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(54) **Title:** ABSORPTION GAS TREATMENT METHOD AND COLUMN

(57) **Abstract:** The invention can be used to purify gas flows from impurities in a wide range of concentrations, as well as to separate gas mixtures into individual components in oil, gas, chemical and other industries. A method of absorption gas sweetening from undesirable impurities has been proposed, comprising countercurrent contact of the gas to be purified and regenerated absorbent in the mass transfer column with resulting purified gas and saturated absorbent, and a column for its implementation, packed contact device, which is separated in height into independent mass transfer sections with countercurrent or crosscurrent movement of the purified gas and regenerated absorbent, at that the flow of purified gas is sequentially passed upwards through all independent mass transfer sections of the mass transfer column, regenerated absorbent flow is introduced into the upper part of each independent mass transfer section, and saturated absorbent flow is withdrawn from the lower part of each independent mass transfer section.



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ABSORPTION GAS TREATMENT METHOD AND COLUMN

TECHNICAL FIELD

Absorption gas treatment method and column can be used for treating gas streams from impurities in a wide range of concentrations and also for separating gaseous mixtures into individual components at oil & gas industry, chemical industry etc.

PREVIOUS TECHNICAL KNOWLEDGE

Classic method of removing undesirable component from a gas is the absorption gas treatment by counter-current contact of a gas under treatment and a selective adsorbent, that is implemented in mass transfer column apparatus (See Aleksandrov V.A. Rectification and absorption apparatus. M.: Chemistry. – 1971. – 296 p.). However, as chemical process development progresses, the necessity of treating gaseous mixture from several undesirable impurities is growing.

A method and a plant for natural gas treating from carbon dioxide (CO₂) and hydrogen sulfide (H₂S) using two stages of absorption is known. At the first stage, the selective treatment from CO₂ is performed with separating a sour gas with CO₂ content of 30%-40% max and treated gas with H₂S content of 5-7 mg/m³, that is passed further to the second stage to obtain treated gas with CO₂ content of 50-200 mg/m³ max and completely free of the H₂S and sour gas with H₂S content of 200 mg/m³ max; at this, alkylamine-based absorbent saturation is of 0.4 mol/mol max at every stage of sour component absorption, and natural gas has H₂S/CO₂ ratio of 1.0 (maximum 1.5), and H₂S concentration 3.5% to 8.0% vol. (Patent of invention RU 2547021, IPC B01D 53/14, B01D 53/52, B01D 53/62, C10L3/10, Filed: February 20, 2014, Applied: April 10, 2015). This invention has the following disadvantages:

- 1) complication of the plant process chart due to, primarily, that different components are absorbed using different absorbers forming process cycle series within the plant;
- 2) ethane cryogenic extraction from natural gas stream is unavailable because of treated gas saturation with moisture while contacting with an absorbent;
- 3) gradual increase of methanol concentration in regenerated absorbent and decrease of amine-water solution absorptivity vs. H₂S and CO₂ due to returning methanol together with condensed water in the regenerated absorbent during absorbent regeneration when supplied natural gas include methanol dissolving in absorbent together with the H₂S and CO₂;
- 4) non-optimal absorbent performance at H₂S and CO₂ simultaneous absorption due to decreasing the absorptivity below its potential value.

A method of natural gas processing that include removing water, CO₂, H₂S,

C₂-hydrocarbons and higher, and inert gases is known featuring separate treatment of natural gases that are substantially different by the content of impurities; at this, low calorie natural gas containing CO₂ more than H₂S and with high CO₂ content is processed consecutively in the first plant of high amine treatment from H₂S and selective treatment from CO₂ by using alkylamine-water solution absorbent and in the second plant of high amine treatment from CO₂ by using mono-, di-, triethanolamine water solutions or their mixtures as an absorbent, and high calorie natural gas containing CO₂ less than H₂S and with low CO₂ content is processed in high amine treatment plant removing CO₂ and H₂S by using mono-, di-, triethanolamine water solutions or their mixtures as an absorbent (patent on an invention RU 2560406, IPC B01D 53/00, Filed: October 29, 2013, Applied: August 20, 2015). The basic disadvantage of this invention is the complexity of plant process chart due to, primarily, that different extracted components are absorbed in different absorbers; at this, changing an initial component ratio (e.g. changing low calorie raw material to high calorie one) requires the change of process chart and, accordingly, the mode of the process.

A method of removing CO₂ from exhaust gases by using regenerated absorbent in partitioned stripping column 13 with contact devices in its lower section 13A is known. Partly treated exhaust gas from the lower section 13A is additionally treated and cooled by pumparound reflux of contact devices with water counter current relative to exhaust gas under treatment in the upper section 13B; at this, a part of circulatory water from the section 13B passes to pumparound contact devices of middle part 13C of partitioned column 13 also counter current relative to exhaust gas under treatment and then is mixed with an absorbent in upper part of section 13A; in particular, the cooled circulatory water can be injected in the partitioned column 13 from absorbent regeneration stage (patent on the invention of WO/2014/024548, IPC B01D 53/62, B01D 53/14, C01B 31/20, Filed: May 29, 2013, Applied: February 13, 2014). This invention has the following disadvantages:

1) the process uses large water flow rates commensurable with the process productivity on total CO₂ removed; the cause is low CO₂ solubility in water, e.g. at 21 °C and 1MPa only 0.33 vol. parts of CO₂ dissolve in 1 vol. part of water, and at 40 °C and 10MPa, 1 part by volume of CO₂ dissolves in 1 volume of water;

2) considerable increase of additional energy consumption required for using ineffective pumparound reflux of upper section 13B, including circulation pump drive supply and circulatory water cooling supply;

3) basic CO₂ absorbent absorbability decrease due to the absorbent dilution with water in basic absorbing section 13A resulting in an additional loading of absorbent regeneration column by the liquid and corresponding increase of energy consumption for regeneration;

4) low efficiency of section 13C, where exhaust gas purged from CO₂ comes in contact with already partly CO₂-saturated water at gas temperature elevated due to absorption calorification in the section 13A, which can result in the negative process of CO₂ desorption from water.

5 An absorber for removing CO₂ from exhaust gases by using regenerated absorbent in partitioned stripping column 13 of tree sections with contact devices is known. In its lower section 13A, exhaust gases coming to lower section 13A are treated by an absorbent coming to upper section 13A, then partly treated exhaust gas from the lower section 13A passes middle section 13C and through a dead plate is led to section 13B lower part where it is additionally treated and cooled by pumparound reflux of contact devices with water counter current relative to exhaust gas under treatment; at this, a part of circulatory water from section 13B passes to pumparound contact devices of middle part 13C of column 13 also counter current relative to exhaust gas under treatment and then is mixed with an absorbent in upper part of section 13A (patent on the invention of WO/2014/024548, IPC B01D 53/62, B01D 53/14, C01B 31/20, Filed: May 29, 2013, Applied: February 13, 2014). This invention has the following disadvantages:

1) low efficiency of contact devices in sections 13B and 13C due to low CO₂ solubility in water that results in the contact devices volume increase in these sections and, accordingly, higher capital costs on building the absorber;

2) additional increase of capital and operating costs due to circulation pump and circulatory water cooler use in the section 13B;

3) necessity to maintain high circulating water level on a dead plate for providing circulation pump operation; this is resulting in the additional increase of absorber height without corresponding increase of its efficiency;

4) caused by basic absorbent absorbability decrease and increase of contact device volume in section 13A due to section 13A basic absorbent dilution with water, which is caused by direct flow of water from section 13C lower contact device to upper contact device of section 13A; increasing capital costs on absorber structure.

A direct flow absorber containing a body with gas inlet and outlet nozzles and liquid inlet and outlet nozzles located into the body together with liquid distributor, mass transfer unit, and demister is known featuring mass transfer unit executed as horizontal shelves equipped with bundles of regular plate-type pack installed; at this, regular pack bundle is made from single corrugated plates separated by flat sheet spacers ensuring the channels between the plates (patent on the invention of RU 2491982 C1, IPC B01D 53/18, Filed: April 03, 2012, Applied: September 10, 2013). This invention has the following disadvantages:

1) low efficiency of direct flow of gas/liquid phase in absorption gas treatment due to

that already very saturated absorbent with high concentration of absorbed component at final stage of the process contacts with partly treated gas with low concentration of a component under treatment and even when phase equilibrium is reached the high gas treatment will be unattainable;

2) partial stratification of gas and liquid phases serially interlaced horizontally and top-down instead of complete phase mixing at direct flow in mass transfer unit; it results in discontinuing mass-transfer between phases in phase stratification zones and decrease of absorption process efficiency in the whole apparatus;

3) growth of capital and operating costs of the process implementation caused by the necessity of multiple increase of contact device height and sharp increasing of system pressure loss due to absorber flow speed and extent increase for providing necessary gas and liquid phase contact time, because the minimum gas speed required to ensure liquid getting up from a shelf and distributing it through a pack volume in direct flow conditions is corresponding to the conditions of turbulence formation in inhomogeneous liquid-gas system and many times exceeds gas stream speed in counter current flow.

Also a fractionating absorber which includes absorbing and stream-stripping mass transfer units, feed zone located between the above units and provided with gas under treatment inlet nozzle, upper separating zone with absorbent inlet and treated gas outlet nozzles, and lower separating zone with absorbate outlet nozzle is known, featuring mass transfer units divided into two subunits containing at least one heat-mass-transfer unit equipped with heat-carrying agent or refrigerant inlet and outlet nozzles, made from heat-mass-transfer elements (e.g. helically-radial type) ensuring internal space for passing heat-carrying agent or refrigerant and external space for counter-current mass-transfer between gas and falling liquid layer; absorbate outlet nozzle and nozzle of lower stream-stripping mass transfer unit adjacent to the feed zone and also treated gas outlet nozzle and upper nozzle of absorbing subsection adjacent to the feed zone are connected in pair by pipelines, and absorbing section's heat-mass-transfer unit external space is filled with mass transfer pack (patent on the invention of RU 2530133 C1, IPC B01D 53/14, Filed: June 11, 2013, Applied October 10, 2014). This invention has the following disadvantages:

1) gas and liquid stream hydrodynamic structure disruption in a pack in the zones where heat-exchange structures are installed, resulting in phase streams speed increase, phase contact time decrease, and mass transfer efficiency decrease in these zones;

2) potential dropping liquid carryover to upper sections causing lower mass transfer efficiency due to increase of gas phase flow velocity in a pack in the zones where heat-exchange structures are installed;

3) implementation of installing heat-exchange structures only in the layers of irregular pack which is less effective compared to regular pack in terms of mass-transfer.

General disadvantages of the considered methods and devices for absorption gas treatment from several undesirable impurities are as follows:

- 1) non-optimal absorbent performance during simultaneous coabsorption of several impurities, resulting in the necessity of increasing absorbent consumption and related increasing absorber column diameter and energy consumption for absorbent regeneration;
- 2) necessity of complicated process flows using several closed absorption-regeneration cycles to provide required degree of gas treatment from certain impurities;
- 3) implementing significant absorbent flow rates required for treating gases with high concentration of impurities to be removed leads to the increase of absorbing column diameter and construction materials consumption;
- 4) modification of absorbing column to increase its productivity requires simultaneous higher absorbent flow rate which is limited by the diameter of existent absorbing column due to the limit of liquid level in liquid distributors and contact device throat area by a liquid phase.

When making of the invention, the tasks of expanding potential possibilities of the method of absorption gas treatment from undesirable impurities and enhancing column structure were as follows:

- 1) separate using several selective absorbents each to remove a certain impurity from the stream of a gas under treatment in one apparatus;
- 2) absorbing extraction of every extractive impurity in its optimal mode;
- 3) column diameter and construction materials consumption reduce due to fractional feeding absorbent in absorption zone in optimal mode;
- 4) substantial increase of column productivity by column reconstruction due to column height increase with simultaneous equivalent increasing absorbent feed without contact mass-transfer devices choking.

DISCLOSURE OF INVENTION

For the method of absorption gas treatment from undesirable impurities by using gas under treatment and regenerated absorbent counter/cross flow, this task solution is achieved by separating the packing contact device of mass transfer column by height into individual mass transfer units with gas under treatment and regenerated absorbent counter/cross flow; at this, the stream of gas under treatment is successively passed from top to bottom through all individual mass transfer units of mass transfer column, the regenerated absorbent is injected in upper part of every individual mass transfer unit and the saturated absorbent is withdrawn from the bottom part of every individual mass transfer unit. Such partitioning of absorbing process by a liquid phase (i.e. absorbent) allows to create optimal absorption gas treatment conditions in every separate section while continuous gas under treatment passing from top to bottom; in particular,

the possibility appears to increase absorbing process motive force and, due to this, intensify the process because regenerated absorbent is entered in every section while in common absorbing column gas under treatment contacts with the already partly saturated absorbent over the column height. In addition, due to reduction of loading contact devices by a liquid phase in mass transfer column per one individual mass transfer unit, the possibility to reduce mass transfer column diameter and contact device throat area by a liquid phase, and to lower construction materials consumption in the whole.

When one extractive impurity is presented in a gas under treatment, one type of selective regenerated absorbent is injected in every individual mass transfer unit and/or group of adjacent individual mass transfer units with flow rate determined by motive force of absorbing process in a certain unit; at this, the streams of saturated absorbent are withdrawn from the bottom of every individual mass transfer unit and/or group of adjacent individual mass transfer units and combined in a general stream for regeneration outside mass transfer column.

It is expediently to adopt the change of extractive impurity concentration for every individual mass transfer unit, dC , the same for all individual mass transfer units as determined by the following equation:

$$dC = (C_H - C_K) / N,$$

where C_K is concentration of extractible impurity in a gas under treatment at mass transfer column inlet,

C_K is concentration of extractible impurity in a gas under treatment at mass transfer column outlet,

N is number of individual mass transfer units over mass transfer column height to ensure the same amount of regenerated absorbent injected in every individual mass transfer unit.

Also, total flow rate of regenerated absorbent can be minimized at the expense of providing optimized flow rate of regenerated absorbent to every individual mass transfer unit; the minimal flow rate of regenerated absorbent is defined based on such a distribution of extractible impurity concentration at gas inlet of j -th individual mass transfer unit, $C_{H,j}$, and extractible impurity concentration at gas outlet of j -th individual mass transfer unit, $C_{K,j}$, that

$$\sum (C_{H,j} - C_{K,j}) / (K \cdot C_{K,j}) = \min,$$

where K is Henry's law constant.

When two or more extractive impurities substantially different by affinity to the absorbents are presented in initial gas, then to extract certain impurity a corresponding selective regenerated absorbent type is injected in every individual mass transfer unit and/or groups of adjacent individual mass transfer units. It allows to maintain the optimal conditions for absorbing each of impurities and to decrease column height and construction materials consumption. Absorption gas

treating temperature in every individual mass transfer unit is controlled through changing the temperature of regenerated absorbent heated or cooled in additional external heat-exchangers.

To increase extraction of certain impurity in one or several individual mass transfer units with cross flow of treated gas and regenerated absorbent, it is expediently to imply an additional injection of one or more streams of one selective regenerated absorbent type for intermediate stages with identical or different parameters.

In mass transfer column for absorption gas treatment, which includes vertical body for gas under treatment and regenerated absorbent counter-flow contact in packing contact device, gas under treatment inlet nozzle, and treated gas outlet nozzle, this task solution is achieved by separating the packing contact device by height into individual mass transfer units with gas under treatment and regenerated absorbent counter/cross flow; at this, every individual mass transfer unit is separated from the adjacent individual mass transfer unit by a dead plate and is equipped with LP liquid distributor with regenerated absorbent inlet nozzle in the upper part; the dead plate is equipped with saturated absorbent collector, outlet nozzle for saturated absorbent withdrawal from mass transfer column body, and connecting piece for passing gas under treatment from lower individual mass transfer unit to upper individual mass transfer unit through the dead plate. Partitioning along the packing contact device height to provide individual mass transfer units and individual supplying with the regenerated absorbent allows to decrease contact device loading by liquid phase, lower contact device cross section, and lower construction metal consumption in the whole.

In an individual mass transfer unit with gas under treatment counter flow or cross flow, it is expediently to use regular PETON pack providing developed phase interface and having high porosity at counter flow of gas and regenerated absorbent and, at phases cross-flow in individual mass transfer unit, ensuring pack bundle with independent cross sections for gas under treatment stream to pass along the horizontal axis and absorbent to drain along the vertical axis of the pack bundle.

To achieve greater phase contact efficiency in individual cross-flow mass transfer unit, it is expedient to use several intermediate regular PETON pack stages separated with intermediate LP liquid distributors and intermediate regenerated absorbent injectors.

It is expediently to place the nozzles of two successively located deaf plates at different sides from regular pack of individual mass transfer unit in the direction of gas under treatment flow.

In the cases when several adjacent individual mass transfer units use the same absorbent type, saturated absorbent outlet nozzle of mass transfer column of the upper individual mass transfer unit and regenerated absorbent inlet nozzle of LP liquid distributor of the lower individual

mass transfer unit are provided with a downcomer; at this, in absorption gas treatment column a group of adjacent individual mass transfer units is formed from M adjacent individual mass transfer units provided with M-1 downcomers and this group is supplied with the same absorbent type. The number of adjacent individual mass transfer units M in a group of adjacent individual mass transfer units is defined based on the condition:

$$Z = \sum_{j=1}^{j=M} Z_j * (1 - Z_j)^{M-1},$$

where Z is required grade of certain impurity extraction in a given group of adjacent mass transfer units.

Z_i is a grade of certain impurity extraction in a individual mass transfer unit.

LIST OF DRAWINGS

The declared invention is illustrated by drawings where Figures 1 to 7 containing the following items include a number of options of structural and technological decisions of method and column of absorption gas treatment from undesirable impurities:

1 – mass transfer column vertical body;

2 – gas under treatment inlet nozzle;

3 – treated gas outlet nozzle;

4 – regular pack;

5 – LP liquid distributor;

6 – regenerated absorbent inlet nozzle;

7 – dead plate;

8 – saturated absorbent collector;

9 – saturated absorbent outlet nozzle;

10 – nozzle;

11 – bridge;

12 – downcomer;

13 – closed valve;

14 – open valve.

BRIEF DESCRIPTION OF DRAWINGS

Figure 1 shows general view of mass transfer column for absorption gas treatment from undesirable impurities, equipper with the packing contact device made as regular PETON pack separated into eight individual mass transfer units with possibility of injecting regenerated absorbent and saturated absorbent withdrawal for every individual mass transfer unit. Treated gas through the gas under treatment inlet nozzle 2 enters mass transfer column vertical body 1 where the regular pack 4 is installed in each of eight individual mass transfer units and, successively moving from top to bottom, in every individual mass transfer unit contacts with regenerated

absorbent stream directed in the top of every individual mass transfer unit through the regenerated absorbent inlet nozzle 6 and LP liquid distributor 5. As a result of contact, the partly treated gas passes through the nozzle 10 of dead plate 7 from lower individual mass transfer unit to upper individual mass transfer unit for deepening the treatment by means of fresh regenerated absorbent stream. After the successive passing all individual mass transfer units from top to bottom, the treated gas stream is withdrawn from mass transfer column vertical body 1 through the treated gas outlet nozzle 3. Saturated absorbent stream after contacting with gas under treatment is collected in saturated absorbent collector 8 of dead plate 7 and then through saturated absorbent outlet nozzle 9 is withdrawn from every individual mass transfer unit outside the mass transfer column vertical body 1 to regeneration. To exclude treated gas slipping, every individual mass transfer unit is provided with a bridge 11 which is joined with mass transfer column vertical body 1 on the one side and with regular pack 4 on the other side.

Figure 2 shows operating principle of one individual mass transfer unit of mass transfer column for absorption gas treatment from undesirable impurities with treated gas and regenerated absorbent cross flow in regular PETON pack; arrowed solid lines show liquid absorbent flow and dotted lines show gas under treatment flow. In the process of gas under treatment horizontal stream contacting with the one descending on regular pack 4 in the layer mode of regenerated absorbent stream, a transfer of extractive impurity from gas phase into liquid phase occurs. Mass transfer column normal section is partly filled with packing contact device due to structure specific.

Figure 3 shows operating principle of one individual mass transfer unit of mass transfer column for absorption gas treatment from undesirable impurities with treated gas and regenerated absorbent counter flow in regular pack; arrowed solid lines show liquid absorbent flow and dotted lines show gas under treatment flow. In the process of gas under treatment vertical stream contacting with the one descending on regular pack 4 in the layer mode of regenerated absorbent stream, a transfer of extractive component from gas phase into liquid phase occurs. Mass transfer column normal section is fully filled with packing contact device due to structure specific.

Figure 4 shows operation option of mass transfer column for absorption gas treatment from undesirable impurities with the packing contact device as regular pack separated into eight individual mass transfer units; at this, regenerated absorbent a_{1r} is injected in every individual mass transfer unit through the regenerated absorbent inlet nozzle 6 at the top and saturated absorbent a_{1s} is withdrawn through the saturated absorbent outlet nozzle 9 at the bottom. In the process of gas under treatment horizontal stream contacting with the one descending on regular pack 4 in the layer mode of regenerated absorbent stream, a transfer of extractive impurity from gas phase into liquid phase occurs; at this, the stream of gas under treatment passes successively from top to bottom all individual mass transfer units, contacting with relatively small

portion of the regenerated absorbent in every individual mass transfer units; that is equivalent to reducing load by a liquid phase on contact mass transfer devices.

Figure 5 shows operation option of mass transfer column for absorption gas treatment from undesirable impurities with the packing contact device as regular pack separated into eight individual mass transfer units; at this, two different regenerated absorbents a_1 and a_2 are used to extract impurities substantially different by affinity with absorbents; regenerated absorbent a_{1r} is injected through regenerated absorbent inlet nozzle 6 at the top and saturated absorbent a_{1s} is withdrawn through the saturated absorbent outlet nozzle 9 at the bottom of each of four lower individual mass transfer units; and regenerated absorbent a_{2r} is injected through regenerated absorbent inlet nozzle 6 at the top and saturated absorbent a_{2s} is withdrawn through the saturated absorbent outlet nozzle 9 at the bottom of each of four upper individual mass transfer units. The stream of gas under treatment passes successively all individual mass transfer units, contacting with relatively small portion of the regenerated absorbent in every individual mass transfer units; that is equivalent to reducing load by a liquid phase on contact mass transfer devices. The use of two selective absorbents allows to select both optimal flow rate of every absorbent and corresponding process mode for every individual mass transfer unit, as well as the sizes of structural elements of regular pack 4.

Figure 6 shows operation option of mass transfer column for absorption gas treatment from undesirable impurities with the packing contact device as regular pack separated into eight individual mass transfer units; at this, three different regenerated absorbents a_1 , a_2 , and a_3 are used to extract impurities substantially different by affinity with absorbents; regenerated absorbent a_{1r} is injected through regenerated absorbent inlet nozzle 6 at the top and saturated absorbent a_{1s} is withdrawn through the saturated absorbent outlet nozzle 9 at the bottom of each of two lower individual mass transfer units; regenerated absorbent a_{2r} is injected through regenerated absorbent inlet nozzle 6 at the top and saturated absorbent a_{2s} is withdrawn through the saturated absorbent outlet nozzle 9 at the bottom of each of four middle individual mass transfer units; and regenerated absorbent a_{3r} is injected through regenerated absorbent inlet nozzle 6 at the top and saturated absorbent a_{3s} is withdrawn through the saturated absorbent outlet nozzle 9 at the bottom of each of two upper individual mass transfer units. The stream of gas under treatment passes successively all individual mass transfer units, contacting with relatively small portion of the regenerated absorbent in every individual mass transfer units; that is equivalent to reducing load by a liquid phase on contact mass transfer devices. The use of three selective regenerated absorbents allows to extract separately three impurity components from gas under treatment, to select optimal flow rate of every absorbent and corresponding process mode for every individual mass transfer unit, as well as the sizes of structural elements of regular pack 4.

Figure 7 shows operation option of mass transfer column for absorption gas treatment from undesirable impurities with packing contact device as regular regular pack sectioned into eight individual mass transfer units; this option use three different regenerated absorbents a_1 , a_2 and a_3 to remove impurities substantially different by affinity with absorbents; at this, three lower individual mass transfer units are incorporated in the first group of adjacent individual mass transfer units through downcomers 12; in the top of the first group of adjacent individual mass transfer units regenerated absorbent a_{1r} is injected through the regenerated absorbent inlet nozzle 6 and through saturated absorbent outlet nozzle 9 at the bottom the saturated absorbent a_{1s} is withdrawn; two middle individual mass transfer units are incorporated in the second group of adjacent individual mass transfer units through downcomer 12; in the top of the second group of units through the regenerated absorbent inlet nozzle 6 the regenerated absorbent a_{2r} is injected and through saturated absorbent outlet nozzle 9 the saturated absorbent a_{2s} is withdrawn; three upper individual mass transfer units are incorporated in the third group of adjacent individual mass transfer units through downcomers 12, in the top of the third group of units through the regenerated absorbent inlet nozzle 6 the regenerated absorbent a_{3r} is injected and through saturated absorbent outlet nozzle 9 the saturated absorbent a_{3s} is withdrawn; at this, the valves 14 on downcomers 12 are opened, and valves 13 on the saturated absorbent outlet nozzles 9 and the regenerated absorbent inlet nozzles 6 are closed for two adjacent units. Thereby, mass transfer column for absorption gas treatment from undesirable impurities, equipped with the packing contact device made as regular pack separated into eight individual mass transfer units, becomes equivalent to three common absorbing columns, consisting accordingly of three, two and three units using different regenerated absorbents. The stream of gas under treatment passes successively all three groups of individual mass transfer units from top to bottom, contacting with relatively small portions of the regenerated absorbent in every group of individual mass transfer units; that is equivalent to reducing load by a liquid phase on contact mass transfer devices. The use of three selective regenerated absorbents allows to extract separately three impurity components from gas under treatment, to select optimal flow rate of every regenerated absorbent and corresponding process mode for every group of individual mass transfer units, as well as the sizes of structural elements of regular pack 4. Unlike the option shown on Figure 6, in this case there is no necessity for additional mixers for pre-regeneration averaging the composition of saturated absorbent withdrawn from every individual mass transfer unit bottom through the saturated absorbent outlet nozzle 9.

An additional advantage of declarable invention is simplicity of existing absorbing columns reconstruction to the features of declarable invention, that include additional installing regenerated absorbent inlet nozzles 6 and saturated absorbent outlet nozzles 9 for every standalone mass transfer unit and also dead plates 7 with saturated absorbent collectors 8 while keeping

absorption column body and operating contact devices either of which turns to individual mass transfer unit.

The advantages of declared invention are illustrated by the examples of calculation of mass transfer columns for absorption gas treatment from undesirable impurities, executed via mathematical modeling of ethane fraction treatment process.

Input data:

- Ethane fraction flow rate is 100,000 nm³/h (143,700 kg/h);
- Ethane fraction composition in % by mass:

Nitrogen – 1.368

Methane – 2.000

Ethane – 60.000

H₂S – 15.742

Carbon dioxide

Propane – 4.654;

- Regenerated absorbent composition in % by mass:

Diethanolamine – 16.141

methyldiethanolamine – 16.872

Water – 66.872

H₂S – 0.081

Carbon dioxide – 0.034;

- absorbing column pressure – 40 kg/cm²;

- Temperature, °C

gas under treatment inlet in a column – 25

regenerated absorbent inlet – 40;

- number of theoretical plates in a column – 8;
- number of individual mass transfer units equivalent to one theoretical dish – 2;
- individual mass transfer unit height – 1m;
- specific loading by liquid phase for cross-flow contact device in a horizontal cross section – 180 m³/(m²*h);

- in a column with diameter D, contact device horizontal section area is D²/4.

Example 1. The calculation was performed for the process of ethane fraction treatment from H₂S and CO₂ by amine-water solution with regenerated absorbent injection in the top of mass transfer column for absorption gas treatment from undesirable impurities and by its gradual saturation with sour components in a common absorbing column corresponding to the option with successive contact of all regenerated absorbent with gas under treatment at all contact devices

apparatus as eight theoretical plates corresponding to one group of individual mass transfer units including sixteen individual mass transfer units in mass transfer column equivalent to common counter current of a gas under treatment and regenerated absorbent in an absorbing column as a prototype. The results of calculation are shown in Table 1. For effective treating ethane fraction from sour gases, it is necessary to provide regenerated absorbent injection with flow rate 960t/h in the top of mass transfer column. In this case horizontal section area of packing contact device in mass transfer column will be of 5.3m² and column diameter will be of 4.6m. Mass transfer column height will be 20.6m.

Example 2. The calculation was performed for the process of ethane fraction treatment from H₂S and CO₂ by amine-water solution with separating mass transfer column into four groups of individual mass transfer units; at this, every group of individual mass transfer units consists of four individual mass transfer units and is equivalent to two theoretical plates. Regenerated absorbent is supplied by equal portions to the top of every group of individual mass transfer units, contacts with gradually clearing up ethane fraction and is withdrawn after saturating with sour impurities from the bottom of every group of individual mass transfer units. Gas and liquid phase stream characterization for all four groups of individual mass transfer units of mass transfer column for absorption gas treatment from undesirable impurities are shown in Table 2. For effective treating ethane fraction from sour gases, it is necessary to provide regenerated absorbent injection with flow rate 240t/h in the top of every group of individual mass transfer units of mass transfer column for absorption gas treatment from undesirable impurities. In this case horizontal section area of packing contact device in mass transfer column for absorption gas treatment from undesirable impurities will be of 1.3m² and column diameter will be of 2.3 m. Height of mass transfer column for absorption gas treatment from undesirable impurities will be 18.3 m.

Comparing calculation results for examples 1 and 2 shows that as a result of partitioning over individual mass transfer column height to provide individual mass transfer units incorporated in four groups of individual mass transfer units and with individual supplying it with the regenerated absorbent allows four times lower construction material consumption for contact devices of mass transfer column for absorption gas treatment from undesirable impurities and, mediated, two times lower capital costs on making column bodies providing practically equal quality of the end product, i.e. treated gas and saturated absorbent. So, for example, contents of ethane, H₂S and CO₂ in the treated gas is 88.0951, 0.0002% and 0.0000% by mass respectively, and in a prototype it is 88.0956%, 0.0001% and 0.0000% by mass respectively, while initial content of these components in initial gas was 60.000, 15.742 and 16.236% by mass respectively.

Example 3. The calculation was performed for the process of ethane fraction treatment

from H₂S and CO₂ by amine-water solution with separating mass transfer column into three groups of individual mass transfer units; at this, every group is equivalent to two theoretical plates and consists of four individual mass transfer units. Regenerated absorbent is supplied by equal portions to the top of every group of individual mass transfer units, contacts with gradually clearing up ethane fraction and is withdrawn after saturating with sour impurities from the bottom of every group of individual mass transfer units. Gas and liquid phase stream characterization for all three groups of individual mass transfer units of mass transfer column for absorption gas treatment from undesirable impurities are shown in Table 3. For effective treating ethane fraction from sour gases, it is necessary to provide regenerated absorbent injection with flow rate 240t/h in the top of every group of individual mass transfer units of mass transfer column for absorption gas treatment from undesirable impurities. In this case horizontal section area of packing contact device in mass transfer column for absorption gas treatment from undesirable impurities, as in Example 2, will be of 1.3m² and column diameter will be of 2.3m. Height of mass transfer column for absorption gas treatment from undesirable impurities will be 14.3m.

Comparing calculation results for examples 3 and 2 shows that as a result of partitioning over mass transfer column height to provide individual mass transfer units incorporated in three groups of individual mass transfer units and with individual supplying it with the regenerated absorbent, quality of treatment is virtually the same as of four-group process; in Example 3, it allows 25% lower regenerated absorbent flow rate and 25% lower construction material consumption of mass transfer column for absorption gas treatment from undesirable impurities compared to Example 2; and compared to Example 1, lower material consumption by more than 2.5 times at equal lower regenerated absorbent flow rate. In addition, the expenses on saturated absorbent regeneration will 25% lower due to reducing flow rate of regenerated absorbent circulating in a plant.

Thus, the declarable invention provides an effective solution for the task of expanding potential possibilities of the method of absorption gas treatment from undesirable impurities and enhancing a structure of mass transfer column for absorption gas treatment from undesirable impurities while sufficient lowering the equipment construction material consumption and/or operating costs on absorbent regeneration.

Item	Unit	Gas under treatment	Treated gas after 16 sections	Regenerated absorbent	Saturated absorbent after 16 Sections
Volume flow rate	m ³ /h	100000	71882	-	-
Mass flow rate	t/h	143.70	95.85	960.00	1007.85
Composition:	% by mass				
- Nitrogen		1.3680	2.0025	-	0.0048
- Methane		2.0000	2.9387	-	0.0060
- Ethane		60.0000	88.0956	-	0.1858
- H ₂ S		15.7420	0.0001	0.0810	6.3414
- Carbon dioxide		16.2360	0.0000	0.0340	2.3277
- Propane		4.6540	6.8578	-	2.3477
- Diethanolamine		-	-	16.1410	15.3731
- Methyl-diethanolamine		-	-	16.8720	16.0688
- Water		-	0.1059	66.8720	63.6799

Table 1

Item	Unit	Gas under treatment	Regenerated absorbent	First group of individual mass transfer units (Section 1 to 4)		Second group of individual mass transfer units (Section 5 to 8)		Third group of individual mass transfer units (Section 9 to 12)		Fourth group of individual mass transfer units (Section 13 to 16)	
				Treated gas	Saturated absorbent	Treated gas	Saturated absorbent	Treated gas	Saturated absorbent	Treated gas	Saturated absorbent
Volume flow rate	m ³ /h	100000	-	85615	230	74221	227	72239	217	71882	216
Mass flow rate	t/h	143.70	240.00	119.90	263.80	99.45	260.45	96.32	243.13	95.85	240.46
Composition:	% by mass										
- Nitrogen		1.3680	-	1.6308	0.0040	1.9544	0.0045	2.0063	0.0046	2.0039	0.0048
- Methane		2.0000	-	2.3851	0.0054	2.8600	0.0059	2.9392	0.0055	2.9395	0.0056
- Ethane		60.0000	-	71.5009	0.1869	85.7084	0.1891	88.0863	0.1622	88.0951	0.1661
- H ₂ S		15.7420	0.0810	5.0778	6.3414	0.7854	2.1127	0.0002	0.4015	0.0002	0.0813
- Carbon dioxide		16.2360	0.0340	13.5087	2.7361	1.6970	5.6026	-	0.7283	-	0.0345
- Propane		4.6540	-	5.5484	0.0132	6.6551	0.0130	6.8468	0.0098	6.8553	0.0098
- Diethanolamine		-	16.1410	-	14.6846	-	14.8737	-	15.9331	-	16.1099
- Methyldiethanolamine		-	16.8720	-	15.3491	-	15.5468	-	16.6542	-	16.8390
- Water		-	66.8720	0.3483	60.6792	0.3396	61.6517	0.1212	66.1009	0.1061	66.7490

Table 2

Parameter	Unit	Gas under treatment	Regenerated absorbent	End product characterization for column with three groups of individual mass transfer units (Section 1 to 12)		End product characterization for column with four groups of individual mass transfer units (Section 1 to 16)	
				Treated gas after Section 12	Saturated absorbent after 1 Section	Treated gas after Section 16	Saturated absorbent after 1 Section
Volume flow rate	m ³ /h	100000	-	72239	230	71882	230
Mass flow rate	kg/h	143.70	240.00	96.32	263.80	95.85	263.80
Contents:	% by mass						
- Nitrogen		1.3680	-	2.0063	0.0040	2.0039	0.0040
- Methane		2.0000	-	2.9392	0.0054	2.9395	0.0054
- Ethane		60.0000	-	88.0863	0.1869	88.0951	0.1869
- H ₂ S		15.7420	0.0810	0.0002	6.3414	0.0002	6.3414
- Carbon dioxide		16.2360	0.0340	-	2.7361	-	2.7361
- Propane		4.6540	-	6.8468	0.0132	6.8553	0.0132
- Diethanolamine		-	16.1410	0.0000	14.6846	-	14.6846
- Methyldiethanolamine		-	16.8720	0.0000	15.3491	-	15.3491
- Water		-	66.8720	0.1212	60.6792	0.1061	60.6792

Table 3

CLAIMS

1 Method of absorption gas sweetening from undesirable impurities comprising
 countercurrent contact of the gas to be purified and regenerated absorbent in the mass transfer column
 with resulting purified gas and saturated absorbent, characterized by the fact that packed contact
 5 device of the mass transfer column is separated in height into independent mass transfer sections
 with countercurrent or crosscurrent movement of the purified gas and regenerated absorbent,
 at that the flow of purified gas is sequentially passed upwards through all independent mass transfer
 sections of the mass transfer column, regenerated absorbent flow is introduced into the upper part of
 each independent mass transfer section, and saturated absorbent flow is withdrawn from the lower
 10 part of each independent mass transfer section.

2 Method according to claim 1, characterized by the fact that when the purified gas
 contains one extractable impurity, one type of selective regenerated absorbent is supplied to each
 independent mass transfer section and/or group of adjacent independent mass transfer sections.

3 Method according to claim 2, characterized by the fact that saturated absorbent flows
 15 withdrawn from the lower part of each independent mass transfer section and/or group of adjacent
 independent mass transfer sections are combined for regeneration into one flow outside the mass
 transfer column

4 Method according to claim 3, characterized by the fact that change in concentration
 of the extractable impurity for each independent mass transfer section dC is taken the same for all
 20 independent mass transfer sections and is determined by the equation:

$$dC = (C_H - C_K) / N,$$

where C_H is a concentration of the extractable impurity in the purified gas at the inlet of mass
 transfer column,

C_K is a concentration of the extractable impurity in the purified gas at the outlet of mass
 25 transfer column,

N is a number of independent mass transfer sections according to the height of the mass
 transfer column.

5 Method according to claim 2, characterized by the fact that the regenerated absorbent
 is supplied in each independent mass transfer section in the same quantity.

6 Method according to claim 5, characterized by the fact that minimum flow rate of the
 30 regenerated absorbent is determined by such distribution of concentrations on the extractable impurity
 at the inlet of gas in the j -th independent mass transfer section $C_{H,j}$ and at the outlet of it $C_{K,j}$, that

$$\Sigma(C_{H,j} - C_{K,j}) / (K \cdot C_{K,j}) = \min,$$

where K is Henry constant at absorption.

7 Method according to claim 1, characterized by the fact that when the purified gas

contains two or more extractable impurities with significantly different affinity to absorbents, the correspondent type of selective regenerated absorbent is supplied to each independent mass transfer section and/or group of adjacent independent mass transfer sections for extraction of a specific impurity.

5 8 Method according to claim 1, characterized by the fact that temperature of absorption sweetening in each independent mass transfer section is controlled by changing the temperature of the regenerated absorbent, heated or cooled in additional external heat exchangers.

 9 Method according to claim 1, characterized by the fact that one ore more additional flows of one type of selective regenerated absorbent is supplied to one ore more independent mass
10 transfer sections with crosscurrent movement of the purified gas and regenerated absorbent on intermediate stages with the same or different parameters.

 10 Mass transfer column of gas absorption sweetening from undesirable impurities, consisting of a vertical body for countercurrent contact of purified gas and regenerated absorbent in the packed contact device of the mass transfer column, nozzle for input of gas to be purified and
15 output of purified gas, characterized by the fact that the packed contact device is separated in height into independent mass transfer sections with countercurrent or crosscurrent movement of the purified gas and regenerated absorbent, at that each independent mass transfer section is separated from the adjacent independent mass transfer section with a dead tray and is equipped in the upper part with low-pressure fluid distributor with inlet nozzle for regenerated absorbent, at that the dead
20 tray is equipped with an accumulator for collection of saturated absorbent with nozzle for removal of saturated absorbent from the body of mass transfer column and branch pipe for transfer of the purified gas from the downstream independent mass transfer section into the upstream independent mass transfer section through the dead tray.

 11 Column according to claim 10, characterized by the fact that in the independent mass
25 transfer section with countercurrent or crosscurrent movement of the purified gas and regenerated absorbent a regular PETON nozzle is used.

 12 Column according to claim 10, characterized by the fact that in the independent mass transfer section with crosscurrent movement of the purified gas and regenerated absorbent several intermediate stages of regular PETON nozzle are used, separated by intermediate low-pressure fluid
30 distributors and intermediate device for injection of the regenerated absorbent.

 13 Column according to claim 10, characterized by the fact that branch pipes of two successive dead trays are located on different sides of a regular nozzle of independent mass transfer section in the direction of movement of the purified gas.

 14 Column according to claim 10, characterized by the fact that the nozzle of removal of
35 saturated absorbent from the body of mass transfer column of the upstream independent mass transfer

section and the nozzle of injection of regenerated absorbent in the low-pressure fluid distributor of the downstream mass transfer section are equipped with a downcomer.

15 Column according to claim 14, characterized by the fact that M adjacent independent mass transfer sections equipped with M-1 downcomer form a group of adjacent independent mass transfer sections, in which one type of selective absorbent is supplied.

16 Column according to claim 15, characterized by the fact that the number of adjacent independent mass transfer sections M in the group of adjacent independent mass transfer sections is determined by the condition:

$$Z = \sum_{j=1}^{j=M} Z_j * (1 - Z_j)^{M-1},$$

10 where Z is a required extraction level of a particular impurity in this group of adjacent independent mass transfer sections,

Z_j is a required extraction level of a particular impurity in one independent mass transfer section.

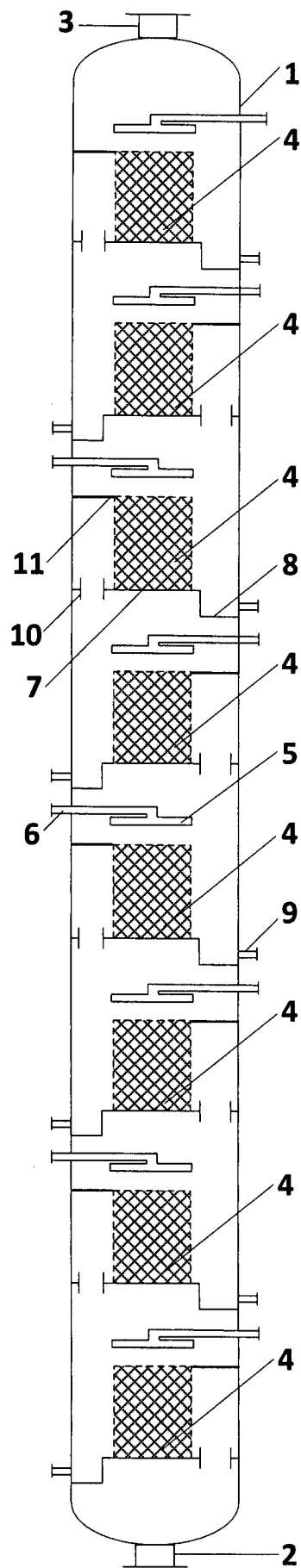


Fig. 1

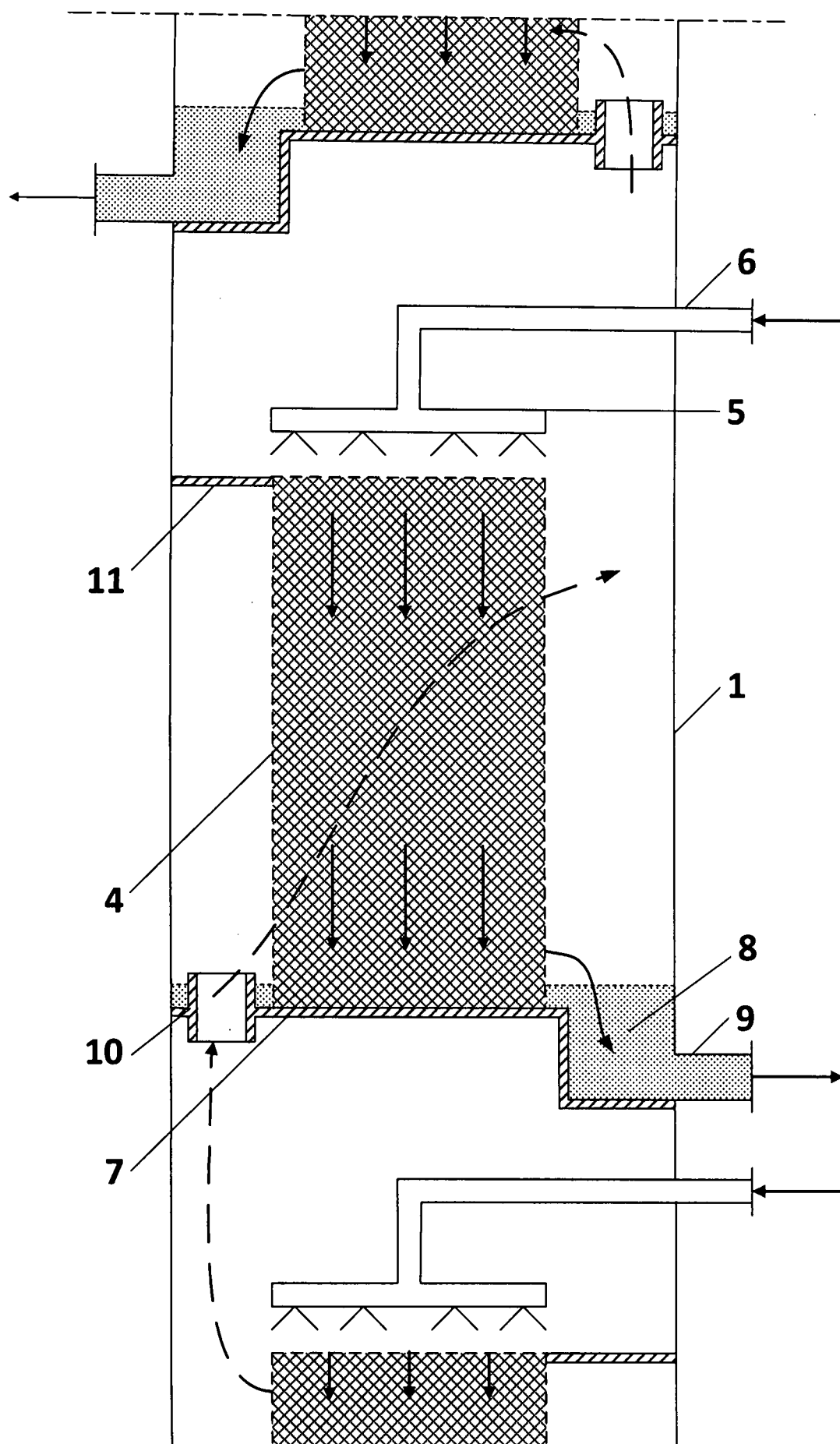


Fig. 2

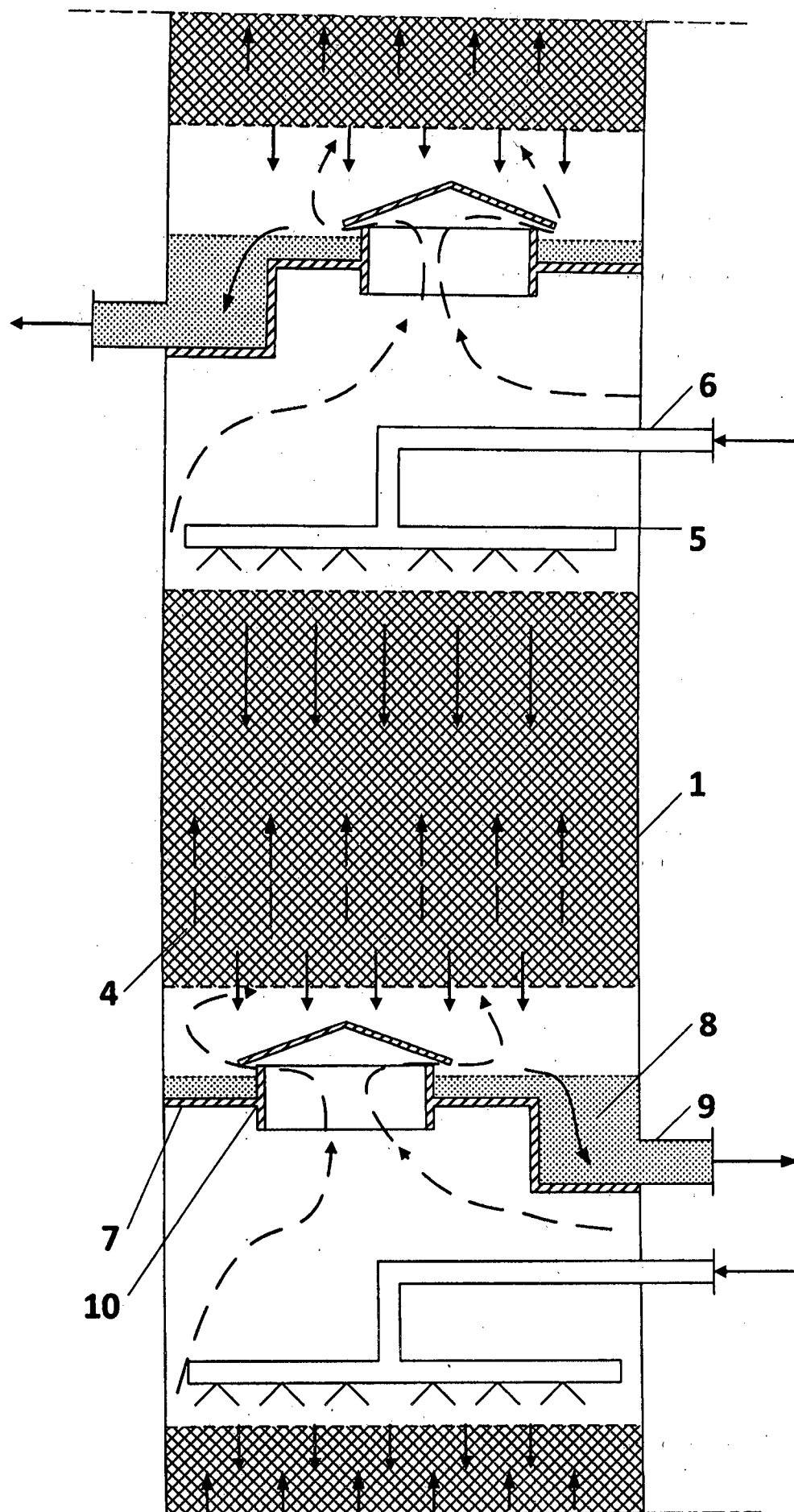


Fig. 3

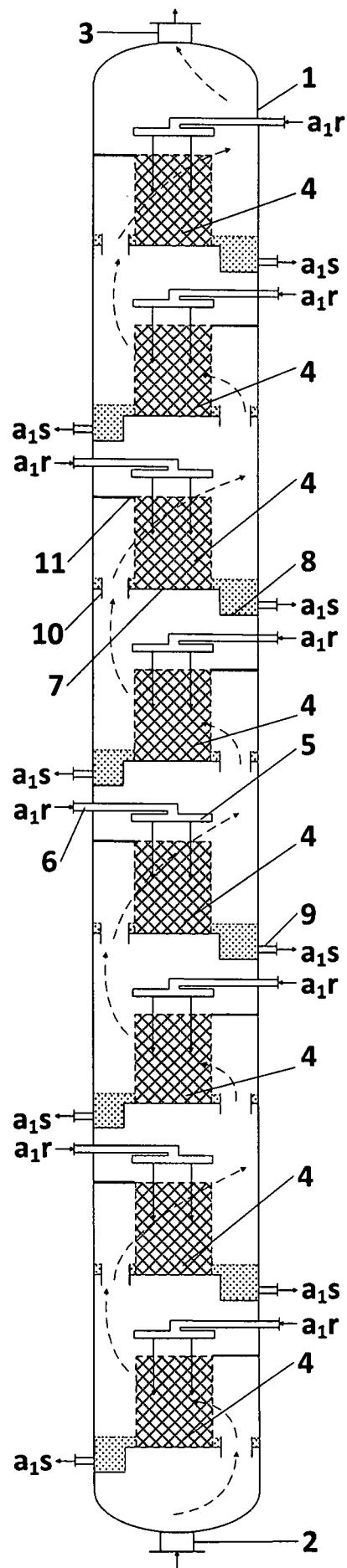


Fig. 4

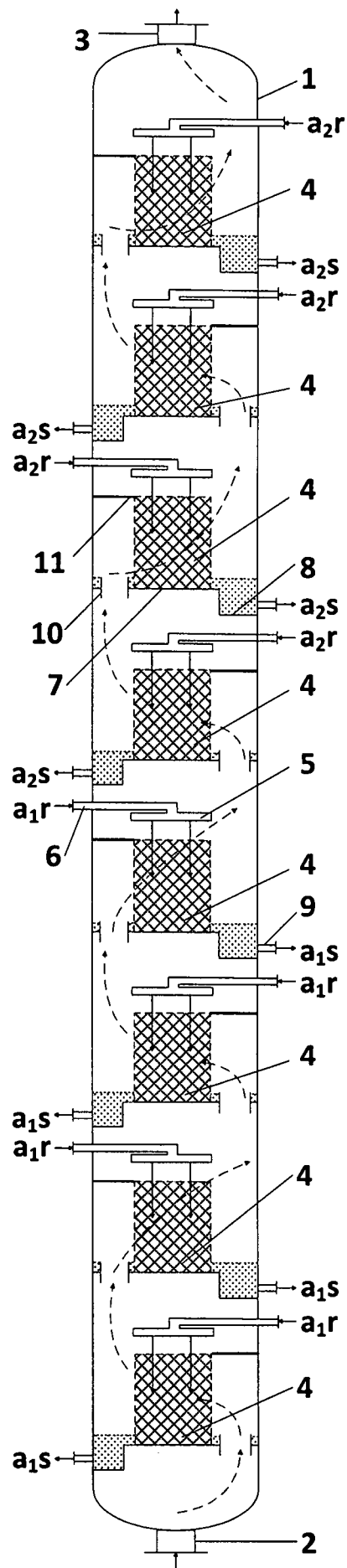


Fig. 5

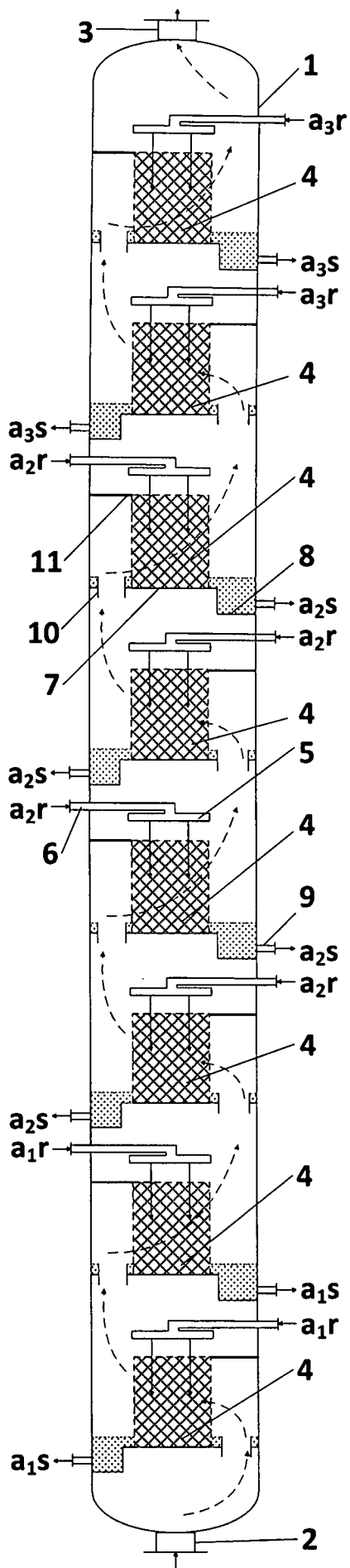


Fig. 6

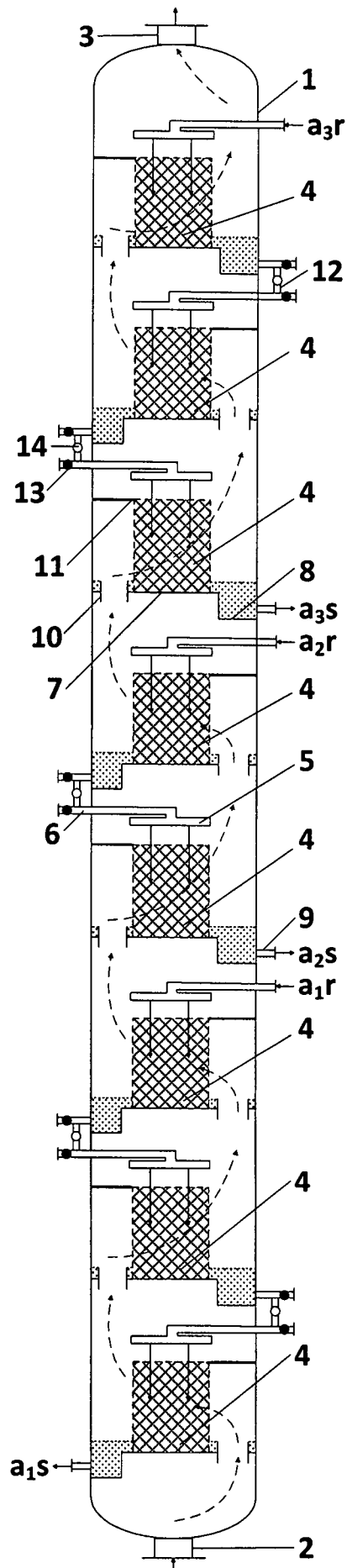


Fig. 7