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(54) NOX REMOVAL FOR CRYOGENIC CARBON CAPTURE FROM FLUE GAS

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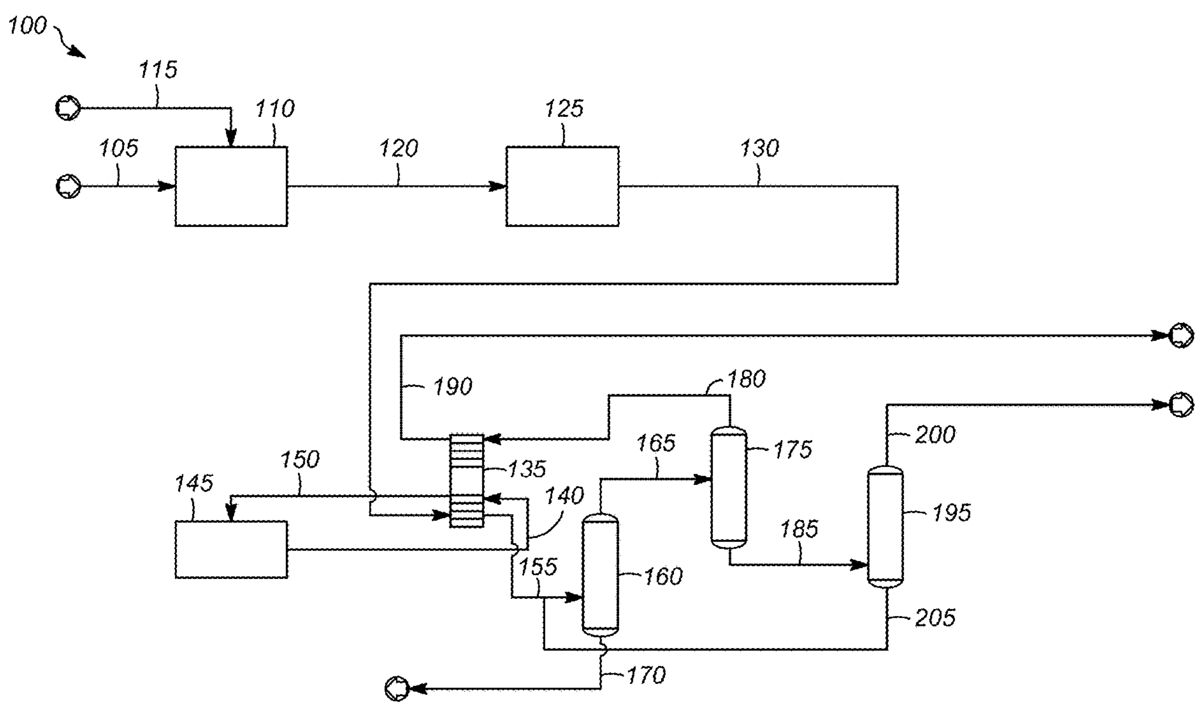
(57) **ABSTRACT**

Processes for recovery of carbon dioxide from a flue gas stream and removal of NOx compounds from the recovered carbon dioxide are described. The processes can recover gaseous, liquid, or supercritical carbon dioxide. The processes incorporate a NOx stripping column after the CO_2 fractionation column to remove NOx compounds formed in the CO_2 fractionation column.



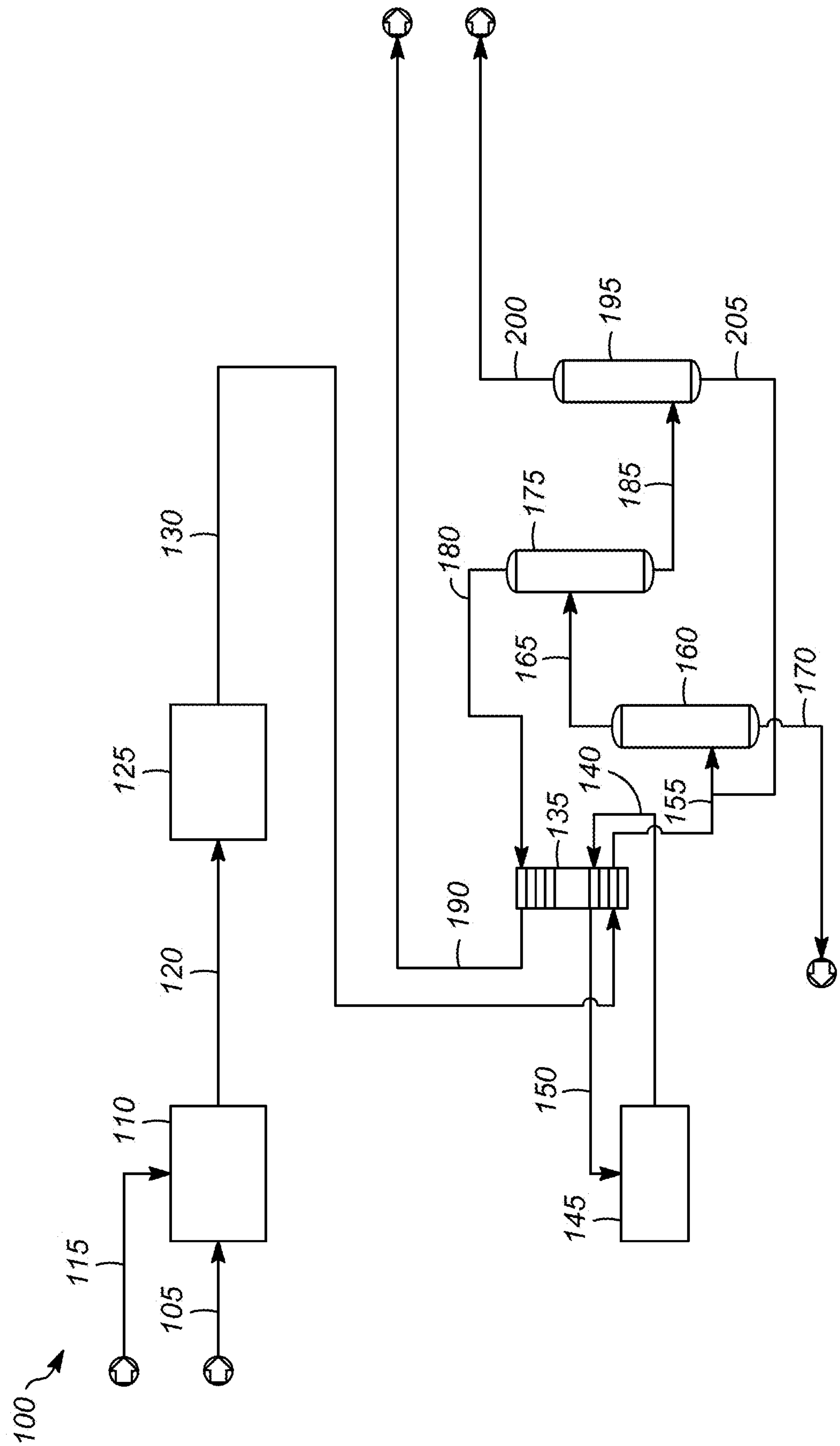

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FIG. 1

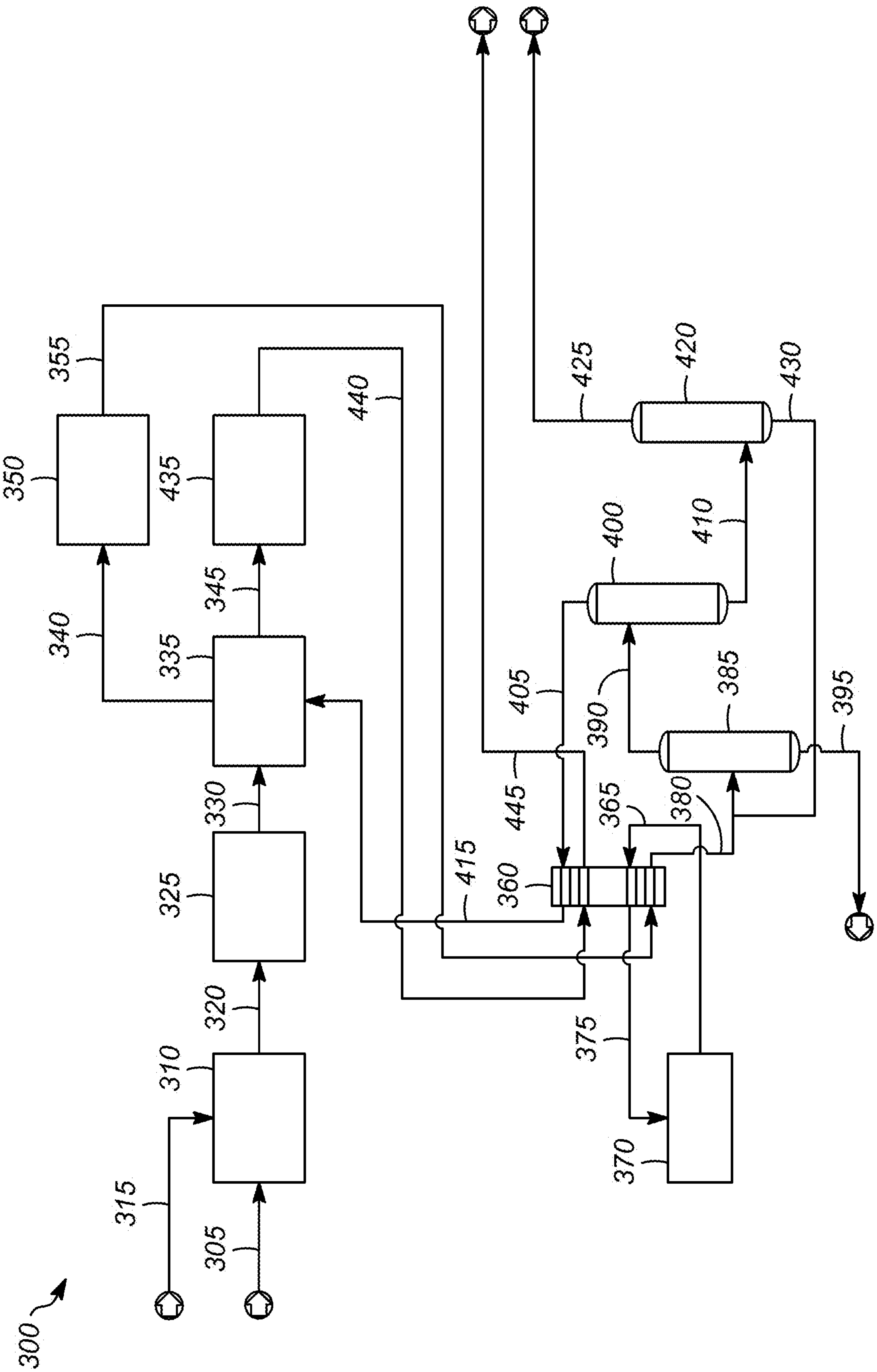
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FIG. 2

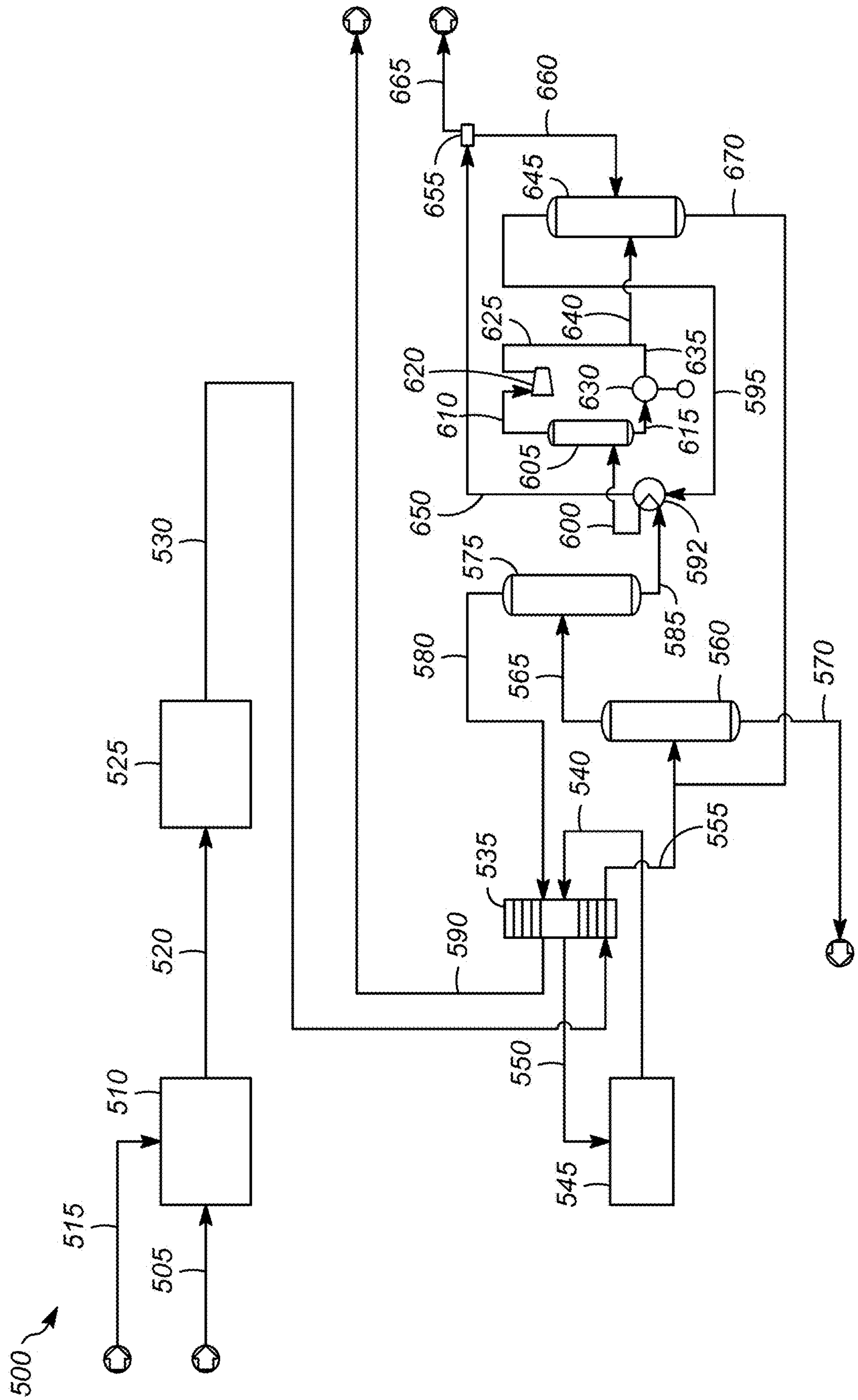
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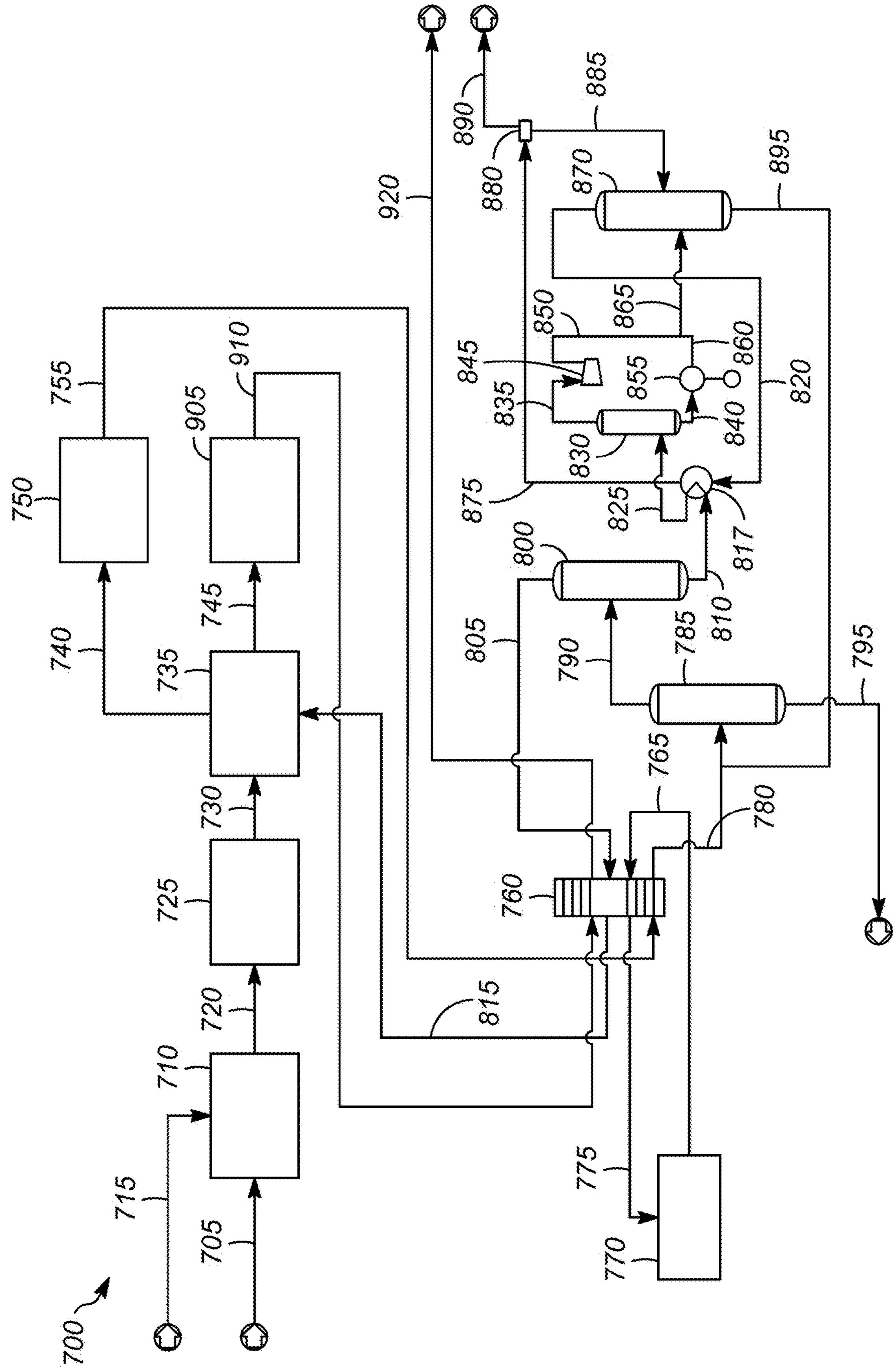
FIG. 3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800
805
810
815
817
820
825
830
835
840
845
850
855
860
865
870
875
880
885
890
895
905
910
920

FIG. 4

NOX REMOVAL FOR CRYOGENIC CARBON CAPTURE FROM FLUE GAS

RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent Application Ser. No. 63/554,456, filed on Feb. 16, 2024, the entirety of which is incorporated herein by reference.

BACKGROUND

[0002] CO_2 capture from flue gas is a key decarbonization strategy for various industries, such as steel, power and cement producers. Flue gas has contaminants that will cause the CO_2 product to be off specification (e.g., NO_2, SO_2, etc.) or cause issues in the PSA-cryogenic system such as mercury issues with brazed aluminum exchanger, etc. The CO_2 capture technologies need to handle the various contaminants in the feed while minimizing the corresponding energy usage and cost.

[0003] In cryogenic carbon capture from a flue gas or other source with NOx compounds present, separation of NOx from the captured CO_2 for sequestration or utilization is highly important. Under certain circumstances and for tight product specifications, the removal of NO_2 upstream of the cryogenic fractionation column may be inadequate to remove NO_2 to the levels required due to the continued reaction of NO and O_2 to form NO_2 in the cryogenic fractionation column and overhead system.

[0004] There is a need for processes which efficiently capture CO_2 in gas feed streams, as well as remove impurities from the feed streams and from the CO_2 product streams.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] FIG. **1** illustrates one embodiment of a process producing a vapor phase carbon dioxide product according to the present invention.

[0006] FIG. **2** illustrates another embodiment of process producing a vapor phase carbon dioxide product according to the present invention.

[0007] FIG. **3** illustrates one embodiment of process producing a liquid or supercritical phase carbon dioxide product according to the present invention.

[0008] FIG. **4** illustrates another embodiment of a process producing a liquid or supercritical phase carbon dioxide product according to the present invention.

DESCRIPTION

[0009] This present invention provides processes to remove additional NOx compounds after the cryogenic CO_2 fractionation column. It addresses situations where removing the NOx compounds upstream of the CO_2 fractionation column is inadequate to remove NOx compounds to the levels required to meet the product specification. This is done while avoiding significant CO_2 product losses. The processes incorporate non-catalytic means of removing NOx while maintaining a vapor, liquid, or supercritical CO_2 product. NOx compounds include one or more or NO, NO_2, N_2O, N_2O_3, and N_2O_4.

[0010] This invention is embodied in two ways, depending on the desired CO_2 product phase. For both implementations, a NOx stripper column is added to strip off NOx from the CO_2 product from the bottom of the cryogenic fractionation column.

[0011] The liquid/supercritical product utilizes a higher pressure NOx stripper column (one or more) to increase the boiling point of the CO_2. The increased pressure allows the CO_2 feed to the NOx stripper column to be used as a condensing medium, saving on refrigeration system load. A pump and compressor are placed after a flash drum to increase the pressure accordingly. The CO_2 is then stripped in a NOx stripper column with the feed on the bottom tray and a liquid product is taken on the overhead to be sent to cooling or additional pumping as needed. The bottom stream is rich in NOx and is sent to the upstream NOx removal zone or a flue gas generating unit.

[0012] The vapor phase product implementation uses the same scheme, but the CO_2 feed from the CO_2 fractionation column (one or more) is sent directly to the NOx stripper column without an increase in pressure. The refrigeration system is used to condense the overhead, and a vapor only product is taken from the top. The bottoms stream is treated in the same manner as the liquid phase case.

[0013] In both cases, the reboiler is heated using either recirculating quench water from the quench column or warm refrigerant from the compressor discharge in the refrigeration loop.

[0014] Additionally, this process allows for low loss of CO_2 by recycling the significant amount of CO_2 purged with NOx to the NOx removal zone in the process where greater purification can take place at lower energy usage levels.

[0015] FIG. **1** illustrates one embodiment of a process **100** for producing a carbon dioxide vapor stream with reduced level of NOx compounds. A flue gas (or other gas) feed stream **105** comprises carbon dioxide, one or more NOx compounds, and one or more of nitrogen, oxygen, water and argon. The flue gas feed stream **105** may be sent to a quench column **110** where it is cooled with quench stream **115** in a quench column. The quench stream **115** can be any suitable quench stream as known to those of skill in the art. Suitable quench streams include, but are not limited to, water, caustic (to remove acidic impurities such as HCl and SO_2), or combinations thereof.

[0016] The quenched flue gas stream **120** is sent to a flue gas compressor and drier **125** where it is compressed and dried to form compressed flue gas stream **130**. The quenched flue gas stream **120** is compressed from a pressure in a range of 75 to 150 kPa to a pressure in the range of 2500 to 5000 kPa for the compressed flue gas stream **130**.

[0017] The compressed flue gas stream **130** is sent to the main heat exchanger **135** where it is cooled with a chilled refrigerant stream **140** from refrigeration system **145**. The warmed refrigerant stream **150** is returned to the refrigeration system **145**.

[0018] The cooled compressed flue gas stream **155** is sent to the NOx removal zone **160** comprising one or more NOx removal columns where the majority of the NOx compounds other than NO and N_2O are removed from the cooled compressed flue gas stream **155**. The reduced contaminant stream **165** comprises carbon dioxide and a reduced level of NOx compounds compared to the cooled compressed flue gas stream **155** entering the NOx removal zone **160**.

[0019] The NOx-enriched bottom stream **170** is highly concentrated in NOx compounds, typically 25-75 percent by mole. The NOx-enriched bottom stream **170** may be sent for treatment including, but not limited to, nitric acid production or fertilizer production. Alternatively, it may be combined with stream **190** and be discharged to the atmosphere, sent to further contaminant treating or a pressure swing adsorption unit.

[0020] The reduced contaminant stream **165** is sent to the CO_2 fractionation column **175** where it is separated into an overhead gas stream **180** comprising light components including, but not limited to, one or more of N_2, O_2, or NO, and a carbon dioxide-enriched bottom stream **185**.

[0021] The overhead gas stream **180** may be warmed in the main heat exchanger **135**, and the warmed overhead gas stream **190** may be sent to atmosphere, further flue gas contaminant treating, or a pressure swing adsorption unit.

[0022] During fractionation in the CO_2 fractionation column **175**, a portion of the NO may be converted to NO_2, which leaves with the carbon dioxide-enriched bottom stream **185**.

[0023] The carbon dioxide-enriched bottom stream **185** from the CO_2 fractionation column **175** is sent to the NOx stripping column **195** where the remaining NOx compounds are stripped from the carbon dioxide-enriched bottom stream **185**. The stripping column overhead stream **200** comprises gaseous carbon dioxide and is depleted of NOx compounds. It is the gaseous carbon dioxide product stream. In some situations, it can be used to cool the upstream process if the temperature specification for the gaseous carbon dioxide product is sufficiently high.

[0024] The stripping column bottom stream **205**, which is enriched in NOx compounds, is typically 0.1-5 mole percent NOx, and more often 0.2-1 mole % NOx. This stream may be recycled to the NOx removal zone **160** for concentration of the NOx and recovery of the CO_2, or to a flue gas generation unit (not shown) for destruction of the NOx and recovery of the CO_2.

[0025] FIG. **2** illustrates a second embodiment of a process **300** for producing a carbon dioxide vapor stream with reduced level of NOx compound. The flue gas (or other gas) feed stream **305** comprises carbon dioxide, one or more NOx compounds, and one or more of nitrogen, oxygen, water and argon. The flue gas feed stream **305** may be sent to a quench column **310** where it is cooled with quench stream **315**, as described above.

[0026] The quenched flue gas stream **320** is sent to a flue gas compressor **325** where it is compressed from a pressure in a range of 75 to 150 kPa to a pressure in the range of 800 to 2500 kPa.

[0027] The compressed flue gas stream **330** is sent to a CO_2 pressure swing adsorption (PSA) unit **335**, which can be a standard CO_2 PSA unit or a CO_2 vacuum pressure swing adsorption (VPSA) unit. The compressed flue gas stream **330** is separated into a CO_2-enriched stream **340** and an off gas stream **345**.

[0028] The CO_2-enriched stream **340** is sent to a compressor and dehydration unit **350** where it is compressed to a pressure in the range of 2500 to 5000 kPa and dried forming dried CO_2-enriched stream **355**. The dehydration unit may comprise any suitable dehydration unit including, but not limited to, a triethylene glycol unit, an activated alumina or a silica gel or a molecular sieve (zeolite A or X) or a combination thereof-based temperature swing adsorption process.

[0029] The dried CO_2-enriched stream **355** is sent to the main heat exchanger **360** where it is cooled with a chilled refrigerant stream **365** from refrigeration system **370** forming cooled CO_2-enriched stream **380**. The warmed refrigerant stream **375** is returned to the refrigeration system **370**.

[0030] The cooled CO_2-enriched stream **380** is sent to the NOx removal zone **385** comprising one or more NOx removal columns where the majority of the NOx compounds other than NO and N_2O are removed from the cooled CO_2-enriched stream **380**. The reduced contaminant stream **390** comprises carbon dioxide and a reduced level of NOx compounds compared to the cooled CO_2-enriched stream **380** entering the NOx removal zone **385**.

[0031] The NOx-enriched bottom stream **395** is highly concentrated in NOx compounds, typically 25-75 percent by mole. The NOx-enriched bottom stream **395** may be sent for treatment including, but not limited to, nitric acid production or fertilizer production. Alternatively, it may be combined with stream **445** and be discharged to the atmosphere, sent to further contaminant treating or a pressure swing adsorption unit.

[0032] The reduced contaminant stream **390** is sent to the CO_2 fractionation column **400** where it is separated into an overhead gas stream **405** comprising light components including, but not limited to, one or more of N_2, O_2, or NO, and a carbon dioxide-enriched bottom stream **410**.

[0033] The overhead gas stream **405** may be warmed in the main heat exchanger **360**, and the warmed overhead gas stream **415** may be sent to the PSA unit **335**. Alternatively, it could be sent to atmosphere, or further flue gas contaminant treating.

[0034] As discussed above, during fractionation in the CO_2 fractionation column **400**, a portion of the NO may be converted to NO_2, which leaves with the carbon dioxide-enriched bottom stream **410**.

[0035] The carbon dioxide-enriched bottom stream **410** from the CO_2 fractionation column **400** is sent to the NOx stripping column **420** where the remaining NOx compounds are stripped from the carbon dioxide-enriched bottom stream **410**. The stripping column overhead stream **425** comprises gaseous carbon dioxide and is depleted of NOx compounds. It is the gaseous carbon dioxide product stream. As discussed above, it can be used to cool the upstream process if the temperature specification for the gaseous carbon dioxide product is sufficiently high.

[0036] The stripping column bottom stream **430**, which is enriched in NOx compounds, is typically 0.1-5 mole percent NOx, and more often 0.2-1 mole % NOx. This stream may be recycled to the NOx removal zone **385** for concentration of the NOx and recovery of the CO_2, or to a flue gas generation unit (not shown) for destruction of the NOx and recovery of the CO_2.

[0037] The off gas stream **345** from the PSA unit **335** is sent to a flue gas expander **435**, and the cooled expanded flue gas stream **440** is sent to the main heat exchanger **360**. The warmed expanded flue gas stream **445** can be further treated and/or released to the atmosphere.

[0038] FIG. **3** illustrates one embodiment of a process **500** for producing a liquid carbon dioxide stream with reduced level of NOx compounds. A flue gas (or other gas) feed stream **505** comprises carbon dioxide, one or more NOx compounds, and one or more of nitrogen, oxygen, water and argon. The flue gas feed stream **505** may be sent to a quench column **510** where it is cooled with quench stream **515** in a quench column. The quench stream **515** can be any suitable quench stream as known to those of skill in the art. Suitable quench streams include, but are not limited to, water, caustic, or combinations thereof.

[0039] The quenched flue gas stream **520** is sent to a flue gas compressor and drier **525** where it is compressed and dried to form compressed flue gas stream **530**. The quenched flue gas stream **520** is compressed from a pressure in a range of 75 to 150 kPa to a pressure in the range of 2500 to 5000 kPa for the compressed flue gas stream **530**.

[0040] The compressed flue gas stream **530** is sent to the main heat exchanger **535** where it is cooled with a chilled refrigerant stream **540** from refrigeration system **545**. The warmed refrigerant stream **550** is returned to the refrigeration system **545**.

[0041] The cooled compressed flue gas stream **555** is sent to the NOx removal zone **560** comprising one or more NOx removal columns where the majority of the NOx compounds other than NO and N_2O are removed from the cooled compressed flue gas stream **555**. The reduced contaminant stream **565** comprises carbon dioxide and a reduced level of NOx compounds compared to the cooled compressed flue gas stream **555** entering the NOx removal zone **560**.

[0042] The NOx-enriched bottom stream **570** is highly concentrated in NOx compounds, typically 25-75 percent by mole. The NOx-enriched bottom stream **570** may be sent for treatment including, but not limited to, nitric acid production or fertilizer production. Alternatively, it may be combined with stream **590** and be discharged to the atmosphere, sent to further contaminant treating or a pressure swing adsorption unit.

[0043] The reduced contaminant stream **565** is sent to the CO_2 fractionation column **575** where it is separated into an overhead gas stream **580** comprising light components including, but not limited to, one or more of N_2, O_2, or NO, and a carbon dioxide-enriched bottom stream **585**.

[0044] The overhead gas stream **580** may be warmed in the main heat exchanger **535**, and the warmed overhead gas stream **590** may be sent to atmosphere, further flue gas contaminant treating, or a pressure swing adsorption unit.

[0045] During fractionation in the CO_2 fractionation column **575**, a portion of the NO may be converted to NO_2, which leaves with the carbon dioxide-enriched bottom stream **585**.

[0046] The carbon dioxide-enriched bottom stream **585** from the CO_2 fractionation column **575** is warmed in heat exchanger **592** with the stripping column overhead stream **595**. The warmed carbon dioxide-enriched bottom stream **600** is sent to flash drum **605** where it is separated into carbon dioxide-enriched bottom vapor stream **610** and carbon dioxide-enriched bottom liquid stream **615**.

[0047] The carbon dioxide-enriched bottom vapor stream **610** is compressed in compressor **620** forming compressed carbon dioxide-enriched bottom vapor stream **625**. The carbon dioxide-enriched bottom liquid stream **615** is pumped in pump **630** forming pumped carbon dioxide-enriched bottom liquid stream **635**.

[0048] The compressed carbon dioxide-enriched bottom vapor stream **625** and the pumped carbon dioxide-enriched bottom liquid stream **635** can be combined, and the combined carbon dioxide-enriched bottom stream **640** is sent to the NOx stripping column **645**. Alternatively, the compressed carbon dioxide-enriched bottom vapor stream **625** and the pumped carbon dioxide-enriched bottom liquid stream **635** can be sent to the NOx stripping column **645** separately.

[0049] The stripping column overhead stream **595** is heat exchanged with the carbon dioxide-enriched bottom stream **585** from the CO_2 fractionation column **575**. The cooled stripping column overhead **650** is sent to overhead receiver **655**.

[0050] The liquid stripping column overhead from the overhead receiver **655** can be split into first portion **660**, which can be refluxed to the NOx stripping column **645**, and a second portion **665**, which is the carbon dioxide product stream. It can be further chilled, or it can be pumped to form supercritical carbon dioxide.

[0051] The stripping column bottom stream **670**, which is enriched in NOx compounds, is typically 0.1-5 mole percent NOx, and more often 0.2-1 mole % NOx. This stream may be recycled to the NOx removal zone **560** for concentration of the NOx and recovery of the CO_2, or to a flue gas generation unit (not shown) for destruction of the NOx and recovery of the CO_2.

[0052] FIG. **4** illustrates a second embodiment of a process **700** for producing a carbon dioxide liquid stream with reduced level of NOx compound. The flue gas (or other gas) feed stream **705** comprises carbon dioxide, one or more NOx compounds, and one or more of nitrogen, oxygen, water and argon. The flue gas feed stream **705** may be sent to a quench column **710** where it is cooled with quench stream **715**, as described above.

[0053] The quenched flue gas stream **720** is sent to a flue gas compressor **725** where it is compressed from a pressure in a range of 75 to 150 kPa to a pressure in the range of 800 to 2500 kPa.

[0054] The compressed flue gas stream **730** is sent to a CO_2 pressure swing adsorption (PSA) unit **735**, which can be a standard CO_2 PSA unit or a CO_2 vacuum pressure swing adsorption (VPSA) unit, as discussed above. The compressed flue gas stream **730** is separated into a CO_2-enriched stream **740** and an off gas stream **745**.

[0055] The CO_2-enriched stream **740** is sent to a compressor and dehydration unit **750** where it is compressed to a pressure in the range of 2500 to 5000 kPa and dried forming dried CO_2-enriched stream **755**. Suitable dehydration units are described above.

[0056] The dried CO_2-enriched stream **755** is sent to the main heat exchanger **760** where it is cooled with a chilled refrigerant stream **765** from refrigeration system **770** forming cooled CO_2-enriched stream **780**. The warmed refrigerant stream **775** is returned to the refrigeration system **770**.

[0057] The cooled CO_2-enriched stream **780** is sent to the NOx removal zone **785** comprising one or more NOx removal columns where the majority of the NOx compounds other than NO and N_2O are removed. The reduced contaminant stream **790** comprises carbon dioxide and a reduced level of NOx compounds compared to the cooled CO_2-enriched stream **780** entering the NOx removal zone **785**.

[0058] The NOx-enriched bottom stream **795** is highly concentrated in NOx compounds, typically 25-75 percent by mole. The NOx-enriched bottom stream **795** may be sent for treatment including, but not limited to, nitric acid production or fertilizer production. Alternatively, it may be combined with stream and sent to further contaminant treating or a pressure swing adsorption unit.

[0059] The reduced contaminant stream **790** is sent to the CO_2 fractionation column **800** where it is separated into an overhead gas stream **805** comprising light components including, but not limited to, one or more of N_2, O_2, or NO, and a carbon dioxide-enriched bottom stream **810**.

[0060] The overhead gas stream **805** may be warmed in the main heat exchanger **760**, and the warmed overhead gas stream **815** may be sent to the PSA unit **735**. Alternatively, it could be sent to atmosphere, or further flue gas contaminant treatment.

[0061] As discussed above, during fractionation in the CO_2 fractionation column **800**, a portion of the NO may be converted to NO_2, which leaves with the carbon dioxide-enriched bottom stream **810**.

[0062] The carbon dioxide-enriched bottom stream **810** from the CO_2 fractionation column **800** is warmed in heat exchanger **817** with the stripping column overhead stream **820**. The warmed carbon dioxide-enriched bottom stream **825** is sent to flash drum **830** where it is separated into carbon dioxide-enriched bottom vapor stream **835** and carbon dioxide-enriched bottom liquid stream **840**.

[0063] The carbon dioxide-enriched bottom vapor stream **835** is compressed in compressor **845** forming compressed carbon dioxide-enriched bottom vapor stream **850**. The carbon dioxide-enriched bottom liquid stream **840** is pumped in pump **855** forming pumped carbon dioxide-enriched bottom liquid stream **860**.

[0064] The compressed carbon dioxide-enriched bottom vapor stream **850** and the pumped carbon dioxide-enriched bottom liquid stream **860** can be combined, and the combined carbon dioxide-enriched bottom stream **865** is sent to the NOx stripping column **870**. Alternatively, the compressed carbon dioxide-enriched bottom vapor stream **850** and the pumped carbon dioxide-enriched bottom liquid stream **860** can be sent to the NOx stripping column **870** separately.

[0065] The stripping column overhead stream **820** is heat exchanged with the carbon dioxide-enriched bottom stream **810** from the CO_2 fractionation column **800**. The cooled stripping column overhead **875** is sent to overhead receiver **880**.

[0066] The liquid stripping column overhead from the overhead receiver **880** can be split into first portion **885**, which can be refluxed to the NOx stripping column **870**, and a second portion **890**, which is the liquid carbon dioxide product stream. It can be further chilled, or it can be pumped to form supercritical carbon dioxide.

[0067] The stripping column bottom stream **895**, which is enriched in NOx compounds, is typically 0.1-5 mole percent NOx, and more often 0.2-1 mole % NOx. This stream may be recycled to the NOx removal zone **785** for concentration of the NOx and recovery of the CO_2, or to a flue gas generation unit (not shown) for destruction of the NOx and recovery of the CO_2.

[0068] The off gas stream **745** from the PSA unit **735** is sent to a flue gas expander **905**, and the cooled expanded flue gas stream **910** is sent to the main heat exchanger **760**. The warmed expanded flue gas stream **920** can be further treated and/or released to the atmosphere.

SPECIFIC EMBODIMENTS

[0069] While the following is described in conjunction with specific embodiments, it will be understood that this description is intended to illustrate and not limit the scope of the preceding description and the appended claims.

[0070] A first embodiment of the invention is a process for recovery of carbon dioxide from a flue gas stream and removal of NOx compounds from the recovered carbon dioxide comprising compressing a flue gas feed stream forming a compressed flue gas stream, wherein the flue gas feed stream comprises carbon dioxide and a NOx compound; removing at least a portion of the NOx compound from the compressed flue gas feed stream in a NOx removal zone comprising a NOx removal column forming a reduced contaminant stream wherein a level of the NOx compound in the reduced contaminant stream is less than a level of the NOx compound in the compressed flue gas stream; fractionating the reduced contaminant stream in a CO_2 fractionation column into a carbon dioxide-enriched bottom stream comprising carbon dioxide and the NOx compound and an overhead gas stream enriched in light components comprising one or more of N_2, O_2, N_2O or NO; stripping at least a portion of the NOx compound from the carbon dioxide-enriched bottom stream from the CO_2 fractionation column in a NOx stripping column forming a stripping column overhead stream comprising carbon dioxide and depleted of the NOx compound and a stripping column bottom stream enriched in the NOx compound. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph further comprising separating the stripping column overhead stream into an overhead liquid stream and an overhead gas stream; and refluxing the overhead liquid stream to the NOx stripping column; wherein the overhead gas stream comprises a gaseous carbon dioxide product stream. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph further comprising compressing at least a portion of the carbon dioxide-enriched bottom stream from the CO_2 fractionation column before introducing the carbon dioxide-enriched bottom stream to the NOx stripping column. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph further comprising heat exchanging the carbon dioxide-enriched bottom stream from the CO_2 fractionation column with the stripping column overhead stream from the NOx stripping column forming a warmed carbon dioxide-enriched bottom stream and a cooled stripping column overhead stream before compressing the at least the portion of the carbon dioxide-enriched bottom stream. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph further comprising separating the warmed carbon dioxide-enriched bottom stream into a liquid carbon dioxide-enriched bottom stream and a vapor carbon dioxide-enriched bottom stream; and wherein compressing the at least the portion of the carbon dioxide-enriched bottom stream comprises compressing the vapor carbon dioxide-enriched bottom stream. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph further comprising introducing the liquid carbon dioxide-enriched bottom stream and the compressed carbon dioxide-enriched bottom stream to the NOx stripping column. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph further comprising pumping the liquid carbon dioxide-enriched bottom stream. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph further comprising heat exchanging the carbon dioxide-enriched bottom stream from the CO_2 fractionation column with the stripping column overhead stream from the NOx stripping column forming a warmed carbon dioxide-enriched bottom stream and a cooled stripping column overhead stream before compressing the at least the portion of the carbon dioxide-enriched bottom stream; refluxing a first portion of the cooled stripping column overhead stream from the NOx stripping column to the NOx stripping column; and wherein a second portion of the cooled stripper column overhead stream comprises a liquid carbon dioxide product stream. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph further comprising cooling the stripping column overhead stream from the NOx stripping column forming a cooled stripping column overhead stream; and wherein the cooled stripping column overhead stream comprises a liquid carbon dioxide product stream. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph further comprising chilling the liquid carbon dioxide product stream; or pumping the liquid carbon dioxide product stream to form a supercritical carbon dioxide product stream; or both. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph further comprising recycling the stripping column bottom stream to the NOx removal zone or a flue gas generation unit. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the first embodiment in this paragraph wherein the CO_2 removal zone comprises a CO_2 pressure swing adsorption (PSA) unit and further comprising separating the compressed flue gas feed stream in a CO_2 pressure swing adsorption (PSA) unit to form a CO_2-enriched stream, and an off gas stream before removing the at least a portion of the NOx compound from the compressed flue gas feed stream; and compressing the CO_2-enriched stream in a compressor forming a compressed CO_2-enriched stream; wherein removing the at least a portion of the NOx compound from the compressed flue gas feed stream comprises removing the at least a portion of the NOx compound from the compressed CO_2-enriched stream.

[0071] A second embodiment of the invention is a process for recovery of carbon dioxide from a flue gas stream and removal of NOx compounds from the recovered carbon dioxide comprising compressing a flue gas feed stream forming a compressed flue gas stream, wherein the flue gas feed stream comprises carbon dioxide and a NOx compound; removing at least a portion of the NOx compound from the compressed flue gas feed stream in a NOx removal zone comprising a NOx removal column forming a reduced contaminant stream wherein a level of the NOx compound in the reduced contaminant stream is less than a level of the NOx compound in the compressed flue gas stream and a NOx-enriched bottom stream; fractionating the reduced contaminant stream in a CO_2 fractionation column into a carbon dioxide-enriched bottom stream comprising carbon dioxide and the NOx compound and an overhead gas stream enriched in light components comprising one or more of N_2, N_2O, O_2, or NO; stripping at least a portion of the NOx compound from the carbon dioxide-enriched bottom stream from the CO_2 fractionation column in a NOx stripping column forming a stripping column overhead stream comprising carbon dioxide and depleted of the NOx compound and a stripping column bottom stream enriched in the NOx compound; treating the NOx-enriched bottom stream from the NOx removal zone; and recycling the stripping column bottom stream to the NOx removal zone or a flue gas generation unit. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph further comprising separating the stripping column overhead stream into an overhead liquid stream and an overhead gas stream; and refluxing the overhead liquid stream to the NOx stripping column; wherein the overhead gas stream comprises a gaseous carbon dioxide product stream. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph further comprising compressing at least a portion of the carbon dioxide-enriched bottom stream from the CO_2 fractionation column before introducing the carbon dioxide-enriched bottom stream to the NOx stripping column. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph further comprising heat exchanging the carbon dioxide-enriched bottom stream from the CO_2 fractionation column with the stripping column overhead stream from the NOx stripping column forming a warmed carbon dioxide-enriched bottom stream and a cooled stripping column overhead stream; separating the warmed carbon dioxide-enriched bottom stream into a liquid carbon dioxide-enriched bottom stream and a vapor carbon dioxide-enriched bottom stream, and compressing the vapor carbon dioxide-enriched bottom stream; introducing the liquid carbon dioxide-enriched bottom stream and the compressed carbon dioxide-enriched bottom stream to the NOx stripping column. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph further comprising pumping the liquid carbon dioxide-enriched bottom stream. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph further comprising heat exchanging the carbon dioxide-enriched bottom stream from the CO_2 fractionation column with the stripping column overhead stream from the NOx stripping column forming a warmed carbon dioxide-enriched bottom stream and a cooled stripping column overhead stream before compressing the at least the portion of the carbon dioxide-enriched bottom stream; refluxing a first portion of the cooled stripping column overhead stream from the NOx stripping column to the NOx stripping column; and wherein a second portion of the cooled stripper column overhead stream comprises a liquid carbon dioxide product stream. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph further comprising chilling the liquid carbon dioxide product stream; or pumping the liquid carbon dioxide product stream to form a supercritical carbon dioxide product stream; or both. An embodiment of the invention is one, any or all of prior embodiments in this paragraph up through the second embodiment in this paragraph wherein the CO_2 removal zone comprises a CO_2 pressure swing adsorption (PSA) unit and further comprising separating the compressed flue gas feed stream in a CO_2

pressure swing adsorption (PSA) unit to form a CO_2-enriched stream, and an off gas stream before removing the at least a portion of the NOx compound from the compressed flue gas feed stream; and compressing the CO_2-enriched stream in a compressor forming a compressed CO_2-enriched stream; wherein removing the at least a portion of the NOx compound from the compressed flue gas feed stream comprises removing the at least a portion of the NOx compound from the compressed CO_2-enriched stream.

[0072] Without further elaboration, it is believed that using the preceding description that one skilled in the art can utilize the present invention to its fullest extent and easily ascertain the essential characteristics of this invention, without departing from the spirit and scope thereof, to make various changes and modifications of the invention and to adapt it to various usages and conditions. The preceding preferred specific embodiments are, therefore, to be construed as merely illustrative, and not limiting the remainder of the disclosure in any way whatsoever, and that it is intended to cover various modifications and equivalent arrangements included within the scope of the appended claims.

[0073] In the foregoing, all temperatures are set forth in degrees Celsius and, all parts and percentages are by weight, unless otherwise indicated.

What is claimed is:

1. A process for recovery of carbon dioxide from a flue gas stream and removal of NOx compounds from the recovered carbon dioxide comprising:

compressing a flue gas feed stream forming a compressed flue gas stream, wherein the flue gas feed stream comprises carbon dioxide and a NOx compound;

removing at least a portion of the NOx compound from the compressed flue gas feed stream in a NOx removal zone comprising a NOx removal column forming a reduced contaminant stream wherein a level of the NOx compound in the reduced contaminant stream is less than a level of the NOx compound in the compressed flue gas stream;

fractionating the reduced contaminant stream in a CO_2 fractionation column into a carbon dioxide-enriched bottom stream comprising carbon dioxide and the NOx compound and an overhead gas stream enriched in light components comprising one or more of N_2, O_2, N_2O or NO; and

stripping at least a portion of the NOx compound from the carbon dioxide-enriched bottom stream from the CO_2 fractionation column in a NOx stripping column forming a stripping column overhead stream comprising carbon dioxide and depleted of the NOx compound and a stripping column bottom stream enriched in the NOx compound.

2. The process of claim **1** further comprising:

separating the stripping column overhead stream into an overhead liquid stream and an overhead gas stream; and

refluxing the overhead liquid stream to the NOx stripping column;

wherein the overhead gas stream comprises a gaseous carbon dioxide product stream.

3. The process of claim **1** further comprising:

compressing at least a portion of the carbon dioxide-enriched bottom stream from the CO_2 fractionation column before introducing the carbon dioxide-enriched bottom stream to the NOx stripping column.

4. The process of claim **3** further comprising:

heat exchanging the carbon dioxide-enriched bottom stream from the CO_2 fractionation column with the stripping column overhead stream from the NOx stripping column forming a warmed carbon dioxide-enriched bottom stream and a cooled stripping column overhead stream before compressing the at least the portion of the carbon dioxide-enriched bottom stream.

5. The process of claim **4** further comprising:

separating the warmed carbon dioxide-enriched bottom stream into a liquid carbon dioxide-enriched bottom stream and a vapor carbon dioxide-enriched bottom stream; and

wherein compressing the at least the portion of the carbon dioxide-enriched bottom stream comprises compressing the vapor carbon dioxide-enriched bottom stream.

6. The process of claim **5** further comprising:

introducing the liquid carbon dioxide-enriched bottom stream and the compressed carbon dioxide-enriched bottom stream to the NOx stripping column.

7. The process of claim **5** further comprising:

pumping the liquid carbon dioxide-enriched bottom stream.

8. The process of claim **3** further comprising:

heat exchanging the carbon dioxide-enriched bottom stream from the CO_2 fractionation column with the stripping column overhead stream from the NOx stripping column forming a warmed carbon dioxide-enriched bottom stream and a cooled stripping column overhead stream before compressing the at least the portion of the carbon dioxide-enriched bottom stream;

refluxing a first portion of the cooled stripping column overhead stream from the NOx stripping column to the NOx stripping column; and

wherein a second portion of the cooled stripper column overhead stream comprises a liquid carbon dioxide product stream.

9. The process of claim **3** further comprising:

cooling the stripping column overhead stream from the NOx stripping column forming a cooled stripping column overhead stream; and

wherein the cooled stripping column overhead stream comprises a liquid carbon dioxide product stream.

10. The process of claim **9** further comprising:

chilling the liquid carbon dioxide product stream; or

pumping the liquid carbon dioxide product stream to form a supercritical carbon dioxide product stream; or

both.

11. The process of claim **1** further comprising:

recycling the stripping column bottom stream to the NOx removal zone or a flue gas generation unit.

12. The process of claim **1** wherein the CO_2 removal zone comprises a CO_2 pressure swing adsorption (PSA) unit and further comprising:

separating the compressed flue gas feed stream in a CO_2 pressure swing adsorption (PSA) unit to form a CO_2-enriched stream, and an off gas stream before removing the at least a portion of the NOx compound from the compressed flue gas feed stream; and

compressing the CO_2-enriched stream in a compressor forming a compressed CO_2-enriched stream;

wherein removing the at least a portion of the NOx compound from the compressed flue gas feed stream comprises removing the at least a portion of the NOx compound from the compressed CO_2-enriched stream.

13. A process for recovery of carbon dioxide from a flue gas stream and removal of NOx compounds from the recovered carbon dioxide comprising:

compressing a flue gas feed stream forming a compressed flue gas stream, wherein the flue gas feed stream comprises carbon dioxide and a NOx compound;

removing at least a portion of the NOx compound from the compressed flue gas feed stream in a NOx removal zone comprising a NOx removal column forming a reduced contaminant stream wherein a level of the NOx compound in the reduced contaminant stream is less than a level of the NOx compound in the compressed flue gas stream and a NOx-enriched bottom stream;

fractionating the reduced contaminant stream in a CO_2 fractionation column into a carbon dioxide-enriched bottom stream comprising carbon dioxide and the NOx compound and an overhead gas stream enriched in light components comprising one or more of N_2, N_2O, O_2, or NO;

stripping at least a portion of the NOx compound from the carbon dioxide-enriched bottom stream from the CO_2 fractionation column in a NOx stripping column forming a stripping column overhead stream comprising carbon dioxide and depleted of the NOx compound and a stripping column bottom stream enriched in the NOx compound;

treating the NOx-enriched bottom stream from the NOx removal zone; and

recycling the stripping column bottom stream to the NOx removal zone or a flue gas generation unit.

14. The process of claim **13** further comprising:

separating the stripping column overhead stream into an overhead liquid stream and an overhead gas stream; and

refluxing the overhead liquid stream to the NOx stripping column;

wherein the overhead gas stream comprises a gaseous carbon dioxide product stream.

15. The process of claim **13** further comprising:

compressing at least a portion of the carbon dioxide-enriched bottom stream from the CO_2 fractionation column before introducing the carbon dioxide-enriched bottom stream to the NOx stripping column.

16. The process of claim **13** further comprising:

heat exchanging the carbon dioxide-enriched bottom stream from the CO_2 fractionation column with the stripping column overhead stream from the NOx stripping column forming a warmed carbon dioxide-enriched bottom stream and a cooled stripping column overhead stream;

separating the warmed carbon dioxide-enriched bottom stream into a liquid carbon dioxide-enriched bottom stream and a vapor carbon dioxide-enriched bottom stream;

compressing the vapor carbon dioxide-enriched bottom stream; and

introducing the liquid carbon dioxide-enriched bottom stream and the compressed carbon dioxide-enriched bottom stream to the NOx stripping column.

17. The process of claim **16** further comprising:

pumping the liquid carbon dioxide-enriched bottom stream.

18. The process of claim **13** further comprising:

heat exchanging the carbon dioxide-enriched bottom stream from the CO_2 fractionation column with the stripping column overhead stream from the NOx stripping column forming a warmed carbon dioxide-enriched bottom stream and a cooled stripping column overhead stream before compressing the at least the portion of the carbon dioxide-enriched bottom stream; and

refluxing a first portion of the cooled stripping column overhead stream from the NOx stripping column to the NOx stripping column;

wherein a second portion of the cooled stripper column overhead stream comprises a liquid carbon dioxide product stream.

19. The process of claim **18** further comprising:

chilling the liquid carbon dioxide product stream; or

pumping the liquid carbon dioxide product stream to form a supercritical carbon dioxide product stream; or

both.

20. The process of claim **13** wherein the CO_2 removal zone comprises a CO_2 pressure swing adsorption (PSA) unit and further comprising:

separating the compressed flue gas feed stream in a CO_2 pressure swing adsorption (PSA) unit to form a CO_2-enriched stream, and an off gas stream before removing the at least a portion of the NOx compound from the compressed flue gas feed stream; and

compressing the CO_2-enriched stream in a compressor forming a compressed CO_2-enriched stream;

wherein removing the at least a portion of the NOx compound from the compressed flue gas feed stream comprises removing the at least a portion of the NOx compound from the compressed CO_2-enriched stream.

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