Sept. 18, 1928. **1,684,406**

D. W. R. MORGAN

AIR EJECTOR APPARATUS

Filed Oct. 12, 1926

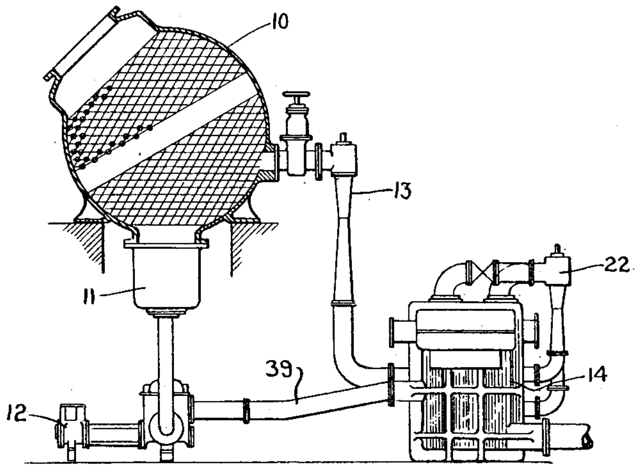

Fig. 1.

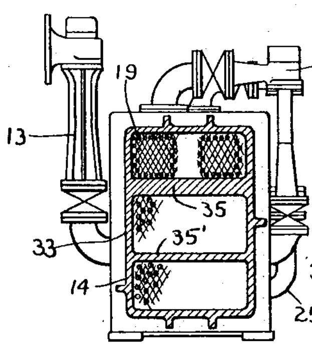

Fig. 4.

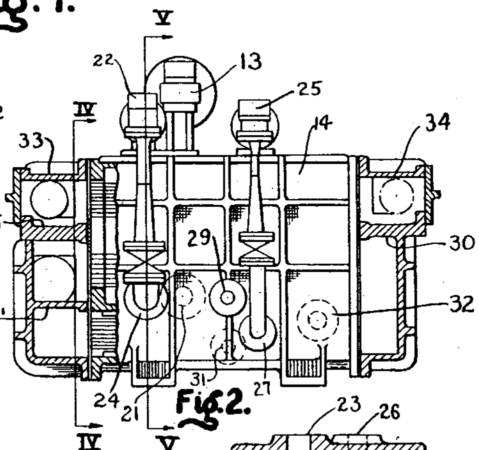

Fig. 2.

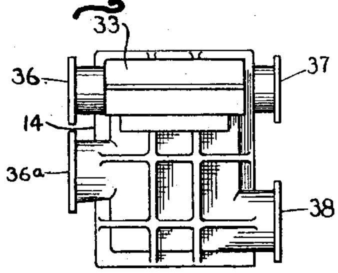

Fig. 3.

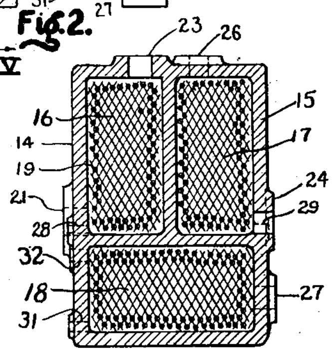

Fig. 5.

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Patented Sept. 18, 1928. 1,684,406

UNITED STATES PATENT OFFICE.

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AIR-EJECTOR APPARATUS.

Application filed October 12, 1926. Serial No. 141,165.

My invention relates to ejector apparatus and particularly to that class of ejector apparatus which is employed for exhausting non-condensable fluids from condensers and it has for an object to provide apparatus of the character designated which shall operate with an extraordinary degree of economy in consumption of motive fluid and which shall at the same time conserve both heat of the gases removed from the condenser as well as heat of the motive fluid utilized in the ejector apparatus. Another object is to improve the construction and arrangement of parts of an apparatus of the character described.

These and other objects, which will be made apparent throughout the further description of my invention, may be attained by the employment of the apparatus hereinafter described and illustrated in the accompanying drawing in which:

Fig. 1 is a diagrammatic arrangement of a condensing system which embodies one form of ejector apparatus constructed in accordance with my invention;

Fig. 2 is a side view, partly in section and partly in elevation, of the ejector apparatus utilized in Fig. 1;

Fig. 3 is an end view, in elevation, of the ejector apparatus shown in Fig. 2; and

Figs. 4 and 5 are sectional views taken on the lines IV—IV and V—V of Fig. 2 respectively.

The advantage gained by expanding steam in turbines to a high vacuum pressure at the exhaust has imposed added duties upon the condensing apparatus of power plants utilizing turbines as prime movers, and especially upon the air removal apparatus of such plants, since the vacuum pressures which it is practicable to utilize are, to a large extent, determined by the efficiency of the air removal apparatus. The type of air removal apparatus frequently employed at the present time consists of a two-stage steam jet ejector apparatus, each stage discharging into an intermediate condenser or intercooler.

When such ejector apparatus was first employed, the intercooler or condenser was not utilized and hence the amount of motive steam consumed was relatively high, about 40 pounds of motive steam being required to remove 1 pound of free dry air at 1″ Hg., absolute pressure. Subsequently it was found that by interposing a condenser or cooler between the two stages of the ejector apparatus, the motive steam required could be reduced from approximately 40 pounds to approximately 12 pounds or about 70 per cent. In order to further reduce the steam consumption, resort was then had to making various detailed refinements in the ejectors themselves and in this way the amount of motive steam required to remove 1 pound of free dry air at 1″ Hg., absolute pressure was ultimately reduced to approximately 9 pounds.

I have found, however, that such performance can be materially improved upon by employing an ejector apparatus arranged in three stages instead of two and which consists primarily of three ejectors connected in series with inter-coolers and inter-condensers fitted between the first and second ejectors and between the second and third ejectors together with a cooler fitted on the discharge side of the third ejector. I have found that with such a form of ejector apparatus, a decrease in steam consumption over the best performance heretofore obtainable of approximately 30 per cent at an absolute pressure of 28″ Hg., 33 per cent at 29″ Hg., 40 per cent at 29.25″ Hg., and 63 per cent at 29.5″ Hg. all referred to a 30″ barometer, can be effected. The increase in air handling capacity of a three-stage ejector apparatus as compared with a two-stage ejector apparatus is more pronounced at the lower absolute pressures and this is principally due to the super-cooling of the non-condensable vapors earlier in the cycle as well as the elimination of some of the motive steam. By employing such a form of ejector apparatus, the efficiency of the entire condensing plant is improved as not only does the air ejector consume less motive fluid, but at the same time a higher vacuum is maintained in the condenser and consequently the efficiency of the entire condensing apparatus is increased.

Referring now to the drawing for a more detailed description of my invention, I show in Fig. 1 a condenser 10 of the conventional type which is provided with a hot well 11 and a condensate pump 12 for removing condensate therefrom. Connected to the side of the condenser is a first stage air ejector 13 connected to a heat exchange device 14. As shown in Figs. 2 to 5, the heat exchange device 14 comprises a shell 15 which is divided by suitable partition means into a first-stage cooler and condenser 16, a second-stage condenser and cooler 17 and an after cooler 18. Suitable cooling tubes 19 extend through each of these compartments.

The first-stage ejector 13 discharges into the first stage compartment 16 through an inlet 21 and a second stage ejector 22 removes the air and non-condensable gases from the compartment 16 through an outlet 23 which is remotely disposed from the inlet 21. The second stage ejector 22 discharges through an inlet 24 into the compartment 17 and the air and non-condensable gases are removed therefrom by a third stage ejector 25 through an outlet 26 remotely disposed from the inlet 24. The third stage ejector 25, in turn, discharges to the compartment 18 through an inlet 27. The compartments 16, 17 and 18 are provided with respective drains 28, 29 and 31 while the compartment 18 is also provided with a vent 32.

The shell 15 is provided with suitable water boxes 33 and 34. As shown in Figs. 2, 3 and 4, the water box 33 is provided with two transverse division walls 35 and 35′ together with a cold water inlet 36, a condensate inlet 36ᵃ and a condensate outlet 38, all arranged in the manner shown. The other water box 34 is also provided with a division wall 30 and a cold water outlet 37 while its lower portion is so arranged that the condensate received from the central portion of the tube nest returns through the lower portion of the tube nest. Condensate is supplied to the inlet 36ᵃ from the condensate pump 12 through a conduit 39. The tubes in the compartments 16 and 17, therefore, receive two cooling media, the upper region of tubes in each compartment receiving water entering the inlet 36 and the lower region of tubes receiving water entering the inlet 36ᵃ.

The operation of the above embodiment of my invention is as follows: Upon exhaust steam being admitted to the condenser 10, condensate is created and this is removed by means of the condensate pump 12 and discharged to the inlet 36ᵃ of the ejector apparatus. All air and non-condensable gases accumulating in the condenser are withdrawn by the first stage ejector 13, compressed and discharged into the first stage cooler and condenser 16 through the inlet 21. Within the compartment 16 the motive steam utilized in this ejector 13 is condensed and the air and non-condensable gases lowered in temperature before being withdrawn through the outlet 23 by the second stage ejector 22.

It will be noted that the fluid in passing from the inlet 21 to the outlet 23 is first brought into contact with a nest of tubes through which condensate discharged by the pump 12 is circulating. In this way, the heat of condensation of the motive steam utilized in the ejector is absorbed by the condensate discharged by the pump 12 and the heat is thus conserved. However, in order to further reduce the temperature and volume of the air and non-condensable gases as well as to further reduce their vapor content, the gases before reaching the outlet 23 are compelled to pass over the upper section of tubes through which extraneous water of relatively lower temperature is circulating. In this way, the gases are further cooled, their specific volume reduced and consequently the amount of motive steam required in the second stage ejector 22 is materially lessened. I have found that the thermodynamic loss incurred in transmitting some of the heat to the extraneous water passing through the upper tubes is more than compensated for by the increase in efficiency of the second stage ejector.

The second stage ejector 22 withdraws the air and non-condensable gases from the compartment 16, further compresses the same and discharges them into the compartment 17 wherein a condensing and cooling action takes place similar to that occurring in the compartment 16. After this, the third ejector 25 removes the air and non-condensable gases from the compartment 17 and further compresses them to atmospheric pressure after which they are discharged to the inlet 27 of the compartment or after-cooler 18. In the latter compartment, the motive steam utilized in the third-stage ejector is condensed and the air and non-condensable gases vented to the atmosphere through the vent 32. All condensate or drainage accumulating in the compartments 16, 17 and 18 is removed through the drains 28, 29 and 31 to proper portions of the power plant as determined by their respective temperatures and pressures.

From the foregoing it will be apparent that I have invented a form of ejector apparatus which has a greater operating efficiency than apparatus of this character heretofore employed. In this connection, applicant wishes to emphasize that this added efficiency is obtained not by merely adding an additional ejector to two-stage ejectors of the present type, but that it is obtained by so arranging and proportioning the apparatus that cooling and condensing of the gases discharged by the initial ejector take place very early in the cycle and in this way, the volume of gases handled by subsequent ejectors is materially reduced. At the same time, as these gases are reduced in volume, the motive fluid required by the ejectors is lessened proportionally and consequently the entire apparatus has a much improved efficiency. While I have shown an arrangement wherein the coolers and condensers 16 and 17 have both condensate and extraneous water circulating therethrough, nevertheless, it is to be understood that it is within the purview of my invention to employ either condensate or extraneous water singly or any combination of both or any other suitable cooling medium.

It will thus be seen that I have provided a single piece of apparatus embodying the three similar and separate chambers 16, 17 and 18, respectively, each of which is rectangular, or oblong in cross-section and thus, provides for the proper heat transfer with minimum of tube surface. By arranging the chambers 16 and 17 with the wider of their lateral sides upright, and arranging the lower chamber 18 with the narrower of its sides upright, a very compact and yet simple construction is provided, as well as one which requires a relatively small amount of space. By virtue of my novel arrangement, it is possible to so dispose the induction and the eduction ports of the two upper chambers 16 and 17 as to provide for passing the gaseous media upwardly so that it passes first over the warmer tubes carrying condensate and then over the cooler tubes which carry extraneous cooling media. In this way it is assured that gaseous media in passing through these chambers will not be heated by condensate dropping from tubes higher up, for as the gaseous media progresses through each chamber it comes into a region where the cooling surface is at a lower temperature. Hence, in each instance, the gaseous media will not be heated, but rather cooled by a rain of condensate. While gaseous media, in passing transversely across the lower chamber 18, is not cooled by condensate falling from upper tubes, neither is it heated, since in this chamber condensate drips directly across the path of flow of the gaseous media.

A still further economy is effected in the overall spacial requirements for my heat exchange apparatus by arranging the steam-operated ejector pumps vertically at the sides thereof, while at the same time it will be observed that ejectors, when so disposed, are most effective and efficient in operation.

While I have shown my invention in but one form, it will be obvious to those skilled in the art that it is not so limited, but is susceptible of various changes and modifications, without departing from the spirit thereof, and I desire, therefore, that only such limitations shall be placed thereupon as are imposed by the prior art or as are specifically set forth in the appended claims.

What I claim is:—

1. In a heat exchanger of the type described, the combination of a shell, means dividing the shell into three adjacent chambers, water tubes in each chamber, and means for passing gaseous media through all of said chambers in series and upwardly through two of said chambers.

2. In a heat exchanger of the type described, the combination of a shell, means dividing the shell into three adjacent chambers, each of said chambers being rectangular in cross section and contiguous to the remaining chambers, heat-transfer tubes in each chamber, and means for passing gaseous media upwardly through two of said chambers in series.

3. In a heat exchanger of the type described, the combination of a shell, means dividing the shell into three chambers, each of said chambers being rectangular in cross section, two of said chambers having their wider sides disposed upwardly, another of said chambers having its wider sides disposed transversely and the upper of its wider sides contiguous to the lower of the narrower sides of said two of said chambers, heat transfer tubes disposed in each of said chambers, and means for passing gaseous media upwardly through said two of said chambers in series and then transversely through said another of said chambers.

4. A heat exchanger of the type described comprising a shell, said shell being rectangular in cross section, a partition extending longitudinally and transversely of the shell between the sides thereof, an upright partition extending longitudinally of the shell and between the upper side thereof and said transverse partition, the shell and the partitions being so constructed and arranged as to provide three separate chambers within the shell, a nest of tubes traversing each of the separate chambers, means providing an induction port in an outer side wall of each of the separate chambers, and means providing an eduction port in an outer wall of each of said chambers, the eduction port for each chamber being remote from the induction port of the same chamber.

5. A heat exchanger of the type described comprising a shell, said shell being rectangular in cross section, a partition extending longitudinally and transversely of the shell between the sides thereof, an upright partition extending longitudinally of the shell and between the upper side thereof and said transverse partition, the shell and the partition being so constructed and arranged as to provide three separate chambers within the shell, a nest of tubes traversing each of the separate chambers, means providing induction ports in the outer side walls of the upper chambers and adjacent the transverse partition, means providing an eduction port in the upper wall of each of the upper chambers, and means providing an induction port in one said wall of the lower chamber and an eduction port in the opposite side wall of said lower chamber.

6. A heat exchanger of the type described comprising a shell, said shell being rectangular in cross section, a partition extending longitudinally and transversely of the shell between the sides thereof, an upright partition extending longitudinally of the shell and between the upper side thereof and said trans-

verse partition, the shell and the partitions being so constructed and arranged as to provide three separate chambers within the shell, a nest of tubes traversing each of the separate chambers, means providing induction ports in the outer side walls of the upper chambers and adjacent the transverse partition, means providing an eduction port in the upper wall of each of the upper chambers and adjacent the upright partition and means providing an induction port in one side wall of the lower chamber and an eduction port in the opposite side wall of said lower chamber.

7. A heat exchanger of the type described comprising a shell, said shell being rectangular in cross section, a partition extending longitudinally and transversely of the shell between the sides thereof, an upright partition extending longitudinally of the shell and between the upper side thereof and said transverse partition, the shell and the partitions being so constructed and arranged as to provide three separate chambers within the shell, a nest of tubes traversing each of the separate chambers, means providing induction ports in the outer side walls of the upper chambers and adjacent the transverse partition, means providing an eduction port in the upper wall of each of the upper chambers, means providing an induction port in an outer side wall of the lower chamber, and means providing an eduction port in another outer side wall of said lower chamber and adjacent said transverse partition.

8. A device according to claim 4, and means for passing cooling media of substantially the same temperature through the upper tubes of the upper chambers in parallel, and means for passing condensate through the lower tubes of the upper chambers in parallel and then through the tubes in the lower chamber.

9. A device according to claim 4, and a steam-operated ejector pump connected between the eduction port of one of the upper chambers and the induction port of the other of the upper chambers, and a steam-operated ejector pump connected between the eduction port of said other of the upper chambers and the induction port of the lower chamber.

10. A device according to claim 4, and steam-operated ejector pumps for translating gaseous media to each of said chambers, each pump being arranged to exhaust through the induction port of one of said chambers, means for transferring heat from motive fluid exhausted into the chambers to condensate from a condenser, and means for cooling gaseous media in the upper chambers to a lower temperature than that of the condensate from the condenser.

11. The combination with a condenser, of means for withdrawing non-condensable media from the condenser including first, second and third stage ejectors, inter-coolers arranged between the first and second stage ejectors and between the second and third stage ejectors, an after cooler arranged to receive media discharged from the third stage ejector, and means for passing condensate received from the condenser in first and second passes through the inter and after coolers, the intercoolers being arranged in parallel in one pass.

12. The combination with a condenser, of means for withdrawing non-condensable media from the condenser including first, second and third stage ejectors, inter-coolers arranged between the first and second stage ejectors and between the second and third stage ejectors, an after cooler arranged to receive media discharged from the third-stage ejector, and means for passing condensate received from the condenser first in parallel through the inter-coolers and then through the after cooler.

13. The combination with a condenser, of means for withdrawing non-condensable media from the condenser including a first-stage ejector, a first inter-cooler having its lower portion receiving media discharged from the first-stage ejector, a second-stage ejector for withdrawing media from the upper portion of the first inter-cooler, a second inter-cooler having its lower portion receiving media discharged from the second ejector, a third stage ejector for withdrawing media from the upper portion of the second inter-cooler, an after cooler for receiving media discharged from the third-stage ejector, and means for passing condensate received from the condenser in first and second passes through the inter and after coolers, the inter-coolers being arranged in parallel in one pass.

14. The combination with a condenser, of means for withdrawing non-condensable media from the condenser including a first-stage ejector, a first inter-cooler having its lower portion receiving media discharged from the first-stage ejector, a second-stage ejector for withdrawing media from the upper portion of the first inter-cooler, a second inter-cooler having its lower portion receiving media discharged from the second ejector, a third stage ejector for withdrawing media from the upper portion of the second inter-cooler, an after cooler for receiving media discharged from the third-stage ejector, means for passing condensate received from the condenser in first and second passes through the lower portions of the inter-coolers and through the after cooler, the inter-coolers being arranged in parallel in one pass, and means for passing cooling water derived from a separate source through the upper portions of the inter-coolers.

15. The combination with a condenser, of means for withdrawing non-condensable media from the condenser including a housing embodying upper parallel first and second in-

ter-cooler chambers and a lower after cooler chamber, a first-stage ejector arranged to withdraw non-condensable media from the condenser and to discharge such media into the lower portion of the first inter-cooler chamber, a second stage ejector for withdrawing media from the upper portion of the first inter-cooler chamber and for discharging media into the lower portion of the second inter-cooler chamber, a third-stage ejector for withdrawing media from the upper portion of the second inter-cooler chamber and for discharging media into the after cooler chamber, nests of tubes arranged in the inter and after cooler chambers, and means for passing condensate received from the condenser in two passes through the tube nests of the inter and after coolers, the nests of the inter-coolers being arranged in parallel in one pass.

16. The combination with a condenser, of means for withdrawing non-condensable media from the condenser including a housing embodying upper parallel first and second inter-cooler chambers and a lower after cooler chamber, a first-stage ejector arranged to withdraw non-condensable media from the condenser and to discharge such media into the lower portion of the first inter-cooler chamber, a second stage ejector for withdrawing media from the upper portion of the first inter-cooler chamber and for discharging media into the lower portion of the second inter-cooler chamber, a third-stage ejector for withdrawing media from the upper portion of the second inter-cooler chamber and for discharging media into the after cooler chamber, nests of tubes arranged in the inter and after cooler chambers, means for passing condensate received from the condenser in first and second passes through the tube nests of the inter and after coolers, the tube nests of the inter-coolers being arranged in parallel in one pass, upper tube nests in the upper portions of the inter-coolers, and means for passing cooling water derived from a separate source through said upper nests.

17. The combination with a condenser, of means for withdrawing non-condensable media from the condenser including a housing embodying upper parallel first and second inter-cooler chambers and a lower after cooler chamber, a first-stage ejector arranged to withdraw non-condensable media from the condenser and to discharge such media into the lower portion of the first inter-cooler chamber, a second stage ejector for withdrawing media from the upper portion of the first inter-cooler chamber and for discharging media into the lower portion of the second inter-cooler chamber, a third-stage ejector for withdrawing media from the upper portion of the second inter-cooler chamber and for discharging media into the after cooler chamber, nests of tubes arranged in the inter and after cooler chambers, means for passing condensate received from the condenser in first and second passes through the tube nests of the inter and after coolers, the tube nests of the inter-coolers being arranged in parallel in one pass, upper tubes nests in the upper portions of the inter-coolers, means for passing condensate received from the condenser first in parallel through the tube nests of the inter-coolers and then through the tube nest of the after cooler, separate tube nests arranged in the upper portions of the inter-coolers, and means for passing cooling water derived from a separate source through the last-named tube nests.

In testimony whereof, I have hereunto subscribed my name this twenty-fourth day of September, 1926.

DAVID W. R. MORGAN.