April 13, 1954 C. OTTO 2,675,215

BENZOL SPRAY SCRUBBER

Filed June 22, 1948

3 Sheets-Sheet 1

Fig. 1.

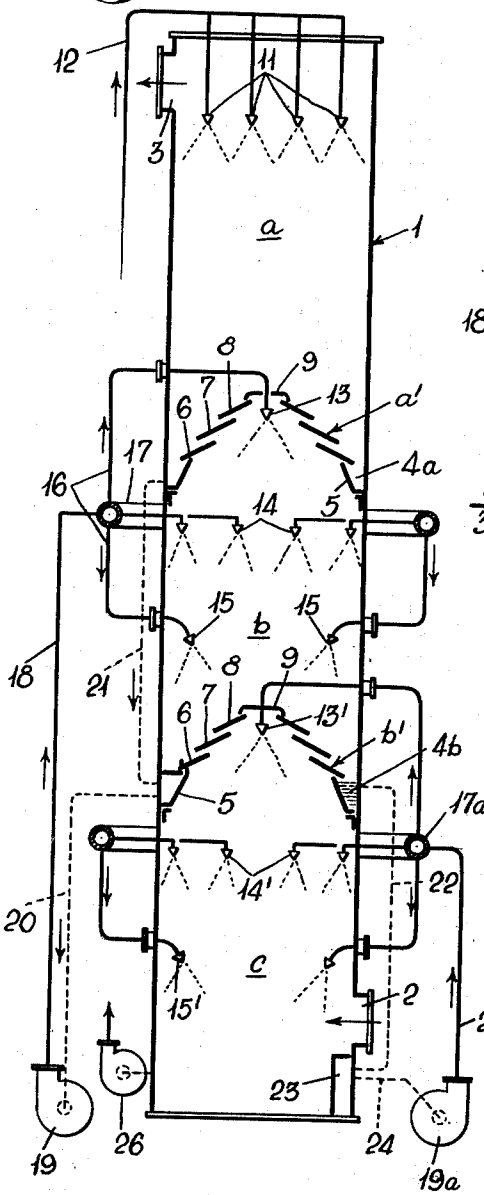
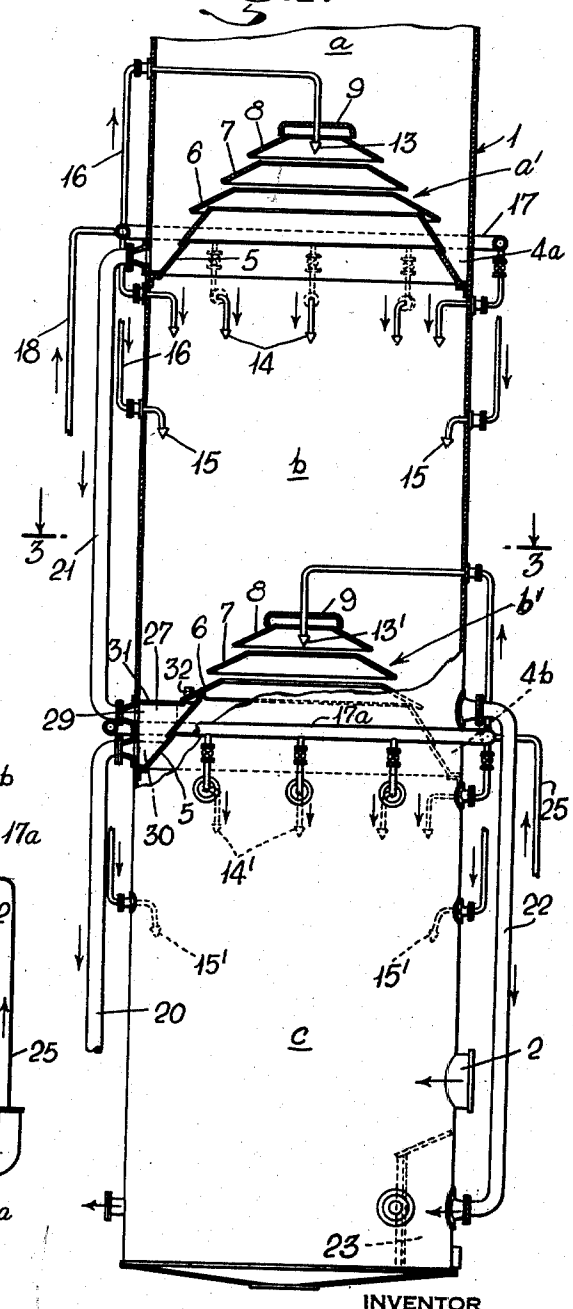


Fig. 2.



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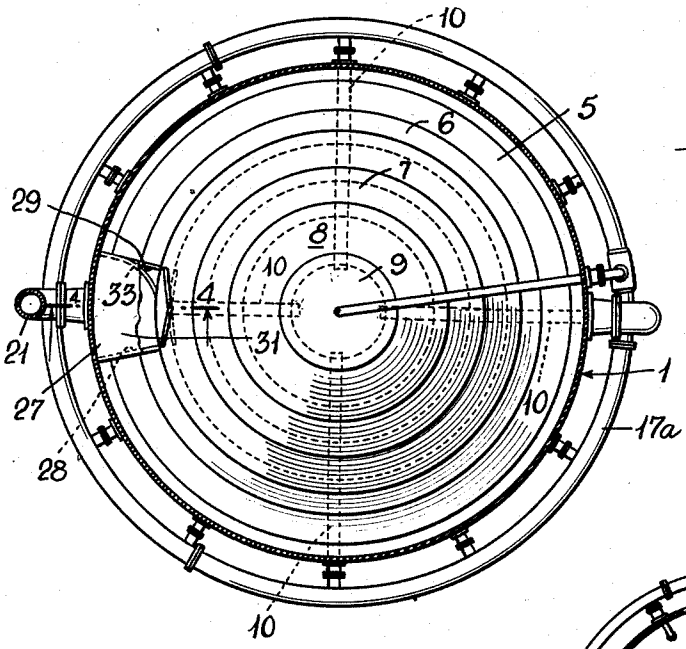
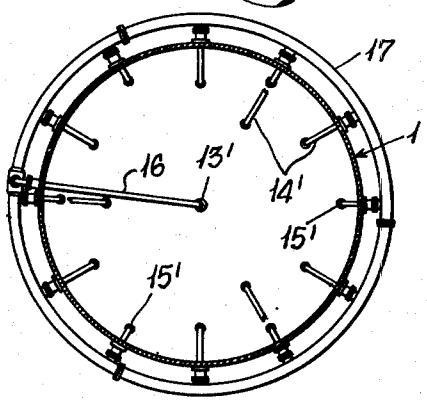


Fig. 3.

Fig. 3a.



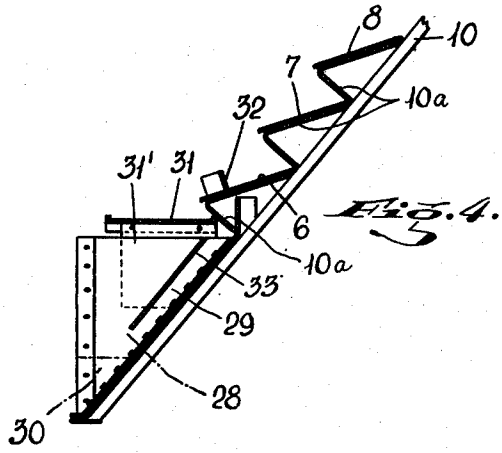


Fig. 4.

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BENZOL SPRAY SCRUBBER

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Fig. 5.

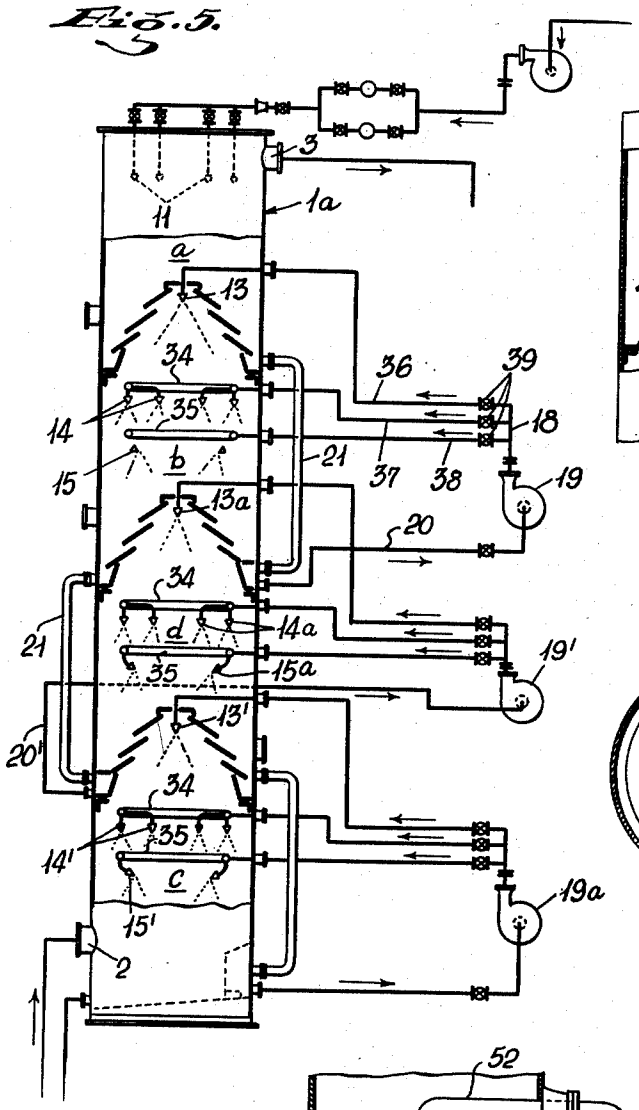


Fig. 6.

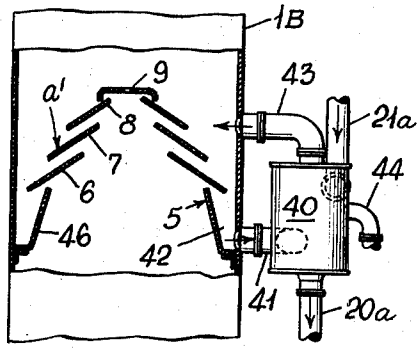
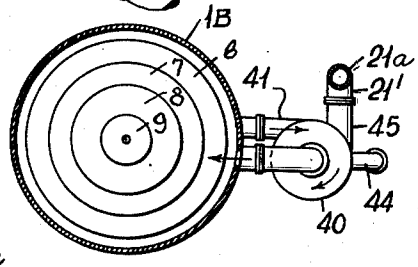


Fig. 7.



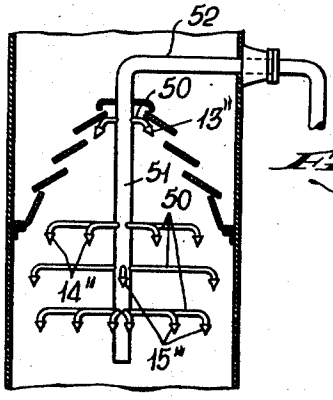


Fig. 8.

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UNITED STATES PATENT OFFICE

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BENZOL SPRAY SCRUBBER

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Application June 22, 1948, Serial No. 34,515

14 Claims. (Cl. 261—36)

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The general object of the present invention is to provide an improved method of, and improved apparatus for separating vapor constituents from a gas by passing the gas through a scrubbing chamber in which the gas is brought into intimate contact with a liquid scrubbing agent adapted to absorb said vapors.

The invention was devised for use, and is of special utility in separating benzol or light oil vapors from distillation gas and particularly coke oven gas, by scrubbing the latter with a vapor absorbing liquid. The latter may well be, and in this country ordinarily is, the petroleum product known as "straw oil", though other wash oils may be used, and in Europe the scrubbing agent usually employed to recover benzol vapors is the tar oil known as creosote oil. The word "benzol" is used generically herein to apply to substances known as light oils including benzene, toluene, xylenes and solvent naphtha in their liquid and gaseous phases. In the ordinary use of the present invention, benzol vapors are separated from coke gas after the latter has been treated in accordance with the usual prior practice in the operation of by-product coke oven plants to eliminate tar and tar oils from the gas, and to recover the gaseous ammonia content of the coke oven gas by converting it into ammonium sulphate. The present invention differs substantially from prior practice in respect to the manner in which benzol is scrubbed out of the gas.

It is theoretically possible to separate benzol vapors from coke oven gas in scrubbing towers of various known types through which the coke oven gas moves upward from the bottom to the top of the tower and through which the scrubbing liquid moves downward from top to the bottom of the tower. For example, the scrubbing towers heretofore theoretically available for use in separating benzol vapors from coke oven gas include towers of bubble still type, and towers of a spray type. However, prior to the present invention it had long been substantially universal practice in by-product coke oven plants in this country to separate benzol vapors from coke oven gas in scrubbing towers, each filled with a pervious mass of liquid and gas distributing material, except for a relatively short liquid distributing space adjacent the upper end of the tower into which the scrubbing liquid is usually sprayed and from which the gas is withdrawn.

Formerly the mass of pervious distributing material usually consisted of a multiplicity of wooden grids stacked or piled in the tower. In

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recent years, expanded metal, and sometimes metal shavings or turnings, have been largely used as the grid materials stacked or piled up in benzol scrubbing towers. As the scrubbing oil moves downward through the scrubbing tower, the grids, whether of wooden or metallic material, divide and redivide the oil into films and finely divided and broken streams. The grids thus provide a large amount of oil surface distributed throughout the tower, with which the gas moving upwardly through the tower is constantly coming into close contact.

The separation of benzol vapors from coke oven gas presents special problems because of the large volume of gas to be scrubbed in a modern by-product coke oven plant of customary capacity. Such a plant may include several grid filled benzol scrubbing towers, each having a height of from ninety to one hundred ten feet and a diameter of from thirteen to fifteen feet. Customarily, the maximum rate at which gas is passed through such a tower is about thirty-five million cubic feet per twenty-four hours. In some of those plants, gas is passed successively in one direction through two such towers while wash oil is passed in the opposite direction through said towers, so that part of the benzol content of the gas stream may be eliminated in each tower.

A grid filled benzol scrubbing tower is relatively inexpensive to construct, and under favorable conditions its action approximates the practically desirable, true counter-flow action in which the benzol vapor content of the gas and benzol liquid content of the scrubbing liquid so progressively diminish from the bottom to the top of the tower that the driving force tending to transfer the benzol from the gaseous phase into the liquid phase need not become undesirably low at any level. Metal grids in the form of expanded metal or lathe turnings or shavings offer less resistance to the gas flow upward through the tower than do wooden grids. It has long been recognized, however, that any grid filled benzol scrubbing tower has the inherent and practically important disadvantage of offering considerable resistance to gas flow through the tower at an economically adequate velocity, and thus entails a substantial installation and operating cost for gas pumping machinery. The grid resistance to the upflow of gas through the grid filled tower is due in part to the reduction of the free flow area through the tower by the grids, in part to the relatively small and tortuous character of the gas flow passages through the mass of grids, and in part

to a "channeling" tendency resulting in unequal flow rates in different portions of the grid mass.

Another disadvantageous characteristic of the customary grid filled benzol scrubber, is the need for frequently cleaning and replacing the grids. In operation, there is a tendency for clogging material to accumulate in the flow passages through the grid stack and thereby reduce the perviosity of the grid stack or mass. Difficulty due to such clogging action is especially pronounced because of the formation and accumulation in the scrubbing oil of a gummy substance having a tendency to adhere to the grid surfaces. The removal of the gummy material adhering to the grid is an especially troublesome but necessary procedure.

A specific object of the present invention is to provide a method of and apparatus for separating benzol vapor from coke oven gas which makes it possible to recover a suitably large percentage of the benzol vapor content of coke oven gas moving upward through a scrubbing tower of given horizontal and vertical dimensions, while maintaining a greater volumetric rate of gas flow upward through the tower than is practically possible with towers constructed and used in the manner heretofore customary. Further specific objects of the invention are to provide a benzol scrubbing tower containing no grids, and offering substantially less resistance to the upflow of gas at a given volumetric rate through a tower of the dimensions heretofore customary, than is practically possible with the benzol scrubbing towers heretofore in general use in this country.

The improved benzol scrubbing tower constructed in accordance with the present invention, is of a novel spray type and is particularly characterized by its provisions for continuously spraying finely subdivided absorbing oil into substantially all portions of the gas space in the tower and thereby maintaining an aggregate interfacial surface of gas and liquid contact in the tower which is substantially larger than can be maintained in a grid filled tower of the same dimensions. In a preferred form of the present invention, an upper group or set of spray nozzles are arranged to spray scrubbing oil into the upper portion or section of the tower and a separate group or set of spray nozzles is located in each of a plurality of tower portions or sections at respectively different distances below the upper group of nozzles. In accordance with the present invention, all of the scrubbing oil sprayed into each of the superposed tower sections below the uppermost section, is oil previously sprayed into a tower section at a higher level and subsequently collected by liquid collecting means adjacent the lower end of each said upper section. Associated with the different liquid collecting spaces are pipes and pumping means for passing liquid from each such collecting space to the spray nozzles in which the liquid is to be again sprayed into the tower.

In the ordinary use of the invention, I now contemplate that there will be some two or three scrubbing sections beneath the top section of each tower. I also contemplate that more oil will be sprayed into each lower section than is sprayed into the top section. This means that some of the oil sprayed into each lower section will be oil previously sprayed into that section and collected at the bottom of the latter. In consequence, each particle of scrubbing oil initially sprayed into the top section of the tower, is resprayed into the tower more than as many times as there are spray sections below the top section before that particle reaches the final oil outlet from the bottom of the tower from which the oil is passed to the apparatus in which the absorbed benzol is stripped from the wash oil.

In the preferred form of the present invention, I spray the scrubbing oil into some, at least, of the tower sections in such manner that the oil sprayed into the lower portion of the section is more finely subdivided than the oil sprayed into the upper portion of the section. In such case the nozzles used to spray the oil into the lower portion of the spray section may be atomizing nozzles of such character that the average diameter of the oil particles discharged by those nozzles may be of the order of one-half millimeter, whereas the nozzle or nozzles spraying liquid into the upper portion of the section may be arranged to discharge a relatively coarse spray comprising particles having an average diameter of the order of two millimeters. The fine subdivision of the oil sprayed into the lower portion of the spray section greatly increases the interfacial surface of gas and liquor contact, and insures a desirably high gas absorption factor in the lower portion of the section. The coarser spray discharged into the upper portion of the section makes the fine subdivision of the oil sprayed into the lower portion of the section practically feasible, by substantially reducing the amount of oil entrained by the gas passing away from the section at the upper end of the latter.

Preferably, the upflow of gas in the improved tower is substantially unobstructed except to the relatively small extent to which it is obstructed by the spray nozzles, associated piping and collecting devices. Each of the collecting devices advantageously comprises an annular liquid receiving space and louvre-like means for deflecting into said space the scrubbing oil sprayed into and passing downward through the portion of the tower immediately above the collecting device.

The various features of novelty which characterize my invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, however, its advantages, and specific objects attained with its use, reference should be had to the accompanying drawings and descriptive matter in which I have illustrated and described a preferred embodiment of the invention.

Of the drawings:

Fig. 1 is a diagrammatic elevation of a scrubbing tower;

Fig. 2 is an elevation, partly in section, of a portion of the scrubbing tower shown diagrammatically in Fig. 1;

Fig. 3 is a plan section on the line 3—3 of Fig. 2;

Fig. 3a is a diagrammatic plan section showing the arrangement of spray nozzles shown in Figs. 1 and 2;

Fig. 4 is a partial section on the line 4—4 of Fig. 3;

Fig. 5 is a diagrammatic elevation of a second scrubbing tower embodiment of the present invention;

Fig. 6 is an elevation of a portion of another tower structure;

Fig. 7 is a plan section of the apparatus shown in Fig. 6; and

Fig. 8 is a diagrammatic elevation of a portion of a third form of tower.

The embodiment of the invention shown diagrammatically by way of example in Fig. 1, com-

prises a scrubbing tower 1 which is provided with a lateral gas inlet 2 adjacent its lower end, and a lateral gas outlet 3 adjacent its upper end. The scrubbing chamber in the tower 1 is divided into upper, intermediate and lower stages or sections *a*, *b* and *c*, respectively. The sections *a* and *b* are separated by a liquid collecting device *a'*, and the sections *b* and *c* are separated by a liquid collecting device *b'* which may be, and as shown is substantially similar to the device *a'*.

The liquid collecting device *b'* shown diagrammatically in Fig. 1, may be of the type and construction shown in more detail in Figs. 2 and 3 and comprises an annular liquid receiving chamber 4*b*. The latter is formed by securing an annular flange member 5 having an out-turned lower edge portion to the inner side of the tower shell, by welding or riveting. The body of the member 5 is in the form of a section of a hollow cone coaxial with the tower. A louvre structure above and associated with the member 5 comprises three superposed coaxial annular members 6, 7 and 8 above and at successively increasing distances from the member 5 and a top member 9 which may comprise a hollow cone body portion. Each of the members 6, 7 and 8 is in the form of a section of a hollow cone. The upper and lower edges of member 7 respectively overlap the lower edge of the member 8 and the upper edge of the member 6. The lower edge of the member 6 overlaps the upper edge of the subjacent member 5, and the lower or outer edge of the top member 9 overlaps the inner upper edge of the member 8. The members 5, 6, 7, 8 and 9 are vertically displaced to provide an annular gas outlet, or louvre opening beneath each of said members 6, 7, 8 and 9.

The collecting device *a'* shown in Fig. 1 may be structurally identical to the collecting device *b'* except in certain respects hereinafter mentioned, but for convenient identification, the annular liquid receiving space of the device *a* is designated 4*a*. The members 6, 7, 8 and 9 of each collecting device *a'* may be supported in any convenient manner. As shown in Fig. 4, each of the members 6, 7, and 8 is directly supported by four bracket like parts 10*a* spaced about the tower axis, and each of the brackets is directly supported by one or another of four inclined rafter parts 10. Each bracket part 10*a* may be a strip of metal plate comprising an upper portion, directly beneath and secured to the corresponding member 6, 7, or 8, and a transverse lower portion. The lower end of the lower portion and the upper end of the upper portion of each bracket 10*a* engage and are secured to the corresponding rafter part 10. The lower end of each rafter part 10 is secured to the tower shell through the corresponding trough part 5 and its upper end is secured to and assists in supporting the corresponding member 9. The parts 10 and 10*a* may be attached to the corresponding parts 5, 6, 7, 8 and 9 by rivets or welding.

Scrubbing oil is sprayed into the upper end portion of the scrubbing stage *a* by a plurality of spray nozzles 11. As shown, the spray nozzles 11 are all located at the same level, though this is not essential, and are arranged to discharge downwardly directed jets into the subjacent portion of the scrubbing chamber. The scrubbing oil is supplied to the nozzle 11 by branch pipes from a scrubbing oil supply pipe 12. In ordinary practice, oil will be passed into the pipe 11 by pumping means not shown, which may receive oil directly or indirectly from the outlet of the associated

debenzolizing apparatus, not shown, to which the oil passing through the tower 1 is passed, for the separation from the scrubbing oil of those benzol constituents absorbed from the gas passing through the scrubbing tower. A suitable amount of fresh make-up scrubbing oil may be added to the scrubbing oil returned to the tower from the debenzolizing apparatus.

Scrubbing oil is sprayed into the upper portion of the scrubbing stage *b* by nozzles shown as comprising a central upper nozzle 13, a plurality of intermediate nozzles 14 and a plurality of lower nozzles 15. As shown, the nozzle 13 is centrally disposed in the dome shaped louvre structure of the device *a'*, beneath and in close proximity to the top member 9 of that structure. The intermediate nozzles 14 are shown as located at a level slightly below the bottom of the liquid receiving chamber 4. The spray nozzles 15 of the stage *b* are located at a level below that of the nozzles 14 and above that of the top member of the louvre structure *b'*. The arrangement of the nozzles 13, 14 and 15 relative to the vertical axis of the tower 1 is shown diagrammatically in Fig. 3*a*. In Fig. 1, each of the nozzles 13, 14 and 15 spraying liquid into the scrubbing stage *b*, receives liquid through an individual branch supply pipe 16 from a bus pipe 17 extending circularly about the tower 1 at a level which advantageously, and as shown, is intermediate the levels of the nozzles 13 and 15 discharging into the scrubbing stage *b*. Spray liquid is supplied under pressure to the bus pipe 17 through the outlet pipe 18 of a pump 19 which has its inlet connected by a pipe 20 to the annular receiving space 4*b* of the collecting device *b'*.

The collecting device *b'* receives the liquid sprayed into the stage *b* through the nozzles 13, 14 and 15 discharging directly into that space, and also receives liquid from the annular receiving space 4*a* of the upper collecting device *a'* through a drain pipe 21. The trough shaped receiving space 4*b* of the collecting device *b'*, thus receives all of the scrubbing oil sprayed into each of the upper scrubbing stages *a* and *b*. The oil received in the receiving space 4*b* of the collecting device *b'* and not withdrawn therefrom by the pump 19, passes through an overflow drain pipe 22 into a liquid holding space 23 in the lower end portion of the tower 1. The space 23 also received oil sprayed into the stage *c* and accumulating in the lower end of the latter. The pump 19*a* draws scrubbing oil from the space 23 through a pipe 24 and discharges it through a pipe 25 into a bus pipe 17*a*, which may be exactly like the bus pipe 17, and which supplies scrubbing oil through individual branch pipes to the spray nozzles 13', 14' and 15' which discharge into the scrubbing stage *c*. The nozzle 13', 14' and 15' are shown as similar in arrangement to, and they may be identical in construction with the previously mentioned nozzles 13, 14 and 15, respectively. A pump 26 draws the enriched scrubbing oil away from the lower end portion of the tower 1, and passes it directly or indirectly to the associated debenzolizing apparatus, not shown.

Figs. 2 and 3 collectively illustrate one form of means which may be employed to prevent the oil passed by the pump 19 to spray nozzles 13, 14 and 15 from entraining an objectionable amount of gas, and for insuring that the oil passed to the nozzles by the pump 19 includes substantially all of the oil coming to the liquid receiving space 4*b* from the liquid receiving space 4*a* through the pipe 21. To this end, the pipes

20 and 21 each communicate with a compartment 27 which may be regarded as a segregated portion of the space 4b. The compartment 4b receives oil sprayed into the tower section b only through the remainder of the space 4b. As shown, the compartment 27 is separated from the remainder of the space 4b by radially extending partitions 28 and 29. The partition is shaped to provide a relatively restricted port 30 through which the compartment 27 is in restricted communication with the body portion of the space 4b. The partition 29 may or may not be provided with a similar port 30.

A plate 31 extends over the top of the compartment 27 and has depending end portions 31' which overlap the upper portions of the partitions 28 and 29. As shown, the portion of the louvre member 6 immediately adjacent the compartment 27 is provided with an uprising lip 32 to divert the oil flowing downward over the member 6 into the portions of the space 4b at the opposite ends of the compartment 27. The rapid separation of entrained gas from the oil passed into the compartment 27 by the pipe 21, is facilitated by displacing the ends of the pipes 20 and 21 communicating with compartment 27, angularly from one another about the vertical axis of the tower, as is shown in Fig. 3, and by providing a curved oil guide 33 in the compartment arranged to give a circular motion to the stream of oil passing into the compartment 27 through the pipe 21. The hood member 30 has its body portion at a level above the tops of the partitions 28 and 29 and above the trough wall member 5, so as to permit the ready escape of the gas separating from the oil in the compartment 27.

In the preferred form of the present invention, the spray nozzles 14 and 14' are of the type commonly referred to as atomizing nozzles, and are adapted to discharge the scrubbing oil in particles or droplets so small that the portion of the spray discharged adjacent each nozzle comprises particles, the average diameter of the bulk of which is of the order of 0.5 millimeter. The upflowing gas stream would entrain and carry out of the scrubbing stages b and c a substantial portion of the oil respectively sprayed into the stages b and c by the corresponding nozzles 15 and 15', if the entraining action were not wholly or large prevented by scrubbing liquid sprayed into the extreme upper end portions of the stages b and c by the corresponding spray nozzles 13 and 13'.

In practice, each of the nozzles 13 and 13' is arranged to discharge a coarse spray of a volume substantially greater than the volume of liquid discharged by each of the nozzles 14 and 14'. Preferably, the amount of liquid discharged by the intermediate group of nozzles of each stage is some greater than the amount of scrubbing oil sprayed into the stage by the corresponding upper nozzle or nozzles 13 and 13'. In practice, the coarse spray nozzles 13 and 13' discharge oil in the form of drops having an average diameter of not less than about two millimeters. The lowermost nozzles 15 and 15' of the scrubbing stations b and c may be atomizing nozzles discharging oil having the same fineness of subdivision as the oil discharged by the nozzles 14 and 14'. In most cases, I consider it preferable, however, to employ nozzles 15 and 15', which discharge a spray somewhat coarser than the spray discharged by the nozzles 14 and 14', though finer than the spray discharged by the nozzles 13 and 13'. When the spray discharged by the nozzles 15 and 15' is as fine as that desirably discharged by the nozzles 14 and 14', there is a tendency for the gas to move an objectionably large portion of the oil discharged by the lowermost nozzle 15 and 15' to upper levels and with the result that more of the oil in spray form is in portions of the scrubbing chamber above the levels of the nozzles 15 and 15', and less of it below the respective levels of the nozzles 15 and 15' than is desirable.

The operation of the tower 1 is highly efficient, and the tower is adapted in regular operation to recover the available light oil vapors in a volume of coke oven gas substantially larger than the volume of gas from which the available light oil vapors can be recovered in a tower of similar dimensions containing the mass of grids heretofore customarily employed in benzol scrubbers. The benzol scrubbing tower illustrated diagrammatically in Fig. 1 is of a design adapted for use in the conversion of an existing grid filled tower of conventional type into a tower having special features, and the mode of operation, characteristic of the present invention. In essence, such a conversion requires the removal of the grids from the old tower shell and the addition to the latter of the liquid collecting devices a' and b' and the associated spray nozzles and piping below the nozzles 11 of Fig. 1. In its original condition, the normal average gas upflow velocity across the tower cross-section is about 1½ feet per second. With the tower shown in Fig. 1, the average gas upflow velocity across the tower cross section may be in excess of three feet per second in regular operation.

The general operation of the tower 1 in its converted form shown in Fig. 1, is generally like that of the tower in its original grid filled condition, in that as the gas ascends and the wash oil descends through the tower, the transfer of benzol from the gas to the wash oil similarly diminishes the benzol content of the gas and increases the benzol content of the wash oil. Under similar operating conditions, the rate at which the benzol content of the gas is being transferred to the wash oil at any one tower level of any particular tower, is dependent on the difference between the partial pressure of the benzol in the gas and the partial pressure of the benzol in the wash oil, and is also dependent upon the aggregate interfacial surface of gas and liquid contact per unit of tower volume.

In the practical operation of a benzol scrubbing tower, the pressure of the benzol in the gas and the benzol in the wash oil must be so related that the actual benzol partial pressure in the gas is appreciably in excess of the partial benzol pressure in the gas under the equilibrium condition in which there is no net transfer of benzol between the gas and wash oil. The difference between the actual and equilibrium partial benzol pressures in the gas provides the "driving force" or partial pressure head necessary to effect the transfer of benzol from the gas to the oil. The necessity for such a driving force or partial pressure head explains why it is not practically possible in the operation of a scrubbing tower, to remove all of the benzol content of the gas entering the tower. Under any given set of operating conditions, the benzol content of the gas entering the scrubbing tower available for recovery therein, is the portion of the initial benzol content of the gas in excess of the benzol content which must be left in the gas leaving the tower

to maintain an adequate driving force differential between the actual and equilibrium partial pressures of the gas at the top of the tower. The aggregate interfacial surface of the gas and liquid contact per unit of the tower volume depends upon the tower construction and mode of operation.

The efficiency of a benzol scrubbing tower is indicated by its H. T. U. characteristic, i. e., by the average height of its transfer units. The tower has as many transfer units as it has superposed sections in each of which the amount of benzol vapor transferred from the gas to the scrubbing oil is that required to make the resultant change in the benzol content of the gas equal to the arithmetical average of the differences between the actual partial pressure of the benzol in the gas and its equilibrium pressure at the upper and lower ends of the section. The efficiency of a tower of given height operating under given conditions, is thus directly indicated by the number of its transfer units, and the relative efficiencies of two benzol scrubbing towers of the same height and operating under the same conditions, is thus directly expressed by the ratio of the transfer units of the two towers. In a scrubbing tower used to scrub benzol vapor out of coke oven gas, the number of transfer units of the tower is approximately inversely proportional to the amount of gas upflow through the tower per unit of tower cross-sectional area, e. g., cubic feet of gas per hour per square foot of tower cross-sectional area.

The described provisions in the apparatus shown in Fig. 1 for spraying the wash oil into contact with the gas passing upward through the tower makes possible a substantially greater aggregate interfacial surface of gas and oil contact per unit of tower volume than is practically attainable with the customary grid filled tower, or other benzol scrubbing tower of which I have knowledge.

Under normal operating conditions in an ordinary by-product coke oven plant, a tower constructed in accordance with the present invention may be expected to have not less than twice as many transfer units as the ordinary grid filled benzol scrubbing tower of the type heretofore in general use in this country, when the two towers are of the same height. In consequence, for the usual percentage reduction in the benzol content of the coke oven gas passing through the two towers, twice as many cubic feet of gas per hour may be passed through the tower constructed in accordance with the present invention as can be passed through the prior grid filled tower when the two towers are of equal height and have the same internal diameters.

The apparatus used in the practice of the present invention may include other forms than that shown in Figs. 1 to 4. Thus, the tower *1a* shown in Fig. 5, differs from the tower 1 in having a section *d* interposed between its sections *b* and *c*. The tower shown in Fig. 5 also differs from the tower shown in Figs. 1–4 in the arrangement of the spray nozzles 14 and 15 and piping through which those nozzles are supplied with wash oil. The additional tower section *d* shown in Fig. 5 may be a counterpart of the other intermediate tower section *b*. Thus, the section *d* has a pump 19′ and conduits 20 and 21′ associated therewith which are counterparts of the pump 19 and pipes 20 and 21, respectively associated with the section *b*. The nozzles 14 and 15 of Fig. 5 are connected to pipe rings 34 and 35 within and coaxial to the tower *1a*. The outlet pipe 18 from the pump 19 of Fig. 5 is directly connected by pipe 36 to the nozzle 13 and is directly connected by pipes 37 and 38 to the pipe rings 34 and 35, respectively. As shown, each of the pipes 36, 37 and 38 includes an individual throttling valve 39. By adjustments of the different valves 39, the pressures, and therefore the amounts of oil supplied to the nozzles 13, 14 and 15 may be proportioned. Similar pipe connections are provided for connecting each of the pumps 19′ and 19*a* of Fig. 5 to the nozzles 13, 14 and 15, respectively associated with those pumps. When a proportioning adjustment in a scrubbing section increases or decreases the amount of oil discharged at the level of the nozzles 15, for example, of one scrubbing section, relative to the amounts of oil discharged at the levels of the nozzles 13 and 14 of the same scrubbing section, the rate at which the adjacent upflowing gas gives up benzol respectively increases or decreases, and thus varies the differential in said scrubbing section between the benzol in the gas and the benzol in the oil at the levels of the nozzles 13 and 14, as well as at the levels of the nozzles 15.

The number of nozzles associated with each tower section and the sizes of the different nozzles may vary with conditions. Thus, for example, in the particular tower design illustrated in Figs. 2, 3 and 4, there are nine nozzles 14 and six nozzles 15 in each of the sections *b* and *c*. In the particular design shown in Fig. 5 eighteen 1½ inch nozzles 14 and twelve 1½ inch nozzles 15 are provided for each of the sections *b*, *c* and *d*. When the number of nozzles are increased, the sizes of the various nozzles may be diminished. In the particular design shown diagrammatically in Fig. 5, there are twelve 2½ inch nozzles 11. The nozzles 13 of Fig. 5 are 2 inch nozzles. It will be understood, of course, that the nozzle numbers and sizes stated above are given by way of illustration and example and not by way of limitation. As previously stated, the vertical extent of a benzol scrubbing tower is ordinarily not less than 90 feet and not more than 110 feet. With a tower height of the intermediate value of 100 feet and four sections as shown in Fig. 5, the average height of each of the three vertically elongated subjacent sections *b*, *c* and *d* will be of the order of 25 feet. With the major portion of the scrubbing oil sprayed into the vertically elongated section *b*, for example, partly through the intermediate nozzles 14 and partly through the lower nozzles 15, there is no such reduction in the absorption of benzol in the lower portion of the section as there would be if all of the scrubbing oil were sprayed into the uppermost portion of the section through the top spray nozzle 13. Such reduction would result in part, from the rapid absorption of benzol by the spray oil passing down through the upper portion of the section, and in part from the coalescence and enlargement of the spray oil particles or droplets moving from the top of the section down to and through the lower portion of the section, and in part, also, from the deposit of spray oil on the exposed internal portions of the tank structure.

With a substantial portion of the scrubbing oil sprayed into and dispersed in the lower half of the section *b* by the nozzles 15 which are about half way between the top of the section *b* and the liquid level in the collecting trough at the bottom of the section, and with the intermediate nozzles 14 at a level nearer the level of the nozzles 15 than the level of the nozzle 13, it is practically possible

to avoid objectionably large variations at different levels between the benzol in the scrubbing oil and the benzol in the gas. As will be apparent, what has just been said with respect to section *b*, applies also to the sections *d* and *c* of Fig. 5. The vertical and horizontal distribution of the spray points shown in Fig. 1 and in Fig. 5, permits of the effective use of benzol scrubbing towers of large diameters and vertical extents without an unduly large number of superposed sections. Any reduction in the number of sections of a tower of given height appreciably reduces the inherent construction cost of the tower.

Each of the liquid collecting devices of such a tower as is shown in Figs. 1, 2 and 5, may have an external reservoir and overflow box **40**, associated with each of its liquid collecting spaces *a'*, *b'* etc. in the general manner shown in Figs. 6 and 7. As there shown, the box **40** receives oil from the trough space **42** of a collecting device b^{10} generally like the device *b'* of Fig. 1 through a pipe **41**, and returns gas separating from the oil through a pipe **43**, and also receives and discharges oil through pipes **21***a* and **20**, respectively corresponding to the pipes **21** and **20** of Fig. 1. The pipe **44** is adapted to serve the purpose of the pipe **22** of Fig. 1. The pipe **21***a* is connected to the reservoir **40** through a congential inlet **45**.

In normal operation, the reservoir **40** acts as a cyclone separator to liberate and return to the tower gas entrained in the oil entering the reservoir through its congential inlets **41** and **45'**. It also contributes to a simple and effective design having the special advantage of reducing the required capacity of the associated oil receiving space **42**. The reduction in said space **42** permits of a relative increase in the diameter of the upper end of the conical member **46** which forms the inner wall of the trough space **42**. The restriction of the path of upflow of the gas moving through the tower may thus be inherently smaller with the arrangement shown in Figs. 6 and 7 than with the form of apparatus illustrated in Figs. 1–4.

The arrangement shown in Figs. 6 and 7 thus permits of an operation with a smaller gas pressure drop in the tower than is possible with the tower construction shown in Figs. 1–4, assuming similar tower diameters and heights and the same volumetric rates of gas flow through the two towers. As will be apparent, the set of superposed conical louvre members **6**, **7**, **8** and **9** of Figs. 1, 2, and 5 or of Figs. 6 and 7, may be so proportioned and disposed that said members will restrict the cross-section of the gas flow path less than it is restricted by the inner wall of the space **4***a* or **4***b* of Fig. 1, or by the inner wall of the space **42** of Fig. 6. It is practically possible with the arrangement shown in Fig. 1 to keep the cross-section of the upper end of the space surrounded by the wall **5** of the receiving space **4***a* or **4***b* in excess of one-half the cross-sectional area of the tower.

The spray nozzles and piping employed in any of the forms of the invention illustrated, offer relatively insignificant resistance to the upflow of the gas, and the provision of the two collecting devices *a'* and *b'* shown in Fig. 1, or the three collecting devices shown in Fig. 5, offer much less resistance to the upflowing gas than is offered by the grids of a grid filled tower of similar dimensions. The gas pressure drop in a tower having each collecting device associated with an external reservoir like the reservoir **40** shown in Figs. 6 and 7, need not be as great as it would need to be if the tower were not provided with external reservoirs analogous in purpose to the reservoir **40** of Figs. 6 and 7.

Fig. 8 illustrates a modified arrangement of the piping supplying wash oil to the spray nozzles associated with each section of a scrubbing tower constructed in accordance with the present invention. In that figure each of the nozzles **14** and **15** and each of a plurality of nozzles **13** are connected to the discharge ends of a corresponding branch **50** from a supply pipe **51**. The latter as shown, comprises a vertical portion to which the branch pipes **50** are connected, and a horizontal portion extending through a nozzle part **52** through which the tower shell supports the pipe **51**. As will be apparent, the piping arrangement shown in Fig. 8 is of simple and relatively inexpensive construction.

This application is a continuation in part of my prior application Serial No. 724,874, filed January 28, 1947, which became abandoned after the instant application was filed.

While in accordance with the provisions of the statutes, I have illustrated and described the best form of embodiment of my invention now known to me, it will be apparent to those skilled in the art that changes may be made in the form of the apparatus disclosed without departing from the spirit of my invention as set forth in the appended claims, and that in some cases certain features of my invention may be used to advantage without a corresponding use of other features.

Having now described my invention, what I claim as new and desire to secure by Letters Patent, is:

1. In separating benzol vapors from coke oven gas, the method which consists in passing the gas upward through substantially unobstructed superposed sections of a vertically elongated scrubbing path, spraying an absorbing oil into the uppermost of said sections and respraying said oil in each of a major number of subjacent sections at a plurality of spray points distributed both vertically and horizontally throughout a major portion of each of said subjacent sections and collecting the oil sprayed into each upper section and spraying it into the immediate subjacent section at the said vertically and horizontally distributed spray points.

2. A method as specified in claim 1, in which the wash oil sprayed into each section is collected at the bottom of said section and in which the wash oil sprayed into each subjacent section consists in part of wash oil collected at the bottom of the section above said subjacent section, and in part of wash oil collected at the bottom of said subjacent section.

3. A method as specified in claim 1, in which the oil being redistributed is degasified prior to its redistribution.

4. Apparatus for separating benzol vapors from coke oven gas comprising in combination a vertically elongated scrubbing tower shell with a gas inlet and a gas outlet at its lower and upper ends respectively, and providing a continuous gas flow path between said inlet and outlet, and means for passing an absorbing oil into the portion of said path in each of a plurality of superposed tower sections comprising means for passing oil into and distributing it in the upper portion of the uppermost of said sections, and a plurality of spray nozzles distributed vertically

and horizontally over a major portion of each of the subjacent sections, a wash oil collecting device at the upper end of each of said subjacent sections arranged to collect the oil sprayed into the section immediately above said subjacent section, and oil pumping means for passing the oil collected in each collecting device under pressure to the different spray nozzles in the subjacent section, each of said subjacent sections having an average vertical extent which is greater than fifteen feet and is substantially unobstructed.

5. Apparatus as specified in claim 4, in which the height of each of said subjacent sections is substantially greater than fifteen feet.

6. Apparatus as specified in claim 4, in which said gas flow path is substantially unobstructed except by said collecting devices.

7. Apparatus as specified in claim 4, in which each collecting device comprises an annular trough space adjacent said shell and surrounding a portion of said gas flow path having a minimum cross-sectional area not less than about one-half of the cross-sectional area of said shell, and in which said device comprises a hood shaped louver structure above said trough and smaller in diameter at its upper end than the internal diameter of said trough path and formed with horizontal gas outlet spaces collectively forming a portion of the gas flow path of greater cross-sectional area than the minimum cross-section of the portion of said path surrounded by said trough.

8. Apparatus as specified in claim 4, in which the means for spraying oil into the lower portion of each subjacent section are arranged to subdivide the oil sprayed by them into particles so fine that the upflowing gas tends to move a substantial portion of said particles up out of said section, and the oil sprayed into the upper portion of the section comprises particles too coarse to be substantially entrained by the up-moving gas, and is so distributed as to coalesce with said fine particles and thereby substantially prevent the latter from being carried out of the section by the gas.

9. Apparatus as specified in claim 4, in which the spray nozzles in each of said subjacent sections include one or more upper nozzles arranged to subdivide the oil into particles having an average diameter of the order of two millimeters, and in which at least some of the lower nozzles are atomizing nozzles adapted to subdivide the oil into particles having an average diameter of the order of one-half millimeter.

10. In separating benzol vapors from coke oven gas, the method which consists in passing the gas upward through substantially unobstructed superposed sections of a vertically elongated scrubbing path, spraying an absorbing oil into the uppermost of said sections and re-spraying said oil in each of a plurality of subjacent sections at a plurality of spray points distributed both vertically and horizontally in each of said subjacent sections and collecting the oil sprayed into each upper section and spraying it into the immediate subjacent section at the said vertically and horizontally distributed spray points, the wash oil sprayed into the upper portion of each subjacent section being in the form of a relatively coarse spray while the oil sprayed into the lower portion of the section is in the form of a relatively fine spray.

11. In separating benzol vapors from coke oven gas, the method which consists in passing the gas upward through substantially unobstructed superposed sections of a vertically elongated scrubbing path, spraying an absorbing oil into the uppermost of said sections and re-spraying said oil in each of a plurality of subjacent sections at a plurality of spray points distributed both vertically and horizontally through a major portion of each of said subjacent sections and collecting the oil sprayed into each upper section and spraying it into the immediate subjacent section at the said vertically and horizontally distributed spray points therein, the vertical extent of each subjacent section being great enough to substantially reduce the interfacial surface of contact of the gas and the portion of the scrubbing liquid passing into the lower portion of the last mentioned section from the uppermost of said spray points, and a substantial portion of the scrubbing oil being initially dispersed in the lower half of the section.

12. Apparatus for separating benzol vapors from coke oven gas comprising in combination a vertically elongated scrubbing tower shell with a gas inlet and a gas outlet at its lower and upper ends respectively, and providing a continuous gas flow path between said inlet and outlet, and means for passing an absorbing oil into the portion of said path in each of a plurality of superposed tower sections comprising means for passing oil into and distributing it in the upper portion of the uppermost of said sections, and a plurality of spray nozzles distributed vertically and horizontally in each of the subjacent sections, a wash oil collecting device at the upper end of each of said subjacent sections arranged to collect the oil sprayed into the section immediately above said subjacent section, and oil pumping means for passing the oil collected in each collecting device under pressure to the different spray nozzles in the subjacent section, each of said tower sections having an average vertical extent which is greater than the tower diameter, and is substantially unobstructed, the nozzles spraying oil into each subjacent section being arranged to discharge oil into an upper portion of the section which is less finely divided than the oil sprayed into a lower portion of the section.

13. In separating benzol vapors from coke oven gas, the method which consists in passing the gas upward through substantially unobstructed superposed sections of a vertically elongated scrubbing path, spraying an absorbing oil into the uppermost of said sections and re-spraying said oil in each of a major number of subjacent sections at a plurality of spray points distributed both vertically and horizontally throughout a major portion of each of said subjacent sections, the vertical extent of each of said subjacent sections being more than 15 feet and some of the spray points in each of the last mentioned sections being located not higher than about midway between the upper and lower ends of the corresponding subjacent section and collecting the oil sprayed into each upper section and spraying it into the immediate subjacent section at the said vertically and horizontally distributed spray points.

14. In separating benzol vapors from coke oven gas, the method which consists in passing the gas upward through substantially unobstructed superposed sections of a vertically elongated scrubbing path, spraying an absorbing oil into the uppermost of said sections and re-spraying said oil in each of a major number of subjacent sections at a plurality of spray points distributed

both vertically and horizontally throughout a major portion of each of said subjacent sections, whereby the benzol content of the gas decreases and the benzol content of the oil increases as the oil moves downward and the gas moves upward past the various spray points, regulating the difference between the partial pressure of the benzol in the gas relative to the benzol in the oil at different levels in one of said subjacent sections by varying the relative rates at which oil is supplied to the different spray points in that section and collecting the oil sprayed into each upper section and spraying it into the immediate subjacent section at the said vertically and horizontally distributed spray points.

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