US 20120189966A1

(19) United States
(12) Patent Application Publication
(10) Pub. No.: US 2012/0189966 A1
(43) Pub. Date: Jul. 26, 2012
Brooker

(54) DETONATION FLAME ARRESTOR INCLUDING A TRANSITION POINT/ATTENUATION MATRIX AND TORTUROUS PATH MEDIA

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(21) Appl. No.: **13/011,583**

(22) Filed: **Jan. 21, 2011**

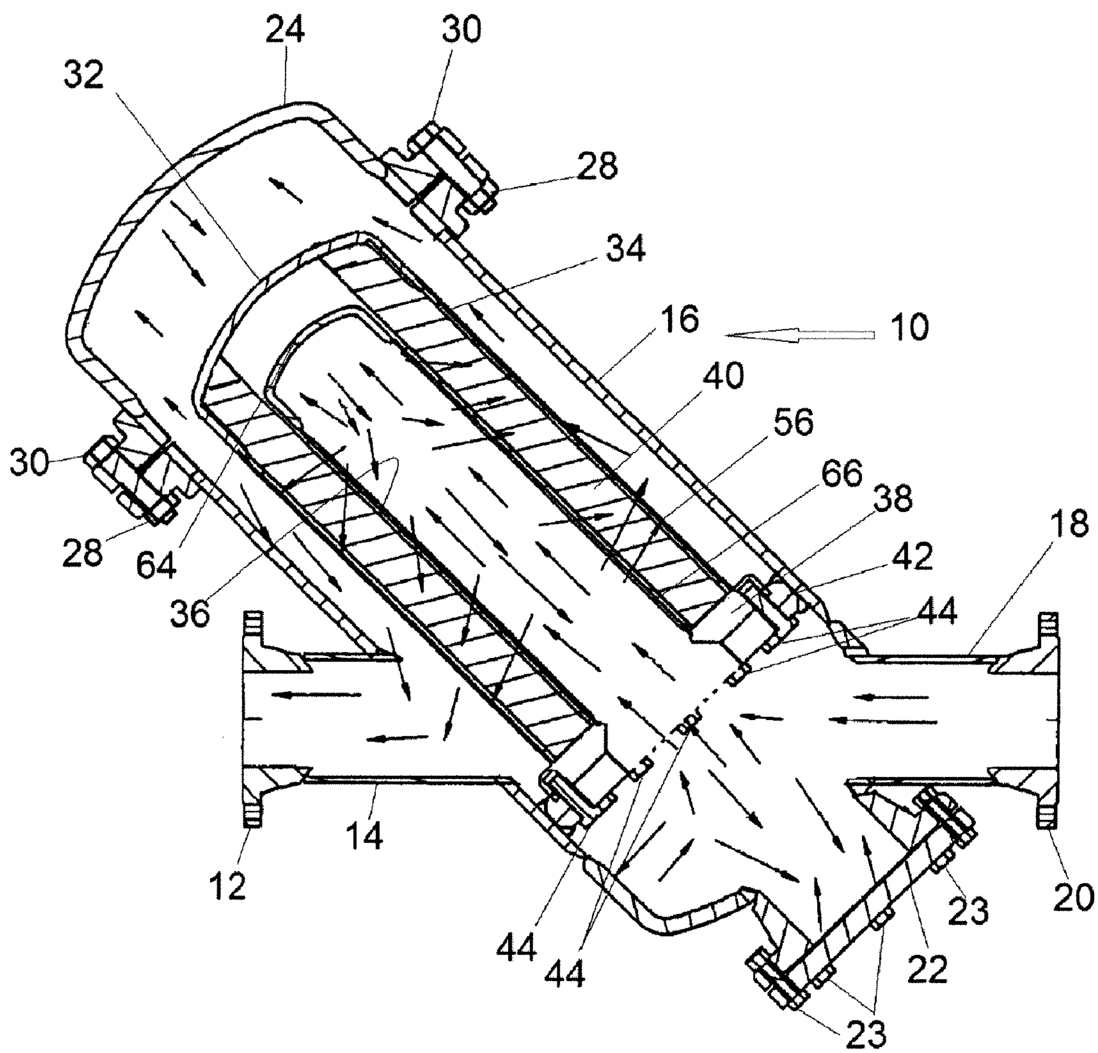
Publication Classification

(51) Int. Cl.
F23D 14/82 (2006.01)

(52) U.S. Cl. 431/346; 220/88.2; 222/189.01

(57) **ABSTRACT**

A detonation flame arrestor including an outer cylinder, an inner cylinder, transition point/attenuation matrix and tortuous path media. The inner cylinder is secured to a canister flange and positioned inside the outer cylinder secured to the canister flange, altogether forming a canister. The torturous path media is positioned in the canister between the inner cylinder and the outer cylinder to to provide turbulence and a large surface area which acts as a heat sink to extinguish a flame. Both the outer cylinder and the inner cylinder include a transition point/attenuation matrix which forms their respective cylindrical circumferences. Helical or parallel wire or rings create the transition point/attenuation matrix which attenuates and creates turbulence as the first stage of quenching a flame front.



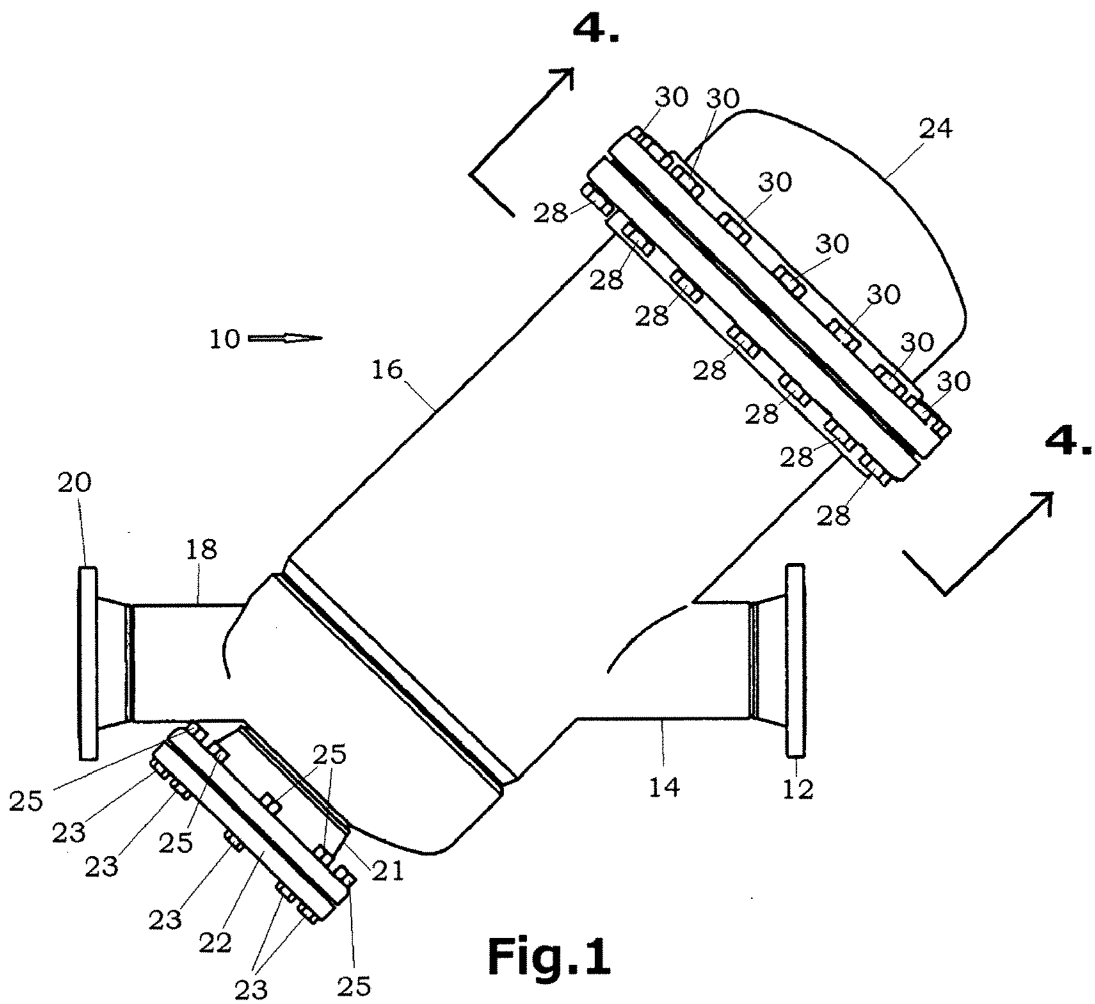

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Fig.1

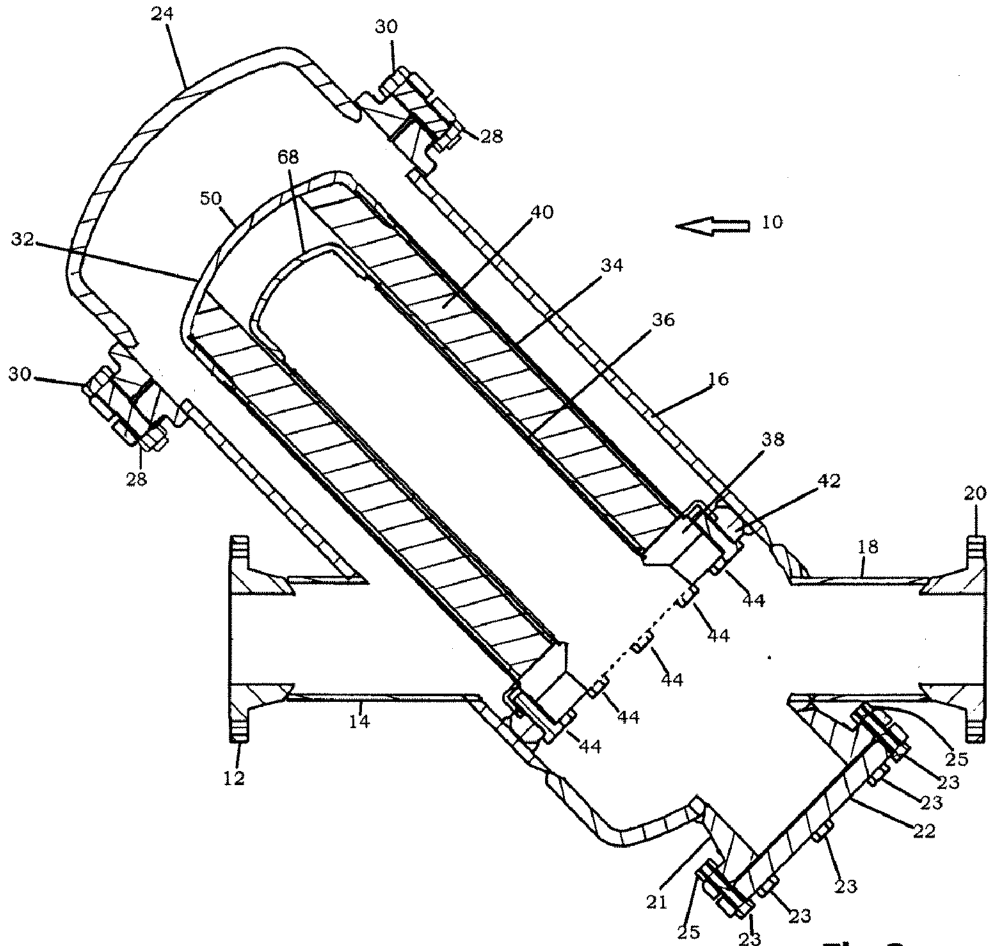
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Fig.2

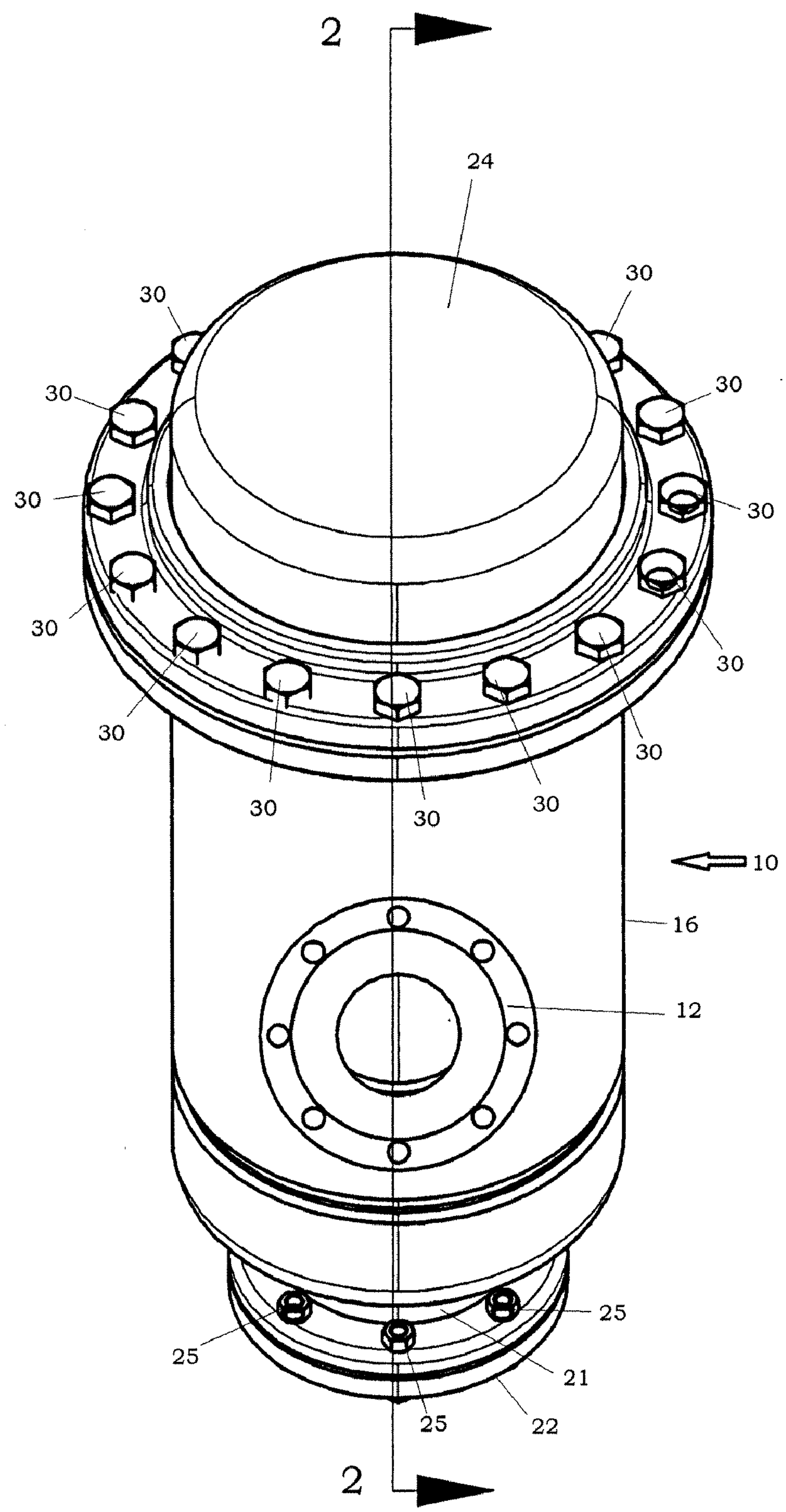
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Fig. 3

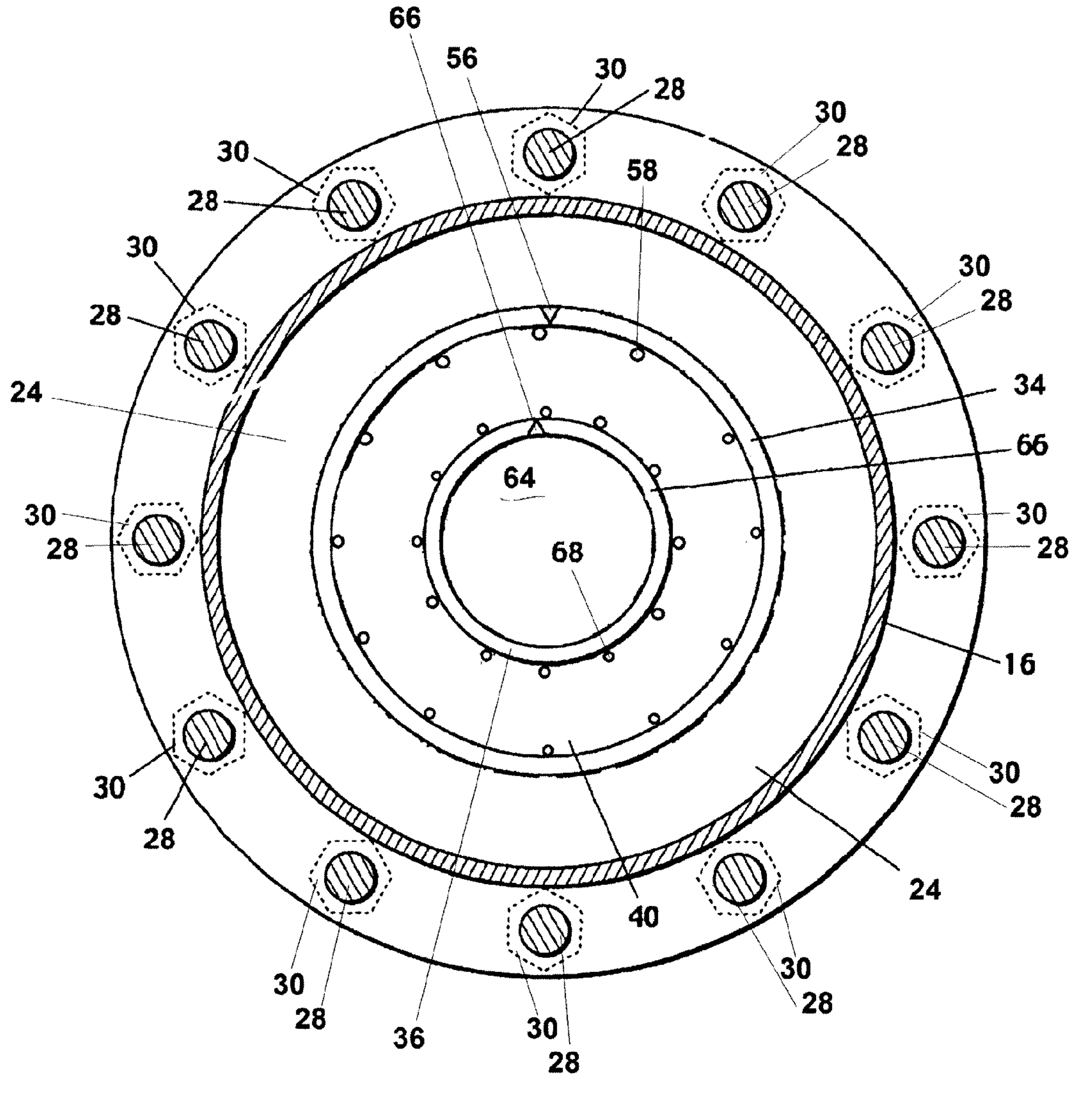
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Fig. 4

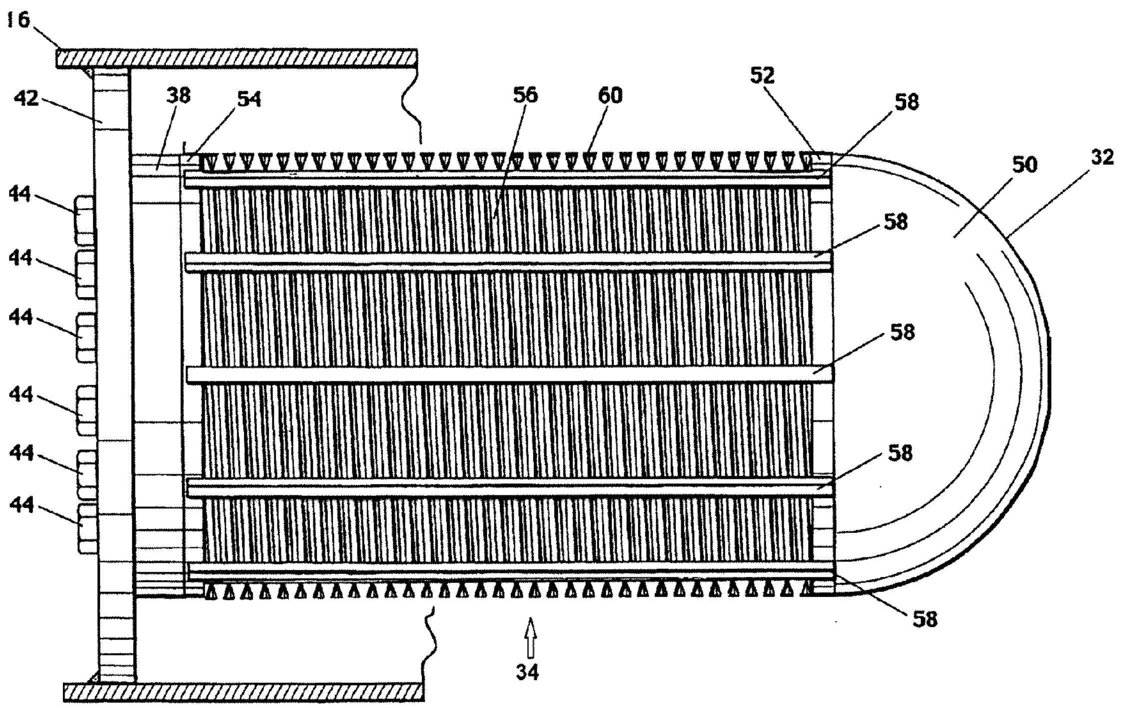

Fig. 5

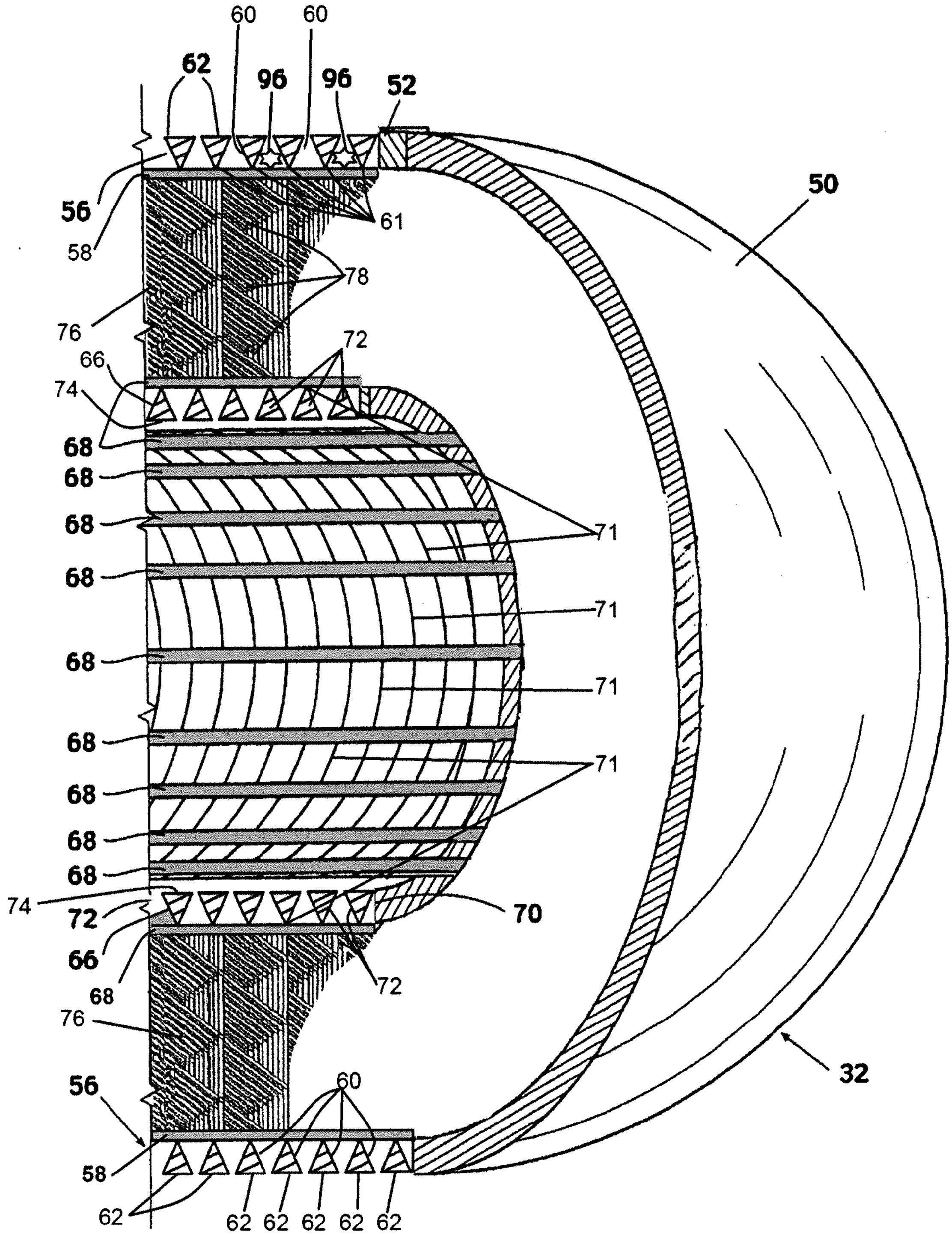
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Fig. 6A

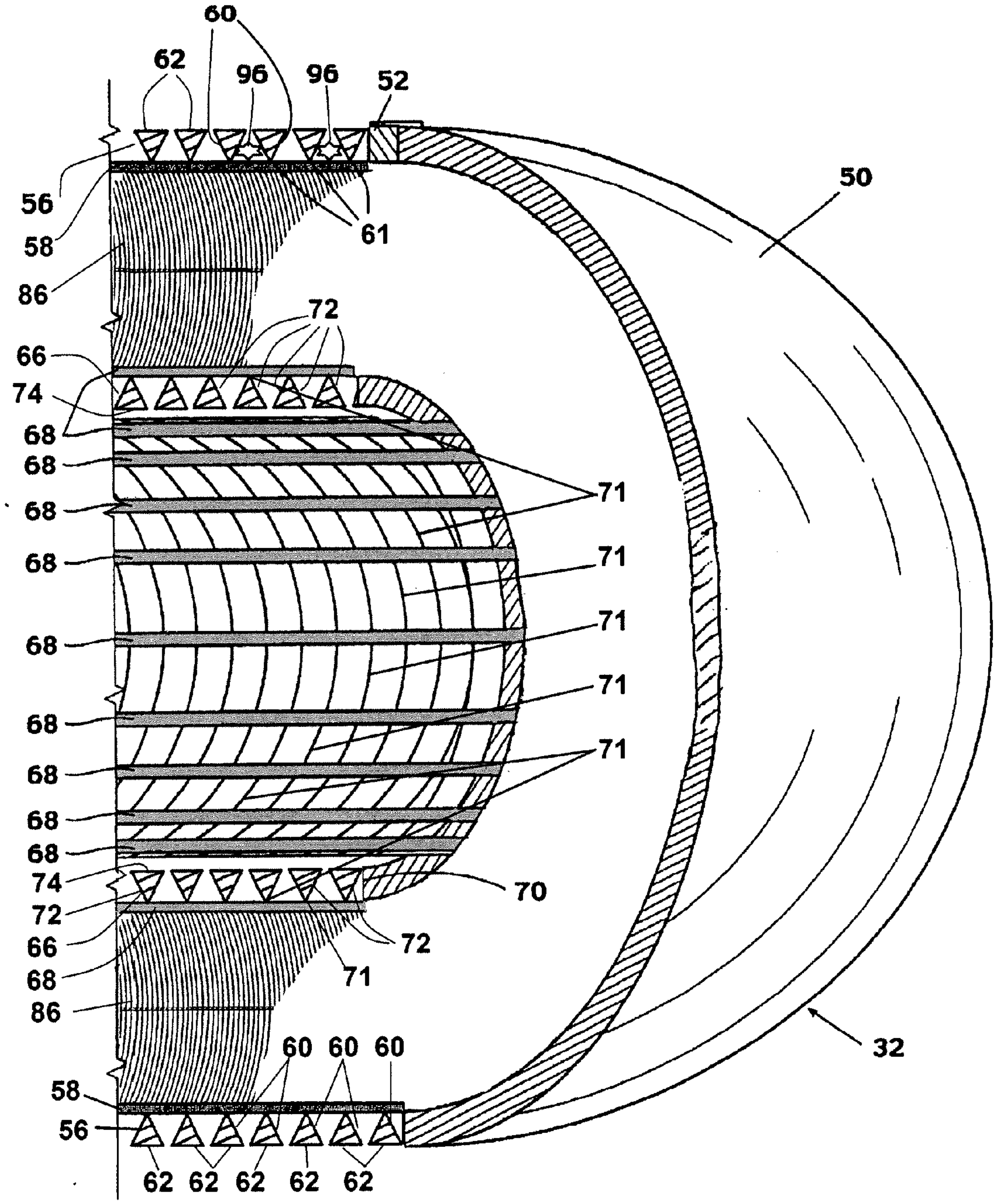
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Fig. 6B

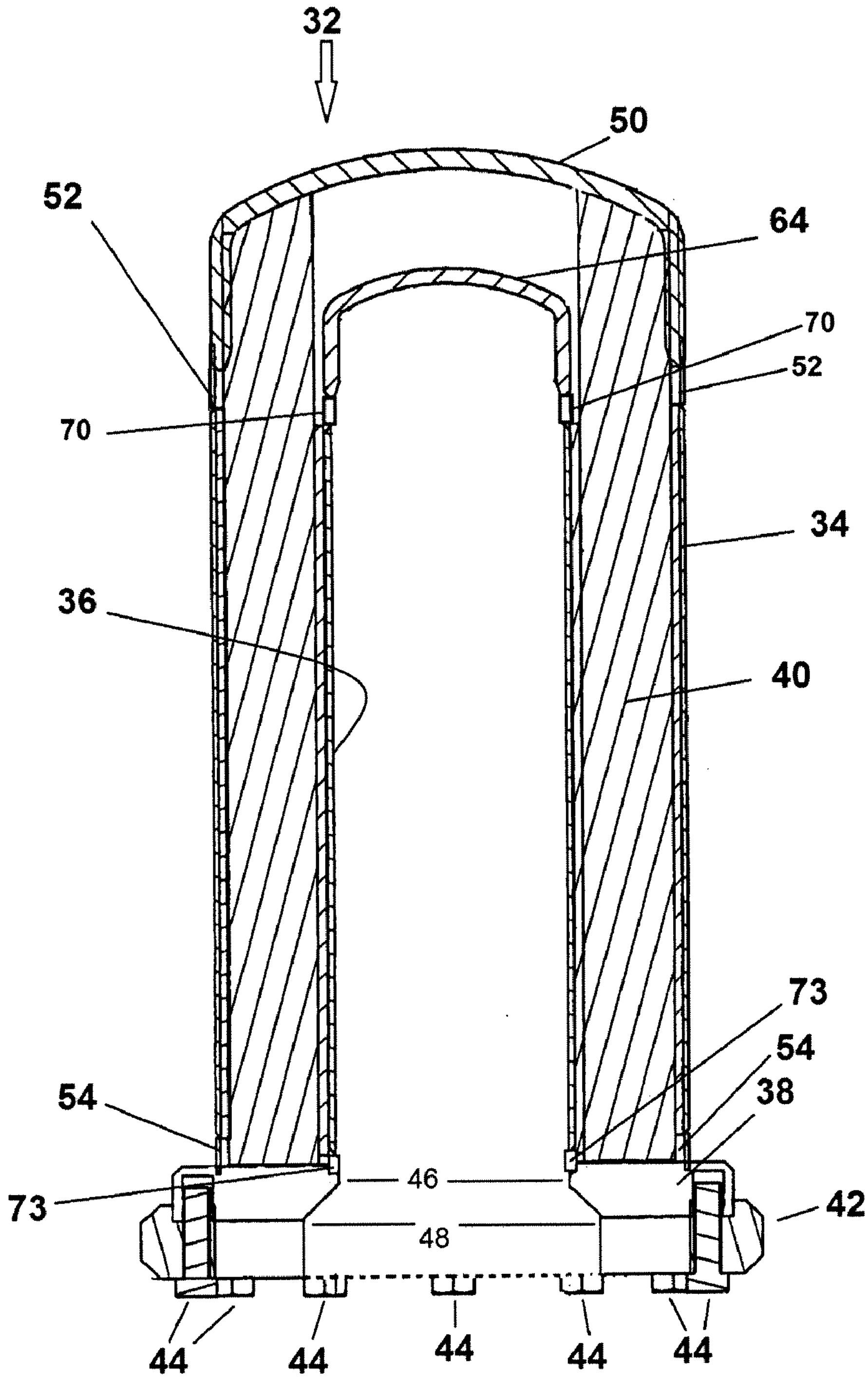

Fig. 7

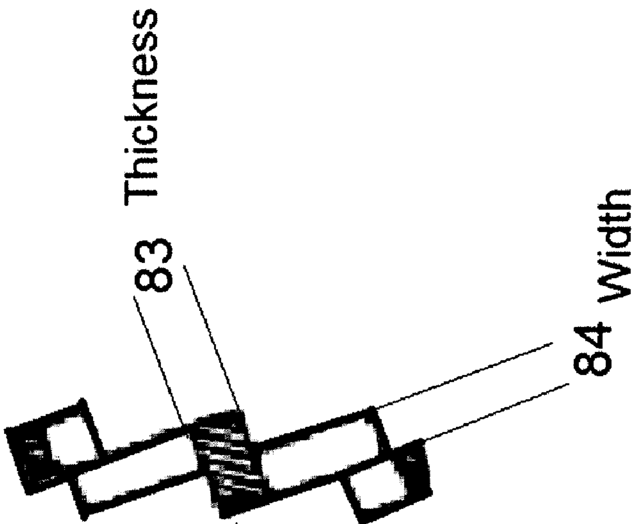

Fig 8B

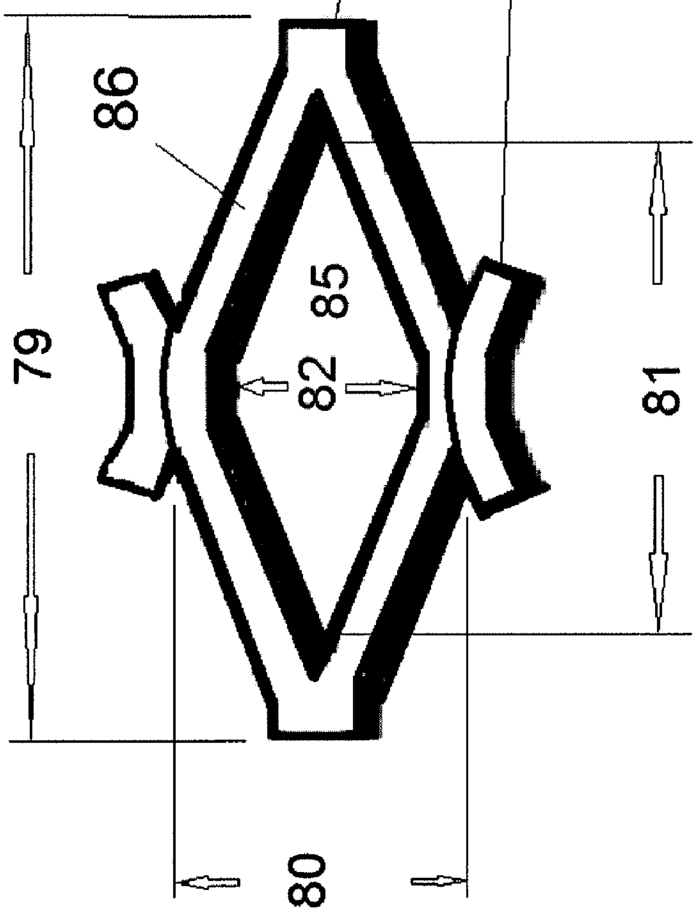

Fig. 8A

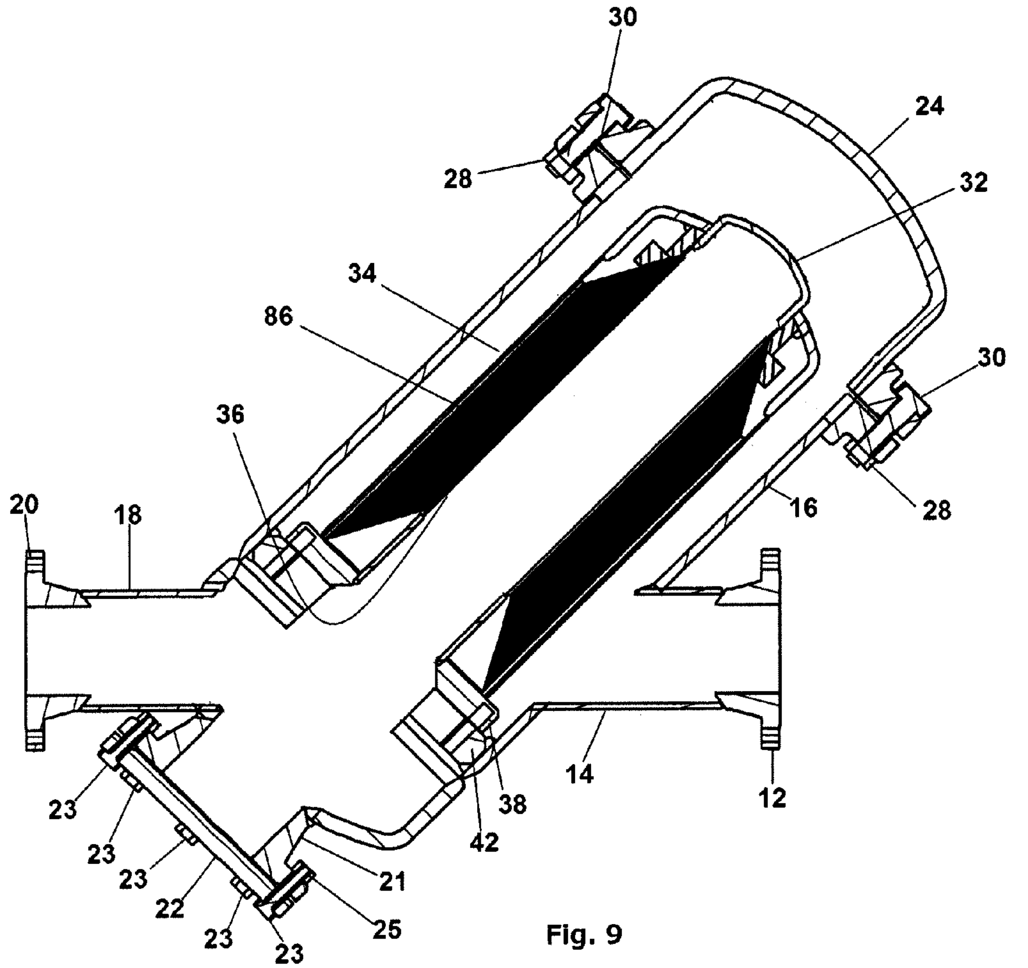

Fig. 9

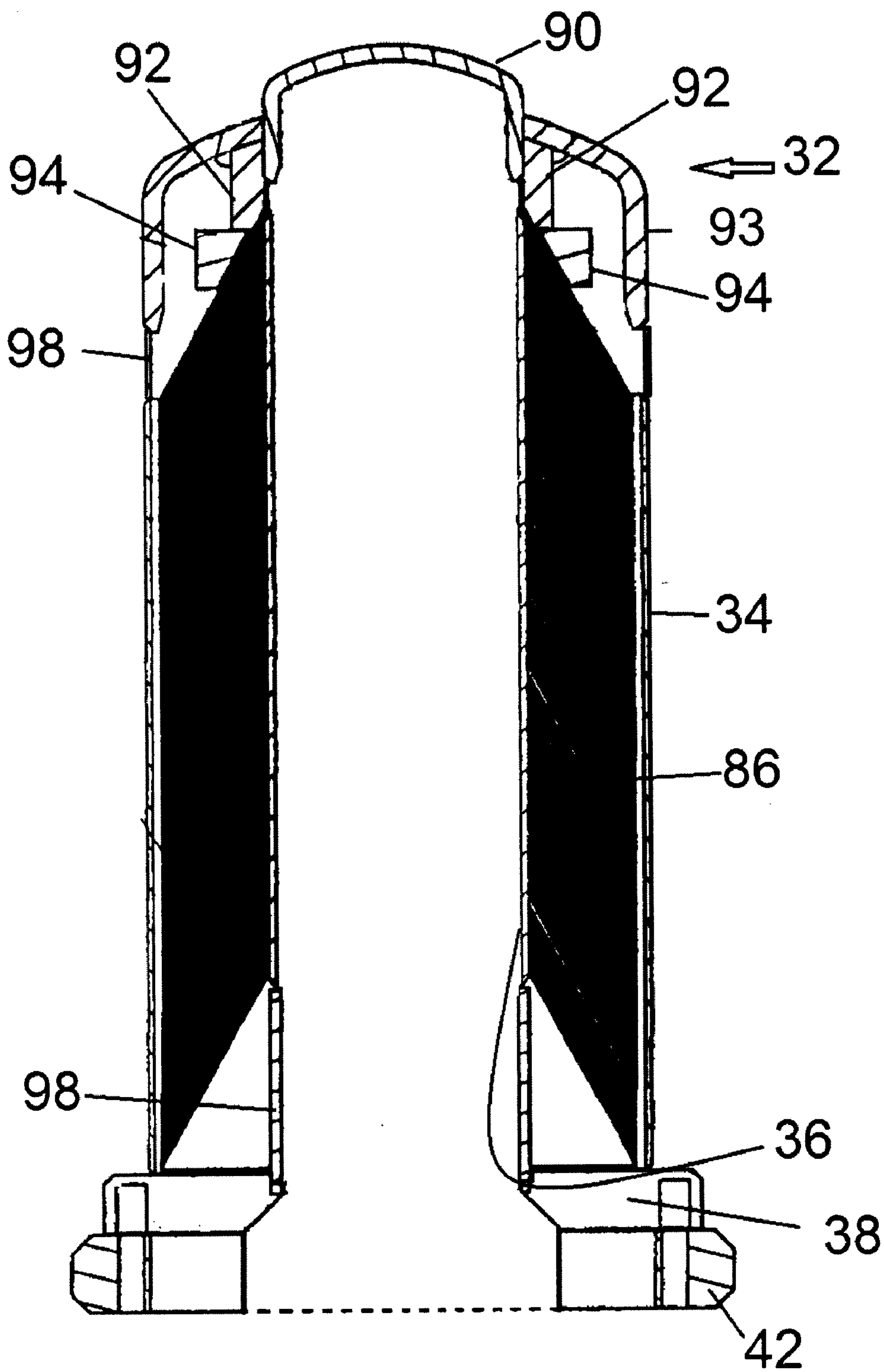

Fig. 10

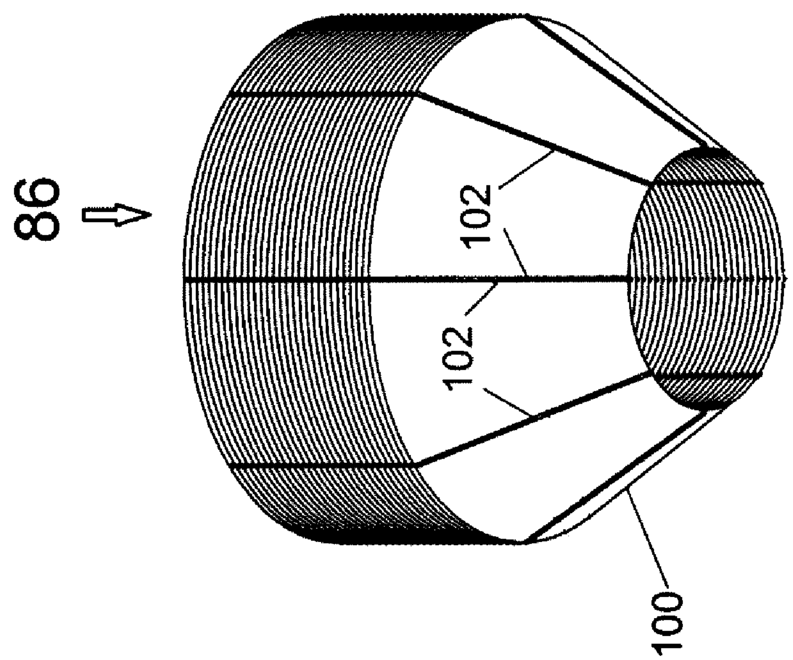

Fig. 11A

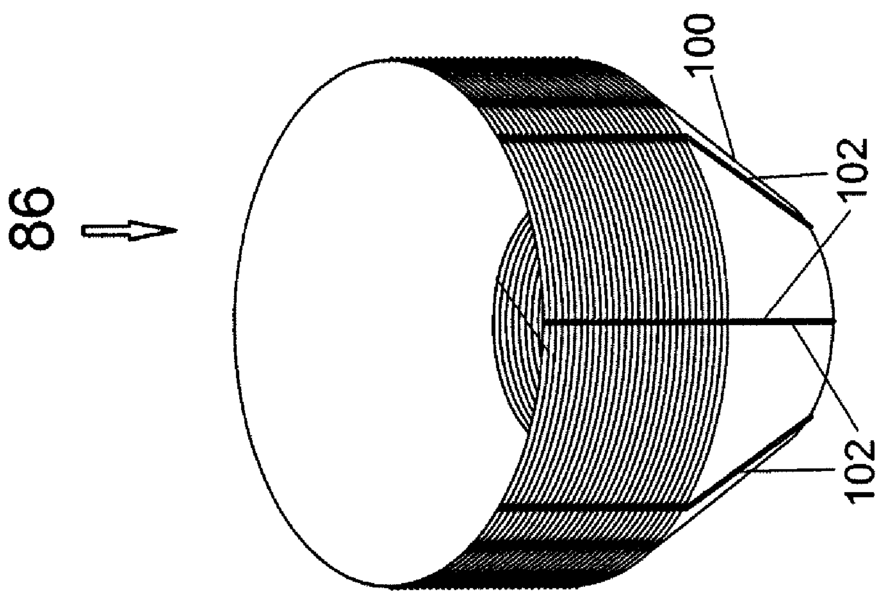

Fig. 11B

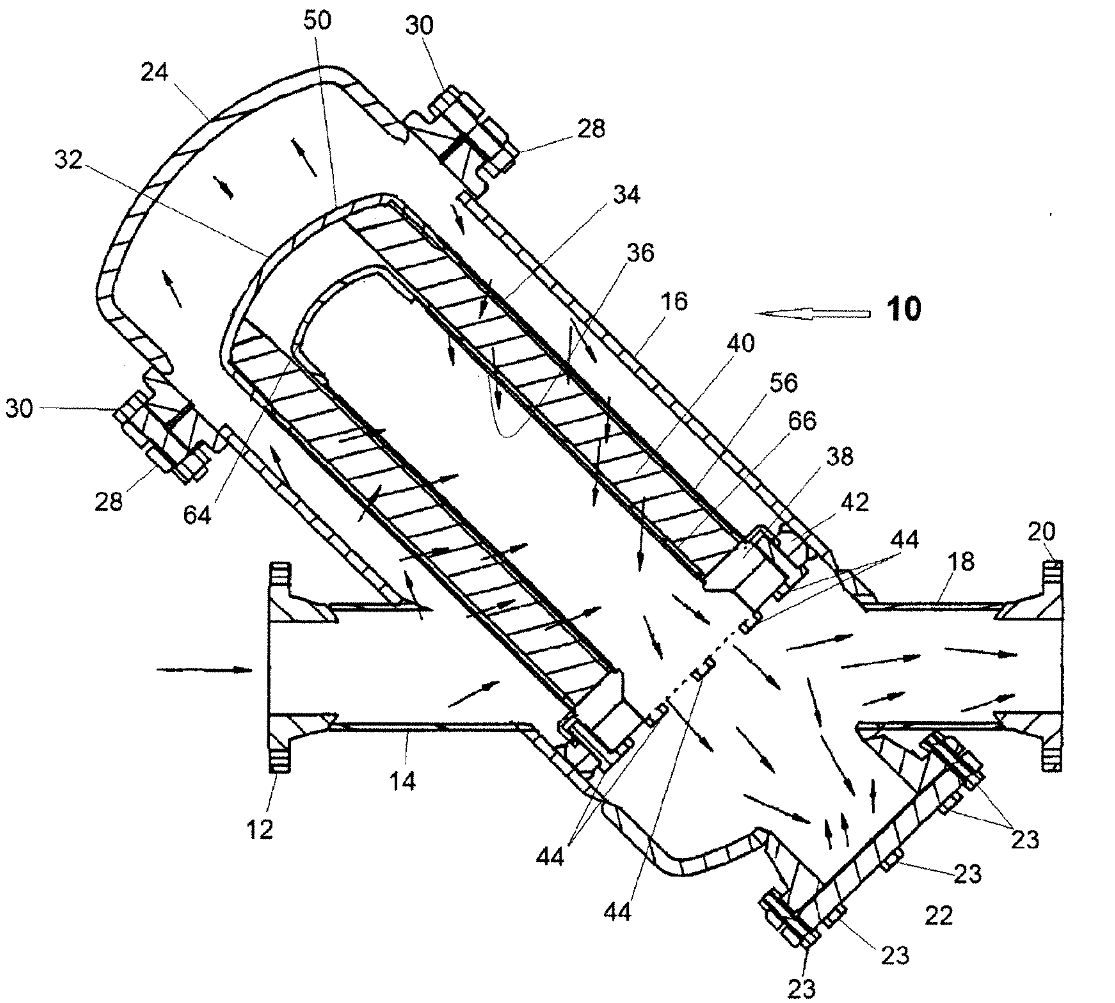
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Fig. 12

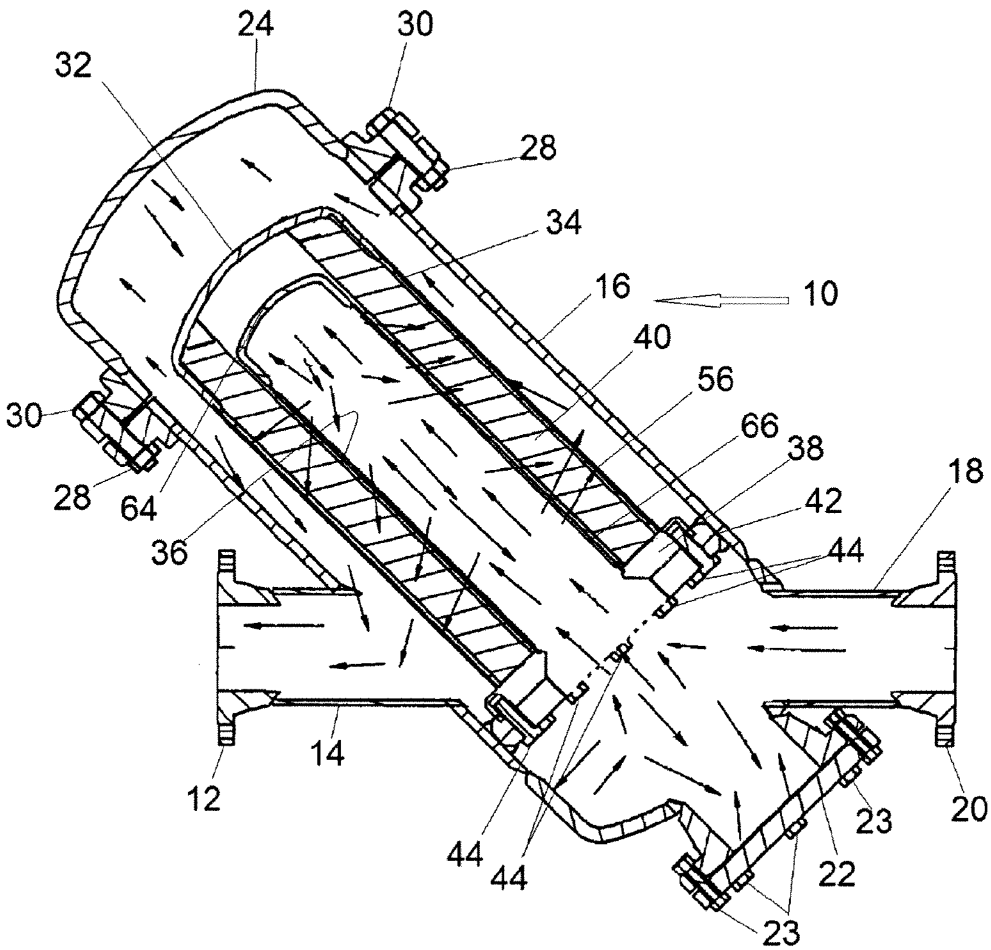
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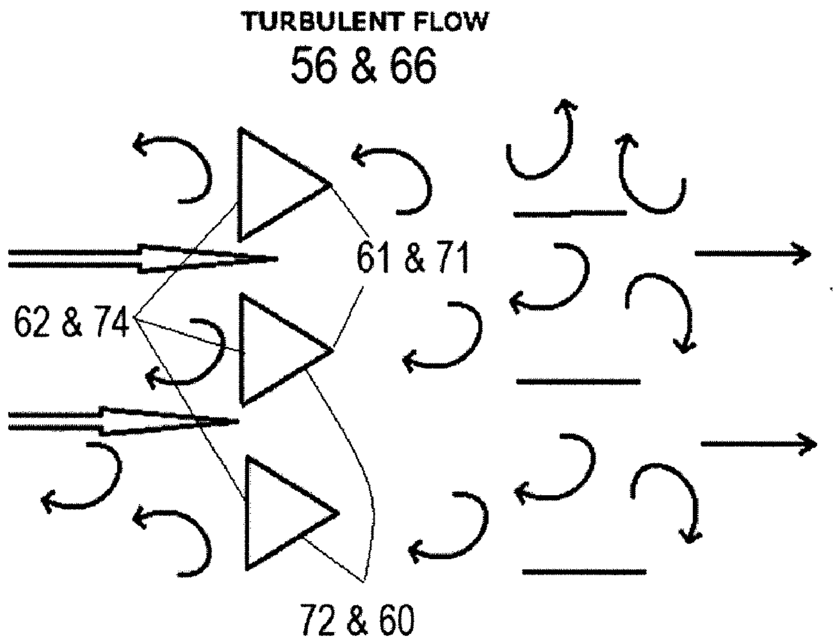
Fig. 13


TURBULENT FLOW
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61 & 71
62 & 74
72 & 60

Fig. 14

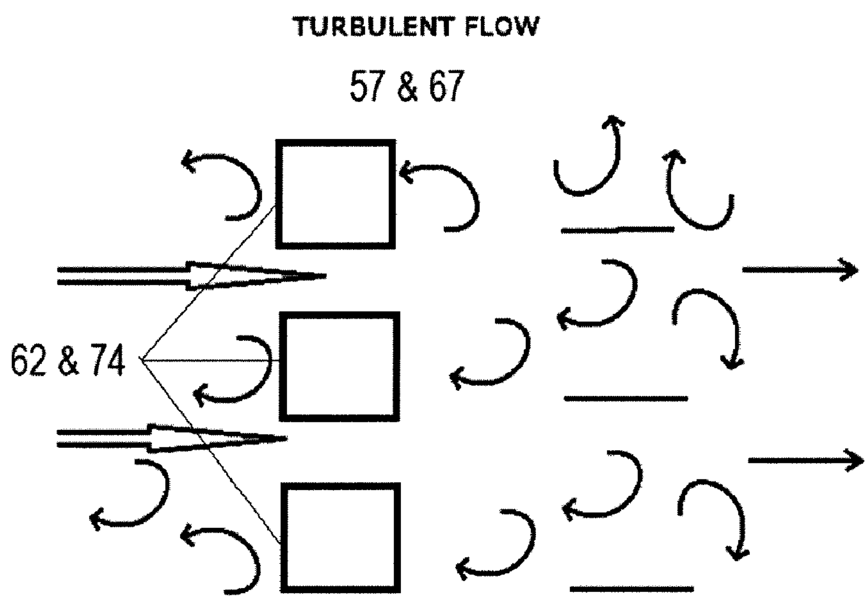
TURBULENT FLOW
57 & 67
62 & 74

Fig. 15

DETONATION FLAME ARRESTOR INCLUDING A TRANSITION POINT/ATTENUATION MATRIX AND TORTUROUS PATH MEDIA

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] This invention relates generally to the field of detonation flame arrestors in flammable vapor pipe line applications.

[0003] 2. Background of the Invention

[0004] Three elements must be present in order for a flame to occur, oxygen, heat (ignition), and a flammable vapor. In a flammable vapor piping system application, which would benefit from the detonation flame arrestor apparatus of the present disclosure, the flammable vapor is flammable gas which mixes with the oxygen introduce from air or other process. If the flammable gas mixes with the oxygen within the LEL and UEL (explosive limits) of the gas, and if/when subjected to an ignition source, a flame will result. If the three requirements remain available, the flame will continue and travel along the piping system with catastrophic consequences. In a stationary flammable mixture, a flame appears to travel toward the unburned gas. This apparent motion is known as flame propagation. Flames generally propagate much faster in piping systems than in the open atmosphere. In addition, flames in piping systems typically propagate upstream against the flow of gas toward its source. However, flames will propagation in any direction as long as the piping system contains a gas/oxygen mixture that is within explosive limits of the gas. This flame propagation usually starts out moving at subsonic velocities called "deflagration". If/and/or pipe length or ignition source is sufficient, the deflagration will transition to supersonic velocities known as a "detonation" and "over-driven detonation" (or "stable detonation"). Other phenomena, like a pipe restriction, debris, varied piping configurations, lightning and more can cause this transition from deflagration to detonation in a shorter length of piping. A purpose of a detonation flame arrestor is to remove heat from the flame front, dropping the temperature below to a point to where the flame cannot be sustained, thereby stopping or arresting it at the point of the detonation flame arrestor along the length of the piping system. It is most desirable if the detonation flame arrestor is capable of doing this regardless of the direction of travel of the flame front and the distance between the detonation arrester and the ignition point. The ability for a detonation flame arrester to arrest the propagating flame front relies on the ability to maintain high temperature differential between the flame front and the detonation flame arrester's element and the elements ability or efficiency as a heat sink. An ideal element design has high transfer rate per in3 of element matrix while maintaining a low pressure drop for the process gas flow.

[0005] A detonation is generally defined as a flame front moving at or above the speed of sound. Detonation entails increased compression of the mixture of oxygen and flammable gases by a pressure front (shock waves) which travel in front of the flame. A detonation may have, for example; 40% hydrogen with 34% oxygen mixture when ignited can have a velocity in the range of 2,450 m/s and dynamic pressure front of 2,000 lbs./in2, with DP/Po of 101.3 using 19.7 lbs./in2 initial pressure. The shock waves resulting from the detonation travel the length of the piping system and are reflected back if there is a restriction in the line.

[0006] A detonation flame arrestor is designed to extinguish a flame front resulting from an explosion or detonation of the gas mixture in the line. However, in addition to extinguishing the flame, the flame arrestor must be capable of dissipating (attenuating) the pressure front that precedes the flame front. The pressure front (shock wave) is associated with the propagation of the flame front through the unburned gas toward the flame arrestor. The flame induced pressure front is always in the same direction as the propagating flame travel. The pressure rise can range from a small fraction to more than 100 times the initial absolute pressure in the system.

[0007] Known flame arrestor apparatuses commonly comprise flame extinguishing plates, ribbon and/or some type of spherical or packed bed media which includes very small gaps of a small diameter (typically at or around the MESG of gases) media with passages that permit gas flow, but prevent flame transmission by extinguishing combustion. This results from the transfer of heat from the flame to the plates, ribbon and/or spherical or packed bed media which effectively provides a substantial heat sink. This heat sink removes one of the required elements for a flame, heat, there by extinguishing the flame.

[0008] Three very common flame arrestor element designs are a crimped ribbon type such as described in U.S. Pat. Nos. 4,909,730, 5,415,233 and 6,644,961, parallel plate type as described in U.S. Pat. No. 5,336,083 and Canadian Patent No. 1,057,187, as well as spherical or packed bed media type described in U.S. Pat. No. 5,336,083. The first two above designs are referred to as straight path flame arrestors because the gas flow takes a straight path from the channel entrance to the exit.

[0009] Flame arrestors are often used in installations where large volumes of gas must be vented with minimal back pressure on the system. It is generally understood that even small deviations in channel dimensions can compromise flame arrestor performance.

[0010] A known significant conflict in flame arrestor design results from the fact that gas line pressure is frequently maintained at atmospheric pressure or higher. Pressure drop resulting from gas passage through a flame arrestor, or back pressure created as a result of gas passage through the flame arrestor, are undesirable. However, pressure drop resulting from passage of a flame through the plates, ribbons, or spherical or packed bed media in the flame arrestor assists in effectively extinguishing the flame. This is because the pressure drop increases the "Residence time" (the average amount of time that a particle spends in a particular system) of the flame passing through the media which results in an increase in heat transfer thus removing the high temperature requirement for the flame to propagate. The extinguishing process (flame arrestment) is based on the drastic temperature difference between the flame and the media material. As such, this is a process that not only depends on the temperature gradient, but also on the hydraulic diameter of the passages and the thermal conduction properties of the gas and the media. As a result, a need, therefore, exists for a detonation flame arrestor design which includes a large pressure drop per unit volume but a small aggregate pressure drop over the entire apparatus.

[0011] The level of turbulence significantly affects the rate of heat loss of the flame within the flame arrestor passages/media. Turbulence is desirable to facilitate the level of heat loss within the flame arrestor by increasing "Residence time". However, straight path flame arrestors of the currently known designs are inefficient in maximizing the amount of turbulence for effective flame arrestment. This is partly because the path of the flame front is unaltered through the flame arrestor. Most commonly, the element is designed so that the gas flows over the surface area of the parallel plates or crimped ribbon so that in the event of a flame front heat transfer will occur so as to extinguish the flame. This flow of gas over the media is most commonly laminar in an effort to reduce the pressure drop through the element. Prior art U.S. Pat. No. 5,415,233, incorporated herein by reference, utilizes a mechanism for increasing turbulence, but the first 20% of the element length is laminar flow with no turbulent flow at all and less than 2% is in the form of turbulent creating sections that add minimal turbulent flow inside the remaining 78% of the laminar flow crimp ribbon sections. In addition, known straight path flame arrestor designs are inefficient in dispensing the initial shock wave or reflective shock wave. A need exists for a flame arrestor design which alters the flow of the flame front as it passes through the flame arrestor.

[0012] Straight path flame arrestors of the currently known designs include retaining bars or support mechanisms which are heavily built of significant mass and strength in order to withstand the high explosion pressure of a detonation. These significant structures add a substantial amount of weight and cost to the device and require extra care to be taken in order to support the piping and the detonation flame arrester. A need exists for a flame arrestor design that is less expensive to construct and lighter in weight.

[0013] In addition, the spherical or packed bed media commonly used for detonation flame arrestors are commonly comprised of ceramic beads. Although ceramic beads have useful thermal characteristics, they are relatively fragile and cannot be compacted without being crushed. Compaction is highly desirable in order to minimize the space between adjacent beads, thereby maximizing surface area of the spherical or packed bed media and varying the path of travel of the flame (creating turbulence). A further concern is that the ceramic media could also be crushed by the shock wave thereby leaving gaps larger than the Maximum Experimental Space Gap (MESG) of the gas which would compromise the performance (flame stopping capabilities) of the flame arrestor. Moreover, All spherical or packed bed media may not pack correctly when the device is loaded (filled), this is referred to as bridging and devices have been designed in an attempt to overcome this potentially disastrous problem, particularly on large systems (see U.S. Pat. No. 5,247,970, for example). It is difficult in small devices like flame arresters to ensure that the media is randomly packed correctly. This so called bridging can and will collapse or settle and produce a gap in the media sufficient enough for the device to allow a flame to pass un-arrested and thereby allow a catastrophic failure to occur in the system. To compensate, some Detonation Flame Arrester standards require the production element to be built 50% larger than a tested element. This brings the cost and size of the units up substantially. A need, therefore, exists for a flame arrestor which can be built so as to consistently maintain the correct hydraulic diameter while maximizing surface area, thereby maximizing the heat sink properties of the media as well as increase turbulent flow through the spaces between adjacent components of the media.

[0014] Prior art constructions have also been known to fail due to the pressures encountered in connection with a reflection pressure front. Although the flame is extinguished within the flame arrestor, a high pressure wave front may exit the outlet side of the flame arrestor as a result of the pressure rise from the initial shock wave. This high pressure wave front continues to travel along the pipe line in the direction of flow. This high pressure wave front, however, will be reflected by any discontinuity located in the pipe line. Discontinuities are the result of bends, stubs, valves, reducers, ice, and the like. As a wave front strikes such a discontinuity, a reflection front is created which travels back towards the flame arrestor. Reflections from many objects along a pipe line can cause transient pressure increases many times the initial pressure. When these reflections enter the outlet side of the flame arrestor, the pressure within the flame arrestor element channels can become many times greater than for which it was designed. While these pressure increases are of extremely short duration and transient in nature (dynamic), they nonetheless are known to cause failures in flame arrestors. Current designs use physical reflectors designed to receive and reflect the shock wave, these work well, however, such reflectors are typically mounted mid-stream (within the gas flow path) and thereby increase the overall pressure drop of the device. A need, therefore, also exists for a flame arrestor that includes the capability of attenuating an initial shock wave and a reflection pressure front, but yet does not cause an increase in pressure drop and can consistently resist damage as a result of high dynamic pressure fronts.

[0015] A detonation flame arrestor must also be capable of attenuating a reflective pressure front in addition to the initial pressure front (shock wave). Initial shock waves impacting flame arrestor elements have been known to cause significant structural damage (element breach) causing the flame arrestor element to fail. Prior art designs including media such as crimped ribbon and expanded metal have been known to suffer significant damage after a detonation has hit them. While this damage does not always lead to failure, it is significant enough to warrant replacement of the device. Compression in flame arrestor design is the force exerted on the outside of the cylindrical element toward the center. Tension is the force exerted from the inside of the cylinder toward the outside. Certain detonation flame arrestor designs employ rolled expanded metal. The rolled expanded metal functions to provide a torturous flow of the flame through the elements to provide heat transfer. Such designs are efficient in attenuating a tensive force. In such designs, however, the detonation shock wave may impact the element from the outside causing a compressive force on the rolled expanded metal media. This compressive force has been known to crush the rolled media resulting in curling at the top and bottom sealing surfaces. If the element is not replaced, this curling may result in failure of the element by allowing a flame path around the element media thus avoiding the function of the media. A need exists for a support structure for the media in an expanded metal design so as to resist compressive forces.

[0016] Another important factor in flame arrestor design relates to the ability to clean the media. Presently known parallel plate, ribbon, and/or packed bed media designs are known to become blocked or clogged as a result of collection of contaminant particles carried in the gas stream. Once significant clogging occurs, which restricts flow and increases pressure drop, the entire flame arrestor must be removed for cleaning or replacement. Cleaning usually requires the introduction of a solvent to the media in a direction opposite of flow so as to dislodge clogging contaminates or particles. A need exists for a flame arrestor design which can be cleaned in stream and/or easily accessed for cleaning and/or replacement of the element.

[0017] Detonation flame arrestors known presently in industrial applications are not known to be effective for low Maximum Experimental Space Gap (MESG) gases, such as Group B gases. In particular, known detonation flame arrestors are not effective for hydrogen gas or enriched oxygen and hydrogen applications. Ribbon or parallel plate detonation flame arrestor constructions cannot be cost effectively produced to meet the requirements of low MESG applications. A need, therefore, exists for a detonation flame arrestor design which can be manufactured in a cost effective manner which is capable of operation in low MESG gas environments.

SUMMARY OF THE INVENTION

[0018] The detonation flame arrestor of the present disclosure includes, generally, an outer cylinder secured to a canister flange; an inner cylinder secured to the canister flange and rolled expanded metal or stacked metal cone torturous path media retained between the outer and inner cylinders. Both the outer cylinder and inner cylinder, while being secured to the canister flange on one end, include a domed face on their other end. The outer cylinder, inner cylinder, and canister flange, together form a canister. The canister is secured within an outer housing bolted to a bulkhead which is welded to the inside of the outer housing. The outer housing is then fitted in the flammable vapor pipe line flow path such that the flow of gas passes into the outer cylinder and through the canister or from the inner cylinder through the canister. The outer housing has a removable cover on the top and bottom for cleaning and/or removal and replacement of the complete element canister without the need to remove the entire flame arrester from the pipeline.

[0019] Both the outer cylinder and the inner cylinder include a transition point/attenuation matrix which forms their respective cylindrical circumferences. The respective transition point/attenuation matrix's of both the outer cylinder and the inner cylinder include helical or parallel wedge wire or rings, the wire having a tapered surface and a blunt (flat) surface such that the direction of the taper on the outer cylinder circumference points towards the center of the cylinder while the tapered surface of the inner cylinder points towards the outer cylinder, with the blunt surface facing the flow from either pipe flange, the device is bi-directional. The inner cylinder is of a smaller diameter than the outer cylinder such that when the canister is assembled, the inner cylinder fits inside the outer cylinder such that the torturous path media is retained between the tapered surface of the transition point/attenuation matrix of the outer cylinder and the tapered surface of the transition point/attenuation matrix of the inner cylinder.

[0020] The domed face of the outer cylinder is pressed onto the torturous path media thereby compacting the media so as to reduce the space between outer and inner cylinders. The torturous path media is tightly bound and has no gaps, and thereby, filling the space between the outer and inner cylinder fully.

[0021] The canister is positioned within the outer housing such that a pressure front which passes through the pipeline and into the outer housing impinges upon the domed face of the inner cylinder, the bulkhead and the blunt face of the transition point/attenuation matrix. The detonation wave front is attenuated by the domed face of the outer cylinder and the bulkhead and the blunt face of the transition point/attenuation matrix. Likewise, after the flame front is extinguished by passage through the canister, a reflected pressure front will impinge the underside of the domed face of the inner cylinder and the blunt face of transition point/attenuation matrix and become attenuated. (This process is reversed if the flame front comes from the opposite direction in a bi-directional application).

[0022] After the flame front impacts the domed face of the outer cylinder, it must make an abrupt (ninety degree (90°)) turn in order to pass through the transition point/attenuation matrix of the inner cylinder. The gap size between adjacent windings of the transition point/attenuation matrix can be chosen for a particular gas or gas group and acts as the first mechanism for arresting the flame passing there through. The flame then passes through the torturous path media and is further quenched as a result of passing through the torturous path media and contacting the surface of the torturous path media (heat sink). Once the quenched gas exits the torturous path media, it passes through the transition point/attenuation matrix of the outer cylinder which is likewise gapped for a chosen gas or gas group. Once the gas exits the outer cylinder, it must again make an abrupt (ninety degree (90°)) turn twice to continue flow through the pipeline.

[0023] Accordingly, flame arrestment is achieved in the detonation flame arrestor of the present invention through the combination of the gaps between adjacent windings of the transition point/attenuation matrix on the inner cylinder and outer cylinder as well as the layered torturous path media. The gap size between adjacent transition point/attenuation matrixes being lower than the MESG of the gas so as to provide the first mechanism for flame arrestment. Layered expanded metal or stacked cones provide a torturous flame path and large heat transfer area between the flame front and the expanded metal media.

[0024] This transverse design of the flame arrestor of the present invention serves two very significant functions. First, it allows the shock wave to impact the high strength surfaces of the domed faces of the outer cylinder and the bulkhead and the blunt face of the transition point/attenuation matrix as stated above. The second function is to allow the total surface area (dictated by the length) of the canister to be varied to accommodate a desired pressure drop simply by lengthening the canister as opposed to increasing the diameter as with a straight path design.

[0025] In the preferred embodiment, the torturous path media consists of layers (by rolling tightly) of expanded metal (or stacked metal cones). The layered media creates a torturous path through the adjacent media. The blunt face of the transition point/attenuation matrix and the torturous path of the expanded metal media disrupts the laminar flow of a flame front (creates turbulence). Moreover, in addition to increasing turbulence, the fact that the combination of the transition point/attenuation matrix and expanded metal screen means that they have greater surface area than crimped ribbon to create a heat sink so as to extinguish a flame passing there through. Accordingly, increased heat transfer is achieved. The canister, including the torturous path media contained therein, is designed to provide an optimum pressure drop per unit volume to provide maximum flame arrestment. Again, as a result of the transverse design, the aggregate pressure drop resulting from the passage of the gas through the canister can be maintained at a low value by varying the length of the canister as required.

[0026] The blunt surface of the wire/ring forming the transition point/attenuation matrix serves the dual purposes of transitioning laminar flow to turbulent flow hence the name "transition point" providing turbulent flow characteristics into the canister and also to provide attenuation and acts as the first mechanism for arresting the flame passing there through. Turbulent flow is created by the blunt side of the wire/ring disturbing normally laminar flow of the gas past. Creating turbulent gas to flow past, improves the heat transfer characteristics by increasing velocity and decreasing pressure of the flame front (akin to flow over an orifice).

[0027] Debris trapped between adjacent windings of the tapered surface of the transition point/attenuation matrix can be easily dislodged upon a reverse flow within the canister by injecting a high pressure cleaning solution through the outer and inner cylinders of the canister or by inserting cleaning rod nozzles directly into the torturous path media during construction. If the element is beyond cleaning, it can be removed through the access ports and replaced while the flame arrestor remains flanged between the pipelines. Most prior art requires the replacement of the entire flame arrester at a substantially higher price.

[0028] The size of the gaps between adjacent windings of the transition point/attenuation matrix of both the outer cylinder and the inner cylinder acts to extinguish a flame passing there through according to known characteristics of selected gases. Thus, a gap size can be selected depending upon the type of gas to be carried by the application, and secondarily, the transition point/attenuation matrix also serves to contain the torturous path media.

[0029] The transition point/attenuation matrix also serves to give needed strength to the entire canister element. Rolled expanded metal alone has shown to distort to failure after being subjected to a detonation, especially when the force is applied to the outside of the cylinder versus inside the cylinder. Other detonation flame arresters rely on bulbous heavily built supports to maintain the integrity of the device as in U.S. Pat. No. 6,644,961 B2. This not required with the transition point/attenuation matrix.

[0030] The transition point/attenuation matrix on the inner and outer cylinders can be effectively produced by spiral winding a tapered wire around their respective cylindrical circumferences or by stacking spaced rings. The gap size can be controlled so as to be lower than the published (known) MESG properties of a particular gas or gas group winding the wire/rings around the cylinders can be done economically while maintaining strict tolerances.

[0031] It is therefore an object of the present invention to provide a detonation flame arrestor that includes a canister which requires the flame front to make an abrupt direction change to pass through the canister

[0032] It is an additional object of the present invention to provide a detonation flame arrestor which includes a transition point/attenuation matrix.

[0033] It is a further object of the present invention to create a detonation flame arrestor including a transition point/attenuation matrix on an inner cylinder and an outer cylinder together forming the canister.

[0034] It is yet a further object of the present invention to provide a detonation flame arrestor including a transition point/attenuation matrix using a wire which may be tapered on at least one surface so as to trap debris and blunted on at least one side to create turbulence characteristics through the wedge wire screen.

[0035] It is a still further object of the present invention to provide a detonation flame arrestor including a transition point/attenuation matrix which also includes a gap between adjacent windings of the transition point/attenuation matrix selected for a particular gas type or gas group.

[0036] It is yet an additional object of the present invention to include an torturous path media made from expanded metal or stacked metal cones, between the inner cylinder and outer cylinder to act as a torturous path and heat sink to extinguish a flame passing there through.

[0037] It is a yet another object of the present invention to include a blunt surface of the transition point/attenuation matrix to attenuate flow and also to increase the turbulence of the gas/flame passing there through.

[0038] It is an object of the present invention to provide a detonation flame arrestor design which is effective for low MESG gas applications.

[0039] It is also an object of the present invention to provide a detonation flame arrestor including an inner cylinder and outer cylinder with torturous path media there between which is capable of being cleaned by injecting a high pressure cleaning solution through the inlet and outlets of the device or from within the torturous path media.

[0040] It is also an object of the present invention to provide a detonation flame arrestor that's inner cylinder and outer cylinder with an torturous path media there between which is capable of being removed and replaced while still flanged between the pipelines.

[0041] Additional objects of the present invention include attenuation of the pressure front and reflective pressure front by designing the flame arrestor to provide a structurally sound domed face on both the outer cylinder and inner cylinder.

[0042] Further objects, features, and advantages of the present invention will be apparent to those skilled in the art upon examining the accompanying drawings and upon reading the following description of the preferred embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0043] FIG. **1**. is a view of the external housing of the flame arrestor of the present disclosure as it would be installed in a flammable vapor piping system.

[0044] FIG. **2** is a side cut-away view taken along line **2-2** of FIG. **3** depicting the detonation flame arrestor of the present disclosure including transition point/attenuation matrix and torturous media.

[0045] FIG. **3** is a view of the flame arrestor of FIG. **1** rotated approximately ninety (90°) degrees.

[0046] FIG. **4** is a view taken along line **4-4** of FIG. **1**.

[0047] FIG. **5** is a partial cut-away side view of the outer cylinder of the flame arrestor of the present disclosure depicting helical wedge shaped wire used for the transition point/attenuation matrix.

[0048] FIG. **6**A is a detail cut-away view depicting the assembly of the helical wedge shaped wire transition point/attenuation matrix of the inner and outer cylinders with expanded metal torturous path media inserted between the inner and outer cylinders.

[0049] FIG. **6**B is a detail cut-away view depicting the assembly of the helical wedge shaped wire transition point/attenuation matrix of the inner and outer cylinders with stacked metal cone torturous path media inserted between the inner and outer cylinders.

[0050] FIG. **7** is a cut-away side view depicting the assembly of the canister with expanded metal torturous path media inserted between the inner and outer cylinders and welded to the canister bottom and bolted to the bulkhead flange.

[0051] FIG. **8**A is a view depicting a section of expanded metal torturous path media of the preferred embodiment.

[0052] FIG. **8**B is a top view depicting the shape of the expanded metal torturous path media of the preferred embodiment.

[0053] FIG. **9** is a side cut-away view of the detonation flame arrestor of the present disclosure including helical wedge shaped wire forming transition point/attenuation matrix and stacked metal cone torturous media.

[0054] FIG. **10** is a cut-away view depicting helical wedge shaped wire as the transition point/attenuation matrix of the inner and outer cylinders and stacked cone torturous metal media inserted between the inner and outer cylinders welded to the canister bottom and bolted to the bulkhead flange.

[0055] FIG. **11**A is an isometric top view of a section of stacked metal cone torturous media.

[0056] FIG. **11**B is an isometric bottom view of a section of stacked metal cone torturous media.

[0057] FIG. **12** is a side cut-away view of the detonation flame arrestor of the present invention including transition point/attenuation matrix and torturous media with flow direction arrows indicating the flow of gas or flame front as it penetrates the matrix from the side of the outer canister.

[0058] FIG. **13** is a side cut-away view of the detonation flame arrestor of the present disclosure including transition point/attenuation matrix and torturous media with flow direction arrows indicating the flow of gas or flame front as it penetrates the matrix from the bottom of the inner cylinder.

[0059] FIG. **14** is a cross section illustration depicting turbulent flow as gas hits the blunt face and flows between each helical or parallel wedge shaped wire or ring as the transition point/attenuation matrix of the present disclosure.

[0060] FIG. **15** is a cross section illustration depicting turbulent flow as gas hits the blunt face and flows between each helical or parallel quadrilateral shaped wire or ring as the transition point/attenuation matrix of the present disclosure.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0061] An external view of the detonation flame arrestor **10** of the present invention is shown in FIG. **1**. Detonation flame arrestor **10** is designed to be placed in line in a gas piping system (not shown) in which the gas line has an inflow end and an outflow end (not shown). FIG. **1** depicts the external housing **16** of flame arrestor **10** which is of a design generally known in the art and includes an inlet flange **12** for connection to the inflow end of the gas line, an inlet port **14**, an external housing body **16**, an outlet port **18**, and an outlet flange **20** for connection to the outflow end of the gas line. External housing body **16** is generally cylindrical and oriented at approximately a forty-five degree (45°) angle from inlet port **14** and outlet port **18**. Inlet flange **12** and outlet flange **20** in the preferred embodiment are raised face weld neck flanges known in the industry for flame arrestor service. The external housing body **16** of flame arrestor **10**, therefore, provides a substantially hollow pressure vessel shell which is in open internal communication with the gas piping system.

[0062] Referring next to FIG. **2** which is a side cut-away view of flame arrestor **10** depicting a canister **32** mounted within external housing **16** of flame arrestor **10**. As depicted in FIG. **2**, canister **32** is mounted within external housing **16** such that its longitudinal axis is parallel to, and concentric with, the longitudinal axis of external housing **16**. This means that the flow pattern through flame arrestor **10** through canister **32** is transverse to the longitudinal axis of external housing **16**, and at approximately a forty-five degree (45°) angle from the longitudinal axis of the pipeline. The transverse orientation of canister **32** within external housing **16** means that gas flow into inlet port **14** through inlet flange **12** from the inflow of the gas line passes around canister **32** and is required to take an abrupt turn, approximately 90° in the preferred embodiment, to pass through canister **32** and takes a second abrupt again approximately 90° turn to exit from canister **32** into and through outlet port **18**, outlet flange **20** on into the outflow end of the pipeline.

[0063] With reference to FIG. **1** in combination with FIG. **2**, external housing **16** includes an access port **21** positioned adjacent outlet port **18**. Access port **21** provides access to the interior of external housing **16** adjacent outlet port **18** below canister **32**. Access port **21** allows access to bolts **44** to enable the removal of canister **32** or also provides access to the interior of external housing **16** for cleaning. Access port **21** is covered by a blank flange **22** in the preferred embodiment which is secured to access port **21** by a plurality of bolts **23** secured by a plurality of nuts **25** so as to securely seal access port **21** against the escape of gas.

[0064] External housing **16** also includes in the preferred embodiment a removable cap **24**. Cap **24** is secured to external housing **16** by a plurality of bolts **30** secured by nuts **28** so as to provide a seal to prevent the escape of gas. Cap **24** is removable from external housing **16** to provide access to the interior of external housing **16** for cleaning and access to canister **32**. For example, Cap **24** may be removed from external housing **16** while blank flange **22** may be removed from access port **21** so that the interior of external housing **16** and particularly canister **32** may be cleaned by flushing with water or more preferably a solvent solution which would flush debris from the interior of external housing **16** and also canister **32** which would drain by gravity out of external housing **16** through access port **21**. Alternatively, with cap **24** and blank flange **22** removed, canister **32** may be removed from external housing **16** through the removal of bolts **44** without having to remove external housing **16** from the piping system. Once removed, canister **32** may be cleaned, serviced, or replaced as necessary.

[0065] FIG. **3** is an isometric view of the exterior of flame arrestor **10** of the present disclosure depicting external housing **16**, inlet flange **12**, access port **21** with blank flange **22** secured thereto. FIG. **3** further depicts cap **24** shown secured to external housing **16** by bolts **30**.

[0066] With reference to FIG. **2** taken in combination with FIG. **7**, canister **32** includes an outer cylinder **34**, an inner cylinder **36**, a canister flange **38**, and media **40** retained between inner cylinder **36** and outer cylinder **34**. Both outer cylinder **34** and inner cylinder **36** are preferably welded to canister flange **38**. A ring-shaped bulkhead **42** is fixed within external housing body **16**. In the preferred embodiment, bulkhead **42** is just less in diameter as, and is permanently welded within, external housing body **16**.

[0067] By way of example, a canister of the following dimensions has been found suitable to arrest a detonation flame in a hydrogen gas environment in a three inch (3") pipeline application. In the preferred embodiment, outer cylinder **34** and inner cylinder **36** are constructed of T-304 stainless steel in order to resist corrosion, however, it is understood that other metals and alloys are suitable, depending upon the gas environment.

[0068] Outer cylinder:

[0069] 8" ID×15" overall length having a 10" length of helical wedge shaped wire screen transition point/attenuation matrix;

[0070] 4" long×8" domed face;

[0071] ½" long first weld ring;

[0072] ½" long second weld ring;

[0073] Inner cylinder:

[0074] 4¼" OD×13¼" overall-length having a 10" length of helical wound wedge wire screen transition point/attenuation matrix;

[0075] 2½" long×4" domed face;

[0076] ⅜" long first weld ring;

[0077] ⅜" long second weld ring;

[0078] ½" thick canister flange, approximately 8½" diameter.

It is understood that this is an example only as other sizes and dimensions as well as other gas environments are contemplated.

[0079] Bulkhead **42** serves several important functions including attenuation of pressure (shock) waves (discussed below), creates a barrier within external housing body **16** to prevent a flame front from bypassing canister **32**, and forms the structure which retains canister **32** in its transverse orientation within external housing **16**. With reference to FIG. **2** taken in combination with FIG. **7**, a plurality of holes are drilled around the annular circumference of ring-shaped bulkhead **42** in order to receive a plurality of bolts, collectively **44**, which thread into canister flange **38**. Bolts **44**, threaded into canister flange **38**, retain canister **32** in its transverse orientation within external housing **16** of flame arrestor **10**. Bolts **44** may be lock wired as to prevent them from working loose and causing a failure.

[0080] Canister flange **38** is likewise ring-shaped, however, canister flange **38** has a smaller diameter than bulkhead **42** in its preferred embodiment. Canister flange **38** is preferably drilled and tapped with holes around its bottom annular surface such that the holes match the holes drilled through bulkhead **42**. The holes drilled in canister flange **38** are tapped with threads which mate the threads of bolts **44**. Moreover, the holes drilled and tapped in canister flange **38** do not extend entirely through canister flange **38** in the preferred embodiment in order to prevent gas, or more significantly a flame front, from escaping into outlet port **18** around bolts **44**. The width of ring-shaped canister flange **38**, in the preferred embodiment, is approximately equal to the space formed between outer housing **34** and inner housing **36** which retains expanded metal media **40**, plus the width of outer housing **34** and inner housing **36** which are welded onto canister flange **38**.

[0081] Both canister flange **38** and bulkhead **42** are ring-shaped and include concentric holes **46** and **48** machined through the center of canister flange **38** and bulkhead **42**, respectively. The size of concentric holes **46** and **48** is approximately the same size or greater as the internal diameter of inner cylinder **36**. The purpose of concentric holes **46** and **48** is to allow the unrestricted passage of gas exiting canister **32** through the inside of inner cylinder **36** to exit the inside of inner cylinder **36** and into outlet port **18** to then exit flame arrestor **10** through outlet flange **20** and into the outbound pipeline (as illustrated by the arrows in FIG. **12**).

[0082] With specific reference to FIGS. **2**, **5** and **7**, the construction of outer cylinder **34** shall next be described. Outer cylinder **34** includes, generally, a domed cap **50**, a first weld ring **52**, a second weld ring **54**, a transition point/attenuation matrix **56** which may be coiled between first weld ring **52** and second weld ring **54**, and a plurality of support ribs, collectively **56** which bound the outer circumference of outer cylinder **34**. In the alternative, transition point/attenuation matrix **56** may include a series of annular rings, each spaced according to the known MESG of the gas application and positioned between first weld ring **52** and second weld ring **54**.

[0083] Weld ring **52** is welded to domed face **50** while weld ring **54** is welded to canister flange **38**. Transition point/attenuation matrix **56** is in a preferred arrangement depicted in FIGS. **4**, **5**, **6**A, and **6**B a helical wound wire with a tapered (wedge) shape. Helical wedge wire **56** is a continuous helical winding from first weld ring **52** to second weld ring **54**. Helical wire **56** of the preferred embodiment is defined by a blunt surface **62** and tapered surfaces **60** which intersect at a point **61**. Port **61** where tapered (wedge) surfaces **60** intersect is spot welded in the preferred embodiment to support rods **58** to form the outer circumference of outer cylinder **34**. The helical wire which forms transition point/attenuation matrix **56** of the preferred embodiment is such that gas entering canister **32** will impinge blunt surface **62** causing turbulent gas flow. The ends of support rods **58** are welded to first weld ring **52** and second weld ring **54** respectively. Accordingly, a unitary, substantially cylindrical outer cylinder **34** is described.

[0084] Likewise, inner cylinder **36** includes a domed face **64**, a transition point attenuation matrix **66**, and support ribs, collectively **68**. Ribs **68** are identified in FIG. **6**A and **6**B collectively and representative rib **68** is identified in FIGS. **4**, **6**A, **6**B and **7**. Inner cylinder **36** also includes a first weld ring **70** in FIG. **6**A and FIG. **6**B and FIG. **7** which is welded to domed face **66** and a second weld ring **73** (FIG. **7**) which is welded to canister flange **38**. The ends of support ribs **68** are welded to weld rings **70** and **73**. In the preferred embodiment, a helical wedge wire **66** is a continuous helical winding between weld rings **70** and **73**. Point **71** where tapered surfaces **72** intersect is spot welded to support ribs **68** to form the inner circumference of inner cylinder **36**.

[0085] Both outer cylinder **34** and inner cylinder **36** of canister **32** include a transition point/attenuation matrix which forms their respective cylindrical circumferences. The transition point/attenuation matrix **56** of outer cylinder **34** and transition point/attenuation matrix **66** of inner cylinder **36** are preferably helical or parallel wedge (FIG. **14**) wire or rings (FIG. **15**). The wire preferably having a tapered surface and a blunt (flat) surface (FIG. **14**). As depicted in FIG. **6**A and FIG. **6**B, transition point/attenuation matrix **56** preferably includes tapered surfaces **60** which intersect at point **61** such that point **61** on the circumference of outer cylinder **34** points towards the center of canister **32**. In contrast, transition point/attenuation matrix **66** preferably includes tapered surfaces **72** which intersect at point **71** such that point **71** on the circumference of inner cylinder **36** points also points towards the center of canister **32**. The blunt surfaces of the transition point/attenuation matrix of both outer cylinder **34** and inner cylinder **36** of canister **32** abut the flow of gas regardless of which direction it is flowing. As a result, the flame arrestor device of the present disclosure is bi-directional. As stated, in the alternative, the transition point/attenuation matrices could be square or rectangular wire shown in cross-section as **57** and **67** in FIG. **15**. Blunt surfaces **62** and **74** to create turbulent gas flow are also present in this embodiment. Additionally, the transition point/attenuation matrix could be configured as rings in either wedge or square (rectangular) geometries.

[0086] Inner cylinder **36** is of a smaller diameter than outer cylinder **34** such that when canister **32** is assembled, inner cylinder **36** fits inside outer cylinder **34** with a torturous path media **40** bounded by and retained between the tapered surfaces **60** of the transition point/attenuation matrix **56** of outer cylinder **34** and the tapered surfaces **72** of the transition point/attenuation matrix **66** of inner cylinder **36** in a preferred arrangement.

[0087] Helical wedge shaped wire screen which forms transition point/attenuation matrix **66** in the preferred embodiment of inner cylinder **36** includes a blunt surface **74** and tapered surfaces **72** which terminates at point **71**. As can be seen in FIGS. **4**, **5**, **6**A, and **6**B, the tapered surfaces **72** of helical wedge shaped wire screen **66** of inner cylinder **64** are oriented in the opposite manner of transition point/attenuation matrix **56** of outer cylinder **34** such that tapered surfaces **72** of helical wound wedge wire screen **66** of inner cylinder **36** points away from the center of inner cylinder **36** while the tapered surface **60** of helical wound wedge wire screen **56** of outer cylinder **34** points toward the inside of outer cylinder **34**. The helical wound wedge wire screen **56** and **66** of outer cylinder **34** and inner cylinder **36**, respectively, in the preferred embodiment is Vee-Wire® screen commercially available from USF Johnson Screens, 1950 Old Hwy NW, New Brighton, Minn. 55112.

[0088] The geometry of the wire forming the transition point/attenuation matrix **56** of the outer cylinder **34** and transition point/attenuation matrix **66** of inner cylinder **36** serve the dual purposes of disrupting or providing turbulent gas flow characteristics through canister **32** and also traps debris and contaminants between adjacent windings of outer cylinder **34** and inner cylinder **36**, respectively. Debris and contaminants trapped between respective adjacent windings can be easily removed in order to restore flow (reduce pressure drop) through canister **32** in a manner described below.

[0089] Turbulent gas flow into and through canister **32** past transition point attenuation matrix **56** of outer cylinder **34** and transition point attenuation matrix **66** of inner cylinder **36** occurs as result of gas flow being disrupted as a result of impact with blunt surface **62** of transition point/attenuation matrix **56** as it flows into canister **32** and contact with blunt surface **74** of transition point/attenuation matrix **66** as the gas flows out of inner cylinder **36** of canister **32** while causing minimal pressure drop. This is because blunt surface **62** of transition point/attenuation matrix **56** and blunt surface **74** of transition point/attenuation matrix **66** cause an increase in the turbulence of the gas passing thereby as a result, increased turbulence correlates to increased heat transfer to the tortuous path media **78** and **86**. This is depicted in FIGS. **14** and **15**. Additionally, the length of the transition point/attenuation matrix **56** and thereby canister **32** can be varied to accommodate a larger volume of gas to minimize pressure drop.

[0090] The size of the gaps between adjacent windings of the respective blunt surfaces **62** and **74** of transition point/attenuation matrices **56** on outer cylinder **34** and **66** on inner cylinder **36** aid in extinguishing a flame passing therethrough according to the known MESG characteristics of a selected gas application. Accordingly, a gap size can be selected depending upon the type of gas to be carried by a certain gas piping system application. For the purposes of exemplification, the known MESG for hydrogen is 0.102 mm or 0.004 in. In an example hydrogen gas application, the gap size between adjacent windings of the blunt surfaces **62** and **74** of transition point/attenuation matrices **56** and **66**, respectively would be sized so as to gain a significant increase in the velocity and a decrease in pressure of the pressure front causing increased turbulence and greater resident time. In a hydrogen application, a gap size larger than the MESG has been found to be acceptable. Accordingly, the gap dimension measured between adjacent blunt surfaces **62** and **74** of adjacent windings of transition point/attenuation matrices **56** and **66**, respectively, serve the additional significant function of increasing the velocity and a decreasing pressure of the pressure front causing increased turbulence and an even greater resident time. aiding to extinguishing a flame front.

[0091] The helical design of the preferred embodiment transition point/attenuation matrix **56** of outer cylinder **34** and transition point/attenuation matrix **66** of inner cylinder **36** is intended to provide a cost effective means of manufacture of a flame arrestor canister such that the gap size between adjacent blunt surfaces **62** and **74** of screen **66** can be consistently and accurately maintained.

[0092] FIG. **4** is a cutaway view taken along line **4-4** of FIG. **1**. FIG. **4** depicts outer housing **16** with cap **24** secured thereto via nuts **28** secured by bolts **30**, collectively. Outer cylinder **34** and inner cylinder **36** are also depicted with torturous path media **40** contained therein. Outer cylinder **34** is depicted showing helical wedge wire **56** as welded to support rods **58**. Likewise, inner cylinder **36** is depicted with helical wedge wire **66** welded to support rods **68**.

[0093] Next referring to FIGS. **2**, **6**A, **8**A, and **8**B, in a preferred embodiment, torturous path media **40** consists of layers (by rolling tightly) expanded metal **76**. An alternate preferred embodiment (FIGS. **6**B, **9**, **10**, **11**A, and **11**B) employs stacked metal cones **86**. Other readily available materials like sintered metal foam, perforated metal, parallel plates or wire mesh can also be substituted for the expanded metal **76**.

[0094] The particular torturous path media selected will depend upon the gas application and is dictated by the known MESG of the gas. By way of example, in the environment of a low MESG gas such as hydrogen (0.102 mm), the torturous path formed by rolling expanded metal **76** can be much larger than the MESG of that gas due to the highly turbulent environment created by the combination of the torturous path media **40** and the transition point/attenuation matrices **56** and **66**. It is preferred that the spaces between the layers of expanded metal **76** as a result of rolling be approximately 0.102 mm or less in a hydrogen gas environment so as to not negate the effect of the transition point/attenuation matrices **56** and **66** and torturous path media **76** to extinguish a hydrogen gas flame front.

[0095] In addition to the flame extinguishing capabilities of the gaps formed between the blunt surfaces **62** and **74** between adjacent windings of helical wound wedge wire screen **56** and **66** of outer cylinder **34** and inner cylinder **36**, respectively, blunt surfaces **62** and **74** serve the purpose of containing expanded metal media **40** within canister **32**. Torturous path media **40** in the preferred embodiment consists of expanded metal which is available commercially and used extensively in industrial applications. In the preferred embodiment the expanded metal (**76** of FIG. **6**A) is rolled and inserted between inner cylinder **34** and outer cylinder **36**.

Expanded metal **76**, when rolled, forms internal passageways that are non-linear and thereby define a torturous path for the gas to travel between outer cylinder **34** and inner cylinder **36**. This torturous path assists the transition point/attenuation matrices in extinguishing a flame front as it enters and passes through canister **32**.

[0096] Expanded metal **76** (FIG. **8**A and **8**B) is defined by lengths, such as **79**, **80**, **81**, **82**, **83** and **84** forming diamond shaped sections **86** with an internal passage **85** through the center of each diamond section **86**. Multiple diamond sections **86** make up a rolled sheet of "regular expanded metal" **76** that is used in the preferred embodiment. Regular Expanded Metal is a finished product as it comes from the press after having been die cut and expanded. Each sheet that comes off the expander is in standard or regular form with the junctions at the strands and bonds forming a ridge surface. FIG. **8**A and FIG. **8**B show that the strands and bonds form a sharp angle to the original plane of the solid sheet. Regular expanded metal **76** is available commercially, such as from Alabama Metal Industries Corporation, 3245 Fayette Ave., Birmingham, Ala. 35208 and Metalex Expanded Metal Products, 1530 Aratius Parkway, Libertyville, Ill. 60048 and formed by piercing a sheet of thin material, most commonly 316 stainless steel, carbon steel, aluminum and even plastics.

[0097] When rolled tightly and inserted into canister **32** between inner cylinder and outer cylinder (FIG. **6**A), expanded metal media **76** creates a torturous path for the gas, or more particularly a flame front, to travel in order to pass through flame arrestor **10**. The blunt faces **62** and **74** of transition point/attenuation matrices **56** and **66**, respectively (FIG. **14**), together with the torturous path created by rolled expanded metal media **76** disrupts the laminar flow of a flame front (creates turbulence and increases residence time). Moreover, in addition to increasing turbulence and increasing residence time, the combination of transition point/attenuation matrices **56** and **66** together with a torturous path media such as expanded metal **76** provides substantial surface area for the flame/gas to contact. The turbulence created and the increased residence time created by the transition point/attenuation matrices **56** and **66** have superior heat transfer characteristics to the heat sink (expanded metal **76** torturous path media) than conventional laminar flow matrixes. The turbulence created as well as the heat sink created by the substantial surface area act to extinguish a flame passing through canister **32**. Canister **32**, including expanded metal **76** torturous path media contained therein, is designed to provide an optimum pressure drop per unit volume to provide maximum flame arrestment. Again, as a result of the transverse design, the aggregate pressure drop resulting from the passage of the gas through canister **32** can be maintained at a low value by varying the length of the canister **32** (and housing **16**—FIG. **2**) as required.

[0098] With reference to FIG. **2** taken in combination with FIGS. **5** and **6**, the entire space formed between inner cylinder **36** and outer cylinder **34** is filled with torturous path media **40** and retained between blunt transition point/attenuation matrix **56** of outer cylinder **34** transition point/attenuation matrix **66** of inner cylinder **36**.

[0099] With reference to FIGS. **9**, **10**, **11**A, and **11**B, in an alternate preferred embodiment torturous path media is disclosed. In this alternate preferred embodiment, an array of stacked metal cones **86** are substituted for the expanded metal and inserted into canister **32** between outer cylinder **34** and inner cylinder **36**. FIG. **9** depicts the flame arrestor **10** of the present disclosure which includes a canister **32** including a stacked metal cone **86** torturous path media.

[0100] With specific reference to FIGS. **11**A and **11**B, an exemplary array of stacked cone media **86** is depicted. Each cone, such as exemplary cone **100** is truncated so as to provide a center hole which is slightly larger than the diameter of inner cylinder **36** (FIG. **10**). Each truncated cone of stacked array **86** such as cone **100** includes a plurality of spacers, collectively **102**, disposed on its outer conical surface. When stacked in array **86**, spacers **102** provide a space or gap between adjacent cones in the stacked array. These spaces can be varied according to the thickness of spacers **102**. The spaces between adjacent cones in stacked array **86** allow the passage of gas therethrough as the gas passes through canister **32** (FIG. **9** and FIG. **10**). The size of the space or gap may be selected according to the known MESG of the gas in the piping application.

[0101] Referring to FIG. **10**, canister **32** may be constructed using the array of stacked cones **86** positioned between outer cylinder **34** and inner cylinder **36**. In this alternate preferred embodiment, array of stacked cones **86** is inserted between outer cylinder **34** and inner cylinder **36** with the gaps or spaces described above between adjacent individual cones. A cone retainer **94**, which is a ring having an angled edge which mates the angle of the array of stacked cones **86** is placed above or on top of stacked cone array **86**. A compressor **92** which may be a pipe sleeve contacts retainer **94**. In this alternate preferred embodiment, domed cap **90** is welded to compressor **92** and serves the function of cap **64** of FIG. **7**. An outer domed cap **93** including a central opening through which cap **90** extends is fitted over domed cap **90** and welded to a weld ring **98** and to compressor **92** so as to seal the interior of the upper space between outer cylinder **34** and inner cylinder **36**. Weld ring **98** is welded to the transition point/attenuation matrix which comprises the exterior of outer cylinder **34**. Likewise, the transition point/attenuation matrix comprising the surface of inner cylinder **36** may be welded to compressor **92**. At the lower segment of canister **32** in this alternate preferred embodiment, a weld ring **98** is welded to the transition point/attenuation matrix which forms inner cylinder **36** and also welded to canister flange **38** so as to seal the interior of canister **32**. Canister flange **38** is bolted to bulkhead **42** as described above so that canister **32** may be secured within external housing **16** (FIG. **9**).

[0102] When installed between outer cylinder **34** and inner cylinder **36** of canister **32**, as depicted in FIG. **6**B, stacked cone media **86** creates a torturous path for the gas, or more particularly a flame front, to travel in order to pass through flame arrestor **10**. Transition point/attenuation matrices **56** and **66** fanning outer cylinder **34** and inner cylinder **36**, respectively, together with the torturous path created by stacked cone media **86** disrupts the flow of a flame front and creates turbulence as well as increasing the residence time of the gas/flame front within canister **32**. In addition to increasing the turbulence and increasing residence time, the combination of transition point/attenuation matrices **56** and **66** together with a torturous path media such as stacked cone array **86** provides substantial surface area for the flame/gas to contact. The turbulence created, as well as the heat sink created by the substantial surface area and increased residence time act to extinguish a flame passing through canister **32** including stacked cone array **86**. Canister **32**, including stacked cone array **86** contained therein, is designed to provide an optimum pressure drop per unit volume to provide maximum flame arrestment. As set forth above, as a result of the transverse design of the present disclosure, the aggregate pressure drop resulting from the passage of the flame/gas through canister **32** can be maintained at a low value by varying the length of canister **32** which can be accomplished by increasing the number of stacked cones in array **86** as required.

[0103] With reference to FIG. **6**A and FIG. **6**B, debris (contaminants) carried in the gas stream, collectively **96**, may be trapped between adjacent windings of transition point/attenuation matrix **56** of outer cylinder **34**. Trapped debris **96** can be easily dislodged upon application of a reverse flow within the canister by injecting a high pressure cleaning solution into torturous path metal media **40** from above through domed cap **24** of outer housing **16** or below through access port **21**. In a particular embodiment, fittings could be placed within torturous path media **40** to allow connection of a source of high pressure cleaning solution to be injected directly into torturous path media **40** through domed face **50** dome cap **24** or through canister flange **38** and blank flange **22** (via access port **21**). Likewise, any debris which may become trapped between adjacent windings of transition point/attenuation matrix **66** of inner cylinder **36** may be dislodged by the flow from the injection of the high pressure cleaning solution as described above.

[0104] Torturous path media **40** can be replaced or recharged by removing canister **32** from outer housing **16** of flame arrestor **10** by removing bolts **30** from domed cap **24** of outer housing **16**. With cap **24** removed, canister **32** can be accessed and removed by removing blank flange **22** which accesses the interior of outer housing **16**. Bolts **44** may then be removed through access opening **21** such that canister flange **38** is disconnected from bulkhead **42**. Canister **32** is then free for removal from outer housing **16**. A new canister can be installed in outer housing **16**, or, alternatively cleaned by placed the canister **32** in a bucket or container of cleaning solution or solvent and placed on an "Ultrasonic Cleaning Device". Canister **32** may then be reinstalled (or a new canister installed) in outer housing **16** and canister flange **38** bolted to bulkhead **42**. Domed cap **24** may next be bolted back on to outer housing **16**. Blank flange **22** is then bolted to outer housing **16** to seal outer housing **16** and flame arrestor **10** returned to service.

[0105] In the event of a change in the type of gas in the piping system, torturous path media **40** could be removed and replaced with a torturous path media of a component diameter which is suitable for the new gas application. This could be accomplished by removal and replacement of canister **32** as described above.

[0106] The direction of flow of gas in FIG. **12** is illustrated by arrows entering the external housing through inlet flange **12**, passing through inlet port **14** around canister **32** between canister **32** and the inside of external housing body **16**, turning abruptly into and through to the center of canister **32**, and turning again abruptly out of canister **32** into outlet port **18** and then exiting through outlet flange **20**.

[0107] Canister **32** is secured to bulkhead **42** in the transverse orientation described above in order that a pressure wave front (shock wave) which passes through the piping system as a result of a detonation of the gas contained in the piping system will enter flame arrestor **10** through inlet flange **12** and inlet port **14**. The shock wave will then impinge domed face **50** of outer cylinder **34** and will also pass into the space defined between external housing body **16** and outer cylinder **34** and impact bulkhead **42**. Both bulkhead **42** and domed face **50** of outer cylinder **34** are constructed to withstand the force of an impinging shock wave. The detonation wave front (shock wave) is thereby attenuated by the combination of domed face **50** of the outer cylinder **34** and bulkhead **42**.

[0108] As stated previously, flame arrestor **10** is bi-directional. The direction of flow of gas in FIG. **13** is in the reverse direction from that of FIG. **12**. Flow in the reverse direction is illustrated by arrows entering external housing **16** through outlet flange **20**, passing through outlet port **18** and into inner cylinder **36** of canister **32** via concentric holes **46** and **48** past transition point/attenuation matrix **66**. Gas flow then turns abruptly into and through torturous path media **40**, and turning again abruptly out of canister **32** through transition point/attenuation matrix **56** and into inlet port **14** to exit through inlet flange **12**.

[0109] Likewise, a pressure front which may be directed upstream in the piping system back toward flame arrestor **10** or which has passed through flame arrestor **10** even though the flame front is extinguished, that may be directed or reflected back into flame arrestor **10** through outer flange **20**, outer port **18** and back into canister **32** will be attenuated by the structural integrity of the inside surface of domed face **64** of inner cylinder **36** without causing damage to canister **32** or the external housing of flame arrestor **10**. The transverse orientation of canister **32** within the outer housing of flame arrestor **10** allows the structural integrity of canister **32** to absorb a pressure front (shock wave) or reflected pressure front.

[0110] While the invention has been described with a certain degree of particularity, it is manifest that many changes may be made in the details of construction without departing from the spirit and scope of this disclosure. It is understood that the invention is not limited to the embodiment set forth herein for purposes of exemplification, but is to be limited only by the scope of the attached claim or claims, including the full range of equivalency to which each element thereof is entitled.

What is claimed:

1. A detonation flame arrestor canister supported within an external housing, comprising:

- an inner cylinder including a first end, a second end, an outer circumference, and an outer diameter;
- said first end of said inner cylinder is supported from said external housing;
- an outer cylinder including a first end, a second end, an outer circumference, and an inner diameter;
- said inner diameter of said outer cylinder being larger than said outer diameter of said inner cylinder such that a space is formed between said inner cylinder and said outer cylinder when said outer cylinder is placed over said inner cylinder;
- said first end of said outer cylinder is supported from the external housing;
- at least a portion of said outer circumference of said outer cylinder being defined by a transition point/attenuation matrix;
- at least a portion of said outer circumference of said inner cylinder being perforated to allow a gas to pass through said perforated portion;
- a torturous path media disposed in said space between said inner cylinder and said outer cylinder.

2. The canister of claim **1** wherein said transition point/attenuation matrix of said outer cylinder is wedge shaped wire.

3. The canister of claim **2** wherein said transition point/attenuation matrix of said outer cylinder is helical wedge shaped wire.

4. The canister of claim **2** wherein said transition point/attenuation matrix of said outer cylinder is parallel wedge shaped wire.

5. The canister of claim **1** wherein said transition point/attenuation matrix of said outer cylinder is ring wire.

6. The canister of claim **5** wherein said transition point/attenuation matrix of said outer cylinder is helical ring wire.

7. The canister of claim **5** wherein said transition point/attenuation matrix of said outer cylinder is parallel ring wire.

8. The canister of claim **1** wherein said perforated portion of said inner cylinder is defined by a transition point/attenuation matrix.

9. The canister of claim **8** wherein said transition point/attenuation matrix of said inner cylinder is wedge shaped wire.

10. The canister of claim **9** wherein said transition point/attenuation matrix of said inner cylinder is helical wedge shaped wire.

11. The canister of claim **9** wherein said transition point/attenuation matrix of said inner cylinder is parallel wedge shaped wire.

12. The canister of claim **8** wherein said transition point/attenuation matrix of said inner cylinder is ring wire.

13. The canister of claim **12** wherein said transition point/attenuation matrix of said inner cylinder is helical ring wire.

14. The canister of claim **12** wherein said transition point/attenuation matrix of said inner cylinder is parallel ring wire.

15. The canister of claim **1** used in association with a gas having a known MESG wherein said transition point/attenuation matrix of said outer cylinder is comprised of coiled adjacent windings of wedge or ring wire such that the gap between said coiled adjacent windings of wedge wire is sized so as to increase velocity and decrease pressure of the shock wave in association with the known MESG of said gas.

16. The canister of claim **1** wherein said torturous path media is rolled expanded metal.

17. The canister of claim **1** wherein said torturous path media is a plurality of stacked cones.

18. The canister of claim **1** wherein said torturous path media is tightly and fully filling said space between said inner cylinder and said outer cylinder.

19. A detonation flame arrestor canister supported within an external housing, comprising:

a canister flange supported within the external housing;

an inner cylinder including a first end, a second end, an outer circumference, and an outer diameter;

said first end of said inner cylinder is supported from said canister flange;

said second end of said canister flange is sealed;

an outer cylinder including a first end, a second end, an outer circumference, and an inner diameter;

said inner diameter of said outer cylinder being larger than said outer diameter of said inner cylinder such that a space is formed between said inner cylinder and said outer cylinder when said outer cylinder is placed over said inner cylinder;

said first end of said outer cylinder is supported from said canister flange;

at least a portion of said outer circumference of said outer cylinder being defined by a helical wedge shaped wire screen;

at least a portion of said outer circumference of said inner cylinder being defined by a helical wedge shaped wire screen;

a rolled expanded metal or stacked cone media contained in said space formed between said inner cylinder and said outer cylinder.

20. The canister of claim **19** used in association with gas having a known MESG wherein said helical wedge shaped wire screen of at least said outer cylinder is comprised of coiled adjacent windings of wedge shaped wire such that the gap between said coiled adjacent windings of wedge shaped wire is sized so as to coincide with said known MESG.

21. A detonation flame arrestor, comprising:

an external housing;

said external housing including an inlet and an outlet each having concentric longitudinal axes;

a canister supported in said external housing, said canister comprising:

a) an inner cylinder including an outer circumference and an outer diameter;

b) said inner cylinder supported from said external housing;

c) an outer cylinder including an outer circumference and an inner diameter;

d) said inner diameter of said outer cylinder being larger than said outer diameter of said inner cylinder such that a space is formed between said inner cylinder and said outer cylinder when said outer cylinder is placed over said inner cylinder;

e) said outer cylinder supported from the external housing;

f) at least a portion of said outer circumference of said outer cylinder being defined by a transition point/attenuation matrix;

g) at least a portion of said outer circumference of said inner cylinder being defined by a transition point/attenuation matrix;

h) a torturous path media disposed in said space between said inner cylinder and said outer cylinder,

wherein said canister includes a longitudinal axis which is offset from said longitudinal axes of said inlet and said outlet of said external housing.

22. The detonation flame arrestor of claim **21** wherein said longitudinal axis of said canister is transverse to said longitudinal axes of said inlet and said outlet of said external housing.

23. The detonation flame arrestor of claim **22** wherein said external housing includes at least one removable port to access said canister.

24. The detonation flame arrestor of claim **23** wherein said canister includes a top end and a bottom end and said external housing includes an access port adjacent said top end and said bottom end of said canister.

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