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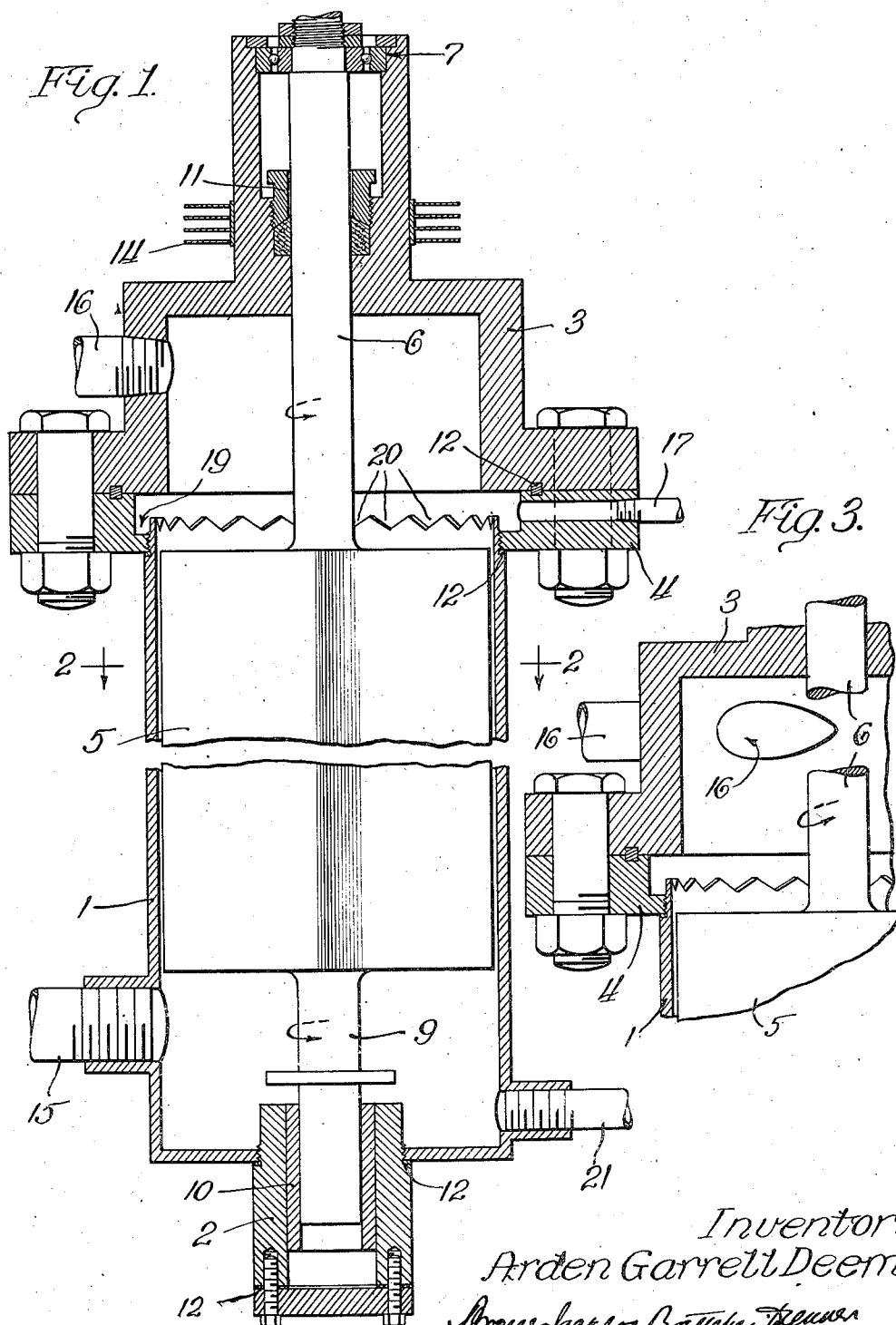
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MEANS FOR EFFECTING MATERIAL AND HEAT TRANSFER

Filed Nov. 8, 1940

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

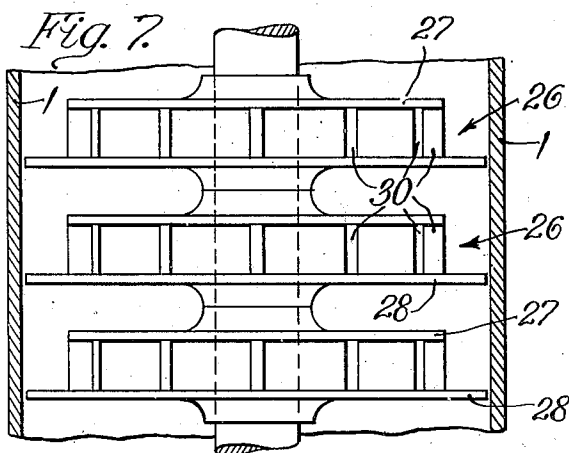
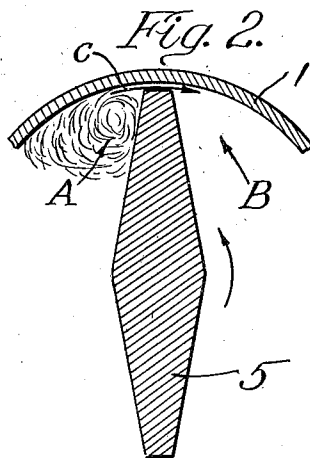
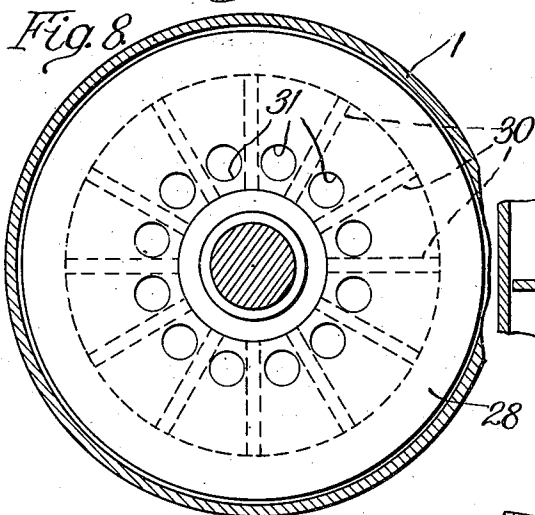
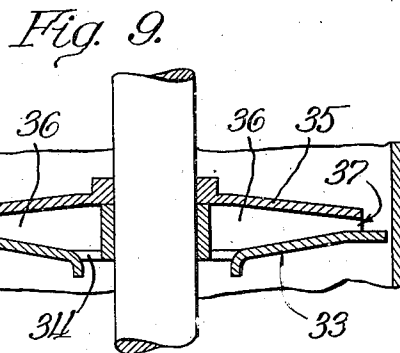
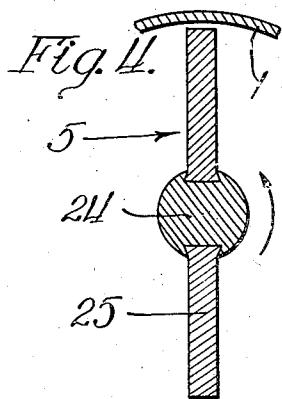
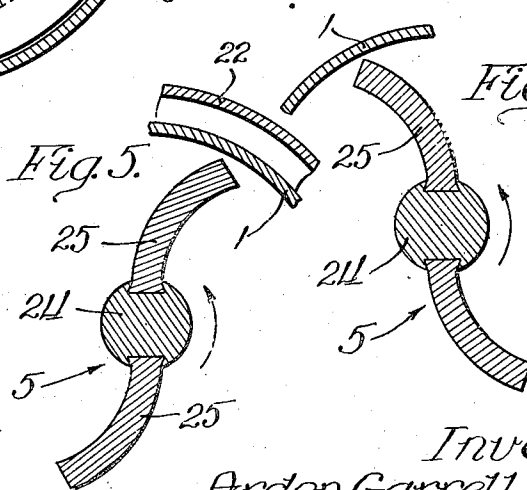


Fig. 6.

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MEANS FOR EFFECTING MATERIAL AND
HEAT TRANSFER

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Application November 8, 1940, Serial No. 364,776

3 Claims. (Cl. 261—83)

My invention relates to means for the transfer of matter and heat between a liquid and a gas phase.

One field of use of my invention is in operations involving gas and liquid contact.

The desideratum in gas and liquid contact operations is to bring, as speedily and intimately as possible, the individual particles of gas into contact with particles of liquid, or vice versa. Since both media are fluids, it is difficult to control the movements of the particles. The problem is to provide a way of getting and keeping control of the particles of gas and of liquid so as to be able to compel their orderly movements to the end of getting the individual particles of gas contacted with particles of liquid, or vice versa.

Another field of use is conversion of a vapor into the liquid phase, or vice versa. For evaporation, the problem again is to provide a way of securing and maintaining control of the vapor particles and of the liquid particles to remove the vapor particles from the surface of the liquid to prevent return. Likewise for condensation, the problem is to get and keep control of the particles of vapor and of liquid, so as to be able to bring the vapor particles rapidly and intimately in contact with liquid particles and keep them there.

Since in each case, motion of the particles of one fluid relative to the particles of the other is essential, some means for imparting motion is implicit in the solution of the problem. A liquid is distinguished from a gas or vapor in the limited degree of freedom of the particles or in other words, in the cohesion of the particles of a liquid as distinguished from the lack of cohesion in a gas or vapor.

According to one phase of my invention, I provide means for intensifying the characteristics of the respective fluids. To this end, I spread the liquid out in a thin film upon a solid wall. By its adhesive effect, through wetting, it is bound to the wall, and has its mobility reduced. By its cohesive effect it presents a thin substantially continuous body of small mass and large area.

The gas is more difficult to control. I move it by a vane and restrain its travel in a generally circular path whereby centrifugal force is developed.

The driven body of gas is thereby pressed against the restraining circular wall, particularly on the forward surface of the vane. An area of reduced pressure is produced back of the vane. The gas moves not only bodily with the vane, but also has an internal movement of eddying or

churning. Now by forming the liquid film upon the circular restraining wall, I am able to hold the liquid in ideal condition for contact with the gas in the region of controlled movement of the gas. Thus I am able, as it were, to hold a thin film of liquid and scour it vigorously with a body of gas having a high degree of internal motion. Gravity flow of the film changes the surface particles of liquid. The scouring of the gas along the liquid surfaces also imparts internal motion to the liquid.

According to the preferred form of apparatus embodying my invention, I provide a cylinder in which a blower blade or vane rotates with the outer edges of the blower blade in close proximity to the walls of the cylinder where the liquid is flowing in a thin film. The blower blade acting on the gas in the cylinder builds up a plenum of gas ahead of the blade and causes a reduction in pressure behind the blade, with the result that this differential in pressure forces the gas past the edge of the blade, and since the edge of the blade is near the film of liquid, a stream of gas is kept in motion adjacent the surface of the liquid and a body of gas is caused to be scoured against the surface of the liquid ahead of the blade.

While the specific illustration and detailed description is directed to the art of distillation, it is to be understood that this is by way of exemplification and not by way of limitation. The invention is applicable to the absorption of one or more components from a gas phase by a suitable absorbing liquid with or without chemical reaction between the absorbed gases and the liquid medium, as for example, the absorption of SO₂ from flue gases by a reactive solution such as sodium sulfite, or the absorption of CO₂, either pure or in the presence of inerts, such as nitrogen, by sodium carbonate solutions. Nor is it required that the liquid phase be homogeneous, as my invention may also be applied to the absorption of gas by suspension or slurries in the liquid phase, as for example, the absorption of CO₂ by a slurry of sodium carbonate in water, or other suitable liquid media. In the same fashion, the means may also be used for the deabsorption of gases or vapor from a solution, for example, in the deabsorption of benzene vapor from straw oil by means of steam.

Likewise, the means may also be used to advantage in humidification or dehumidification operations, for example, in air conditioning where the humidification or dehumidification of air by

water, which is maintained at a suitable temperature, is desired.

In the examples cited above, a net transfer of heat between the gas and liquid phase may or may not result. In general such transfer of heat may be considered as incidental to the operation of material transfer and depends upon the particular system under consideration. In the operation of partial condensation, as for example, in the system water vapor-glycerine vapor, it may be desired to condense the glycerine to a liquid with a minimum condensation of water. The means hereinafter described has been found to be of particular advantage in the operation of partial condensation where the removal of heat is essential for the operation. Similarly, in the absorption of NO_2 in water to form nitric acid, followed by the deabsorption of the NO reaction product, and subsequent reoxidation of the NO to NO_2 by air, in situ, the removal of heat is of great importance. Here again the means to be described is of great advantage.

Also, while the means herein disclosed are particularly applicable to the operations of distillation, absorption, deabsorption, humidification, dehumidification and equilibrium partial condensation, the invention is not limited to so-called diffusional operations as will be apparent hereinafter.

Now in order to acquaint those skilled in the art with the construction and operation of a specific embodiment of my invention, I shall describe, in conjunction with the accompanying drawings, the means for embodying a specific example of my invention.

In the drawings:

Figure 1 is a vertical sectional view of the device of my invention;

Figure 2 is a section on line 2-2 of Figure 1;

Figure 3 is a fragmentary vertical sectional view of the device of Figure 1 showing a modified form of discharge opening for the gases;

Figures 4, 5 and 6 are sectional views of modified forms of impellers;

Figure 7 is an elevational view of a portion of another modified form of impeller;

Figure 8 is a bottom view of one section of the impeller shown in Figure 7; and

Figure 9 is a vertical sectional view of another form of impeller.

The structural features and mode of operation of a specific embodiment of my invention for performing a distilling operation will now be described.

Referring to Figure 1, the device comprises a vertically disposed casing 1 closed at the lower end by an insert 2, and at the upper end by a head 3 suitably secured to the flange 4 mounted at the upper end of the casing. An impeller 5 is rotatably mounted in the casing by means of a shaft 6 at the upper end of the impeller and carried in the radial and thrust bearing 7. The bearing 7 supports the weight of the impeller, and the shaft 9 at the lower end of the impeller is guided in a bearing 10 in the insert 2. A packing gland 11 seals the shaft 6 in the head 3. Gaskets 12 seal the various parts of the assembly. The packing gland and the gaskets may be any of the conventional types as best suited to the requirements of particular conditions of temperature, pressure and corrosion resistance specifically encountered.

Fins 14 are secured to the head 3 around the packing gland 11 for cooling the packing gland. When unusually high head temperatures are en-

countered, the cooling fins may be replaced by a water jacket if desired.

A vapor inlet 15 communicates with the lower end of the casing, and a vapor outlet 16 is provided in the head 3 at the upper end of the casing. A connection 17 is provided for the introduction of the reflux liquid into the apparatus. The liquid enters the channel 19 in the flange 4 and flows through the serrations or weir notches 20 which are cut in the projecting tube periphery and down the inner wall of the casing in a thin uniform film adhering to the wall and draining through discharge opening 21 at the bottom of the casing.

The rate of feed of liquid to the channel 19 is such that all the liquid flows down as a film and the formation of any free liquid bodies as drops or free particles is avoided.

In the operation of the apparatus as an enriching fractionating column, the mixed vapors to be fractionated are introduced at 15 and are caused to swirl or cyclone, as they rise through the casing to the exit 16. Reflux liquid is introduced at 17 and flows down the casing wall as a thin film to the outlet at 21. This mode of contact between the vapor and liquid films as accomplished by my invention is especially effective as will be apparent hereinafter. The velocity of the vapors in the cyclone may be varied at will by changing the speed of rotation of the impeller. In general, I prefer a speed of from 1,000 to 10,000 R. P. M. when using a 2 3/4 inch impeller in a 3 inch I. D. casing. The most desirable speed, however, is from 1,700 to 4,000 R. P. M. In this connection it should be observed that the impeller width is specifically of such dimension as to allow free passage of the gas around the blade tip and also to permit the reflux to flow downward undisturbed on the casing wall. This relationship is shown in Figures 1 and 2.

The impeller does not operate upon liquid but only upon the gaseous medium which may be a gas or vapor or mixture of gas and vapor. No free or unattached bodies or particles of liquid are allowed to form, and hence with all the rapid movement of gas or vapor over the surface of the film of liquid, no liquid as such is carried over.

In the operation of the device, rotation of the impeller in the direction of the arrows builds up a plenum of gas ahead of the blade tips in the region A (Figure 2) and causes a rarefaction of gas in the region B, after the blade tips. This difference in pressure causes the gas to pass by the blade tips in the direction of the arrow c. This action brings the current of gas in close contact with the liquid and keeps the molecules of gas which come in physical contact with the liquid in motion. At the same time a body of gas held by centrifugal force against the inner peripheral wet surface of the casing cylinder 1 is driven ahead of the vane. This body of gas tends to have a fairly large internal movement of eddying or rolling on the surface of the liquid film. It is obvious that such active scouring of the film by the swirling and sweeping gas can not be obtained by drawing gas through a fan and then blowing it against a wall carrying the liquid. It is only the use of a vane rapidly passing close to the surface of the film, driving and scouring the gas over the film that will produce the novel effect characteristic of the present invention.

It will be observed that while the gas is introduced into the apparatus and conducted there-through in a direction counter to the direction of flow of the liquid, this may not, as in special cases

of humidification or dehumidification, be essential. The specific requirements of concurrent or counter-current flow are, of course, well known to one skilled in the art. Accordingly, the gas may in some cases be passed through the apparatus in the same general direction as that of the liquid, if desired.

The length and the diameter of the impeller may, of course, be varied from the proportions shown.

The apparatus as shown comprises a closed circuit for each of the fluids, but it is contemplated that either may be an open circuit. In the event that a liquid is being treated and the resultant gas is waste, the gas on passing through the apparatus may be discharged to the atmosphere; on the other hand, when the liquid on passing through the apparatus is waste, it can of course be run into the sewer.

As a typical example of the results that may be obtained when the apparatus is used as a fractionating column, the data for the distillation of a mixture of benzene-ethylene dichloride at total reflux are shown in Tables I and II.

Table I

[Speed of impeller 3,400 R. P. M.]

Cc./min. of liquid condensate	Mol fraction benzene in residue	Mol fraction of benzene condensate	No. of actual plates
310	52.7	62.5	4.8
490	51.4	62.0	5.0
960	47.8	57.5	4.6
1,430	47.5	53.1	3.2
1,790	47.0	53.4	2.9
2,020	44.1	50.1	2.9

In Table II are shown similar data for an impeller speed of 1700 R. P. M.

Table II

[Speed of impeller 1,700 R. P. M.]

Cc./min. of liquid condensate	Mol fraction benzene in residue	Mol fraction of benzene condensate	No. of actual plates
380	47.5	56.1	4.0
585	46.3	56.5	4.4
1,050	47.3	58.2	5.0
1,400	44.1	58.5	5.4
1,820	44.1	56.1	5.0
2,200	42.6	51.3	4.0

These data show that for a given mixture and rate of through put an optimum speed exists. It is expected, therefore, that one skilled in the art will adjust the speed to give the optimum results for a given through put. By "through put" is meant the rate at which the fluids pass through the device.

In the results given in Tables I and II the impeller was 24 inches long. At the optimum of 5.0 plates, this corresponds to a height for each plate of 4.8". In contrast to this exceptional efficiency, an empty 3" tube has a fractionating efficiency of one plate in 120 inches and when packed with Raschig rings, an efficiency of one plate every 12 to 24 inches. It should further be noted in addition to the exceptional efficiency of my apparatus, at rates of through put heretofore unattainable, that the pressure drop through the apparatus is essentially negligible. This absence of pressure drop is of particular importance in vacuum distillation.

In the above, the column was described as an

enriching section. To one skilled in the art, the apparatus may also obviously be used as an exhausting section. Likewise, when both an enriching and an exhausting section are desired, two columns may be placed in tandem by suitable connections. By the same token when more theoretical plates are required than can be secured by one unit of the apparatus, as many units as desired may be placed in series by suitable interconnecting pipes. Alternatively, units may obviously be placed in parallel to secure any desired through put or capacity over and beyond that obtainable with one unit.

As before mentioned, the apparatus may be used for absorption with results manifold better than can be obtained by previous equipment. When used as an absorption column, the gases to be treated enter at 15, pass through the apparatus, and leave at 16. The absorbing liquid enters at 17, flows down the casing wall as a thin film and leaves at 21. Similarly, in air conditioning, the air to be dehumidified and cooled enters at 15 and leaves at 16, while the cooling water enters at 17 and leaves at 21.

In the general cases of distillation, absorption, deabsorption, humidification, and dehumidification, it is usually desired that the apparatus be rendered adiabatic by a suitable covering of insulating material such as magnesia. The insulating material may be replaced by a heat transfer medium, either for supplying heat or removing heat from the walls of the chamber, to suit particular operations. In the production of nitric acid by the absorption of NO₂ in water, it is particularly desirable that the reaction be carried out with external cooling. Such cooling means conveniently may be supplied by replacing the magnesia insulation with a cooling jacket of any suitable form. Likewise, in the case of humidification it might be desirable to supply heat to the walls of the chamber, in which case a heating jacket of suitable form may be fitted on the device.

In Figure 5, a jacket 22 is shown fragmentarily, which may be a heat transfer medium, either for supplying heat to or removing heat from the casing wall, or an insulating medium.

When used as a partial condenser, the above mentioned cooling jacket is of course provided. The mixed vapor enters at 15 and the denuded vapor leaves at 16. In this case connection 17 is unnecessary as the condensate only is withdrawn at 21.

In Figure 3 I have shown fragmentarily a device similar to that of Figure 1, but with the vapor outlet 16 connected tangentially to the head 3. This type of discharge opening more readily accommodates the swirling motion of the gas.

As is apparent from the foregoing, the designer is allowed considerable latitude in the adaptations of the apparatus without departing from the spirit of my invention. As a further example of the modifications, possible alternative impeller forms are shown in Figures 4 to 6, inclusive. These impeller forms, instead of being solid blade impellers as shown in Figure 2, each comprises a shaft 24 to which are secured blades 25. Figure 4 illustrates a straight radial blade while Figure 5 is a concave backward blade, and Figure 6 a concave forward blade.

Another form of impeller is shown in Figure 7, which comprises a series of blower elements 26 mounted on a shaft. The number of blower elements may be varied to suit the particular conditions under which the device is to be used.

Each blower element consists of an upper plate 27 and a lower plate 28 between which are secured blades 30. These blades may be straight, or forward or backward concave, as may be desired. The lower plate 28 is of such diameter as to allow only sufficient clearance at the wall of the casing to permit the reflux liquid to flow downward undisturbed. The upper plate 27 should be sufficiently smaller than the lower plate to allow free escape of the vapor from the blade tips.

Figure 8 is a bottom view of one of the blower elements. Openings 31 are provided in the lower plate 28 for the entrance of gas to the blower element.

Figure 9 shows a form of centrifugal compressor unit. The number of these units, as in the case of the type shown in Figures 7 and 8, will depend on the particular conditions encountered in use of the apparatus. The unit comprises a throat disc 33 with openings 34 therein located near the center thereof for the passage of gas through the impeller, an upper disc 35, and blades 36 positioned between the discs. The throat disc 33, as in the previous forms, is of such diameter that a small space is left between it and the wall of the casing only sufficient to allow the liquid to fall undisturbed, while the upper disc 35 is somewhat smaller in diameter to allow the free escape of gas. The opening 37 being smaller in vertical dimension than the space in the interior of the unit provides greater velocity of the gas on leaving the unit and striking the surface of the liquid.

One great advantage of my apparatus in addition to the unusually high capacity, low hold up, low pressure drop, and high efficiency is that great economy is effected in the building height required to house the equipment. In general, this is a factor of considerable magnitude.

It is to be understood that the specific embodiment and the modified forms of the apparatus herein shown and described are to be considered as exemplary only, and not limiting, and that various changes in details and rearrangement of parts therein may be made without departing from the spirit and scope of the invention.

I claim:

1. Means for contacting gas and liquid which

comprises a vertical cylinder into which gaseous fluid is adapted to flow, means for depositing liquid in the form of a film upon the inner surface of the cylinder and allowing the same to gravitate downwardly, said means comprising a circumferential distributing channel at the upper end of the cylinder and a liquid supply means extending thereto for supplying liquid at a rate which will maintain said film without formation of free liquid, and a rotatably mounted gas impeller in the cylinder for moving gaseous fluid at high velocity along the surface of said film, said impeller being free of contact with the liquid, said cylinder being substantially free of unattached bodies of liquid.

2. Means for contacting gas and liquid which comprises a vertical cylinder into which gaseous fluid is adapted to flow, means for depositing liquid in the form of a film upon the inner surface of the cylinder and allowing the same to gravitate downwardly, said means comprising an open channel with spaced entry ports to the inner surface of the cylinder, and a rotatably mounted gas impeller in the cylinder for moving gaseous fluid at high velocity along the surface of said film, said impeller being free of contact with the liquid.

3. In combination, a chamber for gaseous fluid having a wall provided with an inner surface which extends in a generally vertical direction, liquid distributing means having a liquid inlet, and having liquid outlets for discharging liquids upon the surface of the wall of the chamber, said outlets distributing said liquid upon the upper part of the wall surface in the form of a liquid film adhering to the surface of the wall and held thereto by the adhesion of the liquid of the film to said surface, but capable of flowing downwardly along said surface under the influence of gravity, a gaseous fluid agitator having a vane movable along the wall transversely of the downward flow of the film of liquid, said agitator vane being mounted to sweep along the wall, but out of contact with the liquid film, means for supplying gaseous fluid to that portion of the chamber in which said agitator moves, and an outlet for discharging gaseous fluid from the chamber.

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