

FLOW CONDITIONER AND METHOD OF DESIGNING SAME

This PCT International application claims priority to U.S. Serial No. 61/825,559, filed on 21 May 2013 in the U.S. Patent and Trademark Office, the entirety of which is
5 incorporated herein by reference.

I. Technical Field

The present invention relates to fluid flow measurement components used in oil and
10 gas pipelines. More particularly, the present invention relates to a flow conditioner and to methods of designing flow conditioners.

II. Background of the Invention

15 Pipelines are used to transport fluids in various industries, including chemical, oil and gas, and manufacturing. These industries use processes that require fluid flow rates to be accurately measured. These measurements are performed at locations known as meter stations using a variety of different meter types. These meters
function in different ways, they can use: differential pressure of the fluid across an
20 obstruction, ultrasonic signal travel times, turbine blade rotational speed, *Coriolis* forces, or even electrical and magnetic fields being generated due to bulk fluid movement. Almost all of these measurement methods require use of the fluid velocity distribution, known as a velocity flow profile.

25 To achieve the most accurate measurements, the flow profile of the fluid entering a metering device must be stable, non-rotating, and symmetric. This type of velocity distribution is known as a fully developed flow profile, and it forms naturally in very long lengths of uninterrupted straight pipe. However, having long lengths of straight pipe is impractical and cost prohibitive. As a result, meter station piping often
30 contains elbows, tees, valves and other assemblies that change the flow profile into an asymmetric, unstable, and distorted configuration. This makes it very difficult to measure the fluid flow rate in a consistently accurate and repeatable manner. Under these conditions, flow conditioners are needed to correct the flow profile of the fluid

such that it forms a fully developed flow profile, which allows accurate, repeatable measurements to be made.

Several types of flow conditioners exist, including straightening vanes, tube bundles,
5 and perforated plates. These flow conditioners are placed within the pipe upstream of the flow meter. A typical perforated plate flow conditioner consists of a perforated metal plate that is arranged within a pipe orthogonal to the fluid flow, i.e., across the entire cross section of pipe. The perforations or holes in the flow conditioner cause the fluid flow to be redistributed such that it forms a fully developed flow profile. The
10 placement of a flow conditioner upstream of the flow meter ensures that the flow is fully developed before it reaches the meter. This allows the meter to perform significantly more accurate and repeatable fluid flow measurements.

However, there remains a need to design flow conditioners based on the fluid
15 dynamics of a particular pipe installation.

III. Summary of the Invention

The invention provides in a first embodiment a flow conditioner characterized by a
20 single disk having a first side and a second side; a central hole that opens on a first side of the disk; at least one inner ring comprising a concentric ring of a plurality of holes, wherein the holes define fluid passages from the at least one inner ring to the first side of said disk; and an outer ring comprising a concentric ring of a plurality of holes, wherein the holes define fluid passages from the outer ring to the first side of
25 said disk. A diameter of the central hole is greater than the diameters of the plurality of holes of the at least one inner ring, and the diameters of the plurality of holes of the at least one inner ring are greater than the diameters of the plurality of holes of the outer ring. The central hole defines a fluid passage having a length which is less than the length of the fluid passages of the plurality of holes of the at least one inner
30 ring, and the length of the fluid passages of the plurality of holes of the at least one inner ring is less than the length of the fluid passages of the outer ring.

The invention provides in a second embodiment to any of the previous embodiments a flow conditioner characterized in that the central hole is recessed from said at least one inner ring.

- 5 The invention provides in a third embodiment to any of the previous embodiments a flow conditioner characterized in that the at least one inner ring comprises two or more stepped, recessed concentric rings, each concentric ring comprising a plurality of holes.
- 10 The invention provides in a fourth embodiment to any of the previous embodiments a flow conditioner further characterized by a flange connection on the first side of said disk.

- The invention provides in a fifth embodiment to any of the previous embodiments a
- 15 flow conditioner further characterized by a flange connection on the second side of said disk.

- The invention provides a method of designing a flow conditioner in a first method embodiment characterized by determining fluid dynamics of a pipe into which a flow
- 20 conditioner according to any of the previous embodiments is to be installed; and calculating a configuration for a plurality of holes of the flow conditioner according to any of the previous embodiments.

- The invention provides a method of designing a flow conditioner in a second method
- 25 embodiment to any of the previous method embodiments characterized in that a length of a fluid passage defined by each hole (x) is a function of the radius (r) from a center of the pipe.

- The invention provides a method of designing a flow conditioner in a third method
- 30 embodiment to any of the previous method embodiments characterized in that a length of a fluid passage is calculated by the following formula: $D=C*\tan^{-1}(VT/Vx)$

wherein D is the depth of the flow conditioner holes, V_T is the tangential velocity of a fluid in the pipe, V_x is the axial velocity of the fluid in the pipe, and C is a coefficient that corrects for fluid viscosity, density, wall roughness and the swirl reduction factor.

- 5 The invention provides a pipe assembly for flow measurement characterized by a fluid flow pipe; a flow conditioner according to any of the previous embodiments disposed within the fluid flow pipe in an orientation substantially perpendicular to an axis of the fluid flow pipe.
- 10 The invention further provides a fluid flow measurement system including a fluid flow pipe; a flow conditioner according to any of the previous embodiments disposed within the fluid flow pipe in an orientation substantially perpendicular to an axis of the fluid flow pipe; and a flow meter.
- 15 As used herein "substantially", "relatively", "generally", "about", and "approximately" are relative modifiers intended to indicate permissible variation from the characteristic so modified. They are not intended to be limited to the absolute value or characteristic, which it modifies but rather approaching or approximating such a physical or functional characteristic.

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In the detailed description, references to "one embodiment", "an embodiment", or "in embodiments" mean that the feature being referred to is included in at least one embodiment of the invention. Moreover, separate references to "one embodiment", "an embodiment", or "in embodiments" do not necessarily refer to the same
25 embodiment; however, neither are such embodiments mutually exclusive, unless so stated, and except as will be readily apparent to those skilled in the art. Thus, the invention can include any variety of combinations and/or integrations of the embodiments described herein.

30 IV. Brief Description of the Drawings

FIG. 1 illustrates a perspective view of a second side of a flow conditioner according to a first embodiment of the present invention.

FIG. 2 illustrates a perspective view of a first side of the flow conditioner of FIG. 1.

FIG. 3 illustrates a perspective view of a second side of a flow conditioner according
5 to a second embodiment of the present invention.

FIG. 4 illustrates a perspective view of a first side of the flow conditioner of FIG. 3.

FIG. 5 illustrates a perspective view of a first side of a flow conditioner according to a
10 third embodiment of the present invention. FIG. 5a is a cut-away view of a flow
conditioner as in FIG. 5, but having an outer ring and an inner ring on both sides of
the flow conditioner.

FIG. 6 illustrates a perspective view of a second side of the flow conditioner of FIG.
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FIG. 7 illustrates a perspective view of a first side of a flow conditioner according to a
fourth embodiment of the present invention.

FIG. 8 illustrates a perspective view of a second side of the flow conditioner of FIG.
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FIG. 9 illustrates a perspective view of a first side of a flow conditioner according to a
fifth embodiment of the present invention. FIG. 9a is a cut-away view of the flow
25 conditioner of FIG. 9.

FIG. 10 illustrates a perspective view of a second side of the flow conditioner of FIG.
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FIG. 11 illustrates a perspective view of a second side of a flow conditioner
30 according to a sixth embodiment of the present invention. FIG. 11a is a cut-away
view of the flow conditioner of FIG. 11.

FIG. 12 illustrates a perspective view of a first side of the flow conditioner of FIG. 11.

FIG. 13 is a graph showing sound level for a flow conditioners of one embodiment of the present invention and a known flow conditioner.

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Given the following enabling description of the drawings, the methods and systems should become evident to a person of ordinary skill in the art.

V. Detailed Description of the Invention

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According to the present invention, a flow conditioner comprises a single disk having a plurality of perforations or holes that are machined out of the same material as the disk itself. A configuration of the perforations or holes may be selected depending on the computational fluid dynamics of a pipe into which a flow conditioner is to be installed.

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In specific embodiments, the configuration of perforations or holes may be in the form of at least one, for example a plurality of, concentric rings of holes. Concentric rings of holes may be in a stepped or recessed configuration, thereby defining fluid passages of unequal length from one side of the flow conditioner to an opposite side of the flow conditioner. Stepped or recessed concentric rings of holes may occur on an upstream side, a downstream side, or on both sides of the flow conditioner. In embodiments, the shape of the holes may be circular. However, different and/or multiple hole patterns or shapes may be used as long as the holes are radially symmetric.

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An optional flange connection may surround the flow conditioner or may be flush with a first end or second end (e.g., an upstream end/face or a downstream end/face) of the flow conditioner. In a specific embodiment, a flange connection may be integral with a concentric ring of a plurality of holes.

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According to the present invention, a flow conditioner may comprise a single disk having a first side and a second side. A central hole opens on a first side of the disk.

At least one inner ring comprises a concentric ring of a plurality of holes, wherein the holes define fluid passages from the at least one inner ring to the first side of the disk. An outer ring comprises concentric ring of a plurality of holes, wherein the holes define fluid passages from the outer ring to the first side of the disk.

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A diameter of the central hole may be greater than the diameters of the plurality of holes of the at least one inner ring, and the diameters of the plurality of holes of the at least one inner ring may be greater than the diameters of the plurality of holes of the outer ring.

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The central hole defines a fluid passage having a length which may be less than the length of the fluid passages of the plurality of holes of the at least one inner ring, and the length of the fluid passages of the plurality of holes of the at least one inner ring may be less than the length of the fluid passages of the outer ring.

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According to a first embodiment, FIG. 1 illustrates a perspective view of a second side of a flow conditioner 10 comprising a disk 11 having a first side and a second side. Flow conditioner 10 comprises 1) a flange 15 on the first side of the disk; 2) an outer ring 17 comprising a concentric ring of a plurality of holes 20 defining fluid passages from the outer ring to the first side of the disk; 3) at least one inner ring 22 recessed or stepped from the outer ring 17 and comprising a concentric ring of a plurality of holes 25 defining fluid passages from the at least one inner ring 22 to the first side of the disk; and 4) a central hole 27 recessed or stepped from the inner ring of holes 25 and opening on the first side of the disk.

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The plurality of holes 20 in the outer ring 17 and the plurality of holes 25 in the at least one inner ring 22 provide fluid passages of unequal length from a second side of the flow conditioner to a first side of the flow conditioner and vice versa. FIG. 2 illustrates a perspective view of the first side of the flow conditioner of FIG. 1.

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As illustrated, the outer ring and at least one inner ring may comprise concentric rings of circular holes. In specific embodiments, the at least one inner ring may

comprise a plurality or series of stepped, recessed concentric rings, each ring comprising a plurality of holes.

According to a second embodiment, FIG. 3 illustrates a perspective view of a second
5 side of a flow conditioner 30 comprising a disk 31 having a first side and a second side. Flow conditioner 30 comprises 1) a flange 35 on a first side of the disk; 2) an outer ring 37 comprising a concentric ring of plurality of holes 40 defining fluid passages from the outer ring to the first side of the disk; 3) an inner ring 42 recessed or stepped from the outer ring 37 and comprising a concentric ring of a plurality of
10 holes 45 defining fluid passages from the inner ring 42 to the first side of the disk; and 4) a central hole 50 within the inner ring 42 opening on the first side of the disk. FIG. 4 illustrates a perspective view of the first side of the flow conditioner of FIG. 3.

According to a third embodiment, FIG. 5 illustrates a perspective view of a first side
15 of a flow conditioner 55 comprising a disk 56 having a first side and a second side. Flow conditioner 55 comprises 1) a flange 60 on a first side of the disk; 2) an outer ring 62 comprising a concentric ring of a plurality of holes 65 on the first side of the disk, wherein the outer holes 65 define fluid passages from the outer ring to the second side of the disk; 3) an inner ring 67 comprising a concentric ring of a plurality
20 of holes 70 recessed or stepped from the outer ring 62, wherein the inner holes 70 define fluid passages from the inner ring to the second side of the disk; and 4) a central hole 75 recessed or stepped from the inner ring 67 and opening on the second side of the disk.

FIG. 5a is a cut-away view of a flow conditioner as in FIG. 5, but having an outer ring and an inner ring on both sides of the flow conditioner. The plurality of holes 65 in the outer ring and the plurality of holes 70 in the inner ring provide fluid passages of unequal length from a first side of the flow conditioner through to a second side of the flow conditioner.

FIG. 6 illustrates a perspective view of a second side of the flow conditioner of FIG. 5.

According to a fourth embodiment, FIG. 7 illustrates a perspective view of a first side of a flow conditioner 80 comprising a disk 81 with a first side and a second side.

Flow conditioner 80 comprises 1) a flange 85 on a first side; 2) a series of stepped, recessed concentric rings 90 on the first side of the disk, wherein each concentric ring comprises a plurality of holes 95 defining fluid passages from the respective ring to the second side of the disk; and 3) a recessed central hole 100 opens on the second side of the disk. FIG. 8 illustrates a perspective view of a second side of the flow conditioner of FIG. 7.

According to a fifth embodiment, FIG. 9 illustrates a perspective view of a first side of a flow conditioner 105 comprising a disk 106 having a first side and a second side. Flow conditioner 105 comprises 1) a flange 110 on a first side of the disk; 2) an outer, first concentric ring 112 extending from a second side of the disk and comprising a plurality of holes 115 defining fluid passages to the second side of the disk, wherein said outer, first concentric ring 112 is recessed from the flange 110; 3) at least one inner concentric ring, for example, a series of stepped concentric rings 120, each ring extending upwards from the outer, first ring 112 and comprising a plurality of holes 125 defining fluid passages to the second side of the disk; and 4) a central hole 130 extending upward from the last of said series of stepped rings 120 and opening on the second side of the disk.

FIG. 9a is a cut-away view of the flow conditioner of FIG. 9. The plurality of holes 115 in the outer, first concentric ring 112 and the plurality of holes 125 in the inner concentric rings 120 provide fluid passages of unequal length from the first side of the flow conditioner to the second side of the flow conditioner. FIG. 10 illustrates a perspective view of the second side of the flow conditioner of FIG. 9.

According to a sixth embodiment, FIG. 11 illustrates a perspective view of a second side of a flow conditioner 135 comprising a disk having a first side and a second side. Flow conditioner 135 comprises 1) a flange 140 on a first side; 2) a series of stepped concentric rings 145, each concentric ring extending upwards from the first side and comprising a plurality of holes 150 defining fluid passages to the first side;

and 3) a central hole 155 extending upward from the last of said series of stepped concentric rings 145 and opening on the first side.

FIG. 11a is a cut-away view of the flow conditioner of FIG. 11. The plurality of holes 150 in each of said series of stepped rings 145 provide fluid passages of unequal length from the first side of the flow conditioner to the second side of the flow conditioner. FIG. 12 illustrates a perspective view of the second side of the flow conditioner of FIG. 11.

- 10 According to the present invention, a method for designing a flow conditioner is provided. The configuration of the holes in a flow conditioner may be selected depending on the experimental or theoretical testing of the fluid dynamics of a pipe into which the flow conditioner is to be installed.
- 15 In specific embodiments, a length of the fluid passages defined by the holes may be calculated based on at least one of fluid profile distortion or fluid swirl intensity (e.g., swirl at the pipe walls). In specific embodiments, the length of a fluid passage defined by each hole (x) may be a function of the radius (r) from a center of a pipe in which the flow conditioner is to be installed. The length may be calculated by the
- 20 following formula (1):

$$D = C \cdot \tan^{-1}(V_T/V_x) \quad (1)$$

- Wherein D is the depth of the flow conditioner holes, V_T is the tangential velocity of fluid in the pipe (i.e., the swirl vector), V_x is the axial velocity of fluid in the pipe (i.e., velocity in a longitudinal direction of the pipe) and C is a coefficient that corrects for the fluid viscosity, density, wall roughness and the swirl reduction factor. C may be experimentally determined from testing results of computational solutions. In specific embodiments, C may be determined through experimental and/or theoretical testing
- 30 where flow conditioner modifications or revisions are subjected to a range of fluid applications and a set amount of upstream swirl. The reduction in swirl is measured and associated with the fluid dynamic properties: fluid viscosity, density and wall

roughness, factors that influence the flow conditioner pressure drop and fluid ability to resist swirl.

Depending on the number of holes in a flow conditioner a calculation using the
5 above formula (1) may be done at a bolt circle distance (e.g., diameter of an outer or inner ring from a center axis of the pipe from which all holes are cut) from the center of the pipe for each ring hole. Thus, more ring holes may give higher resolution of the fluid swirl, and more discrete calculations.

10 The following is a non-limiting example.

EXAMPLE

The Example is taken in fluid scenario with about 25 degrees of swirl in the inlet.

15 The fluid has: a Reynolds number is 24,854,836; a Density of 36.54 kg/m^3 ; and a viscosity of $1.12 \times 10^{-5} \text{ Pa}\cdot\text{S}$ at 300K.

At a pipe inlet in which a flow conditioner is to be installed, V_x is measured as 24.083 m/s, V_T is measured as 10.017 m/s at a radius of 4.728 inches (12.0 cm) from the
20 center of the pipe having a radius of 5.969 inches (15.16 cm). This calculates to approximately 22.584 degrees of swirl. C is determined to be 10.5979. This computes to a flow conditioner thickness of 3.7595 inches (9.55 cm) to give a swirl reduction of 90%. D is the length of the holes/thickness of the plate through which the holes are drilled, which in this example is for the outer ring.

25 Suitable flow conditioners with which to incorporate the configuration or holes of the present invention may include, but are not limited to, CPA TBR and CPA 50E flow conditioners available from Canada Pipeline Accessories of Calgary, Alberta Canada; and the flow conditioners described in U.S. Patent No. 5,341,848.

30 FIG. 13 is a graph showing sound level for a flow conditioner of FIG. 5 (CPA 55E and CPA 65E) and a known flow conditioner (CPA 50E). At a flow velocity of 120

feet/s (36.6 m/s), there is a 30 dB reduction in sound or noise level with a flow conditioner of the present invention.

In specific embodiments, the flow conditioner may be sized to pipe inside diameter D (0.85D – 0.99D). In specific embodiments, the flow conditioner thickness may be about 0.05D – 0.35D. In specific embodiments, an outer ring of holes may end at between 0.65D – 0.97D and an inner ring of holes may be between about 0.30D to 0.65D.

Any flow conditioner according to the present invention may be coated or plated with a composition comprising nickel or a nickel-phosphorous alloy. In specific embodiments, the composition may comprise between 1% and 12% phosphorus and between 87% and 99% nickel by weight. The thickness of the coating or plating may be between about 1 and about 250 microns, for example, between about 10 and about 50 microns.

The flow conditioner according to the present invention may be utilized in existing piping without making modifications. In specific embodiments, the flow conditioner may have a flanged connection, which is frequently available in meter stations.

Thus, it is very simple and extremely compatible with meter station layouts.

VI. Industrial Applicability

Although the present invention has been described in terms of particular exemplary and alternative embodiments, it is not limited to those embodiments. Alternative embodiments, examples, and modifications which would still be encompassed by the invention may be made by those skilled in the art, particularly in light of the foregoing teachings.

Those skilled in the art will appreciate that various adaptations and modifications of the exemplary and alternative embodiments described above can be configured without departing from the scope and spirit of the invention. Therefore, it is to be

understood that, within the scope of the appended claims, the invention may be practiced other than as specifically described herein.

IN THE CLAIMS:

1. A flow conditioner, characterized by:
 - a single disk having a first side and a second side;
 - a central hole that opens on a first side of the disk;
 - at least one inner ring comprising a concentric ring of a plurality of holes,wherein the holes define fluid passages from the at least one inner ring to the first side of said disk; and
 - an outer ring comprising a concentric ring of a plurality of holes, wherein the holes define fluid passages from the outer ring to the first side of said disk;
 - wherein 1) a diameter of the central hole is greater than the diameters of the plurality of holes of the at least one inner ring, and 2) the diameters of the plurality of holes of the at least one inner ring are greater than the diameters of the plurality of holes of the outer ring, and
 - wherein 1) the central hole defines a fluid passage having a length which is less than the length of the fluid passages of the plurality of holes of the at least one inner ring, and 2) the length of the fluid passages of the plurality of holes of the at least one inner ring is less than the length of the fluid passages of the outer ring.
2. A flow conditioner according to Claim 1, characterized in that the plurality of holes of the outer ring and on the plurality of holes of the at least one inner ring each comprise circular holes.
3. A flow conditioner according to Claim 1, characterized in that the central hole is recessed from said at least one inner ring.
4. A flow conditioner according to Claim 1, characterized in that the at least one inner ring comprises two or more stepped, recessed concentric rings, each concentric ring comprising a plurality of holes.
5. A flow conditioner according to any one of Claims 1-4, further characterized by a flange connection on the first side of said disk.

6. A flow conditioner according to any one of Claims 1-4, further characterized by a flange connection on the second side of said disk.

7. A flow conditioner according to any one of Claims 1-4, further characterized by a coating or plating composition comprising nickel or a nickel-phosphorous alloy.

8. A flow conditioner according to any one of Claims 1-4, further characterized by an outer ring and at least one inner ring on both sides of the flow conditioner.

9. A method of designing a flow conditioner, characterized by:
determining fluid dynamics of a pipe into which a flow conditioner is to be installed; and

calculating a configuration for a plurality of holes of the at least one inner ring and the outer ring of a flow conditioner according to any one of Claims 1-4.

10. A method of designing according to Claim 9, characterized in that a length of a fluid passage defined by each hole (x) is a function of the radius (r) from a center of the pipe.

11. A method according to Claim 9, characterized in that the length of a fluid passage is calculated by the following formula:

$$D = C \cdot \tan^{-1}(V_T/V_x)$$

wherein D is the depth of the flow conditioner holes, V_T is the tangential velocity of a fluid in the pipe, V_x is the axial velocity of the fluid in the pipe, and C is a coefficient that corrects for fluid viscosity, density, wall roughness and the swirl reduction factor.

12. A pipe assembly for flow measurement, characterized by:
a fluid flow pipe;
at least one flow conditioner according to any one of Claims 1-4 disposed within said fluid flow pipe in an orientation substantially perpendicular to an axis of said fluid flow pipe.

13. A pipe assembly according to Claim 12, characterized in that the outer ring and at least one inner ring are on an upstream side of the at least one flow conditioner.

14. A pipe assembly according to Claim 12, characterized in that the outer ring and at least one inner ring are on a downstream side of the at least one flow conditioner.

15. A pipe assembly according to Claim 12, characterized in that an outer ring and at least one inner ring are on both sides of the flow conditioner.

16. A fluid flow measurement system, characterized by:
a fluid flow pipe;
at least one flow conditioner according to any one of Claims 1-4 disposed within said fluid flow pipe in an orientation substantially perpendicular to an axis of said fluid flow pipe; and
a flow meter downstream of the flow conditioner.