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(54) **ULTRASONIC METER**

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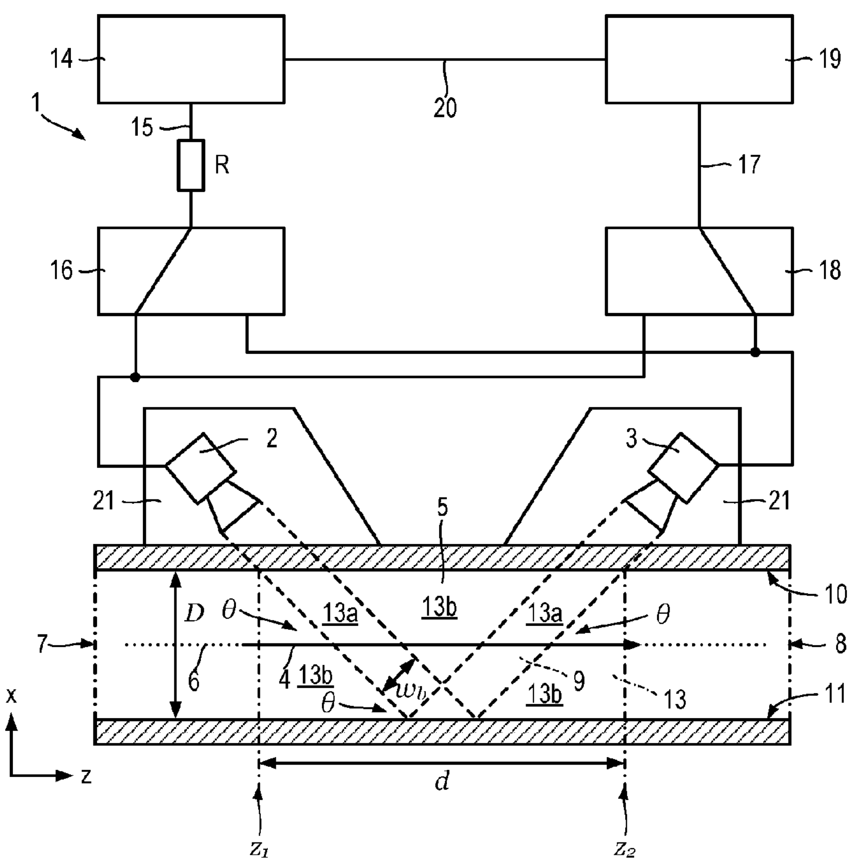
(57) **ABSTRACT**

An ultrasonic meter (**44**) is described for measuring a flow-rate of a fluid, including a flow conduit (**5**) for the fluid. The flow conduit (**5**) extends along a first axis (**6**) between a first opening (**7**) and a second opening (**8**). The ultrasonic meter (**44**) also includes two or more pairs of ultrasonic transducers (**2**, **3**). Each pair of ultrasonic transducers (**2**, **3**) is configured to define a corresponding beam path (**9**) intersecting the flow conduit (**5**) within a measurement region (**13**) of the flow conduit (**5**). Substantially every part of each beam path (**9**) makes a non-zero angle with the first axis (**6**). When viewed projected onto a plane perpendicular to the first axis (**6**), a projection of a first beam path (**91**) intersects (**25**) a projection of a second beam path (**92**). The ultrasonic meter (**44**) also includes a flow deflecting member (**26**) supported between the first opening (**7**) and the measurement region (**13**). When viewed projected onto the plane perpendicular to the first axis (**6**), a projection of the flow deflecting member (**26**) at least partially overlaps the intersection (**25**) of the projections of the first and second beam paths (**91**, **92**).



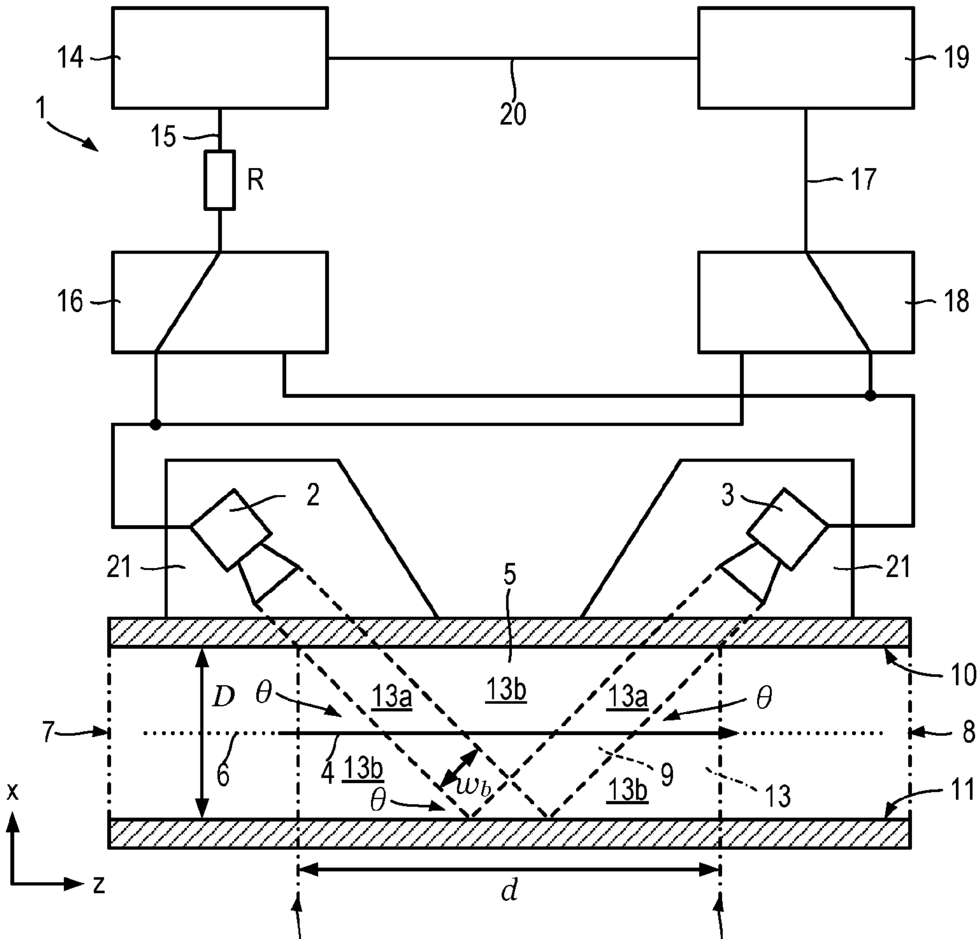

14
19
20
1
15
R
17
16
18
2
3
21
21
5
10
D
θ
13a
13b
13a
θ
7
8
6
4
13b
9
13
11
w_b
θ
13b
x
z
d
z_1
z_2

Fig.1

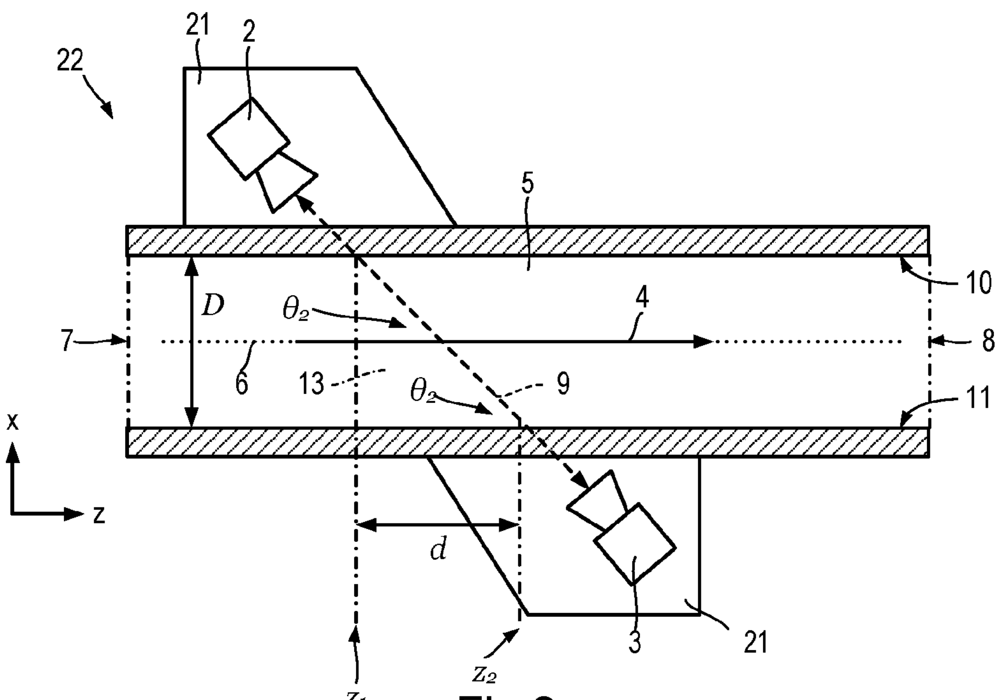

21
2
22
5
10
D
$θ_2$
4
7
8
6
13
$θ_2$
9
11
x
z
d
3
21
z_2
z_1

Fig.2

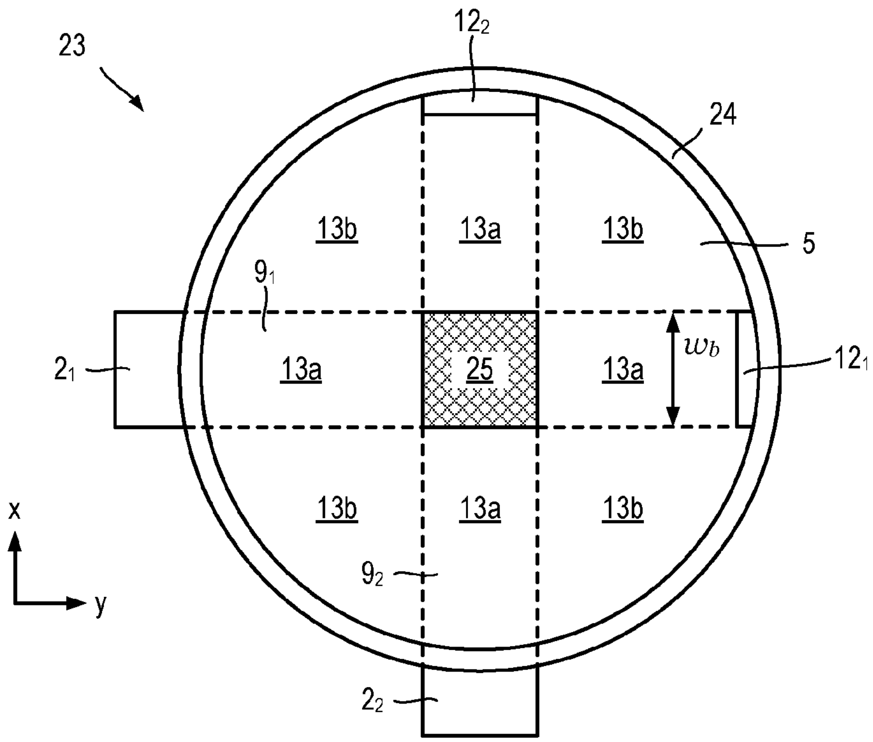

23
12₂
24
13b
13a
13b
5
9₁
2₁
13a
25
13a
w_b
12₁
x
y
13b
13a
13b
9₂
2₂

Fig.3

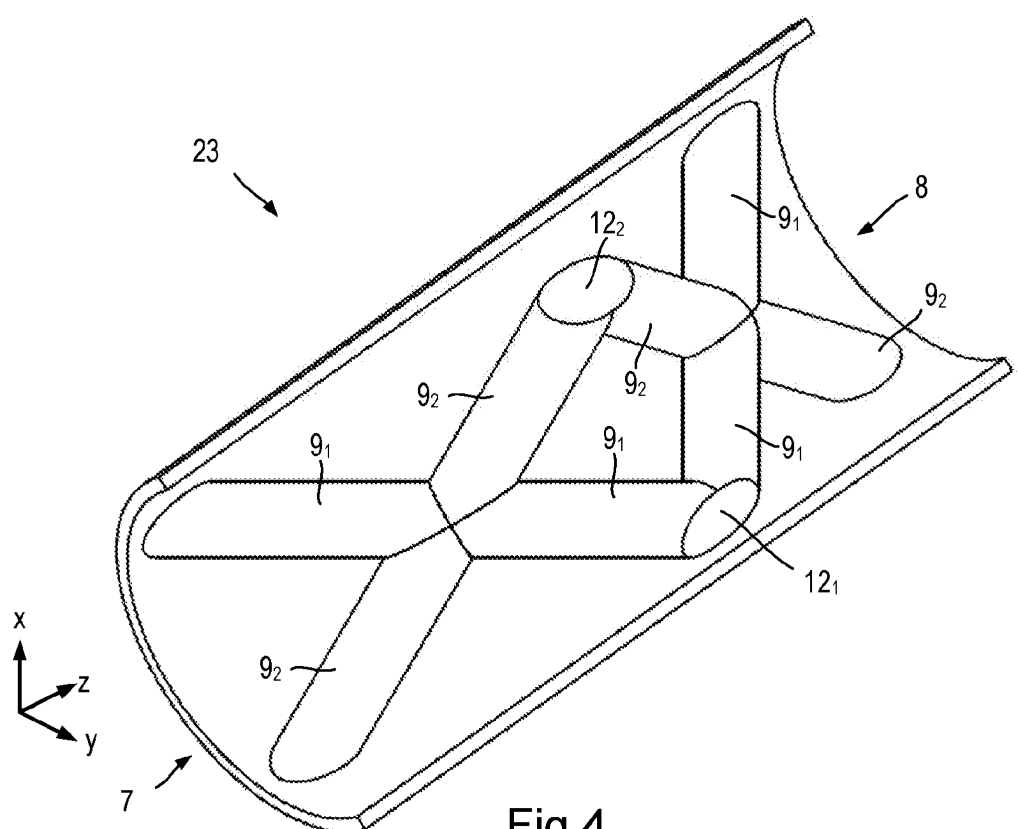

23
8
12₂
9₁
9₂
9₂
9₂
9₁
9₁
9₁
12₁
x
z
y
9₂
7

Fig.4

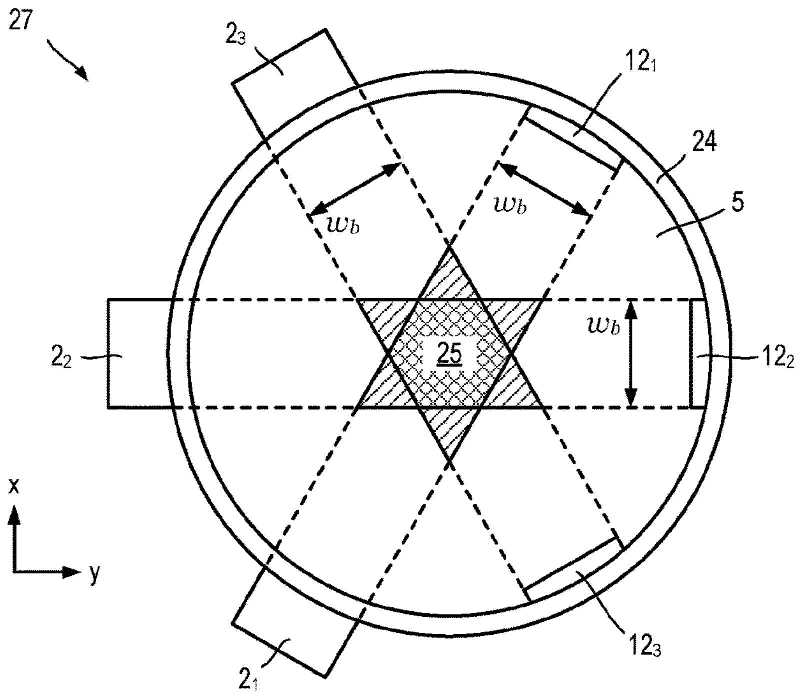

27
2_3
12_1
24
5
w_b
w_b
w_b
25
2_2
12_2
x
y
2_1
12_3

Fig.5

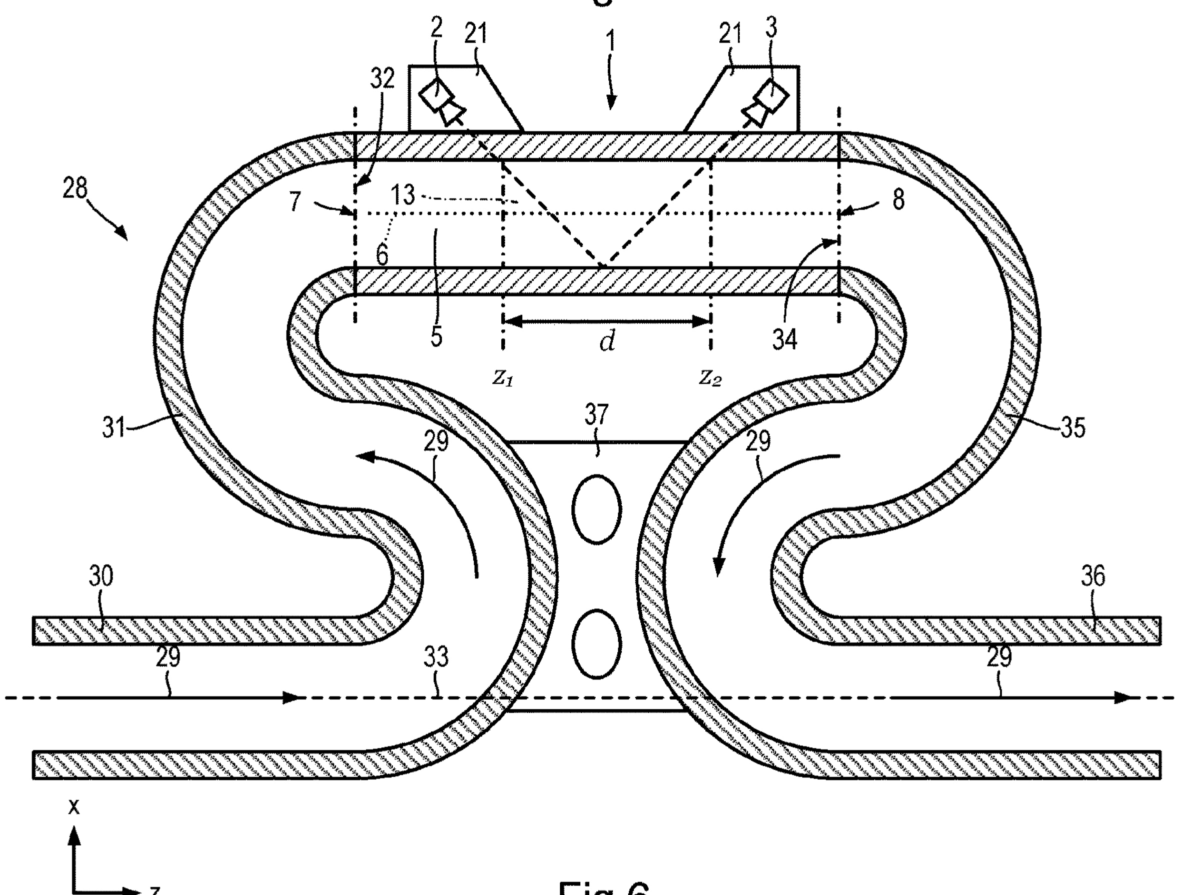

2
21
1
21
3
32
28
7
13
8
6
5
34
d
z_1
z_2
31
37
35
29
29
30
36
29
33
29
x
z

Fig.6

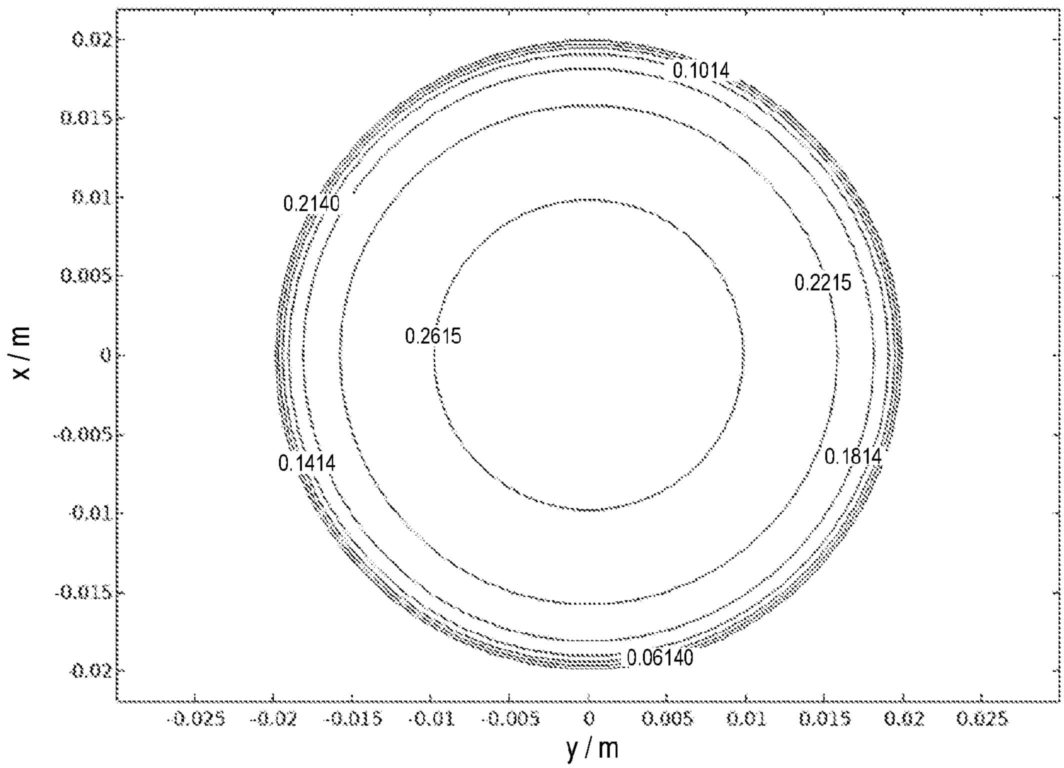

0.1014
0.2140
0.2215
0.2615
0.1414
0.1814
0.06140
x / m
y / m
0.02
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
-0.025
0.025

Fig.7A

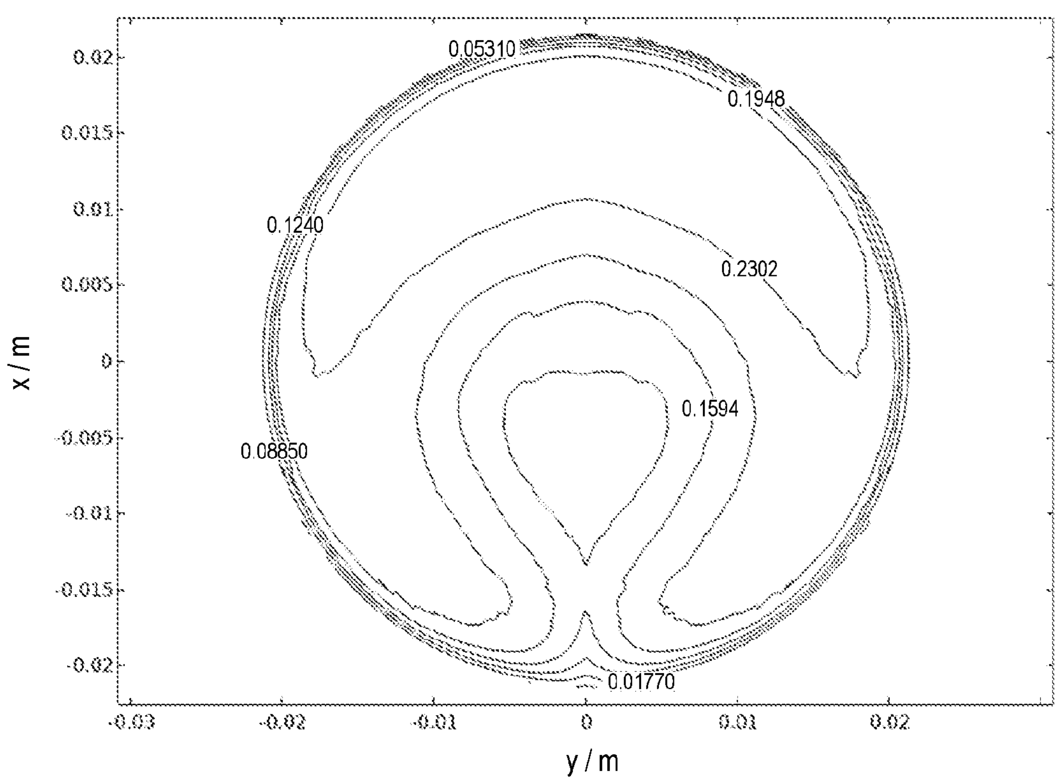

0.05310
0.1948
0.1240
0.2302
0.1594
0.08850
0.01770
x / m
y / m
0.02
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
-0.03

Fig.7B

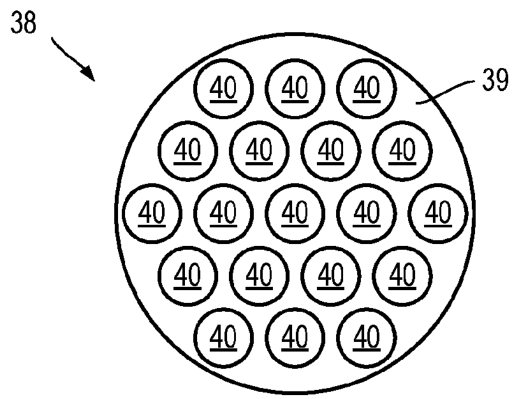


Fig.8A

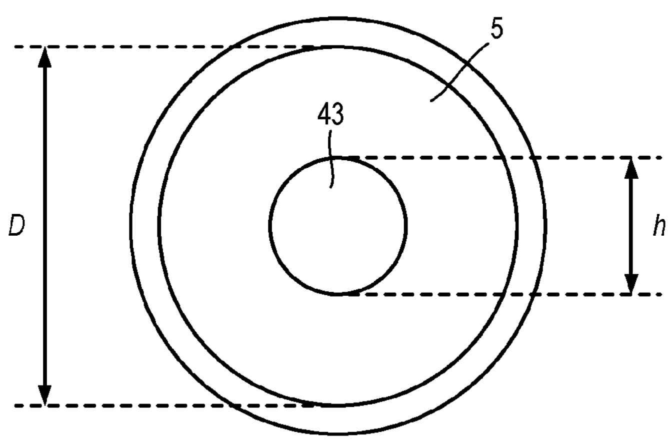


Fig.8B

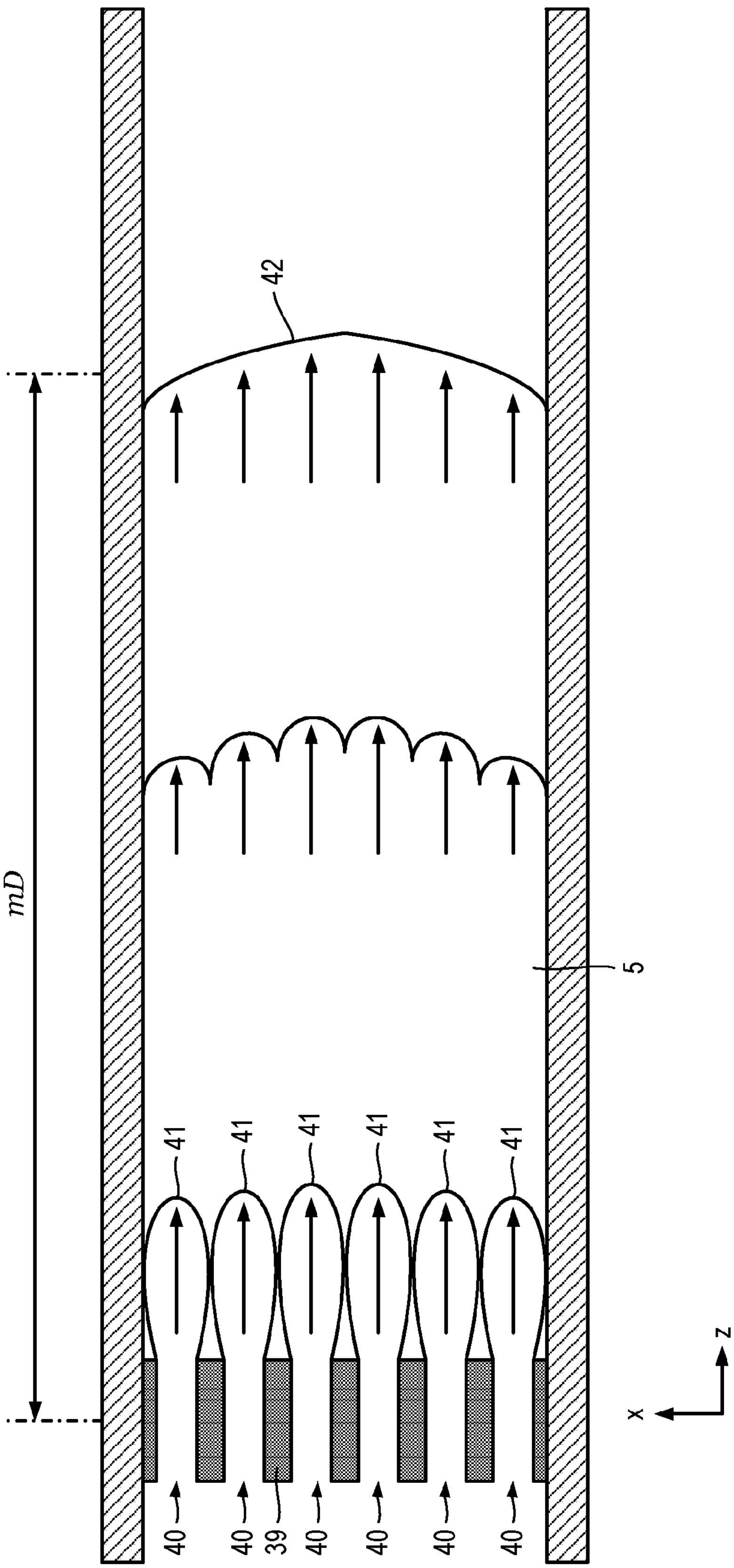


Fig.9

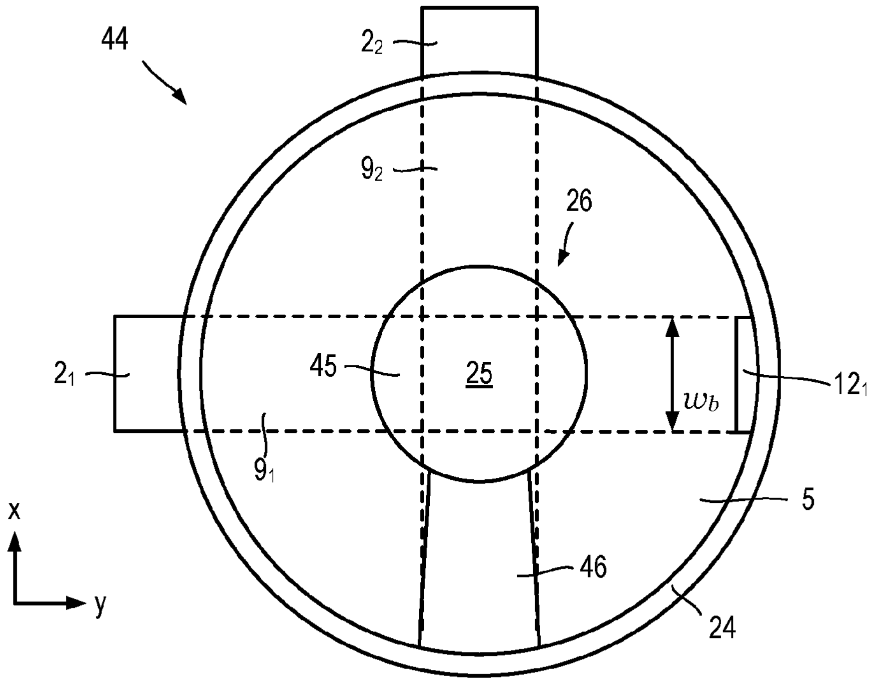

44
2_2
9_2
26
2_1
45
25
w_b
12_1
9_1
5
46
24
x
y

Fig.10

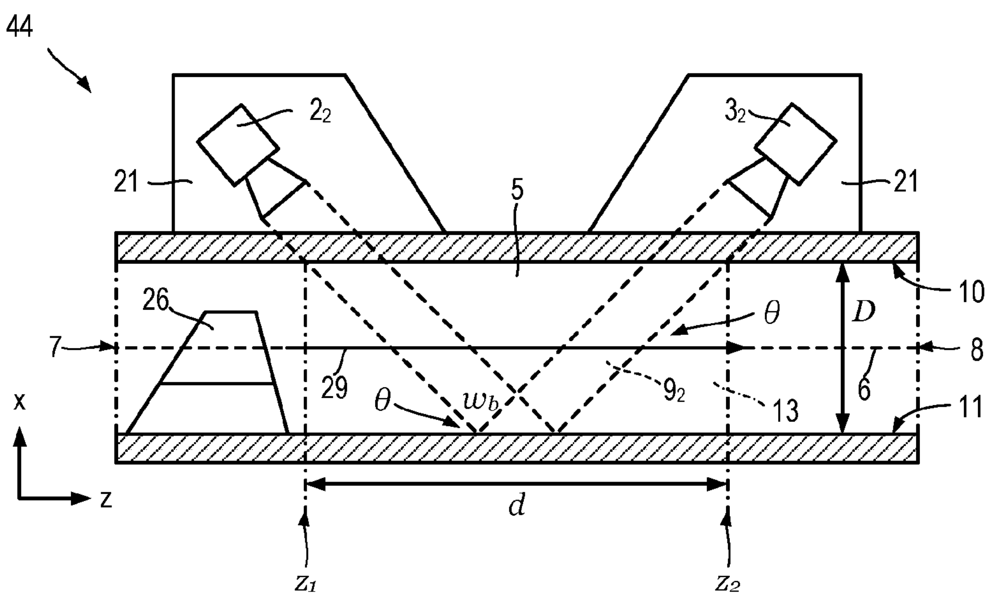

44
2_2
3_2
21
21
5
10
26
θ
D
7
8
29
9_2
6
x
θ
w_b
13
11
z
d
z_1
z_2

Fig.11

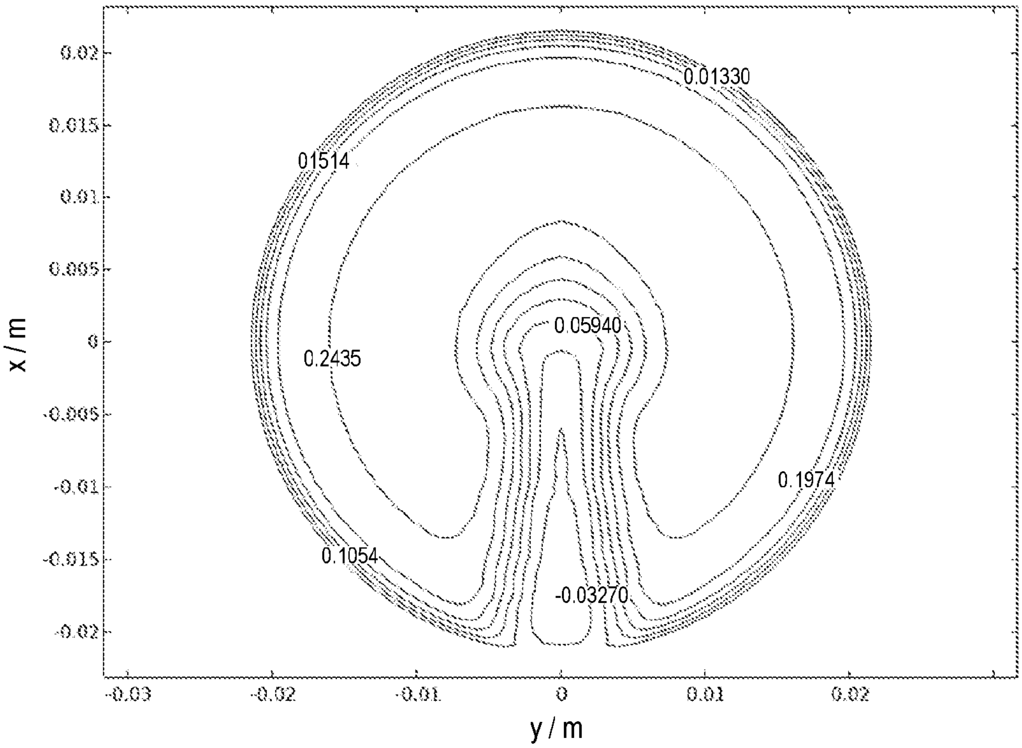


Fig.12A

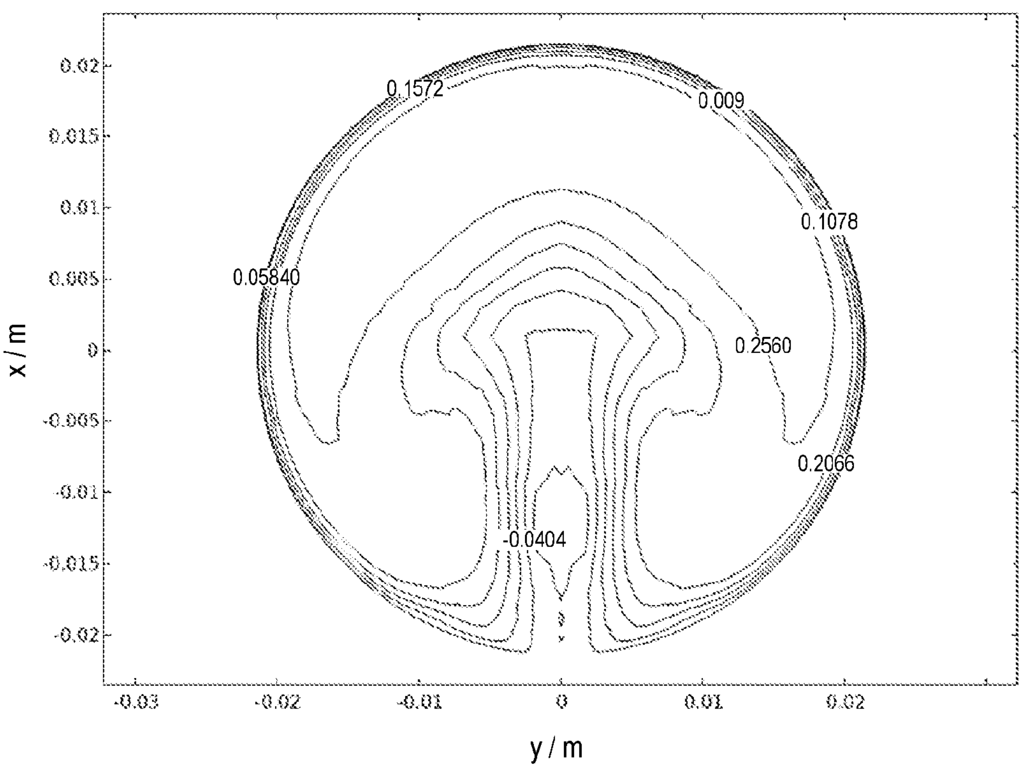


Fig.12B

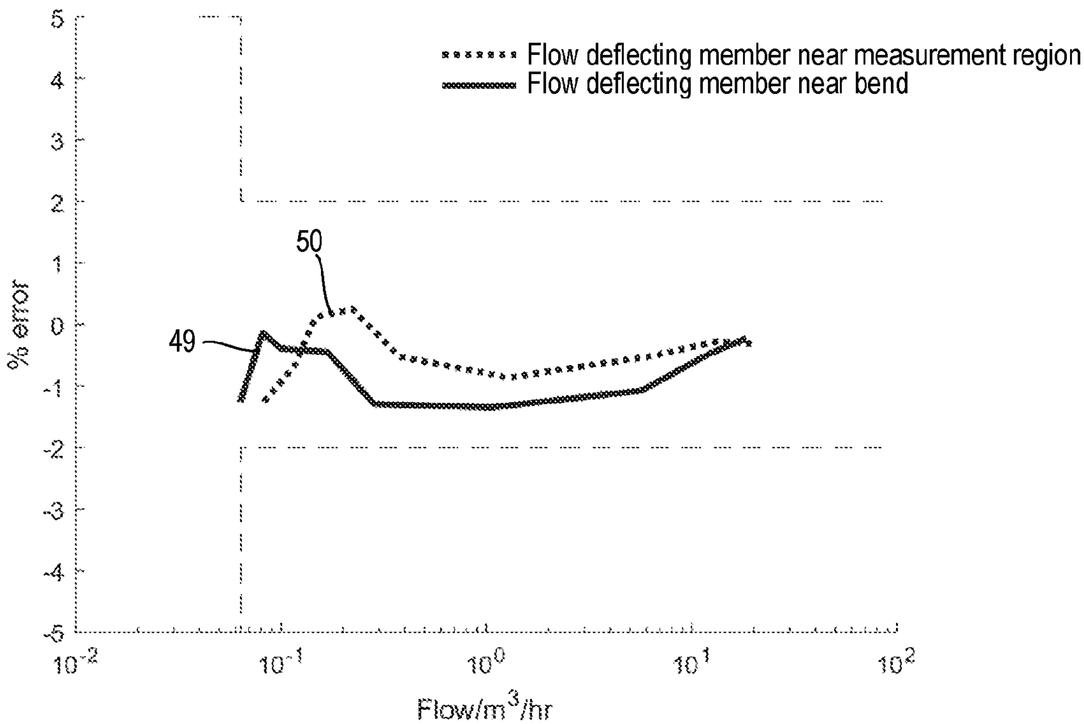

Flow deflecting member near measurement region
Flow deflecting member near bend
50
49
% error
5
4
3
2
1
0
-1
-2
-3
-4
-5
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
Flow/m^3/hr

Fig.13

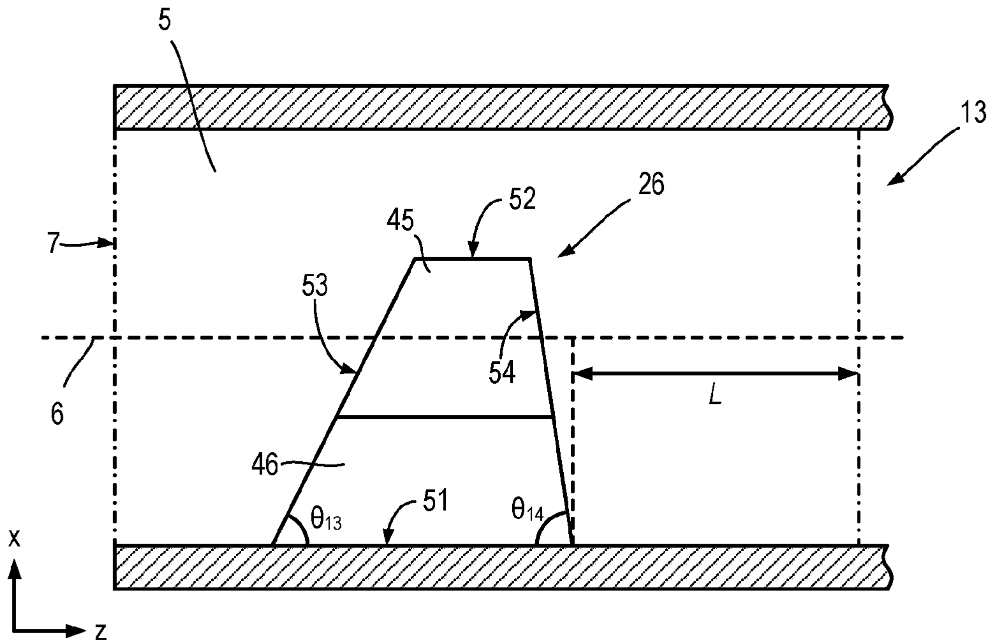


Fig.14

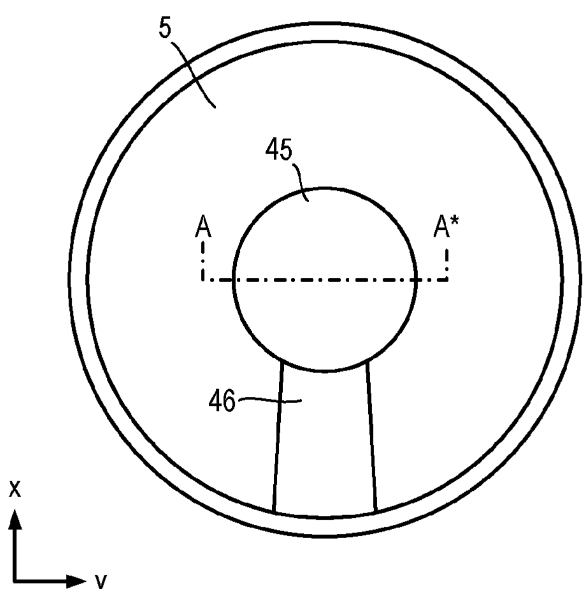


Fig.15A

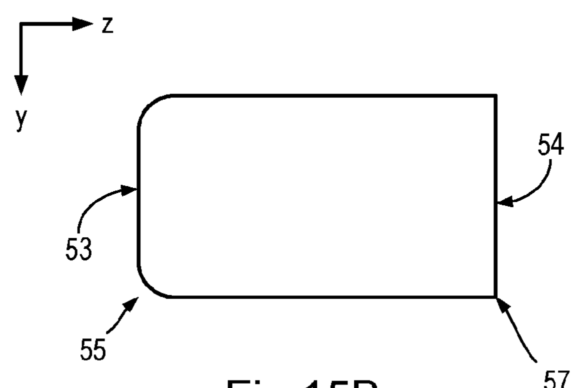


Fig.15B

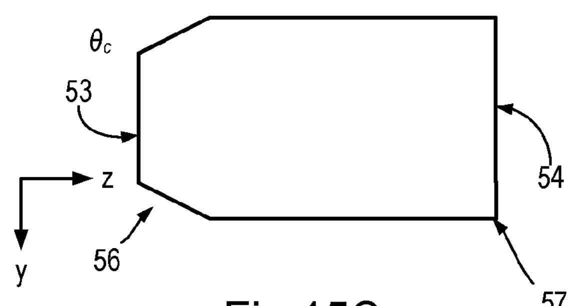


Fig.15C

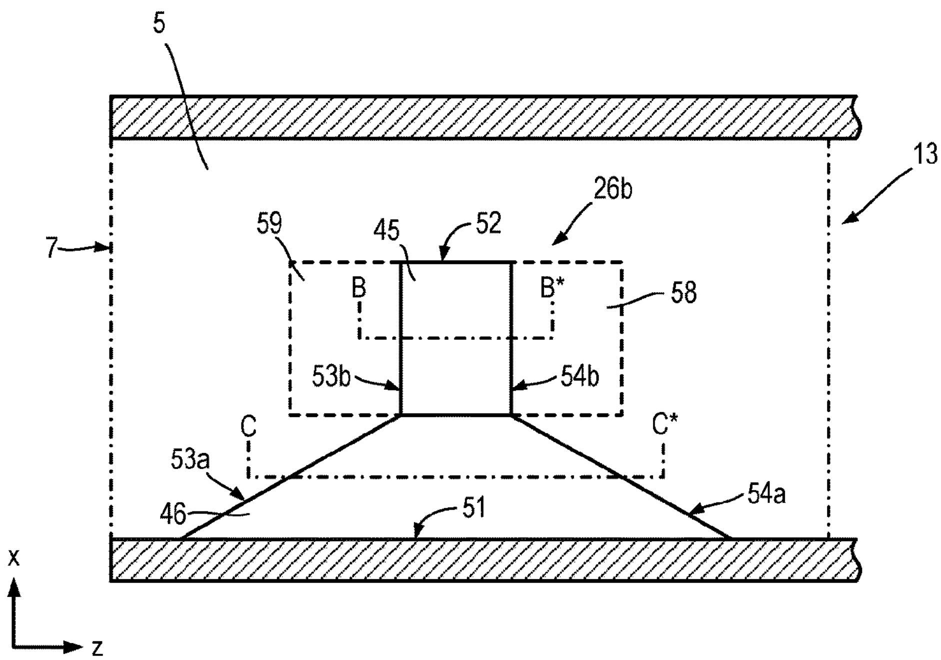


Fig.16A

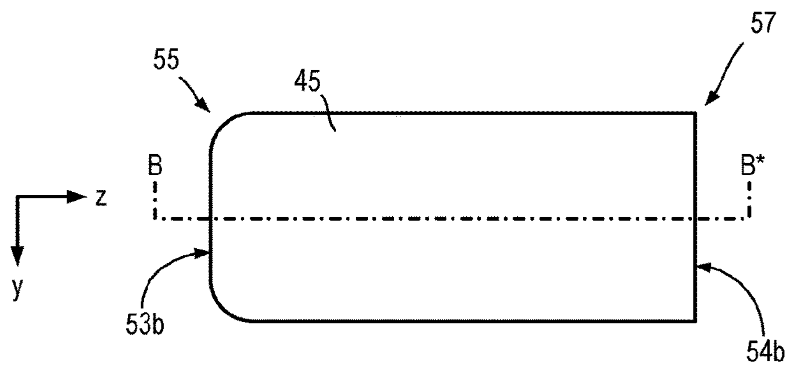


Fig.16B

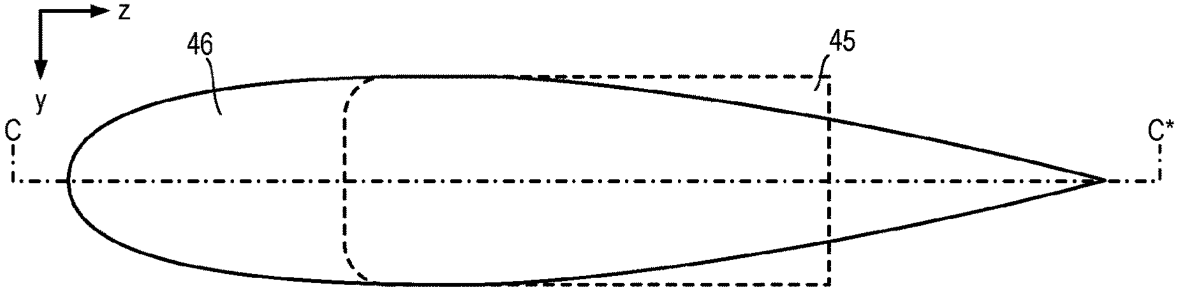


Fig.16C

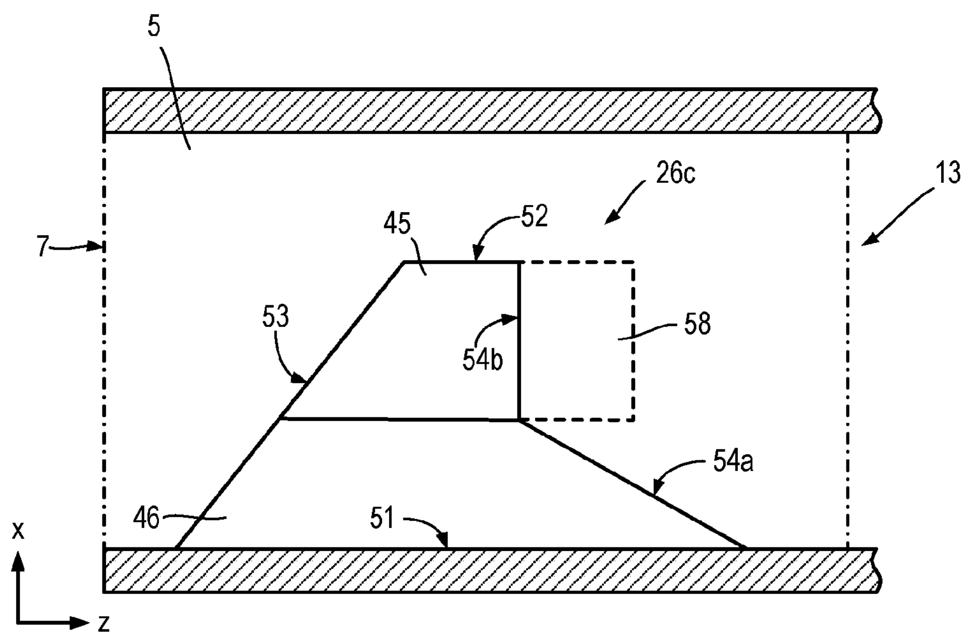

5
26c
13
7
45
52
53
58
54b
54a
46
51
x
z

Fig.17

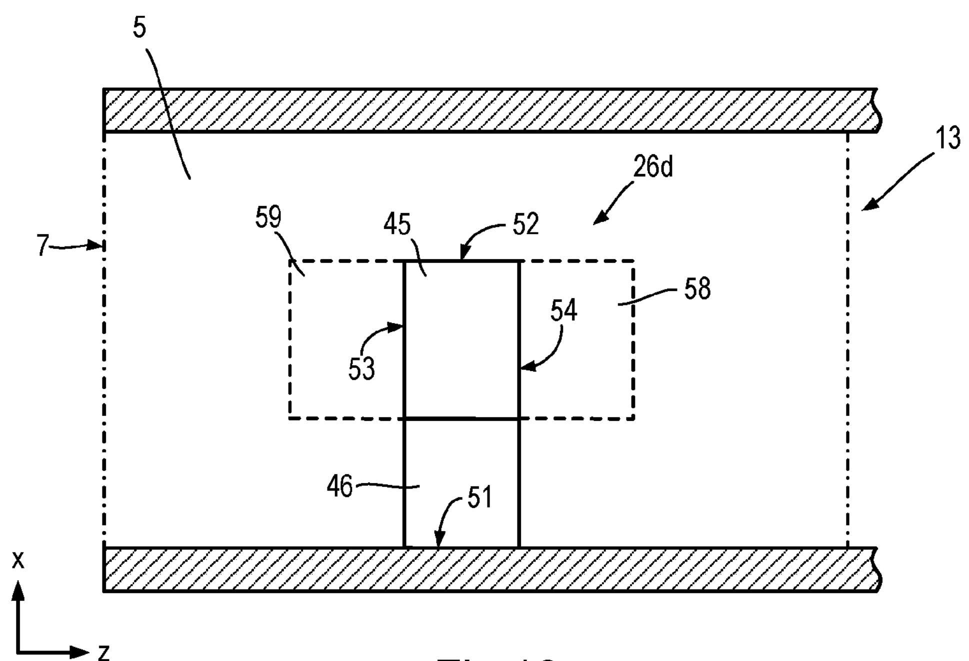

5
13
26d
7
59
45
52
58
54
53
46
51
x
z

Fig.18

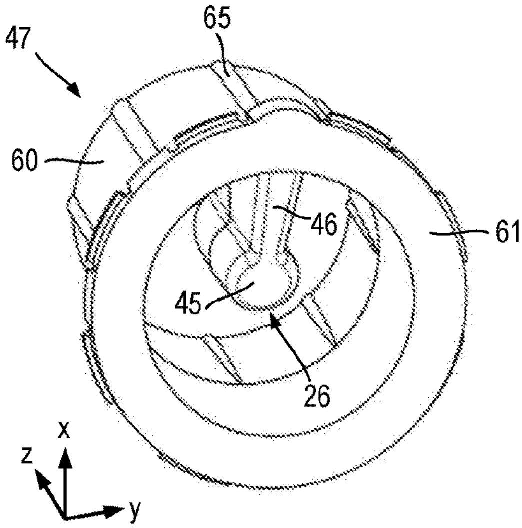


Fig.19A

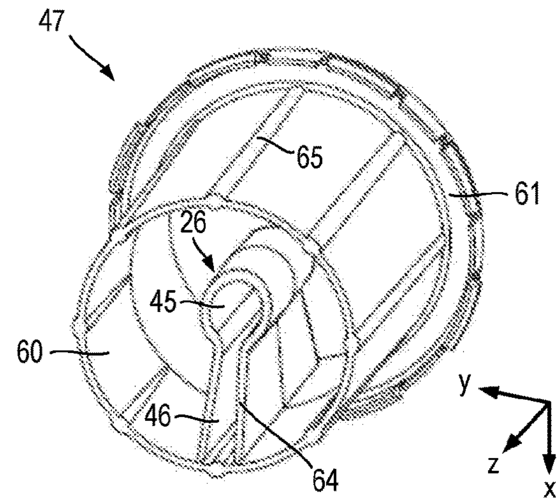


Fig.19B

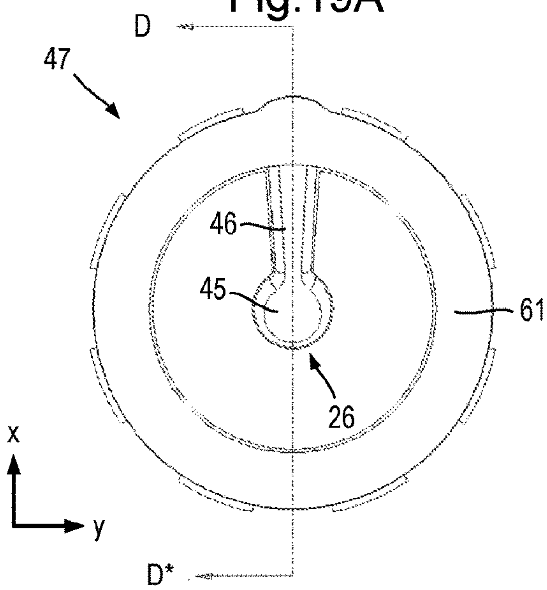


Fig.19C

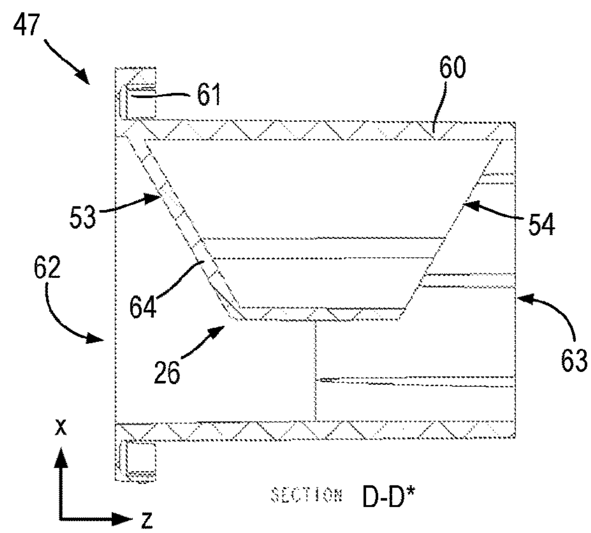


Fig.19D

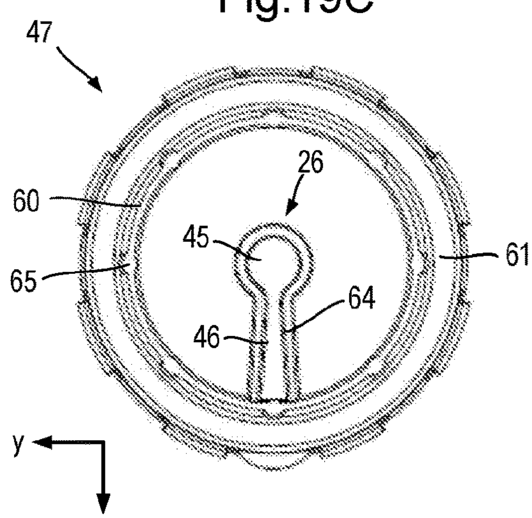


Fig.19E

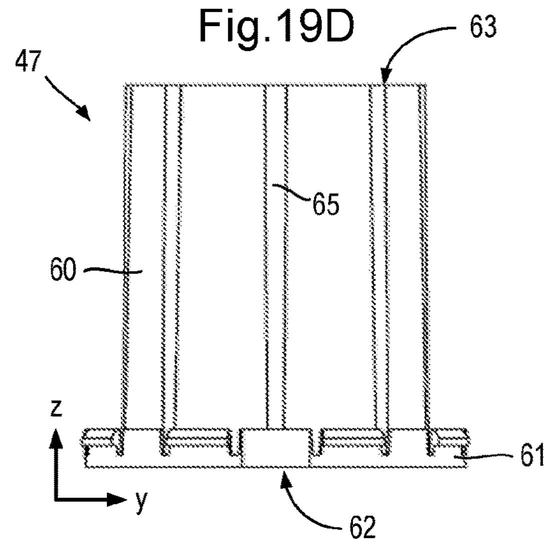


Fig.19F

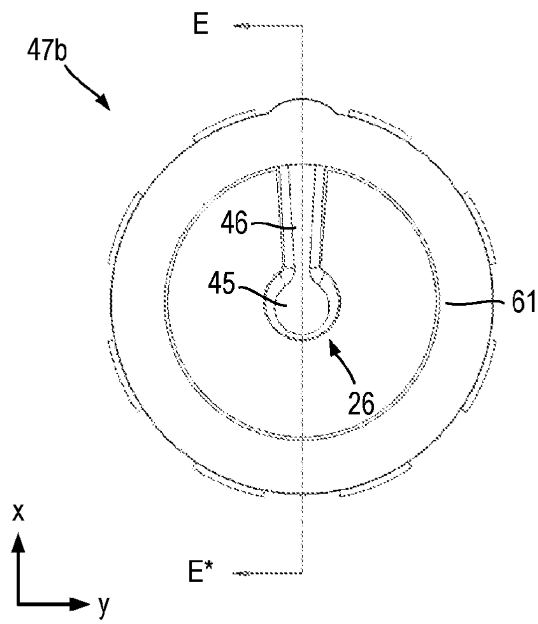


Fig.20A

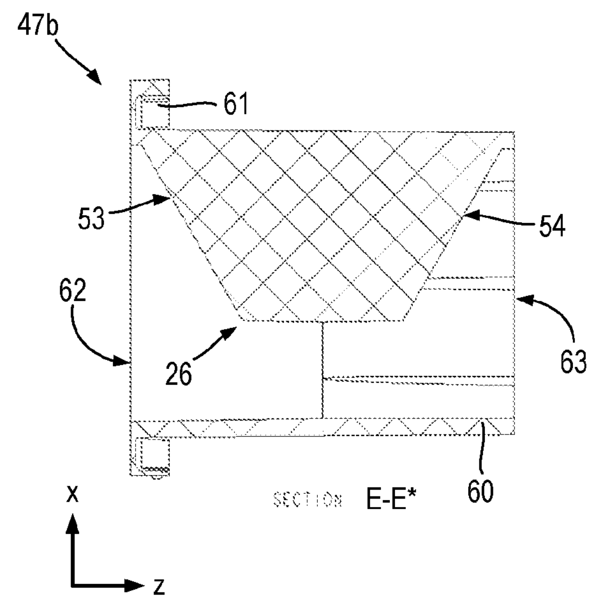


Fig.20B

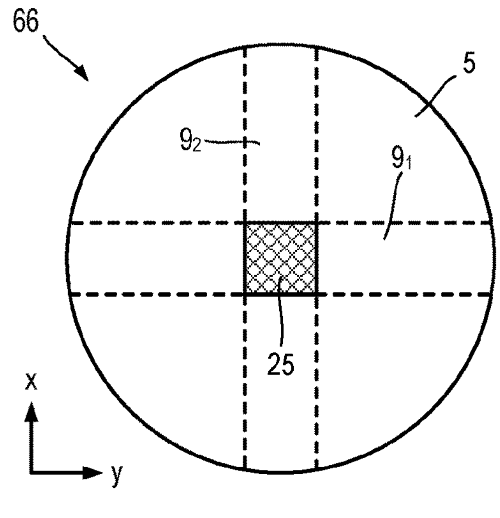


Fig.21

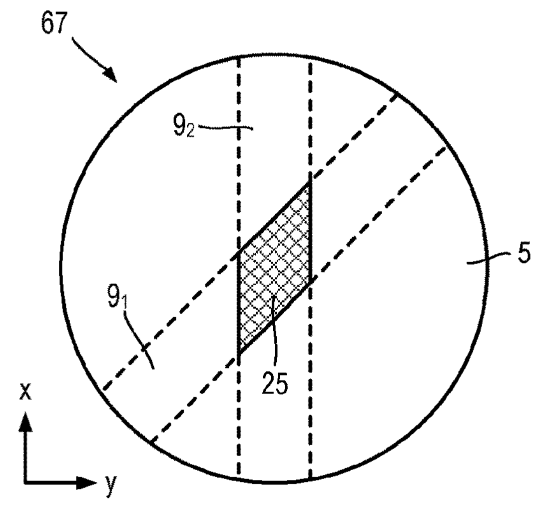


Fig.22

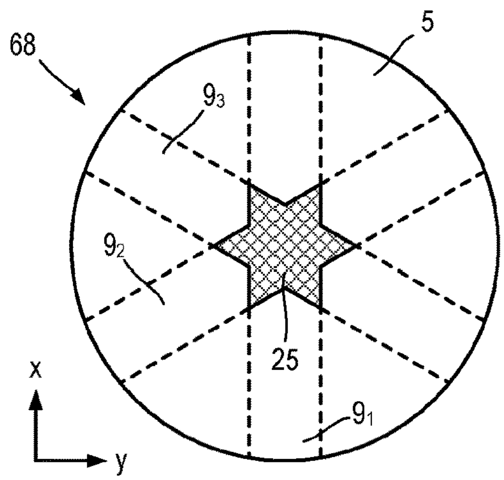


Fig.23

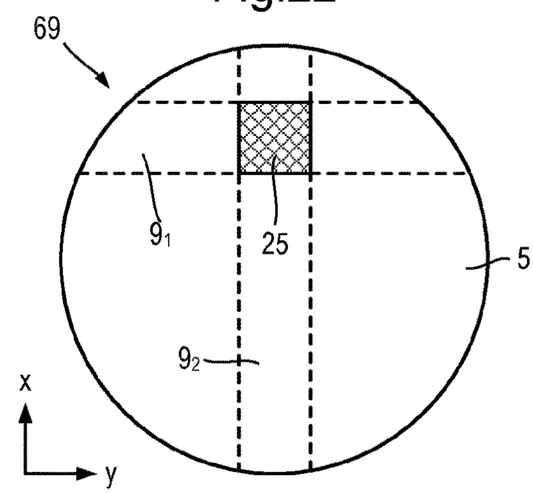


Fig.24

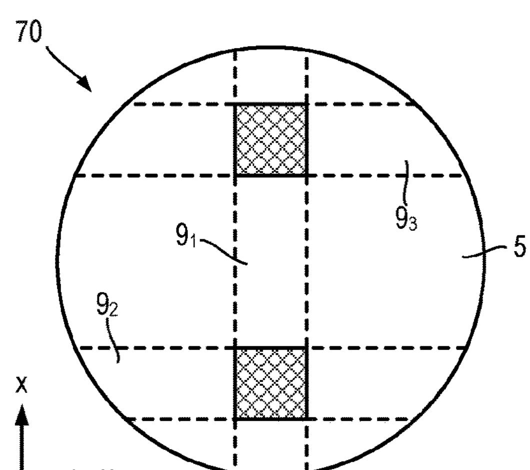


Fig.25A

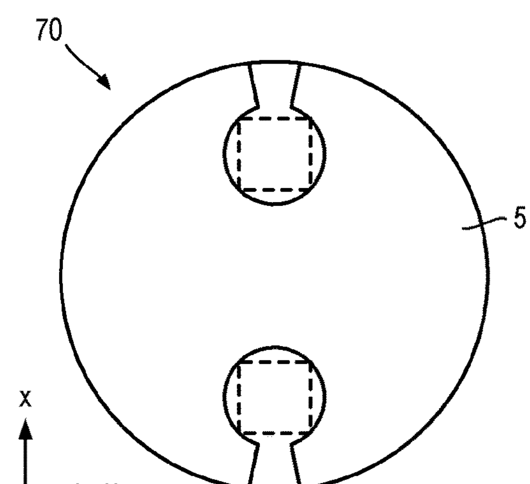


Fig.25B

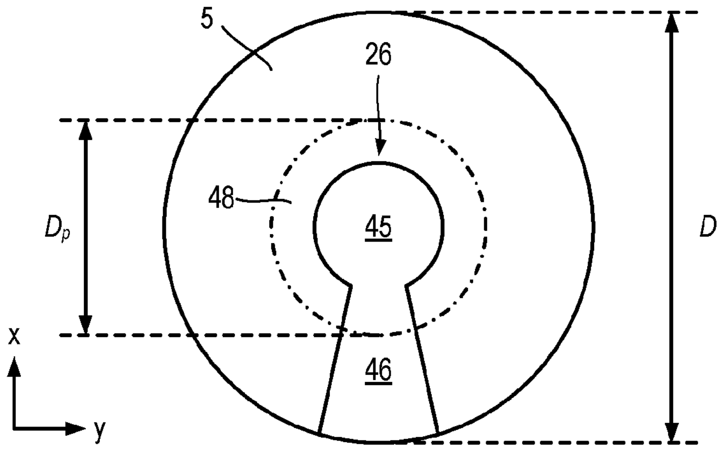


Fig.26

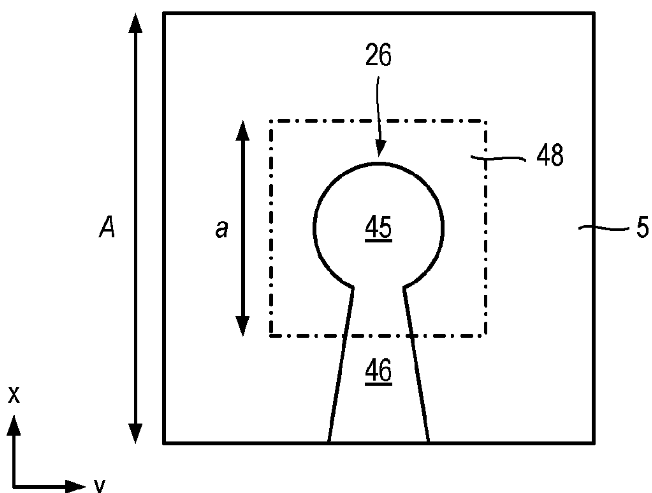


Fig.27

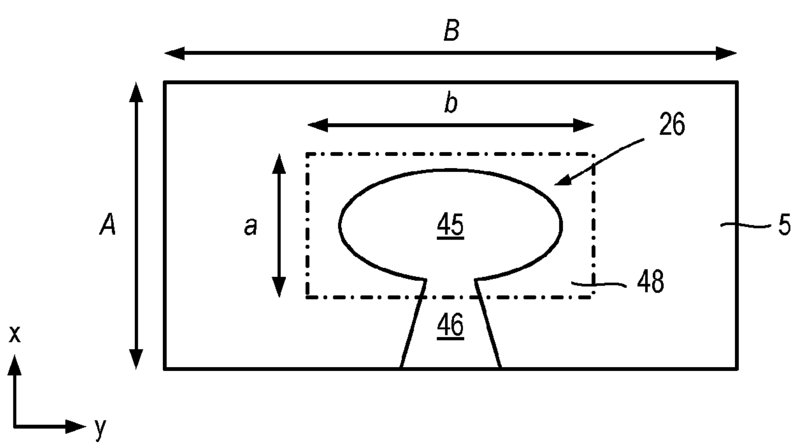


Fig.28

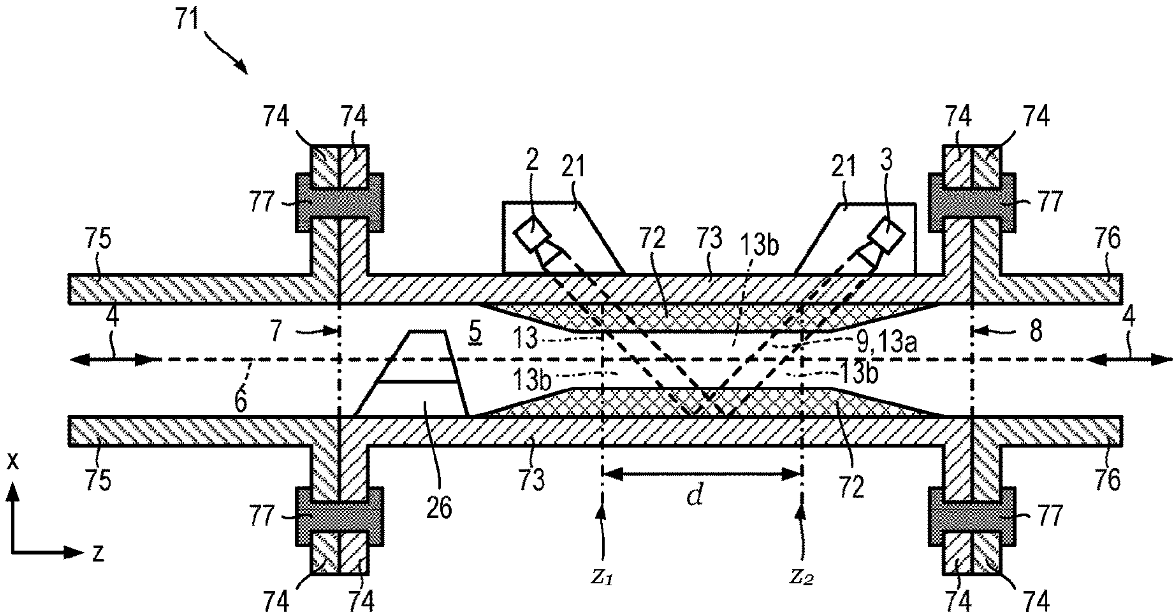

71
74
74
74
74
77
77
2
21
21
3
75
72
73
13b
76
4
7
5
13
9,13a
8
4
13b
13b
6
75
73
72
76
26
d
77
77
x
z
z_1
z_2
74
74
74
74

Fig.29

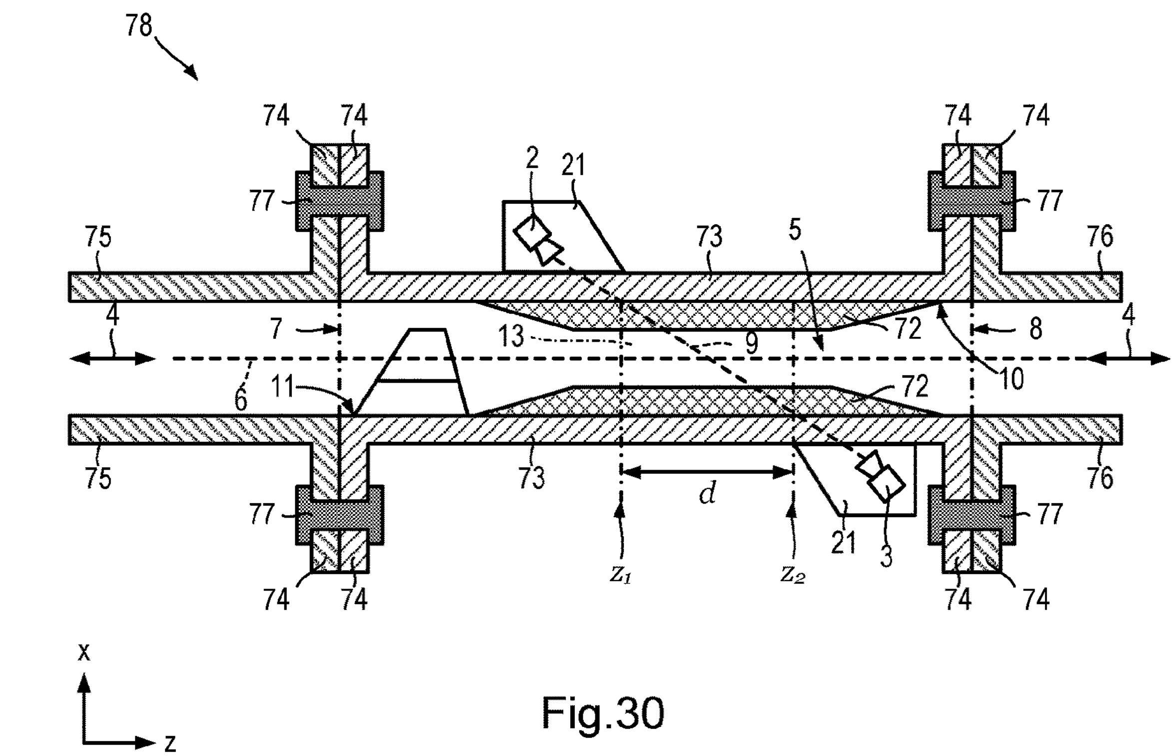
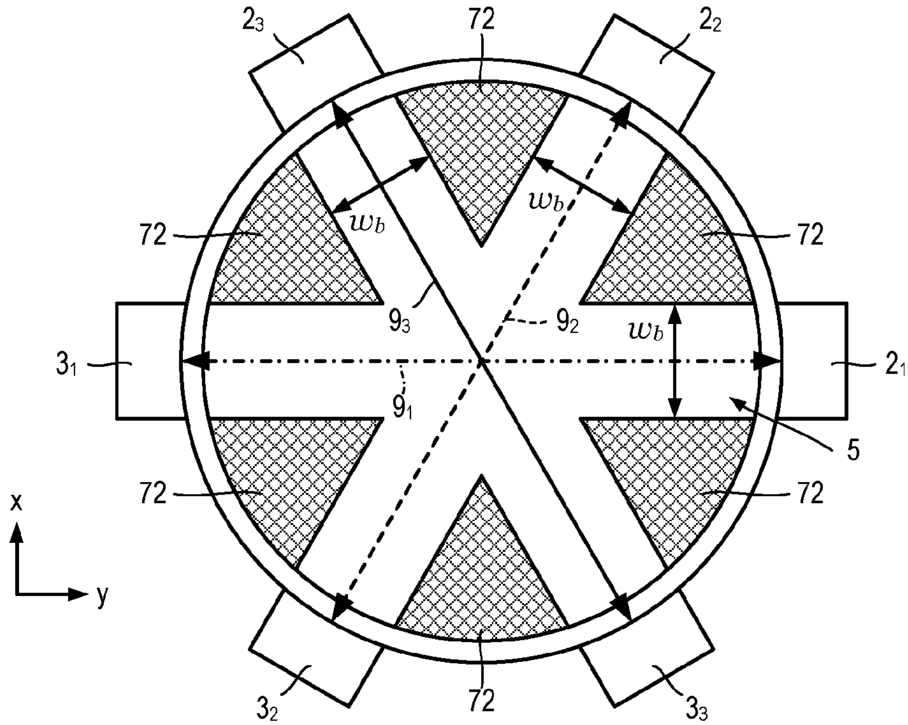
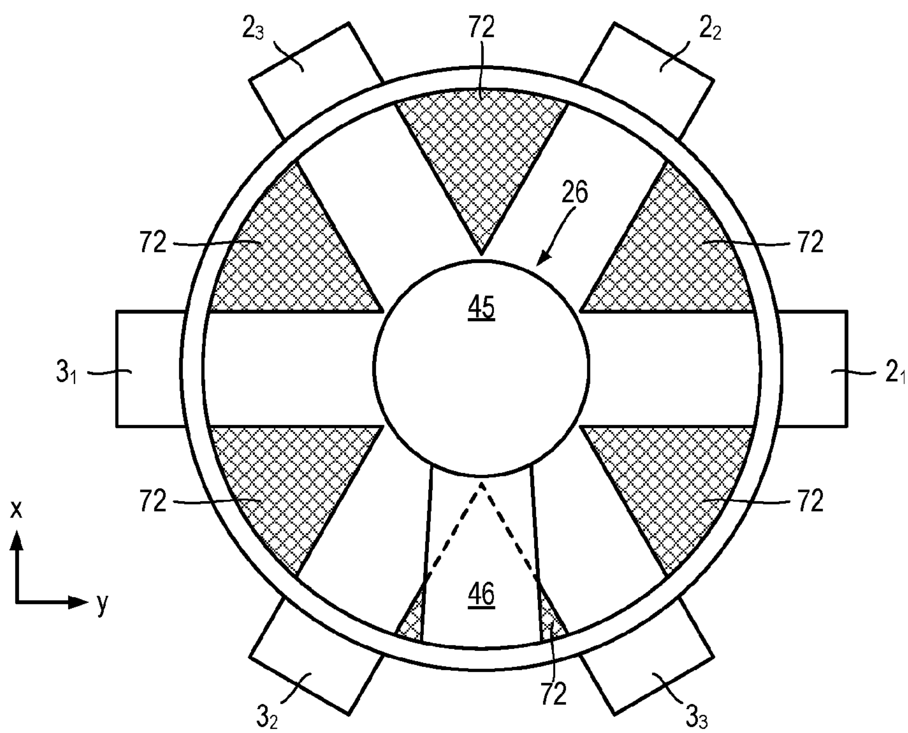

78
74
74
74
74
77
77
2
21
75
73
5
76
4
7
13
72
8
4
9
10
11
72
6
75
73
76
d
77
77
21
3
z_1
z_2
74
74
74
74
x
z

Fig.30



2_3
72
2_2
w_b
w_b
72
72
9_3
9_2
w_b
3_1
2_1
9_1
5
x
y
72
72
3_2
72
3_3

Fig.31



2_3
72
2_2
26
72
72
45
3_1
2_1
x
y
72
72
46
72
3_2
3_3

Fig.32

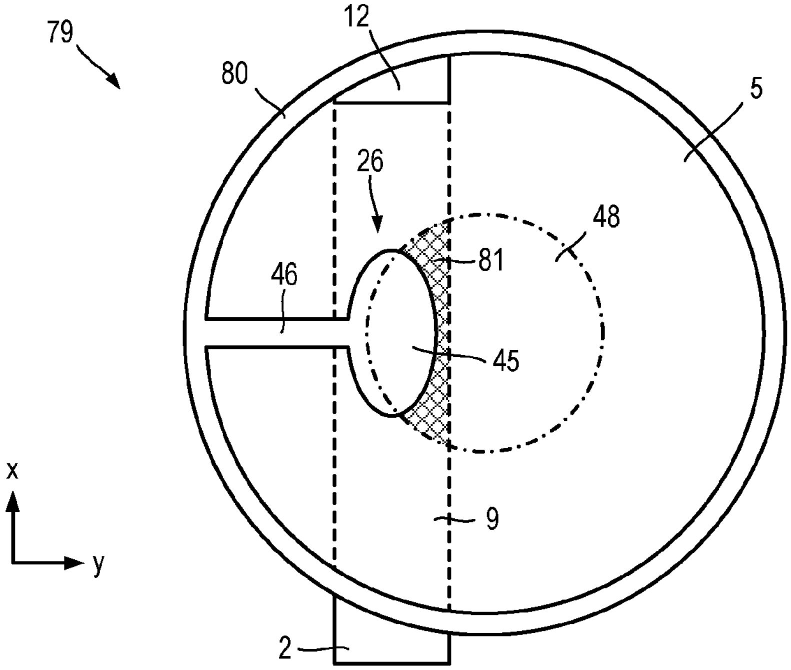


Fig.33

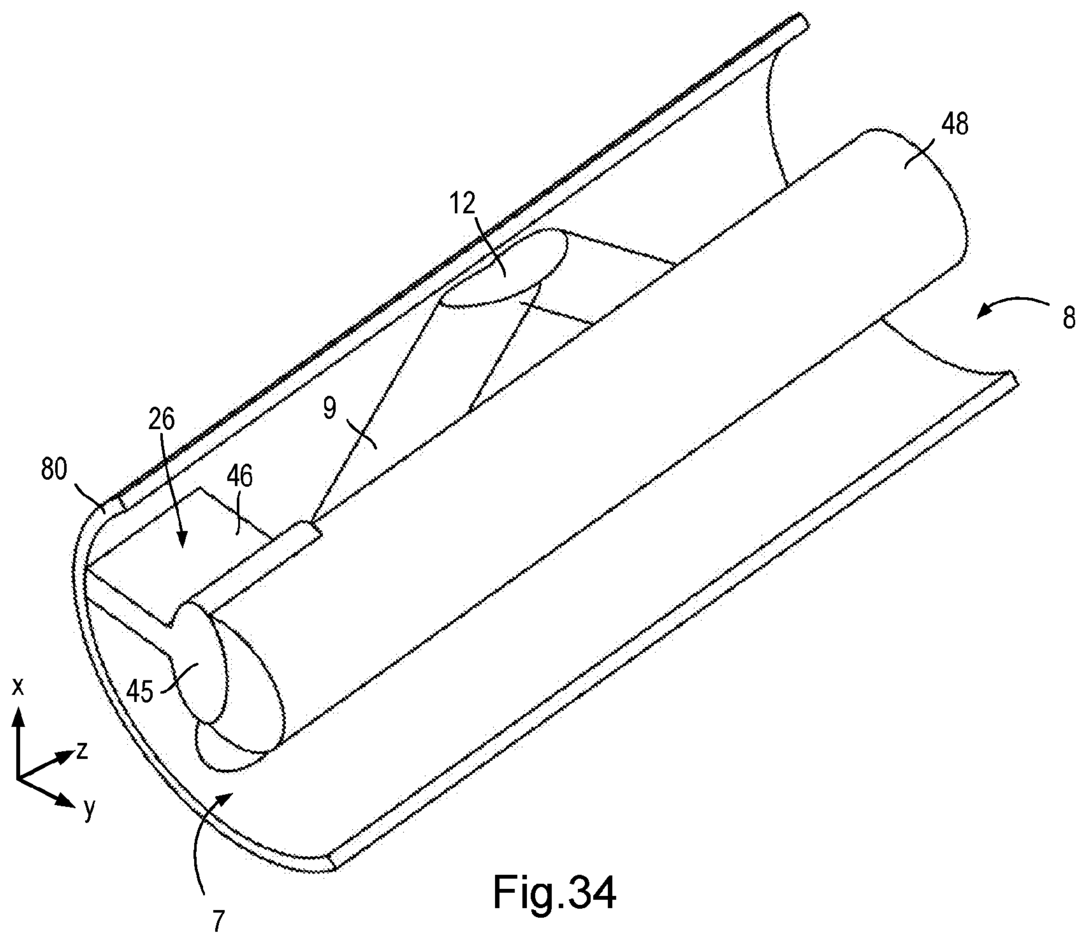


Fig.34

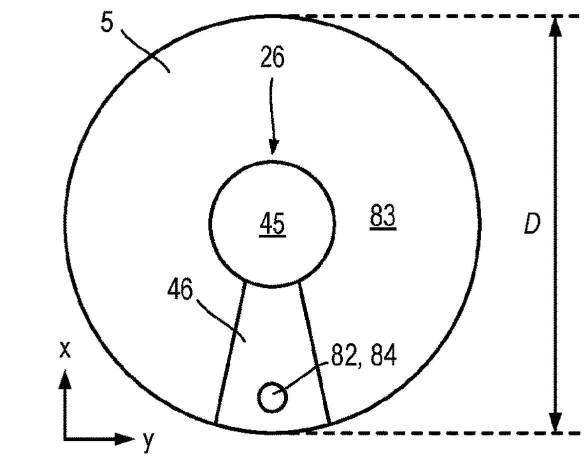


Fig.35

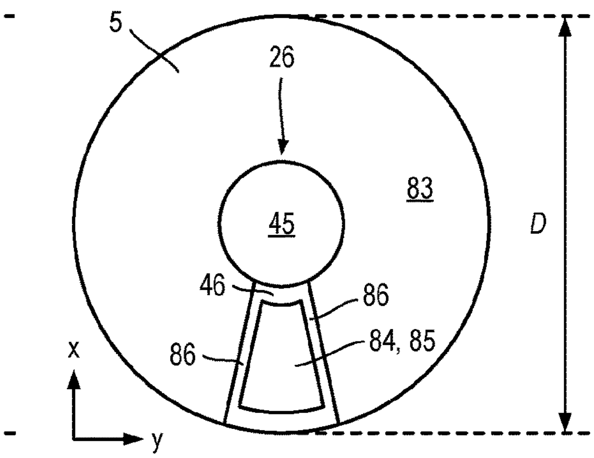


Fig.36

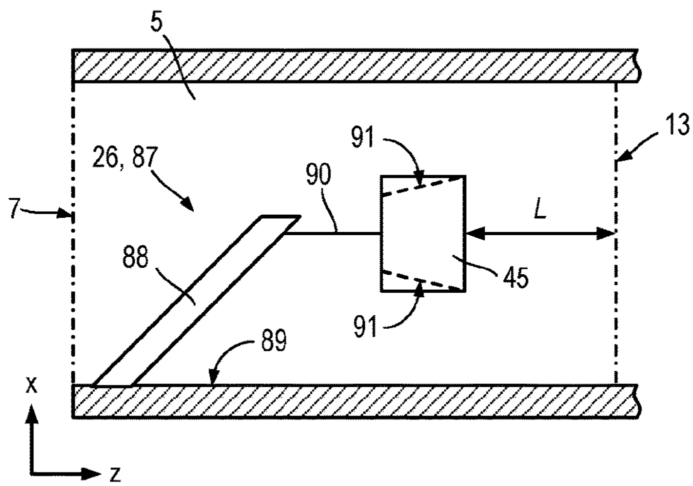


Fig.37A

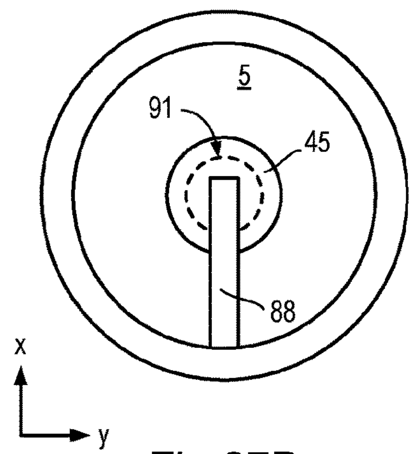


Fig.37B

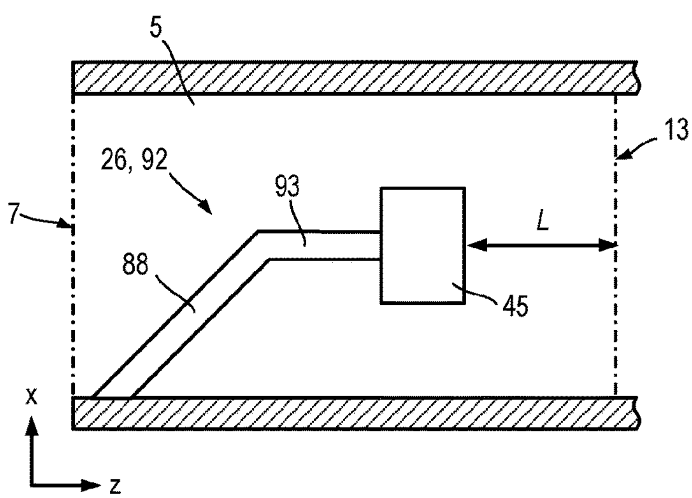


Fig.38A

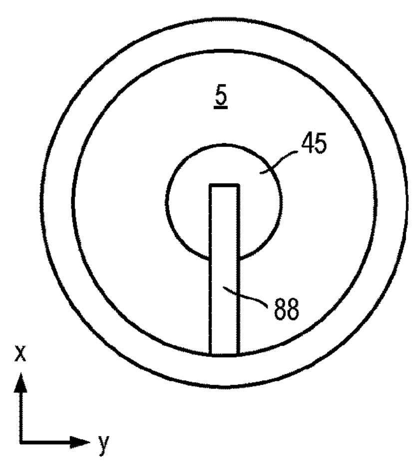


Fig.38B

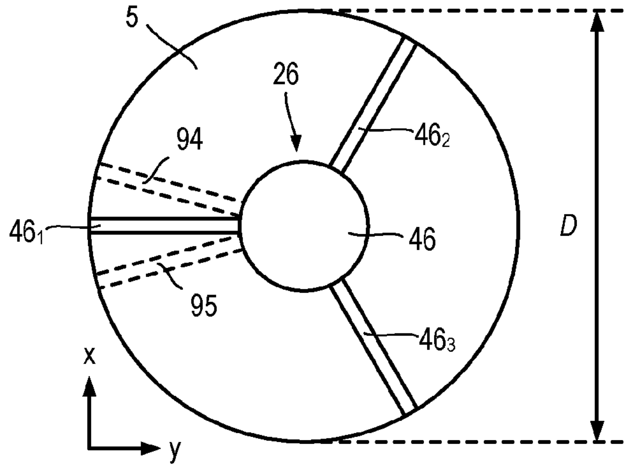


Fig.39

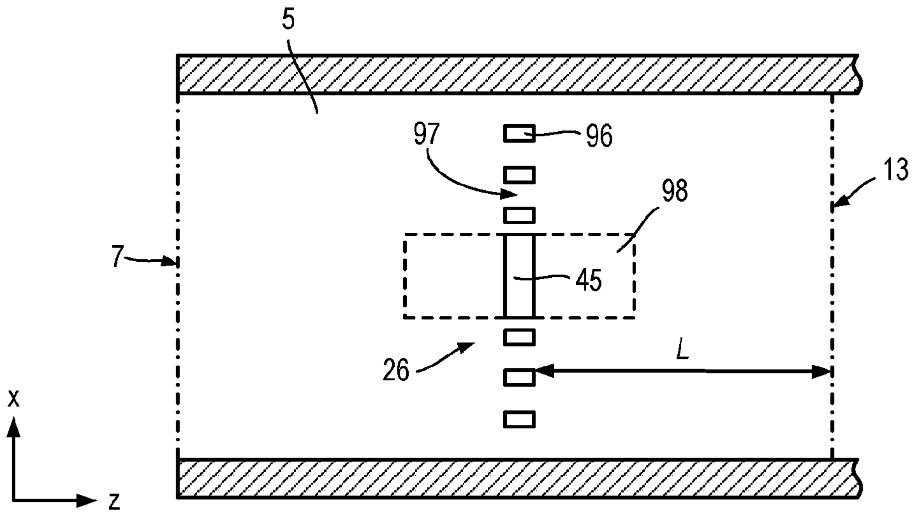


Fig.40A

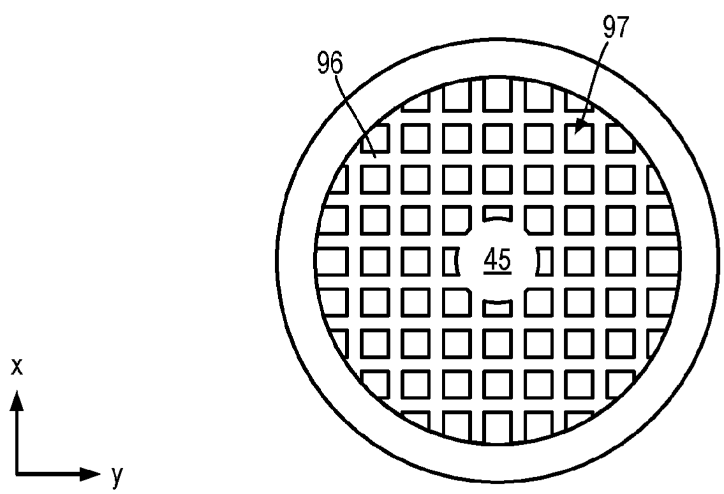


Fig.40B

ULTRASONIC METER

FIELD OF THE INVENTION

[0001] The present invention relates to ultrasonic flow rate meters. In particular, the present invention relates to reducing sensitivity of ultrasonic meters to flow conditions which deviate from calibration conditions.

BACKGROUND

[0002] Ultrasonic flow rate meters have been constructed which measure a flow velocity/speed of a liquid or gas based on time-of-flight measurements. Sometimes a pair of ultrasonic transducers is arranged at opposite ends of a flow tube having a known length. Alternatively, a pair of ultrasonic transducers may be arranged spaced apart along the length of a flow tube by a distance, the ultrasonic transducers arranged at angles to the flow tube such that ultrasound may pass between the pair by reflecting from an internal wall or reflector of the flow tube. By obtaining time-of-flight measurements between the ultrasonic transducers both with, and against, the flow direction of the liquid or gas, a difference may be obtained which relates to the flow speed of the liquid or gas.

[0003] Only a fraction of the liquid or gas (hereinafter both shall be encompassed by the term "fluid") passes through the ultrasonic beam. Consequently, the flow speed measured represents an average over the volume sampled by the ultrasonic beam. In order to convert such an average flow speed to a mass flow of the fluid, for example to allow metering of the fluid, a velocity/speed profile of the fluid must be assumed. When a fluid flows down a straight section of pipe with uniform cross-section, the velocity/speed profile across the pipe will tend towards a predictable profile after flowing for a sufficiently large distance (typically several times a diameter or similar characteristic dimension). Thus, when an ultrasonic meter is installed in, or on, a long straight section of pipe, the approach of assuming a velocity/speed profile may work reasonably well. However, features such as bends, constrictions, valves, pumps and so forth upstream of an ultrasonic meter may cause the velocity/speed profile in a pipe to deviate from the expected profile, reducing the accuracy of the ultrasonic meter. Since a sufficiently long, straight section of pipe may not be available, the accuracy and/or possible installation locations of ultrasonic flow meters may be restricted

[0004] One approach for improving the predictability of a velocity/speed profile is to place one or more flow conditioners upstream (and sometimes also downstream) of an ultrasonic meter. For example, EP 1775 560 A2 describes an ultrasonic flow meter including a flow passage, an ultrasound transducer and a flow straightener for removing or diminishing flow disturbances such as swirls. The flow straightener includes at least a first and a second straightening means being oppositely twisted along a flow direction with a given twisting angle. "Flow conditioning and effects on accuracy for fluid flow measurement", B. D. Sawchuck, D. P. Sawchuck, D. A. Sawchuk, American School of Gas Measurement Technology, 2010, p 1-9, describes the results of testing a flow conditioner.

[0005] WO 2019/229409 A1 describes ultrasonic meters and inserts which use protrusions within a flow conduit to displace a greater fraction of fluid flow through one or more beam paths. This reduces the sensitivity of an ultrasonic meter to deviations from straight flow conditions.

SUMMARY

[0006] According to a first aspect of the invention, there is provided an ultrasonic meter for measuring a flow-rate of a fluid, including a flow conduit for the fluid. The flow conduit extends along a first axis between a first opening and a second opening. The ultrasonic meter also includes two or more pairs of ultrasonic transducers. Each pair of ultrasonic transducers is configured to define a corresponding beam path intersecting the flow conduit within a measurement region of the flow conduit. Substantially every part of each beam path makes a non-zero angle with the first axis. When viewed projected onto a plane perpendicular to the first axis, a projection of a first beam path intersects a projection of a second beam path. The ultrasonic meter also includes a flow deflecting member supported between the first opening and the measurement region. When viewed projected onto the plane perpendicular to the first axis, a projection of the flow deflecting member at least partially overlaps the intersection of the projections of the first and second beam paths.

[0007] In this way, the flow deflecting member acts to deflect fluid flows which would be sampled by the first beam path and the second beam path. The two or more pairs of ultrasonic transducers may define two or more beam paths, including at least the first and second beam paths.

[0008] Substantially every part of each beam path may be considered to make a non-zero angle with the first axis when 75% or more, 80% or more, 90% or more, or 95% or more of the beam path length corresponds to parts which make a non-zero angle with the first axis. Every part of each beam path, i.e. the entire length, may make a non-zero angle with the first axis.

[0009] When a part of a beam path make a non-zero angle with the first axis, that non-zero angle may be between 10 degrees and 80 degrees (inclusive of end-points) to the first axis. Each beam path may be configured so that within the measurement region, each part of each beam path which intersects the measurement region includes a component parallel to the first axis and a component transverse to the first axis.

[0010] When viewed projected onto the plane perpendicular to the first axis, the projection of the flow deflecting member may not divide a projection of the flow conduit into two separate regions.

[0011] When viewed projected onto the plane perpendicular to the first axis, the projection of the flow deflecting member may divides a projection of the flow conduit into two or more separate regions including a primary region. An area of the primary region in the projection may account for 75% or more of the total projected area of the two or more separate regions. The area of the primary region in the projection may account for 80% or more of the total projected area of the two or more separate regions. The area of the primary region in the projection may account for 85% or more of the total projected area of the two or more separate regions. The area of the primary region in the projection may account for 90% or more of the total projected area of the two or more separate regions. The area of the primary region in the projection may account for 95% or more of the total projected area of the two or more separate regions. The projection of the flow deflecting member may divide a projection of the flow conduit into exactly two separate regions including the primary region. The projection of the flow deflecting member may divide a projection of the flow conduit into exactly three separate regions including the primary region.

[0012] When viewed projected onto the plane perpendicular to the first axis, the projection of the flow deflecting member may at least partially overlap a peak flow region of the plane. The peak flow region may be defined relative to a projection onto the plane of a flow conduit of a reference ultrasonic meter which is identical to the ultrasonic meter except for omitting the flow deflecting member. The peak flow region may correspond to a region of the plane in which a flow speed through the reference ultrasonic meter is above a mean flow speed in response to passing a steady state fluid flow through the reference ultrasonic meter at a Reynolds number of approximately 3000. Reynolds number may be determined from theory, simulations (e.g. finite element analysis) and/or experiments.

[0013] The mean flow speed may be determined by measuring the volumetric flowrate though the conduit of the reference ultrasonic meter and dividing by a cross-sectional area (projected area on the plane) of the flow conduit. Alternatively, flow velocities through the reference ultrasonic meter may be simulated, for example using finite element analysis. The simulated flow velocities may then be integrated over the volume and the flow conduit and normalised to the total volume of the flow conduit to obtain the mean flow speed. Simulated flow velocities may include, or take the form of, a vector field, $\underline{v}(x,y,z)$, of fluid velocities. A projection of the flow velocity field onto the plane perpendicular to the first axis may be defined as:

$$v^*(x, y) = \int_0^L \frac{\underline{v}(x, y, z) \cdot \hat{\underline{z}}}{L} dz$$

[0014] In which the unit vector $\hat{\underline{z}}$ is aligned with the first axis, L is the length of the fluid conduit parallel to the first axis and v* is a projected flow speed map. The peak flow region may be defined based on the region(s) of the projected flow speed map in which the projected flow speed exceeds the mean flow speed.

[0015] The projected area of the reference meter is identical in shape and orientation to that of the ultrasonic meter. In other words, the peak flow region is defined relative to the flow profile which would result if the flow deflecting member were removed. A steady state fluid flow corresponds to the flow that would be found in a long straight pipe having a cross section corresponding to the projected area of the flow conduit. In other words, sufficiently far (e.g. at least ten times longer than a maximum dimension perpendicular to the first axis) from any disturbances resulting from bends, variations in cross sectional area, shape, and so forth. A Reynolds number of approximately 3000 may mean within ±10%, or within ±5%.

[0016] Instead of the peak flow region corresponding to flow velocities greater than or equal to the mean flow speed in the reference ultrasonic meter, the peak flow region may instead be defined to correspond to higher flow velocities. For example, if the mean flow speed in the reference ultrasonic meter is U_{avg} and the maximum is U_{max}, the peak flow region may be defined to correspond to flow velocities greater than or equal to $U_{avg}+f(U_{max}-U_{avg})$ with f equal to 0.1, 0.2, 0.25, 0.3, 0.4, 0.5, 0.6, 0.7, 0.75, 0.8, or 0.9.

[0017] Flow speed profiles in the reference ultrasonic meter in response to steady state fluid flow through the reference ultrasonic meter at a Reynolds number of approximately 3000 may be determined from theory, simulations and/or experimental measurements.

[0018] The Reynolds number may be defined as the product of the mean flow speed and the hydraulic diameter, divided by the kinematic viscosity of the fluid, for example water, at a test temperature. It may be noted that the temperature is not important, since if the temperature changes, then the flow rate must change correspondingly to maintain the Reynolds number at the same value (and hence the same flow profile). Hydraulic diameter is defined as four times the area of the flow conduit (perpendicular to the first axis), divided by the perimeter around that area. For a flow conduit in the form of a cylinder, the hydraulic diameter is the cylinder diameter, however, the same definition is applicable to non-cylindrical flow conduits.

[0019] Alternatively, the peak flow region may be approximately defined without consideration of fluid flows through the reference ultrasonic meter. For example, the peak flow region may be defined as a region which:

- **[0020]** is concentric with the projection of the flow conduit;
- **[0021]** is circular, or has the same shape and orientation as the projection of the flow conduit; and
- **[0022]** has one quarter or less of an area of the projection of the flow conduit.

[0023] When viewed projected onto the plane perpendicular to the first axis, at least half the projected area of the flow deflecting member may overlap the peak flow region.

[0024] The flow deflecting member may be separated from the measurement region by a distance along the first axis which is between zero and 5 times a maximum dimension of the flow conduit perpendicular to the first axis. The separation of the flow deflecting member from the measurement region may be no more than 4 times, no more than 3 times, no more than 2 times, no more than equal to, or no more than half the maximum dimension of the flow conduit perpendicular to the first axis.

[0025] A leading side of the flow deflecting member facing towards the first opening may have a rounded bevel profile around at least part of its perimeter and/or may taper towards the first opening. The rounded bevel profile may extend around all of the perimeter of the leading side.

[0026] A trailing side of the flow deflecting member facing towards the measurement region may have a sharp edge around at least part of its perimeter. The sharp edge around at least part of the perimeter of the trailing side may correspond to a Kamm-tail profile. The sharp edge may extend around all of the perimeter of the trailing side. The sharp edge may extend around the portion of the perimeter of the trailing side corresponding to the blocking member defined hereinafter. The remainder of the perimeter of the trailing side may configured for streamlining.

[0027] Along one, some or all edges of the second side, the flow deflecting member may exhibit a rounded profile, for example a filet or chamfer having a characteristic dimension between 0 mm and 0.25 times a dimension of the flow deflecting member perpendicular to the first axis.

[0028] When viewed projected onto a plane parallel to the first axis, the flow deflecting member may have a quadrilateral shape. The plane parallel to the first axis may also be parallel to a mirror plane of the flow deflecting member.

[0029] The quadrilateral shape may have a first side parallel to the first axis and disposed at or near an outer wall of the flow conduit, a second side parallel to the first axis and shorter than the first side, a third (or "leading") side facing towards the first opening and making a first internal angle to the first side, and a fourth (or "trailing") side facing towards the measurement region and making a second internal angle to the first side. The first and second angles may be equal. The first and second angles may be different. The first angle may be between 45 and 80 degrees (inclusive of endpoints). The second angle may be between 45 and 135 degrees (inclusive of endpoints).

[0030] The quadrilateral shape may be a trapezium shape. The quadrilateral shape may be a parallelogram shape.

[0031] The flow deflecting member may include a blocking member disposed within the fluid conduit and held in place by a supporting member. The blocking member and the supporting member may be integrally formed. The blocking member and the supporting member may be separate structures bonded, welded or otherwise attached to one another. When viewed projected onto the plane perpendicular to the first axis, a projection of the blocking member at least partially overlaps the intersection between projections of the first and second beam paths. The supporting member may connect the blocking member to an interior surface of the fluid conduit. The supporting member may connect the blocking member to an annular insert received within the fluid conduit.

[0032] One or more through-holes may be formed through the supporting member to permit passage of fluid. A through-hole may extend through the supporting member parallel to the first axis. A through-hole formed through the supporting member may be elliptical or circular in cross-section (when projected onto the plane perpendicular to the first axis). A through-hole formed through the supporting member may be square or rectangular in cross-section (when projected onto the plane perpendicular to the first axis). A through-hole formed through the supporting member may take the form of a slot.

[0033] When viewed projected onto the plane perpendicular to the first axis, the projections of the through-hole(s) may correspond to 25% or less of a total projected flow area formed by subtracting the projection of the flow deflecting member from the projection of the flow conduit. When viewed projected onto the plane perpendicular to the first axis, the projections of the through-hole(s) may correspond to 20% or less of a total projected flow area formed by subtracting the projection of the flow deflecting member from the projection of the flow conduit. When viewed projected onto the plane perpendicular to the first axis, the projections of the through-hole(s) may correspond to 15% or less of a total projected flow area formed by subtracting the projection of the flow deflecting member from the projection of the flow conduit. When viewed projected onto the plane perpendicular to the first axis, the projections of the through-hole(s) may correspond to 10% or less of a total projected flow area formed by subtracting the projection of the flow deflecting member from the projection of the flow conduit. When viewed projected onto the plane perpendicular to the first axis, the projections of the through-hole(s) may correspond to 5% or less of a total projected flow area formed by subtracting the projection of the flow deflecting member from the projection of the flow conduit.

[0034] When viewed projected onto the plane perpendicular to the first axis, a projection of the supporting member may connect to a projection of the blocking member along a connection direction. A maximum dimension of the projection of the blocking member perpendicular to the connection direction may be greater than a maximum dimension of the projection of the supporting member perpendicular to the connection direction.

[0035] The flow deflecting member may include, or take the form of, a radial member extending inwards from an inner surface of the flow conduit, and a blocking member disposed within the fluid conduit and offset along the first axis away from the first opening relative to the radial member. The blocking member may be held in place by a rod or wire extending along the first axis from the radial member to the blocking member.

[0036] The radial member may be streamlined or otherwise shaped to minimise disruption to incident fluid flow. In this way, and combined with offsetting the blocking member downstream of the protruding member, the disruption to fluid flow of the radial member may be minimised so that the influence of the flow deflecting member on fluid flows is more dominated by the effect of the blocking member.

[0037] When the blocking member is connected to the radial member by a wire, a leading edge (relative to the first opening and the radial member) of the blocking member may be shaped such that a position of the blocking member within the flow conduit will be stabilised by fluid flow from the first opening towards the second opening. The blocking member may have a leading edge which is conical/pyramidal or frustoconical/frustopyramidal.

[0038] The flow deflecting member may include, or take the form of, a blocking member disposed within the fluid conduit and held in place by two or more supporting members. The two or more supporting members may be equiangularly spaced about the first axis. The two or more supporting members may, when viewed projected onto the plane perpendicular to the first axis, be spread to subtend an angle of less than or equal to 45° about the first axis. The two or more supporting members may, when viewed projected onto the plane perpendicular to the first axis, be spread to subtend an angle of less than or equal to 30° about the first axis. The two or more supporting members may, when viewed projected onto the plane perpendicular to the first axis, be spread to subtend an angle of less than or equal to 20° about the first axis.

[0039] The flow deflecting member may include, or take the form of, a blocking member disposed within the fluid conduit and held in place by a mesh. The blocking member may have the same thickness as the mesh in the direction parallel to the first axis. The blocking member may have a larger thickness than the mesh in the direction parallel to the first axis. The mesh may cover the entire cross-section of the flow conduit. The mesh may cover a fraction of the cross-section of the flow conduit, for example a strip. The blocking member may be attached to the mesh. The blocking member may be integrally formed with the mesh. The blocking member may correspond to a region of the mesh in which through-holes of the mesh are wholly or partly filled in.

[0040] The mesh may be attached or bonded to an interior surface of the flow conduit. The mesh may be attached or bonded to an insert received within the flow conduit. The mesh may be received through a slot in the flow conduit and may be removable. The mesh may be received over the first and/or second openings of the flow conduit and sandwiched between the flow conduit and incoming and/or outgoing pipes.

[0041] A thickness of the mesh parallel to the first axis may be less than a dimension of through-holes of the mesh. A thickness of the mesh parallel to the first axis may be less than or equal to half the dimension of through-holes of the mesh. The mesh may be a wire-mesh. When viewed projected onto the plane perpendicular to the first axis, the projected area of the mesh structure may be less than or equal to 20% of the projected area of through holes in the mesh (excluding the projected area of the blocking member.

[0042] When viewed projected onto the plane perpendicular to the first axis, the projection of the blocking member may be substantially oval, elliptical or circular. Substantially oval, elliptical or circular may mean that the projection of the blocking member is oval, elliptical or circular except where it meets the projection of the supporting member. Substantially oval, elliptical or circular may include the respective precise shapes.

[0043] A length of the blocking member along the first axis may be between 0.2 and 2 times a maximum dimension of the blocking member perpendicular to the first axis. The length of the flow deflecting member along the first axis may be between 0.5 and 0.7 times the maximum dimension of the flow conduit perpendicular to the first axis.

[0044] The flow deflecting member may not include any portions which are conical, frustoconical, pyramidal, or frustopyramidal. The blocking member may not include any portions which are conical, frustoconical, pyramidal, or frustopyramidal. The supporting member may not include any portions which are conical, frustoconical, pyramidal, or frustopyramidal.

[0045] The flow deflecting member may be configured such that swirl is not introduced in response to a straight fluid flow passing the flow deflecting member.

[0046] A pressure drop across the flow deflecting member may be 0.15 Pa or less in response to an average flow velocity in the flow conduit of $0.15\ m \cdot s^{-1}$ of fluid in the form of water at 20° C.

[0047] One or more portions of the measurement region which are outside of any of the two or more beam paths may comprise non-sampled volumes. The ultrasonic meter may also include two or more protrusions extending along the first axis. At least part of each protrusion may be arranged to exclude fluid from at least part of one or more non-sampled volumes. The two or more protrusions may be arranged so that, for each beam path, a component transverse to the first axis passes through at least one space defined by a pair of protrusions.

[0048] The two or more protrusions may be integrally formed with the flow conduit. Alternatively, an insert may be secured within the flow conduit, and the insert may at least partly define a through passage comprising at least one of the two or more protrusions.

[0049] When viewed projected onto the plane perpendicular to the first axis, a projection of at least one support member may at least partly overlap with a projection of a protrusion of the two or more protrusions. The projection of the at least one support member may be aligned with the projection of a protrusion.

[0050] When viewed projected onto the plane perpendicular to the first axis, a projection of at least one support member may be aligned with a projection of at least one space defined by a pair of protrusions. The projection of the at least one support member may be aligned with a projection of at least one beam path.

[0051] At least one beam path may include at least one reflection. The reflection is not a 180 degree reflection.

[0052] The first flow deflecting member may be a first flow deflecting member. When viewed projected onto the plane perpendicular to the first axis, a projection of a third beam path may intersect a projection of a fourth beam path. The ultrasonic meter may also include a second flow deflecting member supported between the first opening and the measurement region. When viewed projected onto the plane perpendicular to the first axis, a projection of the second flow deflecting member may at least partially overlap the intersection of the projections of the third and fourth beam paths.

[0053] Either of the third beam path or the fourth beam path may be the first beam path. In other words, there may be a beam path in common between the intersections. Equally, there may be no beam paths in common between the intersections.

[0054] The second flow deflecting member may be substantially the same as the first flow deflecting member. The second flow deflecting member may include features corresponding to any features of the (first) flow deflecting member described herein.

[0055] For each flow deflecting member supported between the first opening and the measurement region, the ultrasonic meter may also include an identical flow deflecting member supported between the second opening and the measurement region.

[0056] When viewed projected onto the plane perpendicular to the first axis, a projection of each flow deflecting member supported between the first opening and the measurement region may entirely coincide with a projection of the corresponding flow deflecting member supported between the second opening and the measurement region. Each flow deflecting member supported between the second opening and the measurement region may be a reflection of the corresponding flow deflecting member supported between the first opening and the measurement region, about a mirror plane perpendicular to the first axis. However, such a mirror plane does not need to coincide with a midpoint of the measurement region.

[0057] According to a second aspect of the invention, there is provided an insert for an ultrasonic meter. The ultrasonic meter includes a flow conduit for the fluid. The flow conduit extending along a first axis between a first opening and a second opening. The ultrasonic meter also includes two or more pairs of ultrasonic transducers. Each pair of ultrasonic transducers is configured to define a corresponding beam path intersecting the flow conduit within a measurement region of the flow conduit. Substantially every part of each beam path makes a non-zero angle with the first axis. When viewed projected onto a plane perpendicular to the first axis, a projection of a first beam path intersects a projection of a second beam path. The insert includes a flow deflecting member configured such that, when the insert is received into the flow conduit, the flow deflecting member is supported between the first opening and the measurement region, and when viewed projected onto the plane perpendicular to the first axis, a projection of the flow deflecting member at least partially overlaps the intersection of the projections of the first and second beam paths.

[0058] The insert according to the second aspect may include features corresponding to any features of the ultrasonic meter according to the first aspect and/or may be configured for use with any ultrasonic meter according to the first aspect. Definitions applicable to the ultrasonic meter according to the first aspect may be equally applicable to the insert according to the second aspect.

[0059] According to a third aspect of the invention, there is provided an ultrasonic meter for measuring a flow-rate of a fluid, including a flow conduit for the fluid. The flow conduit extending along a first axis between a first opening and a second opening. The ultrasonic meter also includes one or more pairs of ultrasonic transducers. Each pair of ultrasonic transducers is configured to define a corresponding beam path intersecting the flow conduit within a measurement region of the flow conduit. Substantially every part of each beam path makes a non-zero angle with the first axis. When viewed projected onto a plane perpendicular to the first axis, a projection of a first beam path intersects a peak flow region. The ultrasonic meter also includes a flow deflecting member supported between the first opening and the measurement region. When viewed projected onto the plane perpendicular to the first axis, a projection of the flow deflecting member at least partially overlaps the intersection of the first beam path and the peak flow region. The peak flow region is defined relative to a projection onto the plane of a flow conduit of a reference ultrasonic meter which is identical to the ultrasonic meter except for omitting the flow deflecting member. The peak flow region corresponds to a region of the plane in which a flow velocity through the reference ultrasonic meter is above a mean flow velocity in response to passing a steady state fluid flow through the reference ultrasonic meter at a Reynolds number of approximately 3000.

[0060] The projected area of the reference meter is identical in shape and orientation to that of the ultrasonic meter. In other words, the peak flow region is defined relative to the flow profile which would result if the flow deflecting member were removed. A steady state fluid flow corresponds to the flow that would be found in a long straight pipe having a cross section corresponding to the projected area of the flow conduit. In other words, sufficiently far (e.g. at least ten times longer than a maximum dimension perpendicular to the first axis) from any disturbances resulting from bends, variations in cross sectional area, shape, and so forth. A Reynolds number of approximately 3000 may mean within ±10%, or within ±5%. Reynolds number may be determined from theory, simulations (e.g. finite element analysis) and/or experiments.

[0061] Instead of the peak flow region corresponding to flow velocities greater than or equal to the average flow velocity in the reference ultrasonic meter, the peak flow region may instead be defined to correspond to higher flow velocities. For example, if the average flow velocity in the reference ultrasonic meter is U_{avg} and the maximum is U_{max}, the peak flow region may be defined to correspond to flow velocities greater than or equal to $U_{avg}+f(U_{max}-U_{avg})$ with f equal to 0.1, 0.2, 0.25, 0.3, 0.4, 0.5, 0.6, 0.7, 0.75, 0.8, or 0.9

[0062] Flow velocity profiles in the reference ultrasonic meter in response to steady state fluid flow through the reference ultrasonic meter at a Reynolds number of approximately 3000 may be determined from theory, simulations (e.g. finite element analysis) and/or experiments.

[0063] Alternatively, the peak flow region may be approximately defined without consideration of fluid flows through the reference ultrasonic meter. For example, the peak flow region may be defined as a region which:

- **[0064]** is concentric with the projection of the flow conduit;
- **[0065]** is circular, or has the same shape and orientation as the projection of the flow conduit; and
- **[0066]** has one quarter or less of an area of the projection of the flow conduit.

[0067] When viewed projected onto the plane perpendicular to the first axis, at least half the projected area of the flow deflecting member may overlap the peak flow region.

[0068] When viewed projected onto the plane perpendicular to the first axis, the result of subtracting the projection of the flow deflecting member from the projection of the flow conduit may be a continuously connected second region.

[0069] When viewed projected onto the plane perpendicular to the first axis, the result of subtracting the projection of the flow deflecting member from the projection of the flow conduit may be two or more separate regions including a primary region. An area of the primary region in the projection may account for 75% or more of the total projected areas of the two or more separate regions. The area of the primary region in the projection may account for 80% or more of the total projected areas of the two or more separate regions. The area of the primary region in the projection may account for 85% or more of the total projected areas of the two or more separate regions. The area of the primary region in the projection may account for 90% or more of the total projected areas of the two or more separate regions. The area of the primary region in the projection may account for 95% or more of the total projected areas of the two or more separate regions.

[0070] The ultrasonic meter according to the third aspect may include features corresponding to any features of the ultrasonic meter according to the first aspect. Definitions applicable to the ultrasonic meter according to the first aspect may be equally applicable to the ultrasonic meter according to the third aspect.

[0071] According to a fourth aspect of the invention, there is provided an insert for an ultrasonic meter. The ultrasonic meter including a flow conduit for the fluid. The flow conduit extends along a first axis between a first opening and a second opening. The ultrasonic meter also includes one or more pairs of ultrasonic transducers. Each pair of ultrasonic transducers is configured to define a corresponding beam path intersecting the flow conduit within a measurement region of the flow conduit. Substantially every part of each beam path makes a non-zero angle with the first axis. When viewed projected onto a plane perpendicular to the first axis, a projection of a first beam path intersects a peak flow region. The peak flow region is defined relative to a projection onto the plane of a flow conduit of a reference ultrasonic meter which is identical to the ultrasonic meter except for omitting the flow deflecting member. The peak flow region corresponding to a region of the plane in which a flow velocity through the reference ultrasonic meter is above a mean flow velocity in response to passing a steady state fluid flow through the reference ultrasonic meter at a Reynolds number of approximately 3000. The insert includes a flow deflecting member configured such that, when the insert is received into the flow conduit, the flow deflecting member is supported between the first opening and the measurement region, and when viewed projected onto the plane perpendicular to the first axis, a projection of the flow deflecting member at least partially overlaps the intersection of the first beam path and the peak flow region.

[0072] The insert according to the fourth aspect may include features corresponding to any features of the ultrasonic meter according to the first and/or third aspects, and/or may be configured for use with any ultrasonic meter according to the first and/or third aspects. Definitions applicable to the ultrasonic meter according to the first aspect and/or the third aspect may be equally applicable to the insert according to the fourth aspect.

[0073] According to a fifth aspect of the invention, there is provided an insert for an ultrasonic meter. The ultrasonic meter including a flow conduit for the fluid. The flow conduit extends along a first axis between a first opening and a second opening. The insert is configured to be received within the flow conduit. The insert includes a flow passage for fluid having the same shape as the flow conduit and extending along the first axis. The insert also includes a flow deflecting member. When viewed projected onto a plane perpendicular to the first axis, a projection of a peak flow region is concentric with a projection of the flow passage, has the same shape and orientation as the projection of the flow passage, and has less than or equal to a quarter of the area of the projection of the flow passage. When viewed projected onto a plane perpendicular to the first axis, a projection of the flow deflecting member at least partially overlaps the peak flow region.

[0074] When viewed projected onto a plane perpendicular to the first axis, the projection of the flow deflecting member may correspond to the projection of the peak flow region.

[0075] The insert according to the fifth aspect may include features corresponding to any features of the ultrasonic meter according to the first and/or third aspects, and/or may be configured for use with any ultrasonic meter according to the first and/or third aspects. Definitions applicable to the ultrasonic meter according to the first aspect and/or the third aspect may be equally applicable to the insert according to the fifth aspect.

[0076] According to a sixth aspect of the invention there is provided use of the ultrasonic meter according to the first aspect, the insert according to the second aspect, the ultrasonic meter according to the third aspect, the insert according to the fourth aspect, or the insert according to the fifth aspect, for metering flow of a fluid. The fluid may be water. The fluid may be natural gas.

BRIEF DESCRIPTION OF THE DRAWINGS

[0077] Certain embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings in which:

[0078] FIG. **1** is a schematic cross-section of a first ultrasonic meter;

[0079] FIG. **2** is a schematic cross-section of a second ultrasonic meter;

[0080] FIG. **3** is a schematic end-on view of a dual-beam ultrasonic meter;

[0081] FIG. **4** is a schematic, cut-away projection view of the dual-beam ultrasonic meter shown in FIG. **3**;

[0082] FIG. **5** is a schematic end-on view of a tri-beam ultrasonic meter;

[0083] FIG. **6** illustrates an ultrasonic meter installed in a setter;

[0084] FIGS. **7**A and **7**B present calculated flow-speed profiles respectively just before and just after a sharp bend;

[0085] FIG. **8**A is a schematic end-on view which illustrates a flow conditioning device

[0086] FIG. **8**B is a schematic end-on view which illustrates a geometry used for comparative calculations of pressure drops;

[0087] FIG. **9** is a schematic cross-section which illustrates the effects of a flow conditioning device;

[0088] FIG. **10** is a schematic end-on view of a second dual-beam ultrasonic meter;

[0089] FIG. **11** is a schematic cross-section of the second dual-beam ultrasonic meter;

[0090] FIG. **12**A presents a calculated flow-speed profile immediately following a flow deflecting member positioned in a straight pipe;

[0091] FIG. **12**B presents a calculated flow-speed profile immediately following a flow deflecting member positioned after a sharp bend in a pipe;

[0092] FIG. **13** presents % errors measured for an ultrasonic meter including a flow deflecting member;

[0093] FIG. **14** is a schematic cross-section of a flow deflecting member;

[0094] FIG. **15**A is a schematic end-on view of the flow deflecting member shown in FIG. **14**;

[0095] FIGS. **15**B and **15**C are alternative cross-sections corresponding to the line labelled A-A* in FIG. **15**A;

[0096] FIG. **16**A is a schematic cross-section of a second flow deflecting member;

[0097] FIGS. **16**B and **16**C are cross-sections corresponding respectively to lines labelled B-B* and C-C* in FIG. **16**A;

[0098] FIG. **17** is a schematic cross-section of a third flow deflecting member;

[0099] FIG. **18** is a schematic cross-section of a fourth flow deflecting member;

[0100] FIGS. **19**A to **19**F illustrate an annular insert providing a flow deflecting member;

[0101] FIGS. **20**A and **20**B illustrate a second annular insert providing a flow deflecting member;

[0102] FIG. **21** schematically illustrates a first beam configuration;

[0103] FIG. **22** schematically illustrates a second beam configuration

[0104] FIG. **23** schematically illustrates a third beam configuration

[0105] FIG. **24** schematically illustrates a fourth beam configuration

[0106] FIG. **25**A schematically illustrates a fifth beam configuration;

[0107] FIG. **25**B is a schematic end-on view of flow deflecting members used with the fifth beam configuration shown in FIG. **25**A;

[0108] FIG. **26** schematically illustrates a peak flow region of a flow conduit having a circular cross-section;

[0109] FIG. **27** schematically illustrates a peak flow region of a flow conduit having a square cross-section;

[0110] FIG. **28** schematically illustrates a peak flow region of a flow conduit having a rectangular cross-section;

[0111] FIG. **29** is a schematic cross-section of a first combined ultrasonic meter;

[0112] FIG. **30** is a schematic cross-section of a second combined ultrasonic meter;

[0113] FIG. **31** is a schematic end-on view which illustrates an exemplary configuration of protrusions for an ultrasonic meter;

[0114] FIG. **32** is a schematic end-on view illustrating the positioning a flow deflecting member relative to the protrusions of the exemplary configuration shown in FIG. **31**;

[0115] FIG. **33** is a schematic end-on view of a single-beam ultrasonic meter;

[0116] FIG. **34** is a schematic, cut-away projection view of the dual-beam ultrasonic meter shown in FIG. **33**;

[0117] FIG. **35** is an schematic end-on view of a flow deflecting member in which a through-hole is formed in a supporting member;

[0118] FIG. **36** is an schematic end-on view of a flow deflecting member in which a supporting member has a differently shaped through-hole to that shown in FIG. **35**;

[0119] FIG. **37**A is a schematic cross-section of a first alternative configuration of a flow deflecting member, FIG. **37**B is a schematic end-on view of the first alternative configuration of a flow deflecting member;

[0120] FIG. **38**A is a schematic cross-section of a second alternative configuration of a flow deflecting member, FIG. **38**B is a schematic end-on view of the second alternative configuration of a flow deflecting member;

[0121] FIG. **39** is an schematic end-on view of a flow deflecting member having a blocking member held in place by three supporting members;

[0122] FIGS. **40**A is a schematic cross-section of a flow deflecting member having a blocking member held in place by a mesh, and FIG. **40**B is a schematic end-on view of the flow deflecting member having a blocking member held in place by a mesh.

DETAILED DESCRIPTION OF CERTAIN EMBODIMENTS

[0123] In the following, like parts are denoted by like reference numbers.

[0124] Whilst the protrusions detailed in WO 2019/229409 A1 can provide an ultrasonic meter with substantial immunity from flow-profile variations arising from the deployed location, further improvements in flow-profile immunity may be obtained using flow deflecting members described herein. This may be particularly useful for fluid meters which need to be installed in the vicinity of significant sections of curvature in supply and/or onward pipes, for example, in water-meter setters. The flow deflecting members described herein may be used in combination with protrusions described in WO 2019/229409 A1 for particularly high-tolerance applications. Equally, flow deflecting members described herein may be used without protrusions described in WO 2019/229409 A1 and may still provide improved flow-profile immunity.

[0125] The term "flow-profile immunity" herein refers to the sensitivity of an ultrasonic meter to differences between a steady state flow-speed profile (e.g. in a long, straight pipe) and the flow-speed profile in use, which may include transients and deviations from the steady state profile.

[0126] Similarly to the protrusions detailed in WO 2019/229409 A1, and by way of contrast to conventional flow conditioners, flow-deflecting members disclosed herein do not attempt to accelerate or force fluid flow to match a particular assumed flow-speed profile. Instead, the flow-deflecting members described herein operate according to a principle of deflecting fluid flows away from a particular region or regions of a fluid conduit, at least as the fluid flows through the measurement beams of an ultrasonic meter.

[0127] Referring to FIG. **1**, an ultrasonic meter **1** for measuring a flow-rate of a fluid is shown.

[0128] The ultrasonic meter **1** is useful for understanding the present invention. The ultrasonic meter **1** includes a first ultrasonic transducer **2** and a second ultrasonic transducer **3**. The first and second ultrasonic transducers **2**, **3** are spaced apart along a fluid flow path **4** in the form of a flow conduit **5**. The flow conduit **5** extends along a first axis **6** (z-axis in the FIG. **1** example) between a first opening **7** and a second opening **8**. The term "flow conduit" encompasses both the volume for fluid flow and also the structure or structures defining that volume. For example, a flow conduit **5** may often take the form of a pipe which encloses a pipe bore through which fluid may flow. However, the flow conduit **5** is not limited to pipes, and may take the form of any structure or structures capable of containing a fluid flow path **4**. The first and second transducers **2**, **3** are configured to define a beam path **9** between the first and second ultrasonic transducers **2**, **3** and having a component in a direction parallel to the first axis **6**. In other words, substantially every part of the beam path **9** makes a non-zero angle with the first axis **6**.

[0129] In the example shown in FIG. **1**, the first and second ultrasonic transducers **2**, **3** are offset from the fluid flow path **4** formed by the flow conduit **5** and oriented at angles $\pm\theta$ to the first axis **6**. Both ultrasonic transducers **2**, **3** are arranged spaced apart along the first axis **6** and on a first side **10** of the flow conduit **5**. The beam path **9** includes a reflection from a second side **11** of the flow conduit **5**, opposed to the first side **10**. The flow conduit **5** may include a separate reflector **12** (FIG. **3**), or the second side **11** of the flow conduit **5** may be integrally formed to function as a suitable reflector for the beam path **9**. The ultrasonic transducers **2**, **3** may be piezoelectric transducers, solenoid transducers, and so forth.

[0130] The beam path **9** has a finite cross-sectional area, and in general the cross-sectional shape of the beam path **9** will be related to the shapes of the first and second transducers **2**, **3**. However, an effective area of the beam path **9** will typically represent a fraction of the total transducer **2**, **3** area, because the power of the emitted ultrasound may be focussed towards the centre of the transducer **2**, **3**. The relative sensitivity of a transducer **2**, **3** used as a receiver is similarly greater towards the centre. Typically, the emitted power/sensitivity varies continuously across a face of a transducer **2**, **3**. Beam path **9** effective width w_b (or other appropriate dimension) may be defined as the width w_b over which the emitted power/sensitivity remains above a threshold value, for example half of maximum. For example, the transducers **2**, **3** may be circular and the beam path **9** may have an effective diameter w_b which is greater than or equal to ⅓ of a diameter of the transducers **2**, **3** and less than or equal to said diameter of the transducers **2**, **3**. In another example the transducers **2**, **3** may be square or rectangular, and the beam path **9** may have a square or rectangular cross-section with side length(s) w_b which is (are) greater than or equal to ⅓ of corresponding side lengths of the transducers **2**, **3** and less than or equal to said side lengths of the transducers **2**, **3**. Hereinafter, the effective beam path **9** width w_b (or other dimension) will be referred to rather than the transducer **2**, **3** dimensions, because the effective beam path **9** width w_b is more closely related to the volume of fluid which is sampled.

[0131] The beam path **9** intersects the flow conduit **5** within a measurement region **13** of the flow conduit. The measurement region **13** is the part of the flow conduit **5** which is sampled by the beam path **9**. The measurement region **13** spans between a first position z_1 and a second position z_2 spaced apart along the first axis **6**, and has a length along the flow path **4** of $d=z_2-z_1$. Portions of the measurement region **13** which intersect the effective width w_b (or other dimension) of one or more beam paths **9** may be referred to hereinafter as sampled volumes **13***a* of the measurement region **13**. Portions of the measurement region which are outside the effective width w_b (or other dimension) of any of the beam paths **9** shall be referred to hereinafter as non-sampled volumes **13***b* of the measurement region **13**. As discussed hereinafter, non-sampled volumes **13***b* of the measurement region **13** do not contribute to determining a calculated flow speed u.

[0132] The flow conduit **5** typically has a circular cross-section in a plane perpendicular to the first axis **6**, but may have other shapes such as square, rectangular, elliptical and so forth. Typically, though not essentially, the cross-sectional shape and/or area of the flow conduit **5** will be matched to pipes/conduits which supply fluid through the first opening **7** and into which the fluid flows through the second opening (or the reverse). In ultrasonic meter **1**, the flow conduit **5** is cylindrical with diameter D, for example the flow conduit **5** may take the form of a cylindrical pipe. The flow path **4** in FIG. **1** illustrates a fluid flow path **4** from the first opening **7** to the second opening **8**. In other examples, the flow path **4** may be directed from the second opening **8** to the first opening **7** instead.

[0133] The ultrasonic meter **1** also Ies a controller **14**, which is configured to drive the first and second ultrasonic transducers **2**, **3** alternately. In order to make a measurement of flow rate, the controller **14** may drive the first ultrasonic transducer **2** and measure a first time-of-flight t_1 based on reception of the signal at the second ultrasonic transducer **3**. The controller **14** then measures a second time of flight t_2 by driving the second ultrasonic transducer **3** and receiving the signal at the first ultrasonic transducer **2**. If the fluid in the flow conduit **5**, which may be a gas or a liquid, is moving from the first opening **7** towards the second opening **8** with a velocity, u, which is typically substantially directed along the first axis **6** then the total velocity of the sound v_1 when measuring the first time of flight t_1 will be:

$$v_1 = c + u \tag{1}$$

[0134] In which c is the velocity of sound in the fluid if the fluid was stationary (and directed along the beam path). Similarly, the total velocity v_2 when measuring the second time of flight t_2 will be:

$$v_2 = c - u \tag{2}$$

[0135] The transit times between the first ultrasonic transducer **2** and the measurement region **13** and between the second ultrasonic transducer **3** and the measurement region **13** are constant, and consequently the difference $\Delta t=t_2-t_1$ depends on the average velocity u in the flow conduit **5**. In this way, the controller **14** may determine the average speed u in the direction of the first axis **6** in the flow conduit **5**, and hence estimate a flow rate by assuming the flow is all parallel to the first axis **6**. In practice, the ultrasonic meter **1** may be calibrated using at least one, and preferably more, known flow rates of fluid passing through the flow conduit **5**.

[0136] However, it should be noted that the calculated flow speed u is an average across the fluid which passes through the beam path **9**. Any fluid which does not pass through the beam path **9** does not contribute to the measurement of the average speed u. In other words, fluid passing through at least one sampled volume **13***a* will contribute to the measurement of the average speed u, whereas fluid which only passes through non-sampled volumes **13***b* does not contribute to the measurement of the average speed u.

[0137] The controller **14** outputs a drive signal **15** to a transmitting ultrasonic transducer **2**, **3** via an impedance matching resistor R and a first switch or multiplexer **16**. The first switch **16** may be controlled to supply the drive signal **15** to either the first ultrasonic transducer **2** or the second ultrasonic transducer **3**. Whichever ultrasonic transducer **2**, **3** receives the drive signal **15** is the transmitting ultrasonic transducer for a measurement. The drive signal **15** may include a pulsed or square waveform having variable frequency, duty cycle and so forth.

[0138] Whichever ultrasonic transducer **2**, **3** does not receive the drive signal **15** is the receiving ultrasonic transducer for a measurement. The receiving ultrasonic transducer **2**, **3** detects an ultrasound signal from the transmitting ultrasonic transducer **2**, **3**, and converts it into a received electrical signal **17**. The received signal **17** is returned to the controller **14** via a second switch or multiplexer **18** and a signal conditioning circuit **19**. The first and second switches **16**, **18** are configured so that when, for example, the first switch **16** connects to the first ultrasonic transducer **2**, the second switch **18** will connect to the second ultrasonic transducer **3**, and vice-versa. The signal conditioning circuit **19** may perform amplification and/or filtering of the received signal **17** to generate a conditioned signal **20**. The controller **14** is configured to determine the times-of-flight t_1, t_2. Determination of the first and second times-of-flight t_1, t_2 may be carried out using a variety of methods. For example, the controller **14** may determine the times-of-flight t_1, t_2 by comparing the drive signal **15** with the conditioned signal **20**. Alternatively, the controller **14** may determine the times-of-flight t_1, t_2 by measuring a time between the start of the drive signal **15** and a reference point on the conditioned signal **20** such as, for example, reaching a certain signal amplitude or the m^{th} zero of the oscillation with m a positive integer (i.e. counting m periods).

[0139] The controller **14** may be a microcontroller, a microprocessor, or any other suitable data processing apparatus configurable to perform the described functions. In some examples, the controller **14**, the signal conditioning circuit **19**, and the first and second switches **16**, **18** may all be integrated into a single integrated circuit (for example an application specific integrated circuit, ASIC) in order to simplify the electronics of the ultrasonic meter **1**.

[0140] The first and second ultrasonic transducers **2**, **3** may be external to the flow conduit **5**, as shown in FIG. **1**. In such a configuration, first and second ultrasonic transducers **2**, **3** may be connected to the flow conduit **5** using impedance matching materials **21** to enhance transmission of ultrasound in and/or out of the flow conduit **5**. Alternatively, the first and/or second ultrasonic transducers **2**, **3** may be embedded within, or integrally formed as part of, a wall defining the flow conduit **5**. In other examples, the first and/or second ultrasonic transducers **2** may be located within the flow conduit **5**.

[0141] Referring also to FIG. **2**, a second ultrasonic meter **22** useful for understanding the present invention is shown. Only the centroid of the beam path **9** is shown in FIG. **2** for clarity of the illustration.

[0142] The second ultrasonic meter **22** is similar to the first ultrasonic meter **1**, except that the second ultrasonic transducer **3** is arranged on the second side **11** of the flow conduit **5**, such that the beam path **5** does not include a reflection, and such that $\tan(\theta_2)=D/d$.

[0143] As described hereinbefore, ultrasonic meters **1**, **22** measure an average fluid speed u which depends only on the fluid which intersects the beam path **9**. Any fluid which passes through the respective measurement region **13** without passing across the beam path **9** at least once (i.e. passes only through non-sampled volumes **13***b*) does not affect the measurement. Including a reflection in the beam path **9**, as in the first ultrasonic meter **1**, may extend the length of the beam path **9** compared to the second ultrasonic meter **22**. However, some fluid will still not intersect the beam path **9**. Consequently, in the first and second ultrasonic meters **1**, **22**, only a fraction of the actual fluid flow, that which passes through sampled volumes **13***a*, is measured. Any measurement of an average fluid speed u then inherently includes assumptions about the flow-speed profile through the meter **1**, **22**.

[0144] Conversion of the measured average speed u into a mass flow rate of the fluid relies upon an assumed speed u across the flow conduit **5** and known cross sectional area. At minimum, it must be presumed that the sampling of the fluid by the beam path is representative, which may often prove an inaccurate assumption. For example, in high volume applications, for example metering of irrigation or industrial water, even small % errors may lead to significant over- or under-estimation of water use.

[0145] The exemplary assumed flow speed profile of a cylindrical flow conduit **5** may be described by the empirical equation:

$$u(y) = u^*\left(\frac{y}{r}\right)^{\frac{1}{n}} \tag{3}$$

[0146] In which y is the distance from the first/second side **10**, **11**, perpendicular to the first axis **6**, u(y) is the local flow speed at position y, u* is the average flow speed measured by the ultrasonic meter **1**, **22**, r is the radius of the cylindrical flow conduit **5** and n is an empirically derived exponent. For an example of this form of assumed flow speed profile **22**, the reader is referred to FIG. **3** of WO 2019/229409 A1, which plots relative speed u(y)/u* on the vertical axis against relative distance across the flow conduit y/r for a value of n=10.

[0147] The value of the exponent n will depend on various properties of the ultrasonic meter **1**, **22** and fluid including, but not limited, to the flow rate, temperature, fluid viscosity and the geometry of the ultrasonic meter **1**, **22**.

[0148] A variety of techniques exist for correcting for an assumed flow-speed profile in an ultrasonic meter **1**, **22**. One option is to empirically, theoretically or computationally determine a correction factor to apply to the flow rate. Another option is to position the ultrasonic beams **9** in such a way that when they are added together they remain constant and independent of the flow profile.

[0149] However, any deviation of the actual local flow speeds from the assumed local flow speeds u(y) will introduce errors into the estimate of the mass flow of fluid passing the ultrasonic meter **1**, **22**. When an ultrasonic meter **1**, **22** is installed in, or directly downstream of, a long, straight section of pipe, an actual flow speed profile may be relatively close to an assumed flow speed profile determined from empirical measurements and/or modelling using fluid dynamics. However, proximity of bends, valves, pumps, constrictions and so forth either upstream or downstream of an ultrasonic meter **1**, **22** will cause the actual flow speed profile to differ from an assumed flow speed profile, reducing accuracy of the ultrasonic meter **1**, **22**. Such disturbances are difficult to predict and may also vary depending on the flow rate, temperature and so forth. In practical installations, there may not be a sufficiently long, straight section of piping in which to install an ultrasonic meter **1**, **22** to ensure accurate measurements. This is particularly the case when an ultrasonic meter is to be installed in a water meter setter, for example, to replace a mechanical meter.

[0150] In ultrasonic meters which include multiple beam paths **9**, there are additional sources of potential calibration error.

[0151] Referring also to FIGS. **3** and **4**, beam paths $\mathbf{9}_1$, $\mathbf{9}_2$ are illustrated for a dual-beam ultrasonic meter **23**.

[0152] The dual beam ultrasonic meter **23** has a cylindrical flow conduit **5** defined by a cylindrical pipe **24**. The dual beam ultrasonic meter **23** includes a pair of beam paths $\mathbf{9}_1$, $\mathbf{9}_2$ defined between respective pairs of first $\mathbf{2}_1$, $\mathbf{2}_2$ and second $\mathbf{3}_1$, $\mathbf{3}_2$ ultrasonic transducers. The first beam path $\mathbf{9}_1$ is effectively the same as the beam path **9** of the first ultrasonic meter **1**, and the second beam path $\mathbf{9}_2$ is identical except that it is rotated by 90° about the first axis **6** (corresponding to the z direction as illustrated). Substantially every part of both beam paths $\mathbf{9}_1$, $\mathbf{9}_2$ makes a non-zero angle with the first axis **6**. In other words, this specification is not concerned with ultrasonic meters in which a measurement is primarily made using a beam running parallel to a flow direction through a flow conduit **5**.

[0153] Referring in particular to FIG. **4**, the beam paths $\mathbf{9}_1$, $\mathbf{9}_2$ intersect at two points through the measurement region. Fluid which flows through the volumes of intersection between the beam paths $\mathbf{9}_1$, $\mathbf{9}_2$ is sampled twice. An ultrasonic meter such as the dual beam ultrasonic meter **23** may be particularly sensitive to deviations from an assumed flow-speed profile which occur in double (triple, etc) sampled regions. As discussed hereinafter in relation to FIG.

21, fluid flows may be double or tripled sampled etc even if the volumes of the beam paths **9** do not actually intersect in 3D space.

[0154] Indeed, referring in particular to FIG. **3**, the inventors have found that it is sufficient to consider the projections of the flow conduit **5** and beam paths $\mathbf{9}_1$, $\mathbf{9}_2$ onto a plane perpendicular to the first axis **6**. In the illustration of FIG. **3**, the first axis **6** is parallel to the z direction as drawn, so the projection plane corresponds to the x-y plane. A projected intersection **25** on the projection plane (x-y) is defined as the intersection between a projection of the first beam path $\mathbf{9}_1$ and a projection of the second beam path $\mathbf{9}_2$. Although flow through the flow conduit **5** will not in practice be completely parallel to the first axis **6**, in almost all practical circumstances, flow velocities through an ultrasonic meter **1**, **22**, **23** will generally have the largest component parallel to the first axis **6**. Consequently, in the absence of being re-directed/deflected, fluid flowing through a portion of the first opening **7** corresponding to the projected intersection **25** is most likely to pass through both the first and second beam paths $\mathbf{9}_1$, $\mathbf{9}_2$.

[0155] As explained further in relation to FIG. **10**, the inventors have found that sensitivity to disturbances of an incident flow-speed profile from a steady state condition may be reduced by intentionally introducing a significant disturbance in the form of a flow deflecting member **26** (FIG. **10**) supported between the first opening **7** and the start of the measurement region **13** (position z**1**). In particular, when viewed projected onto the plane (x-y) perpendicular to the first axis **6**, a projection/projected area of the flow deflecting member **26** (FIG. **10**) at least partially overlaps the projected intersection **25** between the first $\mathbf{9}_1$ and second $\mathbf{9}_2$ beam paths. Whilst seemingly counter-intuitive, the introduction of a controlled disturbance which deflects fluid flow away from a relatively sensitive volume may reduce a degree of difference in measurements in response to a deviation between incident flow-speed profiles during calibration and when installed, improving accuracy.

[0156] Referring also to FIG. **5**, a tri-beam ultrasonic meter **27** is shown.

[0157] The tri-beam ultrasonic meter **27** is the same as the dual-beam ultrasonic meter **23**, except that it includes three beam paths $\mathbf{9}_1$, $\mathbf{9}_2$, $\mathbf{9}_3$ defined between respective pairs of first $\mathbf{2}_1$, $\mathbf{2}_2$, $\mathbf{2}_3$ and second $\mathbf{3}_1$, $\mathbf{3}_2$, $\mathbf{3}_3$ ultrasonic transducers. The beam paths $\mathbf{9}_1$, $\mathbf{9}_2$, $\mathbf{9}_3$ all have the same shape, the second beam path $\mathbf{9}_2$ is rotated by 60° clockwise from the first beam path $\mathbf{9}_1$, and the third beam path $\mathbf{9}_3$ is rotated by 60° clockwise from the second beam path $\mathbf{9}_2$.

[0158] When projected onto a plane (x-y) perpendicular to the first axis **6**, there are multiple regions where the projections of beam paths $\mathbf{9}_1$, $\mathbf{9}_2$, $\mathbf{9}_3$ intersect. In a central, hexagonal shaped region (cross-hatched shading), all three beam paths $\mathbf{9}_1$, $\mathbf{9}_2$, $\mathbf{9}_3$ intersect, whilst surrounding triangular regions (diagonal shading) correspond to intersections of a pair of the beam paths $\mathbf{9}_1$, $\mathbf{9}_2$, $\mathbf{9}_3$. For the purposes of this specification, unless explicitly stated otherwise, the projected intersection **25** corresponds to the union of all such adjacent regions. In other words, the projected intersection **25** for the tri-beam ultrasonic meter **27** has the shape of a six-pointed star. A pair of projected intersections **25** will be considered to be separate where there is not overlap between them (see FIG. **25**A).

[0159] Before discussing the flow deflecting member **26** (FIG. **10**) in further detail, it shall be helpful to briefly discuss the reasons why the flow speed profiles through ultrasonic meters often deviate in use from steady state conditions typically used during calibration.

[0160] Referring also to FIG. **6**, a first ultrasonic meter **1** is shown installed in a "setter" **28**.

[0161] A setter **28** is a structure commonly found in water meter installations, although the same or similar structures may be found in systems for delivering other fluids such as gases. A fluid flow path **29** enters the setter **28** through a first straight pipe section **30**, then enters a first serpentine section **31** which serves to re-direct flow to a first setter opening **32** which is generally parallel to, but offset from, an axis **33** of the first straight pipe **30**. The first setter opening **32** is opposed across a gap by a second setter opening **34** leading into a second serpentine section **35** which re-directs flow to a second straight pipe section **36** running parallel to the original axis **33**. In the example shown in FIG. **6**, the setter openings **32**, **34** are offset upwards relative to the illustrated y-axis. In practice, such configurations are often used to bring fluid flow in a buried pipe closer to the surface to facilitate the installation, servicing, replacement and/or reading of a fluid flow meter.

[0162] In the example shown in FIG. **6**, the second serpentine section **35** is the mirror image of the first serpentine section **31**, and this is often the case for setters **28**. However, in principle there is no reason why the serpentine sections **31**, **35** need to be mirror images of one another. The configuration that each serpentine section **31**, **35** bends back on itself is commonly used to minimise the size (or "footprint") of the setter **28**. For example, such that the entire setter **28** may be contained in as small a hole as possible when included in an underground pipe.

[0163] It is also not essential that the second straight pipe section **36** be parallel and/or oriented in the same direction as the first straight pipe section **30**. In other words, the setter **28** may be disposed at a point where a fluid pipeline changes direction and/or position. The first and second straight pipe sections **30**, **36** may be connected to fluid pipelines (not shown) extending away from the setter **28**, for example, using bolted flange connections (see FIGS. **29** and **30**). Alternatively, the first and second straight pipe sections **30**, **36** may be omitted, and the serpentine sections **31**, **35** may connect directly to a fluid pipeline which is being metered.

[0164] An ultrasonic meter **1** is received between the first **32** and second **34** setter openings, and secured in place using, for example, bolted flanges (not shown in FIG. **6**, see FIGS. **29** and **30**). Although the first ultrasonic meter **1** is shown in FIG. **6**, any ultrasonic meter described hereinbefore or hereinafter may be used instead.

[0165] The first and second serpentine sections **31**, **35** are often connected by one or more support members **37** which serve to maintain relative positions and alignments of the first and second setter openings **32**, **34** when no ultrasonic meter is installed.

[0166] As the fluid flow path **29** enter the first straight pipe section **30**, it may have an approximately steady state flow-speed profile, for example as described by Equation (3) and illustrated in FIG. **3** of Wo 2019/229409 A1.

[0167] For example, referring also to FIG. **7**A, a contour plot of a modelled steady state flow-speed profile is shown for a cylindrical pipe.

[0168] The modelling was finite-element analysis (FEA) modelling conducted using the COMSOL Multiphysics (RTM) software package (version 5.6.0.341). The pipe was modelled for flow of a fluid **29** in the form of water at 293.15 K, and the cylindrical piper had an internal diameter of 4 cm. The flow rate was 1 $m^3 \cdot hr^{-1}$. Selected contours are labelled with the corresponding speed in $m \cdot s^{-1}$. The speeds shown are the components of a calculated velocity field $\underline{v}(x,y,z)$ along the first axis **6**, i.e. $\underline{v}(x,y,z).e_z$, with e_z a unit vector along the first axis **6**. It may be observed that the flow speed profile matches expectations for steady state flow down a pipe with no-slip boundary conditions.

[0169] However, once fluid flows through the first serpentine section **31**, the flow-speed profile is significantly disturbed.

[0170] For example, referring also to FIG. **7**B, a contour plot of a modelled steady state flow speed profile is shown for a cylindrical pipe immediately after a 90° bend.

[0171] The modelling used the same parameters and total flow rate as the model shown in FIG. **7**A, all that was changed was to change the cylindrical pipe from straight to bent.

[0172] It may be observed that the flow speed profile is substantially skewed towards an outer side of the bend, which in this example corresponds to the positive x-axis direction (with the z-axis directed into the page).

[0173] Since ultrasonic meters **1**, **22**, **23**, **27** are calibrated based on known flow rates having flow-speed profiles approximating the steady state case of FIG. **7**A, the disturbances introduced from a bend or similar, as shown in FIG. **7**B, may lead to inaccuracies in measurements of flow speed u of as much as 10%. In addition, the actual deviation (relative to steady state) of a flow-speed profile at a given installation location depends on the details of that installation location, which in general is not known in advance. For example, there may be a setter **28** or similar arrangement, or there may be no setter **28**. Even if you knew that a setter **28** would be used, these can vary widely in terms of shape and so forth.

[0174] In the context of chemical plants or manufacturing processes, accurate knowledge of how much fluid has flowed/is flowing along a flow conduit **5** may be important for process efficiency, process control and/or safety. In an economic context, if an ultrasonic flow meter **1**, **22**, **23**, **27** is used to meter a quantity of fluid supplied from a provider to a consumer, measurement errors will cause the consumer to be overcharged or the provider to be underpaid. Therefore, as discussed elsewhere herein, there has been interest in improving the accuracy of ultrasonic meters **1**, **22**, **23**, **27**.

[0175] One approach has been to add further pairs of ultrasonic transducers **2**, **3** in order to define additional beam paths **9** and increase a fraction of the fluid which is sampled. In other words, in order to increase the relative fraction of sampled volumes **13***a* compared to non-sampled volumes **13***b*. However, adding further pairs of ultrasonic transducers **2**, **3** increases the cost and complexity of an ultrasonic meter **1**, **22**, **23**, **27**, and there will always be some residual non-sampled volumes **13***b* within the measurement region **13**, which are not sampled by any beam path **9**. Additionally, as explained hereinbefore in relation to FIGS. **3** to **5**, sampling the same volume of the measurement region **13** two or more times may actually amplify errors resulting from a flow-speed profile through such multi-sampled volumes deviating from an assumed and calibrated profile.

[0176] Another approach to improving the accuracy of an ultrasonic meter **1**, **22**, **23**, **27** has been to install one of more flow conditioning devices **38** (FIG. **8**A) upstream and/or downstream of an ultrasonic meter **1**, **22**, **23**, **27**. Flow conditioning devices **38** (FIG. **8**A) are used to force the flow speed profile into a known flow speed profile matching that used for calibration of an ultrasonic meter.

[0177] Referring also to FIG. **8**A, an example of a flow conditioning device **38** is shown.

[0178] The exemplary flow conditioning device **38** includes a cylindrical body **39** dimensioned to fit across a cylindrical flow conduit **5**, and including a number of through-holes **40** which permit flow of the fluid.

[0179] Referring also to FIG. **9**, flow of a fluid through, and downstream of, the exemplary flow conditioning device **38** is illustrated.

[0180] As the fluid **29** is forced through the flow conditioning device **38**, a jet **41** emerges from each through-hole **40**. As the fluid continues to flow along the flow conduit **5**, the jets **41** gradually merge. A distance m·D after the flow conditioning device **38**, in which m is a scalar multiplier m>0, the fluid **29** develops a stable, steady state flow-speed profile **42**. The multiplier m is usually a factor of about four or five, i.e. a distance of four or five times the diameter D of a cylindrical flow conduit **5**. An ultrasonic flow meter **1**, **22**, **23**, **27** cannot be placed too close to such a conventional flow conditioning device **38**, since the intention is to obtain the steady state flow speed profile **42**, which requires a distance from the flow conditioning device **38**. For example, if the ultrasonic meter **1**, **22**, **23**, **27** is placed at least m·D away from the flow conditioning device **38**, a repeatable flow speed profile may be obtained.

[0181] The flow conditioning device **38** shown in FIGS. **8**A and **9** is only one example, and a wide range of different structures are available, though all operate according to similar principles based on forcing flow-speed profiles to return more quickly to a steady state distribution.

[0182] Although flow conditioning devices allow greater flexibility in the locations for installing an ultrasonic meter **1**, **22**, **23**, **27**, a straight section of sufficient length to permit development of a steady state flow speed profile **42** is still required. Additionally, as a flow conditioning device **38** is required to effectively reset the flow speed profile, significant impacts on the flow are unavoidable, and pressure drops across flow conditioning devices may be substantial. For example, from FEA modelling using the same parameters as the data shown in FIGS. **7**A and **7**B, and a flow conditioning device including 17 holes of diameter 5 mm each, a pressure drop of **549** Pa was calculated.

[0183] Flow conditioning devices **38** may also increase the complexity of installing an ultrasonic meter **1**, **22**, **23**, **27**, as two devices are installed at two different locations, or else the flow conditioning device must be inserted and secured some distance from a pipe opening. Some applications have requirements which may prevent the use of many common flow conditioning devices **38**. For example, in fluids which include entrained solid matter (a good example being irrigation water containing plant matter), a flow conditioning device **38** as shown in FIGS. **8**A and **9** may be susceptible to clogging.

[0184] This pressure drop associated with a conventional flow conditioning device **38** may be contrasted with pressure drops corresponding to simpler obstructions.

[0185] Referring also to FIG. **8**B, a schematic geometry used for FEA modelling of pressure drops is shown.

[0186] FEA modelling used the same parameters described hereinbefore. The flow conduit **5** was a cylindrical pipe with internal diameter D=40 mm. A cylindrical obstruction **43** with diameter h was modelled positioned concentrically with the cylindrical pipe and extending for a distance 23 mm along the first axis **6**. Pressure drops across the cylindrical obstruction **43** were calculated for three different ratios h/D of obstruction **43** to flow conduit 5 diameters:

h/D	Pressure drop/Pa
0.25	10.73
0.5	25.53
0.75	137.68

[0187] It may be observed that, for modest ratios h/D, the pressure drop due to an obstruction is predicted to be less than that associated with a conventional flow conditioning device **38**.

[0188] The present specification concerns the inventors realisation that ultrasonic meters and/or inserts for ultrasonic meters may be produced which reduce sensitivity to variations in the incident flow-speed profile of fluids, based on the targeted placement of an obstruction upstream of the measurement region **13**. Ultrasonic meters and/or inserts according to the present specification may increase the range of locations in which an ultrasonic meter may be installed whilst providing accurate measurements. Ultrasonic meters and/or inserts according to the present specification may be combined with protrusions and other features described in WO 2019/229409 A1, so as to further reduce the sensitivity to variations in an incident flow-speed profile of measured fluids.

[0189] In contrast to conventional approaches such as conditioning the flow to provide a repeatable and reliable steady state flow-speed profile, the present specification does not try to control the flow-speed profile to a fully developed steady state flow as a prior art flow conditioner would. Instead, the present specification describes using one or more flow deflecting members which are arranged to deflect fluid **29** flow away from corresponding projected intersections **25**, where an ultrasonic meter may be particularly sensitive to variability in an incident flow-speed profile (as compared to a steady state calibration condition). In this way, the present invention does not rely on an assumed flow-speed profile. Consequently, the sensitivity of an ultrasonic meter to disturbances caused by corners, valves, constrictions, pumps and so forth may be reduced.

Ultrasonic Meter Including a Flow Deflecting Member

[0190] Referring also to FIGS. **10** and **11**, a second dual beam ultrasonic meter **44** is shown.

[0191] FIG. **10** shows a projection onto a plane perpendicular to the first axis **6**, and FIG. **11** shows a schematic cross section along the centre of the second dual beam ultrasonic meter **44**.

[0192] The second dual beam ultrasonic meter **44** includes a flow conduit **5** for the fluid **29**. The flow conduit **5** extends along the first axis **6** between a first opening **7** and a second opening **8**. In the example of the second dual beam ultrasonic meter **44**, the flow conduit **5** is a cylindrical flow conduit having internal diameter D. However, this shape is not essential, and an ultrasonic meter according the present invention may include a flow conduit **5** having any shape permitting through-flow of fluid. Whilst the flow conduit **5** preferably has a constant cross-section and area (perpendicular to the first axis **6**), at least through a majority of the measurement region **13**, this is not essential.

[0193] The second dual beam ultrasonic meter **44** includes two pairs of ultrasonic transducers $\mathbf{2}_1$, $\mathbf{2}_2$, $\mathbf{3}_1$, $\mathbf{3}_2$, each pair defining a corresponding beam path $\mathbf{9}_1$, $\mathbf{9}_2$ intersecting the flow conduit **5** within a measurement region **13** of the flow conduit **5**. The beam paths $\mathbf{9}_1$, $\mathbf{9}_2$ of the second dual beam ultrasonic meter **44** are V-shaped with one reflection each (as illustrated in FIG. **1**), so that substantially every part of either beam path $\mathbf{9}_1$, $\mathbf{9}_2$ makes a non-zero angle θ with the first axis **6**. The first and second beam paths $\mathbf{9}_1$, $\mathbf{9}_2$ are rotated 90° from one another about the first axis **6**. When viewed projected onto a plane perpendicular to the first axis **6** (an x-y plane as illustrated, for example corresponding to the first opening **7**), a projection of a first beam path $\mathbf{9}_1$ intersects a projection of a second beam path $\mathbf{9}_2$ to define a projected intersection **25**. In the second dual beam ultrasonic meter **44**, the projected intersection **25** is square, with a projected area of the beam width w_b squared w_b^2.

[0194] A flow deflecting member **26** is supported between the first opening **7** and the measurement region **13**. When viewed projected onto the plane (x-y) perpendicular to the first axis **6** (as in FIG. **10**), a projection of the flow deflecting member **26** overlaps the intersection **25** of the projections of the first $\mathbf{9}_1$ and second $\mathbf{9}_2$ beam paths.

[0195] The second dual-beam ultrasonic meter **44** is essentially the same as the dual-beam ultrasonic meter **23**, except for the addition of the flow deflecting member **26**. The flow deflecting member **26** acts to deflect fluid **29** flows which would be sampled by both the first beam path $\mathbf{9}_1$ and the second beam path $\mathbf{9}_2$ (double sampled).

[0196] In this way, when the second dual-beam ultrasonic meter **44** is calibrated, the action of the flow deflecting member prevents excessive sensitivity to fluid flowing through the projected intersection, by deflecting flow away from multiply-sampled volumes (see FIG. **4**). Consequently, the second dual-beam ultrasonic meter **44** may be less sensitive to variations in an incident flow-speed profile.

[0197] The second dual-beam ultrasonic meter **44** is a specific example, but in the general case a flow deflecting member **26** may be employed in any ultrasonic meter for measuring a flow-rate of a fluid which includes a flow conduit **5** extending along a first axis **6** between a first opening **7** and a second opening **8**, and having two or more pairs of ultrasonic transducers **2**, **3**. Each pair of ultrasonic transducers **2**, **3** is configured to define a corresponding beam path **9** intersecting the flow conduit **5** within a measurement region **13** of the flow conduit **5**, substantially every part of each beam path **9** makes a non-zero angle with the first axis **9**. The beam paths **9** are not restricted to 90° angular separations about the first axis **6**, as shown for the second dual-beam ultrasonic meter **44**, and may be configured in any way provided that substantially every part of each beam path **9** makes a non-zero angle with the first axis **9**. In general, there is not any requirement for beam paths **9** to be related to one another by rotational symmetry about the first axis **6**. In the general case, when viewed projected onto a plane perpendicular to the first axis **6**, a projection of at least a first beam path $\mathbf{9}_1$ should intersect at least a projection of a second beam path $\mathbf{9}_2$. Multiple projected intersections

25 may be present, and each may be associated with a corresponding flow deflecting member **26** (see for example FIGS. **25**A and **25**B).

[0198] In the general case, at least one flow deflecting member **26** is supported between the first opening **7** and the measurement region **13**, and when viewed projected onto the plane perpendicular to the first axis **6**, a projection of the flow deflecting member **26** should at least partially overlap the intersection **25** of the projections of the first $\mathbf{9}_1$ and second $\mathbf{9}_2$ beam paths.

[0199] When it is stated herein that substantially every part of each beam path **9** makes a non-zero angle with the first axis **6**, this may mean that 75% or more of a length along the beam path **9** corresponds to parts which make a non-zero angle with the first axis **6**. Preferably, every part of each beam path, i.e. the entire length, makes a non-zero angle with the first axis **6**, as in the V-shaped beam paths shown of the. When a part of a beam path **9** is said to make a non-zero angle with the first axis **6**, that non-zero angle may be between 10 degrees and 80 degrees (inclusive of end-points). Another way to consider this is that each beam path **9** should preferably be configured so that within the measurement region **13**, the intersection of that beam path with the measurement region **13** includes a component parallel to the first axis **6** and a component transverse to the first axis **6**.

[0200] In the second dual-beam ultrasonic meter **44**, the flow deflecting member includes a blocking member **45** disposed within the fluid conduit **5** and held in place by a supporting member **46**. This configuration is preferred, although in other examples there may be multiple supporting members.

[0201] Preferably, the blocking member **45** and the supporting member **46** are integrally formed. However, it is possible to form a flow deflecting member using a blocking member **45** and a supporting member **46** in the form of separate structures which are bonded, welded or otherwise attached to one another. When viewed projected onto the plane perpendicular to the first axis **6**, a projection of the blocking member **45** should at least partially overlap the intersection **25** between projections of the first $\mathbf{9}_1$ and second $\mathbf{9}_2$ beam paths.

[0202] The flow deflecting member **26**, including the blocking member **45** and supporting member **46** when present, may be formed from polymeric materials, metals (which will not excessively corrode in the fluid **29** to be measured), composite materials, or any other materials suitable for forming rigid and mechanically robust structures. Examples of suitable materials include polyphenylene sulfide (PPS), high density polyethylene (HDPE), polyoxymethylene composites (POMC), for example glass fibre reinforced/filled. Examples of metals include stainless steel, coated cast iron, copper and so forth.

[0203] As illustrated in FIGS. **10** and **11**, the supporting member **46** serves to connect the blocking member **45** to an interior surface of the fluid conduit **5**. However, in some examples the supporting member **46** may instead connect the blocking member **45** to an annular insert **47** (FIGS. **19**A to **19**F) received within the fluid conduit **5**. Provision of the flow deflecting member **26** using an annular insert **47** has advantages for maintenance, cleaning and/or replacement of the flow deflecting member **26**.

[0204] When viewed projected onto a plane perpendicular to the first axis **6** (x-y as illustrated), a projection of the supporting member **46** connects to a projection of the blocking member **45** along a connection direction (parallel to the y-axis in FIG. **10**), and a maximum dimension of the projection of the blocking member **45** perpendicular (along the x-axis as illustrated) to the connection direction y is greater than a maximum dimension of the projection of the supporting member **46** perpendicular to the connection direction y. This is preferred to minimise a pressure drop across the flow deflecting member **26**, however, in other examples there may be no meaningful distinction between a blocking member **45** and a supporting member **46**.

[0205] When viewed projected onto the plane perpendicular to the first axis **6**, the projection of the blocking member **45** may be substantially circular as shown in FIG. **10**. However, in other examples, the projection of the blocking member **45** may be oval or elliptical in shape, or indeed any other suitable shape, for example, the projection of the blocking member **45** may be shaped to match a shape of a corresponding projected intersection **25** of beam paths **9**. When a projection of a blocking member **45** is described as substantially oval, elliptical or circular, this refers to said projection of the blocking member **45** being oval, elliptical or circular except where it meets the projection of the supporting member **46**.

[0206] The purpose of the flow deflecting member **26** is to intentionally disrupt fluid flows, and as such, the flow deflecting member **26** should not include any portions which are conical, frustoconical, pyramidal, frustopyramidal and so forth. This applies to both the blocking member **45** and the supporting member **46**, when present. Additionally, the flow deflecting member should be configured such that swirl is not introduced in response to a straight fluid flow passing the flow deflecting member **26**. This is because it is preferable for the measurement of fluid speed for fluid to follow paths through the measurement region **13** which, as far as possible, lie parallel to the first axis **6**.

[0207] The pressure drop across a flow deflecting member **26** should preferably be no more than 0.15 Pa with an average flow velocity in the conduit of 0.15 m/s with 20° C. water. Pressure drops may be measured experimentally, or may be calculated theoretically, for example using FEA simulations. The pressure drop may be managed primarily by varying the dimensions of the blocking member **45**.

[0208] For example, starting from the geometry and parameters explained in relation to FIG. **8**B, the pressure drop for a cylindrical blocking member **45** of diameter h=12 mm and length 23 mm, and held in position by a supporting member **46** of width 7 mm and length 34 mm, the pressure drop across the flow deflecting member calculated from FEA modelling was 10.66 Pa.

[0209] When viewed projected onto the plane perpendicular to the first axis **6** (e.g. x-y plane in FIG. **10**), the projection of the flow deflecting member **26** should not divide a projection of the flow conduit **5** into two separate regions. This may help to avoid catching/trapping of entrained particles and/or fibres on the flow deflecting member **26**. Compared to, for example, the flow conditioning device **38**, this can make the flow deflecting member **26** less susceptible to clogging. This may be particularly useful when the fluid is, for example, waste-water or irrigation water, which may include natural and/or human produced detritus.

[0210] The effectiveness of the flow deflecting member **26** may be further increased if, in addition to at least partially overlapping a projected beam intersection, the flow deflecting member **26** also at least partially overlaps the projection of a peak flow volume **48** onto the plane perpendicular to the first axis **6**. The peak flow volume **48** corresponds to the volume through which a flow speed through a reference ultrasonic meter would be above a mean flow speed in response to passing a steady state fluid flow through the reference ultrasonic meter at a Reynolds number of approximately 3000. The reference ultrasonic meter in a given case corresponds to an ultrasonic meter which is identical except for omission of any flow deflecting members **26**. The peak flow volume **48** and related parameters are discussed in further detail with reference to FIGS. **26** to **28** hereinafter.

Effect of the Flow Deflecting Member

[0211] Referring also to FIG. **12**A, FEA simulation results are shown corresponding to FIG. **7**A, except that a flow deflecting member **26** was added to the model, having a blocking member **45** of diameter h=12 mm and length 23 mm, and held in position by a supporting member **46** of width 7 mm and length 34 mm The flow speed profile is shown immediately downstream from the flow deflecting member **26**.

[0212] Referring also to FIG. **12**B, FEA simulation results are shown corresponding to FIG. **7**B, with the inclusion of the same flow deflecting member **26** as for FIG. **7**A.

[0213] Comparing FIGS. **12**A and **12**B with FIGS. **7**A and **7**B, it may be observed that the inclusion of the flow deflecting member **26** results in reduced influence of the bend on the flow speed profile, both qualitatively and quantitatively. In other words, the differences between FIGS. **12**A and **12**B are less pronounced that the differences between FIGS. **7**A and **7**B.

[0214] Since the flow-speed profiles of FIGS. **7**A and **12**A correspond to typical calibration conditions, it may be observed that an ultrasonic meter including the flow deflecting member **26** remains closer to the corresponding calibrated state that an ultrasonic meter without a the flow deflecting member **26**, even when installed immediately after a sharp bend.

[0215] Referring also to FIG. **13**, experimentally measured % errors for fluid flows emerging from a sharp bend are plotted as a function of total flow rates when using a flow deflecting member **26** positioned within 1 cm of the exit from a bend (first series **49**—solid line), or when using a flow deflecting member **26** positioned within **1** cm of the measurement region (second series **50**, dashed line). In both cases, the flow deflecting member **26** used was that of the second annular insert **47***b* shown in FIGS. **20**A and **20**B.

[0216] In may be observed that the % error was held within a range of −1.5% to 0.5% throughout, and across most flow rates when just before the measurement region **13**, the % error was held between −1% and 0%.

Flow Deflecting Member Shape

[0217] The following discussion of optional, specific features of flow deflecting member **26** is applicable to any flow deflecting members **26** described hereinbefore and/or hereinafter.

[0218] Referring also to FIG. **14**, a flow deflecting member **26** including a blocking member **45** and a supporting member **46** is shown in a schematic cross section spanning between the first opening **7** and the start of the measurement region **13**.

[0219] Referring also to FIG. **15**A, is a view of the flow deflecting member **26** shown in FIG. **14**, projected onto a plane perpendicular to the first axis **6**.

[0220] Referring also to FIGS. **15**B and **15**C, examples of schematic cross-sections through the blocking member **45** along the line labelled A-A* in FIG. **15**A are shown.

[0221] The flow deflecting member **26** is separated from the measurement region **13** by a distance L along the first axis which is between zero and five times a maximum dimension of the flow conduit **5** perpendicular to the first axis **6**. In the example shown in FIG. **14**, the flow conduit **5** is cylindrical within an interior diameter D, however, in a square or rectangular flow conduit, the maximum dimension may take the form of a diagonal. The separation distance L is shown between the start of the measurement region **13** and the supporting member **46**, however, the distance L may alternatively be defined as a separation of the blocking member **45** from the measurement region **13**.

[0222] When viewed projected onto a plane parallel to the first axis **6**, the flow deflecting **26** member has a quadrilateral shape. In the example shown in FIG. **14**, the plane parallel to the first axis **6** is an x-z plane, and is also parallel to a mirror plane of the flow deflecting member **26**. In the example shown in FIG. **14**, the quadrilateral shape is a trapezium. In general, the quadrilateral shape has a first side **51** parallel to the first axis **6** and disposed at or near an outer wall of the flow conduit **5**, a second side **52** parallel to the first axis **6** and shorter than the first side **51**, a third (or "leading") side **53** facing towards the first opening **7** and making a first internal angle θ_{19} to the first side **51**, and a fourth (or "trailing") side **54** facing towards the measurement region **13** and making a second internal angle θ_{14} to the first side **51**. In the example shown in FIG. **14**, the first internal angle θ_{19} is less than the second internal angle θ_{14}, $\theta_{13}<\theta_{14}$. However, in general the first θ_{13} and second θ_{14} angles may be equal, or may be different. The first angle θ_{19} may range between 45 and 80 degrees (inclusive of endpoints), whilst the second angle θ_{14} may range between 45 and 135 degrees (inclusive of endpoints). The range of the second angle θ_{14} encompasses the quadrilateral shape taking the form of a parallelogram.

[0223] Referring in particular to FIG. **15**B, the leading side **53** of the flow deflecting member **26** facing towards the first opening **7** may have a rounded bevel profile **55** around all, or at least part, of the perimeter of the leading side **53**. The rounded bevel profile **55** may extend around the portion of the leading side **53** corresponding to the blocking member **45** and/or the portion of the leading side **53** corresponding to the supporting member **46**. Instead of a rounded bevel profile **55**, all or part of the leading side **53** may have a fillet, tapering or chamfered profile.

[0224] For example, referring in particular to FIG. **15**C, the leading side **53** of the flow deflecting member **26** facing towards the first opening **7** may have a chamfer profile **56** making a chamfer angle Oc to the first axis **6**.

[0225] In contrast to the first side **53**, the trailing side **54** of the flow deflecting member **26** facing towards the measurement region **13** may have a sharp edge **57** around all, or at least part, of the perimeter of the trailing side **54**. For example, the sharp edge **57** may correspond to a Kamm-tail profile. The sharp edge **57** may extend only around the portion of the trailing side **54** corresponding to the blocking member **45**, whilst the portion of the trailing side **54** corresponding to the supporting member **46** may be configured for streamlining, for example using a rounded bevel profile, a fillet profile, a tapering profile or a chamfered profile.

[0226] A sharp edge **57** around at least the portion of the trailing side **54** corresponding to the blocking member **45** is preferred because this acts to prevent reconnecting streamlines downstream of the blocking member **45**. The intention is to deflect flow away from the volume occluded (when viewed along the first axis **6**) by the blocking member **45** of the flow deflecting member **26**.

[0227] In practice, the sharp edge **57** may have some, small, radius of curvature. In some example, around all, or at least some, of the trailing side **54**, the flow deflecting member may exhibit a rounded profile, for example a fillet or chamfer profile having a characteristic dimension smaller than that of a profile of a perimeter of the leading side **53**. For example, a characteristic dimension of between 0 mm (or as close as possible in practice) and 0.25 times a dimension of the flow deflecting member **26** (alternatively the blocking member **45**) perpendicular to the first axis **6**.

[0228] In some examples, the projection of the flow deflecting member **26** onto a plane parallel to the first axis **6** (i.e. side view) need not be a quadrilateral.

[0229] A length of the blocking member **45** along the first axis **6** is preferably between 0.2 and 2 times a maximum dimension of the blocking member **45** perpendicular to the first axis **6**. The length of the overall flow deflecting member **26** along the first axis **6** is preferably between 0.5 and 0.7 times a maximum dimension of the flow conduit **5** perpendicular to the first axis **6**, for example the diameter D when the flow conduit **5** is cylindrical.

[0230] Referring also to FIGS. **16**A to **16**C, a second flow deflecting member **26***b* is shown. FIG. **16**A shows a cross-section along a mirror plane (x-z) of the second flow deflecting member **26***b*. FIG. **16**B shows a cross section along the line labelled B-B* in FIG. **16**A, and FIG. **16**C shows a cross section along the line labelled C-C* in FIG. **16**A.

[0231] The leading side **53** of the second flow deflecting member **26***b* is divided into a first leading part **53***a* corresponding to the supporting member **46** and a second leading part **53***b* corresponding to the blocking member **45**. When viewed projected onto a plane parallel to the first axis **6** (i.e. side view), the first leading part **53***a* makes an angle to the second leading part **53***b*. Similarly, the trailing side **54** of the second flow deflecting member **26***b* is divided into a first trailing part **54***a* corresponding to the supporting member **46** and a second trailing part **54***b* corresponding to the blocking member **45**. When viewed projected onto a plane parallel to the first axis **6** (i.e. side view), the first trailing part **54***a* makes an angle to the second trailing part **54***b*. Thus, when viewed projected onto a plane parallel to the first axis **6** (i.e. side view), the second flow deflecting member **26***b* is an irregular hexagon.

[0232] Referring in particular to FIG. **16**B, the exterior perimeter of the second leading part **53***b* (i.e. the perimeter except where it adjoins the first leading part **53***a*) may have a rounded bevel profile **55**, or equivalently a fillet, chamfered or tapering profile, or any other profile described in relation to the leading side **53** of the flow deflecting member **26**. Similarly, the exterior perimeter of the second trailing part **54***b* (i.e. the perimeter except where it adjoins the first trailing part **54***a*) preferably has a sharp edge **57**, or any other profile described in relation to the trailing side **53** of the flow deflecting member **26**. In other words, the leading and trailing sides of the blocking member **45** are configured in any way previously described for the blocking member **45** of the flow deflecting member **26**.

[0233] In contrast to this, and referring in particular to FIG. **16**C, the supporting member **46** has a teardrop-shaped profile, or other equivalently streamlined profile. The combination of the sharp edge **57** on the blocking member **45** with streamlining of the supporting member **46** allows maximising the disturbance of the blocking member **45** to re-direct fluid **29** flow away from multiply sampled volumes (corresponding to the projected intersection **25**), whilst minimising the disturbance (and pressure drop) associated with the supporting member **46**.

[0234] In FIG. **16**A, the supporting member **46** is shown with a trapezium shape when viewed projected onto the plane parallel to the first axis **6** (i.e. side view), and the blocking member **45** extends upwards (positive y-direction as drawn) from the short side of the trapezium shape. However, in other examples, the blocking member **45** may include a trailing extension **58** overhanging the first trailing part **54***a*. Additionally or alternatively, the blocking member **45** may include a leading extension **59** overhanging the first leading part **53***a*.

[0235] Referring also to FIG. **17**, a third flow deflecting member **26***c* is shown, in a cross-section along a mirror plane (x-z) of the third flow deflecting member **26***c*.

[0236] When viewed projected onto a plane parallel to the first axis **6** (i.e. side view), the leading side **53** of the third flow deflecting member **26***c* is flush and parallel between the blocking member **45** and the supporting member **46**, in the same way as the flow deflecting member **26** shown in FIGS. **14** to **15**C. The trailing side **54** of the third flow deflecting member **26***c* is divided into first **54***a* and second **54***b* trailing parts which meet at an angle, in the same way as for the second flow deflecting member **26***b*. In this way, when viewed projected onto a plane parallel to the first axis **6** (i.e. side view), the third flow deflecting member **26***c* has the shape of an irregular pentagon.

[0237] All, or at least part, of the perimeter of the leading side **53** corresponding to the blocking member **45** may have any profile described hereinbefore in relation to the leading side **53**, **53***b* of blocking members **45** of the flow deflecting member **26** or the second flow deflecting member **26***b*. Similarly, all, or at least part, of the perimeter of the second trailing part side **54***b* corresponding to the blocking member **45** may have any profile described hereinbefore in relation to the trailing side **54**, **54***b* of blocking members **45** of the flow deflecting member **26** or the second flow deflecting member **26***b*.

[0238] All, or at least part, of the perimeter of the leading side **53** corresponding to the supporting member **46** may have any profile described hereinbefore in relation to the leading side **53**, **53***a* of supporting members **46** of the flow deflecting member **26** or the second flow deflecting member **26***b*. Similarly, all, or at least part, of the perimeter of the first trailing part **54***a* corresponding to the supporting member **46** may have any profile described hereinbefore in relation to the trailing side **54**, **54***a* of supporting members **46** of the flow deflecting member **26** or the second flow deflecting member **26***b*. For example, the supporting member **46** of the third flow deflecting member **26**c may adopt a tear-drop or alternative streamlined profile.

[0239] In some examples, the blocking member **45** may include a trailing extension **58** overhanging the first trailing part **54**a.

[0240] Referring also to FIG. **18**, a fourth flow deflecting member **26**d is shown, in a cross-section along a mirror plane (x-z) of the fourth flow deflecting member **26**d.

[0241] When viewed projected onto a plane parallel to the first axis **6** (i.e. side view), the fourth flow deflecting member **26**d has the appearance of a quadrilateral, differing from the flow deflecting member **26** shown in FIGS. **14** to **15**C in that the first θ_{13} and second θ_{14} interior angles are both equal to 90° so that the quadrilateral is a rectangle.

[0242] All, or at least part, of the perimeter of the leading side **53** corresponding to the blocking member **45** may have any profile described hereinbefore in relation to the leading side **53**, **53**b of blocking members **45** of the flow deflecting member **26** or the second flow deflecting member **26**b. Similarly, all, or at least part, of the perimeter of the trailing side **54** corresponding to the blocking member **45** may have any profile described hereinbefore in relation to the trailing side **54**, **54**b of blocking members **45** of the flow deflecting member **26** or the second flow deflecting member **26**b.

[0243] All, or at least part, of the perimeter of the leading side **53** corresponding to the supporting member **46** may have any profile described hereinbefore in relation to the leading side **53**, **53**a of supporting members **46** of the flow deflecting member **26** or the second flow deflecting member **26**b. Similarly, all, or at least part, of the perimeter of the trailing side **54** corresponding to the supporting member **46** may have any profile described hereinbefore in relation to the trailing side **54**, **54**a of supporting members **46** of the flow deflecting member **26** or the second flow deflecting member **26**b. For example, the supporting member **46** of the fourth flow deflecting member **26**d may adopt a tear-drop or alternative streamlined profile.

[0244] In FIG. **18**, the supporting member **46** is shown with a rectangular shape when viewed projected onto the plane parallel to the first axis **6** (i.e. side view), and the blocking member **45** extends upwards (positive y-direction as drawn) from the short side of the trapezium shape. However, in other examples, the blocking member **45** may include a trailing extension **58** overhanging the supporting member **46** and dividing the trailing side **54** in first **54**a and second **54**b trailing parts. Additionally or alternatively, the blocking member **45** may include a leading extension **59** overhanging the supporting member **46** and dividing the leading side **53** in first **53**a and second **53**b leading parts.

Annular Insert

[0245] Referring also to FIGS. **19**A to **19**F, an annular insert **47** providing a flow deflecting member **26** is shown.

[0246] FIG. **19**A is a projected view of the annular insert **47** from a front direction. FIG. **19**B is a projected view of the annular insert **47** from a rear direction. FIG. **19**C is a view of the annular insert **47** from a front direction (along the positive z-direction as illustrated). FIG. **19**D is a cross section along the line labelled D-D* in FIG. **19**C.

[0247] FIG. **19**E is a view of the annular insert **47** from a rear direction (along the negative z-direction as illustrated). FIG. **19**F is a top view of the annular insert **47**.

[0248] Both of FIGS. **19**C and **19**E represent projections of the annular insert **47** onto planes perpendicular to the first axis **6** (in this case the z-direction as illustrated).

[0249] The annular insert **47** includes a cylindrical portion **60**, having a flange **61** at a first end **62**. A second end **53** of the annular insert **47** may be inserted into the first opening **7** of an ultrasonic meter, for example any of the first ultrasonic meter **1**, the second ultrasonic meter **22**, the dual-beam ultrasonic meter **23** or the tri-beam ultrasonic meter **27**. The annular insert **47** could be used to provide the flow deflecting member **26** of the second dual-beam ultrasonic meter **44**. The annular insert **47** should be pushed into the flow conduit **5** until the flange **61** abuts the end of the flow conduit **5** defining the first opening **7**. The cylindrical portion **60** should fit tightly within the flow conduit **5**.

[0250] For ultrasonic meters **22**, **23**, **27** for which a projected intersection **25** may be defined, the size and position the blocking member **45** of the flow deflecting member **26** should be configured as described hereinbefore. For ultrasonic meters **1** including a single beam path **9**, application of a flow deflecting member **26**, **26**b, **26**c, **26**d is described hereinafter with reference to FIGS. **33** and **34**.

[0251] In the annular insert **47** shown in FIGS. **19**A to **19**F, the flow deflecting member **26** has a rounded bevel profile **55** around the perimeter of the leading side **53**, and a sharp edge **57** (e.g. Kamm-tail profile) around the trailing side **54**. In the annular insert **47** shown in FIGS. **19**A to **19**F, the flow deflecting member **26** is hollow, closed on the leading side **53**, open on the trailing side **54**, and defined by a wall **64**. In the annular insert **47** shown in FIGS. **19**A to **19**F, the blocking member **45** has a substantially circular shape when projected onto a plane perpendicular to the first axis **6** (z-direction as illustrated), and is positioned to overlap a projected intersection **25** located at or close to the central axis of an ultrasonic meter **1**, **22**, **23**, **27**, **44**.

[0252] In the annular insert **47** shown in FIGS. **19**A to **19**F, the cylindrical portion **60** includes rib structures **65** spaced at angular intervals around the perimeter and extending parallel to the first axis **6**. The rib structures **65** may serve to facilitate insertion and retention of the cylindrical portion **60** within a flow conduit **5**. The rib structures **65** may also assist with centring the insert **47** within the flow conduit **5**.

[0253] Although the annular insert **47** shown in FIGS. **19**A to **19**F is illustrated for use with a cylindrical flow conduit **5**, it may be adapted for any shape of flow conduit **5** by replacing the cylindrical portion **60** with an portion shaped to be just received within the flow conduit **5**.

[0254] The annular insert **47** may be injection moulded or 3D printed from engineering plastics such as, for example, polyphenylene sulfide (PPS), high density polyethylene (HDPE), Polyoxymethylene composites (POMC), for example glass fibre reinforced/filled.

[0255] Referring also to FIGS. **20**A and **20**B, a second annular insert **47**b is shown.

[0256] FIG. **20**A is a view of the second annular insert **47**b from a front direction (along the positive z-direction as illustrated). FIG. **20**B is a cross section along the line labelled E-E* in FIG. **20**A.

[0257] The second annular insert **47**b is the same as the annular insert **47**, except that instead of being formed from wall **64** to be hollow and open on the trailing side **54**, the flow deflecting member **26** of the second annular insert **47**b is solid.

Examples of Projected Intersections

[0258] In examples hereinbefore, projected intersections **25** have been described between a pair of beam paths $\mathbf{9}_1$, $\mathbf{9}_2$ (see FIGS. **3** and **4**) or between three beam paths $\mathbf{9}_1$, $\mathbf{9}_2$, $\mathbf{9}_3$ (see FIG. **5**). However, the use of a flow deflecting member **26**, **26***b,* **26***c,* **26***d* is not limited to projected intersections **25** which are centrally located within a flow conduit **5** and formed between equi-angularly spaced beam paths **9** which are essentially identical other than in orientation. In general, any set of two or more beam paths **9** may be projected onto a plane perpendicular to the first axis **6**, and provided that the projection of at least one beam path **9** intersects the projection or at least one other beam path **9**, a projected intersection **25** may be defined and there may be utility in placing a flow deflecting member **26**, **26***b,* **26***c,* **26***d* so as to partially or entirely overlap the projected intersection **25**.

[0259] For example, referring also to FIG. **21**, a first exemplary beam configuration **66** (hereinafter "first beam configuration") is shown, projected onto a plane (x-y as illustrated) perpendicular to the first axis **6** (z-direction as illustrated). In FIG. **21**, ultrasonic transducers **2**, **3** and reflectors **12** are omitted for simplicity of illustration.

[0260] The first beam configuration **66** is similar to that of the dual-beam ultrasonic meter **23** and/or the second dual-beam ultrasonic meter **44**, except that instead of using a pair of "V" shaped beam paths **9** as illustrated in FIG. **1**, the first beam path $\mathbf{9}_1$ is a V-shaped beam path **9** with a reflection as illustrated in FIG. **1**, whilst the second beam path $\mathbf{9}_2$ is a straight-through angled beam path as illustrated in FIG. **2**. This may be useful because, within a given length d of measurement region **13**, the two beam paths $\mathbf{9}_1$, $\mathbf{9}_2$ may make different angles to the first axis **6**.

[0261] In this configuration (and many other possible examples), there may not be any intersection of the actual volumes of the beam paths $\mathbf{9}_1$, $\mathbf{9}_2$. However, since fluid **29** flowing through the measurement region **13** should have a much larger component of velocity parallel to the first axis **6** than in any other direction, fluid **29** entering the first opening at a position corresponding to the projected intersection **25** will still (largely) flow through both beam paths $\mathbf{9}_1$, $\mathbf{9}_2$, leading to elevated sensitivity of an ultrasonic meter to fluid flows corresponding to the projected intersection **25**.

[0262] Consequently, sensitivity of the first beam configuration **66** to changes in an incident flow speed profile with installation location may be reduced by including a flow deflecting member **26**, **26***b,* **26***c,* **26***d* as described herein, and arranged to at least partially (and preferably fully) overlap the projected intersection **25**.

[0263] Referring also to FIG. **22**, a second exemplary beam configuration **67** (hereinafter "second beam configuration") is shown, projected onto a plane (x-y as illustrated) perpendicular to the first axis **6** (z-direction as illustrated). In FIG. **22**, ultrasonic transducers **2**, **3** and reflectors **12** are omitted for simplicity of illustration.

[0264] In the second beam configuration **67**, first $\mathbf{9}_1$, and second $\mathbf{9}_2$ beam paths are not equi-spaced about the first axis **6**, in this illustrating making a 45° angle and defining a projected intersection **25** having the shape of a regular parallelogram. The first $\mathbf{9}_1$ and second $\mathbf{9}_2$ beam paths may have 3D shapes which are identical up to rotation about the first axis **6**, as for the dual beam ultrasonic meter **23** or the second dual beam ultrasonic meter **44**. Alternatively, the first $\mathbf{9}_1$ and second $\mathbf{9}_2$ beam paths may have 3D shapes which are different from one another, as for the first beam configuration **66**.

[0265] In either case, sensitivity of the second beam configuration **67** to changes in an incident flow speed profile with installation location may be reduced by including a flow deflecting member **26**, **26***b,* **26***c,* **26***d* as described herein, and arranged to at least partially (and preferably fully) overlap the projected intersection **25**.

[0266] Referring also to FIG. **23**, a third exemplary beam configuration **68** (hereinafter "third beam configuration") is shown, projected onto a plane (x-y as illustrated) perpendicular to the first axis **6** (z-direction as illustrated). In FIG. **23**, ultrasonic transducers **2**, **3** are omitted for simplicity of illustration.

[0267] The third beam configuration **68** is similar to that of the tri-beam ultrasonic meter **27**, except that instead of using a three "V" shaped beam paths **9** as illustrated in FIG. **1**, each of the first $\mathbf{9}_1$, second $\mathbf{9}_2$ and third $\mathbf{9}_3$ beam paths is a straight-through angled beam path as illustrated in FIG. **2**, with each of the first $\mathbf{9}_1$, second $\mathbf{9}_2$ and third $\mathbf{9}_3$ beam paths oriented at a different angle (between 10° and 80°) to the first axis **6**.

[0268] As explained hereinbefore, even in the absence of any intersection of the actual volumes of the beam paths $\mathbf{9}_1$, $\mathbf{9}_2$, $\mathbf{9}_3$, a projected intersection **25** may still be defined, and sensitivity of the third beam configuration **68** to changes in an incident flow speed profile with installation location may be reduced by including a flow deflecting member **26**, **26***b,* **26***c,* **26***d* as described herein, and arranged to at least partially (and preferably fully) overlap the projected intersection **25**.

[0269] Referring also to FIG. **24**, a fourth exemplary beam configuration **69** (hereinafter "fourth beam configuration") is shown, projected onto a plane (x-y as illustrated) perpendicular to the first axis **6** (z-direction as illustrated). In FIG. **24**, ultrasonic transducers **2**, **3** and reflectors **12** are omitted for simplicity of illustration.

[0270] The fourth beam configuration **69** is the same as the first beam configuration **66**, the configuration of the dual-beam ultrasonic meter **23** or the second dual-beam ultrasonic meter **44**, except the first beam path $\mathbf{9}_1$ is offset from a centre of the flow conduit **5**.

[0271] As explained hereinbefore, even in the absence of any intersection of the actual volumes of the beam paths $\mathbf{9}_1$, $\mathbf{9}_2$, a projected intersection **25** may still be defined, and sensitivity of the fourth beam configuration **69** to changes in an incident flow speed profile with installation location may be reduced by including a flow deflecting member **26**, **26***b,* **26***c,* **26***d* as described herein, and arranged to at least partially (and preferably fully) overlap the projected intersection **25**. Given the offset of the projected intersection **25**, a corresponding flow deflecting member **26**, **26***b,* **26***c,* **26***d* should be correspondingly offset from the centre of the flow conduit **5** so as to wholly or partially overlap the projected intersection **25**.

[0272] In examples described hereinbefore, the intersection(s) of two or more beam paths **9** have, when viewed projected onto a plane perpendicular to the first axis **6**, corresponded to a single, unified projected intersection **25**. However, this is not always the case, and in some ultrasonic meters two or more distinct projected intersections **25** may be defined. Preferably, a separate flow deflecting member **26** should be positioned such that a projection thereof onto the plane perpendicular to the first axis **6** wholly or partially overlaps a respective projected intersection **25**. In other words, a flow deflecting member **26** should be included for each distinct projected intersection **25**.

[0273] For example, referring also to FIG. **25**A, a fifth exemplary beam configuration **70** (hereinafter "fifth beam configuration") is shown, projected onto a plane (x-y as illustrated) perpendicular to the first axis **6** (z-direction as illustrated). In FIG. **25**A, ultrasonic transducers **2**, **3** and reflectors **12** are omitted for simplicity of illustration.

[0274] In the fifth exemplary beam configuration **70**, the projection of a first beam path $\mathbf{9}_1$ extends through the centre of the projected area of the flow conduit **5**. The projection of a second beam path $\mathbf{9}_2$ extends perpendicular to the first beam path $\mathbf{9}_1$, and is offset from the centre of the flow conduit **5** in the negative x-direction as illustrated. The projection of a third beam path $\mathbf{9}_3$ extends perpendicular to the first beam path $\mathbf{9}_1$, and is offset from the centre of the flow conduit **5** in the positive x-direction as illustrated.

[0275] The projections of the first and second beam paths $\mathbf{9}_1$, $\mathbf{9}_2$ define a first projected intersection $\mathbf{25}_1$, and the projections of the first and third beam paths $\mathbf{9}_1$, $\mathbf{9}_3$ define a second projected intersection $\mathbf{25}_2$, entirely separate from the first projected intersection $\mathbf{25}_1$. Since fluid **29** entering the first opening **7** at a position corresponding to either of the projected intersections $\mathbf{25}_1$, $\mathbf{25}_2$ will be sampled by two beam paths **9**, in the result is elevated sensitivity of an ultrasonic meter to fluid flows corresponding to the projected intersection **25**.

[0276] Referring also to FIG. **25**B, the sensitivity to changes in incident flow speed profile may be reduced as described hereinbefore by disposing a first flow deflecting member $\mathbf{26}_1$ to deflect fluid **29** away from the first projected intersection $\mathbf{25}_1$ and a second flow deflecting member $\mathbf{26}_2$ to deflect fluid **29** away from the second projected intersection $\mathbf{25}_2$.

[0277] FIG. **25**B shows the fifth beam configuration **70**, projected onto the same plane (x-y as illustrated) as FIG. **25**A, with projections of the beam paths $\mathbf{9}_1$, $\mathbf{9}_2$, $\mathbf{9}_3$ omitted and projections of first $\mathbf{26}_1$ and second $\mathbf{26}_2$ projected intersections shown. The outlines of the first $\mathbf{25}_1$ and second $\mathbf{25}_2$ projected intersections are shown with dashed lines for comparison. In FIG. **25** B, ultrasonic transducers **2**, **3** and reflectors **12** are omitted for simplicity of illustration.

[0278] FIGS. **25**A and **25**B show a particular example for illustrative purposes. In the general case, any number of projection intersections **25** may be formed between the projections of two, three or more beam paths **9**, depending on the design of a particular ultrasonic meter. At least one, and preferably all, such projected intersections **25** should have a corresponding flow deflecting member **26**. A pair of distinct projected intersections $\mathbf{25}_1$, $\mathbf{25}_2$ may be defined by intersections of projections of two beam paths **9** with a common beam path, for example the first $\mathbf{9}_1$, second $\mathbf{9}_2$ and third $\mathbf{9}_3$ beam paths of the fifth beam configuration **70**. Alternatively, a pair of distinct projected intersections $\mathbf{25}_1$, $\mathbf{25}_2$ may be defined respectively be intersections of projections of first $\mathbf{9}_1$ and second $\mathbf{9}_2$ beam paths and third $\mathbf{9}_3$ and fourth (not shown) beam paths.

[0279] When two or more flow deflecting members **26** are included, these may be may identical (or at least blocking members **45** thereof may be identical) except in terms of relative position. Alternatively, and generally in dependence on the size, shape and/or position of the corresponding projected intersections **25**, two or more flow deflecting members **26** may be different to one another.

[0280] Whilst examples have been described and shown in which beam paths **9** have been illustrated with equal beam widths wb, this is not essential, and different beam paths **9** may have differing effective beam widths wb, with predictable effects on shapes of projected intersections **25**.

[0281] Whilst examples have been described and shown which include cylindrical fluid conduits **5**, this is not essential, and in general the projection of the fluid conduit **5** onto the plane perpendicular to the first axis **6** may have any shape, for example square, elliptical, rectangular, or any other regular or irregular shape (though circular is expected to be the most common).

Peak Flow Region and Flow Deflecting Members

[0282] As described hereinbefore, the effectiveness of the flow deflecting member **26** may be further increased if, in addition to at least partially overlapping a projected beam intersection, the flow deflecting member **26** also at least partially overlaps the projection of a peak flow volume **48** onto the plane perpendicular to the first axis **6**.

[0283] The peak flow volume **48** corresponds to the volume through which a flow speed through a reference ultrasonic meter would be above a mean flow speed in response to passing a steady state fluid flow through the reference ultrasonic meter at a Reynolds number of approximately 3000. The reference ultrasonic meter in a given case corresponds to an ultrasonic meter which is identical except for omission of any flow deflecting members **26**.

[0284] Referring also to FIGS. **26** to **28**, the definition of a peak flow volume **48** shall be discussed in further detail.

[0285] Referring back in particular to FIG. **7**A, this shows a contour plot of a flow speed profile for steady state flow though a cylindrical flow conduit **5**. A flow-speed profile represents the component of velocity along the first axis **6** (z as illustrated herein). Denoting a flow-speed profile as u(x,y,z) and a flow-velocity profile as $\underline{v}(x,y,z)$, the two may be related as:

$$u(x, y, z) = \underline{e}_z \cdot \underline{v}(x, y, z) \tag{4}$$

[0286] For an ultrasonic meter **1**, **22**, **23**, **27**, **27**, the peak flow region **48** may be defined relative to a projection onto a plane perpendicular to the first axis **6** of a flow conduit **5** of a reference ultrasonic meter which is identical to the ultrasonic meter except for omitting the flow deflecting member **26**. For example, the dual-beam ultrasonic meter **23** corresponds to a reference ultrasonic meter for the second dual-beam ultrasonic meter **44**, since the two differ only by the presence or absence of the flow deflecting member **26**.

[0287] The peak flow region **48** is defined as corresponding to a region of the projection plane (perpendicular to the first axis **6**) in which a flow speed u(x, y) through the reference ultrasonic meter is above a mean flow speed U in response to passing a steady state fluid flow through the reference ultrasonic meter. Since the boundary will vary with flow speed and other factors, the peak flow region is defined for a reference value which is a Reynolds number of approximately 3000, for example 3000±300.

[0288] Referring in particular to FIGS. **7**A and FIG. **26**, for a cylindrical flow conduit **5**, the peak flow region **48** should be approximately circular, given the complete rotational symmetry of the flow speed profile u(x,y,z) about the first axis **6** for steady state flows (as illustrated in FIG. **7**A). FIG. **26** shows, for the second dual-beam ultrasonic meter **44**, the projections of the flow conduit **5** and the flow deflecting member **26** onto a projection plane (x-y as illustrated) perpendicular to the first axis **6** (z as illustrated). The flow conduit **5** has diameter D, and the peak flow region **48** takes the form of a concentric circular region of diameter D_p. In this instance, the ratio D_p/D is approximately ⅓.

[0289] Since the peak flow region **48** corresponds to the fastest flow in the reference ultrasonic meter (lacking any flow deflecting member), an ultrasonic meter will be more sensitive to deviations from the steady state flow speed profile within the peak flow region **48**. Consequently, deflecting flows away from the peak flow region **48** using a flow deflecting member **26** may reduce the sensitivity of an ultrasonic meter to differences in incident flow speed profiles between a steady state condition used for calibration and an actual environment when installed.

[0290] The mean flow speed U may be determined by determining a volumetric flowrate ($m^3 \cdot s^{-1}$) through the flow conduit **5** of the reference ultrasonic meter and dividing by a cross-sectional area (projected area on the projection plane) of the flow conduit **5**. Volumetric flowrate may be experimentally measured using a pair of ultrasonic meters one of which includes flow deflecting member(s) **26**, and one which does not. Additionally or alternatively, volumetric flowrate may be determined based on FEA simulations of an ultrasonic meter flow conduit **5** with and without flow deflecting member(s) **26**.

[0291] When FEA simulations are performed, the mean flow speed U may alternatively be determined by integrating the simulated flow velocity field $\underline{v}(x,y,z)$ over the volume of the flow conduit **5** and normalising to the total volume of the flow conduit **5**.

[0292] A projection of the flow velocity field $\underline{v}(x,y,z)$ onto a plane perpendicular to the first axis **6** may be defined as:

$$u(x, y) = \int_0^L \frac{\underline{v}(x, y, z) \cdot \underline{e}_z}{L_{cond}} dz \tag{5}$$

[0293] In which the unit vector ez is aligned with the first axis **6**, L_{cond} is the length of the fluid conduit **5** parallel to the first axis **6** and u(x,y) is a (scalar) projected flow-speed profile. The value of the flow-speed profile u(x, y) at each position (x, y) is the average speed parallel to the first axis **6** along a line extending from that position (x, y) through the flow conduit **5**. The peak flow region **48** may be defined based on the region(s) within which the flow-speed profile u(x, y) exceeds the mean flow speed U.

[0294] Instead of defining the peak flow region **48** as simply the locus for which flow speeds equal or exceed the mean flow speed U in the reference ultrasonic meter, i.e. u(x, y)>U, the peak flow region **48** may instead be defined to correspond to higher flow speeds. For example, if the maximum flow speed is u_{max}, the peak flow region **48** may alternatively be defined to correspond to flow velocities greater than or equal to $U+f(u_{max}-U)$ with fbeing a fraction between $0.1 \le f \le 0.9$.

[0295] Flow velocity fields v(x,y,z) in the reference ultrasonic meter in response to steady state fluid flow through the reference ultrasonic meter at a Reynolds number of approximately 3000 may be determined from theory, simulations and/or experimental measurements. The Reynolds number is defined as the product of the mean flow speed U and the hydraulic diameter, divided by the kinematic viscosity of the fluid **29**, for example water, at a test temperature. It should be noted that the temperature is not important, since if the temperature changes, then the flow rate must change correspondingly to maintain the Reynolds number at the same value (and hence the same flow profile). Hydraulic diameter is defined as four times the area of the flow conduit **5** (perpendicular to the first axis **6**), divided by the perimeter around that area. For a flow conduit **5** in the form of a cylinder, the hydraulic diameter is the cylinder diameter D, however, the same definition is applicable to non-cylindrical flow conduits **5**.

[0296] Referring in particular to FIG. **27**, the peak flow region **48** for a flow conduit **5** having a square cross-section of side length A is shown.

[0297] The peak flow region **48** is approximately square shaped (due to no slip boundary conditions) with a side length a. In reality the corners of contours of the flow speed profile will become increasingly rounded moving towards the centre of the flow conduit **5** (though this is not illustrated in FIG. **27**).

[0298] Referring in particular, to FIG. **28**, the peak flow region **48** for a flow conduit **5** having a rectangular cross-section of side lengths A and B is shown.

[0299] The peak flow region **48** is approximately rectangular shaped (due to no slip boundary conditions), with side lengths a and b. The ratios of side lengths will be substantially equal, i.e. $a/A \approx b/B$. In reality the corners of contours of the flow speed profile will become increasingly rounded moving towards the centre of the flow conduit **5** (though this is not illustrated in FIG. **28**).

[0300] Alternatively, the peak flow region **48** may be approximately defined without consideration of the precise details of fluid flows through the reference ultrasonic meter. This is possible with reasonable accuracy due to the predictable forms of steady state flow speed profiles (as illustrated in FIGS. **26** through **28**). The peak flow region **48** may therefore be approximated as a region which:

- **[0301]** has a centroid coinciding with the projected area of the flow conduit **5**, for example concentric for a cylindrical flow conduit **5**;
- **[0302]** has the same shape and orientation as the projected area of the flow conduit **5**; and
- **[0303]** has one quarter or less of the projected area of the flow conduit **5**.

[0304] For the example of the circular cross-section shown in FIG. **26**, $D_p=D/2$ by the approximate definition. Similarly, for the square cross-section of FIG. **27**, a=A/2, and for the rectangular cross-section of FIG. **28**, a=A/2 and b=B/2.

[0305] If possible when considered in view of the location of one or more projected intersections **25**, and in view of the need to avoid unacceptable pressure drops, when viewed projected onto the plane perpendicular to the first axis, it is preferable if at least half the projected area of the flow deflecting member **26** overlap the peak flow region **48**. For a centrally positioned projected intersection **25**, this condition may be relatively straightforward to achieve, for example, by adjusting the size of a blocking member **45** of the flow deflecting member **26**.

Combining Flow Deflecting Member(s) with Protrusions of WO 2019/229409 A1

[0306] Referring also to FIG. **29**, a first combined ultrasonic meter **71** is shown.

[0307] The first combined ultrasonic meter **71** corresponds to the ultrasonic meter shown in FIG. **6** of WO 2019/229409 A1, modified to include a flow deflecting member **26** in addition to protrusions **72**. The protrusions **72** have properties and/or structures, and are employed, as described in detail in WO 2019/229409 A1. Herein, we shall focus on explaining how to integrate flow deflecting members **26** described herein with protrusions **72** as described in WO 2019/229409 A1, so as to provide further ultrasonic meters having further reduced sensitivity to changes in incident flow speed profiles between deployment and calibration.

[0308] The first combined ultrasonic meter **71** is comparable to the first ultrasonic meter **1**, except that it includes a flow deflecting member **26** and additional features relating to installation of the meter. For brevity, common parts will not be described a second time.

[0309] The flow conduit **5** in the first combined ultrasonic meter **71** is defined by the interior surfaces of a cylindrical tube **73**, terminated at either end by a flange **74**. The cylindrical tube **73** is positioned between a first pipe **75** and a second pipe **76** by bolts **77** passing through respective flanges **74** of the cylindrical tube **73** and pipes **75**, **76**. Joints between the cylindrical tube **73** and the pipes **75**, **76** include gaskets (not shown) or other sealing means to prevent fluids from leaking. The flow path **4** may be either from the first opening **7** towards the second opening **8**, or vice versa.

[0310] The first combined ultrasonic meter **71** includes a V-shaped beam path **9**. One pair of ultrasonic transducers **2**, **3** is illustrated in FIG. **29**, but one or more other pairs of ultrasonic transducers **2**, **3** are be oriented in planes outside the illustrated cross-section to define at least one further beam path **9**. The effective cross-sectional areas of the beam paths **9** define the sampled volume(s) **13***a* and non-sampled volumes **13***b* of the measurement region **13** as described hereinbefore.

[0311] The first combined ultrasonic meter **71** differs from examples described hereinbefore primarily by the addition of one or more protrusions **72** extending along the first axis **6**. At least part of each protrusion **72** is arranged to exclude fluid from at least part of one or more non-sampled volumes **13***b* of the measurement region **13**. In this way, each protrusion **72** is configured to re-direct fluid out of the non-sampled volume(s) **13***b* and through the one or more beam paths **9** (sampled volumes **13***a*).

[0312] Another way to express the effect of the protrusions **72** is that each protrusion **72** acts to increase a mass fraction of the fluid **29** which intersects (passes through) the one or more beam paths **9**. The increase in mass fraction is with respect to an ultrasonic meter (not shown) which is identical to the first combined ultrasonic meter **71**, except for omission of the protrusions **72**. A mass fraction of the fluid which intersects the one or more beam paths **9** may be defined as a mass of fluid which passes through the one or more beam paths **9** in unit time, divided by a mass of fluid which enters (or leaves) the flow conduit **5** via the first or second opening **7**, **8** in unit time.

[0313] As described in WO 2019/229409 A1, re-directing fluid flows out of non-sampled volumes **13***b* and into sampled volumes **13***a* (through the beam paths **9**) has an effect of reducing the sensitivity of an ultrasonic meter to disturbances of an incident flow speed profile from a steady state situation. When combined with flow deflecting member(s) described herein, the cumulative effect may be to provide an ultrasonic meter which has substantial immunity, i.e. <1.5% of reading error (see FIG. **13**), to flow disturbances arising from a specific installation location. This may be compared to typical errors of the order of 10% without any mitigation measures.

[0314] Referring also to FIG. **30**, a second combined ultrasonic meter **78** is shown.

[0315] The second combined ultrasonic meter **78** corresponds to the ultrasonic meter shown in FIG. **7** of WO 2019/229409 A1, modified to include a flow deflecting member **26** in addition to the protrusions **72**.

[0316] The second combined ultrasonic meter **78** is the same as the first combined ultrasonic meter **71**, except that the beam path(s) **9** do not include a reflection (as for the beam path **9** of FIG. **2**). Only the centroid of the beam path **9** is shown in FIG. **30**

Exemplary Configuration of Protrusions

[0317] Referring also to FIG. **31**, an exemplary configuration of protrusions **72** and beam paths **9** is shown.

[0318] A variety of alternative configurations for protrusions are described and illustrated in WO 2019/229409 A1, any of which may be combined with flow deflecting members **26**, **26***b*, **26***c*, **26***d* described herein.

[0319] The exemplary configuration is a configuration of the second combined ultrasonic meter **78** using three pairs of ultrasonic transducers **2**, **3** and six protrusions **72** spread around the perimeter of cylindrical flow conduit **5**. A first pair of ultrasonic transducers $\mathbf{2}_1$, $\mathbf{3}_1$ are spaced on opposite sides of the flow conduit **5** to define a first beam path $\mathbf{9}_1$. A second pair of ultrasonic transducers $\mathbf{2}_2$, $\mathbf{3}_2$ are spaced on opposite sides of the flow conduit **5** to define a second beam path $\mathbf{9}_2$ which is rotated 60° anti-clockwise relative to the first beam path $\mathbf{9}_1$. A third pair of ultrasonic transducers **23**, **33** are spaced on opposite sides of the flow conduit **5** to define a third beam path $\mathbf{9}_3$ having a transverse component which is rotated 60° clockwise relative to the first beam path $\mathbf{9}_1$. All of the ultrasonic transducers **2**, **3** are still spaced apart along the first axis **6** so that each beam path $\mathbf{9}_1$, $\mathbf{9}_2$, $\mathbf{9}_3$ has a longitudinal component along the first axis **6** for measuring flow.

[0320] The protrusions **72** have a generally triangular cross-section extending into the flow conduit **5**, and are spaced with respect to the first beam path $\mathbf{9}_1$ at angles of about 30, 90, 150, 210, 270 and 330 degrees. In this way, the beam paths $\mathbf{9}_1$, $\mathbf{9}_2$, $\mathbf{9}_3$ are located in spaces between the protrusions. Gaps between the protrusions **72** have a width w_b roughly corresponding to the effective width w_b of the beam paths $\mathbf{9}_1$, $\mathbf{9}_2$, $\mathbf{9}_3$. The effective width w_b of the beam paths $\mathbf{9}_1$, $\mathbf{9}_2$, $\mathbf{9}_3$ is typically less than a physical width of the transducers **2**, **3**. In this way, by excluding fluid flow from entering non-sampled volumes **13***b* between the beam paths $\mathbf{9}_1$, $\mathbf{9}_2$, $\mathbf{9}_3$, the protrusions **72** may act to re-direct substantially all of the fluid flowing through the measurement region **13** of the flow conduit **5** through beam paths $\mathbf{9}_1$, $\mathbf{9}_2$, $\mathbf{9}_3$. Consequently, average speeds measured using the first, second and third beam paths $\mathbf{9}_1$, $\mathbf{9}_2$, $\mathbf{9}_3$ may sample substantially all of the fluid flow. This may permit a mass flow to be estimated without a need to make an assumption about a flow speed profile across the flow conduit **5**. In this way, the sensitivity of a combined ultrasonic meter **71**, **78** to flow disturbances may be reduced.

[0321] Further, as the protrusions **72** leave a central region of the flow conduit **5** open, a combined ultrasonic meters **71**, **78** may remain resistant to clogging with debris/fibres entrained in a fluid being measured.

[0322] The exemplary configuration of FIG. **31** has been illustrated with a cylindrical flow conduit **5**. However, this arrangement is not essential, and in general the flow conduit **5** may take any shape described herein, without affecting the capability to utilise protrusions **72** as described in WO 2019/229409 A1.

[0323] Referring also to FIG. **32**, placement of a flow deflecting member **26** relative to the exemplary configuration of protrusions **72** is shown.

[0324] FIG. **32** shows a projection of a second combined ultrasonic meter **78** using the exemplary configuration shown in FIG. **31**, when viewed projected onto a plane perpendicular to the first axis and positioned upstream of the flow deflecting member **26**. The flow deflecting member **26** includes a blocking member **45** and a supporting member **46** as described hereinbefore.

[0325] There are two options for the relative positioning of the flow deflecting member **26** about the perimeter. Firstly, as shown in FIG. **32**, the flow deflecting member **26** may be arranged such that, when viewed projected onto a plane perpendicular to the first axis **6**, a projection of the support member **46** at least partly overlaps with a projection of one of the protrusions. **72**. For example, the projection of the support member may be aligned (centrally) with a projection of one of the protrusions.

[0326] Alternatively, the flow deflecting member **26** may be arranged such that, when viewed projected onto the plane perpendicular to the first axis **6**, a projection of the support member **46** is aligned with a projection of at least one space/gap defined between a pair of protrusions **72**. For example, the projection of the support member **46** may be aligned parallel with the projection of at least one beam path **9** passing between protrusions **72**.

[0327] When protrusions **72** are included, some or all may be integrally formed as part of the flow conduit **5**. Additionally or alternatively, some or all protrusions **72** may be included by securing an insert within the flow conduit **5**, with the insert defining the protrusions.

Non-Intersecting Beam Case

[0328] Some ultrasonic meters may include only a single beam path **9**. Other ultrasonic meters may include multiple beam paths **9** which do not intersect, even when projected onto a plane perpendicular to the first axis **6**.

[0329] Flow deflecting members **26**, **26***b*, **26***c*, **26***d* described herein may still be used in such ultrasonic meters, in order to reduce the sensitivity of measurements to disturbances of an incident flow speed profile from a steady state condition.

[0330] Referring also to FIGS. **33** and **34**, a single-beam ultrasonic meter **79** is shown. FIG. **33** is a projection onto a plane (x-y as illustrated) perpendicular to the first axis **6** (corresponding to the z-direction as illustrated). FIG. **34** is a projection view with a portion of a cylindrical pipe **80** defining the flow conduit cut-away for visibility.

[0331] In the illustration of FIGS. **33** and **34**, the beam path **9** is of the V-shaped type illustrated in FIG. **1**, and is offset from the centre of the flow conduit **5**. However, these details are not essential, and beam path **9** may adopt any shape provided that substantially every part of the beam path **9** makes a non-zero angle with the first axis **6** (so that there is a component of flow velocity along the direction of the beam path **9**).

[0332] When viewed projected onto the plane perpendicular to the first axis **6**, a projection of the beam path **9** intersects the peak flow region **48**. For example, see the intersecting region **81** in FIG. **33**. The peak flow region **48** is defined as described hereinbefore (using the precise or approximated definitions). A flow deflecting member **26** is supported between the first opening **7** and the measurement region **13** so that, when viewed projected onto the plane perpendicular to the first axis **6**, a projection of the flow deflecting member **26** at least partially overlaps the intersecting region **81** between the beam path **9** and the peak flow region **48**. Preferably, the projection of the flow deflecting member **26** at least partially overlaps as much as possible of the intersecting region **81**, though a balance may need to be made between overlapping a larger fraction of the intersecting region **81** and avoiding excessive pressure drops across the flow deflecting member **26**. The flow deflecting member **26** may be configured and/or structured in any way described hereinbefore.

[0333] Although the single-beam ultrasonic meter **79** has been illustrated with the beam path **9** offset from the centre of the flow conduit **5**, this is not required, and the beam path **9** may pass through the centre of the flow conduit **5**.

[0334] If second or further beam paths **9** are present, and projections of the beam paths do not intersect, for example a pair of parallel beam paths **9**, then a flow deflecting member **26** should preferably be positioned to at least partially overlap the intersection of each beam path **9** with the peak flow region **48**.

[0335] Any ultrasonic meters **1**, **22**, **23**, **27**, **44**, **71**, **78**, **79** may be used for metering flow of a fluid. Examples of fluids which are commonly metered include water such as for drinking, irrigation, or waste water, or natural gas.

Modifications

[0336] It will be appreciated that many modifications may be made to the embodiments hereinbefore described. Such modifications may involve equivalent and other features which are already known in the design and use of ultrasonic meters, and which may be used instead of, or in addition to, features already described herein. Features of one embodiment may be replaced or supplemented by features of another embodiment.

[0337] Examples have been described in which a flow deflecting member **26**, **26***b*, **26***c*, **26***d* is disposed between the first opening **7** and the measurement region **13**. However, when an ultrasonic meter is desired to be operable for flows between first **7** and second **8** openings and also the reverse direction, corresponding flow deflecting member(s) **26**, **26***b*, **26***c*, **26***d* may be disposed between the measurement region **13** and the second opening **8**. For example, for each flow deflecting member **26** supported between the first opening **7** and the measurement region **13**, an identical flow deflecting member (not shown) may be supported between the measurement region **13** and the second opening **8**.

[0338] When viewed projected onto the plane perpendicular to the first axis **6**, a projection of each flow deflecting member **26** supported between the first opening **7** and the measurement region **13** may entirely coincide with a projection of the corresponding flow deflecting member (not shown) supported between the measurement region **13** and the second opening **8**. Each flow deflecting member (not shown) supported between the measurement region **13** and the second opening **8** may be a reflection of the corresponding flow deflecting member **26** supported between the first opening **7** and the measurement region **13**, about a mirror plane perpendicular to the first axis **6**. However, such a mirror plane does not need to coincide with a midpoint of the measurement region **13**.

[0339] In examples described hereinbefore, flow deflecting members **26** have been described in which a blocking member **45** is held in place by a supporting member **46** configured so that, when viewed projected onto the plane perpendicular to the first axis **6** (e.g. x-y plane when the first axis **6** is parallel to z), the projection of the flow deflecting member **26** does not divide a projection of the flow conduit **5** into two separate regions.

[0340] However, in other examples it may be acceptable, even advantageous, if one or more through-holes are formed through the supporting member **46** to permit passage of fluid. For example, this may help to avoid a region of stagnant fluid immediately downstream of the supporting member **46**.

[0341] Referring also to FIG. **35**, an example of a supporting member **46** including a through-hole **82** is shown.

[0342] FIG. **35** shows a view projected along the first axis **6** (z as illustrated). The through-hole **82** is in the form of a small circular hole extending through the supporting member **46** parallel to the first axis.

[0343] The through-hole **82** permits passage of fluid and prevents stagnation of fluid immediately behind the supporting member **46**. Although the through-hole **82** may become clogged in the presence of a fluid entraining particles and/or fibres, it is apparent that the worst case scenario in which the through-hole **82** become blocked would still present a cross-section equivalent to the supporting member **46** without the through-hole. In this way, the flow conditioning device remains less susceptible to more extensive clogging (for example leading to significant pressure drops/restricted flow) when compared to prior art such as flow conditioning device **38**.

[0344] Preferably, if the projection of the flow deflecting member **26** divides a projection of the flow conduit into two or more separate regions when viewed projected onto the plane perpendicular to the first axis, the projection of the flow deflecting member should divide a projection of the flow conduit into a primary region **83** and one or more smaller regions **84**, such as through-hole **82**. Preferably, an area of the primary region **83** in the projection accounts for 75% or more of the total projected area of the two or more separate regions **83**, **84**. In this way, even if the smaller regions **84** become clogged, the primary region **83** it likely to remain passable for flow.

[0345] Through-holes in the supporting member **46** are not limited to circular shapes such as through-hole **82**, for example referring also to FIG. **36** a second example of a through-hole **85** in a supporting member **46** is shown.

[0346] The second example through-hole **85** has a cross-sectional shape which is the same as the supporting member **46**, and of reduced area. This provides a supporting member **46** having a hollow, open-ended shape extending parallel to the first axis **6**. The larger through-hole **85** may act to reduce a pressure drop of the flow deflecting member **26**, and reduce the effects of the supporting member **46** on fluid flow. For example, the leading and trailing edges of sides **86** of the hollow-supporting member **46** may be streamlined to cut and connect streamlines (in contrast to the blocking member **45**.

[0347] Similarly to the example of FIG. **35**, in the event that the through-hole **85** does become blocked, the overall cross-section then becomes similar to the supporting member **46** without the through-hole **85**, and so retains the reduced probability of clogging the primary region **83**.

[0348] In general, a through-hole formed through the supporting member **46** may be elliptical, circular, square, rectangular, or any other regular or irregular shape in cross-section (when projected onto the plane perpendicular to the first axis).

[0349] Examples have been described in which the lengths of the supporting member **46** and blocking member **45** along the first axis **6** (z as illustrated) overlap. However, alternative configurations are possible for supporting the blocking member **45** in the desired position.

[0350] Referring also to FIGS. **37**A and **37**B a first alternative configuration **87** of a flow-deflecting member **26** is shown.

[0351] FIG. **37**A shows a cross-section of the first alternative configuration **87** along a plane parallel to the first axis **6** (x-z plane as illustrated) and FIG. **37**B shows a view of the first alternative configuration **87** along the first axis **6** (z as illustrated).

[0352] In the first alternative configuration **87**, the flow deflecting member **26** includes a radial member **88** extending inwards from an inner surface **89** of the flow conduit **5**. The radial member **88** is illustrated as being angled along the first axis **6**, but in other examples could extend inwards perpendicularly to the first axis **6**. The blocking member **45** is disposed within the fluid conduit **5** and offset along the first axis **6** away (positive z direction as illustrated) from the first opening **7** relative to the radial member **88**. The blocking member held in place by a wire **90** extending along the first axis **6** from the radial member **88** to the blocking member **45**. The wire **90** is preferably stiff to provide at least some mechanical constraint against deflection of the blocking member **45** perpendicular to the first axis **6**. Although illustrated as being centrally disposed, appropriate placement and dimensions of the radial member **88** may allow the blocking member **45** to be disposed in any part of the flow conduit **5** cross-section described herein.

[0353] In this way, the effects of the structure supporting the blocking member **45** on the fluid flow may be reduced, which may reduce pressure drops and also asymmetry rotationally about the first axis **6**. For example, the radial member **88** may be streamlined or otherwise shaped to minimise disruption to incident fluid flow. Combined with offsetting the blocking member **45** downstream of the radial member **88**, which permits some recovery of flows divided by the radial member **88**, the influence of the flow deflecting member **26** on fluid flows may be more dominated by the effect of the blocking member **45**.

[0354] When the blocking member **45** is connected to the radial member **88** by a wire **90**, there is a possibility of turbulent flows causing lateral back-and-forth motion of the blocking member **45**. This may be counteracted by shaping a leading edge (relative to the first opening **7** and the radial member **88**) of the blocking member **45** with a tapered profile **91**. The tapering will interact with fluid flows such that a position of the blocking member **45** within the flow conduit will be stabilised by fluid flow from the first opening **7** towards the second opening **8**. For example, the blocking member **45** may have a leading edge which is conical/pyramidal or frustoconical/frustopyramidal. The trailing edge (relative to the first opening **7** and the radial member **88**) of the blocking member **45** should still be relatively sharp as described hereinbefore.

[0355] Referring also to FIGS. **38**A and **38**B a second alternative configuration **92** of a flow-deflecting member **26** is shown.

[0356] FIG. **38**A shows a cross-section of the second alternative configuration **92** along a plane parallel to the first axis **6** (x-z plane as illustrated) and FIG. **38**B shows a view of the second alternative configuration **92** along the first axis **6** (z as illustrated).

[0357] The second alternative configuration **92** is the same as the first alternative configuration **87**, except that the wire **90** is replaced by a rigid rod **93**. The rigid rod **93** preferably has as high a stiffness against bending as possible, for example the rigid rod may be hollow or have another cross-section configured for high flexural rigidity. Compared to the first alternative configuration **87**, the rigid rod **93** may have a greater impact on fluid flows than the wire **90**, bit provides greater stability of positioning the blocking member **45**. The blocking member **45** may be shaped on the leading edge to use fluid flows to further enhance stability (as described in relation to the first alternative configuration **87**), though this is not considered essential when supported by the rigid rod **93**.

[0358] Examples have been described in which the flow deflecting member **26** includes a blocking member **45** disposed within the fluid conduit **5** and held in place by a single supporting member **46**. As mentioned hereinbefore, in some examples there may be multiple supporting members.

[0359] For example, FIG. **39** illustrates a configuration in which the blocking member **45** is supported by three supporting members $\mathbf{46}_1$, $\mathbf{46}_2$, $\mathbf{46}_3$.

[0360] The three supporting members $\mathbf{46}_1$, $\mathbf{46}_2$, $\mathbf{46}_3$ are equiangularly spaced about the first axis **6**, in this example at 120° increments. Using a single supporting member **46** means that supporting member **46** must be sufficiently rigid to avoid undue deflection of the blocking member **45** from a desired position due to the forces applied by fluid flows. Multiple supporting members $\mathbf{46}_1$, $\mathbf{46}_2$, $\mathbf{46}_3$ spread about first axis **6** may be individually much smaller because in the example of FIG. **39** any lateral deflection of the blocking member **45** is opposed by extension of at least one of the supporting members $\mathbf{46}_1$, $\mathbf{46}_2$, $\mathbf{46}_3$. For example, each of the supporting members $\mathbf{46}_1$, $\mathbf{46}_2$, $\mathbf{46}_3$ may take the form of a length of wire.

[0361] Although dividing the flow conduit **5** into separate regions in this way makes the configuration with multiple supporting members $\mathbf{46}_1$, $\mathbf{46}_2$, $\mathbf{46}_3$ more susceptible to entangling materials entrained in the fluid flow, the total projected area of the supporting members $\mathbf{46}_1$, $\mathbf{46}_2$, $\mathbf{46}_3$ may be very small (for example individual wires) compared to the structure of prior art flow conditioners **38**, so that the probability of clogging leading to significant pressure drops/reduced flow is still relatively reduced.

[0362] Whilst three supporting members $\mathbf{46}_1$, $\mathbf{46}_2$, $\mathbf{46}_3$ are shown in FIG. **39**, similar effects may be obtained from fewer (for example two) or more (for example four) supporting members **46**.

[0363] Alternatively, the second supporting member $\mathbf{46}_2$ may be moved to a second position **94** angled at 15° to the first supporting member $\mathbf{46}_1$. Similarly, the third supporting member $\mathbf{46}_3$ may be moved to a third position **95** angled at 15° to the first supporting member $\mathbf{46}_1$ so that the total angle subtended by all the supporting members $\mathbf{46}_1$, $\mathbf{46}_2$, $\mathbf{46}_3$ would be 30° (about the implied origin at the blocking member **45**). The precise angle subtended is not critical. In this way, the configuration with multiple support members **46** may be arranged analogously to a single support member **46** including one or more through-holes **82**, **85**.

[0364] Stability of the blocking member **45** may be obtained by angling the support members **46** away from the perpendicular to the first axis **6**. For example, the three supporting members $\mathbf{46}_1$, $\mathbf{46}_2$, $\mathbf{46}_3$ may be arranged in a tripod configuration.

[0365] Referring also to FIG. **40**A and **40**B, in a still further example the blocking member **45** may be supported by, or integrated with, a mesh **96**.

[0366] FIG. **40**A shows a cross-section of the configuration using mesh **96** along a plane parallel to the first axis **6** (x-z plane as illustrated) and FIG. **40**B shows a view of the configuration **92** using mesh **96** the first axis **6** (z as illustrated).

[0367] The mesh **96** leaves gaps **97**, and in the example shown in FIGS. **40**A and **40**B spans the entire flow conduit **4**. In this example, the blocking member **45** is integrally formed with the mesh **96**, for example the mesh **96** and blocking member **45** may be formed from a sheet of material by punching out the gaps **97** (or equivalent subtractive manufacturing method).

[0368] The mesh **96** configuration differs from the prior art flow conditioner **38** in that the mesh should be as thin as possible relative to the gaps **97**. For example, the thickness of the mesh **96** parallel to the first axis **6** is preferably less than a dimension of gaps **97** (or through-holes) of the mesh **96**, and more preferably less than or equal to half the dimension of gaps **97** of the mesh **96**. Thus, unlike the flow conditioner **38**, the gaps **97** of mesh **96** are not long enough (along the first axis **6**) to force fluid into emerging as jets **41**. This may prevent the mesh **96** from causing an undue pressure drop.

[0369] Pressure drops due to the mesh **96** may be additionally moderated by keeping the mesh **96** structure as thin as possible compared to the gaps **97**, for example, when viewed projected onto the plane perpendicular to the first axis, the projected area of the mesh **96** structure may be less than or equal to 20% of the projected area of gaps **97** in the mesh **97** (excluding the projected area of the blocking member **45**. In some examples, the mesh may be a wire-mesh.

[0370] Instead of being integrally formed with the mesh **96**, the blocking member **45** may be attached to the mesh **96**. When the blocking member **45** is attached to the mesh **96**, the blocking member **45** may extend for a greater distance along the first axis **6** either upstream and/or downstream of the mesh **96**. For example as indicated by the outline **98** shown in FIG. **40**A.

[0371] Instead of covering the entire cross-section of the flow conduit **5**, the mesh may cover a fraction of the cross-section of the flow conduit **5**, for example a strip.

[0372] The mesh **96** is more susceptible to clogging compared to other structures described herein for supporting the blocking member **45**. In some applications it may be intentional, for example to prevent particles traveling further in a system past the meter. The mesh **96** may be used to filter in addition to supporting the blocking member **45**. Therefore, it may be advantageous for the mesh **96** to be easily removable for cleaning. When the blocking member **45** has equal thickness (along the first axis **6**) to the mesh **96**, the mesh and blocking member **45** (forming flow deflecting member **26**) may be received through a slot in the flow conduit **5** (sealed around the mesh **96** by an O-ring for example). Alternatively, the mesh **96** may be supported by an insert (not shown) received into the first **7** or second **9** opening. In another example, the mesh **96** may be sandwiched between the flow conduit **5** and a connecting pipe, for example withing the flanges **74** between first pipe **75** and flow conduit **5** or second pipe **76** and flow conduit **5** as shown in FIG. **29** or **30**, or between the flow conduit **5** and setter **28** shown in FIG. **6**.

[0373] The mesh **96** within the area of the flow conduit **5** may be supported by a structure with a projected area of less than 25% of the flow conduit **5**. The mesh **96** may have an outer frame (not shown) that strengthens the assembly of mesh **96** and blocking member **45** and provides a surface to seal against. The frame (not shown) may be outside the area of the inner diameter of the flow conduit **5**.

[0374] Although claims have been formulated in this application to particular combinations of features, it should be understood that the scope of the disclosure of the present invention also includes any novel features or any novel combination of features disclosed herein either explicitly or implicitly or any generalization thereof, whether or not it relates to the same invention as presently claimed in any claim and whether or not it mitigates any or all of the same technical problems as does the present invention. The applicant hereby gives notice that new claims may be formulated to such features and/or combinations of such features during the prosecution of the present application or of any further application derived therefrom.

1. An ultrasonic meter for measuring a flow-rate of a fluid, comprising:

a flow conduit for the fluid, the flow conduit extending along a first axis between a first opening and a second opening;

two or more pairs of ultrasonic transducers, each pair of ultrasonic transducers configured to define a corresponding beam path intersecting the flow conduit within a measurement region of the flow conduit, wherein substantially every part of each beam path makes a non-zero angle with the first axis, and wherein when viewed projected onto a plane perpendicular to the first axis, a projection of a first beam path intersects a projection of a second beam path;

a flow deflecting member supported between the first opening and the measurement region, wherein when viewed projected onto the plane perpendicular to the first axis, a projection of the flow deflecting member at least partially overlaps the intersection of the projections of the first and second beam paths;

wherein the flow deflecting member is configured such that swirl is not introduced in response to a straight fluid flow passing the flow deflecting member.

2. The ultrasonic meter according to claim **1**, wherein when viewed projected onto the plane perpendicular to the first axis, the projection of the flow deflecting member does not divide a projection of the flow conduit into two separate regions.

3. The ultrasonic meter according to claim **1**, wherein when viewed projected onto the plane perpendicular to the first axis, the projection of the flow deflecting member divides a projection of the flow conduit into two or more separate regions including a primary region, wherein an area of the primary region in the projection accounts for 75% or more of the total projected area of the two or more separate regions.

4. The ultrasonic meter according to claim **1**, wherein when viewed projected onto the plane perpendicular to the first axis, the projection of the flow deflecting member at least partially overlaps a peak flow region of the plane:

wherein the peak flow region is defined relative to a projection onto the plane of a flow conduit of a reference ultrasonic meter which is identical to the ultrasonic meter except for omitting the flow deflecting member;

wherein the peak flow region corresponding to a region of the plane in which a flow speed through the reference ultrasonic meter is above a mean flow speed in response to passing a steady state fluid flow through the reference ultrasonic meter at a Reynolds number of approximately 3000.

5. An ultrasonic meter according to claim **1**, wherein the flow deflecting member is separated from the measurement region by a distance along the first axis which is between zero and 5 times a maximum dimension of the flow conduit perpendicular to the first axis.

6. An ultrasonic meter according to claim **1**, wherein at least one of:

a leading side of the flow deflecting member facing towards the first opening has a rounded bevel profile around at least part of its perimeter and/or tapers towards the first opening;

wherein a trailing side of the flow deflecting member facing towards the measurement region has a sharp edge around at least part of its perimeter; and

when viewed projected onto a plane parallel to the first axis, the flow deflecting member has a quadrilateral shape.

7. (canceled)

8. (canceled)

9. An ultrasonic meter according to claim **1**, wherein the flow deflecting member comprises a blocking member disposed within the fluid conduit and held in place by a supporting member.

10. An ultrasonic meter according to claim **9**, wherein when viewed projected onto the plane perpendicular to the first axis, a projection of the supporting member connects to a projection of the blocking member along a connection direction, and a maximum dimension of the projection of the blocking member perpendicular to the connection direction is greater than a maximum dimension of the projection of the supporting member perpendicular to the connection direction.

11. An ultrasonic meter according to claim **1**, wherein the flow deflecting member comprises:

a radial member extending inwards from an inner surface of the flow conduit;

a blocking member disposed within the fluid conduit and offset along the first axis away from the first opening relative to the radial member, the blocking member held in place by a rod or wire extending along the first axis from the radial member to the blocking member.

12. An ultrasonic meter according to claim **1**, wherein the flow deflecting member comprises a blocking member disposed within the fluid conduit and held in place by two or more supporting members.

13. An ultrasonic meter according to claim **1**, wherein the flow deflecting member comprises a blocking member disposed within the fluid conduit and held in place by a mesh.

14. (canceled)

15. An ultrasonic meter according to claim **9**, wherein a length of the blocking member along the first axis is between 0.2 and 2 times a maximum dimension of the blocking member perpendicular to the first axis.

16. An ultrasonic meter according to claim **1**, wherein the flow deflecting member does not include any portions which are conical, frustoconical, pyramidal, or frustopyramidal.

17. (canceled)

18. An ultrasonic meter according to claim **1**, wherein a pressure drop across the flow deflecting member is 0.15 Pa or less in response to an average flow velocity in the flow conduit of 0.15 $m \cdot s^{-1}$ of fluid in the form of water at 20° C.

19-22. (canceled)

23. An ultrasonic meter according to claim **1**, wherein the flow deflecting member is a first flow deflecting member, and wherein when viewed projected onto the plane perpendicular to the first axis, a projection of a third beam path intersects a projection of a fourth beam path;

the ultrasonic meter further comprising:

a second flow deflecting member supported between the first opening and the measurement region;

wherein, when viewed projected onto the plane perpendicular to the first axis, a projection of the second flow deflecting member at least partially overlaps the intersection of the projections of the third and fourth beam paths.

24. An ultrasonic meter according to claim **1**, wherein for each flow deflecting member supported between the first opening and the measurement region, an identical flow deflecting member is supported between the second opening and the measurement region.

25. An insert for an ultrasonic meter, the ultrasonic meter comprising:

a flow conduit for the fluid, the flow conduit extending along a first axis between a first opening and a second opening;

two or more pairs of ultrasonic transducers, each pair of ultrasonic transducers configured to define a corresponding beam path intersecting the flow conduit within a measurement region of the flow conduit, wherein substantially every part of each beam path makes a non-zero angle with the first axis, and wherein when viewed projected onto a plane perpendicular to the first axis, a projection of a first beam path intersects a projection of a second beam path;

the insert comprising a flow deflecting member configured such that, when the insert is received into the flow conduit:

the flow deflecting is supported between the first opening and the measurement region; and

when viewed projected onto the plane perpendicular to the first axis, a projection of the flow deflecting member at least partially overlaps the intersection of the projections of the first and second beam paths;

wherein the flow deflecting member is configured such that swirl is not introduced in response to a straight fluid flow passing the flow deflecting member.

26. An ultrasonic meter for measuring a flow-rate of a fluid, comprising:

a flow conduit for the fluid, the flow conduit extending along a first axis between a first opening and a second opening;

one or more pairs of ultrasonic transducers, each pair of ultrasonic transducers configured to define a corresponding beam path intersecting the flow conduit within a measurement region of the flow conduit, wherein substantially every part of each beam path makes a non-zero angle with the first axis, and wherein when viewed projected onto a plane perpendicular to the first axis, a projection of a first beam path intersects a peak flow region;

a flow deflecting member supported between the first opening and the measurement region, wherein, when viewed projected onto the plane perpendicular to the first axis, a projection of the flow deflecting member at least partially overlaps the intersection of the first beam path and the peak flow region;

wherein the peak flow region is defined relative to a projection onto the plane of a flow conduit of a reference ultrasonic meter which is identical to the ultrasonic meter except for omitting the flow deflecting member;

wherein the peak flow region corresponds to a region of the plane in which a flow velocity through the reference ultrasonic meter is above a mean flow velocity in response to passing a steady state fluid flow through the reference ultrasonic meter at a Reynolds number of approximately 3000;

wherein the flow deflecting member is configured such that swirl is not introduced in response to a straight fluid flow passing the flow deflecting member.

27. The ultrasonic meter according to claim **26**, wherein:

when viewed projected onto the plane perpendicular to the first axis, the result of subtracting the projection of the flow deflecting member from the projection of the flow conduit is a continuously connected second region.

28. The ultrasonic meter according to claim **26**, wherein when viewed projected onto the plane perpendicular to the first axis, the result of subtracting the projection of the flow deflecting member from the projection of the flow conduit is two or more separate regions including a primary region, wherein an area of the primary region in the projection accounts for 75% or more of the total projected areas of the two or more separate regions.

29-32. (canceled)

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