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(72) Inventor; and
(71) Applicant : **JOHANSSON, Lars** [SE/HR]; Velebitska 143, 21 000 Split (HR).

(74) Agent: **CEGUMARK AB**; P.O.Box 53047, Kungsportsavenyn 10, SE-400 14 Göteborg (SE).

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**(54) Title**: METHOD AND DEVICE FOR CONTINUOUSLY OPERATING PYROLYSIS REACTOR

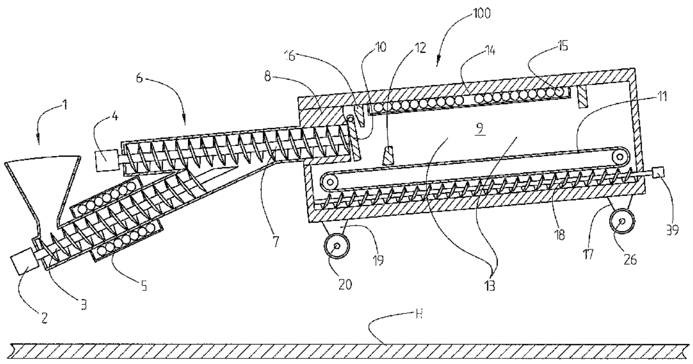

*Fig. 1*

**(57) Abstract**: A method and a device for a pyrolysis reactor which is intended for continuous operation, with which method and device oxygen or any gas mixture containing oxygen gas, such as air, is excluded from or prevented during operation of said reactor from flowing into the interior of the reactor, which reactor incorporates, among other things, a supply duct for the material intended for pyrolysis, means for conveying this material through the supply duct, the pyrolysis reactor with means required for bringing about a pyrolitic segregation, a mechanism for removing gas released during the pyrolysis process and a mechanism for removing residual products such as slag. The material in the supply duct is fed by means of a first screw conveyor to both a slope in the duct and to at least one further second screw conveyor in a feed duct connecting to the supply duct, which second conveyor is driven at a lower speed than that of the first conveyor.

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# Method and device for continuously operating pyrolysis reactor

## Technical field

The present invention relates to a method and device for excluding and preventing oxygen or any gas mixture containing oxygen gas, such as air, from flowing into the interior of the reactor in a pyrolysis reactor which is designed for continuous operation. The reactor incorporates a supply duct for the material intended for pyrolysis, such as plastic or rubber, means for transporting this material through the supply duct, the pyrolysis reactor itself, with means required for bringing out a pyrolitic segregation, a mechanism for removing gas released during the pyrolysis process and a mechanism for removing residual products such as oil residue products and slag.

## Background

Gas generators for segregating combustible material are well known as a phenomenon, not least in the form used previously and they are still used in certain plants for the production of town gas, for example. The basic concept itself is the same, namely anaerobic segregation at increased temperature, and the handling of released gas and residual products. However, the situation is that as far has been determined from exhaustive investigations, no one has so far succeeded in producing a pyrolysis reactor which actually operates continuously. For the unfortunate case that air or free oxygen unintentionally comes into contact with a material undergoing pyrolysis, this unavoidably results in an explosive fire. Basic school physics teaches that three conditions need to be met for combustion, or in common parlance fire, take place: firstly access to a combustible material, secondly the temperature at which the combustible material burns is reached, and thirdly there is access to free oxygen in the required quantity. What, then, is done in a pyrolysis reactor or gas generator? The answer is that conditions must be created for an anaerobic process, more precisely a process in which all the conditions for combustion exist, except for access to free oxygen. Because no one has succeeded in producing a gas generator for continuous pyrolysis of combustible material, designs that have worked so far are characterised in that they must be operated in batches, i.e. a pyrolysis reactor is loaded with a set of pyrolysable material which is then heated under oxygen-free conditions at the same time that the gas released during the process is handled. During the pyrolysis process the pyrolysis reactor is hermetically fully sealed to avoid explosive processes. Prolonged cooling is thereafter required to bring down the temperature in the gas generator to such a level that the residues remaining after pyrolysis do not spontaneously ignite when free oxygen penetrates as the pyrolysis reactor is being opened. This is not, nor has it ever been, a particularly good process, not least because it involves extensive handling relating to loading, heating and cooling. Nor is it all that energy effective.

**The invention in brief**

It is therefore a principal objective of this invention to indicate a method and a device which, despite a continuous supply of material, enables the supply duct to the pyrolysis reactor to guarantee that either oxygen or air is fed into the pyrolysis reactor whilst the continuous pyrolysis process is taking place.

The objective is achieved with the method and device according to the invention in that the material in the supply duct is fed by means of a first screw conveyor to both a slope in the duct and also to at least one second screw conveyor in a feed-in duct connecting to the supply duct, which second conveyor is driven at a lower speed than that of the first conveyor.

According to a further developed design of the invention the material intended for pyrolysis is fed by means of the first conveyor screw to a unit comprising two screw conveyors rotating in the same direction. This enables the material intended for pyrolysis to be compressed so that all the air and oxygen bound by it are pressed away. The compression is favoured and the propulsion of the material is simplified because both the screw conveyors mentioned are rotating in exactly the same direction.

According to a further developed design of the invention the respective screws in the unit comprising two screw conveyors are driven at different speeds. This enables a higher degree of compacting to be achieved than otherwise, thus providing even better sealing than would otherwise be the case. In this particular case the screw conveyor in the unit with two such conveyors that have the maximum speed is nevertheless driven at a speed that is lower than the speed of the first screw conveyor.

This prevents pockets of suction from occurring, which could otherwise, at least technically, cause air to be sucked into the pyrolysis chamber under a pressure that is lower than the surrounding atmospheric pressure.

During the process of starting a continuous pyrolysis process of the type described in the introduction, material is fed, according to a further developed design of the invention, to an openable hatch at the feed-in end of the pyrolysis reactor during an introductory phase of the continuous feeding of material for the continuous pyrolysis process. The hatch favours the build-up of a plug of pyrolysable material translatable by means of the screw conveyors, which natch, after the introductory phase, can be kept open continuously and then has no further function except as a hatch during the reactor heating process as long as the reactor is being driven and material is fed continuously.

In accordance with a final and further developed design of the invention gas is supplied which is lighter than air or oxygen gas, preferably nitrogen gas, to the upper section of the supply pipe, so that as a result of the mass ratio between the gases, all air and any free oxygen gas are successively forced out of the supply pipe in the counter direction of the conveying direction of the pyrolysable material. Because of the sloping assembly of the supply pipe the effect of this is that the supply pipe will operate approximately in the same way as a traditional water lock, but instead with nitrogen gas.

**Brief description of the drawings**

The invention will in the following be described in greater detail on the basis of a preferred exemplary embodiment shown in the attached drawings, in which

Fig 1 shows schematically a cross-section through a pyrolysis reactor from the side thereof,

Fig 2 shows schematically the same reactor as in Fig. 1, but from above instead.

**Detailed description**

Fig 1 shows schematically something which is called a pyrolysis reactor 100 for continuous operation. It should be noted that the entire reactor 100 is suitably arranged at an angle of inclination of approximately 5° to the horizontal plane. At the feed-in end of the reactor there is a feed hopper 1 in which material, e.g. fragmented car tyres, is fed down. At the bottom of feed 1 there is a feed screw device 3 driven by a motor 2, which device propels the fragmented material at an inclination of from 10 to 20°. Around the feed screw there is a preheating jacket 5 for heating the material to just above 100°C, firstly in order to expel any moisture containing bound oxygen from this, secondly to soften the material so that it can be compacted more easily. At the upper end of feed screw device 3 there are nozzles (not shown) for supplying nitrogen gas which, because it is lighter than both air and oxygen gas, will stratify due to the inclination of device 3, so that it will expel any air or oxygen gas present at feed hoper 1. Besides the above-mentioned nozzles for nitrogen gas, a further feed screw device 6 driven by at least one motor 4, with double screws 7 which are driven in the same direction of rotation, but at a lower speed than feed screw device 3, is connected to the upper end of feed screw device 3. One end 8 of feed screw device 6 is arranged connected so that it is tightly sealed against the surrounding air some distance into a reactor chamber 9, at whose end is arranged a hatch 10 which is manoeuvrable between a closed and an open position. The function of hatch 9, when initiating a continuous pyrolysis process, is to enable an establishment of an initial press mass of process material from which all the oxygen can be expelled so that it can be driven out, in the manner described above, to the feed pocket via feed screw devices 3 and 6 respectively. Feed screw device 6 is followed by reactor chamber 9, the press mass falling to the bottom of the chamber and out onto a slow moving conveyor belt 11. A levelling plough 12 is arranged in the initial section of belt 11 in order to distribute the press material evenly over the belt 11. During a continuous process a fragment which is to be pyrolysed remains in chamber 9 for approx. 3 minutes, wherein the chamber in a hot zone 13 keeps an essentially constant temperature of approx. 550°C. In roof 14 of hot zone 13 there are heating elements 15, preferably electrically heated elements of the infra-radiation type, which is why, because the heat supplied is of the radiation type, hot zone 13 is demarcated by radiation protection device 16 at the respective ends of hot zone 13. The radiation protection devices are intended primarily to concentrate the heat discharge within the area in hot zone 13 intended for this. After passage through zone 13 there remains a residual fraction of the material intended for pyrolysis which consists mainly of carbon black which, at the end of conveyor belt, falls down to a conveyor screw 18 arranged in an outlet duct 17 for conveying to an oxygen sealed intermediate store (not shown), which is emptied instantaneously if necessary. A certain proportion of the material intended for pyrolysis will unavoidably behave in a manner that is not desirable and will either drop down alongside belt 11, or will adhere to this and will therefore possibly spontaneously fall off the same at a later stage, whilst the material is located along the underside of the belt. Depending on the position in which this takes place, it either happens that it is handled in the intended manner and drops out as carbon black onto duct 17, or it drops onto the underside of belt 11 in the form of residual material. For this extremely likely eventuality a further conveyor screw 18 is arranged at the bottom of reactor chamber 9, which screw feeds such material and any liquid fraction to an outlet 19 arranged at the feed-in end of reactor chamber 9, from which a feed screw 20 feeds this material to an oxygen-sealed intermediate storage which, like the intermediate storage mentioned above, is instantaneously emptied if required.

Fig. 2 shows pyrolysis reactor 100, viewed from above instead of from its one side, as in Fig. 1. From the left, the motor 2 for the feed screw device 3, followed by feed hopper 1 are shown, then feed screw device 3 surrounded by preheating jacket 5. Device 3 connects to feed screw device 6, which is in turn connected to reactor chamber 9 in the vicinity of a hatch 10 at the outlet end of device 6. Connected to the reactor chamber is firstly a gas outlet pipe 21, via which gas released as a result of the pyrolysis process is handled, secondly the outlet duct 17 for carbon black or the like and thirdly the outlet duct 19 for residual material and liquid fraction according to the above description. Ducts 17 and 19 respectively, and pipe 21, are provided with an intermediate storage functionality which requires to be emptied occasionally. This takes place, of course, without giving oxygen or air the opportunity, so to speak, to get in through the back door and disturb the process in the pyrolysis chamber.

Figure 3 shows schematically an arrangement 22 which may be described as a liquid lock or scrubber arranged in a tank or container 23, at the inlet of which tank or container gas from reactor chamber 9 is pumped in to maintain a gas pressure inside reactor chamber 9, which corresponds to the atmospheric pressure of the area surrounding the pyrolysis reactor. The gas passes through a pipe 24 down below a liquid surface so that it is released under the surface and is allowed to diffuse out into a collection device at P. The gas in question has a high calorific value and can be used in a number of different applications, e.g. a fuel in gas-driven vehicles such as urban buses. At approximately half the height of container 23 there is a drain tap 25 to enable any products of condensation that can be formed and prevent container 23 from being filled over its width.

Pyrolysis reactor 100 arranged for continuous operation slopes downwards towards the feed-in end. Feed hopper 1 is so large that continuous operation can be maintained without any practical problems. Motor 2 is of such a type that its speed can be varied so that effective compression towards double screw 7 can be guaranteed under all conditions, regardless of the type of material fed in. For effective compression, and to ensure that all moisture is expelled from the material intended for pyrolysis, this material should reach a preheating temperature of 120°C in front of hatch 10 for hot zone 13 of reactor chamber 9. Hatch 10 is spring loaded to an open position, but is kept closed by a lock (not shown) as long as an oxygen gas detector (not shown), arranged in the conveyor pipe of feed screw device 6, indicates that there is oxygen gas in the compression zone of the pipe or in hot zone 13. This oxygen gas detector also controls, by means of a computer suitable for the purpose and associated software, whether nitrogen gas is to be supplied or not. For example, if a fault occurs in any of the motors 2, 4 of the feed screw devices, all feed-in and heating elements 15 are closed, as is also hatch 10 with positively controlled means (not shown) arranged according to the intended use. Under such conditions it is appropriate to maintain a nitrogen gas atmosphere in the feed screw pipes and reactor chamber 9 until the temperature in it has dropped to such a level that there is no longer a fire risk in the material intended for pyrolysis. The temperature in hot zone 13, which is maintained by means of heating elements fitted in its roof, is controlled by thermostats and software in a computer so that it is kept at around 550°C +/- 5°, as a result of which as complete a degassing as possible of material supplied and levelled by means of plough 12 as it passes through hot zone 13. The invention should not be regarded as being limited by this description of a preferred embodiment of the same but should only be regarded as limited by the attached claims.

## CLAIMS

1. A method for a pyrolysis reactor, intended for continuous operation, with which oxygen or any gas mixture containing oxygen gas, such as air, is excluded from or prevented from flowing into the interior of the reactor, which reactor incorporates a supply duct for the material intended for pyrolysis, means for conveying this material through the supply duct, the pyrolysis reactor with the means required for bringing about a pyrolytic segregation, a mechanism for removing gas released during the pyrolysis process and a mechanism for removing residual products such as slag, **characterised in that** the material in the supply duct is fed by means of a first screw conveyor towards both an inclination in the duct and towards at least a further second screw conveyor in an in-feed duct connecting to the supply duct, which second conveyor is driven at a speed lower than that of the first conveyor.

2. Method according to claim 1, **characterised in that** the material intended for pyrolysis is fed by means of the first conveyor screw towards a unit comprising two screw conveyors rotating in the same direction.

3. Method according to claim 2, **characterised in that** the respective screws in the unit comprising two screw conveyors are driven at different speeds.

4. Method according to claim 3, **characterised in that** the screw conveyor in the unit with two such conveyors which has the highest speed is nevertheless driven at a speed which is lower than the speed of the first screw conveyor.

5. Method according to any one of the preceding claims, **characterised in that** the material, in an introductory phase of the continuous feed of materials for the continuous pyrolysis process, are fed towards a hatch at the feed-in end of the pyrolysis reactor.

6. Method according to any one of the preceding claims, **characterised in that** a gas which is lighter than air or oxygen gas, preferably nitrogen gas, is supplied in the upper section of the supply pipe so that, as a result of the mass ratio between the gases, all air and oxygen gas are successively forced from the supply pipe.

7. Device in a pyrolysis reactor intended for continuous operation, aimed at preventing gas spontaneously flowing from outside, preferably air, containing oxygen, from flowing into the interior of the reactor, which reactor incorporates a supply duct for the material intended for pyrolysis, means for conveying this material through the supply duct, a pyrolysis reactor with means required for bringing about a pyrolytic segregation, a mechanism for removing gas released during the pyrolysis process and a mechanism for removing residual products such as slag, **characterised in that** it comprises a feed hopper, a driven first screw conveyor arranged at the lower end of the feed hopper, rotatable at a certain speed, in a conveyor duct with a slight upward slope suitably designed for the conveyor, a screw conveying device arranged at the end of the first screw conveyor and its duct, in a supply duct leading to the pyrolysis reactor, which device in itself comprises at least one screw conveyor driven at a lower speed than the first screw conveyor.

8. Device according to claim 7, **characterised in that** it also comprises a hatch manoeuvrable for its opening and closing from an inner end of the supply duct from the outside of the pyrolysis reactor, towards which hatch the material intended for pyrolysis is designed to be packed during a start-up process of a continuous operating period for the pyrolysis reactor.

9. Device according to any one of claims 7 or 8, **characterised in that** it comprises a preheating zone along the conveying duct designed for drying and softening the material intended for pyrolysis.

10. Device according to claim 9, **characterised in that** it comprises firstly oxygen gas detectors arranged in the reactor section and secondly such detectors arranged in the supply duct connecting to the reactor, which detectors are connected to a control system by means of which, if the presence of air or oxygen gas is detected, oxygen expelling gas is supplied in the upper section of the supply pipe so that as a result of the mass ratio between the gases all air and oxygen gas are successively forced from the supply pipe.

11. Device according to claim 10, **characterised in that** the control system is connected to sensors which detect whether the screw conveyors are rotating or not, wherein the control system ensures that the reactor chamber is closed down and an atmosphere consisting mainly of nitrogen gas is maintained in the conveyors and the reactor chamber as long as pyrolysable material is present therein and the temperature is so high that there is a fire risk.

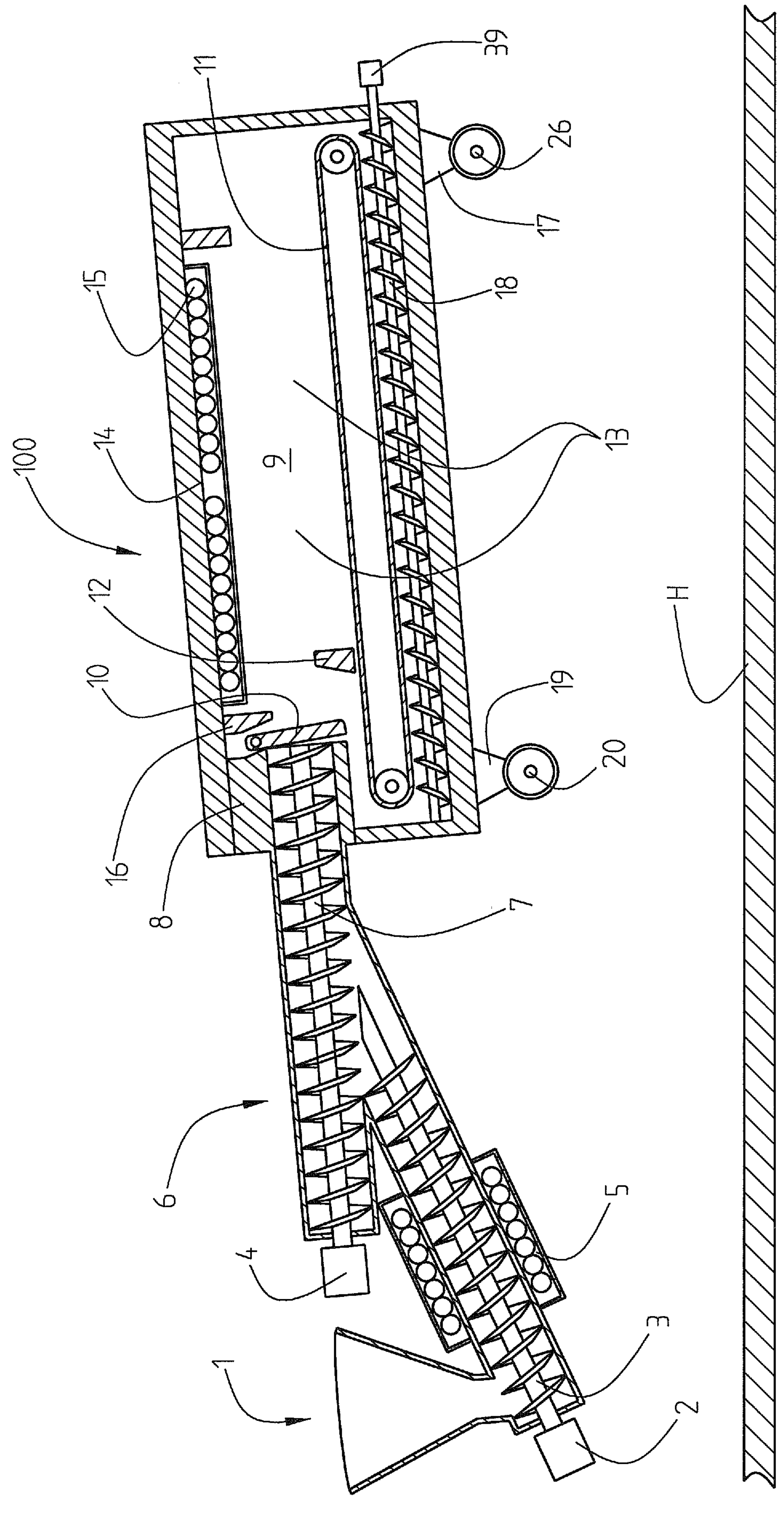


Fig. 1

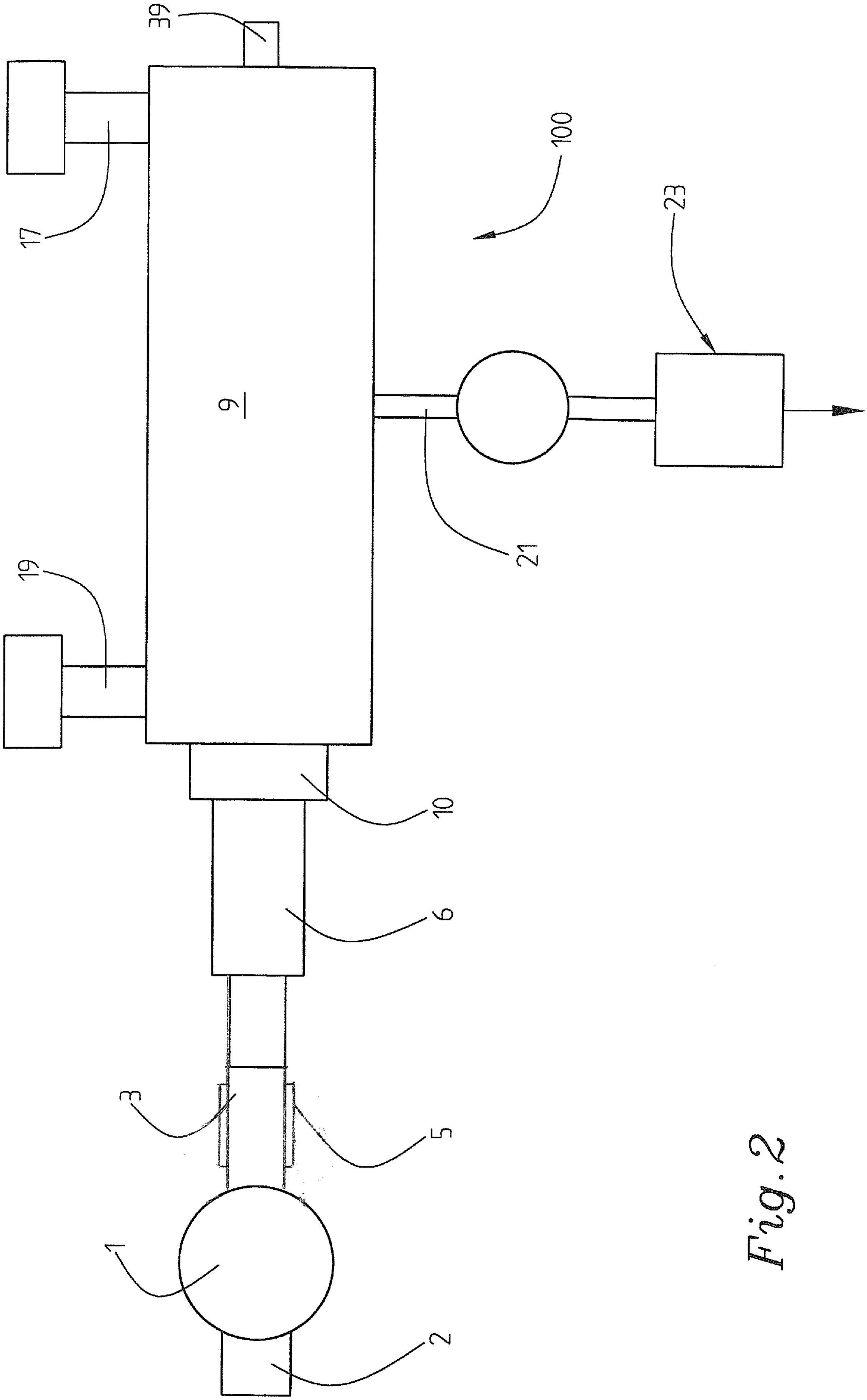


Fig. 2

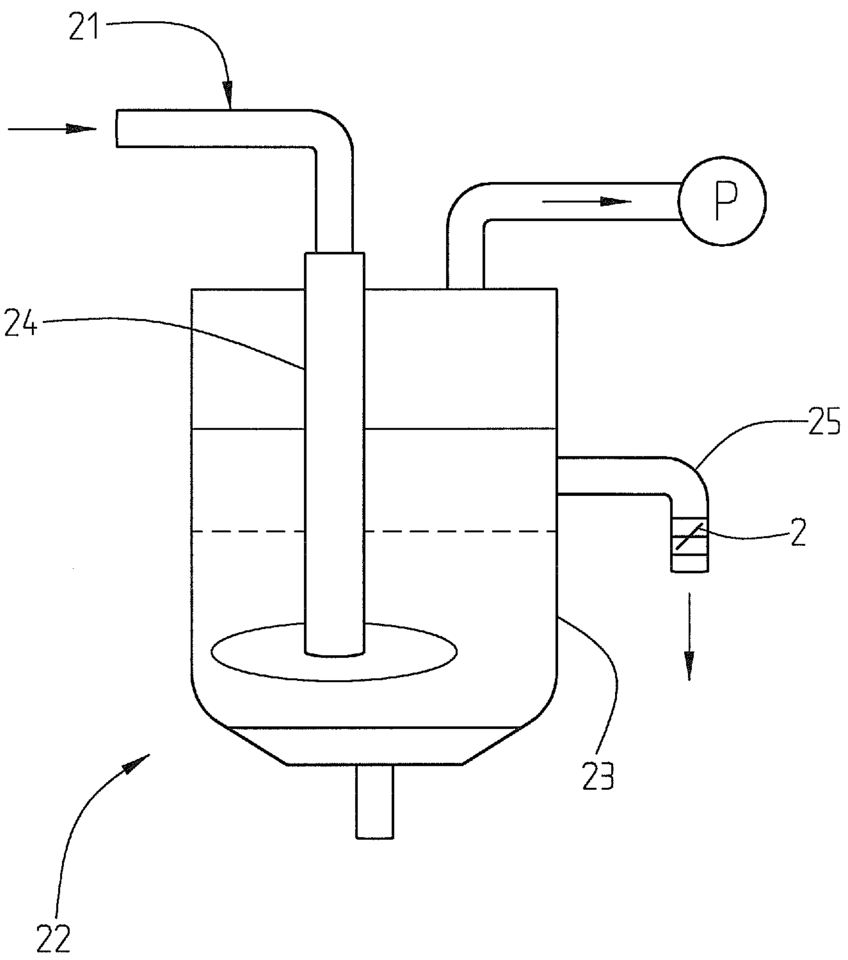


Fig.3

## INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2010/050636

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC: see extra sheet

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)

IPC:C02F, C10B, F23G, F23K

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**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | US 20070029184 A1 (FINLEY DANA J), 8 February 2007 (2007-02-08); abstract; figure 1A; [0010], [0028] -- | 1-11 |
| A | US 5871619 A (FINLEY DANA J ET AL), 16 February 1999 (1999-02-16); abstract; column 1, line 49 - column 1, line 60; column 2, line 25 - column 2, line 60; column 3, line 37 - column 3, line 44; column 3, line 59 - column 3, line 61; figures -- | 1-11 |
| A | US 5022328 A (ROBERTSON JAMES C), 11 June 1991 (1991-06-11); abstract; figures -- | 1-11 |

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Patent- och registreringsverket
Box 5055
S-102 42 STOCKHOLM
Facsimile No. + 46 8 666 02 86

Authorized officer
Krzysztof Kwiatkowski
Telephone No. + 46 8 782 25 00

**Continuation of:** second sheet

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| US | 20070029184 | A1 | 08/02/2007 | US | 7743912 B2 | 29/06/2010 |
| US | 5871619 | A | 16/02/1999 | NONE | | |
| US | 5022328 | A | 11/06/1991 | CA | 2049232 A1 | 17/02/1992 |
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