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(54) Title: METHOD AND APPARATUS FOR WARMING UP A VACUUM PUMP ARRANGEMENT

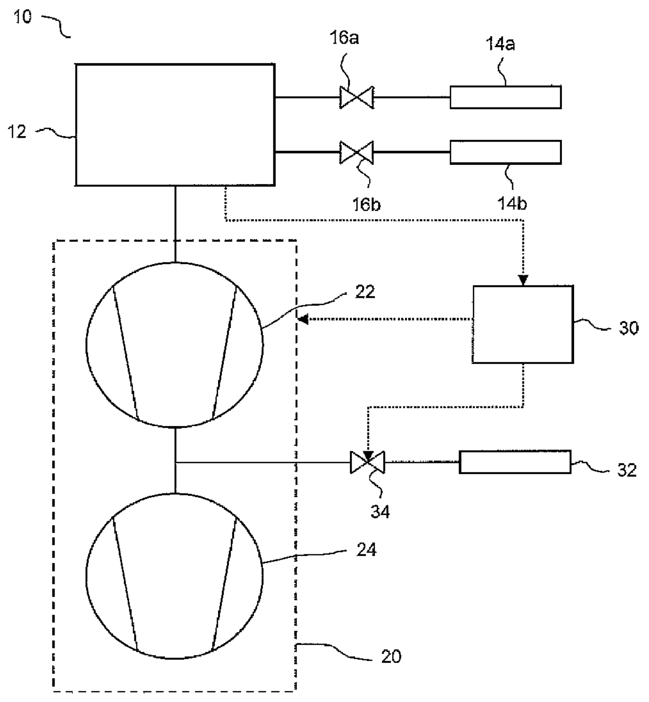

FIG. 1

(57) Abstract: A method for warming up a vacuum pump arrangement having a booster pump and a backing pump downstream of the booster pump for evacuating a process chamber includes setting the booster pump at a first speed higher than an idle speed of the booster pump when the same is in an idle mode; and controlling a backing pressure at an outlet of the booster pump within a range from 0.1mbar to 10 mbar at least for a period of time from when the vacuum pump arrangement is activated from the idle mode to when the booster pump reaches a temperature equal to or exceeding a first predetermined threshold value. Such method is implemented in system where a controlled is configured to carry out the above-motioned actions.

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METHOD AND APPARATUS FOR WARMING UP A VACUUM PUMP ARRANGEMENT

BACKGROUND OF THE INVENTION

[0001] This invention relates to a method and/or apparatus for warming up a vacuum pump arrangement after it was put into an idle mode.

[0002] A system used in manufacturing semiconductor devices typically includes, among other things, a process tool, a vacuum pump arrangement having a booster pump and a backing pump, and an abatement device. The process tool typically includes a process chamber, in which a semiconductor wafer is processed into a predetermined structure. The vacuum pump arrangement is connected to the process tool for evacuating the process chamber to create a vacuum environment in the process chamber in order for various semiconductor processing techniques to take place. The gas evacuated from the process chamber by the vacuum pump arrangement might be directed to the abatement device, which destroys or decomposes the harmful or toxic components of the gas before it is released to the environment.

[0003] It is desired to manage and reduce the utilities, such as electric power, fuel, and water, consumed by the vacuum pumps and abatement device during the semiconductor manufacturing processes. The power consumed by the vacuum pumps and abatement device represents a significant portion of the total power consumed by the entire system in manufacturing semiconductor wafers. Many efforts have been made in the semiconductor industry to improve the efficiency of utility consumption of the vacuum pumps in order to reduce the manufacturing costs of semiconductor wafers. In addition to cost savings, new environmental regulations would often put pressure on semiconductor manufacturers to improve the energy efficiency of their manufacturing processes.

[0004] One conventional method for improving the efficiency is to put the vacuum pump arrangement and the abatement device in an idle mode, when the process tool does not require that the vacuum pump arrangement and the abatement device operate in their normal capacities. The term “idle mode” here is used interchangeably with other terms, such as sleep mode, green mode, hibernation, reduced/low power mode, active utility control mode, that are often customarily used in various industries. For example, when semiconductor wafers are being transferred into or out of the process chamber, the vacuum pump arrangement and abatement device might be put in the idle mode, in which they consume fewer resources than they do in a normal operation mode. When the process tool requires the vacuum pump arrangement and abatement device to operate in their normal capacities, they can be brought back to their normal operation mode from the idle mode.

[0005] One drawback of the conventional method is that it usually takes a long time to bring the vacuum pump arrangement and the abatement device back to the normal operation mode from the idle mode. When the vacuum pump arrangement is in the idle mode, it cools down to a low temperature. Before the vacuum pump arrangement can operate in normal conditions, it needs be warmed up to a certain temperature, which can take a long time. The longer the warming-up takes, the longer the process tool is sitting idle, waiting for the vacuum pump arrangement to be ready. This translates into lost productivity, and decreased throughput.

[0006] Thus, what is needed is a method for quickly warming up the vacuum pump arrangement from the idle mode, thereby shortening the time required for bringing a processing system from the idle mode to the normal operation mode.

BRIEF SUMMARY OF THE INVENTION

[0007] This invention relates to a method and/or apparatus for warming up a vacuum pump arrangement after it was put into an idle mode. In some embodiments of the invention, a method for warming up a vacuum pump arrangement having a booster pump and a backing pump downstream of the booster pump for evacuating a process chamber includes steps of: setting the booster pump at a first speed higher than an idle speed of the booster pump when the same is in an idle mode; and controlling a backing pressure at an outlet of the booster pump within a range from 0.1mbar to 10mbar, wherein suitable backing pressure will need to be selected depending on the size of the booster pump, at least for a period of time from when the vacuum pump arrangement is activated from the idle mode to when the booster pump reaches a temperature equal to or exceeding a first predetermined threshold value.

[0008] In some embodiments of the invention, an apparatus includes: a process chamber; a booster pump having an inlet fluidly connected to an outlet of the process chamber; a backing pump having an inlet fluidly connected to an outlet of the booster pump for, together with the booster pump, evacuating the process chamber; and a controller electrically coupled with the booster pump and the backing pump, the controller being configured to control a backing pressure at the outlet of the booster pump within a range from 0.1mbar to 10mbar at least for a period of time from when the booster pump and the backing pump are activated from an idle mode to when the booster pump reaches a temperature equal to or exceeding a first predetermined threshold value.

[0009] The construction and method of operation of the invention, however, together with additional objectives and advantages thereof will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 illustrates a schematic view of a system where a process chamber, a booster pump, and a backing pump, among other things, are connected in series in accordance with some embodiments of the invention.

[0011] FIGs. 2A and 2B illustrate flow charts showing various processes for warming up a vacuum pump arrangement in accordance with some embodiments of the invention.

[0012] FIG. 3 illustrates a flow charts showing a processes for warming up a vacuum pump arrangement in accordance with some embodiments of the invention.

[0013] FIG. 4 is a graph showing that the disclosed method and/or apparatus shortens the time required to warm up a vacuum pump arrangement.

DEATILED DESCRIPTION OF THE INVENTION

[0014] The disclosure is directed to a method and/or apparatus for warming up a vacuum pump arrangement after it was put in an idle mode. The vacuum pump arrangement in its simplified configuration has a booster pump and a backing pump downstream thereof. An inlet of the booster pump is connected to an outlet of a process chamber, which can be part of a semiconductor process tool, or any other equipment that requires an internal vacuum environment in order to properly function. An outlet of the booster pump is connected to an inlet of the backing pump, of which an outlet is typically in fluid connection with an abatement device, or in some cases directly with an atmospheric environment. As the vacuum pump arrangement is warming up, the speed of the booster pump is raised to and maintained at a level higher than an idle speed of the booster pump when it was in the idle mode. The backing pressure of the booster pump, that is the pressure at the outlet of the booster pump, is also raised to and maintained at a relatively high level, compared to the backing pressure, in either the normal operation mode, or in some cases the idle mode, employed by conventional methods. As a result, the power required to compress the gas through the booster pump during the warm-up period would be increased, and therefore causing the temperature of the booster pump to increase more quickly. Because the booster pump typically takes a longer time to fully warm up than the backing pump, the method and/or apparatus of the disclosure is able to shorten the time required for warming up the entire vacuum pump arrangement from the idle mode. This in turn increases the throughput of the process tool.

[0015] FIG. 1 illustrates a schematic view of a system 10 where a process chamber 12 and a vacuum pump arrangement 20, among other things, are connected in series in accordance with some embodiments of the invention. The vacuum pump arrangement 20 draws gases out of the process chamber 12 and creates a vacuum environment in it to carry out certain processes, such as depositions, etching, ion implantation, epitaxy, etc. The gases can be introduced into the process chamber 12 from one or more gas sources, such as the ones designated by 14a and 14b in this figure. The gas sources 14a and 14b can be connected to the process chamber 12 via control valves 16a and 16b, respectively. The timing of introducing various gases into the process chamber 12 can be controlled by selectively turning on or off the control valves 16a and 16b. The flow rates of the gases introduced from the gas sources 14a and 14b into the process chamber 12 can be controlled by adjusting the fluid conductance of the control valves 16a and 16b.

[0016] The vacuum pump arrangement 20 includes a booster pump 22 and a backing pump 24 connected in series. The inlet of the booster pump 22 is connected to the outlet of the process chamber 12. The outlet of the booster pump 22 is connected to the inlet of the backing pump 24. The outlet of the backing pump 24 might be connected to an abatement device (not shown in the figure) where the exhaust gases emitted from the backing pump 24 are treated in order to reduce the harmful impact the exhaust gases might have on the environment. Sensors (not shown in the figure) can be implemented in the vacuum pump arrangement to collect data of various measurements, such as the temperatures, power consumptions, pump speeds, etc., of the booster pump 22 and the backing pump 24. Sensors can also be implemented to measure the gas pressures at the inlets and/or outlets of the booster pump 22 and/or the backing pump 24. A controller 30 is configured to control various parameters of the booster pump 22 and the backing pump 24 in response to the data collected by the sensors. For example, the controller 30 might put the booster pump 22 and the backing pump 24 in a low utility consumption state, e.g., the idle mode, upon receiving a signal indicating that no immediate process is expected to be performed in the process chamber 12. Such signal might be provided by the process chamber 12, or the process tool incorporating the process chamber 12, directly to the controller 30. Alternatively, such signal might be provided by a central control unit of a semiconductor manufacturing facility to the controller 30.

[0017] Upon receiving a wake-up signal, the controller 30 effects an increase of electric power supply to the vacuum pump arrangement 20, and raises the speeds of the booster and backing pumps 22 and 24 to higher levels from their respective idle speeds. The controller 30 controls, raises, and maintains the backing pressure at the outlet of the booster pump 22 within a range from 0.1mbar to 10mbar at least for a period of time when the vacuum pump arrangement 20 is activated from the idle mode to when the booster pump 22 reaches a temperature equal to or exceeding a predetermined threshold value, which is required in order for the booster pump to operate in normal conditions. The pressure range disclosed herein is higher than the backing pressure of the booster pump 22 in typical, conventional warm-up processes.

[0018] Mathematically, the compression power (W) of the booster pump 22 equals to its swept volume (V) times the pressure differential (dP) there across. Given that the swept volume of the booster pump 22 is constant, raising the pressure differential by raising backing pressure would require higher power to compress the gas through the booster pump 22, and therefore generating more heat as a result. This would cause the temperature of the booster pump 22 to reach the predetermined threshold value suitable for normal pump operation much quickly from the temperature when the booster pump 22 is in the idle mode.

[0019] In some embodiments of the invention, the backing pressure of the booster pump 22 can be controlled by adjusting the speed of the backing pump 24. The slower the speed of the backing pump 24, the higher the backing pressure of the booster pump 22. An exemplary process for controlling the backing pressure of the booster pump 22 is illustrated in FIG. 2A. The process starts at step 200. At step 202, it is determined whether the vacuum pump arrangement 20 has received a signal to wake up from the idle mode. If it is determined that the vacuum pump arrangement 20 has not received such signal, the vacuum pump arrangement 20 will remain in the idle mode. If it is determined that the vacuum pump arrangement 20 has received such signal, the process will proceed to step 204 where the speed of the booster pump 22 is set at a first speed higher than its idle speed. At step 206, the speed of the backing pump 24 is set at a second speed high than its idle speed. It is noted that although steps 204 and 206 are illustrated as two separate actions in FIG. 2A, the speeds of the booster and backing pumps 22 and 24 might be set simultaneously in some embodiments of the invention.

[0020] At step 208, it is determined whether the backing pressure of the booster pump 22 is within the predetermined range from 0.1bar to 10mbar. If the backing pressure is not within the predetermined range, the process proceeds to step 210 where the speed of the backing pump 24 is decreased in order for the backing pressure of the booster pump 22 to fall within the predetermined range quickly. In some embodiments of the invention, the speed of the backing pump 24 is decreased once, and the process waits for the backing pressure of the booster pump 22 to move within the predetermined range. In some other embodiments of the invention, the speed of the backing pump 24 is decreased incrementally over a number of time intervals until the backing pressure of the booster pump 22 moves within the predetermined range. In yet some other embodiments of the invention, the second speed of the backing pump 24 can be set low enough at step 206 for the backing pressure of the booster pump 22 to rise up quickly, such that step 210 can be eliminated all together. All theses embodiments are within the scope of the invention.

[0021] If the backing pressure of the booster pump 22 is determined to be within the predetermined range, the process proceeds to step 212. At step 212, it is determined whether the temperatures of the booster and backing pumps 22 and 24 are equal to or exceed their respective threshold temperatures. If they do, the vacuum pump arrangement 20 will be set to be ready for evacuating the process chamber 12 in a normal operation mode. Until then, the vacuum pump arrangement 20 will remain in the warm-up process, waiting for the temperatures to rise to proper levels. It is noted that the values of the predetermined threshold temperatures of the booster and backing pumps 22 and 24 may or may not be the same. Thereafter, the process ends at step 214.

[0022] In some embodiments of the invention, the backing pressure of the booster pump 22 can be controlled by adjusting the pump speed and comparing the temperature of the booster pump 22 to a threshold temperature, without directly measuring the backing pressure. FIG. 2B illustrates a flow chart showing an exemplary process for controlling the backing pressure of the booster pump 22, without directly measuring it. The process in FIG. 2B is similar to that in FIG. 2A, with differences in that the backing pressure of the booster pump 22 is not measured.

At step 248, the temperature of the booster pump 22 is measured and compared to the threshold temperature of the booster pump. If the measured temperature is lower than the threshold temperature, the speed of the backing pump 24 is increased at step 250. The steps 248 and 250 are repeated periodically until the measured temperature of the booster pump 22 is equal to or exceeds the threshold temperature. Thereafter, the process proceeds to step 252 where it is determined whether the temperature of the backing pump 24 is equal to or exceeds the threshold temperature of the backing pump 24. If it does, the vacuum pump arrangement 20 will be set as ready for evacuating the process chamber 12 in a normal operation mode. Until then, the vacuum pump arrangement 20 will remain in the warm-up process, waiting for the temperatures to rise to proper levels. Thereafter, the process ends at step 254.

[0023] In some other embodiments of the invention, the backing pressure of the booster pump 22 can be raised by injecting a purge gas at the outlet of the booster pump 22 or a location in the conduit between the booster pump 22 and the backing pump 24. As shown in FIG. 1, a source of purge gas 32 and a control valve 34 might be optionally provided. The control valve 34 might be placed between the source 32 and the conduit between the booster pump 22 and the backing pump 24. The controller 30 is configured to adjust the conductance of the control valve 34, thereby controlling the flow rate of the purge gas from the source 32 to the outlet or its downstream proximity of the booster pump 22. This in turns alters the backing pressure at the outlet of the booster pump 22. It is advantageous to select gases that are stable and do not react with the process gas flowing through the vacuum pump arrangement 20 as the purge gas. Examples of the purge gas include nitrogen, helium, and other inert gases.

[0024] FIG. 3 illustrates a process for warming up the vacuum pump arrangement 20 from the idle mode in accordance with some embodiments of the invention. The process illustrated in FIG. 3 is similar to that in FIG. 2, expect that in the latter the backing pressure of the booster pump 22 is controlled and maintained by adjusting the speed of the backing pump 24, whereas in the former the backing pressure of the booster pump 22 is controlled and maintained by injecting the purge gas at the outlet of the booster pump 22, as described by step 300. At step 302, it is determined whether the backing pressure of the booster pump 22 is within the predetermined range. If it is not, the controller 30 might increase the conductance of the control valve 34 to increase the flow rate of the purge gas, until the backing pressure of the booster pump 22 moves within the predetermined range. Like the process in FIG. 2, at step 300, the flow rate of the purge gas can be adjusted incrementally over a number of time intervals or abruptly to a predetermined level at once. If it is determined that the backing pressure of the booster pump 22 is within the predetermined range, the process will proceed to step 304.

[0025] At step 304, it is determined whether the temperature of the booster pump 22 is equal to or exceeds a predetermined threshold temperature. If it does not, the process will wait until it does and then proceed to step 306 where the flow of the purge gas is cut off. At step 308, it is determined whether the temperature of the backing pump 24 is equal to or exceeds a predetermined threshold temperature. If it does not, the process will wait unit it does and then end the process at step 310. Like the process in FIG. 2, here, the threshold temperatures of the booster and backing pumps may or may not be the same.

[0026] FIG. 4 is a graph showing that the disclosed method and/or apparatus shortens the time required to warm up a vacuum pump arrangement after it was put into an idle mode. The left side of the figure illustrates a time line for warming up a vacuum pump arrangement according to conventional methods or apparatus. The right side of the figure illustrates a time line for warming up the vacuum pump arrangement according to the method or apparatus of the disclosure. The comparison between the time lines shows that the disclosed method or apparatus is able to warm up the booster and backing pumps to their desired temperatures much more quickly than the conventional methods or apparatus, due to the increased backing pressure of the booster pump in the warm-up process. The shortened warm-up period means that the process tool can be put into operation much more quickly after the vacuum pump arrangement was instructed to wake up from the idle mode. This in turn translates into higher throughput for the process tool.

[0027] Although the invention is illustrated and described herein as embodied in one or more specific examples, it is nevertheless not intended to be limited to the details shown, since various modifications and structural changes may be made therein without departing from the spirit of the invention and within the scope and range of equivalents of the claims. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the scope of the invention, as set forth in the following claims.

CLAIMS

1. A method for warming up a vacuum pump arrangement having a booster pump and a backing pump downstream of the booster pump for evacuating a process chamber, comprising:

setting the booster pump at a first speed higher than an idle speed of the booster pump when the same is in an idle mode; and

controlling a backing pressure at an outlet of the booster pump within a range from 0.1mbar to 10mbar at least for a period of time from when the vacuum pump arrangement is activated from the idle mode to when the booster pump reaches a temperature equal to or exceeding a first predetermined threshold value.

2. The method of claim 1 wherein the controlling a backing pressure comprising adjusting a speed of the backing pump of which an inlet is connected to the outlet of the booster pump.

3. The method of claim 2 wherein the backing pump is set at a second speed when the vacuum pump arrangement is activated from the idle mode.

4. The method of claim 3 wherein the second speed of the backing pump is decreased to a predetermined level in order for the backing pressure of the booster pump to fall within the range from 0.1mbar to 10mbar.

5. The method of claim 4 wherein the second speed is decreased to the predetermined level incrementally over a number of time intervals.

6. The method of claim 1 wherein the controlling a backing pressure comprising injecting a purge gas at the outlet of the booster pump.

7. The method of claim 6 wherein a flow rate of the purge gas is controlled in a manner that the backing pressure of the booster pump is adjusted into the range from 0.1mbar to 10mbar.

8. The method of claim 1 wherein the vacuum pump arrangement is set to be ready for evacuating the process chamber in a normal operation mode, when the temperature of the booster pump is equal to or exceeds the first predetermined threshold value, and a temperature of the backing pump is equal to or exceeds a second predetermined threshold value, in which the first and second predetermined threshold values may or may not be the same.

9. An apparatus comprising:

a process chamber;

a booster pump having an inlet fluidly connected to an outlet of the process chamber;

a backing pump having an inlet fluidly connected to an outlet of the booster pump for, together with the booster pump, evacuating the process chamber; and

a controller electrically coupled with the booster pump and the backing pump, the controller being configured to control a backing pressure at the outlet of the booster pump within a range from 0.1mbar to 10mbar at least for a period of time from when the booster pump and the backing pump are activated from an idle mode to when the booster pump reaches a temperature equal to or exceeding a first predetermined threshold value.

10. The apparatus of claim 9 wherein the controller controls the backing pressure of the booster by adjusting a speed of the backing pump.

11. The apparatus of claim 10 wherein the controller sets the backing pump at a predetermined speed when the vacuum pump arrangement is activated from the idle mode.

12. The apparatus of claim 11 wherein the controller reduces the predetermined speed of the backing pump to a predetermined level in order for the backing pressure of the booster pump to fall within into the range from 0.1mbar to 10mbar.

13. The apparatus of claim 12 wherein the controller reduces the predetermined speed to the predetermined level incrementally over a number of time intervals.

14. The apparatus of claim 9 further comprising a source of purge gas fluidly connected at the outlet of the booster pump.

15. The apparatus of claim 14 wherein the controller controls a flow rate of a purge gas being injected at the outlet of the booster pump, thereby controlling the backing pressure of the booster pump within the range from 0.1mbar to 10mbar.

16. The apparatus of claim 9 wherein the booster pump and the backing pump are set to be ready for evacuating the process chamber in a normal operation mode, when the temperature of the booster pump is equal to or exceeds the first predetermined threshold value, and a temperature of the backing pump is equal to or exceeds a second predetermined threshold value, in which the first and second predetermined threshold values may or may not be the same.

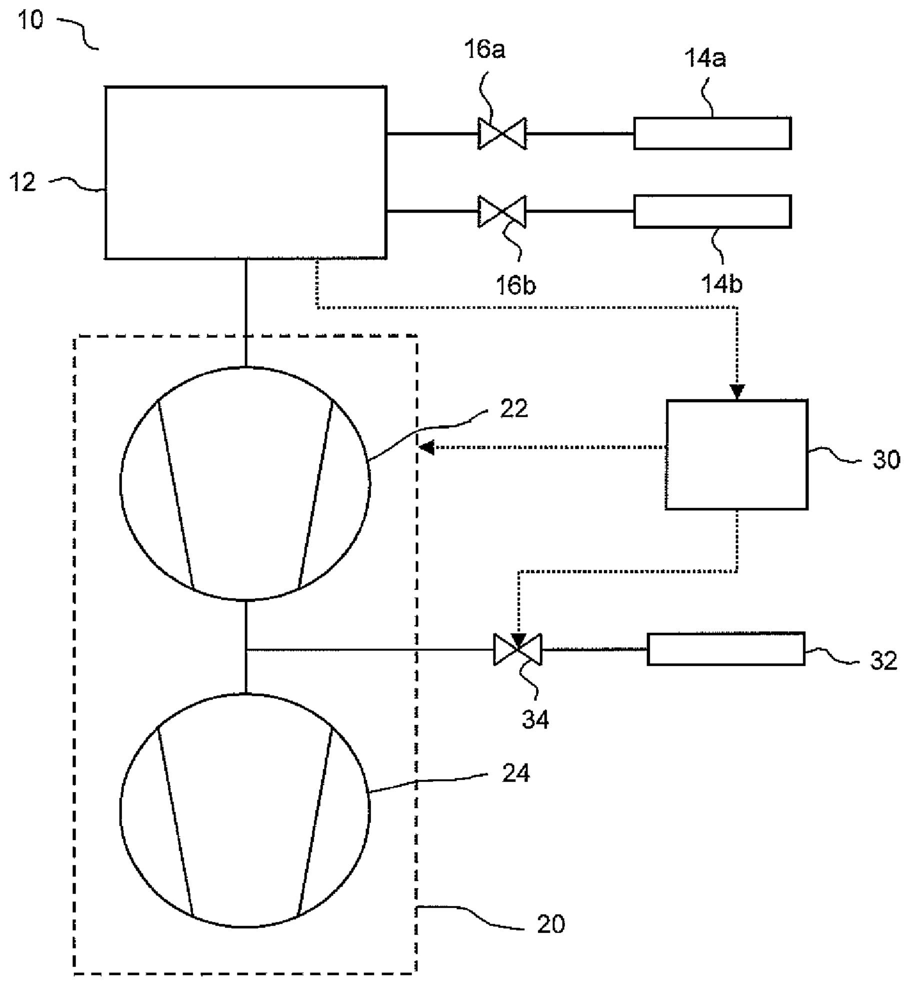

FIG. 1

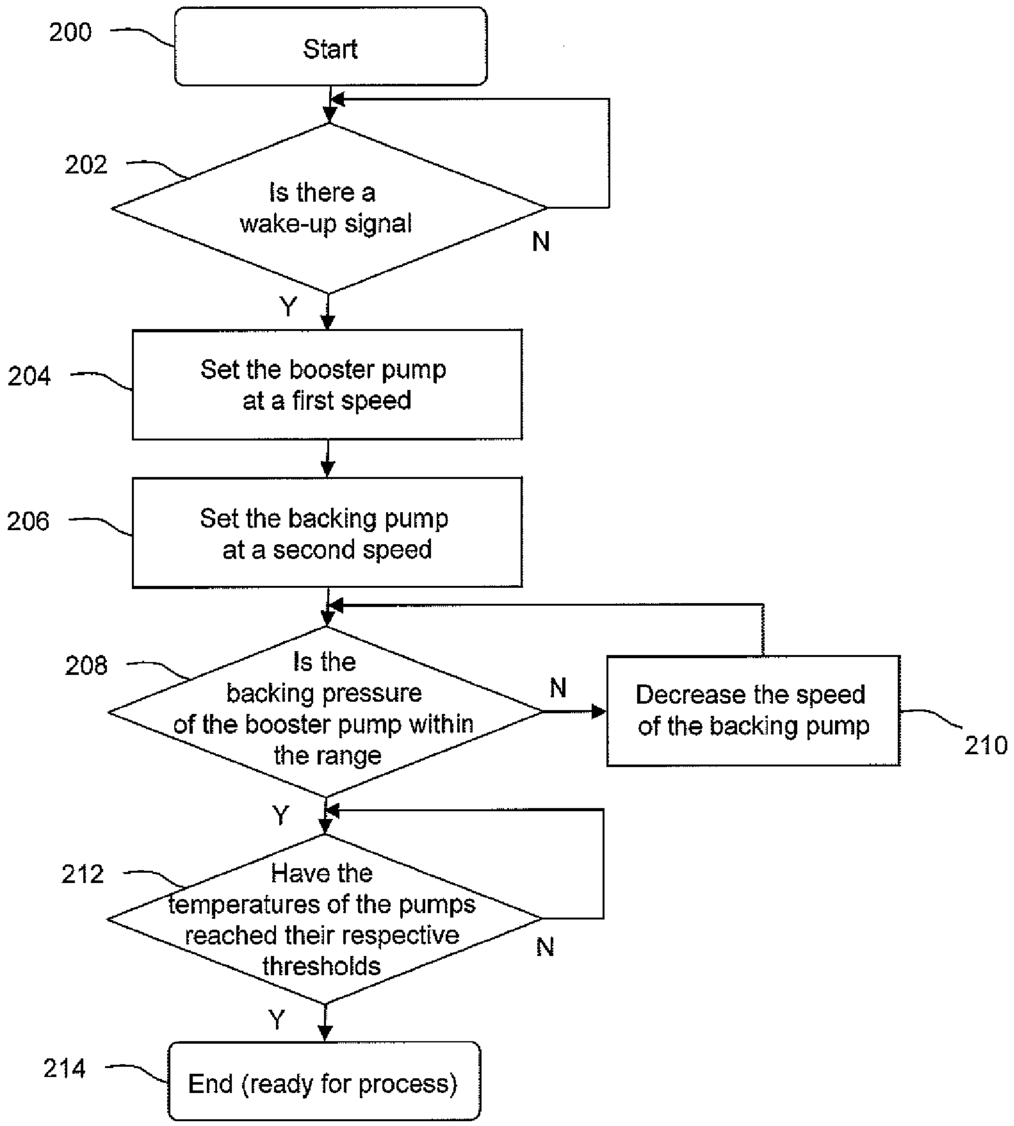
200
Start
202
Is there a wake-up signal
N
Y
204
Set the booster pump at a first speed
206
Set the backing pump at a second speed
208
Is the backing pressure of the booster pump within the range
N
Decrease the speed of the backing pump
210
Y
212
Have the temperatures of the pumps reached their respective thresholds
N
Y
214
End (ready for process)

FIG. 2A

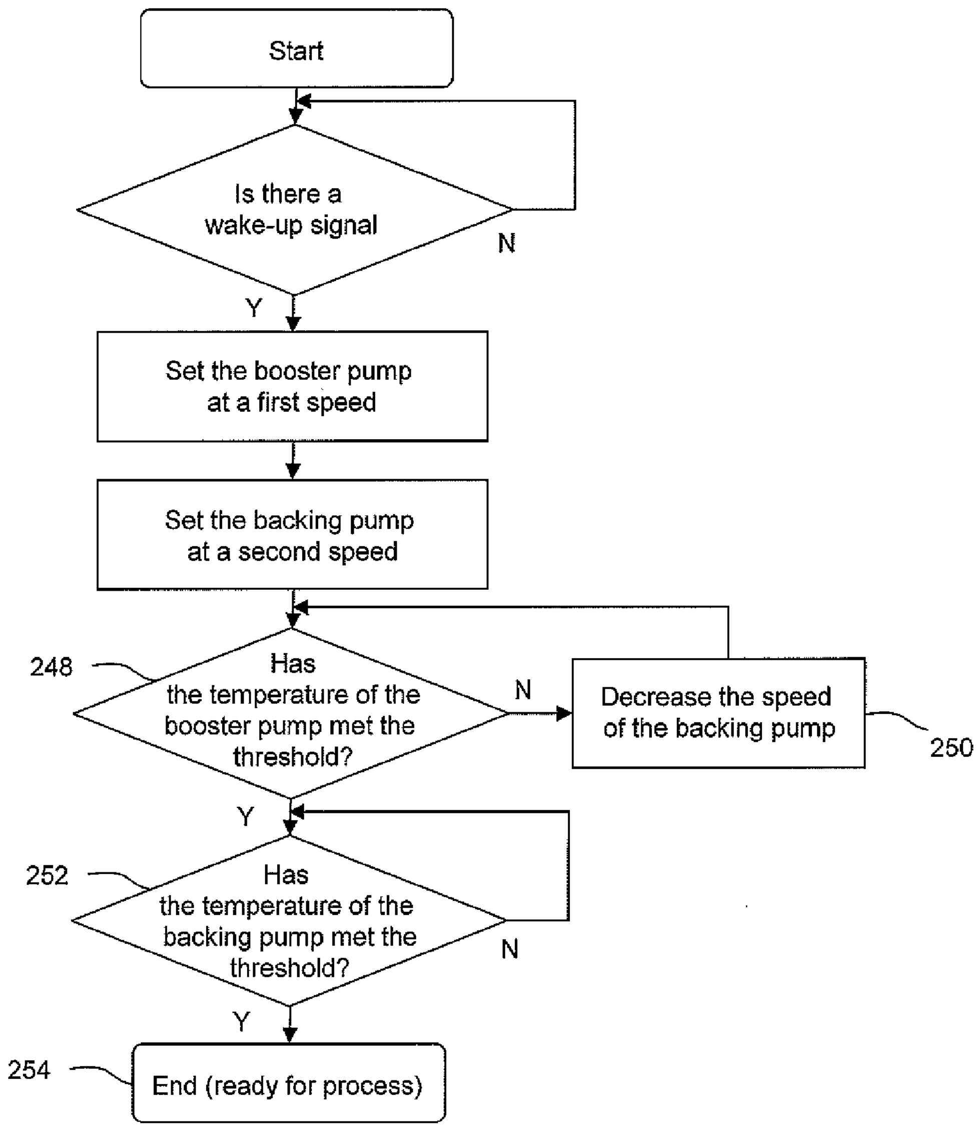
Start
Is there a wake-up signal
N
Y
Set the booster pump at a first speed
Set the backing pump at a second speed
248
Has the temperature of the booster pump met the threshold?
N
Decrease the speed of the backing pump
250
Y
252
Has the temperature of the backing pump met the threshold?
N
Y
254
End (ready for process)

FIG. 2B

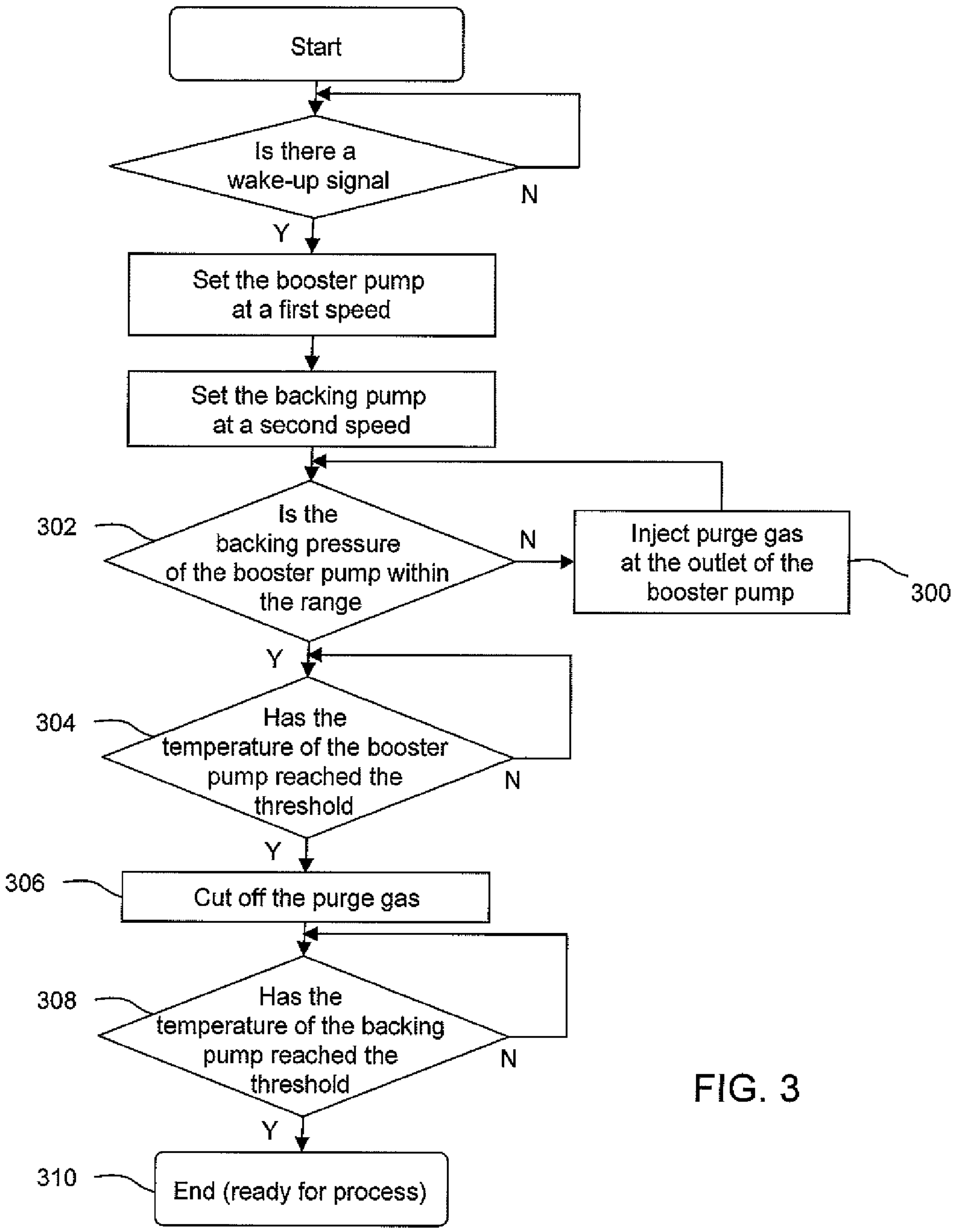
Start
Is there a wake-up signal
N
Y
Set the booster pump at a first speed
Set the backing pump at a second speed
302
Is the backing pressure of the booster pump within the range
N
Inject purge gas at the outlet of the booster pump
300
Y
304
Has the temperature of the booster pump reached the threshold
N
Y
306
Cut off the purge gas
308
Has the temperature of the backing pump reached the threshold
N
Y
310
End (ready for process)

FIG. 3

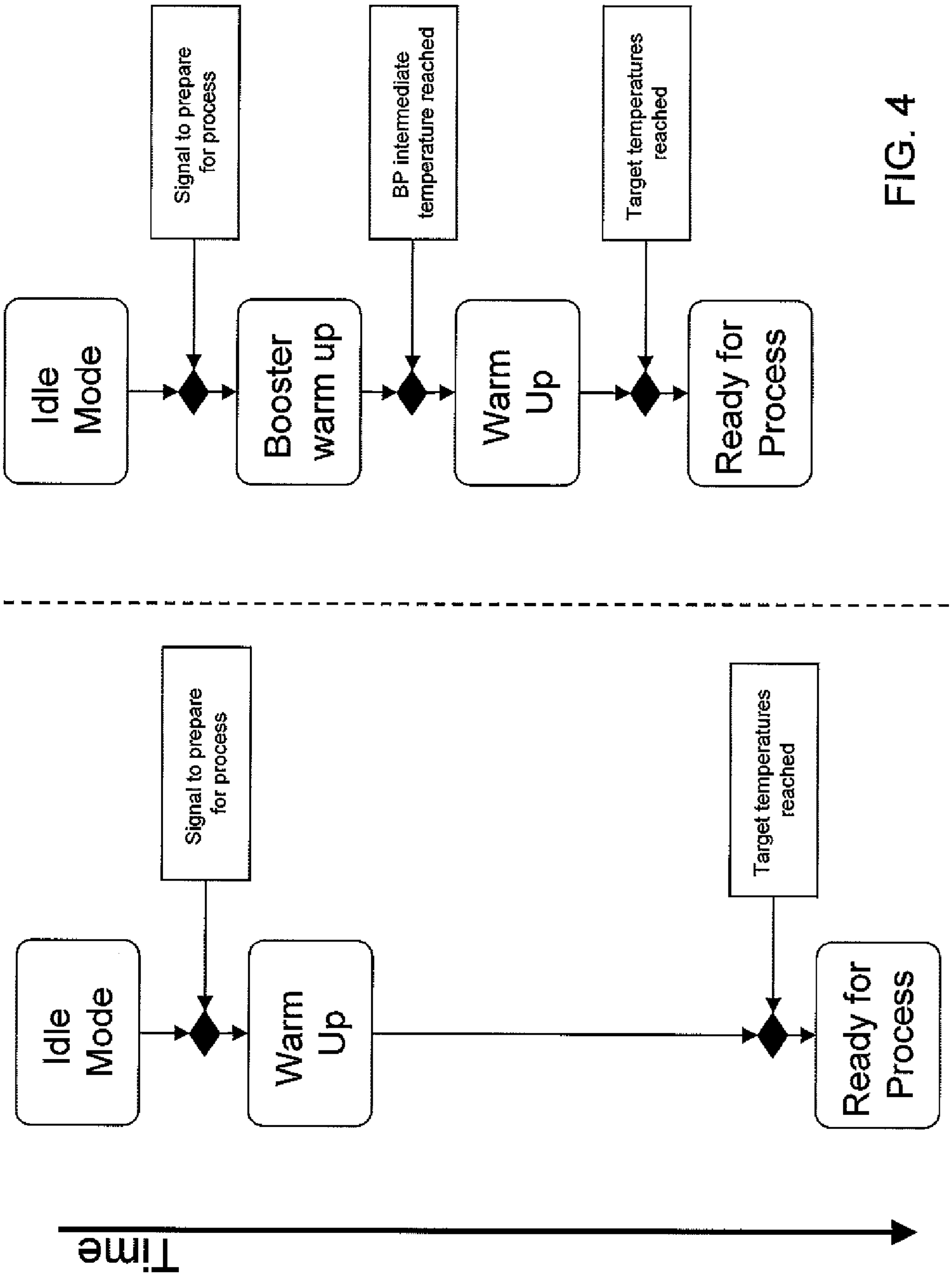
Idle Mode
Signal to prepare for process
Booster warm up
BP intermediate temperature reached
Warm Up
Target temperatures reached
Ready for Process
Idle Mode
Signal to prepare for process
Warm Up
Target temperatures reached
Ready for Process
Time

FIG. 4