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(54) **Title**: APPARATUS FOR MONITORING PARTICLES

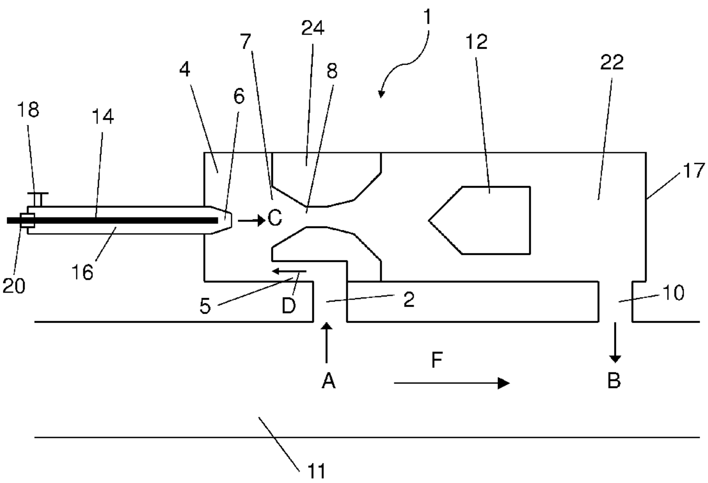

Fig. 1

(57) **Abstract**: The present invention relates to an apparatus (1) for monitoring particles (54) in a channel (11) or a space comprising aerosol. The apparatus (1) comprises an inlet chamber (4), an ejector (24), gas supply (6, 16, 18) arranged to feed essentially particle free gas flow (C) to the ejector (24) via the inlet chamber (4) and at least one sample inlet (2) arranged to provide a sample aerosol flow (A) from the channel (11) or the space into the inlet chamber (4) by means of suction provided by the gas supply (6, 16, 8) and the ejector (24). The apparatus (1) further comprises a sample supply channel (5) arranged between the sample inlet (2) and the inlet chamber (4) for mixing the 1 sample aerosol to the essentially particle free gas flow (C). The sample supply channel (5) is arranged to direct the sample aerosol flow (A) at least partly in opposite direction to the essentially particle free gas flow (C).

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Apparatus for monitoring particles

The present invention relates to an apparatus for monitoring particles and especially to an apparatus as defined in the preamble of independent claim 1.

Background of the invention

Fine particles are formed in many industrial processes and combustion processes. Furthermore, fine particles exist in breathing air flowing in ducts and ventilation systems and in room spaces. For various reasons these fine particles are measured. The fine particle measurements may be conducted because of their potential health effects and also for monitoring operation of industrial processes and combustion processes. The fine particles are also measured in ventilation systems for monitoring air quality. Another reason for monitoring fine particles is the increasing use and production of nanosized particles in industrial processes. The above reasons there is need for reliable fine particle measurement equipments and methods.

One prior art method and apparatus for measuring fine particles is described in document WO2009109688 A1. In this prior art method clean, essentially particle free, gas is supplied into the apparatus and directed as a main flow via an inlet chamber to an ejector provided inside the apparatus. The clean gas is further ionized before and during supplying it into the inlet chamber. The ionized clean gas may be preferably fed to the ejector at a sonic or close to sonic speed. The ionizing of the clean gas may be carried out for example using a corona charger. The inlet chamber is further provided with a sample inlet arranged in fluid communication with a channel or a space comprising aerosol having fine particles. The clean gas flow and the ejector together cause suction to the sample inlet such that a sample aerosol flow is formed from the duct or the space to the inlet chamber. The sample aerosol flow is thus provided as a side flow to the ejector. The ionized clean gas charges the particles. The charged particles may be further conducted back to the duct or space containing the aerosol. The fine particles of the aerosol sample are thus monitored by monitoring the electrical charge carried by the electrically charged particles. Free ions may removed further be removed using an ion trap.

One important demand for the fine particle monitoring apparatuses is reliable operation and efficient operation. Furthermore, it is also preferable that these fine particle monitoring apparatuses may be operated with low energy consumption and continuously for conducting fine particle measurements in real-time.

It has been surprisingly discovered that one problem of the prior art fine particle measurement apparatuses is inefficient charging of the particles of the sample aerosol flow. As the velocity of the essentially particle free ionized gas to ejector is high there is only a limited amount of time for charging the particles of the sample aerosol flow. Inefficient charging of the particles of the sample aerosol flow causes unreliable measurement of the particles.

Brief description of the invention

The object of the present invention is to provide an apparatus so as to overcome or at least alleviate the prior art disadvantages. The objects of the present invention are achieved with an apparatus according to the characterizing portion of claim 1, which apparatus comprises a sample supply channel arranged between the sample inlet and the inlet chamber for mixing the sample aerosol to the essentially particle free gas flow.

The preferred embodiments of the invention are disclosed in the dependent claims.

The present invention is based on the idea of providing an apparatus for monitoring particles in a channel or a space comprising aerosol in which apparatus the sample aerosol is supplied to the apparatus essentially as a countercurrent against the essentially particle free gas. In other words the sample aerosol flow is guided at least partly in opposite direction to essentially particle free gas flow for mixing the sample aerosol to the essentially particle free gas flow. The sample aerosol may be directed directly in opposite direction to the essentially particle free gas flow or at an angle against the essentially particle free gas flow. Thus the sample aerosol flow is supplied to the apparatus and towards essentially particle free ionized gas flow such that the flow direction of the sample aerosol has a flow component in opposite direction to the essentially particle free ionized gas flow.

The object of present invention is achieved by an apparatus comprising a sample supply channel arranged between the sample inlet and the inlet chamber. The sample supply channel is arranged to supply the sample aerosol flow to the inlet chamber at least partly in opposite direction to the essentially particle free gas flow. The sample supply channel may be provided inside the body of the apparatus. In one embodiment the sample supply channel is provided inside the inlet chamber. The sample supply channel may be formed by the body of the apparatus and the ejector or it may be a separate conduit.

The advantage of the present invention is that directing the sample aerosol flow at least partly in opposite direction in relation the essentially particle free ionized gas flow provides effective mixing of the sample aerosol and the essentially particle free ionized gas flow. Effective mixing of the sample aerosol flow and the essentially particle free ionized gas flow enhances and accelerates the charging of the particles of the sample aerosol flow. This ensures that all the particles of the sample aerosol flow are charged. As the operation of the particle monitoring apparatus is based on charging the particles of the sample aerosol flow. Therefore the efficient and reliable charging of the particles of the sample aerosol flow will enhance the operation of the apparatus and provide reliable and correct measurement results.

Brief description of the figures

In the following the invention will be described in greater detail, in connection with preferred embodiments, with reference to the attached drawings, in which

Figure 1 is a schematic view of one embodiment of an apparatus for monitoring fine particles; and

Figure 2 is a schematic view of another embodiment of an apparatus for monitoring fine particles.

Detailed description of the invention

The figure 1 shows one embodiment of an apparatus 1 for monitoring fine particles, especially particles having diameter less than 1 μm. The apparatus comprises a body 17 inside which the sample aerosol flow is guided for monitoring or measuring the fine particles. The apparatus 1 is connected to an aerosol duct 11 in side which is an aerosol flow F. Thus the apparatus 1 is arranged to monitor fine particles in the aerosol flow F. The aerosol duct may be exhaust duct of an industrial process or a ventilation duct. Alternatively aerosol duct may be any space comprising aerosol or any duct or channel having an aerosol flow F.

The apparatus 1 comprises a sample inlet 2 for guiding a sample aerosol flow A into the apparatus 1. The sample inlet 2 is in fluid communication with the aerosol duct 11 and inside of the apparatus 1. The apparatus 1 preferably also comprises a sample outlet 10 through which the analyzed sample aerosol flow B exhausted from the apparatus 1. In the embodiment of figure 1 the analyzed sample aerosol B is returned to the aerosol duct 11. The sample outlet 10 may also be arranged to conduct the analyzed sample aerosol B directly to the ambient atmosphere or some other location. Accordingly the apparatus 1 does not collect or store the sample aerosol A. In an alternative embodiment the apparatus may also comprise a sample-inlet arrangement 2 comprising one or more sample inlets. Furthermore the apparatus may also comprise a sample outlet arrangement 10 comprising one or more sample outlets. In figure 1 the sample inlet 2 and the sample outlet 10 are shown as short channels, but in an alternative embodiment the sample inlet 2 and the sample outlet 10 may be only opening provided to the body 17 of the apparatus 1.

The apparatus 1 comprises an inlet chamber 4 and the sample inlet 2 is arranged to provide a fluid communication between the aerosol duct 11 and the inlet chamber 4. The apparatus further comprises a gas supply for supplying clean particle free gas C into the inlet chamber 4. The gas supply comprises gas supply connection 18 via which the clean gas may be brought from a gas source. The gas may be cleaned in a filter or the like for essentially removing particles from the gas. The clean gas may be air or some other suitable gas. The clean gas may be fed from the gas source to a temperature regulator, which can either heat or cool the air. A magnetic valve may be switched to feed the gas to a flow controller, so that the clean gas flow C may be set to a desired value. The flow controller can be e.g. adjustable valve, critical aperture, flowmeter, mass flow controller or the like. The flow controller may be connected to a filter, which essentially removes particles from the pressurized gas, so that the particle concentration in the pressurized gas is remarkably lower than the particle concentration in the sample aerosol flow A. The clean gas is then fed to the measurement apparatus 1 through the gas supply connection 18.

The apparatus 1 further comprises a clean gas supply channel 16 through which the clean gas is fed to inlet chamber 4 of the apparatus 1. The clean gas supply channel comprises a nozzle head 6 opening into the inlet chamber 4. The clean gas supply is also provided with an ionization device 14 for ionizing at least a portion of the clean gas before or during feeding the clean gas from the nozzle head 6 into the inlet chamber 4. In the embodiment of figure 1 the ionization device is a corona needle 14 extending in the clean gas supply channel 16. The nozzle head 6 and the corona needle 14 are advantageously arranged such that corona needle 14 extends essentially to the vicinity of the nozzle head 6. This helps the corona needle 14 to stay clean and improves the ion production. The corona needle 14 is isolated from the clean gas flow channel and the body 17 of the apparatus 1 by one or more electrical insulators 20. According to the above mentioned the gas supply channel 16 is arranged to provide an essentially particle free ionized gas flow C to the inlet chamber 4.

The apparatus is further provided with an ejector 24. The ejector 24 comprises a converging-diverging nozzle 24 forming thus a converging-diverging flow channel, the throat 8 of the ejector 24. The ejector 24 is a pump-like device utilizing Venturi effect of a converging-diverging nozzle to convert the pressure energy of a main fluid flow to kinetic energy which creates a low pressure zone that draws in and entrains suction for a side fluid flow. The main fluid flow and the side fluid flow are at least partly mixed in the ejector 24. The main fluid flow and the side fluid flow are fed through an ejector inlet opening 7 into the ejector throat 8. After passing through the throat 8 of the ejector 24, the mixed fluid expands and the velocity is reduced which results in recompressing the mixed fluids by converting velocity energy back into pressure energy. In an alternative embodiment the apparatus may also comprise one or more clean gas supply channels 16, corona needles 14 and ejectors 24.

In the embodiment of figure 1 the essentially particle free ionized gas flow C is fed to the throat 8 of the ejector as a main flow. Therefore the clean gas supply channel 16 and the nozzle head 6 are arranged to feed the essentially particle free gas flow C at a high velocity into the throat 8. The velocity of the essentially particle free gas flow C is preferably sonic or close to sonic. In the ejector 24 the essentially particle free gas flow C forms a suction to the sample inlet 2 such that the sample aerosol flow A may be sucked into the inlet chamber 4. The sample aerosol flow A forms a side flow of the ejector 24. The flow rate of the sample aerosol flow A is depended essentially only on the geometry of ejector 24 and the flow rate of the essentially particle free ionized gas flow C. In a preferred embodiment the ratio of the main flow C to the side flow A is small, preferably less than 1:1 and more preferably less than 1:3. According to the above mentioned there is no need for actively feed the sample aerosol flow A into the apparatus 1, but it may be sucked by the by means of the clean gas supply and the ejector 24.

The essentially particle free ionized gas flow C and the sample aerosol flow are mixed in the inlet chamber 4 and in the ejector 24 such that the particles of the sample aerosol flow A are electrically charged during the mixing by the ionized clean gas flow C. The apparatus 1 further comprises ion trapping chamber 22. The ion trapping chamber 22 comprises an ion trap 12 for removing ions that are not attached to the particles of the sample aerosol flow A. The ion tarp 12 is provided with a collection voltage for removing the mentioned free ions. The voltage used for trapping free ions depends on design parameters of the apparatus 1, but typically the ion trap 12 voltage is 10V – 30kV. The ion trap 12 voltage may also be adjusted to removed nuclei mode particles or even the smallest particles in the accumulation mode.

The sample aerosol and the essentially clean gas mixed together are discharged from the apparatus 1 through the outlet 10 together with the ionized particles of the sample aerosol. The outlet 10 is provided in fluid communication with the ion trapping chamber 22 for exhausting the discharge flow B out of the apparatus 1. The outlet 10 may be arranged to supply the discharge flow B back to the aerosol duct 11 or to ambient atmosphere or some other location.

Particles of the aerosol F in the aerosol duct 11 are monitored by measuring the electrical charge carried by the electrically charged particles of the sample aerosol flow A. In a preferred embodiment particles of the aerosol F are monitored by measuring the electrical charge escaping with the electrically charged particles from the apparatus 1. The measurement of the charge carried by the electrically charged particles may be measured by many alternative ways. In one embodiment the charge carried by the electrically charged particles is measured by measuring the net current escaping from the sample outlet 10 To be able to measure the small currents, typically at pA level, the whole apparatus 1 is isolated from the surrounding systems.. An electrometer may be assembled between the isolated apparatus (i.e. a pint in the wall of body 17) and a ground point of the surrounding systems. With this kind of setup, the electrometer may measure the charge escaping from the isolated apparatus 1 together with the ionized particles. In other words this kind of setup measures the escaping current.

In the present invention the mixing of the essentially particle free ionized gas flow and the sample aerosol in the inlet chamber 4 is enhanced by feeding the sample aerosol flow C to the inlet chamber 4 at least partly in opposite direction to the essentially particle free gas flow C. The apparatus 1 is thus provided with a sample supply channel 5. In figure 5 the sample supply channel 5 is arranged to feed the sample aerosol into the inlet chamber 4 essentially in opposite direction to the essentially particle free gas flow C. As shown in figure 1 the sample supply channel 5 extends essentially parallel with ejector throat 8 and the clean gas supply channel 16. Thus the sample aerosol is fed into the inlet chamber 4 in the direction of arrow D, as countercurrent to the essentially particle free ionized gas flow C.

As shown in figure 1 the sample supply channel 5 is arranged between the sample inlet 2 and the inlet chamber 4. This arrangement provides efficient mixing of the sample aerosol and the essentially particle free ionized gas as they flow in opposite directions in the inlet chamber 4. In the embodiment of figure 1 the sample inlet 2 is provided downstream of the nozzle head 6 and the sample supply channel 5 extends from the sample inlet 2 in opposite direction of the clean gas supply channel 16. The sample inlet 2 is furthermore provided downstream of the ejector inlet opening 7 and the sample supply channel 5 extends substantially between the sample inlet 2 and the ejector inlet opening 7 in the flow direction of the essentially particle free gas flow C. In the embodiment of figure 1 the sample supply channel 5 is provided inside the body 17 of the apparatus. The sample supply channel may also be provided at least partly inside the inlet chamber 4. The sample supply channel of figure 1 is formed by the side wall of the body 17 of the apparatus and structures of the ejector 24. However, the sample supply channel may also be provided by a separate conduit, pipe or the like arranged inside the body 17 of the apparatus 1 or inside the inlet chamber 4.

Figure 2 shows another embodiment of the present invention in which the sample aerosol is fed at least partly in opposite direction to the essentially particle free gas flow C or in other words at an angle against the flow direction of the essentially particle free gas flow C. In one embodiment the sample aerosol flow is fed to the inlet chamber 4 at an angle less than 45° against the flow direction of the essentially particle free gas flow C. In another embodiment the sample aerosol flow is preferably fed to the inlet chamber 4 at an angle less than 30° against the flow direction of the essentially particle free gas flow C. The above mentioned angle has to be small enough and the sample supply channel arranged such that the essentially particle free ionized gas flow C does not cause too high pressure into the sample supply channel 5 due to the flow of the essentially particle free ionized gas. This means that the essentially particle free ionized gas flow may not penetrate into the sample supply channel. This ensures that the suction from the aerosol flow channel to the apparatus is maintained. As shown in figure 2 the sample supply channel 5 directs the sample aerosol flow at an angle towards the essentially particle free ionized gas flow C in direction of arrow D such that the flows are mixed efficiently and the particles of the sample aerosol are electrically charged. This provides rapid ionization of the particles of the sample aerosol.

As shown in figure 2 the sample supply channel provides at least partly opposed flow of sample aerosol towards the essentially particle free gas flow C. This is achieved by arranging the sample supply channel 5 to extend at an angle of less than 45º, preferably less than 30º in relation to the ejector throat 8, or the flow direction of the essentially particle free ionized gas flow C or the clean gas supply channel 16, as shown in figure 2. In the embodiment of figure 2 the sample inlet 2 is provided downstream of the nozzle head 6 and the sample supply channel 5 extends from the sample inlet 2 at an angle in opposite direction of the clean gas supply channel 16. The sample inlet 2 is furthermore provided downstream of the ejector inlet opening 7 and the sample supply channel 5 extends substantially between the sample inlet 2 and the ejector inlet opening 7. In the embodiment of figure 2 the sample supply channel 5 is provided inside the body 17 of the apparatus. The sample supply channel may also be provided at least partly inside the inlet chamber 4. The sample supply channel of figure 1 is formed by the structures of the ejector 24. However, the sample supply channel may also be provided by a separate conduit, pipe or the like arranged inside the body 17 of the apparatus 1 or inside the inlet chamber 4. Also other structural feature may be added to the apparatus for providing the sample supply channel 5.

It is apparent to a person skilled in the art that as technology advanced, the basic idea of the invention can be implemented in various ways. The invention and its embodiments are therefore not restricted to the above examples, but they may vary within the scope of the claims.

Claims

1. An apparatus (1) for monitoring particles (54) in a channel (11) or a space comprising aerosol, the apparatus (1) comprising:

- an inlet chamber (4);
- an ejector (24);
- gas supply (6, 16, 18) arranged to feed essentially particle free gas flow (C) to the ejector (24) via the inlet chamber (4); and
- at least one sample inlet (2) arranged to provide a sample aerosol flow (A) from the channel (11) or the space into the inlet chamber (4) by means of suction provided by the gas supply (6, 16, 18) and the ejector (24),

characterized in that

- the apparatus (1) further comprises a sample supply channel (5) arranged between the sample inlet (2) and the inlet chamber (4) for mixing the sample aerosol to the essentially particle free gas flow (C); and
- the sample supply channel (5) is arranged to direct the sample aerosol flow (A) at least partly in opposite direction to the essentially particle free gas flow (C).

2. The apparatus according to claim 1, **characterized** in that the sample supply channel (5) is arranged to direct the sample aerosol flow (A) essentially in opposite direction to the essentially particle free gas flow (C).

3. The apparatus according to claim 1, **characterized** in that the sample supply channel (5) is arranged to direct the sample aerosol flow (A) at an angle against the essentially particle free gas flow (C).

4. The apparatus according to claim 3, **characterized** in that the sample supply channel (5) is arranged to direct the sample aerosol flow (A) at an angle less than 45° against the essentially particle free gas flow (C).

5. The apparatus according to claim 3 or 4, **characterized** in that the sample supply channel (5) is arranged to direct the sample aerosol flow (A) at an angle less than 30° against the essentially particle free gas flow (C).

6. The apparatus according to any one of claims 1 to 5, **characterized** in that the sample supply channel (5) is arranged to provide at least partly opposed flow of sample aerosol flow (A) towards the essentially particle free gas flow (C).

7. The apparatus according to any one of claims 1 to 6, **characterized** in that the gas supply (6, 16, 18) comprises a nozzle head (6) arranged to feed the essentially particle free gas flow (C) to the ejector (24), and that the sample inlet (2) is provided downstream of the nozzle head (6).

8. The apparatus according to any one of claims 1 to 7, **characterized** in that the ejector (24) comprises an ejector inlet opening (7) through which the essentially particle free gas flow (C) and the sample aerosol (A) are supplied into the ejector (24), and that the that the sample inlet (2) is provided downstream of the ejector inlet opening (7).

9. The apparatus according to claim 8, **characterized** in that the sample supply channel (5) extends between the sample inlet (2) and the ejector inlet opening (7) in the flow direction of the essentially particle free gas flow (C).

10. The apparatus according to any one of claims 1 to 9, **characterized** in that the ejector (24) comprises an ejector throat (8) through which the essentially particle free gas flow (C) and the sample aerosol (A) flow, and that the sample supply channel (5) is arranged to extend essentially parallel with ejector throat (8).

11. The apparatus according to any one of claims 1 to 9, **characterized** in that the ejector (24) comprises an ejector throat (8) through which the essentially particle free gas flow (C) and the sample aerosol (A) flow, and that the sample supply channel (5) is arranged to extend at an angle of less than 45º, preferably less than 30º to ejector throat (8).

12. The apparatus according to any one of claims 1 to 11, **characterized** in that the apparatus (1) comprises a body (17), and that the sample supply channel (5) is provided inside the body (17) of the apparatus (1).

13. The apparatus according to any one of claims 1 to 12, **characterized** in that the sample supply channel (5) is provided at least partly inside the inlet chamber (4).

14. The apparatus according to any one of claims 1 to 13, **characterized** in that the sample supply channel (5) is formed by the body (17) of the apparatus (1) and the ejector (24).

15. The apparatus according to any one of claims 1 to 13, **characterized** in that the sample supply channel (5) is formed by a separate conduit arranged inside the body (17) of the apparatus (1).

16. The apparatus according to any one of claims 1 to 15, **characterized** in that the apparatus (1) comprises an ionization device (14) ionizing at least a fraction of the essentially particle free gas flow (C).

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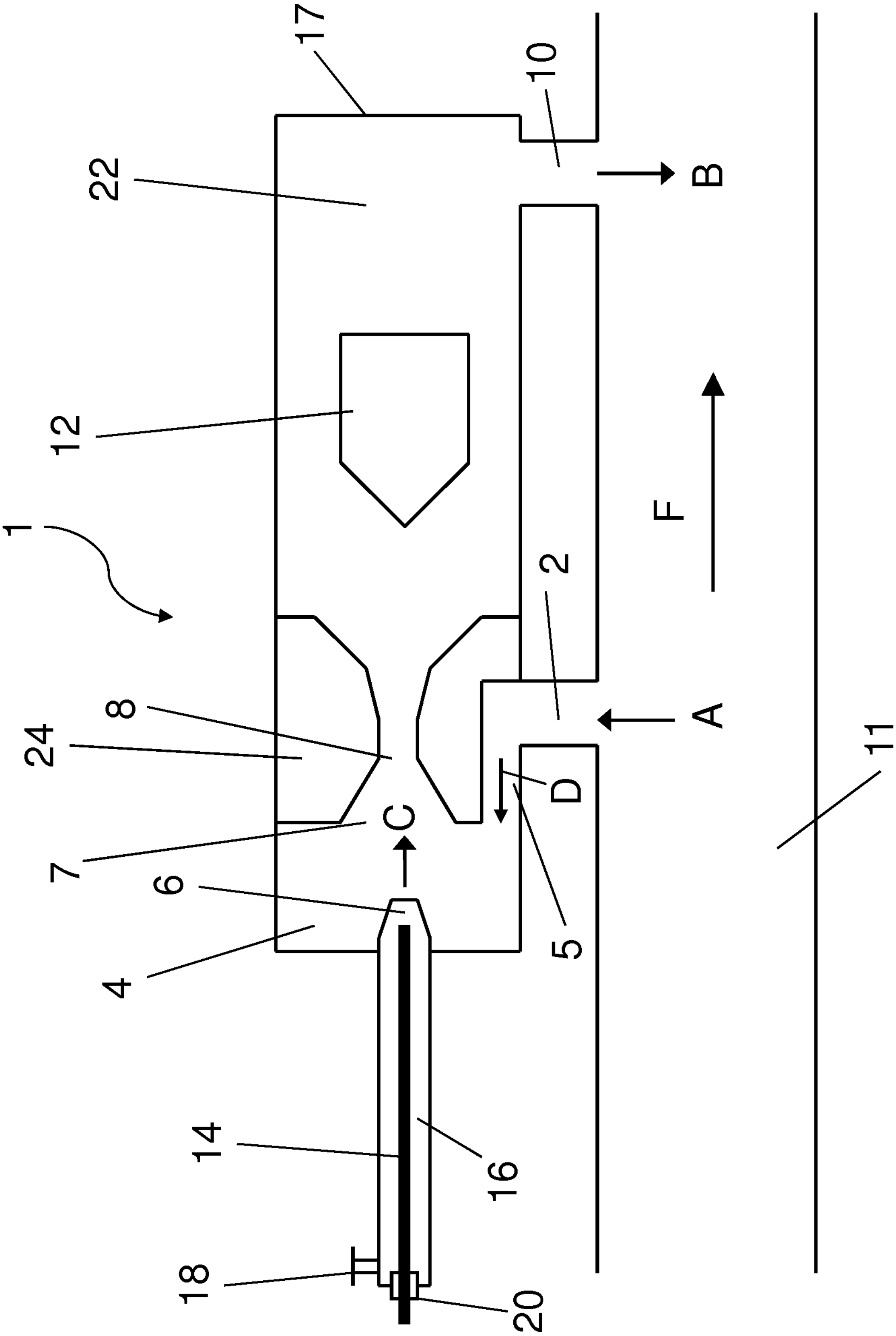

Fig. 1

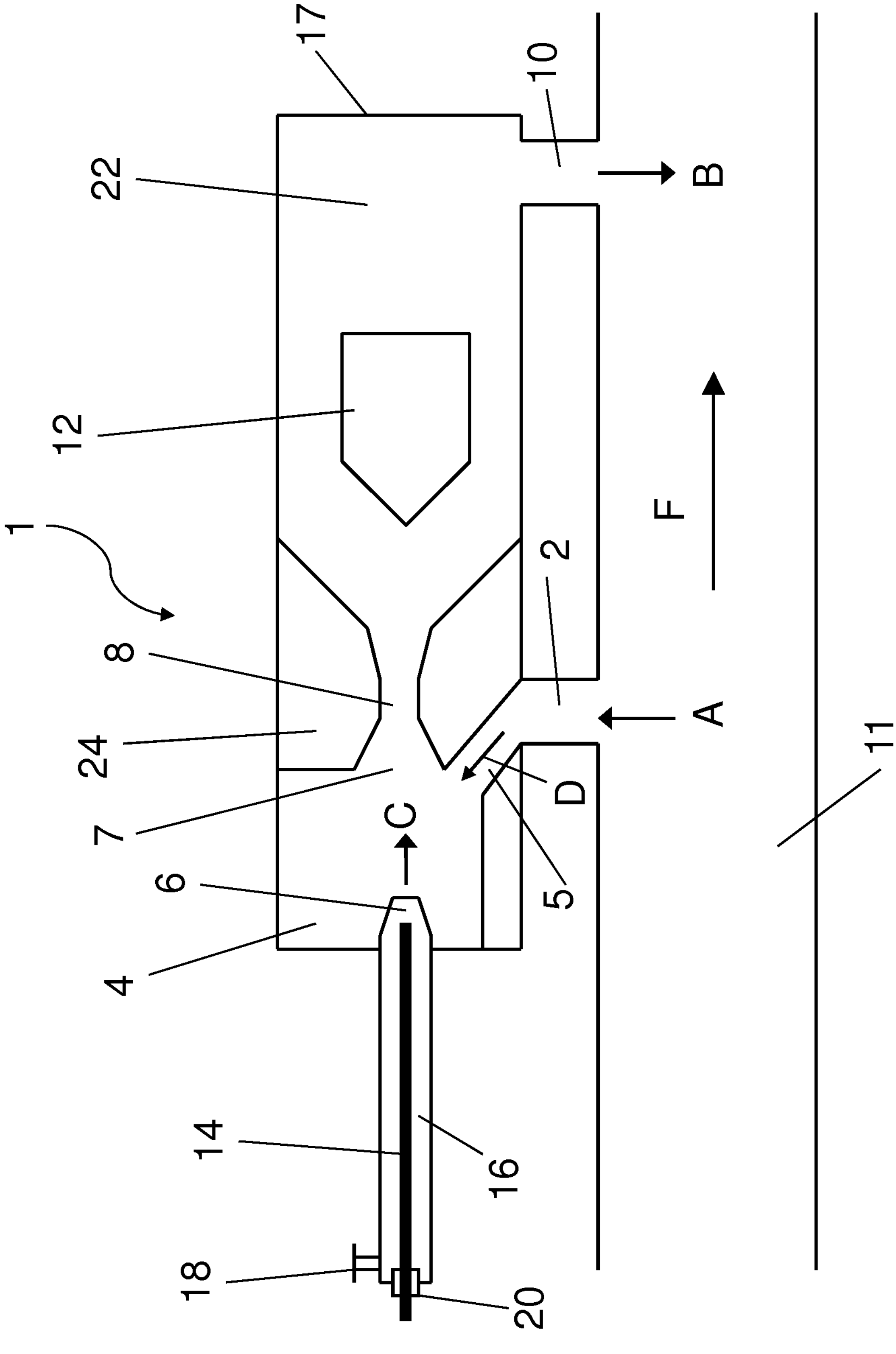

Fig. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/FI2012/050246

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01N1/22 G01N1/24
ADD. G01N1/38 G01N15/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01N F01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2009/109688 A1 (PEGASOR OY [FI]; TIKKANEN JUHA [FI]) 11 September 2009 (2009-09-11) figure 2	1-16
Y	US 3 986 386 A (BELTZER MORTON ET AL) 19 October 1976 (1976-10-19) column 5, line 13 - line 25; figure 1	1-16
A	JP 2004 205253 A (HORIBA LTD) 22 July 2004 (2004-07-22) figure 2	1-16

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
4 June 2012	14/06/2012

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Mauritz, Jakob

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/FI2012/050246

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