GAS FLAME STABILIZATION METHOD AND APPARATUS

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ABSTRACT

A burner includes: a body defining an interior cavity; a burning surface located in the body and defining, at least in part, the interior cavity; a defusing surface located on an exterior portion of the body; ports on the body extending through the defusing and burning surfaces and configured to provide fluid communication between the interior cavity and ambient air outside the body; and an opening larger than at least one of the ports, the opening providing fluid communication between the interior cavity and a space outside of the body. A method of burning a gas and reducing acoustic feedback in a combustion device are also described.
GAS FLAME STABILIZATION METHOD AND APPARATUS

FIELD OF THE INVENTION

[0001] The present invention relates generally to a method and apparatus for stabilizing a gas flame and reducing NOx emissions. More particularly, the present invention relates to a method and apparatus for combusting a air and fuel mixture in a hollow cavity of a burner.

BACKGROUND OF THE INVENTION

[0002] Many household and commercial combustion devices, such as furnaces, hot water heaters, gas dryers, boilers, absorption heat pumps, sterling engines and other devices, often use burners to burn an air and fuel mixture to create heat. The fuel can include natural gas, propane, or other suitable fuels. Usually the burner is located in a combustion chamber and a pre-mixture of air and fuel is provided to the burner for combustion.

[0003] FIG. 1 is an example of a typical burner. As shown in FIG. 1, the burner 10 is generally cylindrical in shape, although typical burners may include other shapes. On the outside of the cylinder is a burning surface 12 upon which the air and fuel mixture will burn. At one end of the cylinder is an end cap 14. The other end may include a flange 16 which may include fastener holes 18 through which bolts or other fasteners extend for securing the burner 10 to a supporting structure.

[0004] The burning surface 12 includes ports 20. The ports 20 are often elongated slits which may be as wide about as much as the wall of the burner 10 is thick. For example, a slit may often be a half a millimeter wide by five millimeters long, but other dimensions are certainly used for the ports. The interior 22 of the burner 10 includes a diffusing surface which cannot be seen in the angle shown in FIG. 1.

[0005] An air and fuel mixture is supplied to the burner 10 in the direction of arrow A and flows into the open end of the burner 10 and into the interior 22 of the burner 10. The air and fuel mixture then exits through the ports 20 in the directions of arrows B. While the directions of arrows B are only shown in right and left orientations, one skilled in the art will appreciate that the air and gas mixture will extend radially out through all of the ports 20. An ignition device will ignite the air and fuel mixture and it will burn on the burning surface 12 of the burner 10. As the air and fuel mixture burns, heat will radiate radially out from the burner 10 in all directions similar to arrows B. Heat also moves by convection as the hot gases created by combustion move in the direction of arrows B.

[0006] If the air and fuel mixture supplied too quickly, the air and fuel mixture may exit through the ports 20 faster than the burn rate of the fuel. Under this condition, combustion may move off of the burning surface 12 of the burner 10 and the burner 10 can experience blow out, a condition where combustion stops and the flame goes out. Blow out can occur in a localized area at an individual port and, under certain conditions, may spread or also occur at other places on the combustion surface 12. Therefore, the air and fuel mixture must be carefully controlled in order to achieve desired burn characteristics and avoid blow out.

[0007] FIG. 2 shows a cross-section of a typical burner 10 located within a heat exchanger 54. The burner 10 may be secured to the combustion device 55 via fasteners 52 connecting to the flange 16. Fasteners 52 may connect directly to the combustion device 55 or in some embodiments as shown in FIG. 2 connect to the air/gas supply duct 64 configured to supply the air and fuel mixture to the burner 10. The air and fuel mixture enters the burner 10 in the direction of arrows A. The air and fuel mixture is diffused by the diffusing surface 24 in the interior 22 of the burner 10 and exits out the ports 20 in the direction of arrows B. The air and fuel mixture is burned on the burning surface 12 generating heat for transferring to the heat exchanger 54. The heat exchanger 54 includes tubes 56 shown in cross section which are filled with a fluid that flows through the tubes 56. As the hot gas generated by the combustion of the air and fuel mixture passes over and around the tubes 56, heat from the hot gases flows through the tubes 56 into the fluid flowing through the tubes 56. After the hot gas pass over the tubes 56, they may move in the direction of arrows E and exit through an exhaust port 60.

[0008] The burner 10 located in the combustion chamber 58 of the heat exchanger 54 is generally spaced from the tubes 56 in order for the tubes 56 to be located outside of the post- combustion zone 62. While combustion generally occurs on the combustion surface 12, chemical reactions still occur in the post-combustion zone. For example, in the post-combustion zone, CO is converted to CO2. An example of a typical post-combustion zone 62 for a household appliance may be about two inches between the burning surface 12 and the tubes 56. Of course, the size of the post-combustion zone 62 depends on many factors, including the size and capacity of the burner, the fuel used and rate of fuel being burned and other factors.

[0009] As one skilled in the art appreciates, not only does the rate of the air and fuel mixture entering the burner 10 affect the burning characteristics, but also factors such as the temperature at which combustion occurs and the temperature of the post-combustion zone 62. Another factor affecting the burning characteristics is feedback from acoustic resonance of the heat exchanger 54. Vibrations or resonance of the combustion chamber 58 sometimes referred to as acoustic feedback, also can affect the chemical reactions that occur in the post-combustion zone 62 and the combustion occurring on the combustion surface 12.

[0010] The combustion device 55, heat exchanger 54 and flow path shown by arrows E can be considered as a Helmholz resonator creating acoustic resonance which can affect the chemical reactions occurring both in the site of combustion and the post-combustion zone. Such resonance can be difficult to control. The resonance can affect the combustion of the air and fuel mixture creating undesirable affects such as more NOx emissions, instability of the flame, or other undesirable burning characteristics. In addition, burners 10 may be tuned or controlled to work despite undesirable feedback rather than being tuned to reduce other undesirable characteristics.

[0011] Today's competitive and environmental concerns constantly place pressure on products such as combustion devices to enhance efficiency and lower emissions. Increasing these performance parameters are becoming more challenging as it is difficult to reach better performance parameters with present known burner technology. The emission limits and efficiency requirements are becoming more difficult to achieve while maintaining or increasing burner performance characteristics, such as modulation range, stability of flame, ignition characteristics, burner load and absence or reduction of resonance combustion noise.

[0012] Accordingly, is it desirable to provide a burner that can increase performance parameters for the emissions
requirements and efficiency, but also maintain desirable burner performance characteristics such as a desired modulation range, flame stability, desired ignition characteristics, desired burner load, and a reduction or absence of resonance combustion noise.

SUMMARY OF THE INVENTION

[0013] The foregoing needs are met, to a great extent, by the present invention, wherein in one aspect a method and apparatus is provided that in some embodiments improve burner efficiency, reduce undesirable emissions, and maintain desirable characteristics such as a desired modulation range, increased flame stability, desired ignition characteristics, desired burner load, and a reduction or absence of resonance combustion noise.

[0014] In accordance with one embodiment of the present invention, a method of burning a gas is provided. The method includes: flowing a air and fuel mixture through a hole in a burner into an interior cavity in the burner; burning the air and fuel mixture on an interior surface defining, at least in part, the interior cavity; and moving heated gas from the interior cavity through a hole in the burner to outside the burner.

[0015] In accordance with another embodiment of the present invention, a burner is provided. The burner includes: a body defining an interior cavity; a burning surface located in the body and defining, at least in part, the interior cavity; a defusing surface located on an exterior portion of the body; ports on the body extending through the defusing and burning surfaces and configured to provide fluid communication between the interior cavity and ambient air outside the body; and an opening larger than at least one of the ports, the opening providing fluid communication between the interior cavity and a space outside of the body.

[0016] In accordance with yet another embodiment of the present invention, a method of reducing acoustic feedback to a combustion device is provided: creating a concentrated flow path for hot gases generated in a combustion device; locating a heat exchanger in the flow path for harvesting heat from the hot gases; and locating in the flow path between the combustion device and the heat exchanger one of: a gap, a connector diverging from the combustion device to the heat exchanger, and a connector converging from the combustion device to the heat exchanger.

[0017] There has thus been outlined, rather broadly, certain embodiments of the invention in order that the detailed description thereof herein may be better understood, and in order that the present contribution to the art may be better appreciated. There are, of course, additional embodiments of the invention that will be described below and which will form the subject matter of the claims appended hereto.

[0018] In this respect, before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and to the arrangements of the components set forth in the following description or illustrated in the drawings. The invention is capable of embodiments in addition to those described and of being practiced and carried out in various ways. Also, it is to be understood that the phrasing and terminology employed herein, as well as the abstract, are for the purpose of description and should not be regarded as limiting.

[0019] As such, those skilled in the art will appreciate that the conception upon which this disclosure is based may readily be utilized as a basis for the designing of other structures, methods and systems for carrying out the several purposes of the present invention. It is important, therefore, that the claims be regarded as including such equivalent constructions insofar as they do not depart from the spirit and scope of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] FIG. 1 is a perspective view illustrating a typical burner.

[0021] FIG. 2 is a cross-section view of a typical combustion device including a heat exchanger and burner.

[0022] FIG. 3 is a perspective view of a combustion chamber including a burner in accordance with one embodiment of the invention.

[0023] FIG. 4 is a perspective view of a burner in accordance with another embodiment of the invention.

[0024] FIG. 5 is a cross-section view of a combustion chamber containing a burner in accordance with an embodiment of the invention. The combustion chamber and burner are fluidly connected to a heat exchanger.

[0025] FIG. 6 illustrates a side view of a burner in accordance with the invention connected with a converging pipe to a heat exchanger.

[0026] FIG. 7 illustrates a cross-section view of a burner in accordance with the invention connected with a diverging pipe to a heat exchanger.

DETAILED DESCRIPTION

[0027] Embodiments in accordance with the invention will now be described with reference to the drawing figures in which like reference numerals refer to like parts throughout. A burner 30 in accordance with an embodiment of the invention is illustrated in FIG. 3. The burner 30 is, in some aspects, similar to the burner shown in FIG. 1. However, the burner 30 shown in FIG. 3 has several key distinctions.

[0028] The burner 30 includes an interior burning surface 32. The interior burning surface 32 may in some embodiments be made of refractory high temperature steel. Alternatively the burning surface 32 could be made of metal fibers or ceramics. Any suitable material may be used to comprise the burning surface 32 in accordance with the invention. The burner 30 is generally cylindrical in shape with one end having a cap 34. Near the other end of the burner is a flange 36 having fastener holes 38 for attaching the burner 30 to a support structure.

[0029] The burner 30 includes ports 40 located on the cylindrical portion 41 as well as the end cap 34. The ports 40 may be similarly sized to those described with respect to FIG. 1. The width of the ports 40 may be approximately the same as the thickness of the material comprising the side wall 41 of the burner 30. One example size of port 40 may be one half millimeter by five millimeters, however, any suitable size port 40 may be used in accordance with the invention. The ports 40 may be sized according to the specific needs of a particular application. The ports 40 provide fluid communication between the ambient environment outside of the burner 30 and the interior 42 of the burner.

[0030] On the outside of the burner 30 is a diffusing surface 44. In some embodiments in accordance with the invention, the diffusing surface 44 may be made of stainless steel, however, any suitable material may be used in accordance with the invention.
As shown FIG. 3, the burner 30 may be located in a pressure chamber 46. The pressure chamber 46 shown in FIG. 3 is merely a representation and is not intended to describe specific geometry of a pressure chamber 46. Any suitable geometry may be used in accordance with the invention. An inlet 48 provides an air and fuel mixture to the pressure chamber 46. The air and fuel mixture flows in the direction indicated by arrows C through the inlet 48 into the pressure chamber 46 and through the ports 40 into the interior 42 of the burner 30.

According to some embodiments of the invention, the inlet 48 and the pressure chamber 46 are pressurized to a positive pressure in order to drive the air and fuel mixture into the burner 30. Some embodiments may include a fan or other means for pressurizing the inlet 48 and pressure chamber 46 upstream from the burner 30. Other embodiments may include a fan or other pressure inducing device downstream from the burner 30. The burner 30 may be used whether the air and fuel mixture is pushed or pulled through the burner 30. In embodiments where air and fuel mixture is pulled through the burner 30 one skilled in the art will appreciate that the air and fuel mixture may be supplied without a pressurized chamber 46. Any suitable means of providing the air and fuel mixture to the burner 30 may be accomplished in accordance with the invention.

Once the air and fuel mixture has flowed in the direction of arrows C through the ports 40 into the interior 42 of the burner 30, the air and fuel mixture is burned in the interior 42 of the burner 30. The air and fuel mixture may be ignited by any suitable igniter system.

The combustion of the air and fuel mixture occurs within the interior hollow cavity 42 defined by the burner 30. Once the air and fuel mixture has been burned in the burner 30 it escapes from the burner 30 out the opening 50 in the direction of arrow D.

As can be seen in FIG. 3 the interior burning surface 32 may have a much larger surface area than the surface area of the opening 50. This characteristic is in contrast to the burner shown in FIG. 1, where the burning surface 12 is roughly the same size (as it is roughly the same area) as the area of heat release. On the burner 10 shown in FIG. 1, heat escapes in the direction shown by arrows B. The ratio of the burning surface 12 and the surface emitting heat 12 is roughly 1 to 1.

With the burner 30 shown in FIG. 3, the burning surface 32 may have a much greater surface area than the area of the opening 50 through which the hot gases and the heat escape the burner 30. This gives the effect of concentrating the hot gases and heat generated by the burner through the opening 50. The ratio of the burning surface 32 to the opening 50 is theoretically unlimited.

FIG. 4 is a perspective view of another burner 30 in accordance with the invention. The burner 30 illustrated in FIG. 4 is box shaped. The burner 30 has ports 40 similar to those described above. The air and fuel mixture enters the burner 30 through the ports 40 in the directions illustrated by arrow C. The burner 30 illustrated in FIG. 4 may contain more than one opening 50 through which hot gases and heat may escape the burner 30. The openings 50 through which the hot gases and heat may escape the burner 30 are shown in irregular patterns to illustrate that the shape of openings 50 for the burner 30 may be selected to satisfy whatever requirements are presented in individual application or to satisfy a particular desire. In addition, while two openings 50 are illustrated in the burner 30 of FIG. 4, any number of openings 50 may be used as desired.

Burners 30 may be in any shape having an interior cavity. Examples may include burners that are in the shape of a cylinder, a box, a sphere, torus, and a U shape. Other shapes, both regular and irregular, may be used.

The burner 30 of FIG. 4 combusts the air and fuel mixture in the interior 42 of the burner 30 and vents the heat through the openings 50 in the direction of arrows D.

According to some embodiments of the invention, the air and fuel mixture provided a burner 30 includes more air than the stoichiometric required amount to achieve combustion. In some embodiments the amount of air supplied to the burner 30 may be 1.1 to 1.5 times the stoichiometric required amount. In other embodiments other air and fuel ratios may also be used. In some embodiments of the invention, applying 1.2 to 1.3 times the stoichiometric required amount of air produces a blue flame within the burner. Using blue flame can reduce NOx emissions.

Certain burners 30 may achieve a few advantages by conducting the combustion inside the interior cavity 42 of the burner 30. For example, the modulation range of the burner 30 is increased because when combustion is being conducted within a smaller space, the burner is less likely to experience flame out. If combustion along any portion of the burning surface 32 goes out for whatever reason (such as an anolomity in the delivery of the air and fuel mixture) rather than merely flaming out, the surrounding combustion can reignite the air and fuel mixture with respect to the individual port or portion of the burning surface 32 that was experiencing flame out.

Such a feature may allow the burner 30 to have increased reliability at higher air and fuel mixture speeds thereby increase its modulation range. At the other end of the spectrum, the modulation range may also be increased by allowing a lower amount of air and fuel mixture to be provided to the burner 30 and the burner 10 still having reliable operation. The burner 30 is able to sustain combustion when both less and more air and fuel mixture is applied to it, thus increasing its modulation range. For the same reasons, flame stability is also increased within the modulation range. Burners 30 in accordance with the invention may have a modulation range at or beyond 10:1.

At low air and fuel mixtures where infrared burning occurs, the flame may be stabilized by the temperature profile. At very low air fuel mixture velocity when the flame is blue, flame stabilization occurs through the temperature of the cavity in the burner 30.

FIG. 5 is a cross-sectional view of a burner 30 fluidly connected to a heat exchanger 66 in accordance with an embodiment of the invention. The burner 30 is mounted in a pressure chamber 46. The air and fuel mixture enters the pressure chamber 46 through the inlet 48. The air and fuel mixture is at a positive pressure within the pressure chamber 46 and moves into the burner 30 via the ports 40.

Arrows C illustrate the direction of movement for the unburned air and fuel mixture. The air and fuel mixture is burned within the interior chamber 42 of the burner 30 and moves in the direction of arrows D through the burner outlet 50 through the pathway 72 of the heat exchanger 66. As the hot gases move through the pathway 72 of the heat exchanger 66, heat is moved from the hot gases through the side walls 67 into the fluid 68 to be heated.
In some heat exchanging systems, the heat exchanging pathway such as the pathway 72 shown in FIG. 5, may be subject to acoustical vibrations and resonance. Passage ways such as passage way 72 shown in FIG. 5 can be modeled as a Helmholtz resonator and amplify vibrations and/or acoustical resonance. The vibrations may result in acoustical feedback to a burner 30.

In accordance with some embodiments of the invention, a gap 70 exists between the opening 60 of the burner 30 and the pathway 72 through the heat exchanger 66. The gap 70 may help prevent acoustical feedback to the burner 30. As hot gases moving through the passage way 72 they can create vibrations and acoustical resonance. These vibrations may travel back towards the burner 30. The gap 70 between the burner and the pathway 72 may reduce the amount of the acoustical resonance transmitted back to the burner 30. By reducing acoustical feedback to the burner 30, combustion can be better controlled within the burner 30.

Because the combustion and post-combustion zones are in the cavity 42 the heat exchanger 54 and combustion chamber/pressure chamber 46 have little or no influence on the cavity 42 conditions.

In accordance with other embodiments of the invention, as shown in FIG. 6 and 7, other techniques for reducing acoustical resonance feedback to the burner 30 can include using a divergent or convergent tube to connect the burner 30 to the heat exchanger 66.

FIG. 6 illustrates a combustion chamber 46 having a burner 30 where combustion is occurring. Hot gases flow in the direction illustrated by arrows D out of the burner 30 toward the pathway 72 through the heat exchanger 66. The burner 30 connects via the flange 36 to the pressure chamber 46. A convergent transition piece or tube 74 connects the interior of the burner 30 to the pathway 72 through the heat exchanger 66. The convergent transition piece 74 may include flanges 76 and 78 similar to that described with respect to the burner 30 in order to allow the convergent transition piece 74 to connect to the pressure chamber 46 and the heat exchanger 66.

Contrast to that shown in FIG. 6, the embodiment shown in FIG. 7 includes a divergent transition piece 80 connecting the interior 42 of the burner 30 to the fluid path 72 within the heat exchanger 66. The divergent transition piece 80 may be a tube having flanges 82 and 84 similar to those described above. The flanges may include holes for providing fasteners to connect the divergent transition piece 80 to the heat exchanger 66 of the pressure chamber 46. Alternatively the flange 84 may also allow fasteners to connect to the flange 36 of the burner 30. Any suitable way of attaching a divergent transition piece 80 or a convergent transition piece 74 as shown in FIG. 6 may be used in accordance with the invention and flanges are not necessary for all embodiments.

The convergent transition piece 74 of FIG. 6 and the divergent transition piece 80 of FIG. 7 serve similar purpose as the gap 70 shown in FIG. 5. The transition pieces 74 and 80 reduce the amount of acoustical resonance generated in the heat exchanger 66 transmitted back to the burner 30. Gaps 70 or convergent transition pieces 74 or divergent transition pieces 80 have been shown to be effective in reducing the amount of acoustical resonance in comparison to a transition piece where the interior diameter of the transition piece is the same as the fluid path 72 and the interior of the burner. In some respects the gap 70 shown in FIG. 5 can be considered to be a divergent transition piece of infinite diameter.

In accordance with some embodiments of the invention, none of the combustion of the hot gases occurs within the fluid path 72 of the heat exchanger 66 but rather the combustion as well as the post-combustion zone occurs within the interior 42 of the burner 30. Keeping the post-combustion zone in the burner 30 can increase the temperature of the hot gases within the post-combustion zone. The post-combustion zone 62 of FIG. 2 is not contained in the interior 42 of a burner. As such, it may not be as hot due to several factors.

For example, the ratio of the combustion surface and the surface exiting hot gases in the burner 20 of FIG. 2 is about 1:1. Thus, the heat and hot gases are not concentrated as described above where the ratio of heat emitting surface and the combustion surface can be much higher.

In addition, the post-combustion zone 62 as shown in FIG. 2 may lose heat to the tubes 56 of the heat exchanger before all chemical reactions occur in the post-combustion zone 62.

In contrast to the burner of FIG. 2, and as shown in FIGS. 3-7, a burner 10 in accordance with some embodiments of the invention maintain the combustion and post-combustion zone in the interior 42 of the burner 10. By keeping the combustion and post-combustion zones in the interior 42 of the burner 10, the heat and hot gases are concentrated. In addition, the hot gases are not able to lose heat to a heat exchanger until the hot gases have exited the post-combustion zone. By maintaining a relatively hot post-combustion zones, the flame is stable and a more complete conversion of CO to CO2 may be achieved thereby reducing CO emissions. Under these conditions NOx emissions may be very low. In some embodiments CO emissions may be at or lower than 10 ppm air free and NOx emissions may be at or lower than 10 ng/J.

A further advantage of a burner 10 according to some embodiments is that the heat and hot gases are easily directed to a desired pathway. The heat can easily be directed to encounter a heat exchanger at a desired angle.

What is claimed is:
1. A method of burning a gas comprising:
   - flowing an air and fuel mixture through a hole in a burner into an interior cavity in the burner;
   - burning the air and fuel mixture on an interior surface defining, at least in part, the interior cavity; and
   - moving heated gas from the interior cavity through a hole in the burner to outside the burner.
2. The method of claim 1, further comprising containing substantially all of the combustion in the cavity.
3. The method of claim 1, further comprising burning the air and fuel mixture with at least one of a blue flame and infrared flame.
4. The method of claim 1, further comprising providing more air to the air and fuel mixture than the stoichiometric required amount to burn the fuel.
5. The method of claim 4, wherein 50% more air is provided than the stoichiometric required amount to burn the fuel.
6. The method of claim 1, further comprising moving the heated gas into a heat exchanger.
7. The method of claim 6, wherein no combustion occurred outside of the burner.
8. The method of claim 6, further comprising moving the heated gas through a gap between the burner and the heat exchanger.
9. The method of claim 6, further comprising moving the heated gas through one of a convergent tube and a divergent tube fluidly connecting the interior of the burner with the heat exchanger.

10. The method of claim 1 further comprising providing an air pressure ambient to the burner greater than an air pressure in the cavity within the burner.

11. A burner comprising:
   a body defining an interior cavity;
   a burning surface located in the body and defining, at least in part, the interior cavity;
   a defusing surface located on an exterior portion of the body;
   ports on the body extending through the defusing and burning surfaces and configured to provide fluid communication between the interior cavity and ambient air outside the body; and
   an opening larger than at least one of the ports, the opening providing fluid communication between the interior cavity and a space outside of the body.

12. The burner of claim 11, further comprising a flange for connecting the burner to a support structure.

13. The burner of claim 11, further comprising a second opening larger than at least one of the ports, the opening providing fluid communication between the interior cavity and a space outside of the body.

14. The burner of claim 11, wherein the burner is generally shaped in of the following: a cylinder, a box, a sphere, torus, and a U.

15. The burner of claim 11, wherein the ratio of the surface area of the burning surface and the opening is at least 1.4 units of burning surface to 1.0 units of opening.

16. The burner of claim 11, further comprising a combustion device, wherein the burner is located in a combustion chamber of the combustion device.

17. The burner of claim 11, wherein the combustion device is configured to provide a air and fuel mixture to the burner at a greater pressure than a pressure of the space in the interior cavity so that the air and fuel mixture will flow through the ports into the interior cavity, and wherein more air is provided than stoichiometrically necessary to burn the fuel.

18. The burner of claim 11, further comprising a heat exchanger located and configured to define a flow path for gas vented out of the interior chamber through the opening.

19. The burner of claim 18, wherein the opening of the burner and an opening in the heat exchanger are separated by a gap.

20. The burner of claim 18, wherein the opening of the burner and an opening in the heat exchanger are connected by a conduit configured to fluid communication between the interior cavity and the heat exchanger wherein the conduit is one of: converging from the cavity and the heat exchanger and diverging from the cavity to the heat exchanger.

21. A method of reducing acoustic feedback to a combustion device comprising:
   creating a concentrated flow path for hot gases generated in a combustion device;
   locating a heat exchanger in the flow path for harvesting heat from the hot gases; and
   locating in the flow path between the combustion device and the heat exchanger one of: a gap, a connector diverging from the combustion device to the heat exchanger, and a connector converging from the combustion device to the heat exchanger.

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