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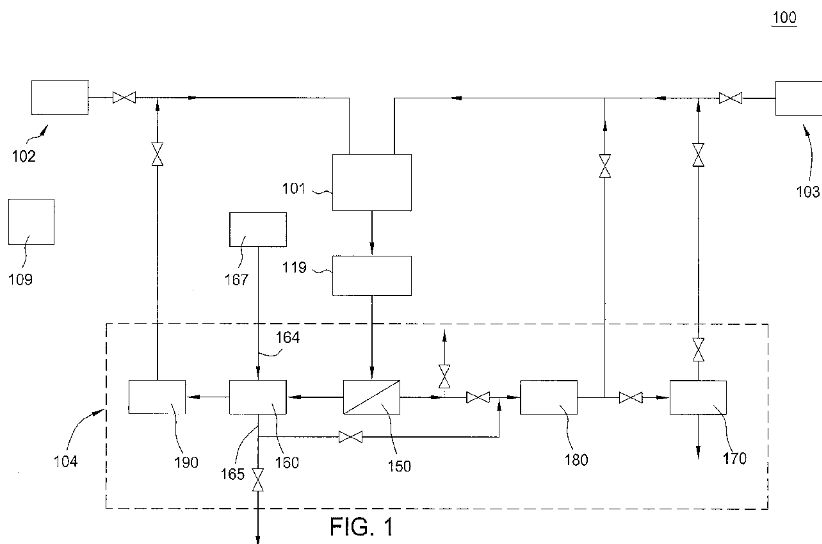

FIG. 1

(57) Abstract: The present invention generally relates to apparatus and method for recycling both polishing slurry and rinse water from CMP processes. The present invention also relates to rheology measurements and agglomeration prevention using centrifugal pumps.

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POINT OF USE RECYCLING SYSTEM FOR CMP SLURRY

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] Embodiments of the present invention generally relate to apparatus and method for recycling polishing slurry and rinse water in a chemical mechanical polishing (CMP) system.

Background

[0002] Due to the high cost of CMP polishing slurry recycling CMP polishing slurry from CMP process has been the subject of numerous studies. Polishing slurries are generally comprises about 3% to about 30% solid particles suspended in water. Polishing slurry generally accounts about 50% of CMP cost.

[0003] However, recycling and reuse of CMP polishing slurries for use in semiconductor processing faces significant challenges. During CMP processing, particle concentration, particle size, particle homogeneity have profound effect in removal rate and defect reduction, therefore, must be carefully controlled. However, these factors are difficult to achieve in recycled polishing slurry because some particles are crushed and some of the particles agglomerate during polishing, and particles of removed materials enter into the polishing slurry.

[0004] Additionally, recycling rinsing water is also of interest to reduce cost of ownership. However, there is concern that recycled water is not satisfactory to perform multiple rinses post polishing.

[0005] Therefore, there is a need for apparatus and method for recycling polishing slurry and rinse water in a chemical mechanical polishing system.

SUMMARY OF THE INVENTION

[0006] The present invention generally relates to apparatus and method for recycling both polishing slurry and rinse water from CMP processes.

[0007] One embodiment of the present invention provides an apparatus for recycling comprising a first filtration unit, wherein the first filtration unit comprises an inlet configured to receive one or more of used polishing slurry, rinsing fluid, such as water, glycol or others, and polishing waste, a water outlet configured to output a first filtered stream for water recycling, and a chemical outlet configured to output a second stream for recycling polishing slurry, a second filtration unit, wherein the second filtration unit comprises an inlet connected with the chemical outlet of the first filtration unit, a product outlet configured to output a stream of recycled polishing slurry, and a water outlet configured to output another filtered stream for water recycling, and an optional UV (ultra violet) unit, wherein the UV unit comprises an inlet connected with the water outlet of the first and / or filtration unit, and an outlet configured to output a stream of UV treated fluid.

[0008] Another embodiment of the present invention provides a method for recycling polishing fluid, comprising filtering one or more of used polishing slurry, rinsing fluid and polishing waste through a first filtration unit to generate a water stream and a suspension stream, filtering the suspension stream through a second filtration unit to separate a stream of reusable polishing slurry from a water stream, flowing the stream of reusable polishing slurry to a polishing slurry source for a polishing station, recycling the water stream, and flowing the recycled water stream to a recycled water source.

[0009] Yet another embodiment of the present invention provides a chemical mechanical polishing system comprising one or more polishing stations, a polishing slurry unit configured to provide polishing slurry to the one or more polishing stations, a rinse water unit configured to provide rinse water to the one or more polishing stations, and a recycling unit configured to recycle polishing slurry and rinse water, wherein the recycling unit comprises a first filtration unit, wherein the first filtration unit comprises an inlet configured to receive a mixture of used polishing slurry, rinsing fluid, and polishing waste from the one or more polishing stations, a water outlet configured to output a first filtered stream for water recycling, and a chemical outlet configured to output a second stream for recycling polishing slurry, a second filtration unit, wherein the second filtration unit comprises an inlet connected

with the chemical outlet of the first filtration unit, a product outlet configured to output a stream of recycled polishing slurry to the polishing slurry unit, and a water outlet, to output another filtered stream for water recycling, an optional UV (ultra violet) unit, wherein the UV unit comprises an inlet connected with the water outlet of the first and / or second filtration unit, and an outlet configured to output a stream of UV treated water, and a treatment unit configured to purify the UV treated water by removing organic compounds, and or to kill bacteria wherein the treatment unit comprises, an inlet connected to the outlet of the UV unit, and an outlet configured to output a stream of purified water to the rinse water unit.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0011] Figure 1 is a schematic chart of a polishing system having a recycling unit in accordance with one embodiment of the present invention.

[0012] Figure 2A is a schematic chart of a polishing system having a recycling unit in accordance with one embodiment of the present invention.

[0013] Figure 2B is a schematic chart of a polishing system having a recycling unit in accordance and a centrifugal separator with one embodiment of the present invention.

[0014] Figure 2C is a schematic chart of a polishing system having a recycling unit in accordance and a centrifugal separator with one embodiment of the present invention.

[0015] Figure 2D is a schematic chart of a polishing system having a diverter valve and a recycling unit in accordance with one embodiment of the present invention.

[0016] Figure 3 is a schematic chart of a polishing station having a dedicated recycled slurry source in accordance with another embodiment of the present invention.

[0017] Figure 4 is a schematic chart of a polishing station having a dedicated recycled rinse water source in accordance with another embodiment of the present invention.

[0018] Figure 5 is a schematic chart of a polishing system having multiple polishing stations and a recycling unit in accordance with another embodiment of the present invention.

[0019] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements disclosed in one embodiment may be beneficially utilized on other embodiments without specific recitation.

DETAILED DESCRIPTION

[0020] Embodiments of the present invention generally relate to apparatus and method for recycling slurry and liquid from various processes that use slurry, such as chemical mechanical polishing, or wire saw cutting applications.

[0021] Embodiment of the present invention provides apparatus and method for recycling polishing slurry and rinse water discharged from a polishing station. The discharge generally comprises one or more of used polishing slurry, debris from planarized or wire cut surface, rinsing fluid, and particles of removed and pad material. One embodiment of the present invention provides a recycling unit that receives waste mixture and outputs recycled water and recycled polishing slurry. In one embodiment, the recycling unit comprises four filtration/treatment units. A first filtration unit is configured to separate the mixture into a water stream which mainly

includes large particles and a concentrate stream which includes solids. The concentration stream then goes through a second filtration unit for further filtration before going back as recycled slurry. Before going back as recycled slurry, a fourth filtration step could be implemented as an option for safety purpose. The stream of water then goes through a third treatment unit to be further purified including optional deionization.

[0022] Depth filtration, centrifugal separation, microfiltration, nanofiltration, and ultrafiltration may be used alone or in combination in the filtration/treatment units. In one embodiment, magnetically levitated pumps are used in the filtration/treatment units to apply a pressure without deleteriously impacting in the nature of the polishing slurry.

[0023] In one embodiment, a centrifugal separation unit is used to remove large particles, agglomerates, and/or polymeric particles. The centrifugal separation unit may be positioned before or after a filtration unit.

[0024] The recycling unit may be configured to recycle polishing slurries from various CMP processes, such as polishing of copper, tungsten, silicon oxides, single crystalline silicon, polycrystalline silicon, or from wire saw applications.

[0025] Embodiments of the present invention also relate to using centrifugal pumps, such as magnetically levitated pumps, in pumping, mixing, and metering to reduce and prevent agglomeration of particles in the CMP polishing slurry and to reduce particle contamination. In one embodiment, particle agglomeration may be reduced by controlling the amount of sheer when pumping, mixing and metering.

[0026] Figure 1 is a schematic chart of a polishing system 100 having a recycling unit 104 in accordance with one embodiment of the present invention. The polishing system 100 may be configured to planarize substrates comprising variety of materials, such as polycrystalline silicon, single crystalline silicon, oxides, tungsten, aluminum, copper, or combinations of different materials. In one embodiment, the polishing system 100 may be used to prepare a polycrystalline silicon substrate for solar panel fabrication.

[0027] The polishing system 100 comprises a polishing station 101 wherein substrates are polished by a polishing slurry with the assistance of relative motion between the substrate being processed and a polishing pad. The polishing slurry is usually sprayed on the substrate or the polishing pad during polishing. After polishing, one or more rinses of the substrate are carried out by spraying deionized water.

[0028] The polishing system 100 further comprises a polishing slurry source 102 configured to supply polishing slurry to the polishing station 101. In one embodiment, the polishing slurry source 102 may comprise one or more slurry tanks configured to store virgin polishing slurry, and/or recycled polishing slurry therein and one or more pumps configured to supply polishing slurry in the tanks to the polishing station 101. In one embodiment, the pumps may be centrifugal pumps, such as magnetically levitated pumps, configured to provide real time rheology measurements and torque requirements to a system controller.

[0029] In another embodiment, the polishing slurry source 102 may comprise a slurry generator configured to manufacturing polishing slurry in-situ. The slurry generator assures "fresh" polishing slurry and avoids settling or other aging problems that associated with pre-made polishing slurry. In one embodiment, the slurry generator may be connected to a small local slurry tank to assure steady flow of slurry during processing.

[0030] The polishing system 100 further comprises a rinse water source 103 configured to supply rinse water to the polishing station 101 for rinsing of the substrates and/or the polishing station 101. The rinse water source 103 may be configured to supply ultra purified water to the polishing station 101.

[0031] In one embodiment, the polishing system 101 may have a tank 119 connected downstream to the polishing station 101 and configured to receive used polishing slurry and used rinse fluid, such as water, glycol or others. In one embodiment, the tank 119 may be coupled to multiple polishing stations and configured to collect mixtures of used polishing slurry and rinsing water from multiple polishing stations.

[0032] The polishing system 100 further comprises a recycling unit 104 configured to receive the mixture from the tank 119 and to generate reusable polishing slurry, reusable rinse water or both from the mixture in the tank 119. In another embodiment, the recycling unit 104 may be directly connected to the polishing station 101.

[0033] The recycling unit 104 comprises a first filtration unit 150 configured to split received mixture into a water stream with chemicals and particles removed and a concentration stream comprising the majority of chemicals and particles. The first filtration unit 150 may also have a waste outlet that provides an exit for waste, such as large particles. The concentration stream is directed to a second filtration unit 160 to obtain reusable polishing slurry. The water stream is directed to an optional sanitization unit 180 and a treatment unit 170 to obtain reusable clean water.

[0034] The first filtration unit 150 may comprise a suitable filtering media for depth filtration and/or surface filtration. In one embodiment, the first filtration unit 150 comprises one or more membranes or other filtration units configured to remove particles of different sizes. In one embodiment, the membranes or other filtration units may be microfiltration membrane, nanofiltration membrane, or ultrafiltration membrane.

[0035] In one embodiment, the first filtration unit 150 may be a cross flow filtration unit. The water stream is the permeate stream that permeates all the one or more membranes and the concentration stream is the reject stream from one of the membranes. In another embodiment, the first filtration unit 150 is a dead-end filtration unit having two or more membranes or other optional filtration technologies, and the water stream is the permeate stream that permeates all the two or more separators. This dead-end filtration unit can optionally utilize a back flush regeneration to clean the membrane surface. The first filtration unit 150 removes particles that are too large for polishing slurry from the concentration stream.

[0036] The second filtration unit 160 is connected downstream to the first filtration 150 to receive the concentration stream. The second filtration unit 160 is configured to stabilize particle size distribution in the output stream. In one embodiment, the

second filtration unit 160 is configured to remove both large particles and small particles from the stream to obtain qualifying abrasive particle size for the stream to be reusable. In one embodiment, the second filtration unit 160 comprises a membrane or other filtering media and a pump configured to pressure the concentration stream through the membrane. The pump may be a magnetically levitated pump that imposes minimal destruction to the abrasive particles in the polishing slurry. The second filtration unit 160 may be cleaned by backward flush to remove waste and surplus water. The water may be exit the second filtration unit 160 through a waste output 165 or will be fed to the treatment unit 170. In one embodiment, the waste may be about 10% to about 15% of feed stream. The concentrate stream from the second filtration unit 160 goes back to polishing from a slurry output 164.

[0037] In one embodiment, the second filtration unit 160 further comprises a dosing unit 167 configured for keeping the abrasive slurries stabilized during processing in the second filtration unit 160. The dosing unit 167 may provide an additional stream of conditioning chemicals, such as KOH or NH_4OH 167 to the second filtration unit 160 either before, during or after filtration.

[0038] The stream from the slurry output 164 may be directed back to a local polishing slurry tank of the polishing station 101 or to combine with virgin polishing slurry in the polishing slurry source 102. In one embodiment, rinse water or additional chemical, particles may be blended with the slurry output 164 to obtain desired concentration of a polishing slurry for reuse.

[0039] In one embodiment, the slurry out of the second filtration unit may be filtered with a polishing filtration unit 190 before directed back to a local polishing slurry tank of the polishing station 101 or to combine with virgin polishing slurry in the polishing slurry source 102.

[0040] The sanitization unit 180 is optional. In one embodiment, the sanitation unit 180 is configured to remove organic species from the fluid flowing therethrough, such as the water stream from the first filtration unit 150 and / or the water stream from the second filtration unit 160. In one embodiment, the sanitization unit 180 may

be an ultra violet (UV) unit configured to oxidize the organic species in the water stream. In another embodiment, the sanitization unit 180 is configured to reduce and control bacteria counts.

[0041] In one embodiment, the sanitized water stream out of the sanitization unit 180 is directly flown back to the polishing station 101 for rinsing or other function. The sanitized water stream may be used in a first rinse, which has low requirement for the purity of the rinse water.

[0042] The treatment unit 170 is configured to purify and/or deionize the water stream. In one embodiment, the treatment unit 170 may comprise a reverse osmosis membrane for a reverse osmosis filtration. In another embodiment, the treatment unit 170 may comprise an ion-exchange resin, which may be continuously regenerated, to deionize the water stream. In another embodiment, the treatment unit 170 may comprise both a reverse osmosis membrane and an ion-exchange resin. The output stream from the treatment unit 170 results in ultra purified water. The rejected stream from the treatment unit 170 exits the recycling unit 104 as waste water. In one embodiment, the waste water is between about 5% to about 20% of feed stream. The purified water from the treatment unit 170 may be sent back to directly to the polishing station 101 or to mix with virgin ultra purified water from the rinse water source 103.

[0043] In one embodiment, the treatment unit 170 may be positioned locally near the polishing station 101. In another embodiment, the treatment unit 170 may located remotely. In one embodiment, a factory water treatment may be used as the treatment unit 170. The water stream from the first filtration unit 150 and or from the second filtration unit 160 may be flown to factory water treatment unit for recycling, which may be located outside the building where the factory wide water treatment systems are positioned.

[0044] Since both polishing and rinsing comprise multiple phases. For example, polishing may be performed in three or more steps to achieve high throughput and high quality. The initial polishing step, such as bulk polishing, is usually more tolerant to variation of polishing slurry than the final polishing step, such as buffing.

Therefore, it can be desirable to direct recycled polishing slurry to the polishing station when it performs bulk polishing and shut off the recycled polishing slurry when the polishing station is performing final step buffing. Similarly, initial rinse after polishing is less sensitive to traces of chemical and ions in the rinse water than the final rinse. Therefore, it is desirable to supply recycled rinse water to the polishing station while the polishing station is performing initial rinsing and shut off the recycled rinse water when the polishing station is performing final rinsing.

[0045] In one embodiment, the polishing system 100 further comprises a system controller 109. In one embodiment, the system controller 109 may control the multiple valves in the polishing system 100 to insure that recycled polishing slurry and/or rinse water is delivered or shut off at desired time. For simplicity of drawing, connections between the system controllers 109 and the components of the polishing system 100 are not shown. In one embodiment, the system controller 109 is a stand alone independent controller for supplying and recycling polishing slurry. In another embodiment, the system controller 109 is integrated in to a CMP tool controller as an integral part.

[0046] Figure 2A is a schematic chart of a polishing system 200A having a recycling unit 204 in accordance with another embodiment of the present invention. The polishing system 200A is similar to the polishing system 100 of Figure 1 but with detailed exemplary embodiments for different units.

[0047] The polishing system 200A may be configured to planarize substrates comprising variety of materials, such as polycrystalline silicon, single crystalline silicon, oxides, tungsten, copper, aluminum, or combinations of different materials. In one embodiment, the polishing system 200A may be used to prepare a polycrystalline silicon substrate for solar panel fabrication.

[0048] The polishing system 200A comprises a polishing station 201 wherein a substrate 213 being processed is retained by a polishing head 212 and pressed against a polishing pad 211. The polishing head 212 and the polishing pad 211 both rotate and provide relative motion between the substrate 213 and a polishing surface of the polishing pad 211. A slurry nozzle 214 provides a polishing slurry to

the polishing pad 211. A rinse nozzle 215 provides rinse water to the polishing station 201.

[0049] The polishing system 200A further comprises a polishing slurry unit 202 configured to supply polishing slurry to the polishing station 201. The polishing slurry unit 202 comprises a source 221 and a local tank 224. In one embodiment, the source 221 may be a source tank storing pre-generated the polishing slurry. The source tank is generally much larger than the local tank 224. In another embodiment, the source 221 may be a slurry generator to generate polishing slurry on-site. During operation, a pump 222 pumps polishing slurry through a filter 223 to the local tank 224, and a pump 225 from connected to the local tank 224 pumps the slurry through a filter 226 to the slurry nozzle 214.

[0050] In one embodiment, the filter 226 may be a point-of-use depth filter and particle filtration to remove any gels and agglomerates just prior to dispensing the polishing slurry to the polishing station 201. In one embodiment, the filter 226 is disposed downstream to the pump 225 and upstream to a delivery arm to which the slurry nozzle 214 is connected.

[0051] The polishing system 200A further comprises a rinse water unit 203 configured to supply rinse water to the polishing station 201 for rinsing of the substrates and/or the polishing station 201. The rinse water unit 203 may comprise a tank 231 configured for store rinse water for supplying to the rinse nozzle. The tank 231 usually connects to a source of virgin ultra purified water.

[0052] In one embodiment, the polishing station 201 comprises a collecting bin 216 configured to receive used polishing slurry, rinse fluid along with removed material. In one embodiment, the collecting bin 216 may be lowered during substrate loading and unloading and raised during polishing and rinsing to catch polishing slurry and rinsing fluid.

[0053] The polishing system 200A may have a tank 219 connected downstream to the collecting bin 216. In one embodiment, the tank 219 may be coupled to

multiple polishing stations and configured to collect mixtures of used polishing slurry and rinsing fluid from multiple polishing stations.

[0054] The polishing system 200A further comprises a recycling unit 204 configured to receive the mixture from the tank 219 and to generate reusable polishing slurry and reusable rinse water from the mixture in the tank 219.

[0055] The recycling unit 204 comprises a first filtration unit 250 configured to split received mixture into a water stream with majority of chemicals and particles removed and a concentration stream comprising chemicals and particles. The concentration stream is directed to a second filtration unit 260 to obtain reusable polishing slurry. In one embodiment, the water stream is directed to an optional sanitization unit 280 and a treatment unit 270 to obtain reusable purified water. In another embodiment, the water stream may be directly going to waste.

[0056] The first filtration unit 250 comprises a pump 251 connected upstream to a filter unit 252. The pump 251 is configured to pressurize income stream from the tank 219 through the filter unit 252. The first filtration unit 250 is configured to remove particles that are too large for polishing slurry from the concentration stream.

[0057] The filter unit 252 comprises suitable filter media, such as depth filter and particle filtration unit. In one embodiment, the filter unit 252 comprises one or more membranes or other filtration technologies. As shown in Figure 2A, the filter unit 252 can comprise one or more membranes, such as a microfiltration membrane, a nanofiltration membrane or an ultrafiltration membrane. In one embodiment, the membranes may be disposed in a staged manner. The income stream would go through the one or more membranes in sequence. In one embodiment, the filter unit 252 comprises a microfiltration membrane, a nanofiltration membrane, and an ultrafiltration membrane in sequence.

[0058] In one embodiment, the first filtration unit 250 comprises a concentration outlet 257 in fluid communication with stream between the microfiltration membrane 253 and the nanofiltration membrane 254. As a result, large particles from the

income stream do not permeate the filter unit 252 and small particles permeate the filter unit 252.

[0059] The first filtration unit 250 further comprises a water output 258 in fluid communication with the permeate stream out of the all stages of membranes in the filter unit 252 to output a water stream with most chemical and particles removed. In another embodiment, the stream from the water output 258 may also exit the system as waste.

[0060] The pump 251 may be a diaphragm pump, a bellow pump, or a magnetically coupled or centrifugal pump. Alternately a vacuum system or gas pressure can be employed for transfer of fluids. In one embodiment, the pump 251 may be a magnetically levitated pump. This low sheer pump has minimum impact on particle size distribution of the polishing slurry.

[0061] The filter unit 252 may be configured for dead-end filtration, cross flow filtration, or back flushable filtration. In one embodiment, the microfiltration membrane 253, the nanofiltration membrane 254 and the ultrafiltration membrane 255 may be polymeric membranes or ceramic membranes. The one or more membranes in the filter unit 252 may be spiral membranes, tubular membranes, plate and frame, or hollow fiber membranes.

[0062] The second filtration unit 260 is connected downstream to the first filtration unit 250 to receive the concentration stream. The second filtration unit 260 is configured to stabilize particle size distribution in the output stream.

[0063] In one embodiment, the second filtration unit 260 comprises a filter media 262 and a pump 261 configured to pressure the concentration stream through the filter media 262. In one embodiment, the filter media 262 comprises a membrane. The pump may be a magnetically levitated pump that imposes minimal destruction to the abrasive particles in the polishing slurry.

[0064] The second filtration unit 260 has a slurry output 264 configured to output a permeated stream, and a back flush port 266 configured to receive a rinse fluid to clean the filter media 262 by backwashing to remove waste. The waste may be exit

the second filtration unit 260 through a waste output 265. In one embodiment, the waste may be about 10% to about 15% of feed stream. In another embodiment, the waste output 265 may be connected to the water recycling branch, such as an inlet of the sanitizing unit 280 for water recycling.

[0065] In one embodiment, the second filtration unit 260 further comprises a dosing unit 267 configured for keeping the abrasive slurries stabilized during processing in the second filtration unit 260. The dosing unit 267 may provide an additional stream of conditioning chemicals, such as KOH or NH_4OH 267 to the second filtration unit 260 either before, during or after filtration.

[0066] The pump 261 may be a diaphragm pump, a bellow pump, or a magnetically coupled or centrifugal pump. In one embodiment, the pump 261 may be a magnetically levitated pump with minimized impact on particles of the polishing slurry.

[0067] The filter media 262 may be a polymeric membranes or a ceramic membrane. The filter media 262 may be a spiral membrane, a tubular membrane, or a hollow fiber membrane.

[0068] The second filtration unit 260 may be a dead-end filtration or a cross-flow filtration.

[0069] In one embodiment, the slurry out of the second filtration unit 260 may be further filtered with a polishing filtration unit 290 before directed back to a local polishing slurry tank of the polishing station 201 or to the polishing slurry unit 202.

[0070] The permeate stream from the slurry output 264 maybe directed to the source 221 or the local tank 224.

[0071] The sanitization unit 280 is configured to reduce and control bacteria and or organic contamination from the fluid flowing therethrough, such as the water stream from the first filtration unit 250 and/or the second filtration unit 260. In one embodiment, the sanitization unit 280 may be an ultra violet (UV) unit configured to oxidize the organic species or kill the bacteria in the water stream.

[0072] In one embodiment, the sanitized water stream is directly flown back to the polishing station 201 for rinsing or other function. The sanitized water stream may be used in a first rinse, which has low requirement for the purity of the rinse water.

[0073] The treatment unit 270 is configured to purify and deionize the water stream. In one embodiment, the treatment unit 270 comprises a pump 271, a reverse osmosis membrane 273 and an ion-exchange resin 274, which may be regenerated continuously via ion selective membranes. The pump 271 is configured to pressurize incoming flow to the reverse osmosis membrane 273 and the ion-exchange resin 274. The output stream from an outlet 276 of the treatment unit 270 results in ultra purified water. The rejected stream from the treatment unit 270 exits through a waste output 278 as waste water. In one embodiment, the waste water is between about 5% to about 20% of feed stream. The purified water from the treatment unit 270 may be sent back to directly to the polishing station 201 or to mix with virgin ultra purified water from a rinse water inlet 232.

[0074] In one embodiment, the treatment unit 270 is a stand alone water recycling unit. In another embodiment, the treatment unit 270 belongs to a pre-existing factory water treatment system.

[0075] In one embodiment, the polishing system 200A further comprises a system controller 209. In one embodiment, the system controller 209 may control the multiple valves in the polishing system 200A to insure that recycled polishing slurry and/or rinse water is delivered or shut off at desired time. For simplicity of drawing, connections between the system controllers 209 and the components of the polishing system 200A are not shown.

[0076] The membranes used in each filtration/treatment unit 250, 260, 270 may be one of depth filter, a spiral membrane, a hollow fiber membrane, a tubular membrane, a plate and frame membrane operated in a dead-end filtration method, a back flushable filtration method, or in a cross flow filtration method.

[0077] In one embodiment, the system controller 209 is a stand alone independent controller for supplying and recycling polishing slurry. In another embodiment, the system controller 209 is integrated in to a CMP tool controller or implemented as a slave to the CMP tool control system.

[0078] In one embodiment, the system controller 209 is connected to at least one of the reservoir pumps 222, 225 and the filtration pumps 251, 261, 271. The system controller 209 is configured to monitor and/or adjust characteristics of polishing slurry according to process parameters of the at least one pump connected to the system controller 209. In one embodiment, the at least pump connected to the system controller 209 is a centrifugal pump, such as an electromagnetically levitated centrifugal pump.

[0079] Each of the pumps 222, 225, 251, 261, 271 may be one of a piston pump, a diaphragm pump, a bellow pump, a peristaltic pump, a magnetically levitated centrifugal pump, and a device for fluid transfer by vacuum draw. In one embodiment, each of the pumps 222, 225, 251, 261, 271 may be a centrifugal pump. Centrifugal pumps provide more controlled shear forces than pumps traditionally used for polishing slurry and/or polishing slurry waste transportation. The high sear forces reduce particle agglomeration drastically. In one embodiment, each of the pumps 222, 225, 251, 261, 271 is a magnetically levitated centrifugal pump. Magnetically levitated pumps add very few particles to the fluid, therefore, reducing particle contamination and damages to substrate being processed. An exemplary magnetically levitated centrifugal pump may made by Levitronix, Switzerland.

[0080] In one embodiment, connecting the system controller 209 to at least one magnetically levitated centrifugal pump enables return of real time rheology measurements and/or torque requirements on each slurry blending and recycling step. Rheology measurements and/ torque requirement can be obtained from pumps at one or more of the following positions: a position where recycled slurry is blended into virgin slurry, a position wherein slurry recycles back to a main reservoir, a position driving agglomeration filtration, a position transport past large reservoir, a

position transport past local reservoir, a position feeding polishing slurry to the polishing pad.

[0081] In one embodiment, magnetically levitated centrifugal pumps may be used to meter polishing slurry to local reservoir or to polishing pads.

[0082] In one embodiment, magnetically levitated centrifugal pumps may be used to afford appropriate levels of shear to the polishing slurry to positively impact rheology and minimize agglomeration.

[0083] In another embodiment, magnetically levitated centrifugal pumps may be used to inject and mix additives, to mix/combine various streams of virgin slurry, recycled polishing slurry, water, and/or chemical additive packages.

[0084] In another embodiment, other metrology sensors positioned adjacent pump housing may be used in addition to or incorporation of magnetically levitated centrifugal pumps.

[0085] In another embodiment, magnetically levitated centrifugal pumps may be used to monitor the back pressure of feed to the filtration and back wash media to (1) alert to plugging issues that would require filtration maintenance, (2) adjust pumping power to compensate for increased pressure drop until process is finished and shut down without interrupting process, and (3) initiate additional frequency, increased flow during cross flow or back wash steps, or optionally inject a cleaning agent bypass the current polishing slurry and ultra purified water recycle until the clean agent is purged as predetermined by the control software based on set point parameters.

[0086] In another embodiment, magnetically levitated centrifugal pumps may be used to provide feedback to the optional integrated controls system that manages the CMP water and slurry recycle system as a holistic set of unit operations along with the CMP tool and water plant rather than operating as a cluster of individually controlled circuits.

[0087] In another embodiment, magnetically levitated centrifugal pumps may be used to lower levels of contamination due to complete encapsulation of all moving parts with an inert polymer and the absence of metal or ceramic drive seals in the pumping system.

[0088] Figure 2B is a schematic view of a polishing system 200B with one embodiment of the present invention. The polishing system 200B is similar to the polishing system 200A of Figure 2A, except that the polishing system 200B has a separation unit 295 configured to separate polymeric particles or large particles, such as large silicon oxide particle, from the flow before recycling. In one embodiment, the separation unit 295 is a centrifugal separator. The separated particles may exit the system from an outlet 296.

[0089] Figure 2C is a schematic view of a polishing system 200C in accordance with one embodiment of the present invention. The polishing system 200C is similar to the polishing system 200B of Figure 2B except that the separator unit 295 is disposed down stream of the first filtration unit 250.

[0090] Figure 2D is a schematic view of a polishing system 200D in accordance with one embodiment of the present invention. The polishing system 200D is similar to the polishing system 200A of Figure 2D, except that the polishing system 200D use a diverter valve 294 to separate a water stream and a concentrations stream in stead of using the first filtration unit 250 as in the polishing system 200A.

[0091] The diverter valve 294 is connected to the collecting bin 216 of the polishing station 201. The collecting pin 216 may be stationary or movable. In one embodiment, the diverter valve 294 is configured to direct the content in the collecting bin 216 to the second filtration unit 260 for slurry recycling or to the treatment unit 270 for water recycling. In one embodiment, the diverter valve 294 is a three way valve. The status of the diverter valve 294 may be controlled by the system controller according to the process in the polishing station 201. For example, the diverter valve 294 may be adjusted to direct the flow to the second filtration unit 260 for slurry recycling when there is polishing slurry flowing from the

slurry nozzle 214 to the polishing station 201, and adjusted to direct the flow towards the treatment unit 270 during rinsing or there no slurry flow from upstream.

[0092] In one embodiment, the polishing system 200D comprises an optional separation unit 295 connected between the diverter valve 294 and the second filtration unit 260 to remove polymeric particles and/or large particle prior to the slurry recycling.

[0093] Figure 3 is a schematic chart of a polishing system 300 having a dedicated recycled slurry tank 324 and a dedicated virgin slurry tank 327 in accordance with another embodiment of the present invention. The polishing system 300 is similar to the polishing system 200 of Figure 2, except for the difference in the slurry unit 302.

[0094] The slurry unit 302 is configured to provide the polishing station 301 with virgin polishing slurry without mixing with the recycled slurry during polishing. This allows the polishing station 301 to perform multiple steps of polishing and use recycled polishing slurry only when process parameter permits.

[0095] Figure 4 is a schematic chart of a polishing system 400 having a dedicated recycled rinse water tank 432 in accordance with another embodiment of the present invention. The polishing system 400 is similar to the polishing system 200 of Figure 2, except for the difference in the rinse water unit 403.

[0096] The rinse water unit 403 comprises a recycled rinse water tank 432 to receive recycled rinse water and a virgin rinse water tank 431 without recycled rinse water. This allows the polishing station 301 to perform multiple rinsing and use recycled rinse water only when process parameter permits, such as during initial rinsing.

[0097] Figure 5 is a schematic chart of a polishing system 500 having multiple polishing stations 501a, 501b, 501c and a recycling unit 504 in accordance with another embodiment of the present invention. The polishing system 500 is configured to perform multiple polishing steps. Each polishing station 501a, 501b, 501c is dedicated to a polishing step with different polishing rate.

[0098] The polishing waste from the polishing stations 501a, 501b, 501c is gathered in a tank 519 and sent to the recycling unit 504, which is similar to the recycling units 104 and 204 described above.

[0099] A polishing source 502 provides recycled and virgin polishing slurry to the polishing stations 501a, 501b, 501c. In one embodiment, the recycled polishing slurry is only supplied to the polishing station that is configured to perform bulk polishing.

[0100] A rinse water source 503 is configured to selectively supply recycled rinse water and virgin rinse slurry to each polishing station.

[0101] Even though three polishing stations are shown in Figure 5, more or less polishing stations may be used according to process requirement.

[0102] While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

What is Claimed is:

1. An apparatus for recycling, comprising:

a separation unit comprising:

an inlet configured to receive a mixture of used polishing slurry, rinsing fluid, and polishing waste;

a water outlet configured to output a first stream for waste or water recycling; and

a slurry outlet configured to output a second stream for slurry recycling polishing; and

a slurry filtration unit comprising:

an inlet connected with the slurry outlet of the separation unit;

one or more filtering media configured for filtration or removal of ions and organics; and

a pump disposed upstream of the one or more filtering media and configured to press a stream of fluid through the one or more membranes.

a product outlet configured to output a stream of concentrated and recycled polishing slurry; and

a water outlet for water recycling or waste.

2. The apparatus of claim 1, wherein the separation unit comprises a diverter valve selectively connecting the inlet to the water outlet and the slurry outlet.

3. The apparatus of claim 2, wherein the pump of the slurry filtration unit is one of a piston pump, a diaphragm pump, a bellow pump, a peristaltic pump, a magnetically levitated centrifugal pump, and a device for fluid transfer by vacuum draw or pressurization.

4. The apparatus of claim 2, wherein the filtering media of the slurry filtration unit and the is a spiral membrane, a hollow fiber membrane, a tubular membrane, a plate and frame membrane operated in a dead-end filtration methods, a back

flushable filtration method, a cross flow filtration method, or a filtering media operated by depth filtration.

5. The apparatus of claim 2, wherein the slurry filtration unit comprises one or more of a microfiltration membrane, a nanofiltration membrane, and an ultrafiltration membrane, and the slurry filtration unit further comprises a backwash or cross flow clean capability.

6. The apparatus of claim 2, further comprising:

a UV (ultra violet) unit configured to reduce bacteria and organic contamination from fluid passing through, wherein the UV unit comprises:

an inlet connected with the water outlet of the separation unit and/or the water outlet of the slurry filtration unit; and

an outlet configured to output a stream of sanitized fluid; and

a water treatment unit configured to purify the sanitized fluid by removing trace of chemicals, wherein the treatment unit comprises:

an inlet connected to the outlet of the UV unit; and

an outlet configured to output a stream of purified fluid.

7. The apparatus of claim 2, further comprising a dosing unit connected to the slurry filtration unit for dosing conditioning chemicals during processing in the slurry filtration unit.

8. The apparatus of claim 1, wherein the separation unit is a filtration unit comprising:

a filtering media comprising:

a microfiltration membrane; and

a nanofiltration membrane disposed downstream to the microfiltration membrane; and

a pump disposed upstream of the microfiltration membrane and configured to press a stream of fluid through the filtering media, wherein the slurry outlet is disposed between the microfiltration membrane and the nanofiltration membrane,

and the water outlet of the separation unit is disposed downstream to the filtration media.

9. The apparatus of claim 1, further comprising a centrifugal separator configured to separate polymeric or large particles, wherein the centrifugal separator is disposed upstream or downstream of the separation unit.

10. A method for recycling polishing fluid, comprising:

generating a waste water stream and a concentration stream from a mixture of used polishing slurry, rinsing fluid and polishing waste;

filtering the concentration stream through a slurry filtration unit to separate a stream of reusable polishing slurry from a water stream;

flowing the stream of reusable polishing slurry to a polishing slurry source for a polishing station; and

flowing the water stream to a recycled water source.

11. The method of claim 10, wherein generating the waste water stream and the concentration stream comprises filtering the mixture through a filtering unit having multiple membranes or using a diverter valve to selectively direct the mixture to a slurry outlet and a water outlet.

12. The method of claim 11, further comprising measuring one or more characteristics of the reusable polishing slurry before flowing the stream of reusable polishing slurry to a polishing slurry source for a polishing station, wherein the one or more characteristics of the reusable polishing slurry comprises one or more of zeta potential, density, particle size, and particle distribution.

13. The method of claim 11, further comprising:

sanitizing the water stream to remove organic species from the water stream prior to flowing the water stream to the recycled water source;

purifying the sanitized water stream by a reversed osmosis process through a treatment unit; and

deionizing the purified water stream by one of a continuous electrodeionization (CEDI) process, ion exchange, or ion removal prior to flowing the water stream to the recycled water source.

14. The method of claim 13, further comprising

supplying rinsing water from the recycled water source to perform one or more initial rinses in a polishing station; and

supplying virgin ultra purified water to perform final rinses in the polishing station.

15. A polishing slurry unit for a polishing system, comprising:

a slurry reservoir having a reservoir pump, wherein the slurry reservoir is connected to a virgin slurry source;

a recycling unit comprising:

one or more filtration units comprising a filtration pump, wherein the recycling unit is connected to the slurry reservoir and is configured to receive used polishing slurry, pump the used slurry through the one or more filtration units and provide filtered polishing slurry to the slurry reservoir, and the filtration pump is a magnetically levitated centrifugal pump; and

a valve system configured to divert excessive polishing slurry during polishing to a slurry recycling unit and rinse fluid during rinse to a rinse water recycling unit; and

a controller connected to at least one of the reservoir pump and the filtration pumps, wherein the controller is configured to monitor and/or adjust characteristics of the polishing slurry according to process parameters of the at least one pump connected thereto.

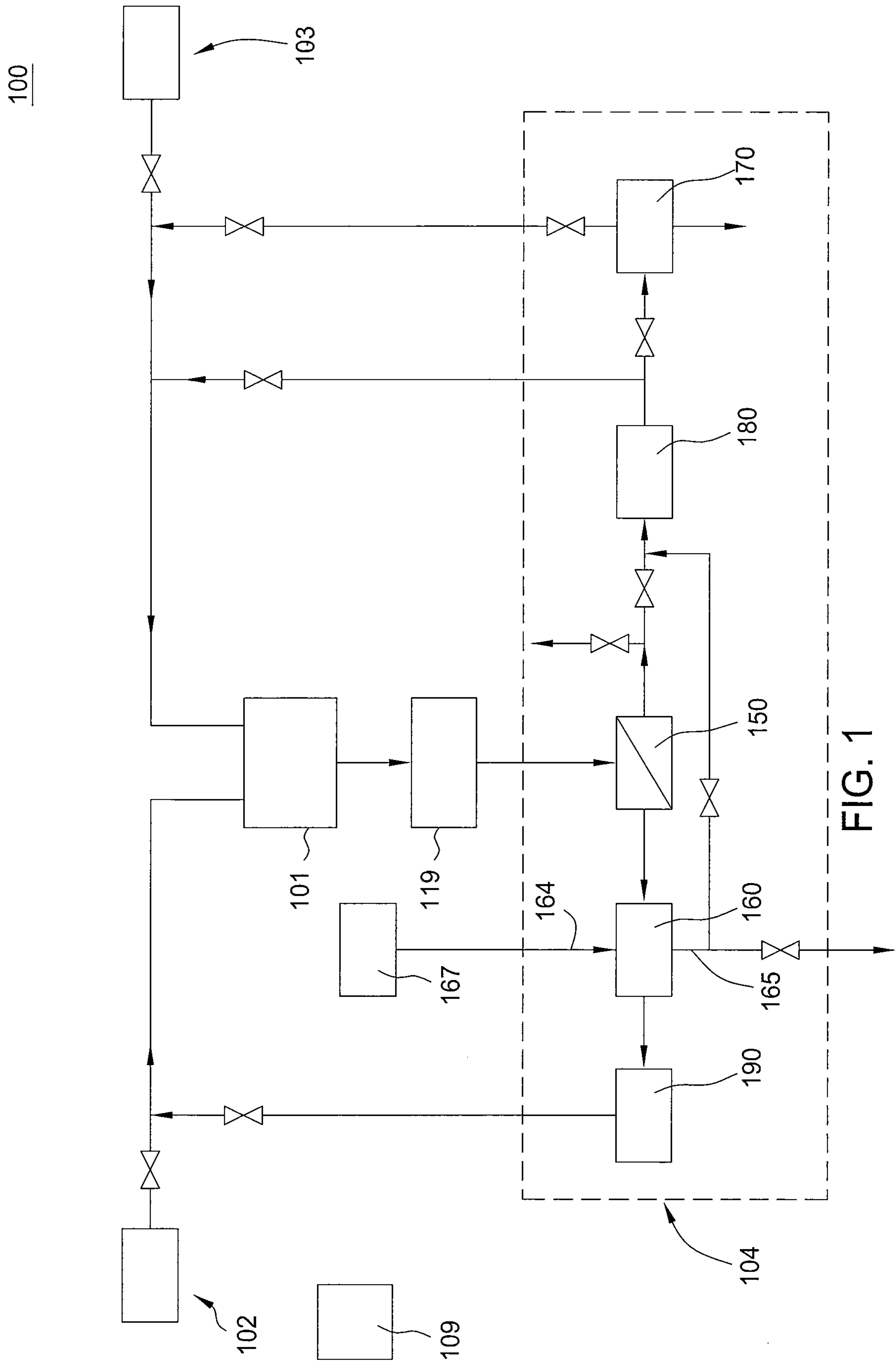

FIG. 1

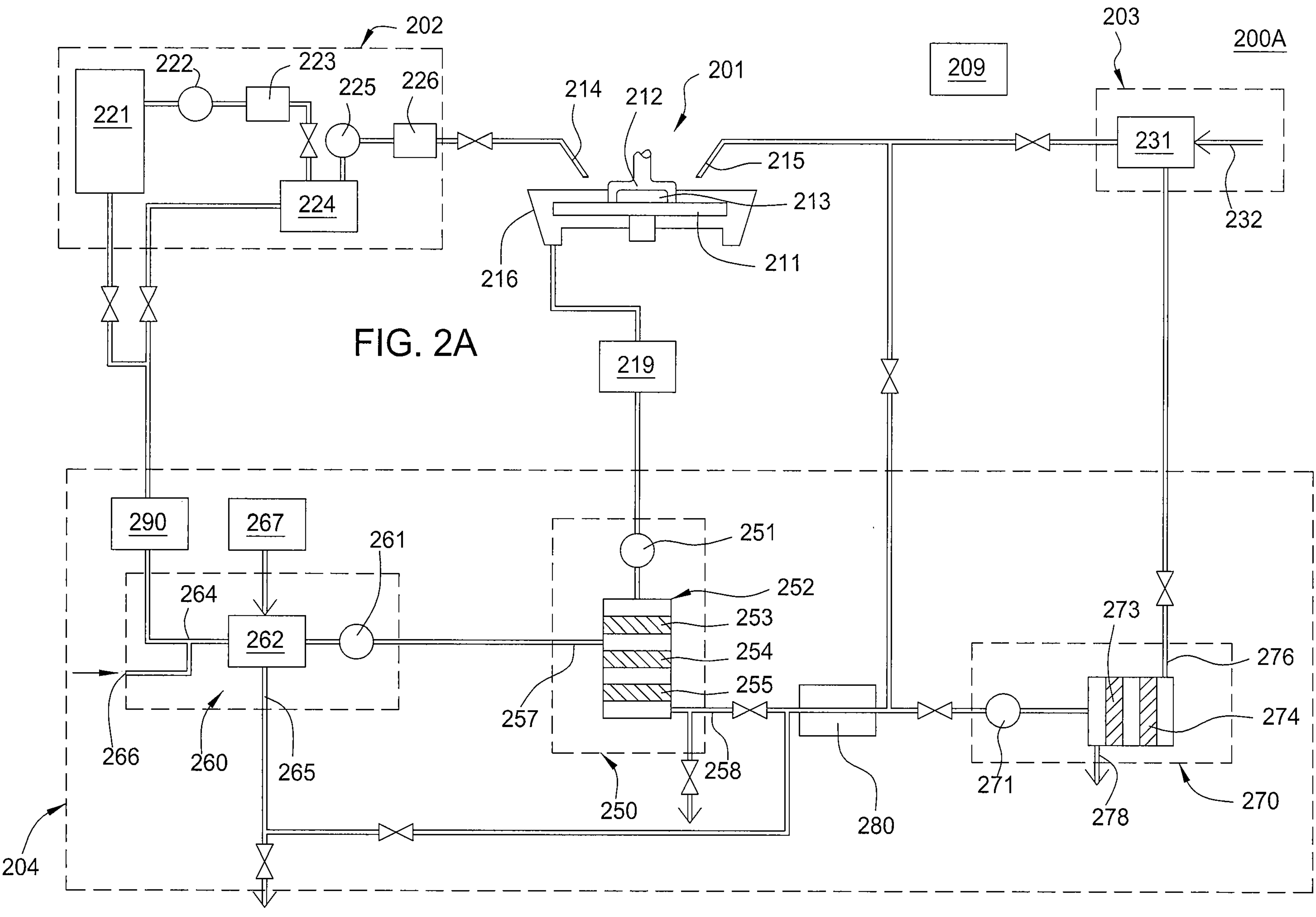

FIG. 2A

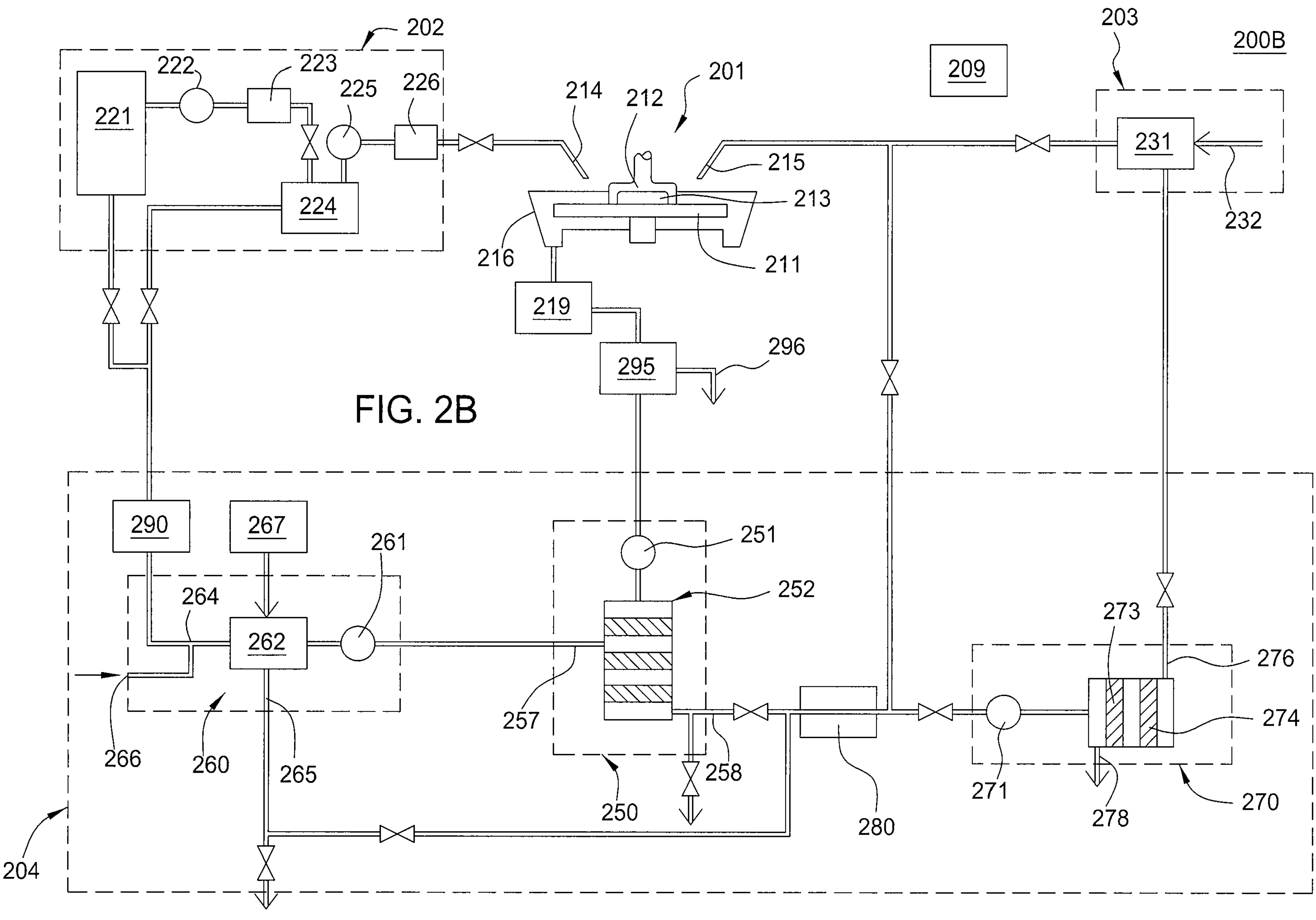

FIG. 2B

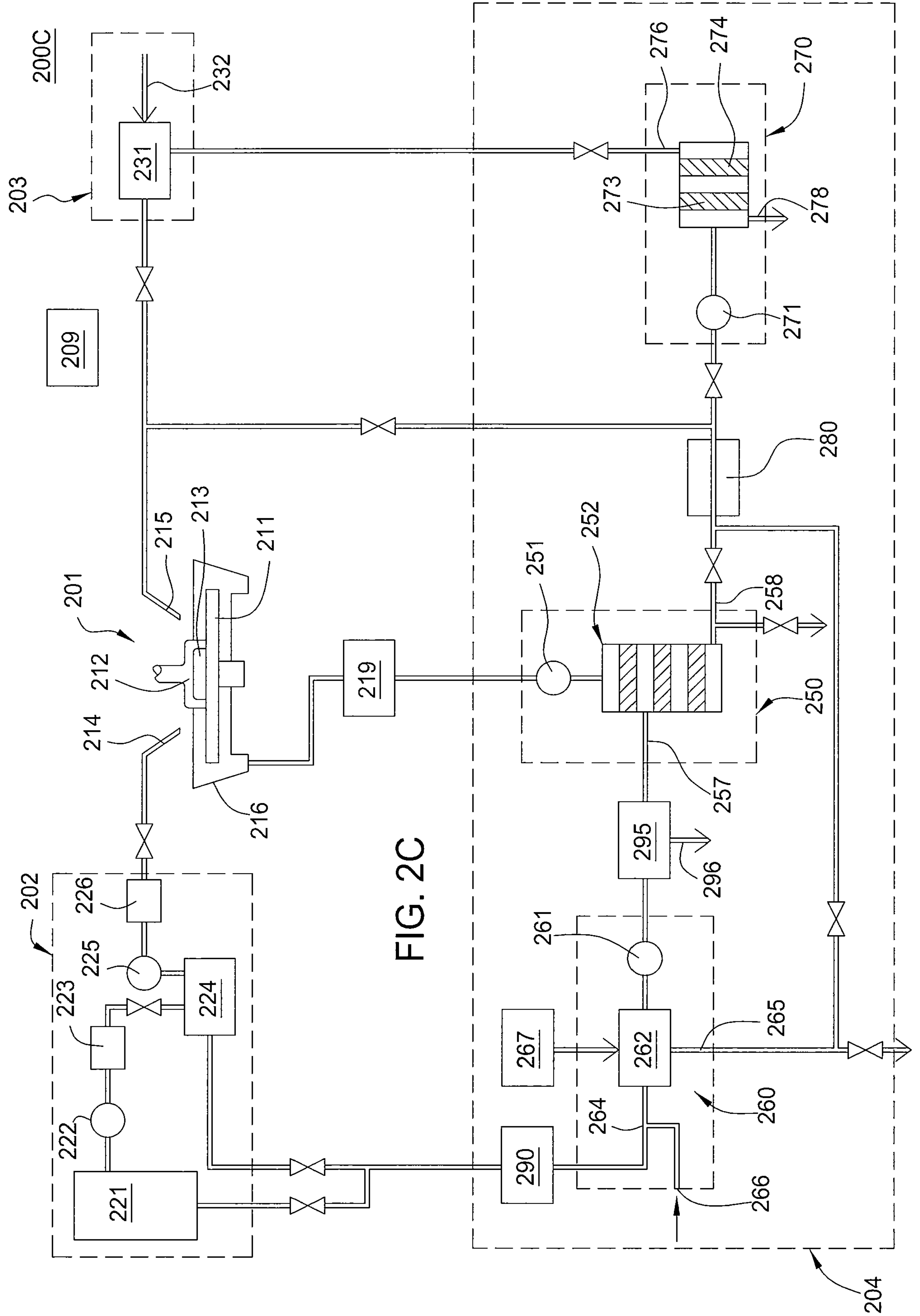

FIG. 2C

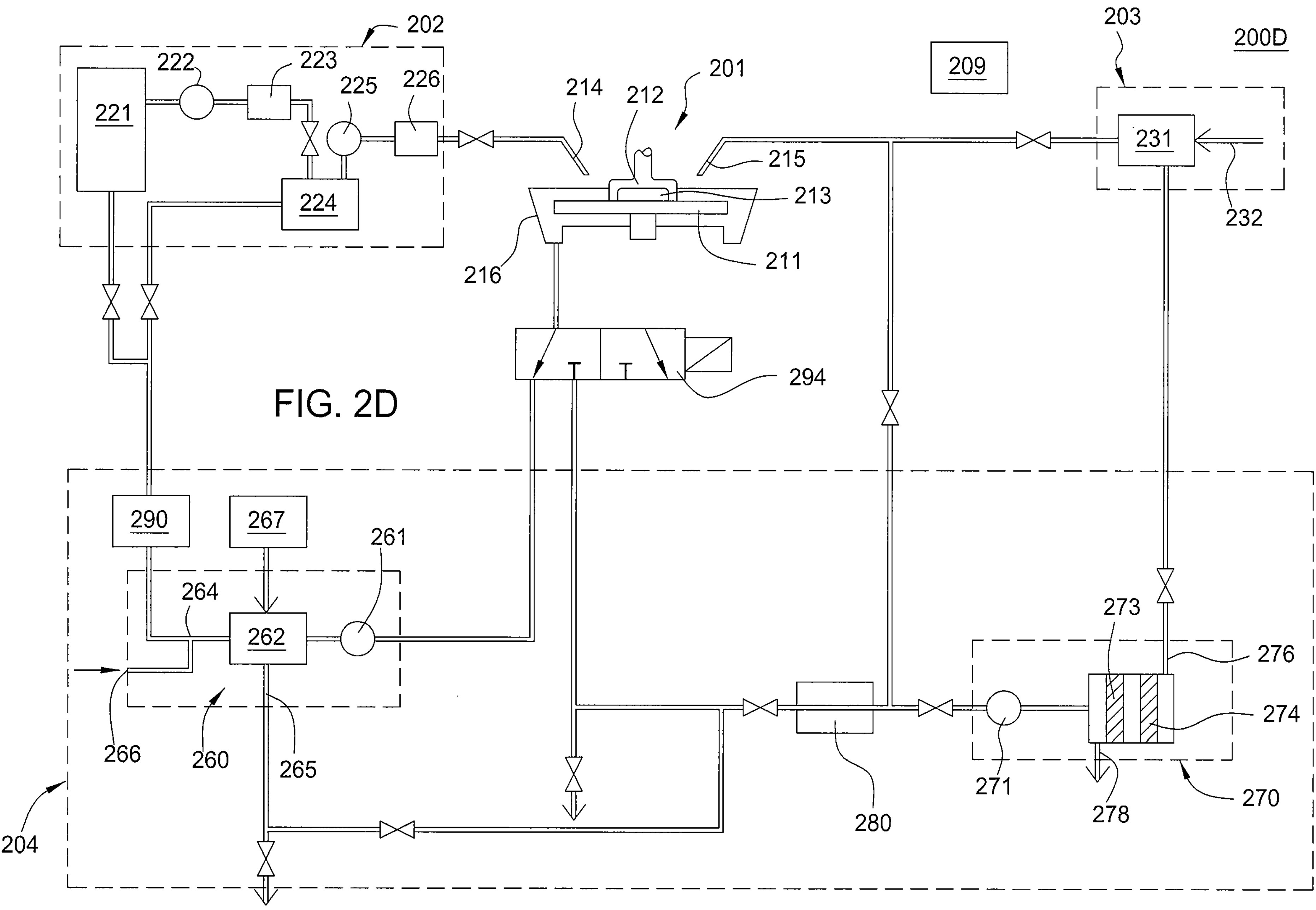

FIG. 2D

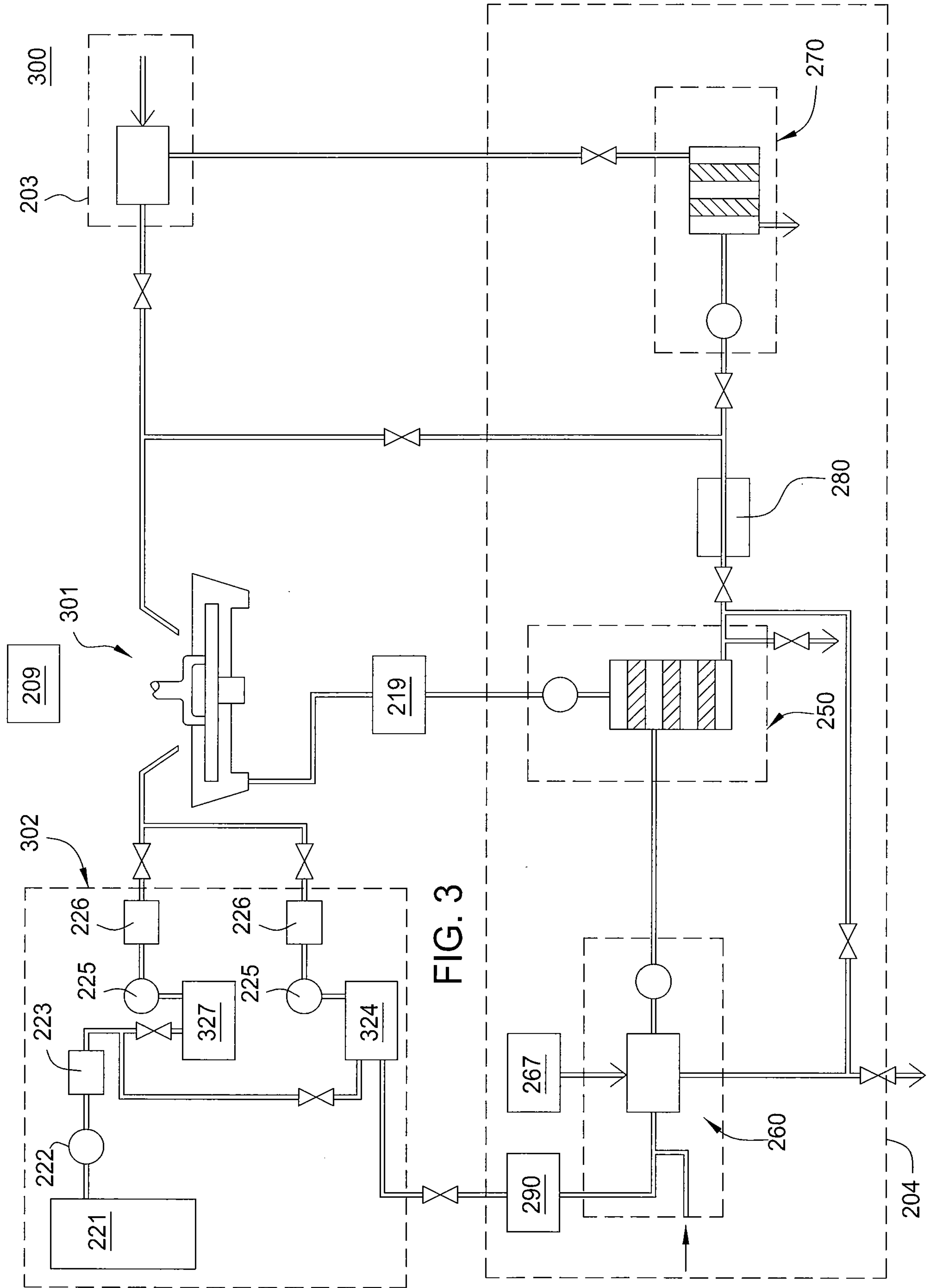

FIG. 3

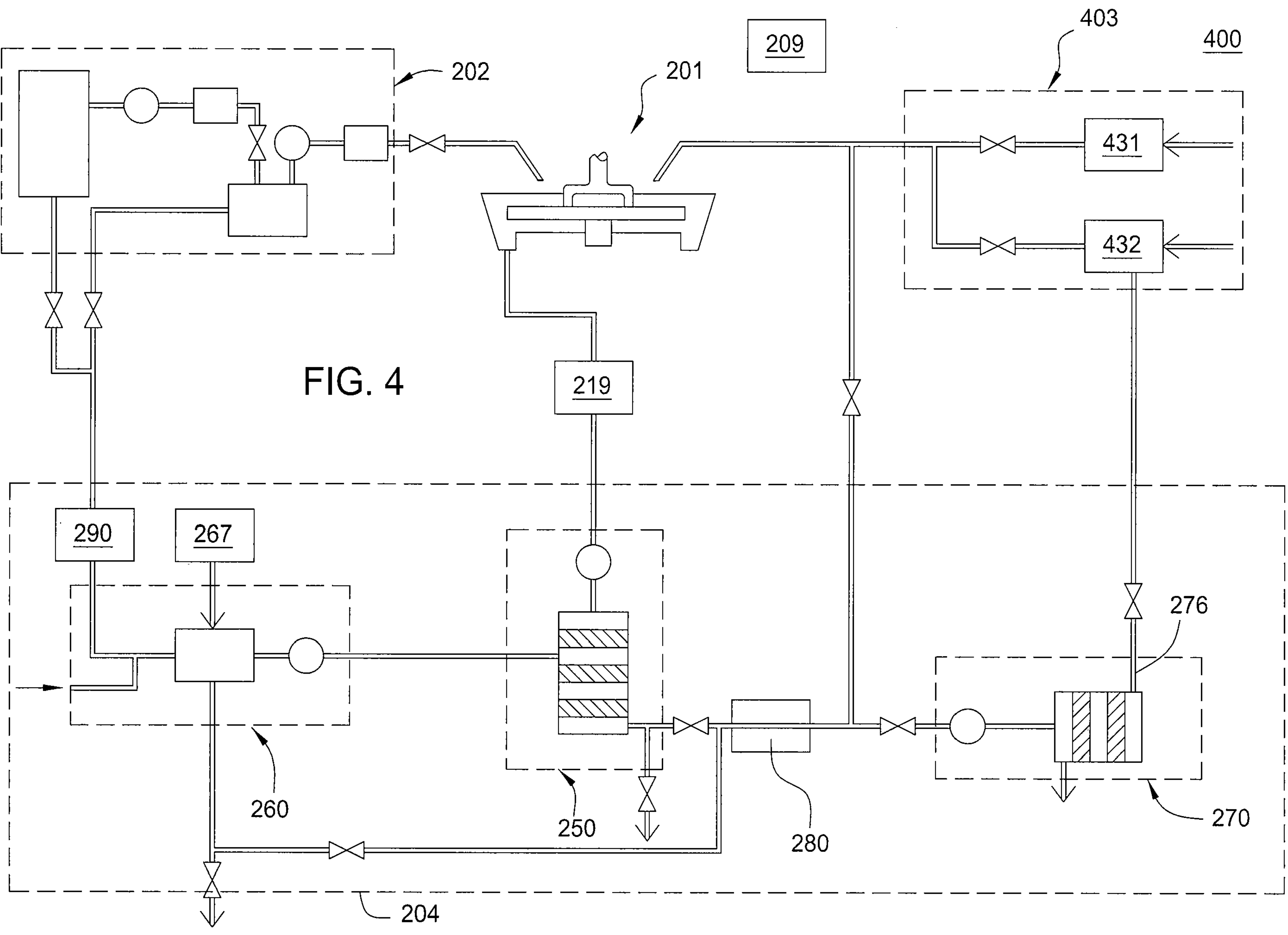

FIG. 4

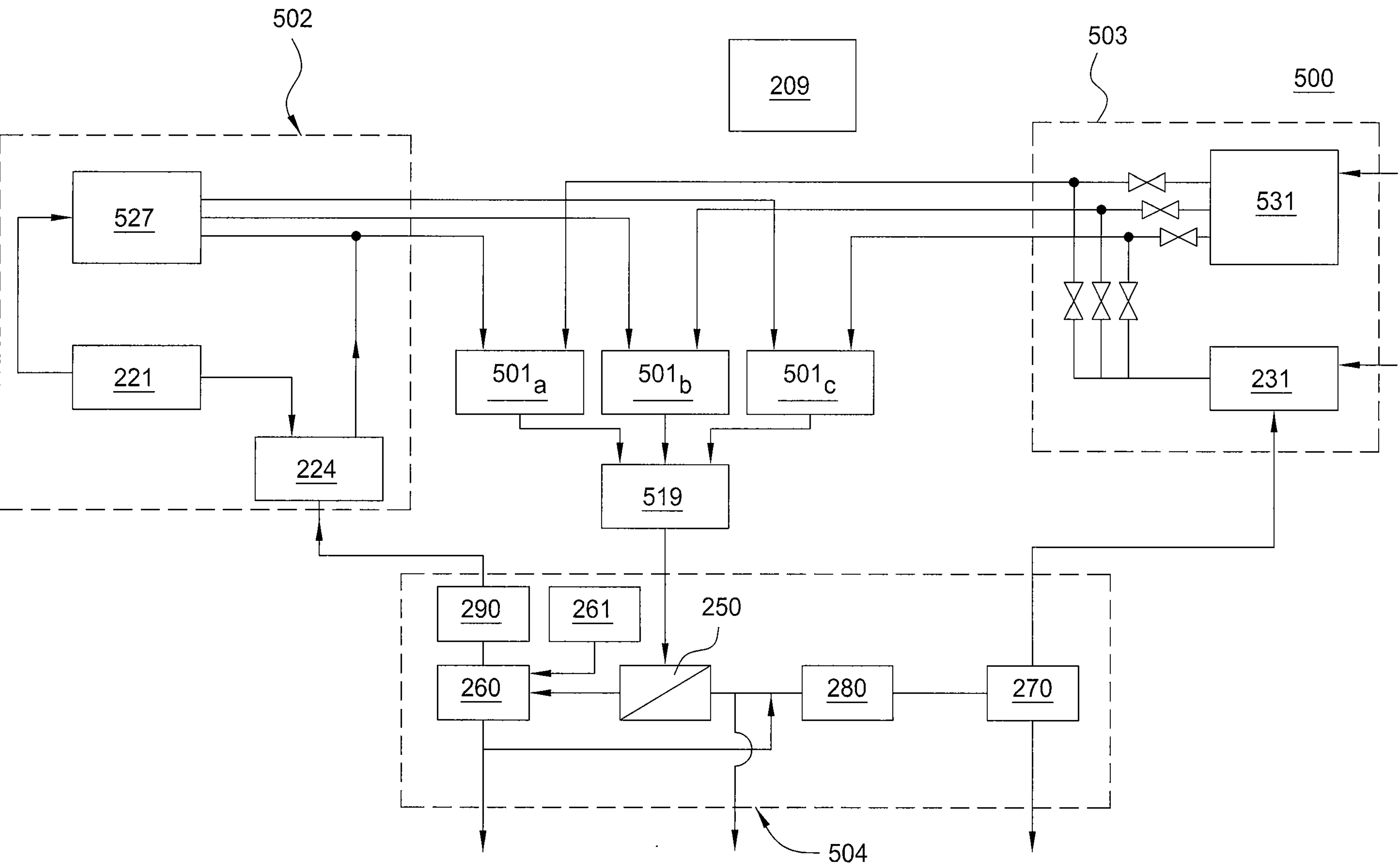

FIG. 5