A reflux splitter which includes within a process shell having nonmagnetic walls: a pivoting funnel to receive a liquid condensate stream; a magnetic material secured to the funnel and adapted for movement therewith; a permanent magnet external of the process shell; means to move the permanent magnet into and out of a close magnetic-flux relationship with the magnetic material, so as to move the funnel in a cyclic timed manner to a diverting and nondiverting position to achieve a desired reflux ratio; and fluid-actuating means to move the permanent magnet and to time the movement of the magnet in each position.

11 Claims, 1 Drawing Figure
SUPPLY WITH REGULATOR FILTER AND SHUT OFF

Fig. 2.
REFLUX SPLITTER AND CONTROL SYSTEM THEREFOR

BACKGROUND OF THE INVENTION

A reflux splitter is primarily used on distillation columns to divert and to regulate the proportion of condensed vapor; i.e., liquid condensate, that is returned to the distillation column as a reflux stream to the condensate which is recovered or sent to further processing. Reflux splitters are of particular importance in laboratory and pilot-plant distillation systems, since in large commercial distillation systems other means are often employed to control reflux. Typically, the reflux splitter is positioned on top of the distillation column under the condenser. A control system is employed which periodically and sequentially provides a means to divert a portion of the condensate which descends by gravity from the condenser outside of the column.

Commercially two means are employed to divert the condensate. One technique is to employ a reflux take-off passage, one end of which is within the process shell and positioned vertically beneath a reflux conduit from the condenser, with the other end extending through the wall of the shell. A movable gate member is positioned over the open passageway of the internal opening. The gate member is then periodically on a timed basis moved by a control system to expose the internal, open end of the reflux takeoff passage to divert the condensate for the preselected period of time, and then moved to a closed position to permit the condensate to enter the top of the column. Such a device for diverting a reflux stream is disclosed in U.S. Pat. No. 3,012,949.

Another means to divert a reflux stream is to employ a tilting, vertically extending funnel or conduit member beneath the condensate reflux conduit, so as to divert the falling reflux stream to obtain the desired reflux ratio. For example, in one position, the member permits the condensate to be diverted from returning to the column, while in another position, the condensate is diverted to the column. The tilting of the conduit or funnel member is typically accomplished by a linkage system within the column secured to the tilting member. The linkage system is operated by an external control system which operates periodically. Such devices are disclosed, for example, in U.S. Pat. Nos. 2,518,574 and 2,903,401.

The control systems employed with present reflux systems are electromechanical systems which, through the use of electric timers and electrically operated solenoids, provide an actuating mechanism to move the gate member or tilt the funnel member on energizing of the electromagnetic solenoid in response to electrical signals from the timer. The employment of such electrically operated control systems requires the presence of available electrical power, an active maintenance program, and precludes the use of such systems in certain hazardous vapor areas without additional expense and special devices to comply with safety regulations.

SUMMARY OF THE INVENTION

Our invention comprises a reflux splitter employing a pivoting-funnel element within a process shell, which funnel member is shifted between a diverting and nondiverting position by the application of an external permanent magnet, which magnet is moved between actuated and nonactuated positions by a pneumatic control system.

In our device, a permanent magnet, placed externally of the process shell, is moved toward: that is, into an actuating position or moved away from; that is, into a nonactuating position, adjacent the process shell wall by a double-action pneumatic or hydraulic cylinder. The process shell is composed of a nonmagnetic material, while the pivoting funnel element has secured thereto a magnetically attractive material, whereby the application of the magnetic force of the permanent magnet through the process shell walls in close actuating position affects the desired pivoting movement of the funnel member within the process shell.

Our fluid-actuated magnetic reflux splitter provides many advantages over prior-art devices. One advantage is that no moving parts need be inserted through the process shell wall as in other devices. Our system, wherein the actuating mechanism is isolated from and external to the process, permits easier performance of maintenance, eliminates the need for shell seals, permits the process shell pressure ratings to be limited solely by the thickness of the process shell as it affects the desired magnetic flux, and permits high process-temperature capability, since the motive device used, i.e., the double-acting cylinder, is easily isolated from the heat. A further and distinct advantage is that our fluid-actuated, control system requires no electrical power and permits its use in areas where electrical systems require an explosion-proof rating. In addition, the use of a fluid control system permits the use of more reliable, simpler and less expensive components, while such a system is easily installed to any pneumatic or hydraulic power source.

For the purposes of illustration, our reflux splitter will be described in connection with its use in a distillation column system.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 represents a partial, sectional view of our reflux splitter in a reflux condenser distillation system with a schematic illustration of a pneumatic control system.

DESCRIPTION OF THE EMBODIMENTS

Our device comprises a distillation system 10 which includes a distillation column 12 with vapor passing upwardly and condensate returned to the column downwardly, a reflux splitter 14 positioned on top of the column and a reflux condenser 16. The reflux splitter 14 includes a cylindrical process shell 18 composed of a nonmagnetic material, such as glass or stainless steel. The wall thickness is dependent on the pressure requirements of the system, but insufficient to prevent the passage of the desired magnetic flux as hereinbefore described. The process shell 18 is secured by flanges 20 and 22 between the condenser 16 and the column 12.

Interior of the process shell in the splitter 14 is a condensate collector 24 which collects condensate from the reflux condenser 16, and an elbow condensate outlet 26. Positioned beneath the open end of the outlet 26 is a hanging funnel element 28 adapted to pivot about
a pivot 30, so as to tilt the outlet end of the funnel. Directly beneath the outlet end of the funnel 28, in its nondiverting, free-hanging position, is a trough element 36 for directing the condensate from the outlet to the central part of the process shell, so that the condensate falls downwardly to the distillation column for additional processing. The trough 36 would not be required other than that the funnel element 28 is positioned toward the internal wall of the process shell.

A reflux-diverting trough 34 is secured to the internal wall of the process shell, the trough leading to a reflux outlet 38 in the process shell wall. The diverting trough 34 is positioned so that the funnel 28 in its nondiverting position will not direct the condensate into the reflux trough 34, but in its diverting, pivoted position, the outlet of the funnel 28 is directed into the reflux trough 34, the clearance of the funnel at its upper mouth and the position of the pivot adapted to permit such movements.

Secured to the lower side of the funnel element 28 and adapted for pivoting movement therewith is a magnetic weight 32 composed of a metal, such as a steel material or permanent magnet, which is attracted or repulsed by a magnetic force. The weight may be plated, coated or otherwise encased in a protective material if desired or required, such as a Teflon-coated magnet. The weight element 32 is preferably shaped so that, when the funnel element 28 is in its reflux-condensation-diverting position, the element 32 is in a close relationship to the internal wall of the process shell.

External to the process shell 18 is a double-acting pneumatic or hydraulic cylinder 46, secured at one end to the flange 22, the cylinder having a reciprocating, movable piston rod 48 secured at its other end to an internal piston. The actuating element 42 is secured to the process shell wall and adapted for movement about a pivot 44. Secured to the element 42 and adapted for movement therewith back and toward the process shell external wall is a permanent magnet 40. The magnet 40 and the actuating element are adapted for pivotable, reciprocating movement between an actuating position, wherein the magnet is positioned in close proximity to the external process shell wall, so as to permit magnetic flux to pass through the wall and attract (or repulse if desired) the weight element 32, or to move away from the process shell wall a sufficient distance to a nonactuating position to permit the pivoting funnel 28 to resume its gravity-directed, free-hanging, nondiverting position. Movement of the actuating element 42 and the magnet 40 is affected by the position of the piston rod 48 which is positioned by response to fluid pressure applied to either side of the piston within the piston cylinder 46 through the fluid-control system.

In the embodiment described, compressed air is employed as a source of air pressure 50 through a shut-off valve 60, an air filter 62 and a pressure regulator valve 64 to a pneumatic cycle controller 66. The controller includes dual, pneumatically actuated timers 70 and 72, the operation of the timers, which may be preset by the user, controlled by a pneumatic or hydraulic logic system 68 operated off the air pressure source 50. The fluid logic circuit used is well known and commercially available, as are the pneumatic cycle timers illustrated. Three-way valves 52 and 54 and needle valves 74 and 76 for each timer are included in the pneumatic system. Valves 74 and 76 are speed or flow-control needle valves with integral check valves 78 and 80. The three-way valves 52 and 54 are actuated through diaphragm actuators 56 and 58 (e.g., see U.S. Pat. No. 1,194,856). As illustrated, the actuator 56 has opened the three-way valve 52 to let air into the upper cylinder port through valve 76, with timer 70 in operation and three-way valve 54 open to exhaust. The logic circuit operates directly or at a reduced pressure; e.g., 3–5 psig, off the air pressure source 50, and senses when one timer is finished and starts the other timer and repeats this cycle. If desired, a selector-type valve (not shown) may be employed in the control system to allow the operator to select full reflux or full takeoff, rather than cycling of the cylinder.

In operation, the reflux ratio desired is set by the selection of time periods for the diverting and nondiverting funnel positions on the timers 70 and 72, for example, from 1 to 60 seconds, such as 1 to 5 seconds for the diverting position, and 3 to 15 seconds for the nondiverting funnel position. One of the timers; e.g., 70, is actuated and one of the valves 52 or 54 switched to allow air pressure to one of the ports of the cylinder 46. As shown, the pivoting funnel 28 is in the nondiverting position, with the magnet 40 held away from the external wall of the process shell 18 by the extended position of the actuating element 42 forced into such position by the extension of piston rod 48 through the application of air pressure through valves 52 and 76 to the opposite side of the piston in the cylinder. At the end of the timing period, the timer 70 stops timing, and the three-way valve 52 deactivates to exhaust the air in the upper portion of the cylinder 46. The logic circuit sensing the change in timing output pressure activates the other timer 72 and the three-way valve 54. The valve 54 switches to permit air pressure into the lower part of the cylinder 46 which forces the piston rod 48 upwardly and pivots the actuating element 42 inwardly toward the external wall of the process shell, with the magnet 40 placed in a close position adjacent the wall. In this position, the diverting position for the funnel 28, magnetic flux of the magnet penetrates the process shell wall and attracts the magnetic weight 32 toward the internal wall surface of the process shell where the magnet 40 is positioned, causing the funnel 28 to pivot also and assume the diverting position, permitting the condensate to be directed for that time period into reflux trough 34 and reflux outlet 36, and be removed. At the end of the second diverting position time period, the other timer stops and the three-way valve exhausts the air in that side of the cylinder 46, and the timing process is then repeated.

The position of the funnel and other elements is shown in a nondiverting position in solid black lines, and in a diverting position by dotted lines. Many types of timers may be employed in our nonelectric-control system, such as mechanical timers such as a clock mechanism which functions purely by mechanical timing means, or pneumatic or fluidic timing devices; for example, as illustrated, which employ the gas or fluid flow out of or into a known volume through an orifice as a means of timing. Both mechanisms are started by pneumatic signals, and both control a pneumatic signal output. As shown, two three-way actuated valves 52 and 54 have been employed, actuated by pneumatic actuators 56 and 58 (i.e., to source, to exhaust and to cylinder). However, it is recognized that other valves may be used, for example, a single four-way valve may be
3,860,491

Our reflux splitter has been illustrated in connection with a reflux condenser; that is, where vapors pass upwardly from a distillation column or other evaporator to a condenser, while condensed distillate flows downwardly from the reflux condenser back to the distillation column. However, our reflux splitter and control system may also be used with an external condenser; that is, a condenser separate from the distillation column, which receives vapor from the column or other sources, and where only the liquid condensate flows through our reflux splitter system.

Our reflux splitter and control system may be employed in connection with distillation systems generally, and in other equipment where it is desired to separate a stream of liquid into separate streams in a periodic sequential manner. The reflux ratio or the proportions of the streams to be divided into two or more streams may be adjusted by appropriate settings of the desired reflux ratio; i.e., the time at which the funnel is in various diverting positions, to the time in the nondiverting position through the selection of such time periods on appropriate timing devices.

Our control system has been described employing air pressure as the motive power source. It is within the scope of our invention to employ any pressurized gaseous source, or to employ in whole or in part a hydraulic system utilizing a liquid as the fluid motive power. Our reflux splitter has been described in connection with a pivoting or tilting funnel device, rather than a gate-opening and closing device or other means for controlling reflux. However, our fluid-control system may be employed with other reflux splitter devices to effect the desired gate movements and control of reflux.

Our reflux splitter and control system provide distinct and important advantages over prior art splitters and control systems as herein set forth.

What we claim is:

1. A reflux splitter which comprises in combination:
   a. a process shell at least a portion of whose wall is composed of a nonmagnetic material, and characterized by a reflux outlet in the process shell wall to discharge reflux externally of the process shell;
   b. means to discharge a liquid condensate into the process shell;
   c. a reflux condensate-receiving element within the process shell adapted to direct liquid condensate therein to the reflux outlet;
   d. movable means to direct liquid condensate discharged into the process shell between a first position wherein the condensate is directed into the reflux outlet, and a second position wherein the condensate is permitted to be discharged downwardly within the process shell;
   e. a magnetic material secured to the movable means and adapted for movement therewith, the magnetic material adapted to be positioned in either the first or second position of the movable means in a close magnetic flux relationship with the nonmagnetic wall of the process shell;
   f. a permanent magnet positioned externally of the process shell;
   g. a source of air pressure;
   h. means to move the permanent magnet between an actuating position and a nonactuating position, one of said positions placing the permanent magnet in a close magnetic flux relationship with the external nonmagnetic wall of the process shell which comprises,
      i. an actuating element adapted for pivotal movement externally of the process shell, the permanent magnet secured to the said element at one end thereof for movement therewith;
      ii. a double-acting pneumatic cylinder having a piston thereon and a piston rod, one end of which is secured to the actuating element at the other end thereof to permit reciprocating movement of the element with the movement of the piston rod;
      iii. means to supply air pressure from the air pressure source to the cylinder; and
      iv. valve means to permit air pressure from the source to be introduced into the cylinder and to be exhausted from the piston; and

2. The splitter of claim 1 wherein the movable means comprises a funnel element having a wide open upper entrance and a narrow open lower outlet, and adapted for pivotal movement about a pivot point between the first position and the second position, the second position being one of an essentially vertical, free-hanging position of the funnel element.

3. The splitter of claim 1 wherein the cylinder at the one end is secured for pivotal movement to the external wall of the process shell, and the actuating element comprises a first extending element secured at the one end to the end of the piston rod, and, at the other end, pivotally secured at a pivot point to the external wall of the process shell, and a second extending element pivotally secured at one end to the same pivot point at the other end of the first element, and adapted for movement with the first element about the pivot to the permanent magnet at the other end, whereby, on movement of the piston rod, the first and second extending elements move to position the permanent magnet in actuating and nonactuating positions.

4. The splitter of claim 1 wherein the air-actuated, cyclic, timing means comprises first and second pneumatic timers, one of which controls the time period of the magnet in the actuating position, and one of which controls the time period of the magnet in the nonactuating position; a pneumatic-logic means to sense the change in timing pressure in one timer and to actuate the other timer; first valve means to direct low-pressure air from the source to the logic means; and second valve means to direct air pressure to the cylinder, to the exhaust and to the first or second timer.
5. The splitter of claim 1 which includes: first and second pneumatic timers, one of which controls the time period of the magnet in the actuating position, and one of which controls the time period of the magnet in the nonactuating position; first and second three-way valves, the valves each adapted to direct the flow of air from the source to the upper and lower parts of the cylinder, to the exhaust or to the source; first and second pneumatic actuators to actuate the three-way valves; and pneumatic-logic means to sense the change in pneumatic pressure of the first or second timer, and to actuate the other timer, whereby, on selection of the desired time period, air flows through the logic-means timer to provide for the timed reciprocating action of the piston rod which places the magnet in actuating and nonactuating positions.

6. A reflux splitter which comprises in combination:
   a. a cylindrical process shell, the wall of which is composed of a nonmagnetic material, the shell characterized by a reflux outlet in the process shell wall to discharge liquid condensate reflux externally within the process shell;
   b. means to collect a liquid condensate from a condenser and to discharge the liquid condensate into a stream within the process shell;
   c. a reflux condensate-receiving elbow element within the process shell adapted to direct liquid condensate toward the internal wall of the process shell;
   d. a movable funnel element to direct liquid condensate discharged into the process shell in a stream between a diverting first position wherein the liquid condensate is directed by the element into the reflux outlet, and a second nondiverting position wherein the liquid condensate is directed downwardly within the process shell, the funnel element adapted for pivotal movement at the upper end thereof, the upper end of the funnel element adapted to receive the liquid condensate stream, and the lower discharge end of the funnel element being of narrower construction;
   e. a magnetic material secured to the movable funnel element and adapted for movement therewith, the magnetic weight material adapted in its first diverting position to move toward and close to the internal nonmagnetic wall of the process shell in response to a magnetic flux, and in the second position to permit the funnel element to have an essentially vertical, free-hanging position within the process shell;
   f. a permanent magnet positioned externally of the process shell;
   g. an actuating element external of the process shell secured to the permanent magnet, the actuating element adapted for movement external of the process shell and to move the permanent magnet between an actuating position and a nonactuating position;
   h. the actuating position placing the permanent magnet in a close magnetic flux relationship with the external wall of the process shell, so as to attract the magnetic weight material secured to the movable funnel element;
   i. a double-acting pneumatic cylinder having a piston rod, one end of said piston rod secured to the actuating element and adapted to induce movement of the actuating element between an actuating and a nonactuating position;
   j. a source of air pressure;
   k. a means to supply air pressure from the source to the double-acting pneumatic cylinder;
   l. a valve means to direct air pressure from the source in a time-sequential sequence to the cylinder, so as to induce, for desired times and periods, the reciprocating action of the piston rod in the double-acting cylinder, and, therefore, the actuating element and the permanent magnet between an actuating and a nonactuating position; and
   m. a cyclic timing means to control the time periods at which air pressure is supplied to the double-acting cylinder, whereby, on setting the desired time periods between the actuating and nonactuating positions, movement of the permanent magnet to the actuating and nonactuating positions in a desired time sequence is effected, and, thereby a reflux ratio as desired is obtained by the movement of the pivotal funnel within the process shell from a diverting to a nondiverging position.

7. The reflux splitter of claim 6 wherein the actuating element is secured for pivotal movement at the one end thereof, and the permanent magnet and piston rod secured to the other end thereof, the actuating element and magnet so secured and formed to place the face of the magnet in a close generally parallel relationship with the external wall of the process shell in the actuating position.

8. The reflux splitter of claim 6 wherein the magnetic material is so secured and formed to place the face of the material in a close generally parallel relationship with the internal wall of the process shell when the funnel element is in its diverting position.

9. The reflux splitter of claim 6 wherein the cyclic means to control the time period includes a valve means in fluid-flow communication to the source of air pressure, to an upper and a lower cylinder port of the cylinder and to exhaust, wherein the timing means is a cyclic pneumatic timer.

10. A distillation system which includes:
    a. a distillation column;
    b. an internal reflux condenser; and
    c. the reflux splitter of claim 6 wherein the reflux splitter is positioned and secured on top of the distillation column and directly beneath the reflux condenser, whereby the condensate stream comprises a vapor stream from the distillation column which has been condensed by the condenser.

11. A distillation system which includes:
    a. a distillation column;
    b. an external condenser adapted to receive vapor from the distillation column and to condense such vapor; and
    c. the reflux splitter of claim 6 wherein the reflux splitter receives the liquid condensate stream of the condenser free of vapor from the distillation column.