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HEAT OPERATED REFRIGERATION APPARATUS HAVING DEVICE UTILIZING FLUE GAS FOR RETURNING CONDENSATE

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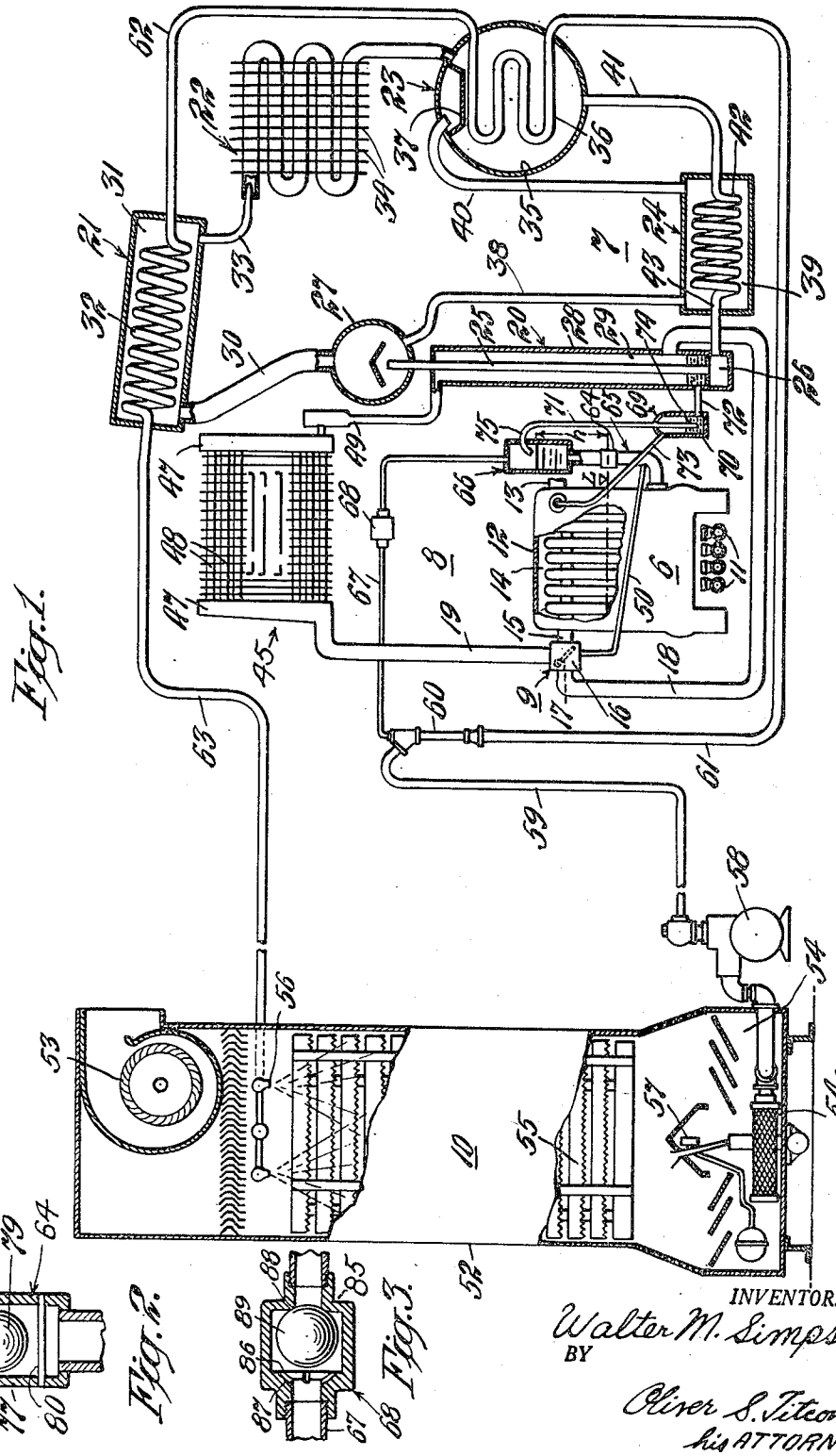


Fig. 1.

Fig. 2.

Fig. 3.

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HEAT OPERATED REFRIGERATION APPARATUS HAVING DEVICE UTILIZING FLUE GAS FOR RETURNING CONDENSATE

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3 Claims. (Cl. 62—119)

The present invention relates to refrigeration and more particularly to improvements in apparatus of the type described and claimed in a copending application for United States Letters Patent of Harry C. Shagaloff Serial No. 254,530 filed November 2, 1951 and entitled "Refrigeration."

The Shagaloff invention relates broadly to a combination with a heat operated refrigeration system having a cooling water circuit of an auxiliary apparatus utilizing the flow of cooling water to produce a suction for returning condensate from a heat receiving element of the system to a steam generating boiler and treating the cooling water with flue gas to reduce the formation of scale on the heat transfer surfaces. More specifically, the Shagaloff invention relates to an intermittently operating apparatus which first lifts condensate to a reservoir vessel above the boiler and then discontinues the lifting of condensate and opens communication between the vessel and boiler for the gravity flow of condensate thereto. The separate steps of first lifting condensate and then delivering lifted condensate to the boiler is controlled by a clock operated valve arrangement.

One of the objects of the present invention is to provide an improved apparatus of the type indicated which operates continuously to lift condensate from the heat receiving element, return lifted condensate to the boiler and supply a controlled amount of flue gas to the cooling water.

Another object is to provide an apparatus of the type indicated which maintains a pressure balancing liquid column in a standpipe extending upwardly from the boiler so that condensate will flow to the boiler by gravity simultaneously with the supply of additional condensate to the standpipe above the pressure balancing liquid column.

Still another object is to provide an apparatus of the type indicated with an automatically operable valve responsive to the weight of the liquid column in the standpipe to permit the flow of condensate to the boiler while preventing flow from the boiler to the standpipe.

These and other objects will become more apparent from the following description and drawing in which like reference characters denote like parts throughout the several views. It is to be expressly understood, however, that the drawing is for the purpose of illustration only and not a definition of the limits of the invention, reference being had for this purpose to the appended claims.

In the drawings:

Fig. 1 is a diagrammatic view of an air conditioning unit incorporating the auxiliary apparatus of the present invention for simultaneously returning condensate to the boiler and delivering flue gas to the cooling water;

Fig. 2 is an enlarged sectional view of an automatically operable valve for controlling liquid flow between a pressure balancing liquid column and steam generating boiler; and

Fig. 3 is an enlarged sectional view of a restricting valve in the flue gas conduit for controlling the flow of flue gas into the cooling water.

Referring to Fig. 1 of the drawings, the present invention is shown applied to an air conditioner for either cooling the air in the summer or heating air in the winter. The air conditioner comprises a source of heat illustrated in the form of a steam boiler 6, a heat operated refrigeration system 7, a heating system 8, a selective valve 9 for directing steam from the boiler to the heating system or refrigeration system, respectively, and a cooling tower 10.

Boiler 6 may be of any suitable type such as the sectional cast-iron boiler illustrated and may be heated by any suitable fuel burner such as the gas burners 11. The sections of the boiler 6 are enclosed in a casing or hood 12 having an outlet pipe 13 and the hood and outlet pipe form a flue 14 for the products of combustion. The heat from the flame and products of combustion is transmitted through the walls of the boiler sections to heat the water therein to generate steam. Steam from the boiler 6 flows through a steam pipe 15 to chamber 16 of selective valve 9 and a valve element 17 in the chamber directs the steam through a conduit 18 to the refrigeration system 7 or through a conduit 19 to the heating system 8.

The heat operated refrigeration system 7 is shown in Fig. 1 as an absorption system of the type illustrated and described in United States Letters Patent to Albert R. Thomas et al. 2,282,503 issued May 12, 1942 and entitled Refrigeration. Such an absorption refrigeration system operates in a partial vacuum and utilizes a refrigerant such as water and a liquid absorbent such as a solution of lithium bromide. The refrigeration system comprises a generator 20, condenser 21, evaporator 22, absorber 23 and heat exchanger 24 interconnected for the flow of refrigerant and absorbent. Generator 20 has at least one vapor liquid-lift tube 25 connected between a lower inlet chamber 26 and an upper separating chamber 27 and the lift tube is enclosed in a jacket 28 providing a heating chamber 29 therebetween. The heat of the steam supplied to the heating chamber 29 is transmitted through the wall of the lift tube 25 to expel refrigerant vapor from absorption solution therein and lift the solution into the separating chamber 27 by vapor-lift action.

Vapor from the separating chamber 27 flows through the conduit 30 to the condenser 21. The condenser 21 is illustrated diagrammatically as comprising a chamber 31 having a cooling coil 32 therein. Liquid refrigerant from the chamber 31 of condenser 21 flows by gravity through a pipe 33 into the top of evaporator 22 illustrated in the form of a serpentine coil having spaced heat transfer fins 34. Pipe 33 may itself control the flow of refrigerant therethrough or may have a suitable flow control means therein to maintain a difference in pressure between the condenser 21 and evaporator 22. Refrigerant vapor from the evaporator coil 22 flows to the absorber 23. The absorber 23 is in the form of a hermetically sealed shell or casing 35 having heat transfer coils 36 therein and liquid distributing means 37 overlying the coils for distributing absorption liquid for gravity flow over the coils.

Simultaneously with the flow of refrigerant vapor to the condenser 21, absorption solution weak in refrigerant flows by gravity from the separating chamber 27 to the liquid distributor 37 in absorber 23 in a path of flow including conduit 38, outer passage 39 of heat exchanger 24 and conduit 40. Due to the high affinity of the refrigerant, water, for the absorption solution, lithium bromide, the refrigerant evaporates in the evaporator 22 at a low pressure and temperature to produce a refrigerating effect and the refrigerant vapor is ab-

sorbed in the absorption solution as fast as it is formed in the evaporator. The absorption solution strong in refrigerant flows by gravity from the absorber **23** to the inlet chamber **26** of generator **20** in a path of flow including conduit **41**, inner passage **42** of liquid heat exchanger **24** and conduit **43**.

The heating system **8** comprises a radiator **45** having spaced headers **47** with finned tubes **48** extending between the headers. The steam conduit **19** from the selective valve **9** is connected to one of the headers **47** and steam flows through the tubes **48** in parallel and condensate returns through the lowermost tube and conduit **19** back to the selective valve **9**. Both the heating chamber **29** for the generator **20** of the refrigeration system and a header **47** of the heating system are vented to the atmosphere by a common vent pipe **49** to maintain the steam from the boiler **6** at atmospheric pressure. Condensate drains from chamber **16** of selective valve **9** back to boiler **6** through a conduit **50** and condensate is returned from the heating chamber **29** of generator **20** by apparatus later to be explained in detail.

Cooling tower **10** is usually located at a place remote from the refrigeration unit and may be of any suitable construction. As illustrated, the cooling tower is generally similar to that illustrated and described in my prior United States Letters Patent 2,562,827 issued July 31, 1951. Suffice it to state herein that the cooling tower comprises an upright casing **52** having a fan **53** at the top of the casing, a sump **54** at the base of the casing, packing **55** in the intermediate portion of the casing, distributing nozzles **56** between the fan and the packing and a water makeup valve **57** in the sump. A pump **58** at the base of cooling tower **10** draws water from sump **54** through a filter **54***a* and circulates it in a circuit through the cooling coils **36** of absorber **23** and cooling coil **32** of condenser **21**. The circuit comprises a conduit **59** connected between the outlet from the pump **58** and a water operated aspirator **60**, later to be described in detail, a conduit **61** connecting the outlet end of the aspirator to one end of the cooling coil **36** in absorber **23**, a conduit **62** connecting the outlet from the cooling coil **36** to one end of the cooling coil **32** of condenser **21** and a conduit **63** connecting the opposite end of the condenser cooling coil **32** to the nozzles **56** in the cooling tower.

While the apparatus thus far described is illustrated diagrammatically in Fig. 1, the commercial apparatus has all of the elements of the system mounted on a frame to provide a self-contained unit. To conserve space and maintain the overall height of the unit to a minimum the boiler **6** and generator **20** are both located on the base of the frame so that the bottom of the heating chamber **29** is located below the liquid level L in the boiler **6** as shown in Fig. 1.

Auxiliary apparatus also is provided which utilizes the flow of water in the cooling water circuit to produce a force for lifting condensate from the heating chamber of the refrigeration system for gravity return to the boiler. Preferably, the same force is also utilized to inject flue gas into the cooling water to reduce or prevent carbonate scale from forming on the heat transfer surfaces. The apparatus comprises the aspirator **60** which draws gas from a source at atmospheric pressure, preferably flue gas from the boiler, and utilizes the flow of the flue gas to lift condensate from the heating chamber of the refrigeration system to a level above the boiler. As thus far described, the apparatus is the same as disclosed in the copending Shagaloff application, referred to above.

In accordance with the present invention, the auxiliary apparatus is so constructed and arranged as to continuously lift condensate from the heating chamber **29** of the heat receiving element or generator **20** of the refrigeration system **7** to a level above the liquid level L in boiler **6** and continuously deliver lifted condensate to the boiler. The apparatus maintains a pressure balance liquid column *h* above the liquid level in the boiler **6** so that additional condensate supplied at the top of the liquid column will cause a corresponding amount of condensate to be delivered from the bottom of the column to the boiler by gravity. An automatically operated valve **64** is also provided which prevents the flow of liquid from the boiler to the pressure balancing liquid column but is responsive to the weight of additional condensate supplied to the top of the column to open the valve and permit flow from the column to the boiler.

In Fig. 1 of the drawings the auxiliary apparatus is shown as comprising a standpipe **65** having its lower end connected to the boiler **6** below the water level L therein. The standpipe **65** extends upwardly to a height above the liquid level L in the boiler to maintain a pressure balancing liquid column *h* therein and is enlarged at its upper end to provide a reservoir vessel **66** for a purpose as will later appear. The top of the reservoir vessel **66**, constituting the upper end of standpipe **65**, is connected to the aspirator **60** by a suction line **67** having a restricting valve **68** therein. A gas operated liquid-lift **69** is connected between the bottom of the heating chamber **29** of generator **20** and the reservoir vessel **66** of standpipe **65** adjacent the top thereof. The gas operated liquid-lift **69** comprises a sump **70** and lift tube **71**. Sump **70** is connected to the bottom of the heating chamber **29** by a conduit **72** and connected to the hood **12** of boiler **6** by a flue gas line **73**. Lift tube **71** has its lower open end **74** projecting into the sump **70** to a position adjacent the bottom thereof and its upper curved end **75** projecting through the side of the reservoir vessel **66**.

The automatically operable valve **64** which controls the flow of liquid between the boiler **6** and standpipe **65** is located in the standpipe adjacent the liquid level L. Valve **64** is shown in detail in Fig. 2 as comprising a valve housing **77** having a valve seat **78**. A suitable ball type valve element **79** is provided in the housing **77** for engagement with the seat **78** when liquid tends to flow from boiler **6** toward the standpipe **65** to close the standpipe. However, the valve element **79** is moved away from seat **78** in response to the weight of liquid above a pressure balancing column *h* of liquid in the standpipe **65** to open the standpipe **65** for the flow of condensate to the boiler **6**. A stop **80** in the valve housing **77** holds the valve element **79** from movement toward the opposite end of the housing while providing a space between its periphery and the housing for the flow of liquid from the standpipe **65** to the boiler **6**.

The restricting valve **68** in suction line **67** is shown in detail in Fig. 3 as comprising a valve housing **85** having a restricting seat **86** with grooves **67** at one end and a sealing seat **88** at its opposite end. A suitable ball type valve element **89** in the housing **85** engages valve seat **86** when the direction of flow is toward the aspirator **60** and engages valve seat **88** when the direction of flow is toward the reservoir vessel **66**. Restricting grooves **87** in seat **86** permit the flow of only the amount of flue gas to the aspirator **60** and cooling water required to control the precipitation of mineral carbonates from the water and the formation of scale on the heat transfer surfaces. The engagement of the valve element **89** with the seat **88** prevents the flow of cooling water to the boiler **69** under any conditions as when the conduit **59** from the cooling tower **10** is located above the aspirator **60**. One form of the invention having now been described, the mode of operation of the complete apparatus is explained as follows.

To initiate operation of the air conditioning unit, the fuel burners **11** are ignited to heat the boiler **6** and generate steam therein. When heating is desired the valve element **17** of the selective valve **9** is shifted to close conduit **18** to the refrigeration system **7** and open conduit **19** to the heating system **8**. Steam then flows from the boiler **6** through the conduit **19** to one of the headers **47** of the radiator **45** and then through the fin tubes **48** between the headers. Air directed over the fin tubes **48** is heated

and the condensate from the radiator returns through the conduit 19 to the chamber of the selective valve 9 and from there back to the boiler 6 through the condensate return conduit 50.

When cooling or dehumidification is desired, the valve element 17 of the selective valve 9 is actuated to close conduit 19 to the heating system 8 and open the conduit 18 to the refrigeration system 7. Steam then flows from the boiler 6 through the conduit 18 to the heating chamber 29 of the generator 20. The heat from the steam is transmitted through the lift tube 25 to expel refrigerant vapor from absorption solution which, during its flow through the system, produces refrigeration in the evaporator 22 and the heating steam is condensed in the generator 20 and flows by gravity to the bottom of the heating chamber 29.

Simultaneously with the supply of steam from boiler 6 to generator 20, operation of the cooling tower 10 is initiated and pump 58 circulates water through the cooling water circuit. Cooling water from the cooling tower sump 54 is delivered under pressure by pump 58 for flow through conduit 59, aspirator 60, conduit 61, cooling coils 36 in absorber 23, conduit 62, cooling coil 32 of condenser 21 and conduit 63 back to the nozzles 56 in the cooling tower. Water is sprayed from the nozzles 56 onto the packing 55 where it flows by gravity in thin sheets toward the sump 54 and is contacted by air flowing in the opposite direction. The air and liquid contact causes evaporation of a portion of the water to reduce its temperature and the cooled water accumulates in the sump 54 where it is again recirculated through the cooling water circuit. The flow of cooling water through the coils 36 and 32 of the absorber 23 and condenser 21 in succession removes the heat of absorption and condensation from the refrigeration system 7.

On the initial start-up of the air conditioning apparatus the flow of cooling water through the aspirator 60 will produce a suction to draw flue gas from the hood 12 of the boiler 6 through the flue gas line 73, lift tube 71, standpipe 65 and suction line 67 but with very little reduction in pressure in sump 70. After steam has been generated in the boiler 6 it will flow at a constant rate to the heating chamber 29 of generator 20 and condensate will be delivered through the conduit 72 to the sump 70 at the same constant rate. Condensate will accumulate in the bottom of the sump 70 until it seals the lower end 74 of the lift tube 71. As the aspirator 60 withdraws gas from standpipe 65, a suction will be produced in lift tube 71 and draw condensate from sump 70 into the lift tube. The withdrawal of a small amount of condensate from sump 70 will again uncover the lower end 74 of lift tube 71 and draw in flue gas until the liquid level in the sump again seals the lower end of the lift tube. Thus, condensate is continuously lifted through the lift tube 73 in interrupted slugs with flue gas therebetween. As the rate at which condensate is supplied to sump 70 and as the rate at which the aspirator 60 draws in gas are substantially constant, an equilibrium condition is soon attained at which the relative lengths of the slugs of condensate and flue gas in the column and the weight of the column are substantially constant.

The condensate and flue gas will be delivered continuously at a substantially constant rate from the upper end 75 of the lift tube 71 into the vessel 66 of standpipe 65 and the flue gas flows through the suction line 67 and restricting valve 68 to the aspirator 60 and then into the cooling water. During the initial period of operation of the air conditioning unit the condensate will accumulate in the standpipe 65 until a solid column of the condensate has been formed of a height h to balance the difference in pressure between the standpipe 65 at the top of the column and the atmospheric pressure in the boiler 6 and the weight of the solid column of condensate in standpipe will equal the weight of the column of condensate and flue gas in lift tube 71. During the time that the liquid column is being formed in standpipe 65, valve 64 prevents the flow of liquid from the boiler 6 to the standpipe. After a pressure balancing liquid column has been formed in the standpipe 65 the weight of additional condensate supplied at the top of the liquid column will automatically depress the valve element 79 away from seat 78 of valve 64 to open the standpipe 65 for the gravity flow of a corresponding amount of condensate to the boiler 6. As condensate is being supplied to the reservoir vessel 66 continuously at a substantially constant rate or, in other words, as fast as it is condensed in the heating chamber 29 of generator 20, condensate will flow continuously from the standpipe 65 to the boiler 6.

During off cycles of the air conditioning unit the cooling tower pump 58 will be stopped which, in turn, will stop operation of aspirator 60. At the beginning of the next on period of operation of the air conditioning unit condensate may have accumulated in the lower end of the heating chamber 29 and in the sump 70. Under such conditions the accumulated condensate may be lifted in a solid stream through the lift tube 73 but the enlarged reservoir vessel 66 in the standpipe 65 will accommodate such surplus condensate without rising above the height of liquid column h before normal operation is restored. Valve 64 will prevent the flow of liquid from the boiler 6 to the standpipe 65 so that the space in the vessel 66 above the liquid level is available for the accumulation of such surplus condensate before the lift tube 71 starts to suck flue gas. At all times during operation of the cooling water pump 58, flue gas will be delivered at a controlled rate to the cooling water.

It will now be observed that the present invention provides an improved apparatus for continuously lifting condensate from the heat receiving element of the refrigeration system and continuously returning the lifted condensate to the boiler. It will still further be observed that the present invention provides a standpipe connected to the boiler and so constructed and arranged as to maintain a pressure balancing liquid column of condensate between the boiler and the gas operated liquid lift so that additional condensate supplied to the standpipe will cause flow of a corresponding amount of condensate to the boiler. It will still further be observed that the present invention provides an automatically operable valve in the standpipe which is responsive to the weight of the column of liquid in the standpipe to control the flow of condensate to the boiler.

While a single embodiment of the invention is herein illustrated and described, it will be understood that changes may be made in the structure and arrangement of elements without departing from the spirit or scope of the invention. Therefore, without limitation in this respect, the invention is defined by the following claims.

I claim:

1. In a heat operated refrigeration system having a heat receiving element, a heat rejecting element, means for flowing cooling water in heat exchange relation with the heat rejecting element and a boiler for producing vapor for heating the heat receiving element, the combination with the elements of said system of apparatus utilizing the flow of cooling water for simultaneously returning condensate from the heat receiving element to the boiler and treating the cooling water with flue gas consisting of a standpipe extending above the liquid level in said boiler, a sump connected to receive condensate from the heat receiving element and flue gas from the boiler, a vapor liquid-lift connecting the sump and standpipe, an aspirator in the means for flowing cooling water and connected to the standpipe adjacent the top thereof, and a single valve in the standpipe having a movable element automatically operated by a differential force at opposite sides of the element.

2. In a heat operated refrigeration system having a heat receiving element, a heat rejecting element, means

for flowing cooling water in heat exchange relation with the heat rejecting element and a boiler for producing vapor for heating the heat receiving element, the combination with the elements of said system of apparatus utilizing the flow of cooling water for simultaneously returning condensate from the heat receiving element to the boiler and treating the cooling water with flue gas consisting of a standpipe extending above the liquid level in said boiler, a sump connected to receive condensate from the heat receiving element and flue gas from the boiler, a vapor liquid-lift connecting the sump and standpipe, an aspirator in the means for flowing cooling water and connected to the standpipe adjacent the top thereof, and a check valve in the standpipe automatically operable to prevent flow from the boiler to the standpipe and permit flow from the standpipe to the boiler when the weight of the column of liquid in the standpipe exceeds the force on the boiler side of the valve.

3. In a heat operated refrigeration system having a heat receiving element, a heat rejecting element, means for flowing cooling water in heat exchange relation with the heat rejecting element and a boiler for producing vapor for heating the heat receiving element, the combination with the elements of said system of apparatus utilizing the flow of cooling water for simultaneously returning condensate from the heat receiving element to the boiler and treating the cooling water with flue gas consisting of a standpipe extending above the liquid level in said boiler, a sump connected to receive condensate from the heat receiving element and flue gas from the boiler, a vapor liquid-lift connecting the sump and standpipe, an aspirator in the means for flowing cooling water and connected to the standpipe adjacent the top thereof, a check valve in the standpipe having a valve seat and a ball element engaging the valve seat to prevent flow from the boiler to the standpipe, and said ball being automatically actuated by the weight of a liquid column in the standpipe to permit flow from the latter to the boiler.

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