

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
10 April 2003 (10.04.2003)

PCT

(10) International Publication Number
WO 03/029776 A2

(51) International Patent Classification⁷: **G01K 7/02**

(21) International Application Number: PCT/US02/31280

(22) International Filing Date: 1 October 2002 (01.10.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/969,092 2 October 2001 (02.10.2001) US

(71) Applicant: **AMETEK, INC.** [US/US]; Station Square,
Paoli, PA 19301 (US).

(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

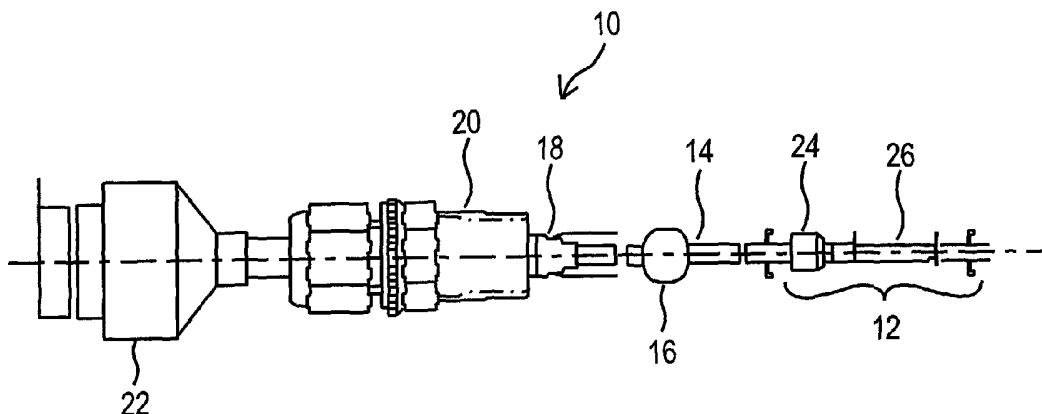
— without international search report and to be republished upon receipt of that report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(72) Inventors: **PARK, Sun**; 2 Fisher Terrace, Woburn, MA 01801 (US). **GINKUS, John, V.**; 16 Concord Drive, Atkinson, NH 03811 (US).

(74) Agent: **SOLOWAY, Norman, P.**; Hayes Soloway P.C., 130 W. Cushing Street, Tucson, AZ 85701 (US).

(54) Title: RAKE THERMOCOUPLE



(57) **Abstract:** A thermocouple probe assembly is provided that includes at least one ball bushing placed along the length of the assembly to dampen vibrations and thereby reduce mechanical stress on the assembly. A rake thermocouple is provided that includes a plurality of probe tubes arranged parallel to one another, and each probe assembly is placed into an individual probe tube. Each probe tube has a window defined therein, and an air inlet port extending from the window generally perpendicular to the probe tube. The rake also includes a mated end cap and cup bushing with a defined gap between the inside diameter of the cup bushing and the outside diameter of the end cap to further dampen mechanical stress on the rake.



WO 03/029776 A2

RAKE THERMOCOUPLE

The present invention relates to temperature measurement technology, and more specifically, to a multi-element rake thermocouple. Particular utility for the present invention is found in temperature measurement in turbine engines.

Rake thermocouple devices are known in the art, and are generally provided as temperature measurement mechanisms for high temperature and/or high air flow environments such as turbine engines. As a general matter, rake thermocouple devices include a plurality of thermocouples arranged at different distances along the length of the rake, and exposed to the airflow in a turbine engine to measure temperature. One such thermocouple is provided in U.S. Patent No. 5,812,588, issued to Deak et al. The '588 patent discloses a temperature probe that includes an outer probe tube projecting into the hot-gas region of the waste-gas diffuser, the probe tube is provided with an inner bore running in the direction of the tube axis of the probe tube. The probe tube includes a number of throughflow ducts over its length running transversely relative to the tube axis and in which are located a number of thermocouples arranged in the throughflow ducts. The thermocouples are connected to a compensating line in a terminal box. Each thermocouple is arranged in a solely heat-movably guided manner in a protective tube which is fixed relative to the inner bore of the probe tube.

One disadvantage of this design is that in order to replace a single defective thermocouple, all the thermocouple units must be removed and replaced. Also, the '588 patent does not provide any mechanism to dampen stress vibrations that occur in turbine environments.

Accordingly the present invention provides a thermocouple probe assembly that includes ball bushings placed along the length of the assembly to dampen vibrations and thereby reduce mechanical stress on the assembly. A rake thermocouple is provided that includes a plurality of probe tubes arranged parallel to one another, and each probe assembly is placed into an individual probe tube. Each probe tube has a window defined therein, and an air inlet port extending from the window generally perpendicular to the probe tube. The rake also includes a mated end cap and cup bushing having a defined gap between the inside diameter of the cup

1 bushing and the outside diameter of the end cap to further dampen mechanical stress
2 on the rake.

3 In one aspect, the present invention provides a thermocouple probe assembly
4 that includes a thermocouple tip section comprising a thermocouple junction coupled
5 to a tapered bushing, a ball bushing, and a connecting cable connecting the ball
6 bushing the said thermocouple tip section.

7 The present invention also provides a thermocouple probe assembly,
8 comprising a thermocouple junction coupled to a ball bushing. The ball bushing is
9 coupled to the thermocouple junction at a predetermined distance from the
10 thermocouple junction. The predetermined distance being chosen to dampen
11 vibration of the thermocouple probe assembly.

12 In yet another aspect, the present invention provides thermocouple probe tube,
13 comprising a tubular member having an inside diameter and a long axis; a window
14 formed within the tubular member formed generally perpendicular to the long axis;
15 and an air inlet port extending from the window in at least one direction.

16 In still another aspect, the present invention provides rake thermocouple,
17 comprising at least one thermocouple probe assembly comprising a thermocouple
18 junction coupled to a ball bushing; and at least one thermocouple probe tube housing
19 said thermocouple probe, said at least one thermocouple probe tube comprising a
20 tubular member having an inside diameter and a long axis; a window formed within
21 the tubular member formed generally perpendicular to the long axis; and an air inlet
22 port extending from the window in at least one direction.

23 It will be appreciated by those skilled in the art that although the following
24 Detailed Description will proceed with reference being made to preferred
25 embodiments, the present invention is not intended to be limited to these preferred
26 embodiments. Other features and advantages of the present invention will become
27 apparent as the following Detailed Description proceeds, and upon reference to the
28 Drawings, wherein like numerals depict like parts, and wherein:

29 Fig. 1 depicts a side view of an exemplary thermocouple probe assembly of
30 the present invention;

31 Fig. 1A depicts a detailed view of the probe of the exemplary thermocouple
32 probe assembly of Fig. 1;

1 Fig. 2 is side view of an exemplary rake for housing a plurality of
2 thermocouple probe assemblies of the present invention;

3 Fig. 2A is an exploded view of a probe tip section of the thermocouple probe
4 assembly of Fig. 1 positioned in an airflow window of the probe tube;

5 Fig. 3 is a cross-sectional view of a probe tip section of the thermocouple
6 probe assembly of Fig. 1 positioned in an airflow window of the probe tube;

7 Fig. 4 depicts a detailed view of an exemplary probe tube and thermocouple
8 probe assembly of the present invention; and

9 Fig. 5 depicts another assembled side view of the exemplary rake
10 thermocouple of the present invention.

11 Fig. 1 depicts a thermocouple probe assembly 10 according to one exemplary
12 embodiment of the present invention. The thermocouple probe assembly of this
13 exemplary embodiment comprises a thermocouple probe tip portion 12 that includes a
14 thermocouple junction 26 coupled to a tapered bushing 24. Each thermocouple probe
15 tip 12 is attached to a ball bushing 16 via a cable segment 14, which is connected to a
16 backshell 22 via an over sheath sleeve 18. As will be described below, tapered
17 bushing 24 is used to secure thermocouple probe 10 into the rake. The backshell 22
18 includes mated connectors (for conductors of the thermocouple) that connect to a high
19 temperature connector 50. These features will be described in greater detail below.

20 Referring now to Fig. 1A, the details of each thermocouple probe assembly 10
21 are provided. Ball bushings $16_1 \dots 16_n$ are placed between the sleeve 18 and the
22 thermocouple probe tip 12. Likewise, connecting each ball bushings $16_1 \dots 16_n$ is a
23 length of mineral insulated cable $14_1 \dots 14_n$, which is used to connect the ball bushing
24 16 to the sleeve 18, and the ball bushing 16 to the thermocouple 12. The ball bushing
25 16 protects the probes from wear and reduce deflections by restricting its movement
26 during vibration. In the exemplary embodiment, the ball bushings are placed along
27 the length between the sleeve 18 and the thermocouple 12 at peak mechanical
28 resonance points, but it is equally contemplated herein that other points along the
29 length of the probe tube can be chosen in accordance with the exemplary embodiment
30 of the present invention. For example, near peak resonant points, or off-peak resonant
31 points may be chosen to provide sufficient mechanical damping, depending on the
32 materials chosen and the desired sensitivity. Thus, the present invention is intended

1 to broadly cover the use of ball bushing (or equivalents thereof) placed anywhere
2 along the length of the thermocouple probe assembly. In the exemplary embodiment,
3 the cable 14₁ ... 14_n is formed of mineral insulated cable which has sufficient
4 flexibility to resist breakage when the entire thermocouple is fixed at either end but
5 stiff enough to allow the probe to be inserted into the probe tube.

6 Fig. 2 depicts the rake thermocouple 100 of the exemplary embodiment. The
7 rake thermocouple assembly includes a plurality of thermocouple probe assemblies 10
8 disposed within probe tubes 28. The probe tubes 28 are arranged generally parallel to
9 one another and are comprised of a tubular member having an inside diameter to
10 receive the probes, connected on either end to an outer housing 38 (that includes a
11 flange portion 40) and an end cap 36. Since each thermocouple probe assembly 10 is
12 independent of the others in the rake, the present invention improves cost and
13 efficiency by permitting individual probe assemblies to be removed/repaired instead
14 of having to remove all the probe assemblies. Figure 2A is an exploded view of one
15 probe tip section 12 positioned in a window 30 of the probe tube 28, as will be
16 described below.

17 Fig. 3 depicts a detailed view of the probe tip section of the thermocouple
18 probe positioned in a window defined in the exemplary probe tube 28. In the
19 exemplary embodiment, each individual thermocouple probe assembly is inserted
20 such that the tapered bushing 24 mates against a tapered stop 32 formed within the
21 probe tube. Bushing 24 and stop 32, when mated together, form a stop mechanism
22 that secures each thermocouple probe assembly to the rake thermocouple. The stop
23 mechanism is provided in the exemplary embodiment to allow each thermocouple
24 probe assembly to be independent from other probe assemblies. Securing both ends
25 of the probe assembly with the fitting 20 and tapered bushing 24 is preferable (but not
26 necessary) to yield better dampening and better longevity in high vibration
27 environments observed in the gas turbines. Tapered surfaces are used in the stop
28 mechanism to allow easy disengagement during transient thermal growth. This
29 minimizes thermal stress due to thermal expansion. Fig. 3 is depicted in cross-
30 section, and will be understood that the stop 32 is an annular ring member formed
31 within the probe tube 28. The probe tube 28 includes a window 30 (or opening) that
32 permits air to flow across the thermocouple 26. The window 30 is defined within the

1 probe tube such that an air inlet portion of the window 30A and an air egress portion
2 of the window 30B are generally aligned and are generally perpendicular to the long
3 axis (X-axis) of the probe tube and generally parallel to the air flow. As will be
4 described in detail below, port 34 is provided in the window 30 to provide more
5 efficient airflow across the thermocouple 26.

6 Fig. 4 depicts a cross-sectional view of the rake thermocouple of Fig. 2. In
7 this example, the probe tubes 28A through 28F are positioned in a stacked triangular
8 arrangement as shown. This arrangement allows each independent thermocouple
9 probe assembly exposure to the flow of air while reducing the cross-sectional
10 diameter of the rake. Other arrangements can be provided without departing from the
11 scope of the present invention, and the present invention is not intended to be limited
12 to this arrangement as those skilled in the art will recognize that the present invention
13 is not limited to the number of probe tubes used. Probe tube 28E, in this
14 configuration, is provided for support, and does not include a thermocouple probe
15 assembly, window or air inlet port (but, of course, may be so provided). Weld spots
16 50 are provided at locations along the length of the rake to hold the individual probe
17 tubes together. In the exemplary embodiment, extending from each window 30 of
18 each probe tube is a port 34A-34D and 34F. Ports 34A, 34B, 34C, 34D and 34F are
19 hatched since they are positioned at different lengths along the length of the rake
20 thermocouple in Fig. 3. Accordingly, taking the inlet port 34D as an example, the
21 inlet port essentially comprises an extension to the window 30 that is formed
22 generally perpendicular to the long axis of the probe tube. The inlet ports are added
23 to each window so that similar dynamic temperatures are observed across each probe
24 of the thermocouple. Generally perpendicular, as defined herein, may vary widely
25 (+/- 45 degrees), depending on application parameters, desired air flow, operating
26 conditions, etc. The inlet ports generally provide an equal pressure drop across all the
27 probe tubes by insuring that air flow within each probe tube has a similar velocity and
28 therefore similar dynamic temperature. Each probe measures the total temperature,
29 which is a measure of the dynamic temperature (T_{dynamic}) and the static temperature
30 (T_{static}). By providing inlet ports for each thermocouple window, the present
31 invention provides a more accurate temperature measurement than conventional
32 means since a similar dynamic temperature is observed across all the thermocouples.

1 Note that the length of each inlet port depicted in Fig. 4 need not be exactly equal.
2 Indeed, in the exemplary embodiment of Fig. 4, the three different lengths shown in
3 the figure reflect the hole size in turbine casings. While this will cause some pressure
4 change between the lengths of inlet ports, the pressure change between shorter and
5 longer ports may only vary 10 to 20%, which is sufficiently accurate for most
6 applications, but may be adjusted as desired for given tolerance parameters.

7 Fig. 5 depicts the rake thermocouple 100 of the present invention that includes
8 the housing 38 disposed on one end of the rake, and end cap 36 disposed on the other
9 end of the rake, and a cup bushing 42. The end cap is disposed on one of said probe
10 tube and the cup bushing is affixed to an external member (e.g., turbine wall) and
11 adapted to receive the end cap thereby holding the rake. In most applications the rake
12 is fixed to the turbine walls via the flange 40 and cup bushing 42. In the exemplary
13 embodiment, the outside diameter of the end cap 36 and the inside diameter of the cup
14 bushing 42 are formed to define a gap between them. The dimensions of the gap
15 between the outside diameter of the end cap and the inside diameter of the bushing is
16 chosen in accordance with, for example, the overall thickness of the rake
17 thermocouple, expected minimum and maximum air flow velocities, temperature,
18 vibration, and/or other consideration, and is generally provided to allow movement
19 between the rake thermocouple and the bushing to flatten the amplitude of resonance
20 by introducing non-linearity at resonance vibration. In this manner, the stress on the
21 unit is thereby reduced. The actual dimension of the aforementioned gap is
22 determined by the factors set forth above, and the present invention is intended to
23 broadly cover a range of such gaps, depending on the physical dimensions of the rake
24 and the particular operating environment.

25 Thus, there has been provided a thermocouple probe assembly, a probe tube
26 and rake that provide increased mechanical dampening, permit removal of each
27 individual thermocouple probe assemblies, and provide and more accurate
28 temperature measurement, as is detailed above. Those skilled in the art will recognize
29 numerous modifications to the present invention, and all such modifications are
30 deemed within the scope of the present invention, only as limited by the claims.

1 What is claimed is:

2 1. A thermocouple probe assembly, comprising:

3 a thermocouple tip section comprising a thermocouple junction coupled to a
4 tapered bushing;

5 a ball bushing; and

6 a connecting cable connecting said ball bushing with said thermocouple tip
7 section.

8 2. A thermocouple probe as claimed in claim 1, further comprising a backshell
9 section connected to said ball bushing and connector coupled to said backshell
10 section, said backshell section comprising mated connectors for conductors of said
11 thermocouple junction which connect to connectors.

12 3. A thermocouple probe as claimed in claim 1, wherein said ball bushing is
13 coupled at a predetermined distance from said thermocouple tip section, said
14 predetermined distance being chosen to dampen vibration of said thermocouple probe
15 assembly.

16 4. A thermocouple probe as claimed in claim 3, wherein said predetermined
17 distance comprising a peak mechanical resonance point.

18 5. A thermocouple probe assembly, comprising a thermocouple junction coupled
19 to a ball bushing, wherein said ball bushing is coupled to said thermocouple junction
20 at a predetermined distance from said thermocouple junction, said predetermined
21 distance being chosen to dampen vibration of said thermocouple probe assembly.

22 6. A thermocouple probe as claimed in claim 5, further comprising a backshell
23 section connected to said ball bushing and connector coupled to said backshell
24 section, said backshell section comprising mated connectors for conductors of said
25 thermocouple junction which connect to connectors.

26 7. A thermocouple probe as claimed in claim 5, wherein said predetermined
27 distance comprising a peak mechanical resonance point.

28 8. A thermocouple probe tube, comprising a tubular member having an inside
29 diameter and a long axis; a window formed within said tubular member formed
30 generally perpendicular to said long axis; and an air inlet port extending from said
31 window in at least one direction.

- 1 9. A thermocouple probe tube as claimed in claim 8, wherein said air inlet port
2 being positioned generally parallel to a direction of airflow flowing through said air
3 inlet port, and extending from said window generally perpendicular to said long axis.
- 4 10. A rake thermocouple, comprising:
5 at least one thermocouple probe assembly comprising a thermocouple junction
6 coupled to a ball bushing; and
7 at least one thermocouple probe tube housing said thermocouple probe, said
8 at least one thermocouple probe tube comprising a tubular member having an inside
9 diameter and a long axis; a window formed within said tubular member formed
10 generally perpendicular to said long axis; and an air inlet port extending from said
11 window in at least one direction.
- 12 11. A rake as claimed in claim 10, said thermocouple probe assembly further
13 comprising a tapered bushing coupled to said thermocouple junction.
- 14 12. A rake as claimed in claim 10, said thermocouple probe assembly further
15 comprising a backshell section connected to said ball bushing and connector coupled
16 to said backshell section, said backshell section comprising mated connectors for
17 conductors of said thermocouple junction which connect to connectors.
- 18 13. A rake as claimed in claim 10, wherein said ball bushing is coupled at a
19 predetermined distance from said thermocouple junction, said predetermined distance
20 being chosen to dampen vibration of said thermocouple probe assembly.
- 21 14. A rake as claimed in claim 13, wherein said predetermined distance
22 comprising a peak mechanical resonance point.
- 23 15. A rake as claimed in claim 10, wherein said air inlet port being positioned
24 generally parallel to a direction of airflow flowing through said air inlet port, and
25 extending from said window generally perpendicular to said long axis.
- 26 16. A rake as claimed in claim 10, wherein each said thermocouple junction
27 placed in said window and said air inlet port, thereby exposing said thermocouple
28 junction to airflow.
- 29 17. A rake as claimed in claim 11, said probe tube further comprising a tapered
30 stop bushing mated to said tapered bushing, said tapered stop bushing being
31 positioned in said probe tube so that, when said tapered bushing is mated to said stop,
32 said thermocouple is positioned in said air inlet port.

1. 18. A rake as claimed in claim 10, further comprising an end cap disposed on one
2 of said probe tube and a mated cup bushing, said cup bushing affixed to an external
3 member and adapted to receive said end cap thereby holding said probe tube.
- 4 19. A rake as claimed in claim 18, wherein the outside diameter of the end cap and
5 the inside diameter of the bushing are chosen to provide a gap between them.
- 6 20. A rake as claimed in claim 10, wherein each said thermocouple probe
7 assembly is removably disposed within said probe tube, respectively.

FIG. 1

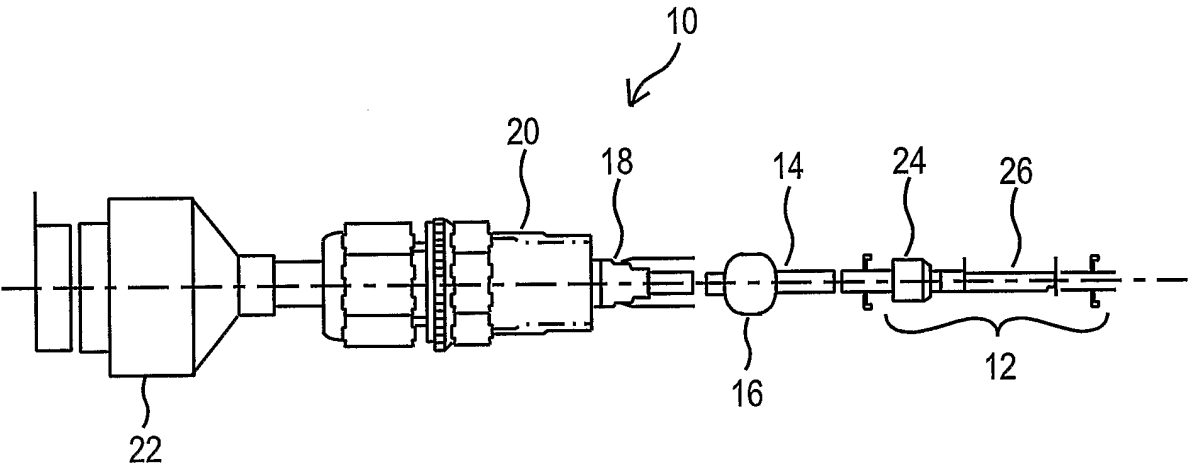


FIG. 1A

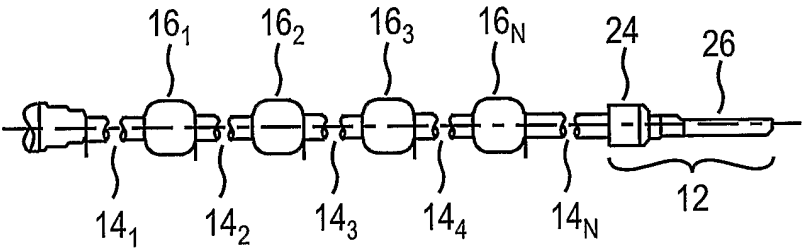


FIG. 2

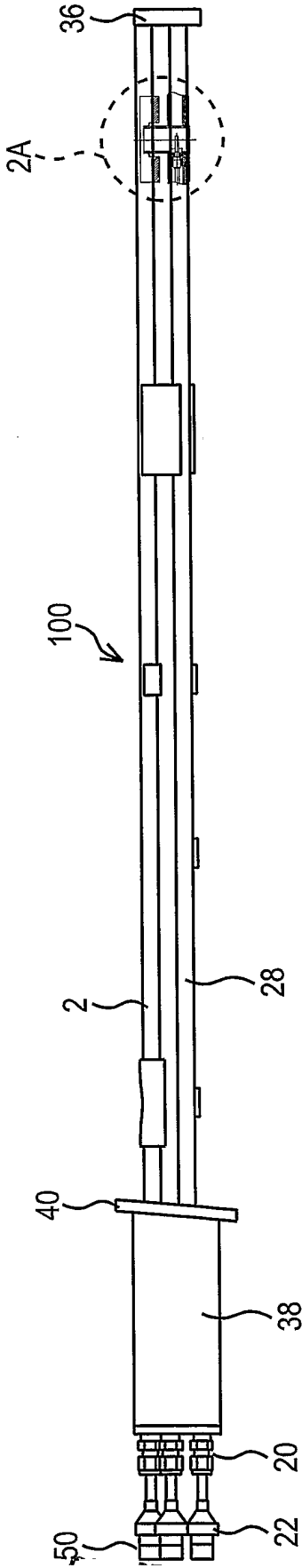


FIG. 2A

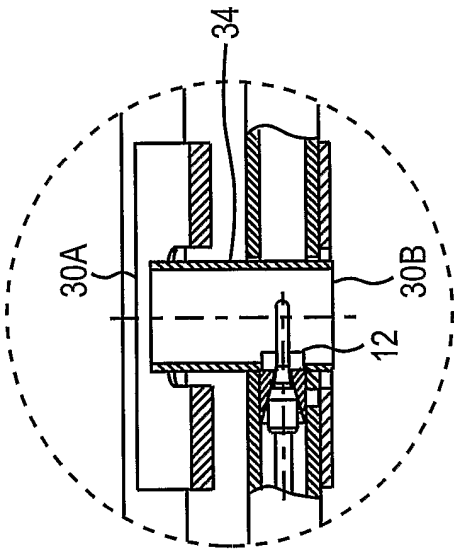


FIG. 3

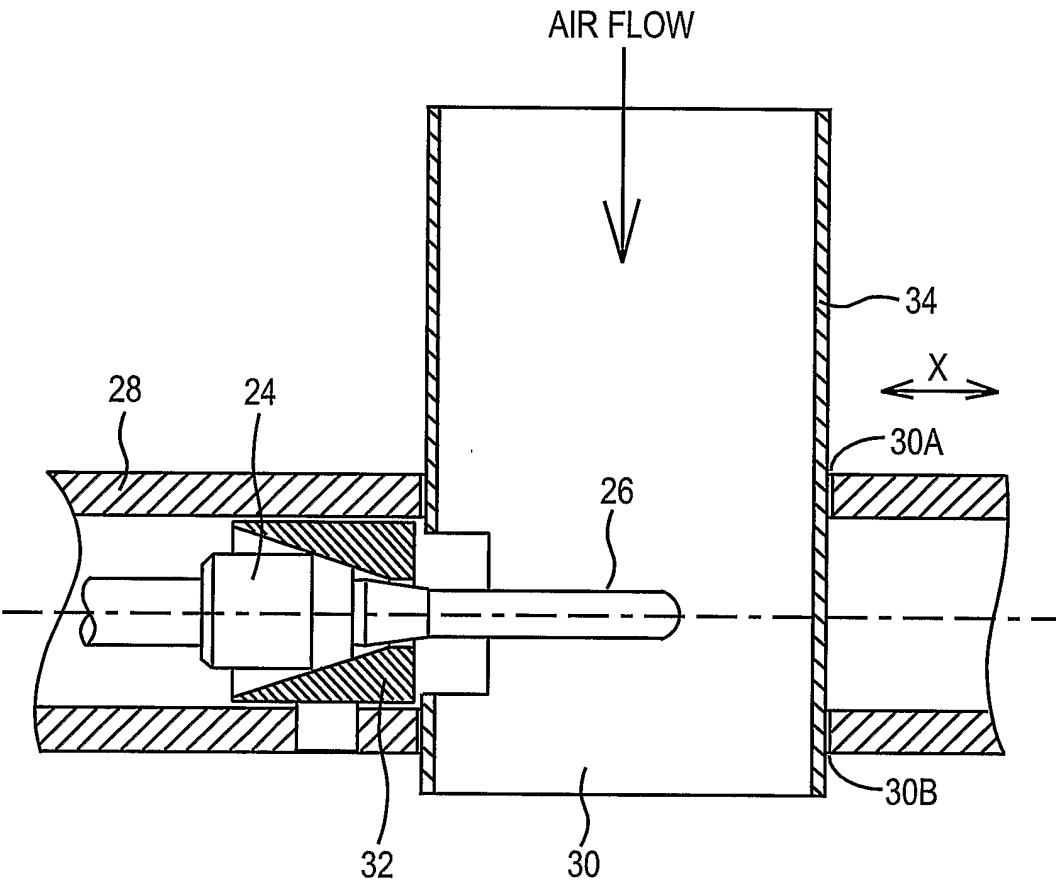


FIG. 4

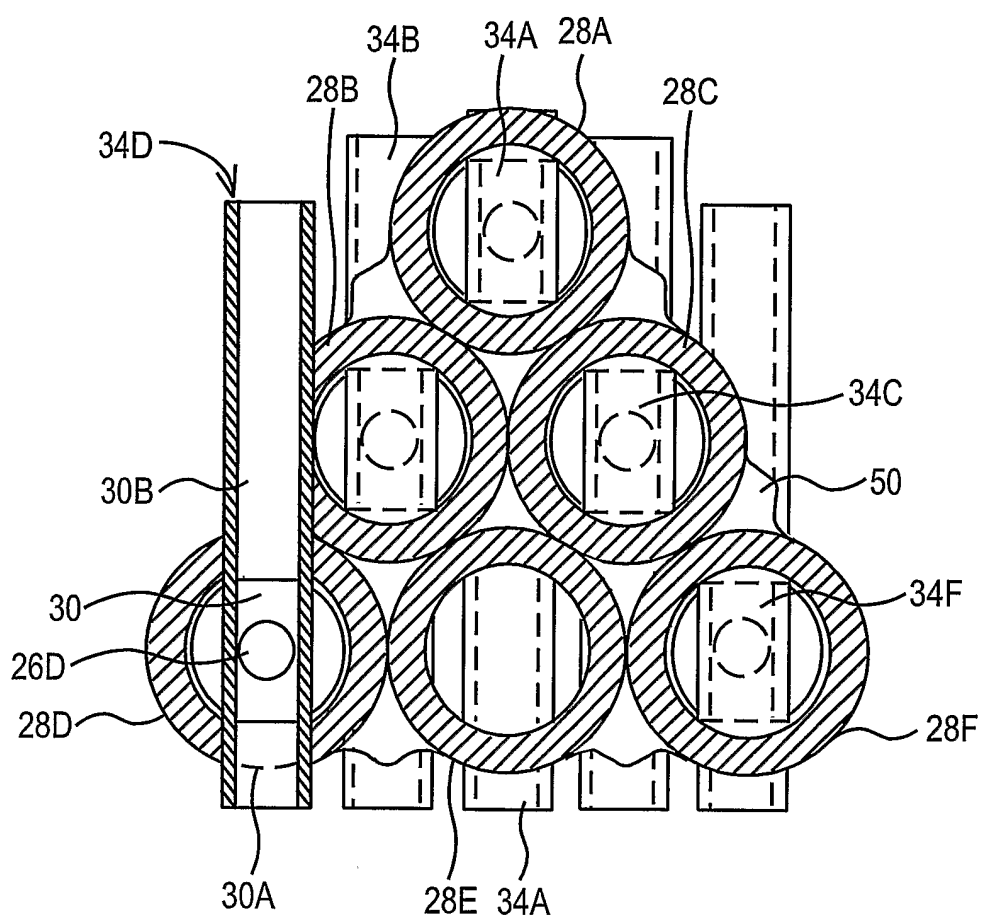


FIG. 5

