CLAIMS

1. A vertically-oriented scrubber apparatus for removing a plurality of distinct contaminants from a contaminated gas stream, comprising:

a) a scrubber vessel having a ceiling, a floor, a cylindrical wall connecting the ceiling to the floor, a plurality of vertically-spaced heads, a volume above each head, a gas inlet, an induced draft fan, and a gas outlet;

b) a submerged lower head positioned horizontally across a lower end of the scrubber vessel, wherein the submerged lower head includes a horizontal plate having a plurality of narrow slots extending throughout;

c) a first scrubbing fluid reservoir disposed within the bottom end of the scrubber vessel below the submerged lower head, and a first reaction zone volume to a desired level above the submerged scrubbing head, a first scrubbing fluid selected to remove a first group of contaminants from the contaminated gas stream;

d) a first scrubbing fluid inlet extending into a first volume above the submerged head, first spraying means in fluid connection with the first scrubbing fluid inlet for spraying the first scrubbing fluid into the first scrubbing fluid reaction zone volume, and a first scrubbing fluid outlet in the floor;

e) a first flooded head extending horizontally across the entire cross-section of the scrubber vessel at a position above the first scrubbing fluid inlet, wherein the first flooded head comprises a plate having a plurality of narrow slots extending throughout;

f) a second scrubbing fluid reaction zone volume disposed to a desired level above the first flooded head, the second scrubbing fluid selected to remove a second group of contaminants from the contaminated gas stream; and

g) a second scrubbing fluid inlet extending into a second volume above the first flooded head, second spraying means in fluid connection with the second scrubbing fluid inlet for spraying the second scrubbing fluid into the second scrubbing fluid reaction zone volume, and a second scrubbing fluid outlet above the first flooded head passing through the scrubber vessel wall.

2. A vertically-oriented scrubber apparatus for removing a plurality of distinct contaminants from a contaminated gas stream, comprising:

a) a scrubber vessel having a ceiling, a floor, a cylindrical wall connecting the ceiling to the floor, a plurality of vertically-spaced heads, a volume above each head, a gas inlet, an induced draft fan, and a gas outlet;

b) a first scrubbing fluid reservoir disposed within the bottom end of the scrubber vessel to a desired level, the first scrubbing fluid selected to remove a first group of contaminants from the contaminated gas stream;

c) a first flooded head extending horizontally across the scrubber vessel at a position above the gas inlet, defining a first volume between the first scrubbing fluid reservoir and the first flooded head, wherein the first flooded head comprises a plate having a plurality of narrow slots extending throughout;

d) a first scrubbing fluid reaction zone volume disposed to a desired level above the first flooded head, the reaction zone volume in fluid connection with the reservoir via one or more overflow tubes, each extending from the first scrubbing fluid reservoir through the first flooded head to a desired level above the first flooded head;

e) a first scrubbing fluid inlet extending through the wall into a second volume above the first flooded head, first spraying means in fluid connection with the first scrubbing fluid inlet for spraying the first scrubbing fluid into the second scrubbing fluid reaction zone volume, and a first scrubbing fluid outlet in the floor;

f) a second flooded head extending horizontally across the entire cross-section of the scrubber vessel at a position above the first flooded head, defining the second volume between the first scrubbing fluid reaction zone volume and the second flooded head, wherein the second flooded head comprises a plate having a plurality of narrow slots extending throughout;

g) a second scrubbing fluid reaction zone volume disposed above the second flooded head to a desired level, the second scrubbing fluid selected to remove a second group of contaminants from the contaminated gas stream; and

h) a second scrubbing fluid inlet extending into a third volume above the second flooded head, second spraying means in fluid connection with the second scrubbing fluid inlet for spraying the second scrubbing fluid into the second scrubbing fluid reaction zone volume,

and a second scrubbing fluid outlet above the second flooded head passing through the wall of the scrubber vessel.

3. The scrubber apparatus of claim 1, further comprising:

a) one or more additional flooded heads extending horizontally across the entire cross-section of the scrubber vessel and serially stacked vertically above the other heads, each defining an additional volume in relation to the head below;

b) one or more additional scrubbing fluid reaction zone volumes, each disposed above a corresponding flooded head to a desired level, each additional scrubbing fluid selected to remove a desired additional group of contaminants from the contaminated gas stream; and

c) one or more additional scrubbing fluid inlets extending through the wall into the corresponding additional volume above the corresponding additional flooded head, additional corresponding spraying means in fluid connection with the additional scrubbing fluid inlet for spraying the additional scrubbing fluid into the corresponding additional scrubbing fluid reaction zone volume, and one or more corresponding additional scrubbing fluid outlets above the corresponding flooded head passing through the wall of the scrubber vessel.

4. The scrubber apparatus of claim 2, further comprising:

a) one or more additional flooded heads extending horizontally across the entire cross-section of the scrubber vessel and serially stacked vertically above the other heads, each defining an additional volume in relation to the head below;

b) one or more additional scrubbing fluid reaction zone volumes, each disposed above a corresponding flooded head to a desired level, each additional scrubbing fluid selected to remove a desired additional group of contaminants from the contaminated gas stream; and

c) one or more additional scrubbing fluid inlets extending through the wall into the corresponding additional volume above the corresponding additional flooded head, additional corresponding spraying means in fluid connection with the additional scrubbing fluid inlet for spraying the additional scrubbing fluid into the corresponding additional scrubbing fluid reaction zone volume, and one or more corresponding additional scrubbing fluid outlets above the corresponding flooded head passing through the wall of the scrubber vessel.

5. The scrubber apparatus of claim 2, wherein the gas inlet is located at the top end of the vessel and a gas inlet duct conducts the gas to a position below the lowermost head.

6. The scrubber apparatus of claim 2, wherein the gas inlet is located at the side of the vessel and a gas inlet duct conducts the gas to a position below the lowermost head.

7. The scrubber apparatus of claim 2, wherein the size of the slots in the flooded heads are selected to prevent passage therethrough of scrubbing fluid in the presence of pressurized gas below the flooded heads.

8. A method of removing multiple contaminants from a contaminated gas stem, the method comprising the steps of:

a) introducing a first scrubbing fluid into the apparatus of claim 1 to a desired fluid level above the submerged scrubber head;

b) introducing a second scrubbing fluid into the apparatus of claim 1 to a desired level above the flooded scrubber head;

c) cooling the contaminated process gas using a prior art gas conditioner;

d) introducing the cooled contaminated gas under pressure from an induced draft fan into the apparatus of claim 1 at a position below the submerged scrubber head;

e) allowing the gas to pass upwardly through the submerged scrubber head to transfer a first group of contaminants from the contaminated gas into the first scrubbing fluid in a first scrubbing fluid reaction zone volume above the submerged scrubber head;

f) allowing the gas to continue passing upwardly through the flooded head to transfer a second group of contaminants from the contaminated gas into the second scrubbing fluid in a second scrubbing fluid reaction zone volume above the flooded head;

g) spraying the exiting gas to remove additional contaminants and slow the gas flow velocity;

h) allowing the exiting gas to exit the scrubbing apparatus;

i) separately removing first and second scrubbing fluids from the scrubber vessel to maintain a desired level of each scrubbing fluid; and

j) cleaning the first and second scrubbing fluids removed in step (i) for reuse in the scrubbing apparatus.

9. The use of the scrubber apparatus of claim 1 to remove multiple contaminants from a contaminated gas stream according to the method of claim 8.

10. The method of claim 9, further comprising the additional step (ff) after step (f) of:

ff) allowing the gas to continue passing upwardly through one or more serially vertically stacked additional flooded heads to transfer one or more additional groups of contaminants from the contaminated gas into one or more additional scrubbing fluids in each of one or more additional scrubbing fluid reaction zone volumes above each of the corresponding flooded heads.

11. A method of removing multiple contaminants from a contaminated gas stream, the method comprising the steps of:

a) introducing a first scrubbing fluid into the apparatus of claim 2 to a desired fluid level above the first flooded scrubber head;

b) introducing a second scrubbing fluid into the apparatus of claim 2 to a desired level above the second flooded scrubber head;

c) cooling the contaminated process gas using a prior art gas conditioner;

d) introducing the cooled contaminated gas under pressure from an induced draft fan into the apparatus of claim 2 at a position below the first flooded scrubber head;

e) allowing the gas to pass upwardly through the first flooded head to transfer a first group of contaminants from the contaminated gas into the first scrubbing fluid in a first scrubbing fluid reaction zone volume above the first flooded head;

f) allowing the gas to continue passing upwardly through the second flooded head to transfer a second group of contaminants from the contaminated gas into the second scrubbing fluid in a second scrubbing fluid reaction zone volume above the second flooded head;

g) spraying the exiting gas to remove additional contaminants and slow the gas flow velocity;

h) allowing the exiting gas to exit the scrubbing apparatus;

i) separately removing first and second scrubbing fluids from the scrubber vessel to maintain a desired level of each scrubbing fluid; and

j) cleaning the first and second scrubbing fluids removed in step (i) for reuse in the scrubbing apparatus.

12. The use of the scrubber apparatus of claim 2 to remove multiple contaminants from a contaminated gas stream according to method of claim 11.

13. The method of claim 11, further comprising the additional step (ft) after step (f) of:

ff) allowing the gas to continue passing upwardly through one or more serially vertically stacked additional flooded heads to transfer one or more additional groups of contaminants from the contaminated gas into one or more additional scrubbing fluids in each of one or more additional scrubbing fluid reaction zone volumes above each of the corresponding flooded heads.

14. The use of the apparatus of claim 1 to remove from a contaminated gas stream multiple contaminants selected from the group of contaminants comprising particulate matter, metals, hydrogen chloride, hydrogen fluoride, nitrous oxide, nitric oxide, carbon dioxide, and sulfur dioxide.

15. The use of the apparatus of claim 2 to remove from a contaminated gas stream multiple contaminants selected from the group of contaminants comprising particulate matter, metals, hydrogen chloride, hydrogen fluoride, nitrous oxide, nitric oxide, carbon dioxide, and sulfur dioxide.

16. A method of removing multiple contaminants from a contaminated gas stream, the method comprising the steps of:

a) introducing a first scrubbing fluid into the apparatus of claim 2 to a desired fluid level above the first scrubber head;

b) introducing a second scrubbing fluid into the apparatus of claim 2 to a desired level above the second scrubber head;

c) cooling the contaminated process gas using a prior art gas conditioner;

d) introducing the cooled contaminated gas under pressure from an induced draft fan into the apparatus of claim 2 at a position below the first scrubber head;

e) allowing the gas to pass upwardly through the first head to transfer a first group of contaminants from the contaminated gas into the first scrubbing fluid in a first scrubbing fluid reaction zone volume above the first head;

f) allowing the gas to continue passing upwardly through the second head to transfer a second group of contaminants from the contaminated gas into the second scrubbing fluid in a second scrubbing fluid reaction zone volume above the second head;

g) spraying the exiting gas to remove additional contaminants and slow the gas flow velocity;

h) allowing the exiting gas to exit the scrubbing apparatus;

i) separately removing first and second scrubbing fluids from the scrubber vessel to maintain a desired level of each scrubbing fluid; and

j) cleaning the first and second scrubbing fluids removed in step (i) for reuse in the scrubbing apparatus.