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(54) Title: APPARATUS AND METHOD FOR MINIMIZING SMOKE FORMATION IN A FLARING STACK

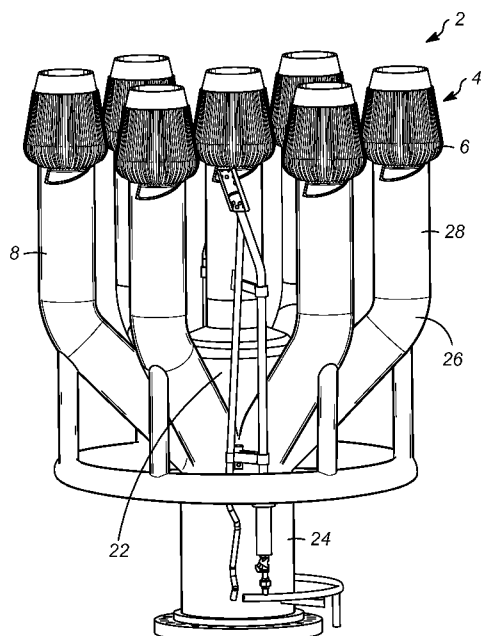


FIG. 1

(57) Abstract: An apparatus and method for minimizing smoke formation in the operation of a flaring stack. The apparatus includes a generally annular gas deflector having an outer surface for deflecting the waste gas therealong. A plurality of lobes extend radially from the deflector to provide improved mixing between the waste gas, steam, and combustion air during combustion to reduce smoke formation.



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APPARATUS AND METHOD FOR MINIMIZING SMOKE FORMATION IN A FLARING STACK

STATEMENT OF PRIORITY

[0001] This application claims priority to U.S. Application Nos. 14/266,972 and 14/266,952 which were filed on May 01, 2014, which claim benefit of U.S. Provisional Application Nos. 61/819,173 and 61/819,184 which were filed May 03, 2013.

FIELD OF THE INVENTION

[0002] The subject application relates to an apparatus for minimizing smoke formation in a flaring stack.

BACKGROUND OF THE INVENTION

[0003] Flare apparatus have traditionally been utilized for burning and exhausting combustible gases. Flare apparatus are commonly mounted on flare stacks and located at production, refining, and processing plants for disposing of flammable waste gases or other flammable gas streams, which are diverted for any reason, including but not limited to venting, shut-downs, upsets, and/or emergencies. Primarily, flare stacks are used for venting unwanted waste gas streams from a facility.

[0004] It is generally desirable that flammable gas be burned without producing smoke, and reduction in smoke production during burning may be mandated by regulatory requirements.

[0005] One method that has been adopted for reducing smoke formation during burning includes mixing the waste gas stream to be burned with ambient air to maximize oxidation of the flammable waste gas to prevent the production of smoke. Another method that has been used includes supplying steam to the combustion zone, such as, for example, by an eductor to increase oxidation to restrict smoke formation. In some applications, ambient air and steam introduction are used together to further reduce smoke formation.

[0006] When sufficient ambient air and/or steam is available to contact the combustible waste gas, the mixture may be smokelessly burned. In typical flare apparatus, only a portion of the desired amount of air and/or steam is present for mixing with the waste gas.

[0007] A wide variety of apparatus and processes have been proposed to increase the smokeless burning of combustible gas from a flare. For example, U.S. Patent No. 3,833,337 to Desty et al. and U.S. Patent No. 8,337,197 to Poe et al. propose the use of a tulip shaped Coanda tip. Coanda tips have been used in flares with high flow rates and pressures to cause the adherence of the waste gas to the surface. The negative pressure and viscous forces caused by the Coanda effect cause the fluid to be drawn against the surface in a relatively thin film, which allows proximate fluid (e.g. ambient air) to be mixed efficiently with the fluid stream. Poe describes that to achieve a Coanda effect, the surface of the Coanda surface should be substantially smooth.

[0008] While current apparatus and methods have improved the smokeless combustion of waste gas streams, it is desirable to further reduce the amount of smoke formation based on regulatory and environmental considerations.

SUMMARY OF THE INVENTION

[0009] By one aspect, an apparatus is provided minimizing the formation of smoke in the operation of a flaring stack. The apparatus includes a support arm having a generally hollow waste gas passageway for connection to a waste gas source. The apparatus further includes a generally annular gas deflector having an outer surface for deflecting waste gas and steam therealong. A waste gas outlet is provided between the gas deflector and the support arm. The apparatus further includes a steam distributor for distributing steam with an outlet configured to direct the steam along the outer surface of the gas deflector. The gas deflector includes a plurality of lobes extending generally radially from the gas deflector outer surface for providing improved mixing between the steam, waste gas, and combustion air during combustion.

[0010] By another aspect, a method is provided for combusting a waste gas to reduce the formation of smoke. The method includes passing steam along an outer surface of a generally annular gas deflector including a plurality of lobes extending radially outwardly therefrom. The method includes passing the waste gas along the outer surface of the gas deflector, including over the plurality of lobes. The method further includes drawing ambient air toward the outer surface for mixing with the waste gas and steam and igniting the waste gas mixture.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1 is a perspective view of an apparatus including a plurality of support arms and a plurality of corresponding gas deflectors in accordance with various embodiments;

[0012] FIG. 2 is a perspective view of a support arm of the apparatus with a gas deflector in accordance with various embodiments;

[0013] FIG. 3 is a cross-sectional view of the support arm of FIG. 2 with the gas deflector supported thereon in a lowered position;

[0014] FIG. 4 is a top view of the gas deflector of FIG. 2;

[0015] FIG. 5 is a side cross sectional view of the gas deflector of FIG. 4 taken along line A-A;

[0016] FIG. 6 is a side cross sectional view of the gas deflector of FIG. 5 taken along line B-B;

[0017] FIG. 7 is a perspective view of a support arm of the apparatus with a gas deflector in accordance with another approach;

[0018] FIG. 8 is a perspective view of a steam chamber in accordance with various embodiments;

[0019] FIG. 9 is a perspective view of a steam chamber in accordance with other embodiments; and

[0020] FIG. 10 is a perspective view of a steam chamber in accordance with other embodiments.

[0021] Skilled artisans will appreciate that elements in the figures are illustrated for simplicity and clarity and have not necessarily been drawn to scale. For example, the dimensions and/or relative positioning of some of the elements in the figures may be exaggerated relative to other elements to help to improve understanding of various embodiments of the present invention. Also, common but well-understood elements that are useful or necessary in a commercially feasible embodiment are often not depicted in order to facilitate a less obstructed view of these various embodiments of the present invention. It will further be appreciated that certain actions and/or steps may be described in a particular order of occurrence while those skilled in the art will understand that such specificity with respect to sequence is not actually required. It will also be understood that the terms and expressions used herein have the ordinary technical meaning as is accorded to such terms and expressions by persons skilled in the technical field as set forth above except where different specific meanings have otherwise been set forth herein.

DETAILED DESCRIPTION

[0022] The apparatus and method presented herein, in accordance with various aspects, relates to reducing smoke formation during combustion of a waste gas in a flare stack. The apparatus may be used with a flare stack, for example, at a refinery or production facility for flaring waste gas or other gas streams to the atmosphere. As used herein, the term “waste gas” refers to any combustible gas stream that is combusted by the flare stack, including, but not limited to undesired gas streams, product streams combusted during shutdown or emergency situations, and other streams.

[0023] Referring now to FIGS. 1 and 2, an apparatus 2 for the combustion of a waste gas stream in accordance with various aspects is provided. The apparatus 2 includes a gas deflector 4 for deflecting fluid along a surface 6 thereof. The apparatus also includes a steam distributor 7 for distributing steam along the surface of the gas deflector. The apparatus 2 may also include a support arm 8 for supporting the gas deflector 4 thereon. One or both of the waste gas and the steam may be passed through the support arm 8 to the gas deflector 4. In this regard, the support arm 8 may have a waste gas passageway 10 and/or a steam passageway 11 formed therein, as illustrated in FIG. 3 for facilitating the flow of the waste gas and the steam therethrough. A waste gas outlet 12 is provided for introducing the waste gas from the waste gas passageway 10 to the gas deflector 4. A steam outlet 13 is provided

for dispersing the steam from the steam passageway 11 to the gas deflector 4. As illustrated in FIG. 3 and described further below, the outlets 12 and 13 may include annular openings 14 and 15 respectively between the support arm 8 and the gas deflector 4 so that the waste gas flows through the opening 14 and along the gas deflector outer surface 6. By one aspect, the steam outlet 13 may be positioned radially inwardly of the waste gas outlet 12.

[0024] The waste gas deflector includes a plurality of lobes 16 that extend radially therefrom. In this regard, as steam and waste gas flow along the outer surface of the gas deflector 4, the steam and gas flow over and between the lobes 16. It has been identified that including radially extending lobes 16 on the gas deflector 4 improves mixing of the waste gas stream and the steam, and also combustion air where present during operation of the flare stack resulting in a reduction in the amount of smoke that is produced during combustion. It has further been identified that including radially extending lobes 16 as described herein provides a lower flame temperature and reduced emissions of unwanted by-products into the atmosphere, such as NO_x. By one aspect, the lobes 16 include a plurality of generally vertically oriented ribs 18 spaced circumferentially about the gas deflector 4 such that the steam and gas flow along the ribs and through channels 20 formed between adjacent ribs 18.

[0025] According to various aspects, the support arm 8 is provided for supporting the gas deflector 4 thereon. The support arm 8 may also include a gas passageway 10 for passing the waste gas to be combusted from a gas source to the gas deflector 4. The support arm may also include a steam passageway 11 for passing steam from a steam source to the gas deflector. In one approach, as illustrated in FIG. 1, the apparatus 2 may include a plurality of support arms 8 supporting a plurality of gas deflectors 4. In this manner, the size of each gas deflector 4 may be decreased as opposed to having a single large gas deflector. This may improve the ability for smoke free combustion by increasing the amount of combustion air available for mixing with the gas at each of the plurality of gas deflectors 4 as opposed to a single larger gas deflector.

[0026] The support arm 8 may extend from a central plenum 22 as illustrated in FIG. 1. As shown, one support arm 8 extends upwardly from the top of the plenum 22 while additional support arms 8 extend at inclined angles from side portions 24 of the plenum 22 and extend generally vertically at bent portions 26 thereof. In one example, the vertical

portions 28 of the support arms 8 extend vertically at an angle of less than 5 degrees from the vertical, less than 3 degrees from the vertical axis in another example, and at less than 1 degree from the vertical in yet another example.

[0027] The support arm 8 may include the gas passageway 10 as illustrated in FIG. 3 for passing the waste gas through the support arm 8 toward the gas deflector 4. In one approach, as shown in FIG. 3, the gas passageway 10 may include a hollow passageway through the support arm 8. In this regard, the support arm 8 may be formed by a generally hollow tube providing the passageway 10. The tube may be cylindrical as illustrated in FIG. 3 or other suitable configurations.

[0028] The support arm 8 may also include the steam passageway as illustrated in FIG. 3 for passing the steam through the support arm 8 toward the gas deflector 4. In one approach, as shown in FIG. 3, the steam passageway 11 includes a tube or pipe 13 positioned within the gas distributor. The tube 13 may run through a generally central portion of the support arm 8 to form a generally annular gas passageway 12 thereabout. The steam distributor 7 may include a steam distribution system 29, including steam conduits external of the support arm 8 and plenum 22 for passing the steam into the support arm 8.

[0029] As mentioned previously, the apparatus 2 according to various aspects includes a gas deflector 4. In one preferred form, the gas deflector 4 includes a gas deflector bowl 36 having a Coanda surface 38 as illustrated in the figures. The Coanda bowl 36 may have a tulip-shaped configuration as illustrated in FIG. 3 having a generally horizontal lower portion 40, a vertical or inclined upper portion 42, and a convex portion 44 connecting the lower portion 40 to the upper portion 42. The remainder of the description will be made with reference with use of the Coanda bowl 36 as the gas deflector. Coanda bowls are generally known and understood by those of skill in the art, and are known to produce a “Coanda effect”, wherein gases flowing along the outer surface thereof tend to follow the surface forming a thin film and drawing in surrounding gas or air. In one approach, the Coanda bowl has a generally round cross-section taken along a plane orthogonal to a longitudinal axis 46 of the bowl, although the bowl 36 may also include other suitable cross-sectional configurations, for example oval or polygonal.

[0030] By one aspect, the Coanda bowl 36 includes a plurality of lobes 16 extending radially outwardly from its outer surface 38. As illustrated in the figures, the lobes 16 may include a plurality of generally vertical ribs 18 spaced circumferentially about the bowl outer surface 38. In one approach, the ribs extend radially outwardly from the Coanda bowl outer surface 38 (or floors 20 of the channels). As used herein, the phrase “total outer surface” refers to the outer surface formed along all outer surface of the gas deflector, including by one example along the outer surfaces of the Coanda bowl 36, ribs 18, and channels 20, such that the “total outer surface” of a ribbed portion of the Coanda bowl 36 has a larger surface area than the outer surface of a corresponding Coanda bowl without ribs.

[0031] According to one approach, the ribs 18 extend generally vertically along the Coanda bowl outer surface 38. It should be understood that as described herein, the ribs 18 extend generally vertically as viewed head-on and that where the upper portion 42 of the bowl 36 is inclined as illustrated in FIG. 5, the vertically extending ribs may similarly be inclined toward the longitudinal axis 46 of the bowl 36 when viewed from profile (i.e. 90 degrees from head-on as shown by the side-cross section of FIG. 5). With this in mind, by one approach, the ribs have a generally vertical axis 48 when viewed head-on as shown in FIG. 2 that is less than 5 degrees from vertical in one example, less than 2 degrees in another example, and less than 1 degree from vertical in yet another example.

[0032] The ribs are circumferentially spaced so that a plurality of corresponding channels 20 are formed between adjacent ribs 18 as illustrated in FIG. 2. The channels 20 extend generally vertically between the ribs 18 and can have a variety of different shapes and configurations. The channels 20 include a channel floor 50 at a base thereof. The channel floor 50 may be flush with the Coanda bowl outer surface 36, or may be raised or indented relative thereto.

[0033] The ribs 18 may have a generally constant radial profile (i.e. distance the ribs extend from the bowl outer surface 36 and/or channel floor 50). Alternatively, the ribs 18 may have a varying radial profile as illustrated in FIG. 5. By one approach, as seen in FIGS. 2 and 5, the ribs 18 are tapered from a lower rib portion 52 to raised rib portion 54. In this regard, the tapered lower portion 52 may be slightly elevated with respect to, or flush with, the bowl surface 36 to provide a smooth transition surface over which steam and gas

traveling upwardly therealong can flow. The ribs 18 may also include a tapered upper rib portion 56 to provide for smooth flow of the steam, waste gas and combustion air mixture as it exits the Coanda surface. It should be understood that the radially extending ribs may be radially extending relative to an outer surface of a Coanda bowl and/or relative to channels. In this regard, the ribs may be formed, for example by providing ribs along the outer surface of a Coanda bowl, or by forming channels or indentations in a Coanda bowl so that the ribs are formed above the channels.

[0034] The ribs may have a constant circumferential width or a varying width about the perimeter of the Coanda bowl 36 as illustrated in FIG. 2. Similarly, the channels 20 may have a constant or varying circumferential width. Typically, where the Coanda bowl includes an inwardly tapered upper portion 42 as illustrated, at least one of the ribs and channels will have a varying width to account for the upwardly decreasing circumference.

[0035] By one aspect, the ribs 18 may have inclined sidewalls 58 extending between rib top portions 60 and the channel floors 50 as best seen with reference to FIGS. 3 and 5. The inclined sidewalls 58 can be generally flat, or may be curved or formed in other manners. The inclined side walls 58 provide a smooth surface over which the steam and gas can flow by reducing the amount of sharp angles between the ribs and the channels.

[0036] Without intending to be bound by theory, it is believed that the addition of ribs 18 to the Coanda bowl 36 increases the total surface area of the Coanda bowl 36 to improve mixing of the steam and waste gas, and also combustion air when it is present, without providing a corresponding increase in outer diameter of the bowl. In this manner, the Coanda bowl 36 can advantageously be kept relatively small while providing sufficient surface area for mixing of the steam, gas and combustion air reducing smoke formation.

[0037] To this end, by one aspect, the ribbed Coanda bowl has a relatively high ratio of a perimeter (as shown in FIG. 4) to an outer radius 62. As used herein, outer radius refers to the distance between the bowl longitudinal axis 46 and the rib top portions 60. For example, a traditional un-ribbed Coanda bowl has a ratio of perimeter (circumference) to outer radius of $2\pi r/r = 2\pi$. In one example, the ratio of the perimeter to the outer radius of the ribbed bowl described herein is greater than 2π . In another example, the ratio of perimeter to outer radius

is between 6.5 and 20, between 7.5 and 16 in another example, and between 8.5 and 12 in yet another example.

[0038] According to one aspect ribs 18 may be formed along the entire outer surface 38 of the Coanda bowl 36. In this regard, the surface area of the entire bowl 36 is increased such that mixing between the steam, waste gas and the combustion air is improved along the total outer surface as described above.

[0039] According to another aspect, the ribs 18 may extend along one or more portions of the Coanda bowl 36, but less than the full outer surface 38 thereof, such that a portion of the gas deflector is unribbed and provides a relatively smooth surface for gas flow. For example, as illustrated in FIG. 2, the lower portion 40 and/or the intermediate portion 44 of the Coanda bowl 36 may be unribbed, while an upper portion 42 includes ribs. In this regard, gas may better flow along the lower portion 40 of the Coanda bowl 36, along the convex intermediate portion 44, and to the ribbed upper portion 42 before flowing over and between the ribs 18. In one example, between a bottom 5 to 50 percent of the Coanda bowl is unribbed with an upper portion including ribs. In another example between a bottom 10 to 40 percent of the Coanda bowl is unribbed with an upper portion including ribs. In another example, as illustrated in FIG. 7 a bottom portion may include ribs with at least an intermediate portion and/or a top portion being unribbed.

[0040] As illustrated in FIGS. 2 and 7, different numbers and sizes of ribs 18 may be included on the Coanda bowl to maximize the steam/waste gas/combustion air mixing. For example, it may be beneficial to select the number of ribs extending circumferentially about the Coanda bowl 36 to provide increased surface area and the associated improvement in steam/gas mixing, while still ensuring that the steam and gas will flow smoothly over the total surface area during operation. FIG. 2 illustrates an example of a Coanda bowl 36 that includes a smaller number of relatively wider ribs 18 while FIG. 7 illustrates another example where a larger number of narrower ribs 18 are used. With this in mind, in one example a ratio of a combined circumferential width of the one or more ribs 18 to a combined circumferential width of a plurality of channels 12 between the ribs 18 is between 0.5 and 5 and between 1 and 3 in another example. In another example, a ratio of a rib radial height

above the channel floor to the outer radius of the bowl is between 0.01 and 0.2 in one example and between 0.03 and 0.2 in another example.

[0041] As mentioned previously, by one aspect, a steam outlet 13 is provided for introducing the steam toward the outer surface of the Coanda bowl. With reference to FIGS. 2 and 3, the steam outlet may include a generally annular opening 15 of the steam passageway extending about the longitudinal axis of the Coanda bowl 36 for distributing the steam along the surface thereof. The annular opening 15 may be formed of a single opening, or a plurality of smaller openings as illustrated in FIGS. 2 and 3. By one approach, the steam outlet 13 includes a steam disperser 70 as illustrated in FIG. 3. The steam disperser may be formed in a variety of different configurations. As illustrated, the steam disperser 70 includes an inverted frusto-conical chamber 72 having a narrower bottom portion 74 and a broader top portion 76. One or more chamber openings 78 are formed about the perimeter of the top portion 76 to provide the annular opening 15 for dispersing the steam. In this manner, steam may be dispersed from the generally central steam passageway 11 along the surface of the Coanda bowl 36.

[0042] As illustrated in FIG. 8, by one approach, the chamber 72 includes upper apertures 80 formed through the top portion 76 of the chamber forming the chamber openings 78. By one aspect, as illustrated in FIGS. 9-10, the chamber 72 includes a notched upper rim portion 82. In this regard, with the chamber 72 in position below the Coanda bowl 36, the openings are formed between the Coanda bowl outer surface 38 and indentations 84 formed in the notched upper rim portion. Various configurations are possible for the notched upper rim portion 82. In one example, as illustrated in FIG. 9 the notched upper rim portion includes serrations 86 providing a saw tooth appearance with triangular openings formed between the Coanda bowl 36 and the serrations 86. By another approach, the notched upper rim portion may be formed of alternating crenels 88 and merlons 90 as illustrated in FIG. 10 to form openings between the crenels and the Coanda bowl 36.

[0043] By one aspect, the openings 78 may be aligned with the ribs 18 to provide for increased flow of steam over the ribs 18. By another approach, the openings 78 may be aligned with the channels 20. By yet another approach, openings may be aligned with both the ribs and the channels or may be offset relative to one or both.

[0044] As mentioned, by one aspect, the gas outlet 12 is provided for introducing the waste gas toward the outer surface of the Coanda bowl. As illustrated in FIGS. 2-3, the gas outlet 12 may include a generally annular opening 14 of the waste gas passageway 10 formed about the outer surface 38 so that the waste gas can flow through the opening and along the outer surface. The annular opening 14 may include a relatively round shape, or another shape, such as an oval or polygon. By one approach, the annular opening includes a single annular opening, but may also include a plurality of openings formed about the Coanda bowl 36. The annular opening 14 may be formed by a gap between the support arm upper seating portion 30 and the Coanda bowl lower portion 40, such that waste gas flowing through the gas passageway 10 exits through the opening 14 and flows along the outer surface 38.

[0045] According to one aspect, the gas outlet 12 is provided radially outwardly of the steam outlet 13 as illustrated in FIGS. 2 and 3. In this manner, steam is directed along outer surface 38 and the waste gas is directed toward the outer surface 38 and the steam flowing thereover. Not to be bound by theory, it is believed that by forming the gas outlet radially outwardly of the steam outlet 13, a thin layer of steam is formed over the outer surface 38 of at least a portion of the Coanda bowl 36. The waste gas is directed toward the steam and forms a layer of waste gas flowing along the layer of steam. Combustion air may then be available radially outwardly of the waste gas layer. In this manner, as the steam and gas stream flow over the ribbed surface of the Coanda bowl, 36 improved mixing may occur as the waste gas layer is contacted by the steam on one side and the combustion air on the other side, resulting in reduced smoke formation during combustion.

[0046] According to various aspects, during operation, the steam flows through the steam passageway 11 and through the annular opening 15 along the Coanda bowl outer surface 38. The waste gas to be combusted flows through the gas passageway 10 and through the annular opening 14. As the steam and waste gas flow along the outer surface 38, they mix together and may further mix with combustion air (for example surrounding ambient air) that is drawn toward the waste gas and steam and mixed therewith. The steam and waste gas pass over the ribs 18 and through the channels 20 therebetween. The mixture is ignited and combusted with reduced smoke formation.

[0047] The above description and examples are intended to be illustrative of the invention without limiting its scope. While there have been illustrated and described particular

embodiments of the present invention, it will be appreciated that numerous changes and modifications will occur to those skilled in the art, and it is intended in the appended claims to cover all those changes and modifications which fall within the true spirit and scope of the present invention.

[0048] One embodiment of the invention involves an apparatus for minimizing the formation of smoke in the operation of a flaring stack, the apparatus comprising: a support arm having a generally hollow waste gas passageway for connection to a waste gas source; a generally annular gas deflector having an outer surface for deflecting waste gas; a waste gas outlet between the gas deflector and the support arm; a steam distributor for distributing steam; an outlet of the steam distributor configured to direct steam along the outer surface of the gas deflector; and a plurality of lobes extending generally radially from the gas deflector outer surface for providing improved mixing between the steam, waste gas, and combustion air during combustion. The gas deflector may include a tulip-shaped Coanda bowl. The lobes may include circumferentially spaced generally vertical ribs extending radially from the outer surface of the gas deflector. The steam distributor may include an annular outlet positioned about the annular gas deflector for directing steam therealong. The steam distributor annular outlet may include a plurality of circumferentially spaced openings positioned about the annular gas deflector. The openings may be generally aligned with the ribs. The openings may be generally aligned with channels formed between the ribs. The waste gas outlet may include a generally annular outlet positioned radially outwardly of the steam distributor. The apparatus may have a ratio of a perimeter of a ribbed portion of the bowl to an outer diameter of the ribbed portion is between 6.5 and 20. The ribs may be tapered radially with respect to the outer surface from a generally lower rib portion flush with the outer surface to a raised rib portion above the outer surface. The apparatus may include inclined sidewalls extending from channels between the ribs to upper raised rib portions.

[0049] Another embodiment involves an apparatus for minimizing the formation of smoke in the operation of a flaring stack, the apparatus comprising: a support arm having a generally hollow waste gas passageway for connection to a waste gas source; a generally annular gas deflector having an outer surface for deflecting waste gas; a waste gas outlet between the gas deflector and the support arm; a steam distributor for distributing steam; a plurality of circumferentially spaced generally vertical ribs extending radially from the gas

deflector outer surface for providing improved mixing between the steam, waste gas, and combustion air during combustion; and a generally annular outlet of the steam distributor configured to direct steam along the outer surface of the gas deflector. The support arm may include a steam passageway positioned within the waste gas passageway. The steam distributor may include a steam chamber and the steam chamber outlet includes plurality of upper openings. The steam chamber may include an inverted generally hollow frustoconical member with the upper openings about an upper portion thereof. The steam chamber upper openings may include a notched upper rim adjacent to a bottom portion of the steam distributor. The steam chamber upper openings may include a plurality of apertures about the upper portion of the steam chamber. The upper openings may be generally aligned with the ribs. The upper openings may be generally aligned with channels between the ribs. The waste gas outlet may be generally annular and positioned radially outwardly of the steam distributor outlet to provide steam along the outer surface of the gas deflector.

[0050] Another embodiment involves a method for combusting a waste gas to reduce the formation of smoke, the method comprising: passing steam along an outer surface of a generally annular gas deflector including a plurality of lobes extending radially outwardly from the gas deflector; passing the waste gas along the outer surface of the gas deflector including over the plurality of lobes; drawing ambient air toward the outer surface for mixing with the waste gas and steam; and igniting the waste gas. Passing the waste gas along the outer surface may include passing the waste gas over a plurality of circumferentially spaced generally vertical ribs extending radially from the outer surface. Passing the steam along the outer surface may include distributing the steam radially inwardly of the waste gas.

Distributing the steam may include distributing the steam from a generally annular steam distributor outlet positioned radially inwardly from a generally annular waste gas outlet.

Distributing the steam may include forming a layer of steam over at least a portion of the outer surface, and passing the waste gas over the layer of steam to mix with the steam.

Distributing the steam may include distributing the steam from a plurality of openings arranged circumferentially about the gas deflector and generally aligned with the ribs.

Distributing the steam may include distributing the steam from a plurality of openings arranged circumferentially about the gas deflector and generally aligned with channels between the ribs. Passing the steam along the outer surface may include passing the steam over a Coanda surface of a generally tulip-shaped Coanda bowl. Passing the steam over the

Coanda surface may include passing the steam over an unribbed convex portion of the Coanda surface and then over a ribbed portion of the Coanda surface. Passing the steam along the Coanda surface may include passing the steam over a ribbed convex portion of the Coanda surface. Passing the steam along the outer surface may include passing the steam along inclined sidewalls extending from channels between the ribs to rib upper portions.

[0051] Another embodiment involves a method for combusting a waste gas to reduce the formation of smoke, the method comprising: passing steam through an annular outlet along an outer surface of a generally annular gas deflector including a plurality of lobes extending radially from an outer surface thereof; passing the waste gas along the outer surface of the gas deflector including over the plurality of lobes; drawing ambient air toward the outer surface for mixing with the waste gas and steam; and igniting the waste gas. Passing the steam through the annular outlet may include passing the steam to a steam chamber and distributing the steam through a plurality of openings of the steam chamber toward the outer surface. Passing the steam through the plurality of openings may include passing the steam through openings formed between an upper notched portion of the steam chamber and a lower portion of the gas distributor. Passing the steam through the plurality of openings may include passing the steam through a plurality of apertures in an upper portion of the steam chamber. Passing the waste gas along the outer surface may include passing the waste gas through a generally annular outlet of a support arm radially outwardly of the steam chamber. Distributing the steam may include forming a layer of steam over at least a portion of the outer surface, and passing the waste gas along the layer of steam to mix with the steam. The method may further comprise passing the steam through a steam passageway of a support arm supporting the gas deflector and passing the waste gas through an annular waste gas passageway of the support arm formed about the steam passageway.

CLAIMS:

1. An apparatus for minimizing the formation of smoke in the operation of a flaring stack, the apparatus comprising:

a support arm having a generally hollow waste gas passageway for connection to a waste gas source;

a generally annular gas deflector having an outer surface for deflecting waste gas;

a waste gas outlet between the gas deflector and the support arm;

a steam distributor for distributing steam;

an outlet of the steam distributor configured to direct steam along the outer surface of the gas deflector; and

a plurality of lobes extending generally radially from the gas deflector outer surface for providing improved mixing between the steam, waste gas, and combustion air during combustion.

2. The apparatus of claim 1, wherein the gas deflector includes a tulip-shaped Coanda bowl.

3. The apparatus of claim 1, wherein the lobes include circumferentially spaced generally vertical ribs extending radially from the outer surface of the gas deflector.

4. The apparatus of claim 3, wherein the steam distributor includes an annular outlet positioned about the annular gas deflector for directing steam therealong.

5. The apparatus of claim 4, wherein the steam distributor annular outlet includes a plurality of circumferentially spaced openings positioned about the annular gas deflector.

6. A method for combusting a waste gas to reduce the formation of smoke, the method comprising:

passing steam along an outer surface of a generally annular gas deflector including a plurality of lobes extending radially outwardly from the gas deflector;

passing the waste gas along the outer surface of the gas deflector including over the plurality of lobes;

drawing ambient air toward the outer surface for mixing with the waste gas and steam; and

igniting the waste gas.

7. The method of claim 6, wherein passing the waste gas along the outer surface includes passing the waste gas over a plurality of circumferentially spaced generally vertical ribs extending radially from the outer surface.

8. The method of claim 6, wherein passing the steam along the outer surface includes distributing the steam radially inwardly of the waste gas.

9. The method of claim 8, wherein distributing the steam includes distributing the steam from a generally annular steam distributor outlet positioned radially inwardly from a generally annular waste gas outlet.

10. The method of claim 8, wherein distributing the steam includes forming a layer of steam over at least a portion of the outer surface, and passing the waste gas over the layer of steam to mix with the steam.

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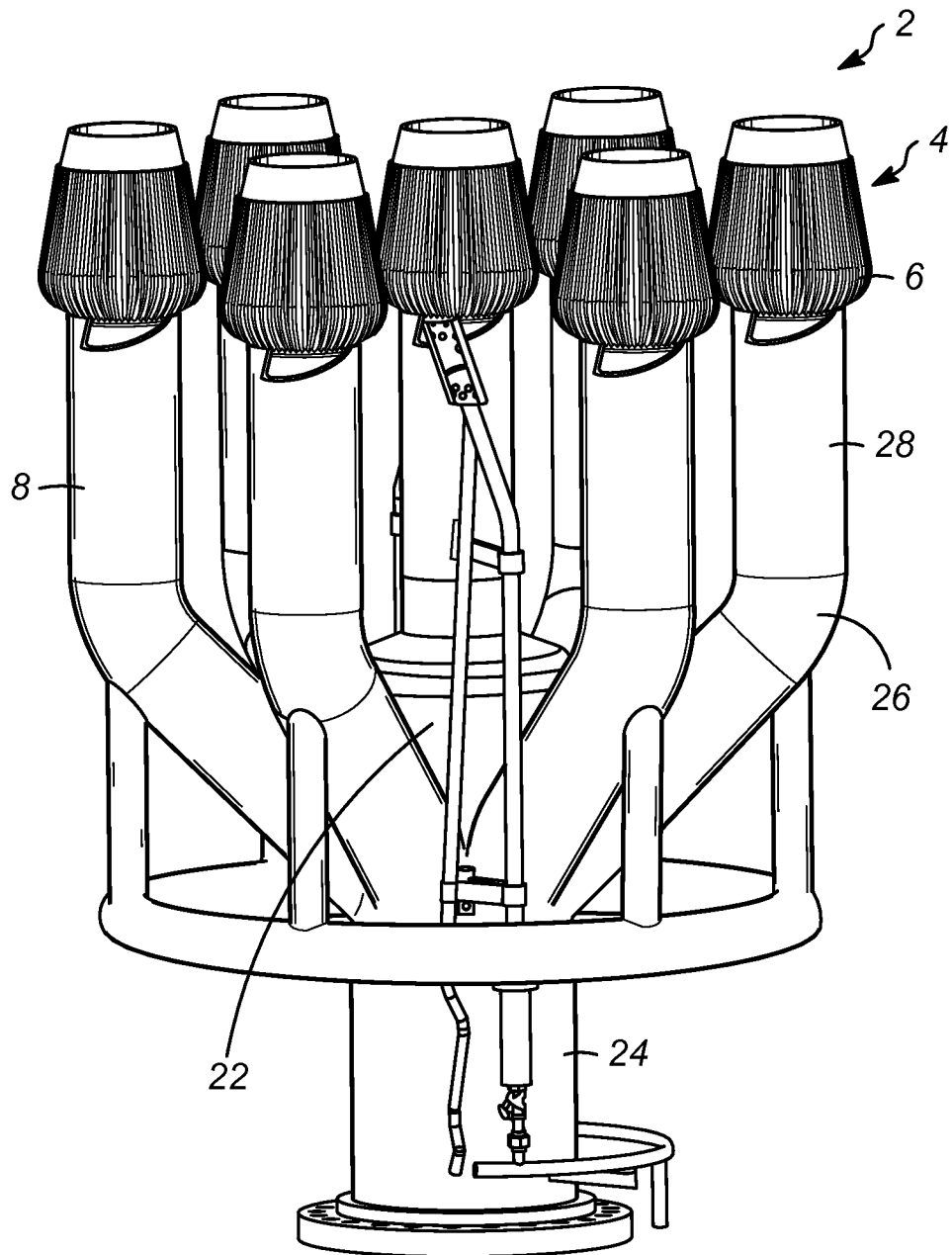


FIG. 1

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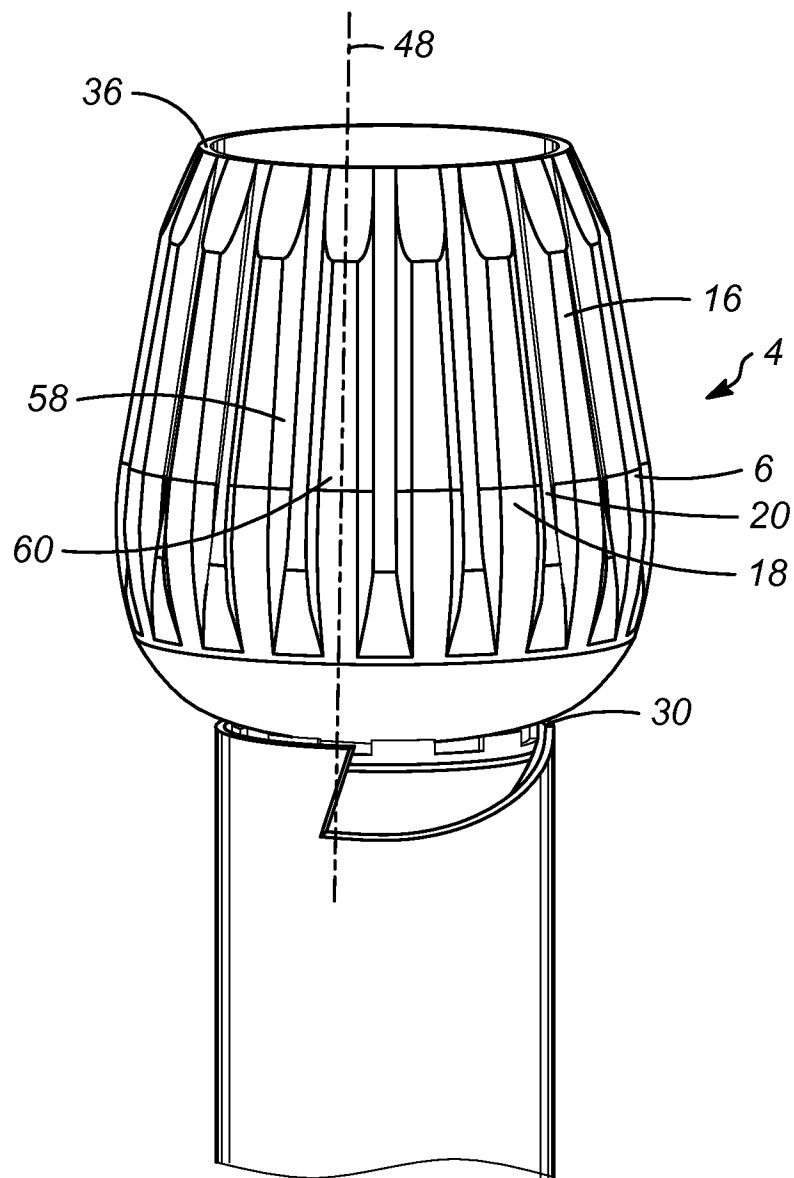


FIG. 2

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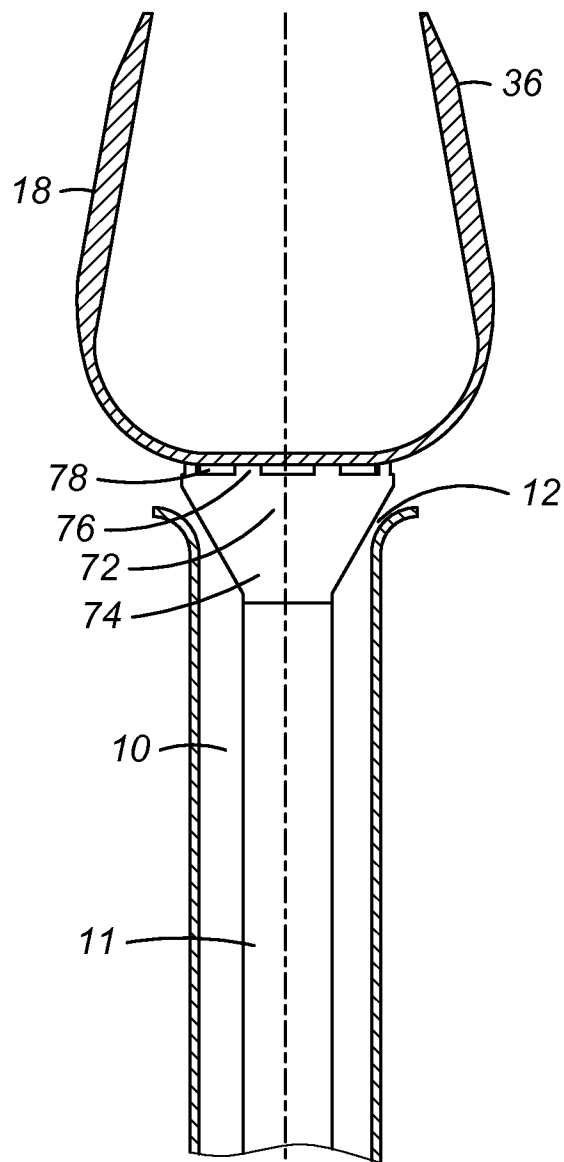


FIG. 3

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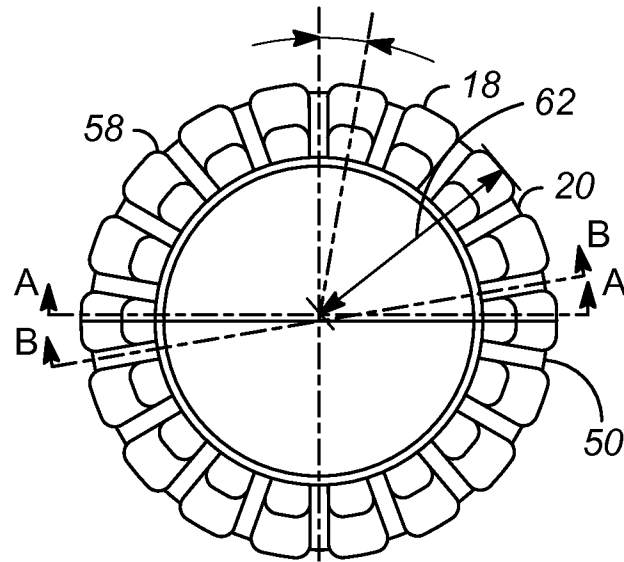


FIG. 4

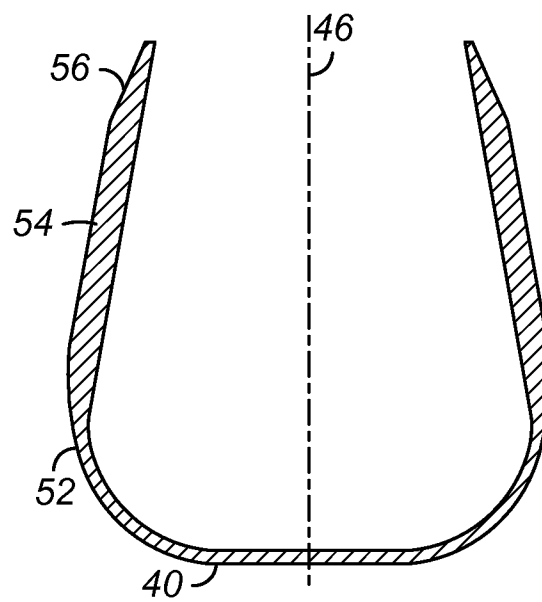


FIG. 5

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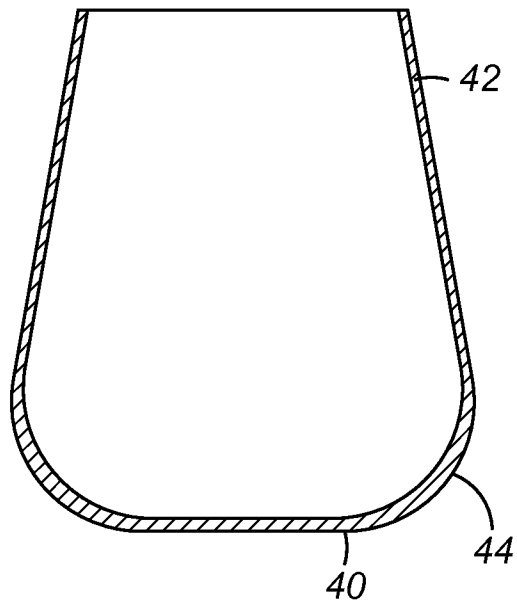


FIG. 6

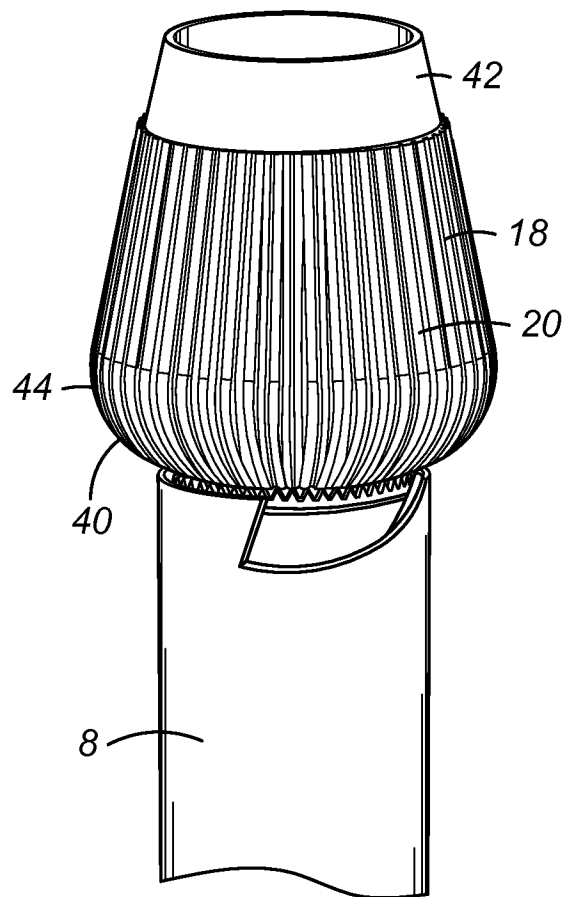


FIG. 7

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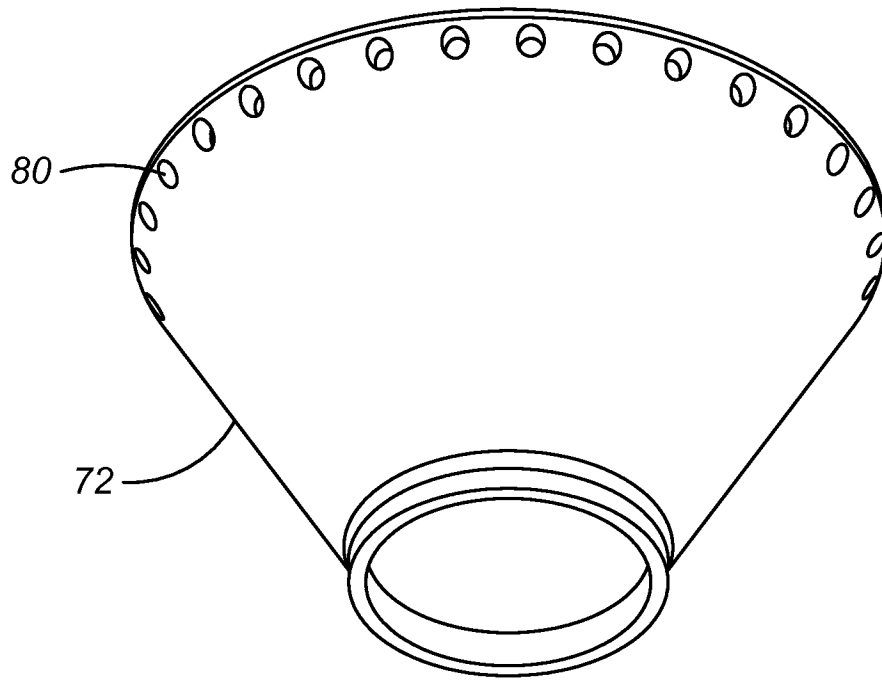


FIG. 8

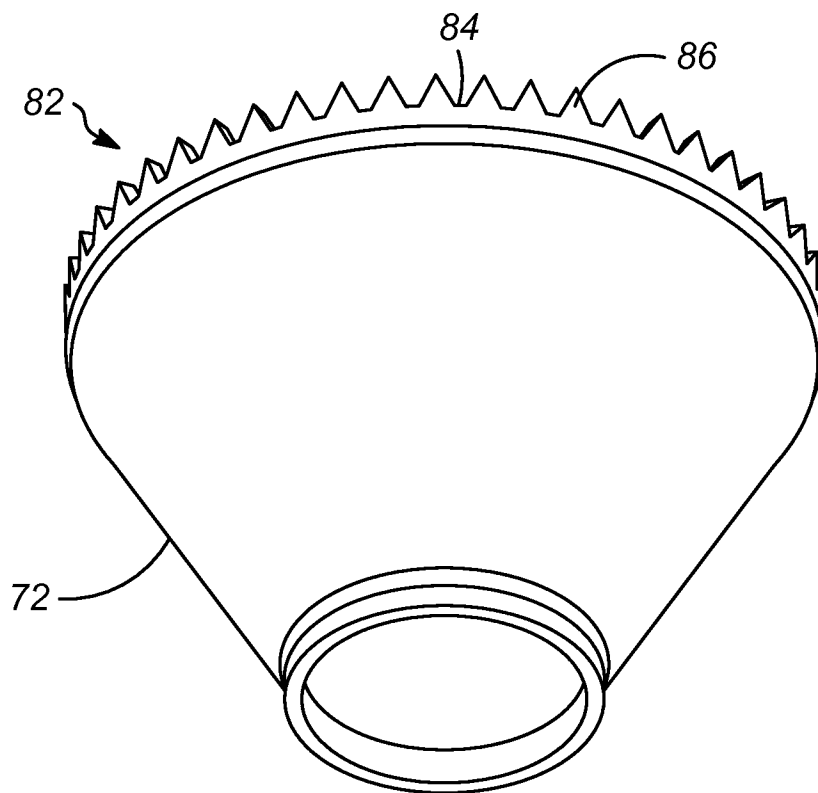


FIG. 9

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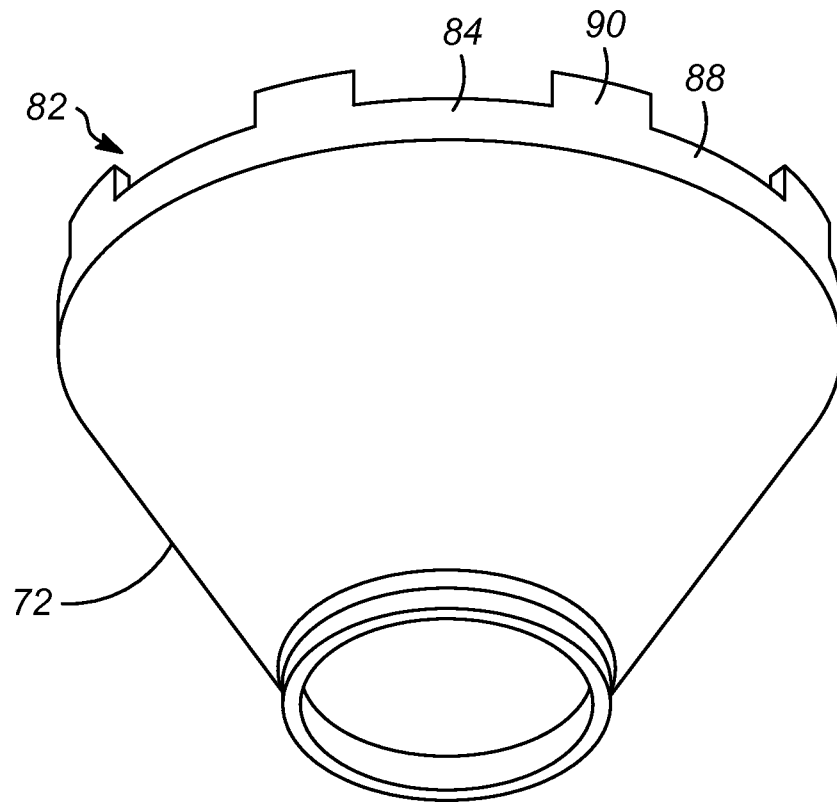


FIG. 10