

March 5, 1968

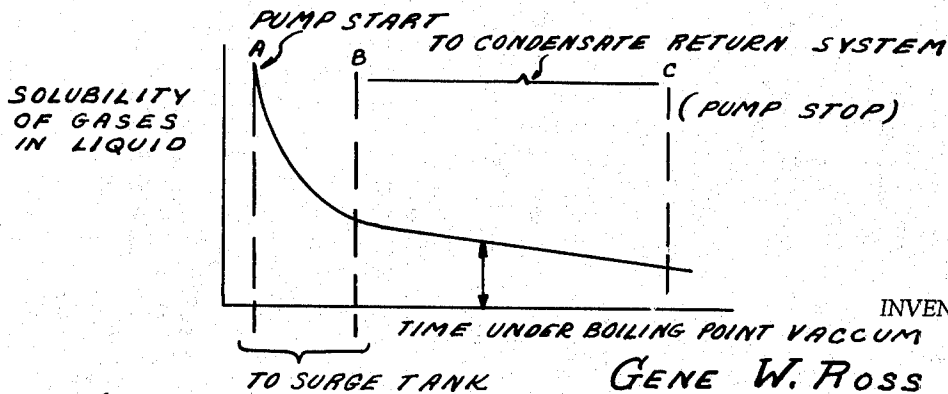
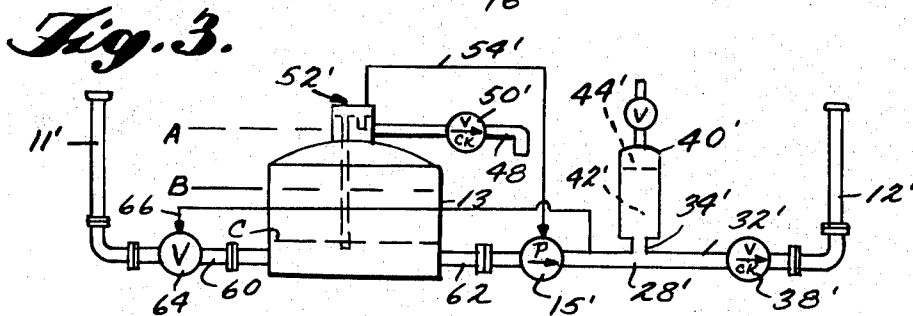
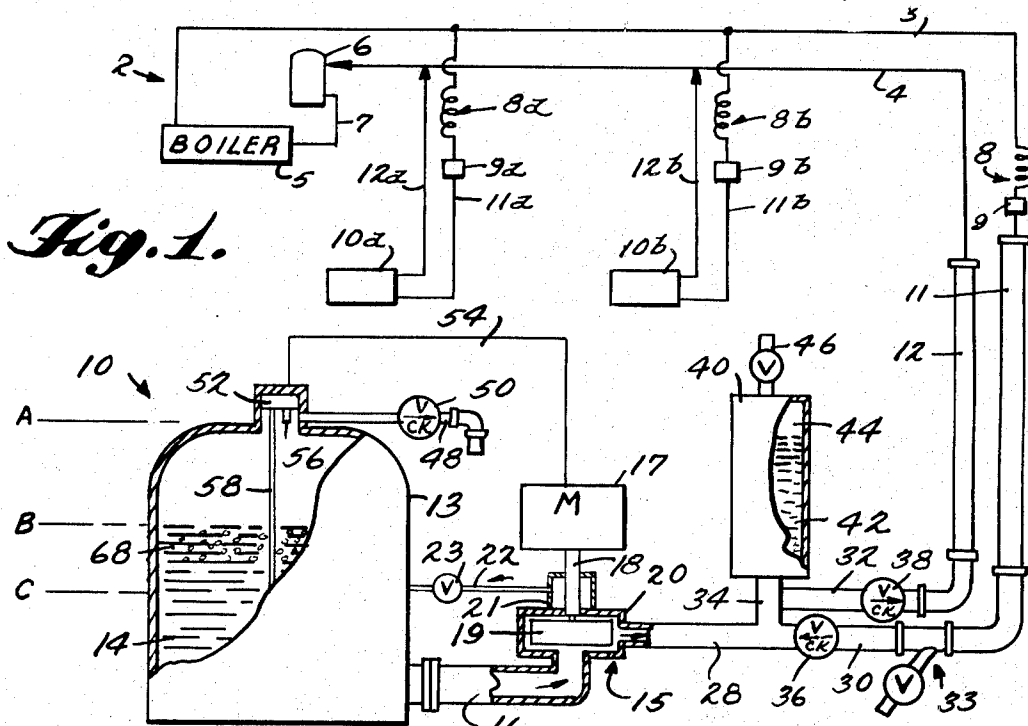
G. W. ROSS ET AL

3,371,865

DEAERATING APPARATUS

Filed May 20, 1966

2 Sheets-Sheet 1



INVENTORS

GENE W. ROSS

DAVID S. ROSS

BY

Cushman, Dwyer & Cushman
ATTORNEYS

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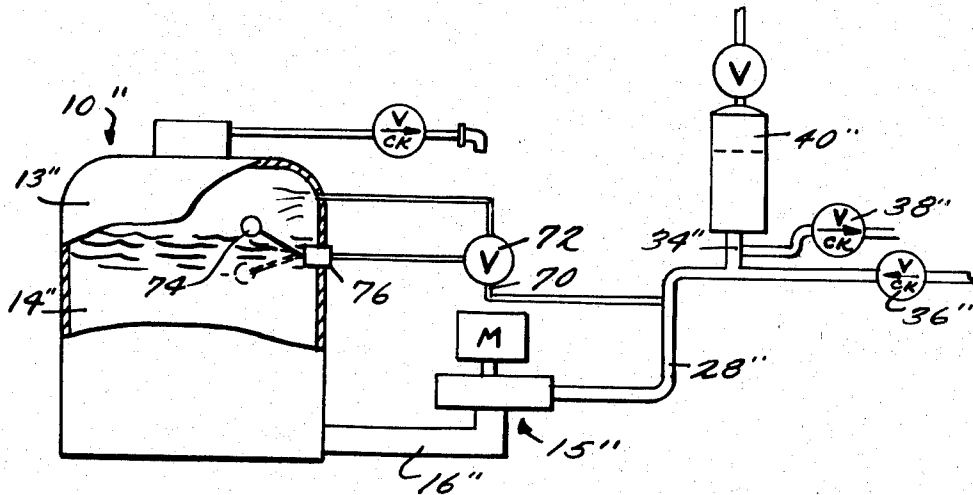


Fig. 4.

INVENTORS
GENE W. ROSS
DAVID S. ROSS
Cushman, Darby & Cushman
ATTORNEYS

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3,371,865

DEAERATING APPARATUS

Gene W. Ross and David S. Ross, Lorain, Ohio, assignors,
by mesne assignments, to Ritter Pfaudler Corp., Roch-
ester, N.Y., a corporation of New York

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This invention relates to the removal of dissolved gases from a liquid by subjecting the liquid to a vacuum and in particular to improved equipment for carrying out the vacuum treatment. It also relates to improvements in the deaeration of water in heating systems, particularly steam heating systems.

Degasification, or more specifically, deaeration of liquids has application in the fields of heating, water treatment, distillation, concentration, drying and hardness removal and other installations where scale and corrosion are a source of high operating and equipment costs. One example of such an installation is a steam heating system of the kind in which a central boiler system supplies steam to one or more locations, for example separate buildings, which are remote from the boiler system. In installations of this kind it is conventional to return the condensate from each location to the boiler system. The condensate, as it forms, invariably becomes contaminated with dissolved gases with the result that the pipe or pipes which return the condensate to the boiler system are subjected to corrosion. In many installations the main condensate return line has a useful life of only a few years.

Vacuum degasifiers of one known type operate by pumping a portion of a batch of liquid out of a sealed tank, the displaced portion of the liquid producing a boiling-point vacuum in the tank. The vacuum causes a small part of the liquid to boil and at the same time causes the dissolved gases to come out of solution and rise to the surface of the remaining liquid in the form of small bubbles. When the vacuum is relieved and fresh liquid is re-supplied to the tank, the gases which were previously liberated are forced by displacement out of a vent at the top of the tank, and the pumping process is repeated after again sealing the tank. The operation of this type of system is based on the known principle that the solubility of most gases in a liquid approaches zero at the boiling point of the liquid.

From the above description it will be apparent that the portion of liquid which is first pumped out of a newly sealed tank has not been subjected to a vacuum for any appreciable period and therefore has not been degasified. In one known form of this type of equipment the first-pumped portion of liquid, which may still contain dissolved gas, is introduced into the system which receives the liquid from the pump, such as the boiler of a steam heating system. Obviously, this is an undesirable feature because over a long period of time a considerable volume of gas will be introduced into the boiler. In a more complex form of known equipment the deaeration equipment includes two deaeration tanks and a special piping and valve arrangement which, together with a pump, withholds the first-pumped liquid and sends only completely deaerated liquid to the system. This type of equipment is extremely efficient but represents a capital investment which may not be warranted in a small heating plant.

A full disclosure of the first-mentioned arrangement may be found in Baker Patent 2,339,369, issued Jan. 18,

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1944, and a full disclosure of the more complex arrangement may be found in Baker Patents 2,357,445, issued Sept. 5, 1944, 2,735,623, issued Feb. 21, 1956, 2,997,129, issued Aug. 22, 1961 and 3,104,163, issued Sept. 17, 1963.

It is one of the objects of the present invention to reduce the corrosion in the condensate return line of steam generating systems, particularly where the boiler is remote from the location at which the steam condenses, by providing a low-cost deaerating system at the condensing location for directly receiving condensate and for delivering deaerated condensate to the condensate return line. In a preferred arrangement the deaerating system is arranged below the level of the steam condensing equipment to receive condensate by gravity and to employ the gravity flow to contribute to the operation of the system.

It is another object of the present invention to provide a low-cost, simply constructed form of displacement type vacuum degasification equipment which withholds the first-pumped portion of liquid without the use of a double deaeration tank and an interconnecting pipe and valve arrangement.

It is a still more specific object to provide a low-cost form of degasification equipment having a single deaeration tank from which liquid is pumped to create a deaerating vacuum therein and a relatively small inexpensive surge tank associated with the outlet of the pump in a manner to accept and hold the first-pumped portion of liquid and subsequently to return that portion to the deaerating tank.

The invention will be further understood from the following detailed description taken with the drawings in which:

FIGURE 1 is a schematic elevational view, partly broken away, of a steam heating installation including a condensate deaerating and return system embodying the principles of the present invention;

FIGURE 2 is a graph illustrating the operation of the deaerating unit of FIGURE 1;

FIGURE 3 is a schematic elevational view of a second embodiment of a condensate deaerating system; and

FIGURE 4 is a schematic elevational view, partly broken away, of a third embodiment of the deaerating unit of FIGURE 1.

Referring to FIGURE 1 there is shown a steam generating installation which includes a main boiler system 2, a main steam line 3, a main condensate return line 4 and three steam consumption stations remote from the boiler system 2. The latter is illustrated as including a boiler 5, a steam condensate storage tank 6 and a piping arrangement 7 for delivering condensate to the boiler 5 as required. It will be understood that the system 2 may include any equipment conventionally employed in boiler feed arrangements and need not necessarily include the storage tank 6. For simplicity each of the steam consumption stations may be considered as a separate building which is to be heated, the heating equipment including radiators 8, 8a and 8b or the like and a steam trap 9, 9a and 9b for passing condensed steam out of the heating equipment. According to the principles of one feature of the present invention the main condensate return line 4, which may be of great length, is protected from internal corrosion by providing a low-cost vacuum-type condensate deaerating system at each steam consumption station. These low-cost deaerating systems, of which a preferred

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construction is illustrated in detail at 10 and schematically at 10a and 10b, remove the dissolved gas from the condensate soon after it forms with the result that the main condensate line 4 is not subjected to the corrosive effect of normal, gas-containing condensate. Each system 10, 10a and 10b is arranged to receive condensate from the respective steam trap 9 by gravity, and the gravity flow is employed to contribute to the operation of the system as will become apparent from the following description.

Referring to the lower portion of FIGURE 1 it will be seen that the condensate deaerating system 10 is disposed below the level of the respective radiators 8 and steam trap 9 and below the level of the main condensate return line 4. Fresh condensate enters the system 10 by gravity from the trap 9 through a line 11, and deaerated condensate is pumped to the main condensate line 4 through a line 12. Deaeration of fresh condensate takes place in a deaerating tank 13 when the latter has been sealed and some of the liquid 14 therein is displaced by means of a centrifugal pump 15. The pump 15 is disposed below the liquid level in the tank 13 and has its inlet connected to the lower portion of the tank 13 by a pipe 16, the latter forming both inlet and outlet for the tank 13.

The pump 15 forms part of a conventional motor-pump unit which includes an electric motor 17 and shaft 18 for driving a rotor 19 within a pump casing 20. In the illustrated embodiment the pump 15 is provided with a shaft lubricating and sealing arrangement which also contributes to the deaerating function of the apparatus. The arrangement includes a housing 21 surrounding the shaft 18 and a bleed conduit 22 extending between the tank 13 and the space between the housing 21 and the shaft 18. The bleed conduit 22 contains a valve 23 which may be adjusted to control the flow of water from the housing 21 into the tank 13.

The outlet of the pump 15 is connected to a discharge pipe 28 which leads to a hold-up and discharge portion of the system. The end of the pipe 28, remote from the pump casing 20, connects with the line 11 through a branch 30 and a valve 36 which permits liquid flow only from the line 11 into the pipe 28. Conveniently, the valve 36 is a check valve which opens automatically when the pressure in the line 11 exceeds the pressure in the condensate receiving pipe 28. To protect the valve 36 and the pump 15 from solid matter entering with condensate from the line 11, the branch includes a conventional screen and flush unit 33. Intermediate its ends the pipe 28 communicates with an upwardly extending branch 34 which leads to a surge or holdup tank 40 and to another branch 32. The latter connects with the line 12 through a valve 38 which, conveniently, is a check valve arranged to pass liquid into the line 12 when the pressure in the branch is high enough to open the valve against the pressure in the line 12. If necessary, the valve 38 may be biased toward a closed position. Both valves 38 and 36 may be provided with separate controls for opening and closing them in the desired sequence although the use of check valves is preferred from the standpoint of cost and simplicity.

The liquid holdup tank 40 which is of much smaller volume than the deaerating tank 13, is disposed above the pump discharge pipe 28 and connects at its lower end with the branch 34. A body of condensate liquid 42 and an overlying capacitive gas cushion 44 are contained within the tank 40. The volume of the cushion 44 may be adjusted by introducing or removing gas through a valved tap 46 located on top of the tank 40.

Referring again to the deaerating tank 13 it will be seen that the top of the tank is provided with a gas vent line 48 containing a check valve 50 for passing gas only out of the tank 13. The top of the tank 13 is also provided with an electrically operated liquid level sensing device 52 for controlling the operation of the deaerating pump motor 17 through an electrical control line 54. The sensing device includes an upper probe 56 which effects a pump-on signal when condensate 14 rises to level A at

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the lower end of the probe 56. A lower probe 58 effects a pump-off signal when condensate falls to level C at the lower end of the probe 58.

Referring to FIGURE 3 there is shown a deaerating system 10' which differs from the system 10 of FIGURE 1 in the piping by which condensate enters and leaves the system. In the FIGURE 3 construction a deaerating tank 13' is provided with separate pipes 60 and 62 for transferring condensate into and out of the tank 13', respectively. The inlet pipe 60 receives fresh condensate from a steam heating system, such as that illustrated in FIGURE 1, through a line 11' and passes the condensate through a pressure-to-close valve 64 into the deaerating tank 13'. The outlet pipe 62 conducts condensate from the tank 13' to the inlet of a pump 15'. The pump discharge line 28' divides into two branches 32' and 34', the former connecting with the bottom of a holdup tank 40' and the latter connecting with the condensate return line 12' through a check valve 38'. The holdup tank 40', like the holdup tank 40 of FIGURE 1, contains a gas cushion 44' overlying a body of condensate 42'.

The pump 15' is controlled by a liquid level sensitive control system 52', 54' associated with the deaerating tank 13' which turns the pump on when the liquid rises to the level A and turns the pump off when the liquid drops to the level C. The condensate inlet valve 64 is normally open and is closed by operation of the pump 15' by means of a pressure signal transmitted from the pump discharge line 28', to the valve 64 through a control line 66.

FIGURE 4 illustrates a modified deaerator unit 10'' in which provision is made for recirculating a portion of the withdrawn liquid back to the deaerator tank 13'' after the liquid 14'' in the tank 13'' has been partially pumped out. The apparatus is similar to that of FIGURE 1 in that liquid enters and leaves the tank 13'' through a single pipe 28'' and a pump 15''. However, in the FIGURE 4 arrangement there is, in addition, a bleed line 70 connecting the pipe 28'' with the upper portion of the tank 13''. The bleed line 70 contains a valve 72 which is controlled by a float 74 within the tank 13''. The float 74 and an associated control arrangement 76 maintain the valve 72 closed when the liquid 14'' within the tank 13'' is high. When the liquid level drops to the dotted-line position of the float 74 as a result of the operation of the pump 15'', the valve 72 opens to allow a relatively small proportion of the flow in pipe 28'' to return to the tank 13'' through the bleed line 70. The connection of the line 70 is shown as being well above the level of the liquid 14'' at which the valve 72 opens so that the recirculated liquid is sprayed into the tank 13''.

During operation of the heating installation of FIGURE 1 fresh condensate drains by gravity into the deaerating tank 13 through the condensate line 11, the check valve 36 and the pump 15. When the level of condensate 14 in the deaerating tank 13 rises to the bottom of the probe 56 a pump-on signal is transmitted to the pump motor 17 through the electrical control line 54. During accumulation of condensate 14 in the tank 13 gases above the liquid level are forced by displacement through the check valve 50 in the vent line 48 and discharged to the atmosphere. However, as soon as the pump 15 begins to operate, the check valve 50 closes thus sealing the tank against entry of either gas or liquid.

Upon operation of the pump 15 a boiling point vacuum is created in the tank 13 as a result of the sealing action of the check valve 50 and the displacement of some of the condensate from the tank 13. The vacuum very soon reduces to zero the solubility of dissolved gas in the remaining condensate 14 with the result that the gas comes out of solution and rises to the surface in the form of small bubbles 68. Simultaneously the gas-containing condensate which is first pumped out of the tank 13 passes into the pump discharge line 28 and upwardly into the holdup tank 40 through the branch line 34. At this time no condensate flows into the return line 12 through

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the branch line 32, because the pressure in the latter is insufficient to open the check valve 38 against the pressure which normally exists in the line 12. If this pressure is insufficient to maintain the valve 32 closed, the latter may be spring loaded toward a closed position. Alternatively, the valve 38 may be caused to open under the control of a pressure signal from the pump or after a predetermined period of pump operation. No flow occurs in the branch line 30, because the outlet pressure of the pump 15 in the latter is higher than in the line 11 thereby causing the check valve 36 to remain closed.

As the fresh gas-containing condensate is pumped into the holdup tank 40 the gas cushion 44 is gradually compressed, and the pressure in the pump discharge line 28 gradually rises. When the pressure becomes sufficient to overcome the pressure difference across the check valve 38, the latter opens and permits deaerated condensate to be forced from the pump discharge line 28 through the branch line 32 and into the line 12. The main condensate line 3 will therefore receive only deaerated water. Since this line may be of great length, its protection from corrosion will result in a savings which in almost all cases will be more than offset by the cost of the deaeration system 10. The portion of condensate which was previously pumped into the holdup tank 40 remains in the tank 40, because the pressure of the water flowing in the pump discharge line 28 is slightly higher than the static pressure in the tank 40.

During operation of the pump 15 the vacuum in the tank 13 will draw water through the bleed conduit 22 from the housing 21 thereby lubricating the shaft 13. In addition, the stream of water entering the tank 13 agitates the liquid 14 thereby increasing the rate at which dissolved gas comes out of solution. A further effect of the entering stream results from the fact that the water passing into the tank 13 from the bleed conduit 22 is subjected to a deaerating vacuum for a longer period of time than the water which does not become by-passed through the bleed conduit 22.

When the condensate 14 has been pumped down to the bottom of the probe 53, illustrated by the dashed line C, a pump-off signal is transmitted through the control line 54 to shut off the motor 17. The pressure in the pump discharge line begins to drop, and thereupon the gas cushion 44 in the top of the holdup tank 40 expands and forces some of the condensate 42 from the tank 40 into the line 28 and then in a reverse direction through the non-operating pump 15 and into the deaerating tank 13. After the pressure in the tank 40 has been thus relieved, the check valve 36 opens and gas-containing condensate from the line 11 flows by gravity into the line 28 and subsequently into the tank 13. Simultaneously the check valve 50 opens and permits the liberated gases in the tank 13 to be displaced to atmosphere through the vent 48, 50.

It will thus be seen that the first-pumped, air containing portion of condensate 14 which is pumped out of the deaerating tank 13 is withheld from the return line 12 and is subsequently returned to the tank 13 for deaeration. The effect of withholding this first-pumped portion is illustrated graphically in FIGURE 2 where the solubility of gases in a given liquid at a constant temperature is plotted against time under a boiling point vacuum. It will be seen that the concentration of gases in a liquid drops rapidly in the first few moments of vacuum and then drops very much more slowly. Thus, substantially all dissolved gas is liberated between the initiation of a boiling point vacuum, illustrated at A, and a time B occurring shortly thereafter. At a later time, illustrated at C, only a small additional amount of gas has been liberated from solution. Applying the graph to the FIGURE 1 system it will be seen that substantially all dissolved gas will be liberated from the condensate 14 in the deaerating tank 13 within a relatively short time after starting the pump 15. Accordingly, the volume of the holdup tank 40 need

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not be large, and in the illustrated arrangement it is constructed to hold only that amount of condensate which is pumped during the period of time from A to B on the graph of FIGURE 2. The dashed lines A, B and C in FIGURE 1 indicate the level of condensate in the tank 13 at the times A, B and C, respectively. It will thus be appreciated that in the most economical construction the holdup tank 40 is constructed no larger than necessary. For different systems the size of the tank 40 will increase with an increase in the capacity of the pump 15, but not necessarily with an increase in the size of the deaerating tank 13.

It will also be apparent from the graph of FIGURE 2 that the bleed water entering the tank 13 will contribute to the gas removal efficiency of the apparatus, because the bleed water will be maintained under a vacuum for a relatively long period of time due to its recirculation between pump 15 and tank 13.

The construction and operation of the deaerating systems 10a and 10b are the same as the system 10.

The operation of the FIGURE 3 system is similar to the operation of the FIGURE 1 system. However, in the FIGURE 3 system condensate from the heating system (not shown) enters the deaerating tank 13' through a separate line 60 rather than through the deaerating pump 15' as in the FIGURE 1 system. When the pump 15' starts after receiving a pump-on signal through the control line 54', the deaerating tank 13' becomes sealed by the closing of the check valve 50' and by the closing of the valve 64. The latter is normally open to permit condensate to drain by gravity through line 11' into the tank 13', but closes when a pressure signal is delivered thereto through the control line 66 from the pump discharge line 28'. The pumping of condensate from the sealed tank 13' immediately creates a boiling point vacuum therein and dissolved gas begins to be liberated from the condensate in accordance with the relationship illustrated in FIGURE 2.

The first-pumped portion of condensate, which is a mixture of completely undeaerated water and partially deaerated water, passes upwardly into the holdup tank 40' against the gas cushion 44'. When the pressure in the pump discharge line 28' becomes sufficient to overcome the pressure difference across the check valve 38', the latter opens and permits substantially completely deaerated water to flow from the line 28' into the return line 12'. The holdup tank 40' is of a size which will accept a volume of liquid equal to the volume between levels A and B in FIGURE 3, this volume representing the volume pumped between time A and time B in FIGURE 2. At time C and level C the pump 15' stops, check valve 38' closes and some of the water 42' in the surge tank is forced back into the deaerating tank 13' in a reverse direction through the pump 15'. When the pressure in the pump discharge line 28' drops, the valve 64 in the condensate inlet line 60 opens and permits condensate to flow by gravity into the tank 13' thereby displacing previously liberated gases through the check valve 50' and the vent 48'.

The operation of the deaerator 10'' of FIGURE 4 is the same as the deaerator of FIGURE 1 with the additional effect produced by the recirculation of liquid through bleed line 70. The bleed line 70 is inoperative at the beginning of a pump-out operation, because the float 74 and control arrangement 76 maintain the valve 72 closed. After the pump 15'' operates for a short time, the float 74 drops to the dotted-line position, and the valve 72 opens. Since the liquid now flowing through the pipe 28'' has been subjected to a vacuum in the tank 13'' it is at least partially deaerated. The portion which returns to the top of the tank 13'' is sprayed into the vacuum space above the liquid 14'' with the result that the spray becomes highly deaerated. It will also be appreciated that recirculation through the bleed line 70 increases the average time to which the liquid in the pipe 28'' has been subjected to a vacuum. From a considera-

tion of the graph of FIGURE 2 it will be seen that the liquid in the pipe 28" will therefore contain less dissolved gas than if no recirculation was present.

In the interest of further economy it may be desirable under some circumstances to omit the holdup tank feature of the present invention. This, of course, would return the first-pumped, gas-containing condensate to the main condensate line, but under some circumstances the small amount of dissolved gas might be deemed insufficient to warrant the investment in the holdup tank. It is known, of course, to employ deaerators at the boiler as part of the boiler feed system, and in the event that a boiler feed deaerator were employed the small amount of gas in the main condensate would be removed prior to feeding the condensate to the boiler. It is important, however, that the deaerating systems, regardless of whether a holdup tank is employed, be associated with the remote stations and be arranged so that filling of the deaerating tanks and consequent venting of gases therefrom is accomplished automatically by the pressure at which the condensate is available. In the case of steam systems a gravity condensate feed can be obtained because it is usually convenient to locate the deaerating system below the level of the steam condensing equipment. However, the invention is applicable to any liquid processing installation in which gas-containing liquid is available at a pressure, either static head or produced by a pump, which is sufficient to force the liquid into the deaerating tank.

It will be understood, also, that the utility of the here-indescribed combination of a holdup tank with a deaerating tank is not limited to its incorporation in a particular type of liquid processing installation. That is, the combination of a holdup tank with a deaerating tank may be employed wherever it is desired to degasify a liquid regardless of the source of the gas-containing liquid or the destination of the degasified liquid.

From the above descriptions it will be apparent that the invention is not limited to the precise embodiments illustrated and that the disclosed details are exemplary of the principles involved and are not intended to be limiting except as they appear in the appended claims.

What is claimed is:

1. Liquid degasifying apparatus comprising:

a degasification tank for containing a batch of liquid which is to be degasified;

vent valve means in communication with the top of said tank for sealing said tank against ingress of fluid when closed and for passing gases out of said tank when open;

a liquid receiving conduit for receiving liquid from said tank; and

means for producing a vacuum in said tank thereby to degasify liquid in said tank and for conducting substantially completely degasified liquid from said tank to said liquid receiving conduit, said means including a pump for withdrawing liquid from said tank whereby when said vent valve means is closed a degasifying vacuum may be produced in said tank, said pump having an inlet disposed below the liquid level in said tank and an outlet, said outlet being connected to said liquid receiving conduit, a holdup tank of lesser volume than said degasification tank and having an upper and a lower portion, said lower portion containing a liquid and being in communication with said liquid receiving conduit, said upper portion containing a gas cushion compressible by liquid in said lower portion and sealed from the atmosphere; and a liquid control valve in said liquid receiving conduit and located more remotely from said pump than the point of communication between said conduit and said holdup tank;

whereby when said vent valve and control valve are closed and said pump is operated, the first-pumped portion of liquid which is withdrawn liquid from said degasification tank is forced into said lower

portion of said holdup tank against said gas cushion and whereby when said liquid control valve is subsequently opened, substantially completely degasified liquid is passed from said degasification tank through said liquid control valve.

2. Apparatus as in claim 1 wherein said vent valve is a check valve arranged to pass gases out of said degasification tank when liquid is introduced therein and to close automatically upon creation of a vacuum therein and wherein said liquid control valve is a check valve arranged to open under the influence of a predetermined high pressure in said conduit on the pump side of said check valve whereby substantially completely degasified liquid will be passed automatically by said valve after said gas cushion has been compressed to said predetermined pressure.

3. Apparatus as in claim 1 including a liquid inlet conduit connecting at one end with said degasification tank, a normally open valve in said inlet conduit, and means responsive to operation of said pump for closing said valve.

4. Apparatus as in claim 1 including a liquid inlet conduit connecting at one end with said liquid receiving conduit, and a check valve in said inlet conduit arranged to pass liquid into said receiving conduit when open.

5. Apparatus as in claim 1 including recirculation conduit means for returning a portion of the liquid passing through said pump outlet to said degasification tank to thereby again subject the portion to a deaerating vacuum, said means including a conduit communicating at one end with said degasification tank and at its other end with said pump outlet.

6. In a steam generating and condensing installation including a boiler system, steam condensing means remote from said boiler system and a steam condensate return line for conducting condensate from said condensing means to said condensate return line, the improvement comprising;

a low-cost, simply constructed vacuum deaerator located substantially at said station for deaerating steam condensate and thereby protecting said return line from steam condensate internal corrosion, said deaerator including a deaerating tank disposed below said steam condensing means so as to permit gravity flow of condensate into said tank; vent means associated with the top of said deaerating tank to pass gases out of said tank upon introduction of condensate into said tank; a vacuum producing pump disposed below the level of condensate in said tank and connected to pump condensate out of said tank;

said installation further comprising deaerated condensate conduit means connected between said pump and said condensate return line at a location remote from said boiler system for conducting deaerated condensate to said condensate return line; valve means in said conduit means for controlling the flow of deaerated condensate into said condensate return line; means for opening said valve means when said pump operates and for closing said valve means when said pump is stopped; a conduit connected at one end to said condensing means and at its other end to said deaerator for conducting fresh condensate to the latter; valve means in said fresh condensate conduit; and means for opening said last-named valve means when said pump is stopped to thereby allow fresh condensate to flow into said deaerator by gravity, said means being further operative to close said last-named valve means when said pump operates.

7. An installation as in claim 6 wherein said other end of said conduit for conducting fresh condensate from said condensing means to said deaerator connects with said deaerated condensate conduit means at a location between said pump and the valve means in said

deaerated condensate conduit means whereby fresh condensate enters said deaerating tank by flowing in a reverse direction through said pump.

8. An installation as in claim 6 wherein said other end of said conduit for conducting fresh condensate from said condensing means to said deaerator connects with said deaerating tank.

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