

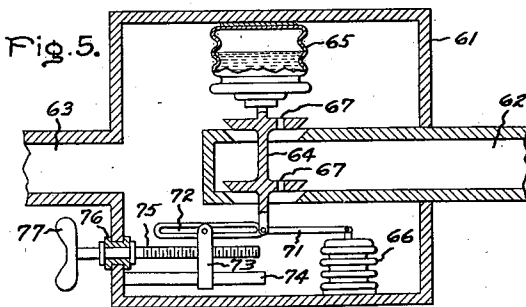
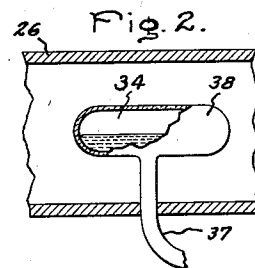
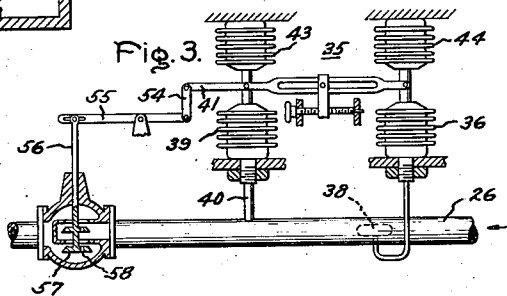
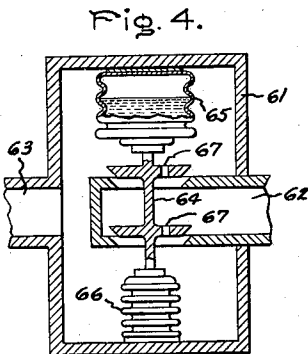
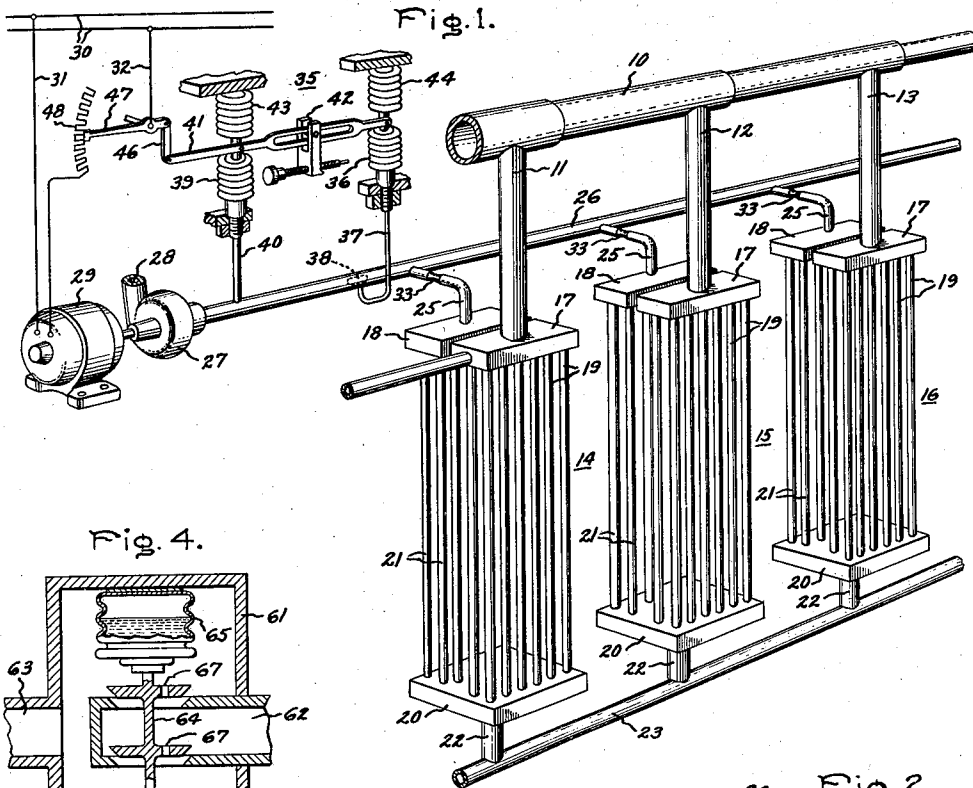
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2,247,056

CONDENSER CONTROL APPARATUS

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## UNITED STATES PATENT OFFICE

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## CONDENSER CONTROL APPARATUS

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15 Claims. (Cl. 257—2)

The present invention relates to condensers and more particularly to means for regulating the extraction of non-condensibles therefrom.

Heat exchangers provided for condensing the exhaust from an elastic fluid turbine are usually provided with means for extracting non-condensibles such as air therefrom. The extraction of the non-condensibles from the heat exchanger is usually accomplished by some means such as an ejector or a motor driven evacuating pump connected to an after-cooler section of the heat exchanger. Depending upon the various operating conditions of the power plant, a certain amount of steam is usually extracted along with the non-condensibles. This loss of water is ordinarily not very serious but in some applications such as in a turbine driven locomotive vehicle designed for long run operation, the excessive loss of water may be undesirable.

It is accordingly an object of this invention to provide a new and improved arrangement for controlling the operation of heat exchanger apparatus so as to preclude excessive amounts of vapor from being withdrawn from the heat exchanger with the non-condensibles.

Another object of this invention is to provide a new and improved arrangement for controlling the relative proportions of a mixture of condensibles and non-condensibles flowing through a conduit.

In accordance with one illustrated embodiment of my invention I provide a condenser with a pump for extracting non-condensibles from after-cooler portions, the operation of which pump is regulated by means responsive to vapor pressure and the total pressure so as to maintain a substantially constant proportion between the non-condensibles and the vapor extracted. In accordance with a second modification of the invention the regulating means is adapted for controlling a valve arranged adjacent to the inlet of the evacuating pump. In accordance with still further modifications of the invention the regulating means is arranged directly within the non-condensibles extraction conduit for controlling the mixture flow therethrough.

For a consideration of what I believe to be novel and my invention, attention is directed to the following specification and the claims appended thereto taken in connection with the accompanying drawing.

In the drawing Fig. 1 is a perspective view illustrating a heat exchanger system embodying one modification of my invention; Fig. 2 is an enlarged view, partly in section, of one detail

of Fig. 1; and Figs. 3, 4 and 5 are views illustrating additional modifications of the invention.

In the drawing 10 indicates a feeder conduit for conducting elastic fluid, such as steam, which is to be condensed, from the exhaust of elastic fluid turbines or other elastic fluid apparatus, (not shown). A plurality of branch feeders 11, 12 and 13 connect the feeder 10 to a plurality of individual heat exchanger units such as 14, 15 and 16 arranged in parallel. While in this instance I have shown but three such units, it is understood that any desired number of units of any suitable type may be used connected in a similar manner as those shown. It is equally obvious that instead of employing a number of separate and individual units, a single condenser may be used. For purposes of illustration, I have shown the units as being similar in construction and each comprising two sections, a main condenser section having an upper header chamber 17 and an after-cooler section having an upper header chamber 18. A plurality of heat exchange tubes 19 communicate between the upper headers 17 and the lower headers 20 forming the main condenser section, while similar groups of tubes 21 extending between the lower headers 20 and the upper headers 18 form the after-cooler section. The heat exchange tubes may be of any suitable design and may be provided with fins as desired. Cooling air or other cooling fluid may be passed in contact with the heat exchanger surfaces to conduct the heat therefrom. Elastic fluid fed from the conduit 10 into the headers 17 passes downwardly through the tubes 19 wherein most of the vapors are condensed, the condensate draining into the lower headers 20 from which headers the condensate is discharged through connections 22 and the conduit 23 into a suitable reservoir or hot well (not shown).

The fluid vapor which enters the lower headers 20 without condensing in the down pass tubes 19 and the admixed non-condensibles pass upwardly through the tubes 21 of the after-cooler section. The condensate drains from the after-cooler tubes downwardly into the lower headers while a mixture of saturated vapor and non-condensibles is withdrawn from the upper headers 18 through the connections 25 and extraction conduit 26 by a suitable evacuating pump 27 which in turn exhausts through an outlet 28 to atmosphere or to an auxiliary after-cooler (not shown). The evacuating pump 27 may be driven by any suitable means such as the electric motor 29 illustrated as being directly coupled to the pump shaft and adapted to be energized

from a suitable source of supply, indicated by lines 30 through connections 31 and 32. To insure that a suction will be applied upon each of the headers 18, even in the event that the pressures may be varied in the different individual units, the connections 25 are preferably provided with restrictions or orifices 33. These orifices are of such size as will insure the maintenance of a pressure in the conduit 26 substantially below any pressure which might obtain in any one of the condenser units.

Depending upon the operating conditions of the power plant, the supply of vapor to the condenser units may vary between relatively wide limits. The percentage of air and other non-condensibles leaking into the vapor system may also vary considerably. Thus when the percentage of air admixed with the vapor drops to a relatively low proportion, a considerable amount of saturated vapor may be withdrawn through the extraction conduit 26 by the pump 27, resulting in a more or less serious loss of water. Conversely, if the percentage of air leaking into the system is abnormally high, the efficiency of the condensers may be materially diminished by the improper purging thereof.

In accordance with my invention I provide means for regulating the extraction of non-condensibles from the condenser after-cooler sections so as to maintain a relatively constant proportion between the non-condensibles and the vapor as is consistent with the most efficient operation of the condenser system. It is obvious that in certain power plant installations, space limitations will not permit condenser capacity for reducing all of the vapor to condensate under all load conditions. In a locomotive vehicle, for example, the condenser capacity must be restricted to that required for normal running conditions and a certain loss of vapor through the non-condensibles extraction system must be tolerated for obvious reasons. It is desirable, however, that this loss be maintained as low as is practicable.

In the modification illustrated in Fig. 1, I provide a pressure differential regulator 35 for controlling the speed of operation of the pump driving motor 29. The regulator 35 comprises one expansible element or bellows 36 which is connected by the tube 37 to the lower portion of a bulb 38 which is arranged within the extraction conduit 26. The bulb and bellows are evacuated and filled with water. During normal operation, the steam of the mixture flowing through conduit 26 will heat the water within the bulb 38 causing the formation of vapor therein, as indicated at 34 in Fig. 2. The bellows 36 will be actuated in accordance with the vapor pressure within the bulb which will correspond with the temperature of the mixture flowing through the extraction conduit 26 and, hence, to the partial pressure of the water vapor of the mixture. A second expansible element or bellows 39 is in open communication by the tube 40 with the interior of the conduit 26 whereby the bellows 39 is actuated in accordance with the static or total pressure obtaining within the extraction conduit 26. The movable ends of the expansible bellows 36 and 39 are connected to a lever 41 which is supported upon an adjustable fulcrum 42 between the connections with the bellows. In order to compensate for variations in atmospheric pressure, a pair of evacuated bellows 43 and 44 are connected to the lever and oppositely arranged with respect to the bellows

39 and 36, respectively. The left end of the lever 41 is connected by a link 45 to one end of a rotatable contact arm 47 of the adjustable resistance unit 48 in series circuit with the connection 32 for the motor 29.

With this arrangement the ratio of the force exerted by the bellows 36 to that exerted by the bellows 39 is the ratio of the partial pressure of the steam within the extraction conduit 26 to the total pressure existing therein. As is well known, the total pressure within the conduit is equal to the pressure of the air plus the pressure of the steam, while the pressure of the steam is determined by its temperature. The position of the arm 41 therefore indicates the relative proportions of air and steam in the mixture. The position of the arm 41 is not affected by changes in the atmospheric pressure because, as pointed out above, atmospheric pressure changes are compensated by the bellows 43, 44. From this viewpoint the pairs of bellows 39, 43 and 36, 44 are responsive to changes of the absolute pressure and the absolute partial vapor pressure in the conduit 26. The two pairs of bellows then effect movement of the lever 41 in response to changes of the ratio of the absolute total pressure and the absolute partial vapor pressure in the conduit 26. The position of the fulcrum 42 may be adjusted so that a level position of the arm 41 corresponds to any predetermined desired ratio between the total pressure and the partial pressure of the steam. When the pressure deviates slightly from the predetermined ratio, the lever arms will be correspondingly rotated and the speed of the pump motor varied accordingly so as to maintain a substantially constant ratio of the vapor pressure with respect to the total pressure. Thus if the percentage of air flowing through the conduit 26 increases, the temperature of the mixture will be lowered causing vapor to condense in bulb 38. The bellows member 36 will correspondingly collapse and the lever 41 will be rotated in the clockwise direction resulting in a decrease of the amount of the resistance 48 included in the motor circuit. The motor will accordingly be accelerated to increase the suction from the conduit 26 thereby decreasing the pressure therein. Such a decrease in pressure in conduit 26 will cause a further decrease in the steam temperature and hence bellows 36 will tend to be collapsed still more. Such tendency will be offset, however, by a corresponding collapsing movement by bellows 39 due to the decrease in the total pressure of the conduit and the lever 41 will be retained in the adjusted condition. Conversely, if the proportion of steam in the extraction conduit is greater than the predetermined desired amount, then the pressure within the bellows 36 will be relatively greater than the pressure within the bellows member 39 so that the lever 41 will be rotated in the counterclockwise direction to increase the amount of the resistance 48, thereupon reducing the speed of the motor 29 and pump 28. The pressure within the extraction conduit 26 will thereupon build up and also the pressure within bellows 39 to resist the return of lever 41 to its previous position due to the resultant increase in steam temperature and the regulator will be balanced in its new position.

Since this regulating apparatus is designed for use primarily in conjunction with locomotive power plants which during the course of a run will be required to operate at widely varying altitudes, compensation must be made for the

variations in atmospheric pressure. By the arrangement of the compensating bellows 43 and 44 acting upon the lever 41 in an opposing relationship with respect to the bellows 39 and 36, respectively, the influence of atmospheric pressure may be effectively eliminated. The pressure of the atmosphere acts on the bellows 43 and 44 in a manner identical as upon the bellows 39 and 36 so that the atmospheric forces are balanced. The net forces acting upon the lever arm are those due to the partial steam pressure and the total pressure obtaining within the extraction conduit 26.

Instead of adapting the regulator 35 for controlling the speed of the pump driving motor 29, it may be equally well adapted for adjusting a suitable valve arranged within the extraction conduit substantially as illustrated in Fig. 3 with substantially the same results. In this modification the regulating device 35 is substantially similar to the arrangement described in connection with the modification of Fig. 1 with the exception that the operating lever 41 is connected by link 54 to one end of a pivoted lever 55, the other end of which is connected to the stem 56 of the balanced type valve 57. The valve disks are preferably perforated as indicated at 58 to preclude a complete closure of the extraction pipe. In the operation of this arrangement, in the event of an increase in the amount of steam within the extraction conduit 26, the lever arm 41 is rotated in the counter-clockwise direction to move the valve 57 to a more closed position thereby effecting an increase in the total pressure within the extraction conduit. Conversely, in the event of an increase in the proportion of air within the extraction conduit, the lever arm 41 will be rotated in the clockwise direction, thereby moving the valve 57 to a more opened position. As in the modification previously described, a substantially constant ratio of air with respect to steam will be maintained in the flow of the mixture through the extraction conduit.

In Fig. 4 is illustrated a still further modification of the invention in which the regulator is compactly arranged within the casing 61 adapted to be included in the extraction conduit. The casing 61 is provided with an inlet opening 62, an outlet opening 63, and a balanced type valve 64 arranged therebetween. It will become obvious, as the description proceeds, that the device is equally operable for either direction of fluid flow. Connected to the upper end of the valve stem is a collapsible bellows 65 which is evacuated and partially filled with water so that it will be actuated in accordance with the temperature or partial steam pressure of the mixture flowing through the casing. Connected to the lower end of the valve stem is a second evacuated collapsible bellows 66 which is adapted to be actuated in accordance with the total pressure obtaining within the casing and substantially balance the effect of the external pressure acting upon the bellows 65 against the internal vapor pressure. The collapsible elements are so selected as to relative sizes and areas that with normal condenser operating conditions obtaining, the valve will be balanced in a predetermined mid-opened position which will maintain the proper proportions of non-condensibles and steam of the mixture flowing through the valve. If for some reason the condenser operating conditions should change, the valve will be automatically readjusted so as to maintain sub-

stantially constant the proportions of the mixture components. For example, if the load on the condenser should be increased and the proportion of steam passing into the extraction conduit is increased, the temperature of the mixture will rise resulting in an increased vaporization of the liquid within the bellows 65 until the vapor pressure therein coincides with the partial steam pressure of the mixture. Upon the expansion of bellows 65, the valve will be moved to a more closed position. If the percentage of air in the mixture flow is increased, the temperature at a given pressure will become lower and the bellows 65 will correspondingly collapse to move the valve 64 to a more opened position. The relative area of the bellows 65 and 66 will determine what proportions of air and steam in the mixture flow will be maintained by the valve. Since the pressure sensitive elements 65 and 66 of the modifications of Figs. 4 and 5 are wholly enclosed within a surrounding casing, they need not be compensated for variations in atmospheric pressure. The bellows 66 and 65 are responsive to changes in absolute total pressure and absolute partial vapor pressure in the container or chamber 61.

The disk elements of the valve 64 are provided with relatively small holes 67 therethrough so that there will be a limited flow of mixture through the conduit even when the valve is closed to prevent a complete blocking of the air extraction pump and also so that the pressure conditions surrounding the bellows 65 and 66 will be proportional to the conditions in the inlet connection 62. The holes 67 will also preclude superheating of the steam passing through the valve, which might otherwise possibly occur during very small opened conditions of the valve.

In Fig. 5 is shown a modification of the last described device in which provision is made for adjusting the operational characteristics thereof. The lower end of the valve stem 64 is pivotally connected to a lever 71, the right end of which is pivotally connected to the movable end of the evacuated bellows 66. The left end of lever 71 is provided with a slot 72 for cooperatively receiving a pin secured to the adjustable support 73. The lower end of the support 73 is slidably arranged upon a guide member 74 while the support itself is cooperatively threaded upon the adjusting screw 75. The end of the screw 75 extends through a suitable bushing 76 arranged in the wall of the casing 61 and is provided with a head 77 whereby the screw may be rotated, and the position of the support 73 shifted relative to lever 71. By means of this adjusting arrangement, the relative proportions of air and vapor in the mixture allowed to pass through the valve may be varied as desired.

The modifications of Figs. 3, 4 and 5 have been described as adapted for controlling the mixture flow in the extraction conduit 26 adjacent the inlet to the evacuating pump. It is obvious that any one of these modifications of the regulator may be arranged immediately adjacent the extraction outlet for each condenser section, as in the connections 25, in which event the regulator valve will be substituted for the orifices 33. The advantage of such an arrangement would be that the most efficient operation of each individual condenser section would be maintained. Thus if a leak occurred in one of the condensers allowing a relatively large volume of air to enter into it, the extraction regulator valve for that condenser would be moved to a wide open posi-

tion whereupon the air would be rapidly withdrawn therefrom. The operation of the remaining condenser sections would not be affected by the defect in the one.

While I have described the invention as being adapted for use in a steam condenser system, it is obvious that it is equally applicable for use in a condenser system for other fluids. In the event that it is used in such other systems, it is to be understood that the bulb 38 and bellows 36, and 65 would be filled preferably with a liquid the same as the condensate of the system or with one having similar vapor properties. Thus, an arrangement according to my invention includes means responsive to changes in the ratio of the total pressure of condensibles and non-condensibles over the partial pressure of non-condensibles for maintaining such ratio constant. More generally, such means is responsive to the ratio of the total pressure of a condensible and a non-condensable fluid over the partial pressure of one of the fluids. From this it follows that with an arrangement according to my invention the ratio of the partial pressure of the non-condensable fluid over the partial pressure of the condensible fluid is maintained constant. The ratios in terms of pressures being maintained constant, the proportions in terms of weight of the condensible and non-condensable fluids will also be maintained substantially constant except for small variations due to the fact that a condensible fluid, such as steam, is not a perfect gas.

For example, in a locomotive condenser in which the total pressure of condensible and non-condensable fluids may vary between 4 lbs. per sq. in. abs. and 40 lbs. per sq. in. abs., it may be desired to maintain the amount of non-condensable fluid by weight at about 10% of the total amount of fluid by weight. Or, from another viewpoint, it may be desired to maintain the partial pressure of the non-condensable fluid equal to 10% of the total pressure within the pressure change of from 4 lbs. to 40 lbs. This, in the above example, means that at a total pressure of 4 lbs. the partial pressure of the non-condensable fluid would be kept at .4 lb. and at the maximum total pressure of 40 lbs., the partial pressure of the non-condensable fluid would be kept at 4 lbs. Thus, the partial pressure of the non-condensable fluid is permitted to rise with increasing total pressure of the condensible and non-condensable fluids. In a preferred embodiment as pointed out above, the rise of the partial pressure of the non-condensable fluid is maintained proportional to the rise of the total pressure of condensible and non-condensable fluids.

With an arrangement of this kind a condenser may be operated at high efficiency with comparatively little waste of condensate, keeping in mind that the waste of condensate becomes comparatively smaller as the partial pressure of non-condensable fluid is permitted to rise with increasing total pressure than the waste of condensate would be if said partial pressure of non-condensable fluid had to be kept constant. This is important in certain power plants such as are used in locomotives where the amount of make-up water is limited and the waste of condensate must be kept at a minimum.

In Fig. 1, assuming that the bellows are all of the same diameter, the distances of the connections thereto, to the left and right, respectively, from the fulcrum 42, should be in the ratio of 9 to 10 if the partial pressure of the steam

is to be maintained at nine-tenths of the total pressure, as in the example cited above.

With reference to the example illustrated in Fig. 5, the following equation applies for a balanced condition:

$$a_1 l_1 p_n = a_2 l_2 p_T$$

in which

$a_1$  represents the effective area of the bellows 65,

$l_1$  represents the lever arm of the bellows 65,  $p_n$  represents the partial pressure of the non-condensibles,

$a_2$  represents the effective area of the bellows 66,

$l_2$  represents the lever arm of the bellows 66, and

$p_T$  represents the total pressure of condensibles and non-condensibles;

or,

$$\frac{p_n}{p_T} = \frac{a_2 l_2}{a_1 l_1}$$

Thus, the ratio of

$$\frac{1}{10} \text{ for } \frac{p_n}{p_T}$$

may be maintained by making  $a_1 l_1$  equal ten times  $a_2 l_2$ ; for  $l_2$  equal  $2l_1$ , then the area  $a_2$  of the bellows 66 would be one-twentieth of the area of the bellows 65.

Having described the principle of operation of my invention together with the apparatus which I now consider to represent the best embodiment thereof, I desire to have it understood that the apparatus shown is only illustrative and that the invention may be carried out by other means.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In combination, a condenser, means for extracting non-condensibles from said condenser, and means for controlling the extracting means and responsive to changes of the pressure ratio of condensibles and non-condensibles to maintain substantially constant the proportion of condensibles admixed with the non-condensibles being extracted.

2. In combination, a condenser having an outlet for withdrawing primarily non-condensibles therefrom, and means connected to said outlet for automatically limiting the proportion of condensibles with respect to non-condensibles withdrawn from said outlet and causing an increase in partial pressure of the non-condensibles with increasing total pressure in the condenser.

3. In combination, a condenser having an outlet connection for withdrawing primarily non-condensibles therefrom, and means for controlling the withdrawal of non-condensibles and responsive to vapor temperature and total pressure in said outlet connection for maintaining constant the relative proportions of vapor with respect to non-condensibles withdrawn from said outlet connection.

4. In combination, a condenser having an outlet for extracting a mixture of condensibles and non-condensibles therefrom, means responsive to partial condensibles pressure and total pressure of the extracted mixture, and means for controlling the extraction and responsive to changes of the ratio of said pressures for maintaining substantially constant the relative proportions of condensibles and non-condensibles of said mixture extracted from said outlet.

5. In combination, a steam condenser having an air outlet, suction means connected to said outlet, and pressure responsive means arranged in said outlet for regulating the rate of flow of

steam and air withdrawn from said outlet by said suction means to maintain constant the relative amounts by weight of air and steam in the condenser.

6. A conduit adapted for conducting a mixture of condensible vapor and non-condensibles, a valve arranged in said conduit, first valve actuating means responsive to vapor pressure and second valve actuating means responsive to total pressure in said conduit, means including an adjustable lever for connecting the first and second means to said valve to maintain substantially constant the proportion by weight of condensibles with respect to non-condensibles in the flow through said conduit.

7. A conduit adapted for conducting a mixture of condensible liquid vapor and non-condensibles, a valve in said conduit, an expansible bellows member partially filled with liquid of said vapor responsive to temperature of said vapor within said extraction conduit, an expansible bellows member responsive to total pressure within said extraction conduit, and lever means connecting said expansible bellows members and said valve for adjusting said valve in response to changes of the ratio of condensibles and non-condensibles.

8. A conduit adapted for conducting a mixture of condensible vapor and non-condensibles, a housing arranged in said conduit including a valve for adjusting the flow of mixture there-through, an expansible bellows member containing a vapor fluid responsive to the partial vapor pressure of the mixture flowing through said conduit, a second expansible bellows member responsive to the total pressure within said conduit, means connecting said bellows members to move said valve to maintain a substantially constant pressure ratio of said vapor and said non-condensibles flowing through said conduit.

9. In combination, a condenser having an inlet for vapor and admixed non-condensibles, a first outlet for condensate, a second outlet, means for extracting a mixture of vapor and non-condensibles from said second outlet, control means for controlling said extracting means, and means responsive to changes of the pressure ratio of the vapor and non-condensibles flowing through said second outlet for adjusting said control means.

10. In combination, a condenser having an outlet primarily for non-condensibles, a pump for withdrawing non-condensibles from said outlet, a motor for driving said pump, speed control means for said motor, and means responsive to the relative proportions by weight of non-condensibles and condensibles flowing through said outlet connected for adjusting said speed control means so as to maintain substantially con-

stant the relative proportions by weight of condensibles and non-condensibles withdrawn through said outlet by said pump.

11. A regulator for adjusting a valve arranged in a conduit for conducting a mixture of saturated condensibles and non-condensibles, said regulator comprising an expansible element subject to the total pressure in said conduit, an evacuated expansible element containing a liquid having properties similar to those of the condensibles of said mixture and subjected to the temperature of said mixture, and means including an adjustable lever connecting said two elements to said valve.

12. A container for condensible vapor and non-condensibles, means for removing from the container non-condensibles and condensible vapor, a control mechanism for actuating the last named means including a device responsive to changes in the ratio of absolute total pressure in the container and absolute partial vapor pressure in the container to cause an increasing partial pressure of the non-condensibles with increasing total pressure.

13. A container for receiving varying relative amounts of condensible vapor and non-condensibles, means including a conduit through which vapor and non-condensibles are removed from the container, a control mechanism for the last named means for maintaining a substantially constant pressure ratio of condensibles and non-condensibles and including a device responsive to variations in ratio of the absolute total pressure in the conduit and the absolute partial vapor pressure in the conduit, and means for adjusting the device to vary said ratio.

14. A container for receiving varying amounts of condensible and non-condensable fluids, means including a conduit through which non-condensable fluid mixed with condensible fluid is removed from the container, and a control mechanism for operating the last-named means to maintain substantially constant the ratio by weight of said fluids, said mechanism including a device responsive to variations in ratio of the absolute total fluid pressure in the conduit and the absolute partial pressure of one of said fluids.

15. A container for receiving a varying mixture of condensible and non-condensable fluids at a pressure varying between wide limits, means for removing primarily non-condensable fluid from the container, and a control mechanism for operating said means to maintain substantially constant the ratio of the partial pressures of the two fluids within a wide range of total pressure.

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