WHAT IS CLAIMED IS:

1. An integrated desulfurization and decarbonization method using ammonia to remove sulfur oxides and CO_2 in process gas, the method comprising:

1) removing, using a desulfurization circulating fluid, sulfur oxides from the process gas, to provide a desulfurized process gas;

2) removing, using a decarbonization circulating fluid, CO_2 from the desulfurized process gas, to provide a decarbonized process gas; and

3) removing, using a desulfurization circulating fluid, free ammonia from the decarbonized process gas; and returning the desulfurization circulating fluid, having absorbed the free ammonia, to a desulfurization apparatus,

wherein the desulfurization circulating fluid includes a concentrated circulating fluid and an absorbing circulating fluid;

the concentrated circulating fluid has:

a pH of 1-6;

ammonium sulfite at a concentration of 0-0.2 wt.%; and

ammonium sulfate at a concentration of 10-60 wt.%; and

the absorbing circulating fluid has:

a pH of 4.5-6.5;

ammonium sulfite at a concentration of 0.1-3 wt.%; and

ammonium sulfate at a concentration of 10-38 wt.%, and

wherein the absorbing circulating fluid is used in step 3) for the removing of free ammonia.

2. The method of claim 1, having at least one of the following features:- products of the method include ammonium sulfate fertilizer and ammonium bicarbonate fertilizer; and

- a removing rate of CO_2 in step 2) ranges from 30 to 98%;

3. The method of claim 1, having at least one of the following features:

- the concentrated circulating fluid has:

a pH of 2-4.5;

ammonium sulfite at a concentration of 0-0.2 wt.%; and

ammonium sulfate at a concentration of 10-60 wt.%;

the absorbing circulating fluid has:

a pH of 4.8-6.2;

ammonium sulfite at a concentration of 0.1-3 wt.%; and

ammonium sulfate at a concentration of 10-38 wt.%; and

- the decarbonization circulating fluid has:

a pH of 7-11;ammonium bicarbonate at a concentration of 10-22 wt.%; andan NH_3/CO_2 molar ratio of 2-2.5;

- a temperature for the removing of sulfur oxides from the process gas is in a range from 5-55 °C; and

- a temperature for the removing of CO_2 from the process gas is in a range from 5-40 °C.

4. The method of claim 1, wherein the decarbonization circulating fluid has:

a pH of 8-9.5;

ammonium bicarbonate at a concentration of 10-22 wt.%; and

an NH_3/CO_2 molar ratio of 2-2.5.

5. Apparatus for implementing the method of any one of claims 1 to 4, wherein the apparatus includes an ammonia-based desulfurization functional area, an ammonia-based decarbonization functional area, an ammonia washing functional area, an ammonium sulfate post-processing system, and an ammonium bicarbonate post-processing system; ammonia is used as a desulfurizing agent and a decarbonizing agent; a process gas enters first the ammonia-based desulfurization functional area for desulfurization to produce ammonium sulfate fertilizer; the desulfurized process gas enters the ammonia-based decarbonization functional area for removal of carbon dioxide therein, to produce an ammonium bicarbonate solution/slurry; the decarbonized process gas, that comprises free ammonia, enters the ammonia washing functional area for washing with an desulfurization circulating fluid and then with a

process water; after the washing, the desulfurization circulating fluid and a process water solution are returned to the ammonia-based desulfurization functional area, where they serve as an absorbing agent for desulfurization, and part of ammonium sulfate-containing ammonium bicarbonate solution is returned to the ammonia-based desulfurization functional area.

6. The apparatus of claim 5, wherein the ammonia-based desulfurization functional area is divided into a plurality of sections including a cooling and concentrating section, an absorbing section, and the particulate removing section, with each section being provided with at least one spraying layer, and with a device/component for gas to pass through being provided between any two adjacent sections.

7. The apparatus of claim 6, wherein the particulate removing section comprises:

a first particulate removing part configured to wash with a concentrated circulating ammonium sulfate-containing solution; and

a second particulate removing part configured to wash with a dilute circulating ammonium sulfate-containing solution,

with a device/component for gas to pass through being provided between the two parts;

the first particulate removing part utilizing the concentrated circulating ammonium sulfate-containing solution having an ammonium sulfate concentration in a range of 10-38 wt.% and a pH in a range of 2.5-7.5; and

the second particulate removing part utilizing the dilute circulating ammonium sulfate-containing solution having an ammonium sulfate concentration in a range of 0-5 wt.% and a pH in a range of 3-7.

8. The apparatus of claim 7, wherein the first particulate removing part utilizes the concentrated circulating ammonium sulfate-containing solution having an ammonium sulfate concentration in a range of 12-30 wt.% and a pH in a range of 3-5.5; and the second particulate removing part utilizes the dilute circulating ammonium

sulfate-containing solution having an ammonium sulfate concentration in a range of 0.02-2 wt.% and a pH in a range of 3-7.

9. The apparatus of claim 5, wherein the ammonia-based desulfurization functional area includes a cooling apparatus that is configured to maintain a temperature of process gas after desulfurization in a range of 5-55°C,

with a circulate water and/or a chilled water being used as a coolant in the cooling apparatus.

10. The apparatus of claim 9, wherein the cooling apparatus is arranged on a circulating pipeline configured to transport desulfurization circulating fluid, to cool the desulfurization circulating fluid and in turn the post-desulfurization process gas; alternatively, on a process gas/flue gas conduit in the ammonia-based desulfurization functional area, to directly cool the process gas.

11. The apparatus of claim 5, wherein the ammonia-based decarbonization functional area includes a cooling apparatus that is configured to maintain a temperature of process gas after decarbonization in a range of 5-40°C.

12. The apparatus of claim 5, having at least one of the following features:

- the desulfurization circulating fluid used for ammonia washing comes from the ammonium sulfate-containing washing fluid used for the particulate removing section of the ammonia-based desulfurization functional area, and the desulfurization circulating fluid, after having been used in the ammonia washing, is returned to the ammonia-based desulfurization functional area for desulfurization, with a pH of the ammonium sulfate-containing washing fluid being controlled at 2.5-7.5;

- the desulfurization circulating fluid used for ammonia washing comes from the ammonium sulfate-containing washing fluid used for the absorption section of the ammonia-based desulfurization functional area, and the desulfurization circulating fluid, after having been used in the ammonia washing, is returned to the absorption section of the ammonia-based desulfurization functional area for

desulfurization, with a pH of the ammonium sulfate-containing washing fluid being controlled at 3-7;

- part of a resulting water solution after the ammonia washing enters, as makeup water, the circulating fluid for the particulate removing section of the ammonia-based desulfurization functional area, with a concentration of ammonia in the ammonia washing circulating fluid being controlled at 0-5 wt.%.

13. The apparatus of claim 7, wherein part of the dilute circulating ammonium sulfate-containing solution is pumped out and sent to a purification membrane separation apparatus to be separated, with a produced purified water being used as makeup water for the ammonia washing functional area to control the ammonia concentration in the washing water and the concentration of the dilute circulating ammonium sulfate-containing solution for desulfurization washing, the excess being discharged from the apparatus for external use, and a concentrated solution resulting from the separation entering the absorbing section in the ammonia-based desulfurization functional area.

14. The apparatus of claim 5, having at least one of the following features:- each of the ammonia-based desulfurization functional area, the ammonia-based decarbonization functional area and the ammonia washing functional area utilizes one or a combination of a sprayer absorption, a plate absorption, a packed column absorption, and a floating-valve absorption column;

- the ammonium sulfate post-processing system is configured to conduct solid-liquid separation of an ammonium sulfate slurry produced from the ammonia-based desulfurization, drying and packing into an ammonium sulfate product, alternatively, directly output a wet ammonium sulfate product;

- the ammonium bicarbonate post-processing system is configured to conduct solid-liquid separation of an ammonium bicarbonate slurry produced from the ammonia-based decarbonization, with a separated solution being returned to the ammonia-based decarbonization functional area, with a separated ammonium

bicarbonate being dried and packed into a product, alternatively, being output directly as a wet ammonium bicarbonate product;

- the apparatus further comprises a unit to heat part of the ammonium bicarbonate solution/slurry produced from the ammonia-based decarbonization to produce CO_2 and an ammonia solution, with the ammonia solution being returned to the ammonia-based decarbonization functional area for further use;

- the ammonia-based desulfurization functional area is configured to remove, using the desulfurization circulating fluid, sulfur oxides from the process gas to provide a desulfurized process gas and to operate under the following process parameters:

1) an empty tower gas velocity at 0.5-5 m/s;

2) a circulating fluid spraying density for each spray layer at 4-100 m^3/m^2-h; and

3) a circulating fluid temperature at 5-55°C;

- the ammonia-based decarbonization functional area is configured to remove, using the decarbonization circulating fluid, CO_2 from the desulfurized process gas to provide a decarbonized process gas and to operate under the following process parameters:

1) an empty tower gas velocity at 0.1-5 m/s; and

2) a temperature at 5-40°C; and

- the ammonia washing functional area is configured to remove, using the desulfurization circulating fluid from the oxidation chamber of the desulfurization circulating tank, free ammonia from the decarbonized process gas and to operate under the following process parameters:

1) an empty tower gas velocity at 0.25-5 m/s; and

2) a temperature at 0-50°C.