Feb. 7, 1967 H. F. MENZEL 3,302,620

CIRCULAR CROSS FLOW IN STEAM GENERATOR

Filed Nov. 18, 1963

Fig 1

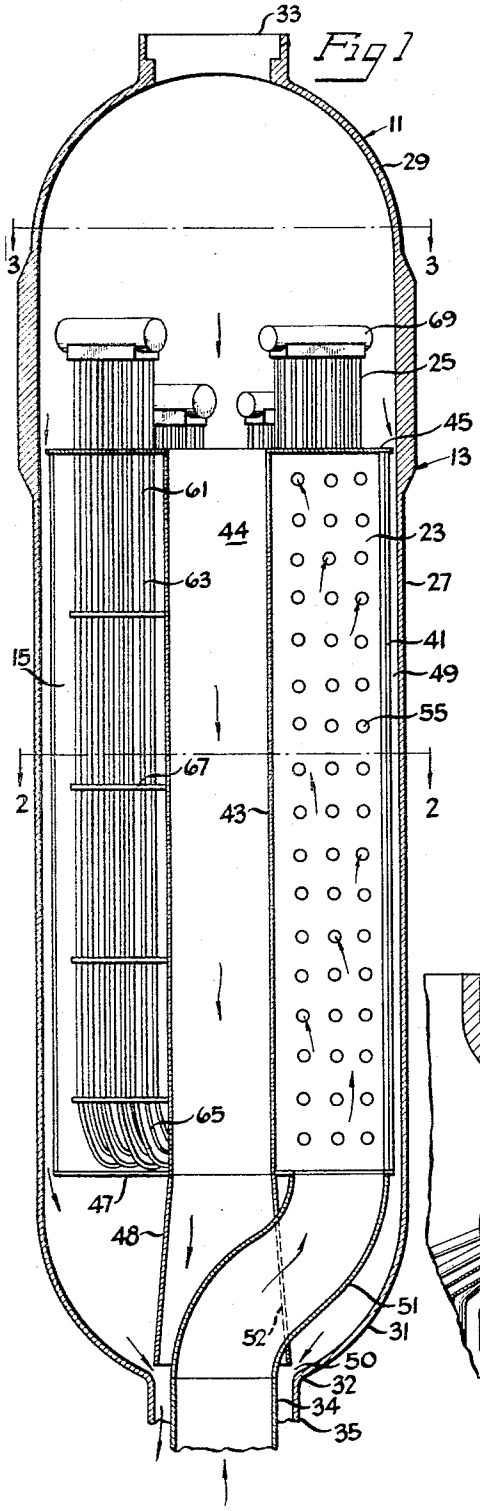


Fig 2

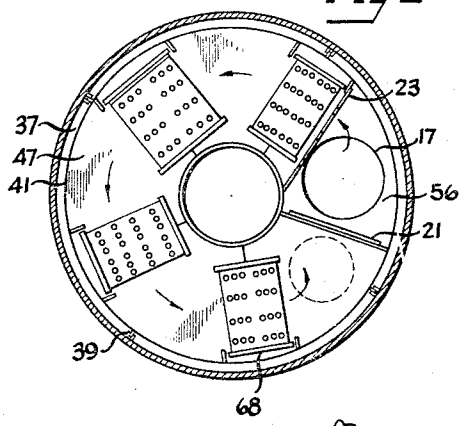


Fig 3

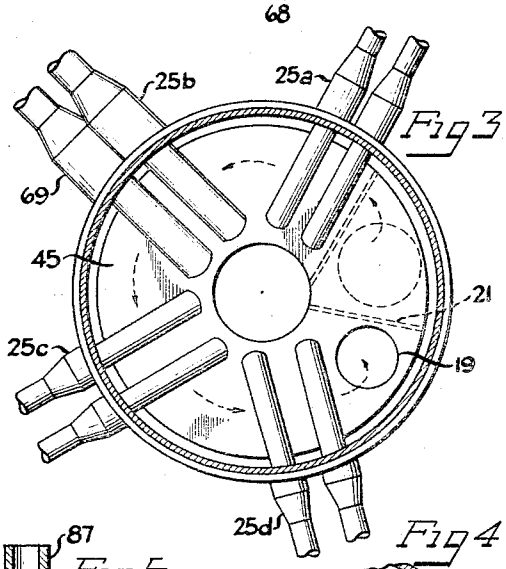


Fig 5

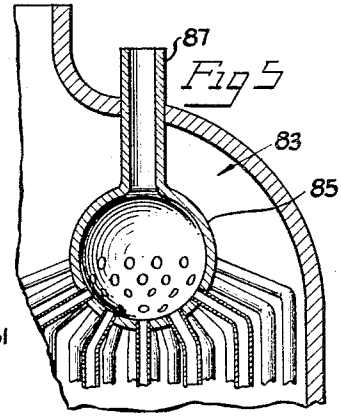
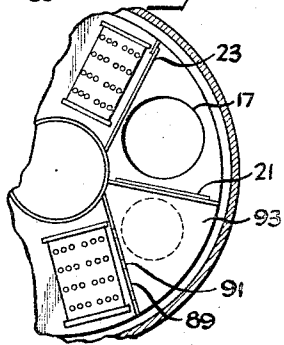


Fig 4



Inventor
Horst F. Menzel

By Anderson, Luedeka, Fitch, Even & Tabin
Atty's

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CIRCULAR CROSS FLOW IN STEAM GENERATOR

Horst F. Menzel, Poway, Calif., assignor to General Dynamics Corporation, New York, N.Y., a partnership

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This invention relates to steam generators. More specifically, the invention relates to steam generators particularly adapted for use in conjunction with high-temperature gas-cooled nuclear reactors.

In nuclear power plants utilizing a circulating gas such as helium to conduct heat away from the reactor core, steam for the operation of a work-producing element of the power plant system is normally obtained by the transfer of heat from the gas to the fluid of a water/steam system. Conventionally, such heat transfer is accomplished in a steam generator.

In such a gas-cooled reactor/generator system, it is frequently desirable that the gas be caused to make only a single pass through the steam generator before being returned to the reactor. It is therefore important that the greatest possible amount of heat be withdrawn from the gas during the single pass in order that maximum efficiency be achieved. However, it is also important that there be as little restriction to gas flow as possible in order that work expended in transporting the gas through the system be held to a minimum.

Accordingly, it is the principal object of the present invention to provide an improved steam generator.

Another object of the invention is to provide an improved steam generator capable of achieving an efficient transfer of heat between a working fluid and a gas making a single pass through the generator.

An additional object of the invention is to provide an improved steam generator capable of providing an efficient withdrawal of heat from a gas in a single pass through the generator without a significant restriction to gas flow.

A further object of the invention is to provide an improved steam generator which causes a gas to flow in a circular path in making a single pass through the generator.

Other objects and advantages of the invention will become apparent with reference to the following description and the accompanying drawings.

In the drawings:

FIGURE 1 is an elevational view, partially in section, of an apparatus showing various of the features of the invention;

FIGURE 2 is a sectional plan view taken along line 2—2 of FIGURE 1;

FIGURE 3 is a fragmentary sectional plan view taken along line 3—3 of FIGURE 1;

FIGURE 4 is a fragmentary sectional plan view similar to the sectional view of FIGURE 3, but showing an alternate embodiment; and

FIGURE 5 is a fragmentary elevational view, partially in section, showing an alternate construction of a portion of the apparatus.

Very generally, there is illustrated in the drawings a steam generator **11** comprising a containment shell **13** having defined therein an elongated flow chamber **15** of annular cross-section provided with an inlet port **17** near its lower end and an outlet port **19** near its upper end, each of which is located adjacent to, but on opposite sides of, a gas impervious upwardly extending baffle plate **21**. Gas entering the chamber **15** through the inlet port **17** is thus caused to flow in a circular path through the chamber to the outlet port **19**. A perforated baffle plate **23** is disposed adjacent the inlet port **17** opposite the baffle **21**

to cause uniform distribution of the incoming gases, and a series of tube bundles **25** are circumferentially arranged within the annular chamber in the path of the circulated gas and define conduits for the water or steam to be heated in the generator for later production of work by conversion of heat energy to mechanical energy at another part of the lower plant system.

Thus, the heat generated by the reactor core is transferred to a fluid which in turn expends the heat absorbed in a work producing element of the system.

Though the steam generator of the illustrated embodiment is particularly adapted to be used in conjunction with a gas-cooled nuclear reactor and is described with relation thereto, it should be appreciated that it has other applications and may readily be used with any system utilizing a fluid medium for transfer of heat from a source to the fluid to be heated.

More specifically, the containment shell **13** includes a generally cylindrical side wall **27** closed at its upper end by a top head **29** and at its lower end by a bottom head **31**. The top head is generally hemispherical in shape and is provided with a central opening **33** adapted to accept a circulator (not shown) for causing movement of the helium gas. The bottom head is also generally hemispherical in shape and is provided with a central opening **32** through which gas enters and is discharged from the generator by means of concentrically arranged inlet and outlet ducts **34** and **35** respectively.

The annular flow chamber **15** is defined within the shell **13** by an elongated vertically disposed vessel **37** suitably supported, as by brackets **39** extending inwardly from the side walls **27** of the shell, and includes an outer cylinder **41**, a concentrically arranged inner cylinder **43** and horizontally positioned upper and lower annular shroud sections **45** and **47**. The inner cylinder **43** serves as a conduit **44** for gases which have passed through the flow chamber and has a discharge diffuser **48** of downwardly flaring configuration secured to its lower end to conduct the gas to the central opening **32** in the bottom head **31**. The lower edge of the diffuser is spaced from the periphery of the central opening **32** to provide a gap **50**, the function of which will become apparent shortly.

The inner surface of the outer cylinder **41** and the outer surface of the inner cylinder **43** are preferably covered with an insulating material (not shown) to reduce heat loss. The vessel **37** is of a somewhat lesser height than the shell **13** and is arranged therein so as to provide ample space above the upper shroud **45** to accommodate headers at the upper ends of the tube bundles, as hereinafter more fully described. In addition, the outer diameter of the vessel is slightly less than the inner diameter of the cylindrical side wall **27** of the shell, thus providing a narrow annular passageway **49** intermediate the adjacent walls of the shell and vessel through which gas may be caused to flow.

Positioned within the annular chamber **15** is the gas-impervious baffle plate **21** which extends upwardly from the upper surface of the lower shroud **47** to the lower surface of the upper shroud **45**, in parallel relation to the longitudinal axis of the vessel **37**, and which extends laterally between the inner surface of the outer cylinder **41** and the outer surface of the inner cylinder **43**. The edges of the baffle plate are suitably attached to the adjacent surfaces of the vessel **37**, as by welding, so as to prevent the passage of gas therearound. Hence, gas entering the chamber through the inlet port **17** adjacent one side of the baffle can travel in only one direction, i.e., counterclockwise in the illustrated embodiment (FIGS. 2 and 3), in moving to the outlet port **19**, as will be explained in more detail shortly. The baffle plate **21** also acts as insulation between hot incoming gas and cooler exit gas leaving outlet port **19**.

The inlet port **17** is in the form of an opening provided in the lower shroud **47** adjacent the gas-impervious baffle **21** but spaced in a counterclockwise direction therefrom (FIGS. 2 and 3). An S-shaped conduit **51** passes through an opening **52** in the diffuser and connects the inlet port **17** to the inlet duct **34** which extends through the opening **32** at the bottom of the containment shell in concentric relation to the outlet duct **35**.

Adjacent the side of the inlet port **17** opposite the baffle **21**, i.e., spaced in a counterclockwise direction therefrom, is the perforated distribution baffle **23** which is provided with a plurality of orifices **55**. The perforated baffle is coextensive with the gas-impervious baffle **21** and, like the latter, is arranged in parallel relation to the longitudinal axis of the annular chamber **15**. Accordingly, the inlet port **17** is bordered on opposite sides by the impervious and perforated baffles **21** and **23** respectively which thereby define a vertical passageway **56** through which the incoming gases are conducted upwardly. However, because of the perforated nature of the baffle **23**, these upwardly conveyed gases will flow into the chamber through the orifices **55** and thus enter the chamber at various heights so as to provide for a more uniformly distributed flow of gas. If desired, the orifices **55** can be made with varying flow areas in order to insure uniform gas flow through all portions of the baffle **23**. In this respect, since the pressure of the incoming gas will gradually decrease in ascending the vertical inlet passageway **56** as part of the gas passes through orifices **55**, the area of the orifices near the lower shroud **47** would be made smaller than the area of the orifices near the upper shroud **45**.

The outlet port **19** is in the form of an opening provided in the upper shroud **45** adjacent the gas-impervious baffle **21** and spaced in a clockwise direction therefrom (FIGS. 2 and 3) so as to be located on the opposite side of the baffle **21** from the inlet port **17**. As shown by the arrows in FIGURES 2 and 3, the gas enters the annular flow chamber **15** through the inlet port **17** and is carried upwardly through the inlet passageway **56**. The gas then flows through the orifices **55** of the baffle **23** into the chamber **15** and follows a circular path to the outlet port **19**. It will be appreciated that as the gas follows such a path, it is caused to pass through the entire chamber wherein the tube bundles **25** are disposed, thus providing for efficient heat exchange from the gas to the water or steam contained within the tube bundles. However, the path of the gas is not so irregular or devious as would cause a substantial pressure drop within the generator. Due to the uniform gas distribution in the chamber **15** caused by the baffle **23**, the gas flow in the chamber is essentially circular until the gas has passed the last of the tube bundles **25**.

After passing through the outlet port **19**, the gas flows into the space defined by the top head **29** of the containment shell **13** and then is divided into two unequal masses, the larger of which flows downwardly through the conduit **44** defined by the inner cylinder **43** of the vessel **37** to and through the discharge diffuser **48**. The smaller portion of the mass of gas from the outlet port **19** flows downwardly from the space defined by the top head **29** through the narrow annular passageway **49** intermediate the side walls **27** of the shell **13** and the outer surface of the wall **41** of the vessel **37**. This downwardly flowing mass flows into the space defined by the bottom head **31** and then through the gap **50** to the outlet duct **35** where it re-combines with the larger mass of gas flowing through the conduit **44** and diffuser **48**. The action of the gas flowing through the narrow annular passageway cools the side wall **27** of the containment shell **13** and, in addition, tends to equalize the pressure on opposite sides of the outer cylinder **41** of the vessel **37**.

The water/steam system of the steam generator comprises a set of four of the tube bundles **25**, each of which includes a plurality of tubes **61** formed into a U-shape so as to provide vertically disposed parallel tubular sections **63**, pairs of which are connected at their lower ends by return bends **65**. All of the tubular sections **63** of the various tubes **61** of each bundle are connected at their upper ends by a cylindrical horizontally disposed distribution header **69**. Periodically spaced horizontally disposed baffles **67** maintain the tubes in spaced relation to one another in a rectangular horizontal cross-sectional pattern, and a vertically disposed baffle **68** is disposed on each of a pair of opposite sides of the bundles in generally parallel relation to the side walls of the vessel **37**.

The tubes **61** extend through holes provided in the upper shroud **45** with the headers **69** located above the shroud and the greater portion of the tubes below the shroud. The four bundles which the tubes form are circumferentially arranged within the annular chamber **15** in the space outside of the vertical passageway **56** defined by the baffles **21** and **23**. Each of the set of tube bundles is connected to a different portion of the water/steam system, as hereinafter described.

It should be appreciated that as the gas travels in a counterclockwise direction through the annular chamber **15** and across the tube bundles in its path, its temperature is gradually lowered and the water or steam flowing within the tubes of the bundles successively encountered absorbs proportionately less heat. Accordingly, a tube bundle **25***a* positioned adjacent the perforated baffle **23** and spaced therefrom in a counterclockwise direction (FIGS. 2 and 3), encounters gas at the highest possible temperature, and is theerfore designated the super-heater tube bundle. The remaining three tube bundles **25***b*, **25***c* and **25***d*, which are sequentially arranged in a counterclockwise direction and are circumferentially spaced within the chamber **15** from one another and from the tube bundle **25***a*, are designated reheater, evaporator and economizer tube bundles respectively.

As water or steam flows through the tube bundles from the inlet headers to the outlet headers, heat exchange between the high temperature gas and the fluid to be heated is accomplished by the circular cross-flow of the respective fluids, the direction of flow of the water or steam being either vertically upwardly or vertically downwardly and the gas flow being circular.

Referring now to FIGURE 5, there is illustrated an alternative header arrangement **83** comprising spherical distribution headers **85** and vertical risers **87**. The tube ends enter and are secured to the lower hemisphere of the headers and depend therefrom to form a bundle of rectangular cross-section. The riser **87** passes through the top head **29** and is welded thereto to form a gas-tight seal. The spherical header requires less material for a given volume, and material of a reduced thickness may be used as compared to the cylindrical header for the same pressure range application.

To further improve the circular flow characteristics of the gas flowing through the annular flow chamber **15**, an alternative embodiment is shown in FIGURE 4 which includes a perforated baffle **89** similar to perforated baffle **23** and provided with a plurality of orifices **91** similar to the orifices **55**. The baffle **89** is placed adjacent the outlet port **19** opposite the gas-impervious baffle **21**. Accordingly, the outlet port **19** is bordered on opposite sides by the baffles which thereby define a vertical outlet passageway **93**.

In the alternate embodiment, the gas flows through the annular chamber **15** and passes into the outlet passageway **93** at vertically spaced points therealong through the orifices **91** and thereafter flows vertically upwardly through the passageway **93** and out the port **19** into the top head **29**.

As can be appreciated, a steam generator particularly adapted for use with a high temperature gas cooled nuclear reactor has ben provided which accomplishes heat exchange from the high temperature gas to the fluid to be

heated through circular cross-flow of fluids, and incorporates either cylindrical or spherical headers in the water/steam fluid system of the generator. This arrangement provides for compact construction, efficient heat transfer between the fluids and requiring a minimum amount of work to circulate the heated gas.

Various of the features of the invention are set forth in the following claims.

What is claimed is:

1. A stream generator comprising an outer containment shell having a vertically elongated cylindrical side wall, a top head and a bottom head, a vessel defining an elongated vertically disposed chamber of annular cross-section closed at opposite ends concentrically positioned within the space defined by said cylindrical side wall of said shell, said annular chamber being of a reduced diameter as compared to said cylindrical side wall and forming therebetween an annular vertically elongated passageway, a vertically elongated gas-impervious baffle plate within said vessel extending transversely across said annular chamber, a vertically elongated perforated baffle plate adjacent one side of said gas-impervious baffle plate, circumferentially spaced therefrom and forming therewith an inlet passageway within said chamber on one side of said gas-impervious baffle adapted to be connected to a source of pre-heated gas through the lower end of said chamber, said perforated baffle plate defining a plurality of vertically spaced orifices providing communication between said inlet passageway and said annular chamber, means defining an outlet opening in the upper end of said chamber adjacent the opposite side of said impervious baffle through which the gas may be discharged from said chamber into the space defined by said top head, the relative positions of said inlet passageway and said outlet causing the gas to travel in a general circular path through said chamber from said inlet orifices to said outlet opening, said annular chamber defining vessel additional defining a cylindrical passageway concentric with said chamber and interiorly located with respect thereto communicating between said top head and said bottom head adapted to cause said gas to flow downwardly therethrough into said bottom head, said annular passageway defined by said cylindrical side wall and said annular chamber also being in communication with said top and bottom heads whereby a portion of said gas is caused to travel therethrough to cool said shell, means defining an annular discharge passage connected to the lower end of said bottom head whereby said gas may be caused to discharge from said shell, and at least two vertically disposed horizontally spaced tube bundles adapted to transport the fluid to be heated, said tube bundles being disposed in said path of circular gas flow within said annular chamber.

2. A steam generator comprising an outer containment shell having a vertically elongated cylindrical side wall, a top head and a bottom head, a vessel defining an elongated vertically disposed chamber of annular cross-section closed at opposite ends concentrically positioned within the space defined by said cylindrical side wall of said shell, said annular chamber being of a reduced diameter as compared to said cylindrical side wall and forming therebetween an annular vertically elongated passageway, a vertically elongated gas-impervious baffle plate within said vessel extending transversely across said annular chamber, a first vertically elongated perforated baffle plate adjacent one side of said gas-impervious baffle plate, circumferentially spaced therefrom and forming therewith an inlet passageway within said chamber on one side of said gas-impervious baffle adapted to be connected to a source of pre-heated gas through the lower end of said chamber, said perforated baffle plate defining a plurality of vertically spaced orifices providing communication between said inlet passageway and said annular chamber, a second vertically elongated perforated baffle plate adjacent the opposite side of said gas-impervious baffle plate circumferentially spaced therefrom and forming therewith an outlet passageway within said chamber on said opposite side of said gas-impervious baffle adapted to discharge the gas from said chamber through the opposite end thereof into the space defined by said top head, said perforated baffle plate defining a plurality of vertically spaced orifices providing communication between said outlet passageway and said annular chamber, the relative positions of said inlet passageway and said outlet passageway causing the gas to travel in a generally circular path through said chamber from said inlet orifices to said outlet orifices, said annular chamber defining vessel additionally defining a cylindrical passageway concentric with said chamber and interiorly located with respect thereto communicating between said top head and said bottom head adapted to cause said gas to flow downwardly therethrough into said bottom head, said annular passageway defined by said cylindrical side wall and said annular chamber also being in communication with said top and bottom heads whereby a portion of said gas is caused to travel therethrough to cool said shell, and means defining an annular discharge passage connected to the lower end of said bottom head whereby said gas may be caused to discharge from said shell, and at least two vertically disposed horizontally spaced tube bundles adapted to transport the fluid to be heated, said tube bundles being disposed in said path of circular gas flow within said annular chamber.

3. A steam generator including in combination, a vessel comprised of an axially elongated cylindrical outer wall and an axially elongated cylindrical inner wall centrally of said outer wall, said vessel further comprising first and second end walls closing the space between said inner and outer walls at the ends thereof to define an annular elongated chamber, an elongated gas-impervious baffle plate within said chamber extending between said first and second end walls and transversely between said inner and outer walls, an elongated perforated baffle plate within said chamber extending between said first and second end walls and transversely between said inner and outer walls, said perforated baffle plate being circumferentially spaced from said gas-impervious baffle plate and forming therewith an inlet passageway within said chamber on one side of said gas-impervious baffle plate, said first end wall having an inlet opening therein communicating with said passageway and adapted to be connected to a source of preheated gas, said perforated baffle plate having a plurality of axially spaced orifices therein providing communication between said inlet passageway and said annular chamber, said second end wall having an outlet opening on the side of said gas-impervious baffle plate opposite from said inlet opening and through which the gas may be discharged from said chamber, the relative positions of said inlet and said outlet openings causing the gas to travel in a generally circular path through said chamber from said orifices to said outlet opening, heat exchanger means located in the path of circular gas flow within said chamber, and casing means enclosing said vessel, said casing means cooperating with said outlet opening to direct the flow of gas discharged therethrough externally of said chamber to the first end wall thereof.

4. A steam generator including in combination, a vessel comprised of an axially elongated cylindrical outer wall and an axially elongated cylindrical inner wall centrally of said outer wall, said vessel further comprising first and second end walls closing the space between said inner and outer walls at the ends thereof to define an annular elongated chamber, an elongated gas-impervious baffle plate within said chamber extending between said first and second end walls and transversely between said inner and outer walls, an elongated perforated baffle plate within said chamber extending between said first and second end walls and transversely between said inner and outer walls, said perforated baffle plate being circumferentially

spaced from said gas-impervious baffle plate and forming therewith an inlet passageway within said chamber on one side of said gas-impervious baffle plate, said first end wall having an inlet opening therein communicating with said passageway and adapted to be connected to a source of preheated gas, said perforated baffle plate having a plurality of axially spaced orifices therein providing communication between said inlet passageway and said annular chamber, said second end wall having an outlet opening on the side of said gas-impervious baffle plate opposite from said inlet opening and through which the gas may be discharged from said chamber, the relative positions of said inlet and said outlet openings causing the gas to travel in a generally circular path through said chamber from said orifices to said outlet opening, heat exchanger means located in the path of circular gas flow within said chamber, and means adjacent said outlet opening and cooperating therewith to direct the flow of gas discharged through said outlet opening centrally of said inner wall such that said inner wall defines a return passage for the gas externally of said chamber to the first end wall thereof.

5. A steam generator according to claim 3 including a second elongated perforated baffle plate within said chamber extending between said first and second end walls and transversely between said inner and outer walls, said

perforated baffle plate being circumferentially spaced from said gas-impervious baffle plate on the side opposite from said first perforated baffle plate and forming with said gas-impervious baffle plate an outlet passageway comunicating with said outlet opening and adapted to discharge the gas from said chamber.

6. A steam generator according to claim 3 wherein the perforations in said perforated baffle plate vary in size to provide uniform flow of gas through all portions of the baffle plate.

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KENNETH W. SPRAGUE, *Primary Examiner.*
D. G. BLACKHURST, *Assistant Examiner.*