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**(54) APPARATUS AND METHOD FOR INHIBITING THE PROPAGATION OF A FLAME FRONT**

VORRICHTUNG UND METHODE ZUM VERHINDERN DES AUSBREITENS EINER  
FLAMMENFRONT

APPAREIL ET METHODE POUR INHIBER LA PROPAGATION D'UN FRONT DE FLAMMES

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**Description**

**[0001]** The present invention relates to apparatus for, and a method of, inhibiting the propagation of a flame front ignited by a pumping mechanism drawing a waste stream from a process chamber as defined in the preambles of claims 1 and 22 respectively, and corresponding to already known apparatuses and methods.

**[0002]** As semiconductor processes become increasingly sophisticated, the fluid used in these processes are becoming increasingly aggressive. There is an increasing risk associated with these processes that the atmosphere within a vacuum pump used to evacuate the process chamber may comprise pockets of flammable gas or, in the extreme, may be entirely flammable. Vacuum pumps have not conventionally been designed with such environments in mind. A vacuum pumping mechanism typically comprises a metal rotor cooperating with a metal stator to convey fluid from an inlet of the vacuum pump to an outlet thereof. These components of the pumping mechanism are required to have a close tolerance such that fluid being pumped is inhibited from leaking back towards the inlet of the pump. The proximity of these two metal components is by its very nature inclined to represent an ignition source as any clashing of components may generate a spark. Given the aggressive nature of the processes being undertaken by these pumps, deformation of the metal components (through corrosion) is increasingly likely such that these tolerances are significantly reduced. Furthermore, the reactions of materials used in semiconductor processes often lead to a deposition of materials on the surfaces of the rotor and the stator. Such deposits further reduce the clearances such that the alignment of the components of the pumping mechanism may be affected and clashing of the metal components may result.

**[0003]** Where a flammable atmosphere comes into contact with a point of ignition an explosion may result. If this explosion leads to damage of the apparatus safety issues are likely to be raised. Where there is a catastrophic breach of integrity projectiles may be formed from the components of the pump, creating a hazardous environment to any other equipment in the vicinity and ultimately to any personnel located in the area. Where the breach is less abrupt, leakage of flammable gas may occur into the environment surrounding the apparatus. If further ignition sources are available in this area, there may be a risk of further explosion. In the event that damage is caused by the explosion, the entire pumping arrangement may need to be taken out of service to permit maintenance to be undertaken. This results in down time for the overall process system and therefore a loss of production.

**[0004]** Conventionally, it has therefore been regarded as desirable to minimise the risk of such explosions occurring within the vacuum pump. For example, it is known to introduce large amounts of inert gas into the vacuum pump to dilute the flammable mixture within the pump to bring the concentration of the mixture well below the lower explosive limit of the particular mixture. In this way, it is thought that explosions within the pump can be prevented, as a flammable environment is never generated. However, where significant quantities of inert gas are being introduced to the pump, the volumetric capacity of both the pump and any abatement system provided downstream, from the pump must be increased to accommodate the increased volume of fluid. Since space is at a premium in semiconductor processing tools, it is desirable to avoid any increases in the capacity of such apparatus. There are also significant costs associated with installing and running larger capacity apparatus.

**[0005]** Furthermore, unless the mixing between the flammable mixture and the inert gas is particularly good, it is possible for pockets of flammable gas to be formed within the pump. This is particularly likely where the inert gas is introduced part way down the pump to avoid fluctuations in pressure in the upstream process chamber. In this scenario, whilst some of the inert gas will be transmitted back towards the process chamber to effect some dilution in the lower pressure region, the quantity may be insufficient to achieve the appropriate dilution levels, in other words the mixture (or at least pockets of the mixture) may remain within the flammable range.

**[0006]** It is an object of at least the preferred embodiment of the present invention to seek to solve these and other problems.

**[0007]** According to one aspect of the present invention there is provided an apparatus for inhibiting the propagation of a flame front ignited by a pumping mechanism of a vacuum pumping arrangement drawing a waste stream from a process chamber, the apparatus comprising:

a foreline for conveying the waste stream from the process chamber to the pumping mechanism  
 means for detecting a pressure, arranged to detect the pressure within the foreline through which the waste stream is drawn by the pumping mechanism; and  
 means for regulating the delivery of at least one process fluid to the process chamber, said means comprising at least one shut off valve for preventing the delivery of at least one process fluid to the process chamber, and a controller for receiving the signal indicative of the detected pressure:  
 characterised in that the shut of valve is controlled by the controller, and said controller is configured to instruct the valve to close when the detected pressure is greater than a predetermined pressure value above which the flame front can be sustained by the waste stream.

**[0008]** The vacuum pumping arrangement may comprises a further pumping mechanism located upstream of the

pumping mechanism. The further pumping mechanism is preferably provided by a booster pump, for example a Roots blower.

**[0009]** Means for cooling the waste stream may be provided between the process chamber and the pumping mechanism. The aforementioned booster pump may serve as the cooling mechanism. Alternatively, it could be provided as a separate feature, especially if the requirement for additional pumping capacity is minimal. The cooling means may comprise an internal cooling mechanism located within the foreline, for example, one or more cooling baffles, one or more cooling fingers and/or one or more cooling coils. Alternatively the cooling means may comprise an external cooling mechanism located adjacent the outer surface of the foreline, for example a Peltier device and/or a cooling coil.

**[0010]** The apparatus may comprise an exhaust pipe connected to an exhaust of the vacuum pumping arrangement. The pipe may be configured to inhibit escalation to detonation of a deflagration occurring within the pipe. The exhaust pipe may comprise at least one of the group of one or more detonation barriers, one or more purge ports, one or more sections of varying diameter and one or more sections of varying orientation.

**[0011]** There may be provided means for delivering inert gas into the waste stream in dependence on the detected pressure. This inert gas delivering means may comprise at least one purge port located within a stator of the pumping mechanism or the purge port may be located so as to introduce inert gas to the waste stream exhaust from the pumping mechanism. The delivering means may comprise heating means configured to heat the purge gas prior to delivery thereof.

**[0012]** The apparatus may comprise abatement apparatus for receiving the waste stream exhausted from the pumping mechanism. The abatement apparatus may comprise a combustion chamber having an inlet for receiving the waste stream exhausted from the pumping mechanism. The combustion chamber may also comprise means for generating a flame for burning a flammable component of the waste stream within the combustion chamber. Where the chamber is so configured, the abatement apparatus may comprise means for detecting the presence of a flame in the combustion chamber.

**[0013]** The regulating means may be configured to regulate the delivery of at least one process fluid to the process chamber when no flame is detected within the combustion chamber. Means for delivering inert gas into the waste stream exhausted from the pumping mechanism when there is no flame is detected within the combustion chamber may be provided.

**[0014]** The inlet of the combustion chamber may be configured to prevent a flame from the combustion chamber from propagating into the waste stream upstream from the combustion chamber.

**[0015]** The regulation means may be dependent not only on the pressure in the inlet region of the pump but also on the presence of a flame within the combustion chamber.

**[0016]** The regulation of the supply may be dependent solely on the presence of a flame within a combustion chamber positioned downstream of a pumping mechanism.

**[0017]** According to another aspect of the present invention there is provided a method of inhibiting the propagation of a flame front ignited by a pumping mechanism drawing a waste stream from a process chamber, **characterised in that** the method comprising the steps of:

detecting a pressure at a location through which the waste stream is drawn by the pumping mechanism; and  
regulating the delivery of at least one process fluid to the process chamber when the detected pressure is greater than predetermined pressure value above which the flame front can be sustained by the waste stream.

**[0018]** Features described above in relation to apparatus of system aspects of the invention are equally applicable to method aspects and vice versa.

**[0019]** By providing pressure detection means, and causing the supply of the source of flammable material to be dependent thereon, it is possible to mitigate against and inhibit potential damage that may be caused by or associated with explosions within vacuum pumps as discussed above, thus enabling flammable mixture to be pumped with increased levels of safety.

**[0020]** Rather than attempting to prevent a flammable mixture from occurring at all, various features are introduced to inhibit the escalation of any deflagration that may occur, thus preventing or at least limiting the damage that can be done thereby. This can all be achieved using standard capacity equipment rather than having to increase the volumetric capacity and the associated consumable materials. Consequently, the costs associated with providing and running such equipment can be constrained.

**[0021]** In known pumping arrangements where it is recognised that ignition may occur, conventional flame arresters are typically implemented at the inlet and/or the outlet of the vacuum pump. However, such devices typically lead to a reduced value of conductance and corresponding reduction in pumping efficiency. This is especially notable when used in processes which generate deposit forming particulate matter as often found in semiconductor processes. As deposits form on the flame arresting device the open cross-sectional area through which pumped fluids may pass reduces significantly, thus further reducing conductance. Consequently, it is inappropriate to use flame arresters in such circumstances if frequent servicing and maintenance is to be avoided.

**[0022]** An embodiment of the present invention will be described in relation to the following drawings in which:

Figure 1 illustrates schematically a first embodiment of an apparatus for inhibiting the propagation of a flame front ignited by a pumping mechanism drawing a waste stream from a process chamber;

Figure 2 shows a second embodiment of an apparatus for inhibiting the propagation of a flame front ignited by a pumping mechanism drawing a waste stream from a process chamber;

Figure 3 shows a detailed view of an inlet to a combustion chamber that may be used with the apparatus of Figure 1;

Figure 4 shows a third embodiment of an apparatus for inhibiting the propagation of a flame front ignited by a pumping mechanism drawing a waste stream from a process chamber; and

Figure 5 illustrates a flow chart representing a two fault tolerant start up system associated with any of the aforementioned embodiments.

**[0023]** Figure 1 illustrates a process chamber 10 having at least one fluid inlet 20 for introducing one or more process fluids, typically gases, to be used in the processing of a sample, for example a semiconductor wafer or a flat panel display device, contained therein. A shut off valve 25 is provided in the fluid inlet 20 for selectively interrupting the flow of fluid to the chamber 10. An outlet from the process chamber 10 is connected via a foreline 40 to an inlet of a vacuum pump 30 comprising a pumping mechanism suitable for drawing a waste stream from the process chamber 10. In order to detect the pressure of the waste stream drawn from the pump 30, a pressure detector 45 is provided within either the foreline 40 (as shown) or within an inlet of the pump 30 for determining the local pressure in this region. A signal indicative of this foreline pressure is output from the pressure detector 45 to a controller 50.

**[0024]** An exhaust of the vacuum pump 30 is connected, in turn, to an inlet of an abatement system 55 via pipe 60. The object of abatement is to convert one or more species of the waste stream into one or more different compounds that can be more conveniently disposed of, for example by a scrubber connected to an exhaust conduit 70 for conveying the waste stream from an outlet of the abatement system, or which can be safely exhausted to the atmosphere via exhaust conduit 70. In this example, a bypass line 80 is provided for directly connecting the pipe 60 to the exhaust conduit 70, thereby by-passing the abatement system 55 to permit the abatement system to be put on standby or even shut down during the intervals prior to and between processing within the chamber 10, thus reducing costs. A three way valve 90 is provided at the junction between the bypass line 80 and the pipe 60 to control whether a fluid path from the waste stream passes through the abatement system 55 or whether it is diverted through the bypass line 80. The activation of valve 90 is controlled by controller 50.

**[0025]** As illustrated in Figure 1, a purge system 75 may be provided for introducing quantities of inert gas into the vacuum pump 30. The purge system 75 typically comprises one or more purge ports located along the length of the vacuum pump 30. Here, a further purge port 65 for introducing an inert gas downstream of the vacuum pump 30 may be located within pipe 60, preferably between the exhaust of the vacuum pump 30 and the valve 90. Means for detecting a flowrate of purge gas into the vacuum pump 30 and/or into pipe 60 is preferably provided within the purge system 75.

**[0026]** In this embodiment, the abatement system 55 comprises a combustion chamber in which combustion of any flammable components of the waste stream takes place. A flame detector 95 is provided within the abatement system 55 for sensing whether there is a flame present inside the combustion chamber. A signal indicative of this condition is output from the flame detector 95 to the controller 50.

**[0027]** Where a flammable mixture is introduced into the process chamber 10 via the fluid inlet(s) 20, or is generated within the process chamber 10 by the processes carried out on the sample located therein, the waste stream may comprise a flammable mixture. Consequently, a flammable atmosphere may be generated within the pump 30. Testing has been carried out on a typical vacuum pump 30 (a BOC Edwards iH160F pump) to confirm that that pump is capable of withstanding an initial internal explosion due to ignition of a region of flammable material. These tests showed that the pump is capable of enduring pressure loading twice the peak pressure experienced in a deflagration initiated when the pump is flooded with a stoichiometric flammable mixture under operating conditions.

**[0028]** The conditions within the vacuum pump 30 may be such that a deflagration may occur if an ignition source is present. Where a flame front is generated by such a deflagration, this will be transmitted away from the source of ignition through the flammable atmosphere. The conditions encountered by the flame front will affect how the flame propagation proceeds.

**[0029]** For instance, where the flame front is being transmitted upstream into the foreline 40, it encounters a region of low pressure. For the majority of flammable mixtures there is a critical pressure below which the mixture will not burn. For most flammable mixtures, this critical pressure is around 60 mbar, but for some mixtures may be as low as 1 mbar. During use of the process chamber 10, the pressure in the foreline 40 of the pump 30 is generally maintained below this

critical pressure. As the flame front encounters this low pressure region the flame front cannot be sustained and the flame is extinguished.

**[0030]** Where the flame front is being transmitted downstream from the pump 30 it will travel down the pipe 60 and into the abatement system 55. As previously mentioned, the flame in the combustion chamber of the abatement system 55 ignites any flammable fluid that enters the chamber such that the waste stream exhausted from the abatement system 55 contains little, preferably no, flammable component. Consequently if the flame front propagates as far as the abatement system 55 the combustion chamber effectively acts as a flame arrester such that further propagation of the flame front is prevented and the flame is extinguished, since there is no fuel remaining to burn.

**[0031]** Alternatively, where an abatement system 55 is not provided, or in addition, inert gas may be introduced into the pipe 60 through purge port 65. This inert gas dilutes the flammable mixture to a concentration below that represented by the lower flammability limit thus providing a non-flammable atmosphere. Hence, where a flame front propagates downstream of the pump 30 it will enter the non-flammable atmosphere in the pipe 60 and will be extinguished.

**[0032]** In normal operation of the apparatus, the extent of propagation of a flame front will be limited due to the extinguishing effects of the features discussed above. However, in order to provide a safer system it is desirable to implement one or more of the following safety devices.

**[0033]** As mentioned previously, a pressure detector 45 is located within the foreline 40 or at the inlet of the pump 30. This detector 45 outputs a signal indicative of its local pressure to the controller 50 which monitors the local pressure in this region to ensure that it remains below a predetermined value, typically the critical pressure required to sustain a flame front, as discussed above. Where this predetermined pressure is exceeded, then there is a risk that the flame front may be sustained within the foreline 40. In addition, if the flame within the combustion chamber of the abatement system 55 were to be extinguished for some reason, the flammable components of the waste stream would not be ignited and a flammable atmosphere would therefore be maintained. This flammable atmosphere would be capable of sustaining a flame front propagating through the abatement system 55 and into the exhaust conduit 70. As discussed above, the flame detector 95 outputs a signal to the controller 50 to confirm presence of the flame.

**[0034]** As also discussed above, the valve 25 is provided at the inlet 20 of the process chamber 10 to enable the introduction of at least one process fluid into the process chamber 10 to be interrupted when necessary. Operation of the valve 25 is controlled by the controller 50. In the event that the predetermined pressure in the foreline 40 is exceeded, the flame in the combustion chamber has been extinguished or in the event that delivery of purge gas to the pump 30 has been interrupted, the controller 50 is configured to output a signal to the valve 25 to instruct the valve 25 to close, and thereby stop the flow of the process fluids to the chamber 10. By interrupting the flow of these fluids the concentration of the flammable mixture within the apparatus downstream from the process chamber 10 can be rapidly reduced below the lower explosive limit of the flammable mixture such that the risk of deflagration occurring is reduced.

**[0035]** In addition to shutting off a source of flammable fluid, further mitigating action can be taken by the controller 50 in the form of an instruction to the purge system 75 to flood the pump 30 with inert gas to more rapidly reduce the concentration of the flammable mixture within the pump 30. Such a purge can be delivered to any part of the apparatus downstream from the process chamber 10 but would typically be delivered directly to the pump 30 through one of a number of standard purge ports formed in the stator of the pump or directly into pipe 60 leading from the exhaust of the pump 30 via purge port 65.

**[0036]** In addition to the above-mentioned mitigating actions, further safety features can be introduced. For instance, the controller 50 can control the three-way valve 90 to close the bypass line 80 when the shut off valve 25 is open. In other words, when there is any chance of a flammable mixture being present in the apparatus the bypass line is closed, so that fluid must pass through the abatement system 55.

**[0037]** Alternatively, when the valve 25 is in an open position, such that a flammable mixture can be expected to be present downstream from the process chamber 10, the controller 50 can instruct the purge system 75 to cause inert gas to be delivered through purge port 65 such that the concentration of the flammable mixture within the pipe 60 is reduced below the lower flammable limit such that any incident flame front cannot be sustained in this region.

**[0038]** Where a flame front is propagated along a sufficiently long path, under the appropriate conditions detonation may occur, thus resulting in a significantly increased level of damage to the equipment and surrounding apparatus. Such a long path may be found in the form of pipe 60 extending between the vacuum pump 30 and the abatement system 55. For this reason it is preferable to design the pipe 60 leading from the vacuum pump 30 in such a way that it inhibits formation of a detonation. Factors affecting this behaviour are diameter of the pipe 60, length of any straight sections of pipe 60 and the presence of any obstacles, commonly referred to as detonation barriers, within the pipe 60.

**[0039]** In some circumstances, the flammable waste stream contains condensable flammable gases. The pipe 60 presents an environment at elevated pressure and lower temperature than that found in the upstream part of the apparatus and thus provides conditions particularly suitable for condensation to form. Where pools of flammable liquid do form, these provide an unpredictable source of flammable material. A rate of release of flammable material from a pool depends upon the rate of evaporation of that liquid into the surrounding atmosphere which in turn depends on a number of factors including pressure and temperature of the region together with content and saturation level of any fluid present in gaseous

form.

**[0040]** A further problem associated with condensable flammable material is that where a totally gaseous mixture can be expected to pass through the apparatus in a predictable manner, pools of condensate may remain in the apparatus far longer. In some cases, different processing steps carried out within the process chamber may incorporate incompatible materials. When the fluids are gaseous the process steps can be discretised such that a degree of certainty exists that one step is finished and the waste stream has been removed from the system before the next begins. However when there are pools of flammable liquid within the pipe 60 that continue to evaporate, these are still present when the next step of the process is initiated such that the incompatible materials are permitted to mix and react upon contact, within the pipe 60. A particular example of such a scenario is when a cleaning step follows a process step and the flammable mixture is combined with a material having a particularly high oxide content the combination of these materials can be particularly reactive.

**[0041]** It is therefore desirable to avoid such condensates forming in the first place and so, in an alternative configuration, heating elements may be provided around pipe 60 to prevent cold spots from forming which may encourage the fluid to condense out. In this way the fluid exhausted from the pump 30 can be maintained in gaseous form. To further avoid formation of condensates within the vacuum pump 30 and within pipe 60, any purge gas to be delivered via the purge system 75 is preferably heated prior to delivery. In so doing, the waste stream avoids unnecessary cooling which, in turn, helps to avoid formation of condensates. In apparatus configured to heat purge gas a sensor for monitoring the temperature of the purge gas is preferably provided. A signal may be generated by the sensor in circumstances where the temperature of the purge gas reduces below a predetermined value. The flow of process fluid into the process chamber 10 may be terminated by activating valve 25 in response to this signal.

**[0042]** Figure 2 illustrates how the vacuum pump 30 and the abatement system 55 may be contained within an enclosure 100 to prevent any flammable fluid leaking from that part of the apparatus from coming into contact with an external ignition source and causing a deflagration. The environment within this enclosure 100 may be controlled by forced extraction. As illustrated, a further detection unit, flow detector 105, is incorporated into an extraction duct 110 of the enclosure to detect the extraction rate of fluid therefrom. A signal indicative of the extraction rate is output from the flow detector 105 to the controller 50. The controller monitors the extraction rate and if the rate drops below a predetermined value during operation of the process chamber 10 then action discussed above can be initiated.

**[0043]** The table below which summarises some of the various mitigating actions that may be taken:-

| Condition                                 | Condition detected and signal sent by | Action taken by                       | Consequence                                           |
|-------------------------------------------|---------------------------------------|---------------------------------------|-------------------------------------------------------|
| foreline pressure above critical pressure | pressure detector (45)                | valve (25)                            | process fluid shut off - process stops                |
| process fluid flowing                     | shut off valve (25)                   | three way valve (90)                  | inhibit bypass line (80) function                     |
|                                           |                                       | purge system (75) and purge port (65) | introduce purge gas upstream of bypass line (80)      |
| enclosure extraction fails                | flow detector (105)                   | valve (25)                            | process fluid shut off - process stops                |
| combustion fails                          | flame detector (95)                   | valve (25)                            | process fluid shut off - process stops                |
|                                           |                                       | purge system (75) and purge port (65) | introduce purge gas upstream of abatement system (55) |

**[0044]** The controller 50 may be replaced with hard wired connections between each of the detecting components 45, 95, 105 and valve components 25, 65, 90. Since the detecting and valve components are safety critical components, where possible, they are provided in a fail safe configuration and or redundancy is provided such that their functionality is duplicated in the arrangement.

**[0045]** A further safety feature as illustrated in Figure 3 can be implemented in any of the above embodiments comprising an abatement system 55 having a combustion chamber. As discussed above, when any flammable components of the waste stream come into contact with the flame provided within the combustion chamber, they are incinerated, thus generating a non-flammable atmosphere. However, there is a risk that as the flame contacts the flammable atmosphere

a flame front may propagate out of the inlet to the combustion chamber and into the pipe 60. This is commonly referred to as "flash back". As it is desirable to prevent this from happening, a modified inlet may be provided which presents a restriction to the incident waste stream, thus causing it to speed up. If the incident flow rate is sufficiently large the flame front initiated within the combustion chamber can be arrested at a location with a suitable aperture, which serves to anchor the flame front. One particular example of such a device is a thin section metal cone 120 provided in the inlet of the combustion chamber, as illustrated in Figure 3. If a flame front were to anchor on the smaller aperture, the temperature of the cone would rapidly increase in the direction of increasing diameter. By providing a thermal sensor to the cone it is possible to detect flash back early to enable mitigating action to be carried out as described in detail above.

**[0046]** For some mixtures, as discussed above, the critical pressure can be as low as 10mbar for example those having a high hydrogen content in the presence of oxygen. In such circumstances it may be necessary to supplement the pumping capacity of the vacuum pump 30 to ensure that the pressure does not exceed the critical pressure. Alternatively, the thermal environment can be altered so that the value of the critical pressure is elevated.

**[0047]** Figure 4 illustrates a third embodiment comprising a further vacuum pump 130, for example a booster pump, located in series with vacuum pump 30 and connected thereto by a conduit. The booster pump preferably comprises a Roots pumping mechanism. An additional pressure detector 145 is positioned in the conduit to enable a further indication of the status of each of the vacuum pumps 30, 130 to be provided to controller 50.

**[0048]** Introduction of the further vacuum pump 130 not only potentially reduces the pressure in foreline 40 but also serves to quench the waste stream being drawn from the process chamber 10. Quenching cools the waste stream so that the value of critical pressure below which propagation of a flame front is sustained increases. Furthermore, were a flame front to propagate upstream from the pumping mechanism and enter the booster pump 130, the quenching action coupled with a restriction to the flow as presented by the close tolerances of a booster pump causes the booster pump 130 to effectively act as a flame arrester element.

**[0049]** For some mixtures, quenching alone would reduce the critical pressure to an extent that a further vacuum pump 130 was not required. In such circumstances quenching of the waste stream may be effected by alternative means either within or external to the foreline. For example, cooled baffles, fingers or a cooling coil may be provided within the interior of the foreline or the external surface of the foreline may be cooled by using a cooling coil or a Peltier device.

**[0050]** In relation to any of the aforementioned embodiments, the detectors (45, 95, 145) can be used to enhance the safety of a start up procedure of the pump and the subsequent process to be carried out in the process chamber 10. The start up procedure is illustrated in the flow chart of Figure 5. Once the power to the overall system is switched on the detectors 45, 95, 145 will recognise a failed status in so much as the pressures upstream of the vacuum pumps 30, 130 will be in excess of the predetermined critical pressure and there will be no flame present in the abatement system 55. The pump 30 will not be permitted to start until a "fail" signal is received from each of these detectors, signifying that each of the detectors is functioning appropriately. If a "fail" status signal is not received from each detector, it is assumed that at least one of the detectors is faulty and the pump will be prevented from starting.

**[0051]** Once the pump 30 and the abatement system 55 have been started and normal operating conditions have been established, each of the detectors ought to be recognising a non-fail or operational status. Once an operational status has been established throughout, the process may be initiated. As discussed above, in the event that any one of the detectors 45, 95, 145 subsequently indicates a "fail" status the process will be terminated by actuating valve 25 and stopping the delivery of one or more process fluids to the process chamber 10.

## Claims

1. Apparatus for inhibiting the propagation of a flame front ignited by a pumping mechanism of a vacuum pumping arrangement drawing a waste stream from a process chamber (10), the apparatus comprising:

a foreline (40) for conveying the waste stream from the process chamber to the pumping mechanism  
means (45) for detecting a pressure, arranged to detect the pressure within the foreline through which the waste stream is drawn by the pumping mechanism; and

means (25, 50) for regulating the delivery of at least one process fluid to the process chamber (10), said means comprising at least one shut off valve (25) for preventing the delivery of at least one process fluid to the process chamber (10), and a controller (50) for receiving the signal indicative of the detected pressure;

**characterised in that** the shut off valve (25) is controlled by the controller, and said controller is configured to instruct the valve 25 to close when the detected pressure is greater than a predetermined pressure value above which the flame front can be sustained by the waste stream.

2. Apparatus according to Claim 1, wherein the vacuum pumping arrangement comprises a further pumping mechanism located upstream of the pumping mechanism.

3. Apparatus according to Claim 1, comprising a booster pump located upstream from the pumping mechanism.
4. Apparatus according to Claim 1, wherein means for cooling the waste stream is provided between the process chamber and the pumping mechanism.
- 5 5. Apparatus according to Claim 4, wherein the cooling means comprises a booster pump.
6. Apparatus according to Claim 4 or Claim 5, wherein the cooling means comprises an internal cooling mechanism located within the foreline.
- 10 7. Apparatus according to Claim 6, wherein the internal cooling mechanism is one or more of the group of one or more cooling baffles, one or more cooling fingers and one or more cooling coils.
- 15 8. Apparatus according to any of Claims 4 to 7, wherein the cooling means comprises an external cooling mechanism located adjacent the outer surface of the foreline.
9. Apparatus according to Claim 8, wherein the external cooling mechanism is one or more of the group of a Peltier device and a cooling coil.
- 20 10. Apparatus according to any preceding claim, comprising an exhaust pipe connected to an exhaust of the vacuum pumping arrangement, wherein the pipe is configured to inhibit escalation to detonation of a deflagration occurring therein.
- 25 11. Apparatus according to Claim 10, wherein the exhaust pipe comprises at least one of the group of one or more detonation barriers, one or more purge ports, one or more sections of varying diameter and one or more sections of varying orientation.
- 30 12. Apparatus according to any preceding claim, comprising means for delivering inert gas into the waste stream in dependence on the detected pressure.
- 35 13. Apparatus according to Claim 12, wherein the inert gas delivering means comprises at least one purge port located within a stator of the pumping mechanism.
14. Apparatus according to Claim 12 or Claim 13, wherein the inert gas delivering means comprises at least one purge port for introducing inert gas to the waste stream exhaust from the pumping mechanism.
15. Apparatus according to any of Claims 12 to 14, wherein the inert gas delivery means comprises heating means configured to heat purge gas prior to delivery thereof.
- 40 16. Apparatus according to any preceding claim, comprising abatement apparatus for receiving the waste stream exhaust from the pumping mechanism.
- 45 17. Apparatus according to Claim 16, wherein the abatement apparatus comprises a combustion chamber having an inlet for receiving the waste stream exhaust from the pumping mechanism, and means for generating a flame for burning a flammable component of the waste stream within the combustion chamber.
18. Apparatus according to Claim 17, comprising means for detecting the presence of a flame in the combustion chamber.
- 50 19. Apparatus according to Claim 18, wherein the regulating means is configured to regulate the delivery of at least one process fluid to the process chamber when no flame is detected within the combustion chamber.
20. Apparatus according to Claim 18 or Claim 19, comprising means for delivering inert gas into the waste stream exhaust from the pumping mechanism when there is no flame is detected within the combustion chamber.
- 55 21. Apparatus according to any of Claims 16 to 20, wherein the inlet of the combustion chamber is configured to prevent a flame from the combustion chamber from propagating into the waste stream upstream from the combustion chamber.

22. A method of inhibiting the propagation of a flame front ignited by a pumping mechanism drawing a waste stream from a process chamber, **characterised in that** the method comprising the steps of:

detecting a pressure at a location through which the waste stream is drawn by the pumping mechanism; and regulating the delivery of at least one process fluid to the process chamber when the detected pressure is greater than a predetermined pressure value above which the flame front can be sustained by the waste stream.

## Patentansprüche

1. Einrichtung zum Hemmen der Fortpflanzung einer Flammenfront, die durch einen Pumpenmechanismus einer Vakuumpumpenanordnung gezündet wird, die einen Abgasstrom aus einer Prozesskammer (10) absaugt, wobei die Einrichtung aufweist:

eine Vorleitung (40) zum Fördern des Abgasstroms von der Prozesskammer zum Pumpenmechanismus, Mittel (45) zum Erfassen eines Drucks, die dafür angeordnet sind, den Druck innerhalb der Vorleitung zu erfassen, durch welche der Abgasstrom durch den Pumpenmechanismus abgezogen wird, und Mittel (25, 50) zum Regulieren der Zufuhr mindestens eines Prozessmediums zu der Prozesskammer (10), wobei die Mittel mindestens ein Absperrventil (25) zum Verhindern der Zufuhr mindestens eines Prozessmediums zu der Prozesskammer (10) und einen Regler (50) zum Empfang des den erfassten Drucks anzeigenden Signals umfassen,

**dadurch gekennzeichnet, dass** das Absperrventil (25) durch den Regler gesteuert wird, und dass der Regler dafür konfiguriert ist, das Ventil (25) im Sinne des Schließens anzusteuern, wenn der erfasste Druck größer als ein vorgegebener Druckwert ist, oberhalb dessen die Flammenfront durch den Abgasstrom unterstützt werden kann.

2. Einrichtung nach Anspruch 1, wobei die Vakuumpumpenanordnung weiter einen Pumpenmechanismus umfasst, der stromauf des Pumpenmechanismus angeordnet ist.

3. Einrichtung nach Anspruch 1, mit einer stromauf des Pumpenmechanismus angeordneten Vorpumpe.

4. Einrichtung nach Anspruch 1, wobei Mittel zum Kühlen des Abgasstroms zwischen der Prozesskammer und dem Pumpenmechanismus vorgesehen sind.

5. Einrichtung nach Anspruch 4, wobei die Kühlmittel eine Vorpumpe umfassen.

6. Einrichtung nach Anspruch 4 oder Anspruch 5, wobei die Kühlmittel einen inneren Kühlmechanismus umfassen, der innerhalb der Vorleitung angeordnet ist.

7. Einrichtung nach Anspruch 6, wobei der innere Kühlmechanismus ein oder mehr Elemente der Gruppe aus einer oder mehreren Kühlblechen, einen oder mehreren Kühlfingern, und einer oder mehreren Kühlschlangen umfasst.

8. Einrichtung nach einem der Ansprüche 4 bis 7, wobei die Kühlmittel einen externen Kühlmechanismus umfassen, der angrenzend an die Außenoberfläche der Vorleitung angeordnet ist.

9. Einrichtung nach Anspruch 8, wobei der externe Kühlmechanismus ein oder mehr Elemente aus der Gruppe Peltier-Gerät und Kühlschlange umfasst.

10. Einrichtung nach irgendeinem vorhergehenden Anspruch, mit einem Abgasrohr, das an einen Auslass der Vakuumpumpenanordnung angeschlossen ist, wobei das Rohr so konfiguriert ist, dass es eine Eskalation zur Detonation einer darin auftretenden Verpuffung hemmt.

11. Einrichtung nach Anspruch 10, wobei das Abgasrohr mindestens ein Element aus der Gruppe einer oder mehrerer Detonationssperren, einer oder mehrerer Spülöffnungen, einem oder mehreren Abschnitten variierender Durchmesser, und einem oder mehreren Abschnitten variierender Orientierung aufweist.

12. Einrichtung nach irgendeinem vorhergehenden Anspruch, mit Mitteln zum Zuführen von Inertgas in den Abgasstrom in Abhängigkeit von dem erfassten Druck.

13. Einrichtung nach Anspruch 12, wobei die Inertgaszufuhrmittel mindestens eine Spülöffnung umfassen, die innerhalb eines Stators des Pumpenmechanismus angeordnet ist.
14. Einrichtung nach Anspruch 12 oder Anspruch 13, wobei die Inertgaszufuhrmittel mindestens eine Spülöffnung zum Einleiten von Inertgas in den Abgasstromauslass aus dem Pumpenmechanismus aufweisen.
15. Einrichtung nach einem der Ansprüche 12 bis 14, wobei die Inertgaszufuhrmittel Heizmittel aufweisen, die dafür konfiguriert sind, das Spülgas vor dessen Zuführung zu erwärmen.
16. Einrichtung nach irgendeinem vorhergehenden Anspruch, mit einer Vernichtungseinrichtung zum Aufnehmen des Abgasstromausstoßes aus dem Pumpenmechanismus.
17. Einrichtung nach Anspruch 16, wobei die Vernichtungseinrichtung eine Brennkammer mit einem Einlass zur Aufnahme des Abgasstromausstoßes aus dem Pumpenmechanismus und Mittel zum Erzeugen einer Flamme zum Verbrennen einer brennbaren Komponente des Abgasstroms innerhalb der Brennkammer aufweist.
18. Einrichtung nach Anspruch 17, mit Mitteln zum Erfassen der Anwesenheit einer Flamme in der Brennkammer.
19. Einrichtung nach Anspruch 18, wobei die Regulierungsmittel dafür konfiguriert sind, die Zufuhr mindestens eines Prozessmediums in die Prozesskammer zu regulieren, wenn keine Flamme in der Brennkammer festgestellt wird.
20. Einrichtung nach Anspruch 18 oder Anspruch 19, mit Mitteln zum Zuführen von Inertgas in den Abgasstromausstoß aus dem Pumpenmechanismus, wenn keine Flamme in der Brennkammer festgestellt wird.
21. Einrichtung nach einem der Ansprüche 16 bis 20, wobei der Einlass der Brennkammer so konfiguriert ist, dass das Ausbreiten einer Flamme aus der Brennkammer in den Abgasstrom stromauf der Brennkammer verhindert wird.
22. Verfahren zum Hemmen der Fortpflanzung einer Flammenfront, die durch einen Pumpenmechanismus gezündet wird, der einen Abgasstrom aus einer Prozesskammer absaugt, **dadurch gekennzeichnet, dass** das Verfahren die Schritte aufweist:
  - Erfassen eines Drucks an einer Stelle, durch welche der Abgasstrom durch den Pumpenmechanismus gesaugt wird, und
  - Regulieren der Zufuhr mindestens eines Prozessmediums zu der Prozesskammer, wenn der erfasste Druck größer als ein vorgegebener Druckwert ist, oberhalb dessen die Flammenfront durch den Abgasstrom unterstützt werden kann.

## Revendications

1. Dispositif pour inhiber la propagation d'un front de flamme provoqué par un mécanisme de pompage d'un groupe de pompage par le vide aspirant un courant d'effluent d'une chambre de traitement (10), le dispositif comprenant :
  - une conduite de vide primaire (40) pour acheminer le courant d'effluent de la chambre de traitement au mécanisme de pompage ;
  - des moyens (45) pour détecter une pression, disposés pour détecter la pression dans la conduite de vide primaire à travers laquelle le courant d'effluent est aspiré par le mécanisme de pompage ; et
  - des moyens (25, 50) pour réguler le débit d'alimentation d'au moins un fluide de traitement à la chambre de traitement (10), lesdits moyens comprenant au moins une vanne d'arrêt (25) pour empêcher l'alimentation d'au moins un fluide de traitement à la chambre de traitement (10), et un contrôleur (50) pour recevoir le signal indicatif de la pression détectée ;**caractérisé en ce que** la vanne d'arrêt (25) est contrôlée par le contrôleur, et ledit contrôleur est configuré pour donner l'ordre à la vanne (25) de se fermer lorsque la pression détectée est supérieure à une valeur de pression prédéterminée au-dessus de laquelle le front de flamme peut être entretenu par le courant d'effluent.
2. Dispositif selon la revendication 1, dans lequel le groupe de pompage comprend un mécanisme de pompage supplémentaire situé en amont du mécanisme de pompage.

3. Dispositif selon la revendication 1, comprenant une pompe de surpression située en amont du mécanisme de pompage.
- 5 4. Dispositif selon la revendication 1, dans lequel des moyens pour refroidir le courant d'effluent sont prévus entre la chambre de traitement et le mécanisme de pompage.
5. Dispositif selon la revendication 4, dans lequel les moyens de refroidissement comprennent une pompe de surpression.
- 10 6. Dispositif selon la revendication 4 ou la revendication 5, dans lequel les moyens de refroidissement comprennent un mécanisme de refroidissement interne situé dans la conduite de vide primaire.
- 15 7. Dispositif selon la revendication 6, dans lequel le mécanisme de refroidissement interne est l'un ou plusieurs, dans le groupe comprenant une ou plusieurs boîtes de refroidissement, un ou plusieurs doigts de refroidissement et un ou plusieurs serpentins de refroidissement.
8. Dispositif selon l'une quelconque des revendications 4 à 7, dans lequel les moyens de refroidissement comprennent un mécanisme de refroidissement externe situé adjacent à la surface externe de la conduite de vide primaire.
- 20 9. Dispositif selon la revendication 8, dans lequel le mécanisme de refroidissement externe est un ou plusieurs du groupe comprenant un dispositif Peltier et un serpentín de refroidissement.
- 25 10. Dispositif selon l'une quelconque des revendications précédentes, comprenant un tuyau d'échappement raccordé à un échappement du groupe de pompage par le vide, dans lequel le tuyau est configuré pour inhiber une escalade allant jusqu'à une détonation d'une déflagration s'y produisant.
- 30 11. Dispositif selon la revendication 10, dans lequel le tuyau d'échappement comprend au moins l'un du groupe comprenant une ou plusieurs barrières anti-détonation, un ou plusieurs orifices de purge, une ou plusieurs sections de diamètre variable, et une ou plusieurs sections d'orientation variable.
- 35 12. Dispositif selon l'une quelconque des revendications précédentes, comprenant des moyens pour fournir un gaz inerte dans le courant d'effluent en fonction de la pression détectée.
13. Dispositif selon la revendication 12, dans lequel les moyens pour fournir le gaz inerte comprennent au moins un orifice de purge situé dans un stator du mécanisme de pompage.
- 40 14. Dispositif selon la revendication 12 ou la revendication 13, dans lequel les moyens pour fournir le gaz inerte comprennent au moins un orifice de purge pour introduire le gaz inerte dans l'échappement du courant d'effluent en provenance du mécanisme de pompage.
- 45 15. Dispositif selon l'une quelconque des revendications 12 à 14, dans lequel les moyens pour fournir le gaz inerte comprennent des moyens de chauffage configurés pour chauffer le gaz de purge avant qu'il ne soit fourni.
16. Dispositif selon l'une quelconque des revendications précédentes, comprenant un dispositif d'abattement destiné à recevoir le courant d'effluent sortant du mécanisme de pompage.
- 50 17. Dispositif selon la revendication 16, dans lequel le dispositif d'abattement comprend une chambre à combustion ayant une entrée destinée à recevoir le courant d'effluent sortant du mécanisme de pompage, et des moyens pour générer une flamme destinée à la combustion d'un composant inflammable du courant d'effluent dans la chambre de combustion.
- 55 18. Dispositif selon la revendication 17, comprenant des moyens pour détecter la présence d'une flamme dans la chambre de combustion.
19. Dispositif selon la revendication 18, dans lequel les moyens régulateurs sont configurés pour réguler la fourniture d'au moins un fluide de traitement à la chambre de traitement lorsqu'aucune flamme n'est détectée dans la chambre de combustion.

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20. Dispositif selon la revendication 18 ou la revendication 19, comprenant des moyens pour fournir le gaz inerte dans le courant d'effluent sortant du mécanisme de pompage lorsqu'aucune flamme n'est détectée dans la chambre de combustion.

5 21. Dispositif selon l'une quelconque des revendications 16 à 20, dans lequel l'entrée de la chambre de combustion est configurée pour empêcher une flamme de la chambre de combustion de se propager dans le courant d'effluent en amont de la chambre de combustion.

10 22. Procédé pour inhiber la propagation d'un front de flamme provoqué par un mécanisme de pompage aspirant un courant d'effluent d'une chambre de traitement, **caractérisé en ce que** le procédé comprend les étapes de :

détection d'une pression en un emplacement à travers lequel le courant d'effluent est aspiré par le mécanisme de pompage ; et

15 régulation de la fourniture d'au moins un fluide de traitement à la chambre de traitement lorsque la pression détectée est supérieure à une valeur de pression prédéterminée au-dessus de laquelle le front de flamme peut être entretenu par le courant d'effluent.

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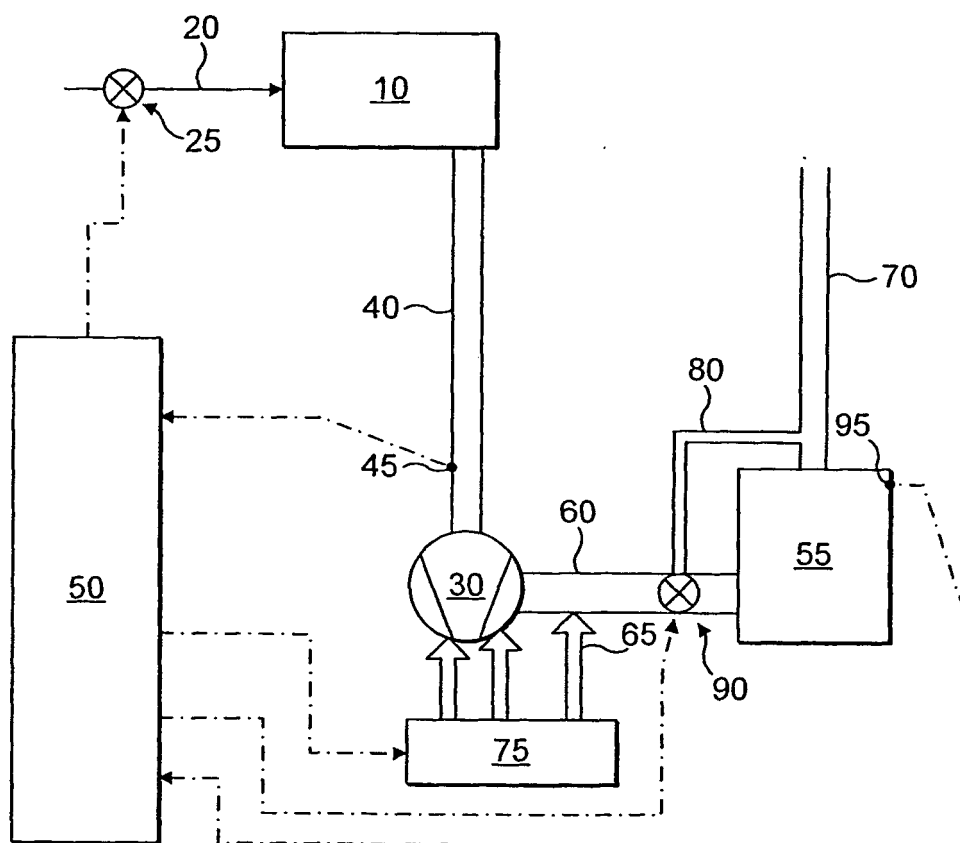


FIG. 1

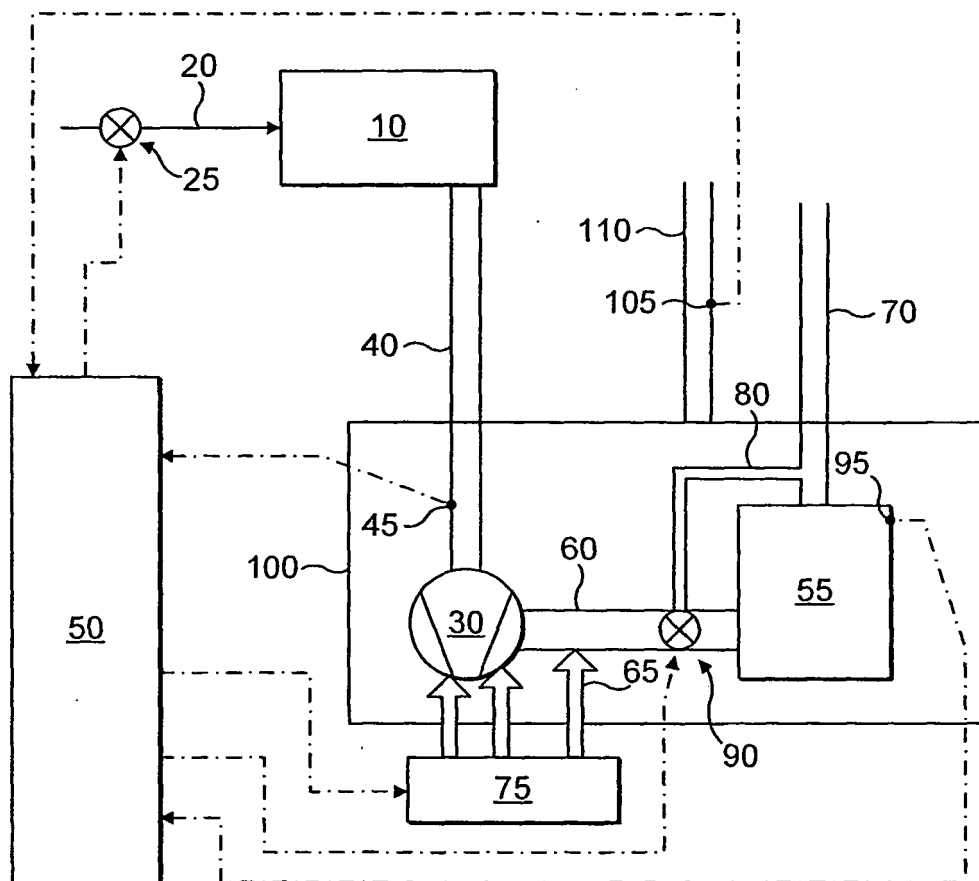


FIG. 2

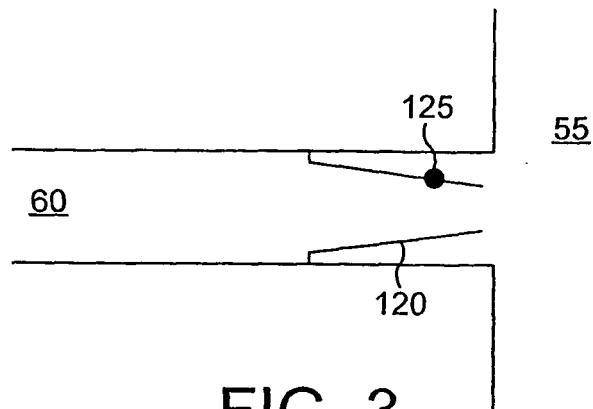


FIG. 3

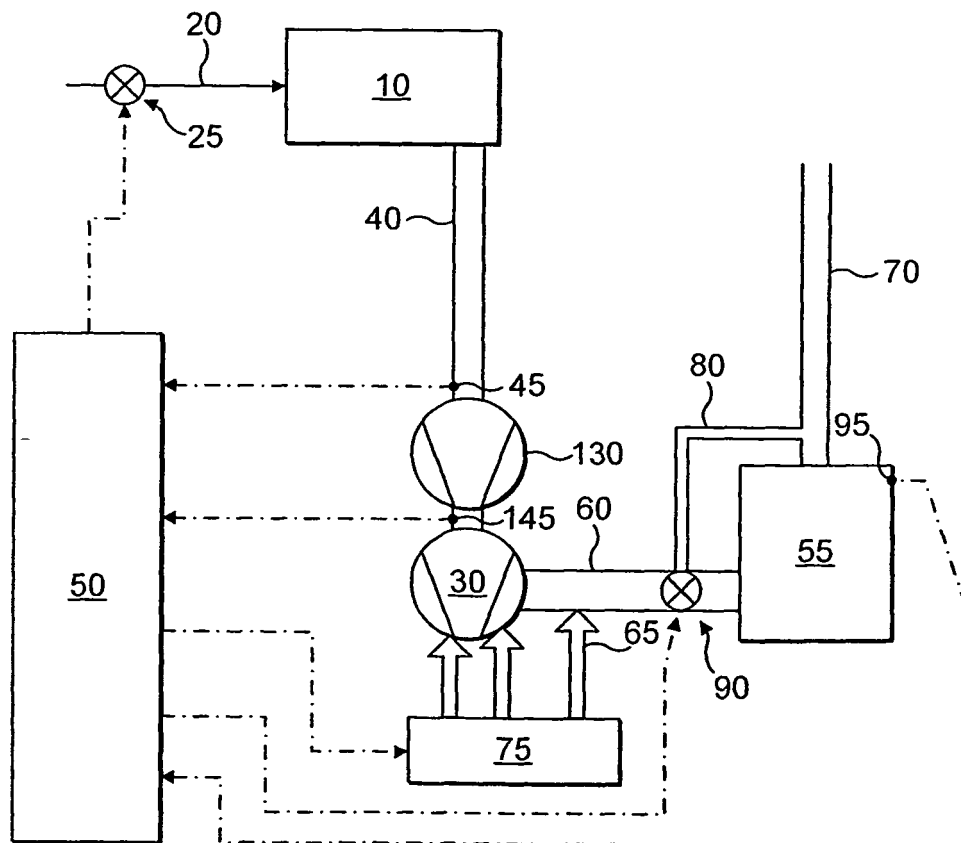


FIG. 4

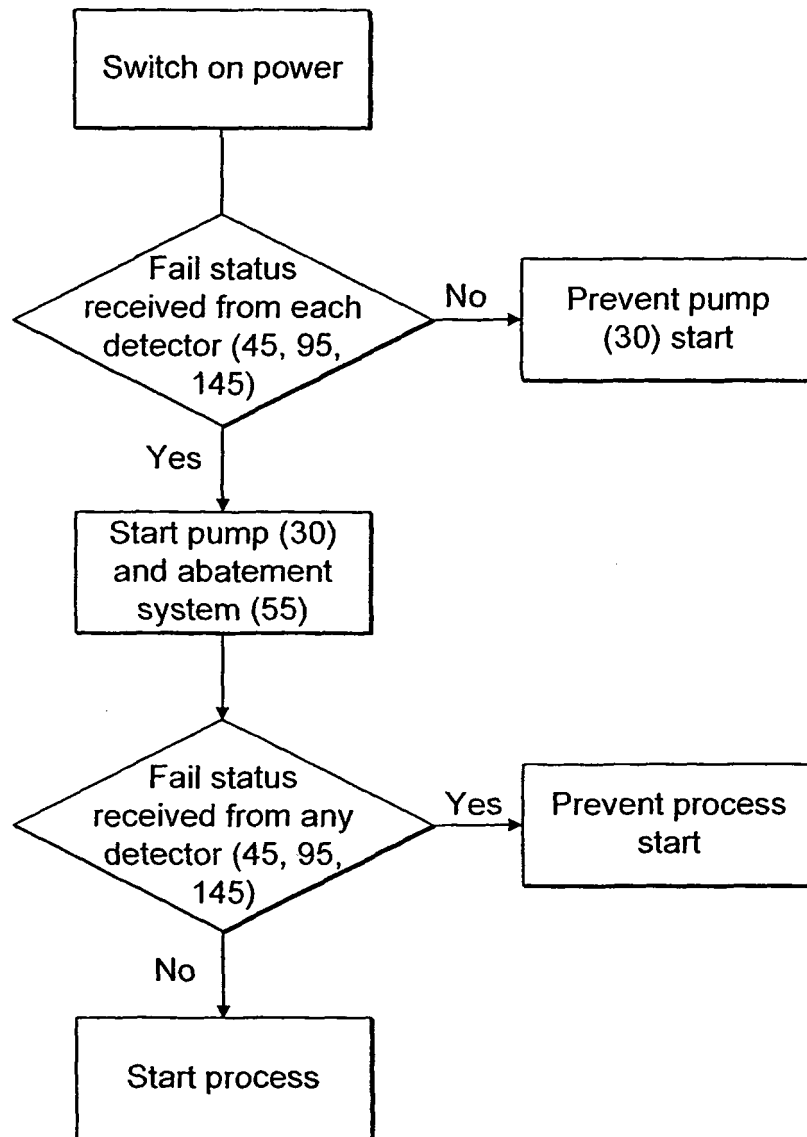


FIG. 5