of heat to the heat radiating portions of the carrier tube.

The invention will now be described by way of example only and with reference to the accompanying drawings, in which:

Figure 1 is a schematic drawing of a prior art gas burner;

Figures 2a to 2g are schematic drawings of prior art radiant tube heater systems incorporating burners of the type shown in Figure 1;

Figure 3 is a schematic drawing of a prior art pre-mix gas burner;

Figure 4 is a schematic drawing of a radiant tube heater system incorporating pre-mix gas burners as shown in Figure 3; and

Figure 5 is a schematic drawing of a gas-fired radiant heater system in accordance with the invention.

Figure 1 shows a prior art gas burner 1 which operates on the "bunsen burner principle". Gas is supplied at a pressure of about 10 mbar to a jet 3 within a housing 5 which is connected to a radiant carrier tube 7. The flow of gas induces air to flow along the direction of the arrows 9 or combustion to occur, the hot combustion products passing along the carrier tube 7 in the direction of the arrow 11. A baffle 10 is provided, adjacent the jet 3 in order to assist the combustion process.

A fan 13 is used to assist the flow of hot combustion products along the carrier tube 7 and to exhaust the combustion process. The fan 13 may be mounted at the distal end of the carrier tube 7 (see Figures 2a and 2c) or within the housing 5 (as shown in Figures 2b and 2d, the combined housing and fan being denoted as 1'). Simple gas-fired radiant tube heater systems comprising only one such burner may have a carrier tube of U configuration (Figures 2a and 2b) or it may be linear (Figures 2c and 2d).

Figure 2e shows a double linear configuration system in which two gas burners 1 feed into a common linear carrier tube 7, a fan 13 being provided in the centre of the carrier tube to draw the combustion products therealong and to exhaust these from the system.

Figure 2f illustrates a multiple burner system in which the individual gas burners are arranged in separate branch tubes 15 in a parallel, herringbone configuration relative to the carrier tubes 7, which feed into a single fan 13.

Figure 2g illustrates what is known as a linked system, in which individual burners 1 feed into separate branch tubes 15 which are perpendicular to the main carrier tube 7.

In each of the embodiments shown in Figures 2a to 2g, air is allowed to enter the burner housing 5 in order for combustion to take place and such an arrangement leads to undesirable $NO_x$ and CO emissions.

In the multiple burner systems, the lengths of the branch tubes and the distances between burners is set so as to optimise the distribution of the heat radiated by the carrier tube at a particular total heat output, or temperature. When it is desired to vary the total heat output of the system, the amount of gas supplied is varied. The operation of the fan may also be varied, so as to alter the flow rate of air and hot combustion products along the carrier tube in order to maintain a constant distribution of heat radiation therealong. However, this is relatively ineffective, since varying the air flow rate can substantially affect the combustion process at each burner. Therefore prior art systems using such gas burners are only effective at providing an even distribution of radiant heat at a given total heat output, or temperature, or in a limited range thereof.

A pre-mix gas burner 21 is shown in Figure 3 and is generally recognised as giving rise to lower $NO_x$ and CO emissions. Gas 23 and air 25 is fed into a burner head 29, usually in a stoichiometric ratio. The gas/air mix 27 flows out of a plurality of holes 31, of between 1 and 2 mm diameter, producing a flame 33, the length of which is determined partly by the gas/air pressure and principally by the flow rate of air passing the burner head 29 in the direction of the flame 33.

Figure 4 shows a typical radiant tube heater system incorporating several pre-mix gas burners 21. The burner head 29 of each burner 21 is located in a common carrier tube 7 (two parallel carrier tubes are illustrated). Air is drawn into the carrier tubes 7 at the ends 35 thereof by a fan 13, which provides a suction of about 15 mbar. This "carrier air" flows along the carrier tube 7 and draws the gas mixture 27 out of the burner heads 29 and draws the flame, or combustion zone, and the hot products of combustion along the carrier tube 7 towards the fan 13.

In order to vary the total heat output of the system in Figure 4, the flow rate of carrier air is altered. This varies the amount of gas/air drawn through the burner heads 29, altering the total heat output thereof and also varying the length of the combustion zone. If the combustion zone is lengthened substantially, the combustion products from one burner head 29 affects combustion at the next burner head 29. If the combustion zone is shortened substantially, the hot combustion products from one burner head 29 transfer all of their heat to the carrier tube 7 before reaching the next burner head 29. Accordingly, systems of the type shown in Figure 4 cannot produce an even radiant heat distribution along the length of the carrier tube 7 over more than a very limited range of temperature, or total radiant heat output. Moreover, the interference effect of the hot combustion products from one burner head 29 on the combustion process at the next burner head 29 leads to an undesirable increase in $NO_x$ and CO emissions.

In the gas-fired radiant tube heater system in accordance with the invention shown in Figure 5, a premix burner 21 (two are shown) is disposed at the end of a burner tube 37. Each burner tube 37 feeds into a common carrier tube 7 along which air is induced to flow in the direction of the arrows 35 by a fan (not shown). The fan is preferably located at the downstream end 39 of the carrier tube 7 and is adapted to draw air into the upstream end, or end vent, 41 of the carrier tube 7 (although the fan could equally be located at the upstream end 41 of the carrier tube 7 and blow air in the direction of the arrows 35). The flow of air along the carrier tube 7 creates a low pressure in each of the burner tubes 37 which draws the gas/air mixture from the burners 21. Varying the fan speed varies the pressure drop at the ends of the burner tubes 37 and hence the amount of gas/air mixture drawn from the burners 21. It is therefore possible to vary the total heat output from the burners 21, and the burner tube temperature, simply by varying the fan speed. The same effect can be produced by varying the amount of air able to enter the upstream end 41 of the carrier tube 7, using means which vary its cross-sectional area, such as a motorised or damper fixed variable restrictor. Greater control of the total heat output and of the burner tube temperature can be achieved by varying both the fan speed and the amount of air allowed to enter the end vent 41.

The burner tube 37 is of sufficient length to exceed the maximum length of combustion zone created by the burner 21, so that only hot combustion products emerge from each burner tube 37 and mix with the carrier air. There is no opportunity for interference between combustion processes at adjacent burners 21 because of the respective flow directions and, in order to vary the total heat output of the system it is only necessary to adjust the flow rate of carrier air. Because the hot combustion products merging from each burner tube 37 mix with the carrier air, an even distribution of radiant heat along the carrier tube 7 can be provided at any desired total heat output.

The efficiency of the system may be improved by pre-heating the air entering the end vent 41 of the carrier tube 7 and/or the air which is mixed with the gas prior to being drawn out of the burners 21. This pre-heating may be carried out using the hot air and exhaust gases expelled from the downstream end 39 of the carrier tube 7, by means of a heat exchanger or recuperator (not shown) as is known in the art. Alternatively, a proportion of the hot air and exhaust gas expelled from the downstream end 39 of the carrier tube 7 may be directed to the upstream end 41, at least partially recycling the gases flowing through the system along the phantom line 43 in Figure 5. Ideally, sufficient of the hot gas expelled from the down stream end 39 is fed back into the upstream end 41 of the carrier tube so that little or no ambient air is drawn into the end vent 41 and the volume of gas removed from the system is equal to the volume of gas and combustion air burnt.

It will be apparent to those skilled in the art that the concept of controlling the flow rate of carrier air so as to control the total heat output and the burner tube temperature may be used in combination with the concept of pre-heating the end vent air and/or the air mixed with the gas in the burners 21 and the concept of recycling the hot gases expelled from the carrier tube 7 to provide a highly controllable and efficient radiant tube heater system.

Figure 5 shows a single herringbone configuration system. It will be appreciated that the principles of the present invention may be applied to systems having any number of burners in configurations such as parallel, linked, or any intermediate configuration between linked and herringbone (as shown in Figures 2f and 2g).

The distance between adjacent burner tubes is a matter of design, depending upon the burner heat output, the size and material of the burner and carrier tubes and the carrier air flow rate, or range thereof. For a typical system in which the burner output varies between 10 kW and 60 kW, the burner tube should be between 0.2 m and 1.5 m in length.

The burner tubes may be thermally insulated to maximise the heat transferred to the carrier tube and thermal insulation and materials of different thermal conductivity and/or radiant emissivity may be used for the carrier tubes as is known in the art.

Finally, the invention has been described in relation to a single pre-mix gas burner located in a burner tube. It will be appreciated that two or more burners may be provided, side-by-side, in each burner tube and provided that these are arranged so that the adjacent combustion zones do not interfere, then such an arrangement would provide the same advantages as the invention hereinbefore described. Moreover, such an arrangement enables the variation of total heat output to be carried out over a greater range, simply by switching off one or more of the gas burners in the burner tube, by interrupting the supply of gas/air mix thereto.

## Claims

1. A gas-fired radiant tube heater system comprising one or more pre-mix gas burners (21), a radiant carrier tube (7) and fan means (13) for inducing a flow of carrier air (35) into and along the carrier tube, wherein the or each gas burner (21) is located in a burner tube (37), an end of each burner tube (37) being connected to the carrier tube (7) so that the hot combustion products from the burner(s) (21) are drawn from the burner tube(s) (37) into and along the carrier tube (7) by the flow of carrier air.

2. A system as claimed in Claim 1 wherein the length of each burner tube (37) is greater than or equal to the maximum length of the combustion zone from the gas burner (21) associated therewith.

3. A system as claimed in Claim 1 or 2 wherein two or more gas burners (21) are located in each burner tube (37) and so disposed relative to each other that the combustion zones thereof do not interfere.

4. A system as claimed in any preceding Claim comprising three or more burner tubes (37) wherein the distances between adjacent burner tubes, at the point they join the carrier tube (7), are substantially the same.

5. A system as claimed in any preceding Claim wherein the or each gas burner (21) is located at the end of the burner tube(s) (37) remote from the carrier tube (7).

6. A system as claimed in any preceding Claim wherein the end of the or each burner tube (37) remote from the carrier tube (7) is closed to prevent the ingress of air thereinto.

7. A system as claimed in any preceding Claim comprising means for varying the rate of flow of carrier air into and along the carrier tube (7).

8. A system as claimed in any preceding Claim comprising heat exchanger means to transfer heat from the hot gases expelled from the carrier tube (7) to the air flowing into the carrier tube and/or to the air supplied to the gas burner(s) (37).

9. A system as claimed in any preceding Claim comprising means for conducting a proportion of the hot

gases expelled from the carrier tube (7) to the upstream end thereof.

**10.** A method of use of a gas-fired radiant tube heater system as claimed in any of Claims 1 to 9 comprising varying the quantity of air and/or gas supplied to the or each gas burner (21).

**11.** A method as claimed in Claim 10 wherein two or more gas burners (21) are located in the or each burner tube (37), the method comprising interrupting the operation of one or more of the gas burners in the or each burner tube.

**12.** The method as claimed in Claim 10 or Claim 11 comprising heating the air drawn into the carrier tube (7).

**13.** A method as claimed in any one of Claims 10 to 12 comprising heating the air supplied to the gas burner(s) (21).

FIG. 1

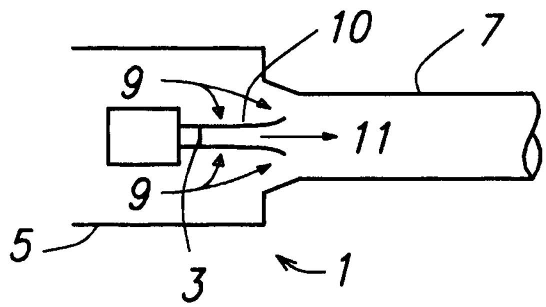



FIG. 2a

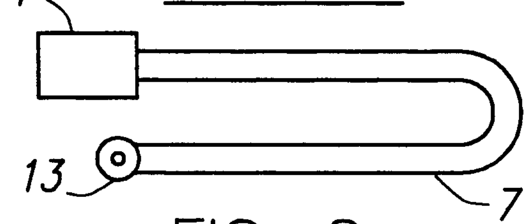



FIG. 2b

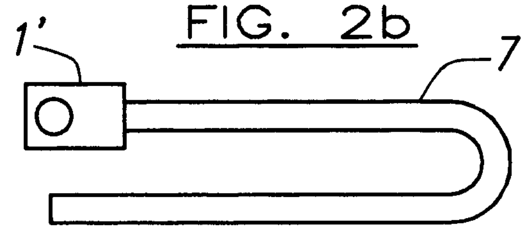



FIG. 2c

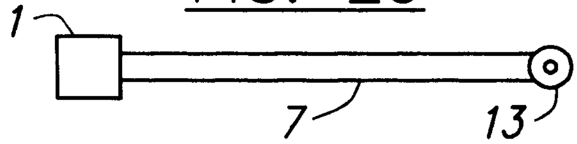



FIG. 2d

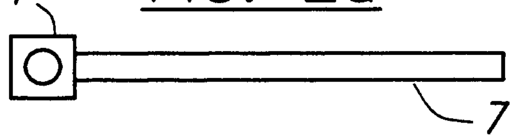



FIG. 2e

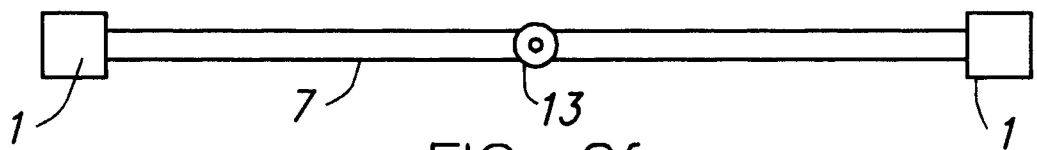
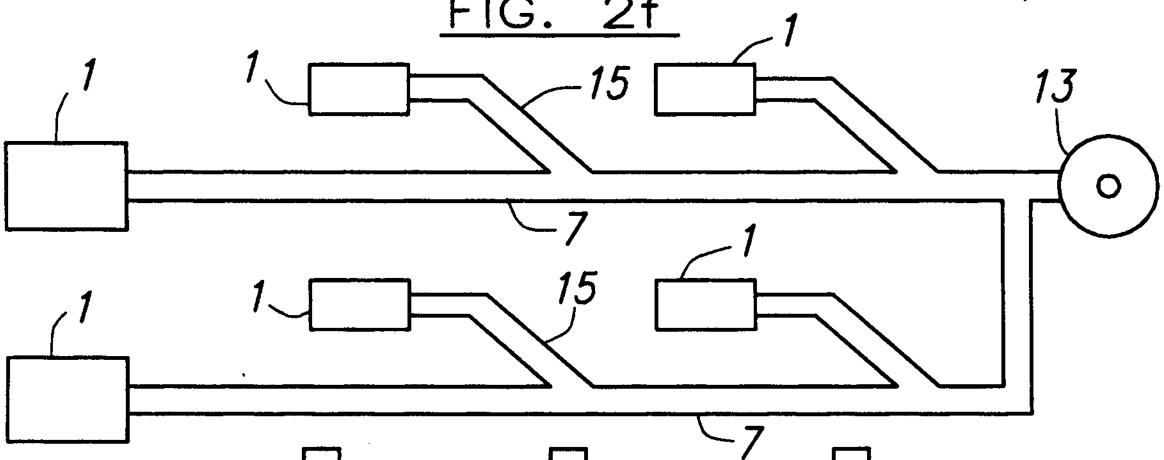



FIG. 2f



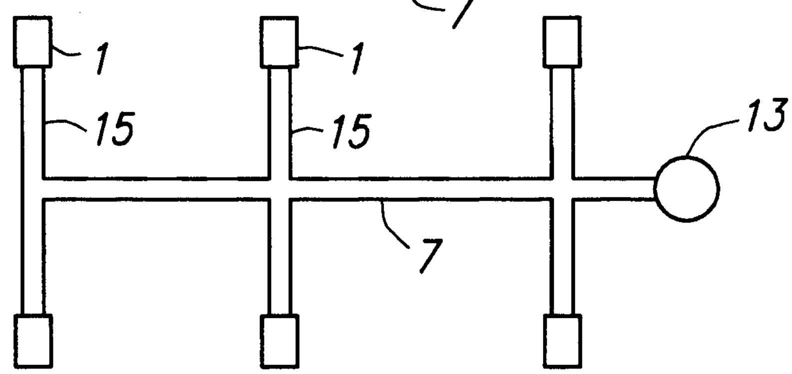




FIG. 2g

FIG. 3

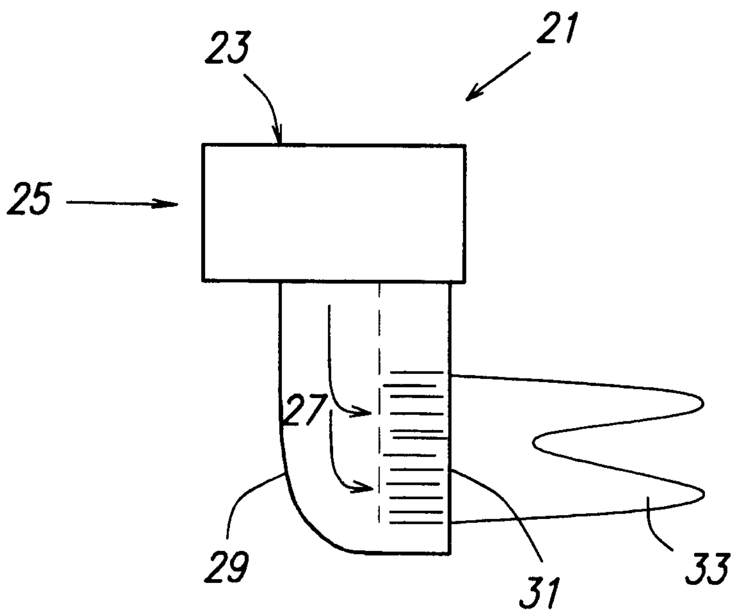



FIG. 4

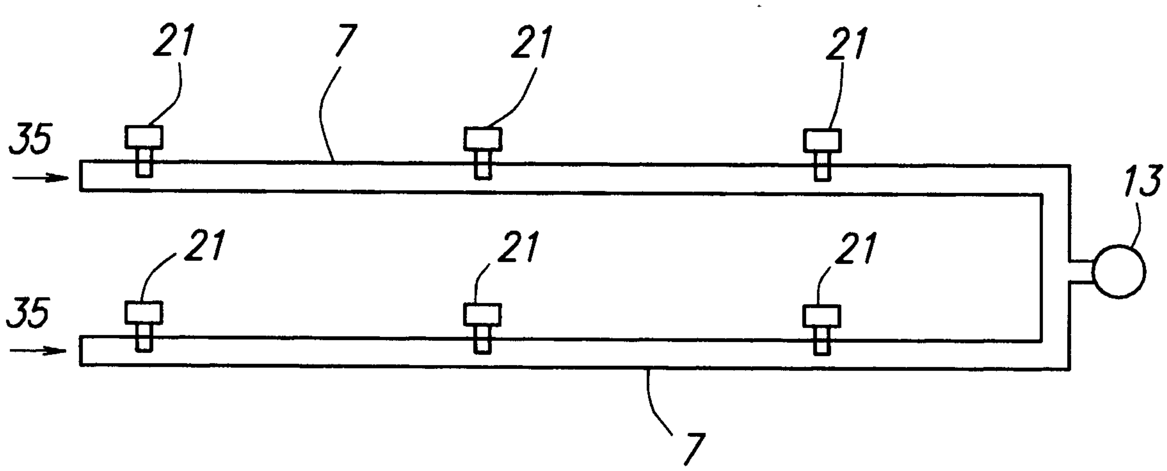
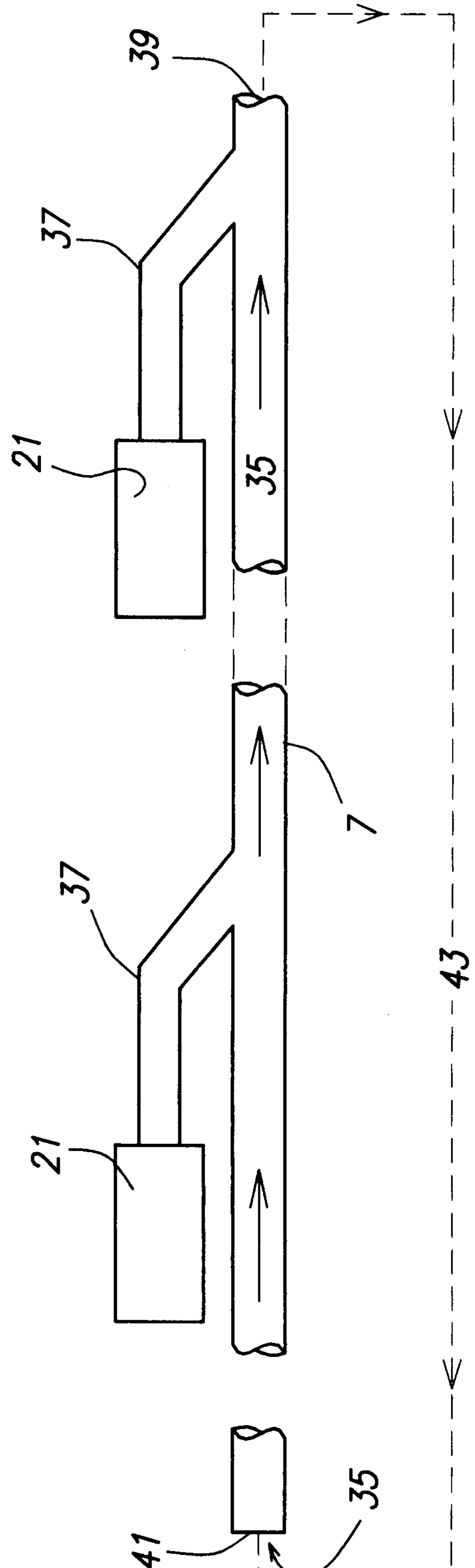


FIG. 5



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# EUROPEAN SEARCH REPORT

Application Number
EP 97 30 0688

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int.Cl.6) |
|---|---|---|---|
| X | US 4 848 315 A (ADLER LEE J) 18 July 1989<br>* the whole document *<br>--- | 1,2,5,6 | F24D5/08 |
| X | EP 0 169 689 A (RADIANT SYSTEMS TECHN LTD) 29 January 1986<br>* the whole document *<br>--- | 1,2,5,6 | |
| A | GB 2 236 406 A (RADIANT SYSTEMS TECHNOLOGY LTD) 3 April 1991<br>* figures *<br>--- | 1-4 | |
| A | DE 91 03 004 U (PENDER STRAHLUNGSHEIZUNG) 13 June 1991<br>* claims 1,7-14; figures *<br>----- | 1,7-11 | |

TECHNICAL FIELDS SEARCHED (Int.Cl.6)

F24D

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| THE HAGUE | 4 June 1997 | Van Gestel, H |

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