United States Patent

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[45] Jan. 18, 1972

[54] **INFRARED BURNER AND METHOD OF INCREASING THE HEAT FLUX RADIATED THEREFROM**

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[21] Appl. No.: **3,943**

[52] **U.S. Cl.** **431/9,** 431/328

[51] **Int. Cl.** **F23d 13/36**

[58] **Field of Search** 431/328, 7, 9, 329, 326; 239/601

[56] **References Cited**

UNITED STATES PATENTS

1,313,196	8/1919	Lucke	431/329
2,515,845	7/1950	Van Den Bussche	431/9 X
3,434,791	3/1969	Hayashi et al.	431/328

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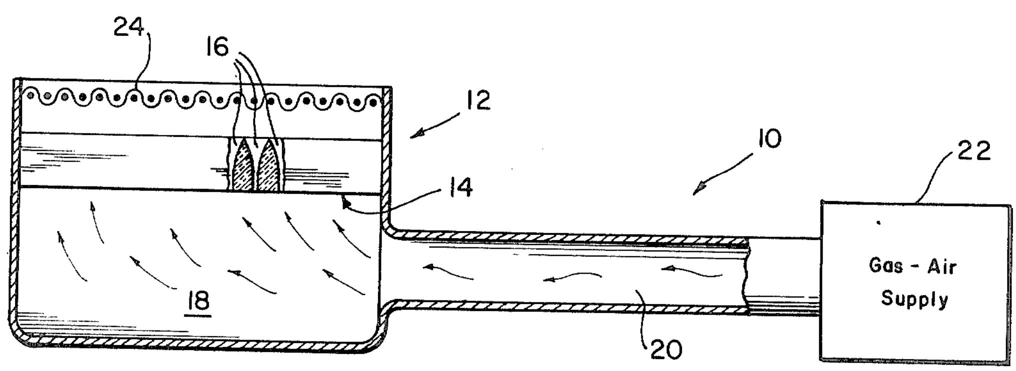
[57] **ABSTRACT**

In an infrared burner having orifices through which a combustible mixture of air and a combustible gas passes, each orifice is provided with a throat portion of relatively small cross-sectional area extending from an inlet for the air-gas mixture to an expanding or diverging outlet portion into which, particularly when the air-gas mixture is supplied to the burner at a relatively high-mass flow rate, a substantially laminar flow or jet established in the throat portion of the orifice is projected centrally and separates from the surface of the diverging outlet portion to create a turbulent recirculating flow around the laminar flow or jet for substantially increasing the infrared radiation produced by the burner when the air-gas mixture is ignited within such outlet portion.

4 Claims, 5 Drawing Figures



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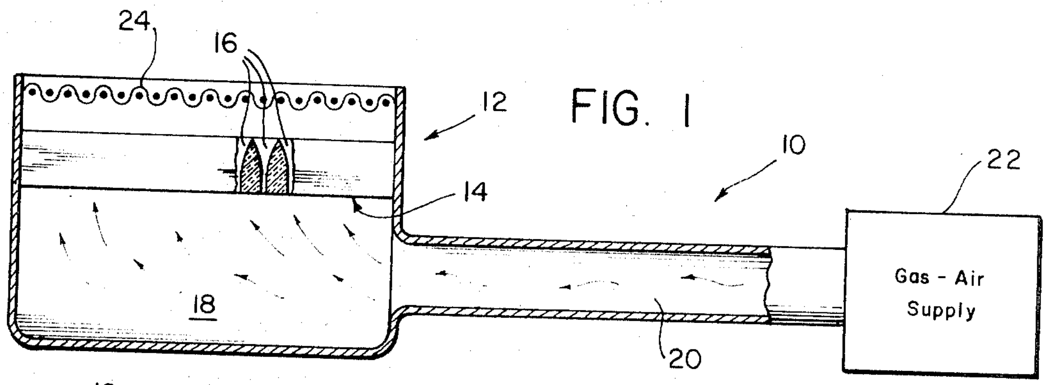

FIG. 1

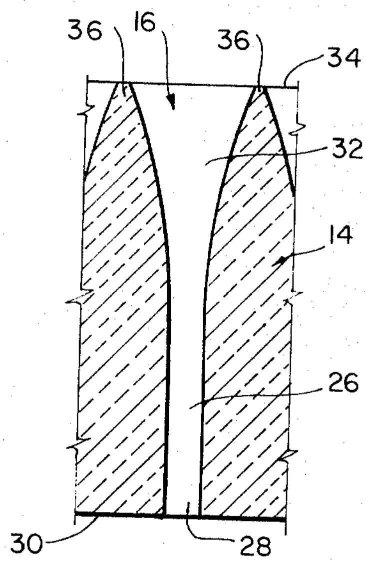

FIG. 2

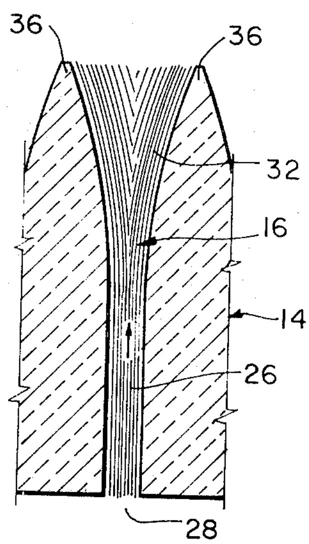

FIG. 3

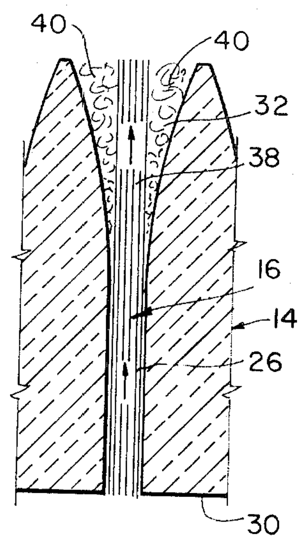

FIG. 4

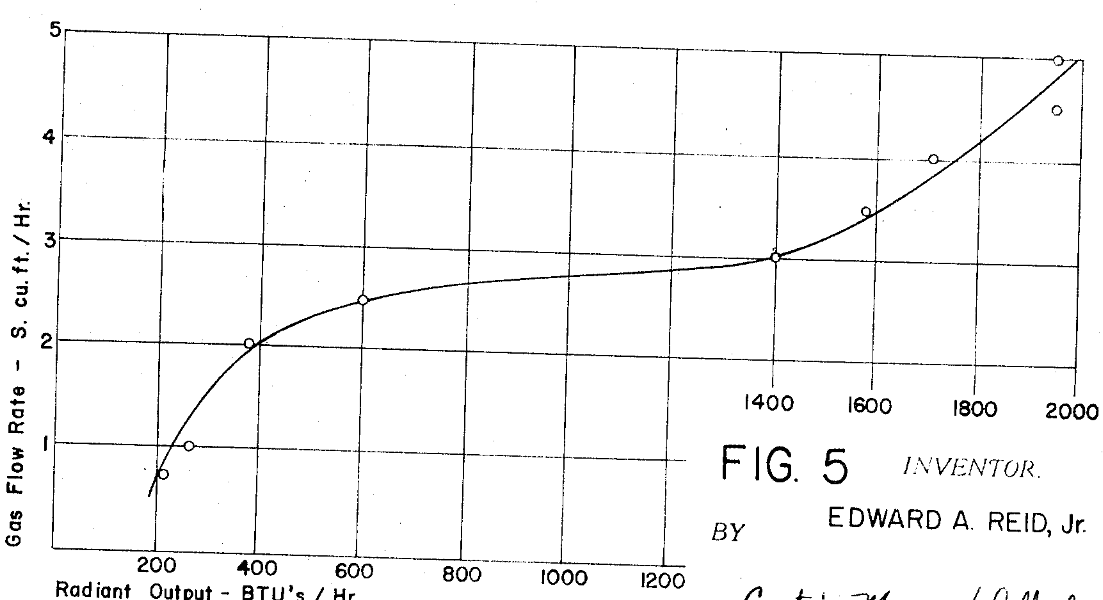

FIG. 5

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INFRARED BURNER AND METHOD OF INCREASING THE HEAT FLUX RADIATED THEREFROM

This invention relates generally to gas-fired infrared burners, and more particularly to infrared burners of the type having a burner plate with a plurality of orifices or ports through which the air and combustible gas mixture passes and is ignited to provide infrared radiation from portions of the burner plate.

Infrared gas burners of the above type, the burner plate may be formed of a ceramic material and, as the gas-air mixture exits from the orifices or ports therein and burns in combustion zones adjacent outlet portions of the orifices, adjacent portions of the plate are intensely heated to incandescence for producing infrared radiation or radiant heat flux. In order to ensure proper operation of the burner, it is essential that the velocity of the air-gas mixture moving through each of the orifices or ports be greater than the speed of propagation of the flame in such mixture in order to avoid flashback of the flame into the plenum chamber through which the mixture is supplied to the several orifices.

It has been proposed, more specifically as disclosed in copending U.S. Pat. Application Ser. No. 775,978, filed Oct. 2, 1968, now abandoned, having a common assignee herewith, that flashback of the flame through the orifices can be avoided, while permitting operation of the burner within a relatively large range of gas flow rates, by forming each orifice with a venturilike configuration. When each orifice has a venturilike configuration, it affords a throat portion of small cross section leading to an expanding or diverging outlet portion so that at least the requisite flow velocity is maintained within the throat portion for avoiding flashback over a relatively wide range of gas flow rates, whereas the flow velocity varies within the expanding outlet portion in dependence on the actual flow rate to determine the location within the outlet portion where the combustion of the air-gas mixture commences.

In the earlier proposed use of venturilike orifices in the burner plate, it was contemplated that, within the range of gas flow rates to be employed therewith, laminar flow of the air-gas mixture would be maintained in the throat portion and also in the expanding or diverging outlet portion of each orifice for most efficient combustion of the air-gas mixture with the heat flux radiated from the burner plate varying generally in correspondence with the selected gas flow rate.

It is an object of this invention to very substantially increase the infrared radiation produced by an infrared gas burner of the described type, and more particularly to effect an increase in the infrared radiation that is proportionately very much greater than the increase in the gas flow rate required therefor.

Another object is to increase the infrared radiation from a burner of the described type by increasing the areas thereof which are made incandescent for emitting such radiation.

In accordance with an aspect of this invention, each of the orifices in the infrared burner is provided with a throat portion of relatively small cross section extending from an inlet for the air-gas mixture to an expanding or diverging outlet portion into which, particularly when the air-gas mixture is supplied to the burner at a relatively high mass flow rate, a substantially laminar flow or jet established in the throat portion is projected centrally and separates from the surface of the diverging outlet portion to create a turbulent recirculating flow around the central laminar flow or jet. When the laminar flow or jet projected from the throat portion into the diverging outlet portion of the orifice is separated from the surface of such outlet portion, which separation is dependent upon the velocity of the laminar flow or jet issuing from the throat portion and also upon the angle of divergence of the surface of the outlet portion, the resultant turbulent recirculating flow provides a self-igniting or pilot action for igniting the gas-air mixture issuing from the throat portion of the orifice to ensure that combustion will occur within the diverging outlet portion of the orifice, rather than at a location beyond the exit from the orifice, even when very high mass flow rates are employed.

Further, operation in accordance with this invention achieves incandescence of the surface of the diverging outlet portion of each orifice in addition to incandescence of the relatively narrow surface areas between the exists from such outlet portions, and the combined effects of the very high mass flow rates that can be employed without lift-off of the flame front from the burner plate and of the increased incandescent areas results in surprisingly great increases in the infrared radiation output.

The above, and other objects, features and advantages of this invention, will be apparent in the following detailed description of an illustrative embodiment of this invention which is to be read in connection with the accompanying drawing, wherein:

FIG. 1 is a side elevational view, partly in vertical section, of an infrared burner unit of a type in which the present invention may be employed;

FIG. 2 is an enlarged sectional view of one of the ports or orifices provided in the burner of FIG. 1;

FIGS. 3 and 4 are views similar to that of FIG. 2 which illustrate the nature of the flow of the air-gas mixture through the orifice as previously proposed and in accordance with the present invention, respectively; and

FIG. is a graph showing the relation of radiant heat output from the burner to the mass flow rate of the air-gas mixture therethrough, and to which reference will be made in describing the advantages of this invention.

Referring to the drawing in detail and initially to FIG. 1 thereof, it will be seen that an infrared burner unit 10 of the type in which the present invention may be employed generally comprises a burner 12 including a ceramic burner plate 14 having a plurality of orifices or ports 16 extending therethrough, and a plenum chamber 18 having the burner plate 14 extending across its upper portion so that a combustible mixture of air and a combustible gas supplied to chamber 18 will issue from the latter through the orifices or ports 16 of plate 14. The air-gas mixture is supplied to plenum chamber 18 through a tube 20 from a schematically illustrated source 22.

As mentioned, the air and combustible gas supplied to chamber 18 are in a combustible mixture and, therefore, will support complete combustion of the gas without the introduction of auxiliary air into the combustion zone or zones. If desired, as shown on FIG. 1, a metal screen or mesh 24 may be disposed a short distance above burner plate 14 so as to be heated to incandescence by the combustion of the air-gas mixture and thereby produce radiant heat in addition to that issuing from incandescent portions of ceramic burner plate 14.

As shown particularly on FIG. 2, each of orifices or ports 16 has a venturilike configuration to include a throat portion 26 extending from an inlet 28 opening at the lower surface 30 of plate 14 to an expanding or diverging outlet portion 32 opening at the upper surface 34 of the burner plate. As shown, inlet portion 28 of each orifice may have a rounded surface converging to throat portion 26 to achieve a smooth entrance flow of the air-gas mixture from chamber 18 into the orifice. The throat portion 26 has a relatively small cross-sectional area which is preferably substantially uniform throughout its length, and the expanding or diverging outlet portion 32 is generally in the form of an inverted, truncated cone so as to have cross-sectional areas increasing progressively from throat portion 26 to the opening of outlet portion 32 in surface 34, that is, in the direction of the flow of the air-gas mixture through orifice 16. Further, each orifice is preferably of circular cross section throughout its length.

In operating the above-described burner unit 10, the air-gas mixture is supplied to plenum chamber 18 through tube 20 from source 22 so as to pass upwardly through orifices 16 of plate 14, and the mixture is initially ignited adjacent the upper surface 34 of plate 14, as by a conventional piezoelectric igniter or pilot flame (not shown). In the previously proposed mode of operation of burner unit 10, for example, as specifically disclosed in U.S. Pat. application Ser. No. 775,978, the range of mass flow rates of the mixture is selected so that, at the upper and lower limits of such range, the velocity of the flow through the throat portion **26** of each orifice is greater than the velocity of flame propagation in the mixture, thereby to avoid flashback of the flame through the orifices into chamber **18**. Further, as shown on FIG. **3**, in the previously proposed mode of operation, the angle of divergence of the outlet portion **32** of orifice **16** and the maximum mass gas flow rate to be employed are selected in relation to each other so that, all of the varying flow rates, there is a substantially laminar flow of the mixture through throat portion **26** and also in diverging outlet portion **32**. In other words, the relatively high velocity flow through throat portion **26** expands progressively in outlet portion **32** to maintain a substantially uniform flow velocity across the entire area of each cross section of diverging outlet portion **32**, with the velocities decreasing progressively in the longitudinal direction from throat portion **26** to the exit or opening **36** of outlet portion **32** at surface **34**.

With the range of mass gas flow rates selected so that laminar flow of the mixture is maintained in outlet portion **32** of each orifice, combustion of the mixture will commence at the level within diverging outlet portion **32** where the flow velocity has been reduced substantially to the flame propagation velocity. Thus, at the lowest mass flow rate at which the burner is to be operated, combustion will commence adjacent the end of diverging outlet portion **32** extending from throat portion **26**. At higher mass flow rates within the range at which laminar flow is maintained in outlet portion **32**, combustion of the mixture will commence at locations progressively closer to the opening of outlet portion **32** at surface **34**. Thus, with the highest mass flow rate of the mixture at which laminar flow is maintained in outlet portion **32**, combustion of the air-gas mixture issuing from each of orifices **16** will occur at or near the opening of such orifice in surface **34** so that the combustion intensely heats and causes incandescence of outlet portion **32** of ceramic plate **14**. Therefore, although the previously proposed mode of operation of burner unit **10** makes it possible to relatively widely vary the infrared radiation produced by burner plate **14** without the danger of flashback when the radiated heat flux is reduced to its lowest level, the maximum radiated heat flux that is attainable is generally limited by the relatively small areas of plate **14** that are made incandescent at the maximum mass flow rates for which laminar flow is maintained within outlet portion **32**.

It has been previously assumed that the maximum radiant heat attainable from burner unit **10** is that achieved with the maximum mass flow rate at which the velocity within the laminar flow in diverging outlet portion **32** would be reduced to the flame propagation velocity at a location at or near the opening of outlet portion **32** in surface **34**, and further that any increase in the mass flow rate beyond such value would result in the "lift-off" of the flame front from plate **14**, that is, the combustion of the air-gas mixture substantially above surface **34** of burner plate **14**, with consequent reduction in incandescence, and hence in the emission of infrared radiation from such plate. However, it has been surprisingly determined that the emission of infrared radiation is very drastically increased when, for a particular angle of divergence of the outlet portion **32** of each orifice, the mass flow rate of the air-gas mixture is sufficiently increased to disrupt the laminar flow in outlet portion **32**. Thus, in accordance with the present invention, as illustrated on FIG. **4**, the mass flow rate of the air-gas mixture is increased sufficiently so that the laminar flow established within throat portion **26** of each orifice is projected into diverging outlet portion **32** as a central jet **38** which separates from the surface of diverging outlet portion **32** so as to create a zone **40** of relatively low velocity, turbulent recirculating flow **40** between the central jet **38** and the surface of outlet portion **32**. In this zone **40** of recirculation, eddy currents of relatively lower velocity and pressure than that of the central jet **42** are formed.

When air-gas mixture discharged from orifices **16** is ignited, the lower velocity gases in zone **40** are also caused to ignite. Burning gases in zone **40** very efficiently transfer heat to the tapered wall of each outlet portion **32** to heat such ceramic wall portion of the burner plate to a temperature at which it incandesces. In this manner, the area of incandescing ceramic is greatly increased to significantly increase the infrared radiation given off by the burner. The central jet of air-gas mixture flows through throat portion **26** of each orifice at a sufficiently high velocity to prevent flashback of the flame front into plenum chamber **18**.

Since the eddy currents in zone **40** effect a restriction of orifice **16**, the pressure drop across plate **14** is increased and the high velocity flow of jet **38** is maintained.

The burning gases in the zone **40** of recirculation also serve as a pilot burner for igniting the air-gas mixture as it flows out of the throat portion **26** of each orifice. Thus, burning of the air-gas mixture in jet **38** begins within the end outlet portion **32** adjacent to throat portion **26** as a result of the described self-piloting action, whereby to prevent lift off of the flame front from the burner plate. The foregoing permits the use of mass flow rate of the air-gas mixture through plate **14** that is several times greater per unit combustion surface area than is possible with any known existing infrared burner.

The temperature profile generated within each burner orifice **16** is such that the hottest portion of the burner is located just beyond the exist from throat portion **26** and the temperature of the ceramic plate decreases along the wall of tapered outlet portion **32** as the cross section thereof increases. However, at each point along the surface of outlet portion **32**, the temperature is above that at which the ceramic will incandesce. As previously noted, the velocity of the mixture through throat portion **26** is greater than the speed of flame front propagation so that the gases therein will not burn and flashback will not occur. The flow of nonburning gases in throat portion **26** ensures that the temperature of the ceramic at the inlet **28** to each orifice, that is, at the upstream side of plate **14** is maintained at a temperature substantially below that at the surface **34** of the burner plate.

The mass flow rate at which the described flow separation will occur is, of course, a function of the angle of divergence of the outlet portion **32** of each orifice **16**. Thus, with a greater angle, that is, greater divergence, a lower mass flow rate will be required to effect the separation of the flow from the surface of outlet portion **32**.

It has been found that, as the mass flow rate of the air-gas mixture through orifices **16** of plate **14** is increased beyond the flow rate at which the mixture flow separates from the wall of the expanding outlet portion **32** of orifice **16**, the infrared radiation generated per unit gas input is approximately doubled. FIG. **5**, which illustrates this phenomenon, is a graph in which gas flow rate is plotted in units of standard cubic feed per hour as the ordinate and radiant heat output is plotted in units of BTU's per hour as the abscissa. The graph represents typical test data for a burner of the character described, and it is clearly seen that for the burner tested, merely increasing the gas flow rate 0.5 cubic feet per hour (from 2.5 to 3.0 cubic feet per hour) causes an increase in the radiant heat output from 600 BTU's per hour to 1,400 BTU's per hour. Thus, the heat output was more than doubled. This result is due to the fact that flow separation occurred with the higher flow rate (3.0 cubic feet per hour) and not with the lower flow rate (2.5 cubic feet per hour).

The source **22** of the air-gas mixture preferably comprises pressurized gas and air supplies to provide a mass flow rate through orifices **16** sufficient to achieve the described flow separation characteristic of this invention. However, a conventional venturi aspirator supply system may be used. In this case the gas must be supplied at a sufficiently high pressure so that the mixture of gas and aspirated air achieves a sufficiently high mass flow rate to effect flow separation in orifices **16** as described above.

Although an illustrative embodiment of the invention has been described herein with reference to the accompanying drawing, it is to be understood that the invention is not limited to that precise embodiment, and that various changes and modifications may be effected therein by one skilled in the art without departing from the scope or spirit of this invention.

What is claimed is:

1. A method of producing high heat flux in a radiant heat gas burner unit comprising, the steps of providing said burner unit with a ceramic radiant heating plate having plurality of orifices wherein each orifice has an inlet opening connecting into a throat portion of uniform diameter and a tapered outlet portion having a rounded surface extending from said throat portion to a surface of said plate, flowing a combustible air-gas mixture through said orifices at a mass flow rate having a velocity substantially higher than the flame propagation velocity of the mixture such that there is an established central jet of said mixture flowing through each of said orifices, and producing flow separation between said jet and the surface of said outlet portion of each orifice to provide therebetween a zone of turbulent, low velocity recirculating flow in which substantially unrestricted flame propagation occurs.

2. A method of producing high heat flux in a radiant heat gas burner unit having a radiant heating orifice plate wherein each of the orifices in said plate is defined by a port having a straight throat portion leasing to a tapered combustion portion having a rounded surface and increasing cross section in the direction of gas flow and which opens at a face of said plate comprising, the steps of producing a relatively high velocity flow of a combustible air-gas mixture in said throat and combustion portions, said flow having a generally uniform cross-sectional area and a velocity greater than the velocity of flame propagation of said mixture, producing a relatively lower velocity recirculation flow of said air-gas mixture in said combustion portion in a zone between said high velocity flow and the surface of said tapered combustion portion, and effecting combustion of said lower velocity flow to heat said surface to incandescence and to ignite said high velocity flow as it leaves said throat portion.

3. A method of obtaining increased radiant heat flux from an infrared gas burner having a plurality of orifices each of which includes a throat portion of relatively small cross section and tapered outlet portion having a rounded surface extending from said throat portion to a surface of said burner and having cross sections that increase progressively in the direction away from said throat portion, comprising passing a combustible gas mixture through said orifices in the direction toward said outlet portions, and establishing a mass flow rate of said mixture through said orifices such that the velocity of flow of the mixture through said throat portion of each orifice is greater than the velocity of flame propagation in said mixture and establishes a substantially laminar flow in said throat portion which projects a jet of said mixture centrally into said outlet portion with separation of said jet from the surface of said outlet portion to create a zone of turbulent, low velocity recirculating flow between said jet and said surface of the outlet portion, and initially igniting said mixture issuing from said orifices, whereupon intense combustion of said mixture occurs in said zone to ignite the mixture issuing from said throat portion in said jet and to effect incandescence of substantially the entire surface of said outlet portion.

4. The method according to claim 3, in which said mixture is a combustible mixture of air and gas and said air and gas are both pressurized to attain said mass flow rate.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,635,644 Dated January 18, 1972

Inventor(s) Edward A. Reid, Jr.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 5, line 7 (Claim 1) insert --a-- after "having";

Column 5, line 23 (Claim 2) "leasing" should be --leading--;

Column 6, line 9(Claim 3) insert "a" after --and--.

Signed and sealed this 1st day of August 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents