

[54] LIQUID HEATING FEEDBACK SYSTEM

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[22] Filed: Jan. 10, 1973

[21] Appl. No.: 322,521

[52] **U.S. Cl.**..... **239/135, 222/146 R**

[51] Int. Cl. B05b 1/24, B44d 3/42

[58] **Field of Search** 239/135-139,
239/124; 222/146 R

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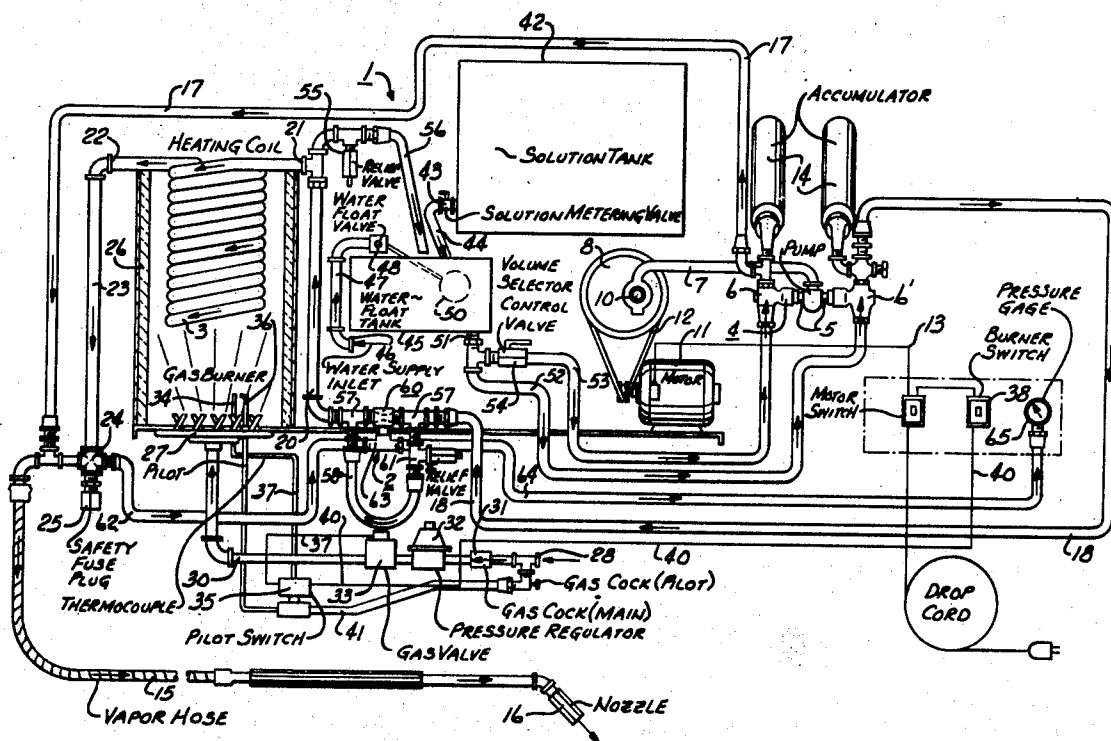
Primary Examiner—Lloyd L. King

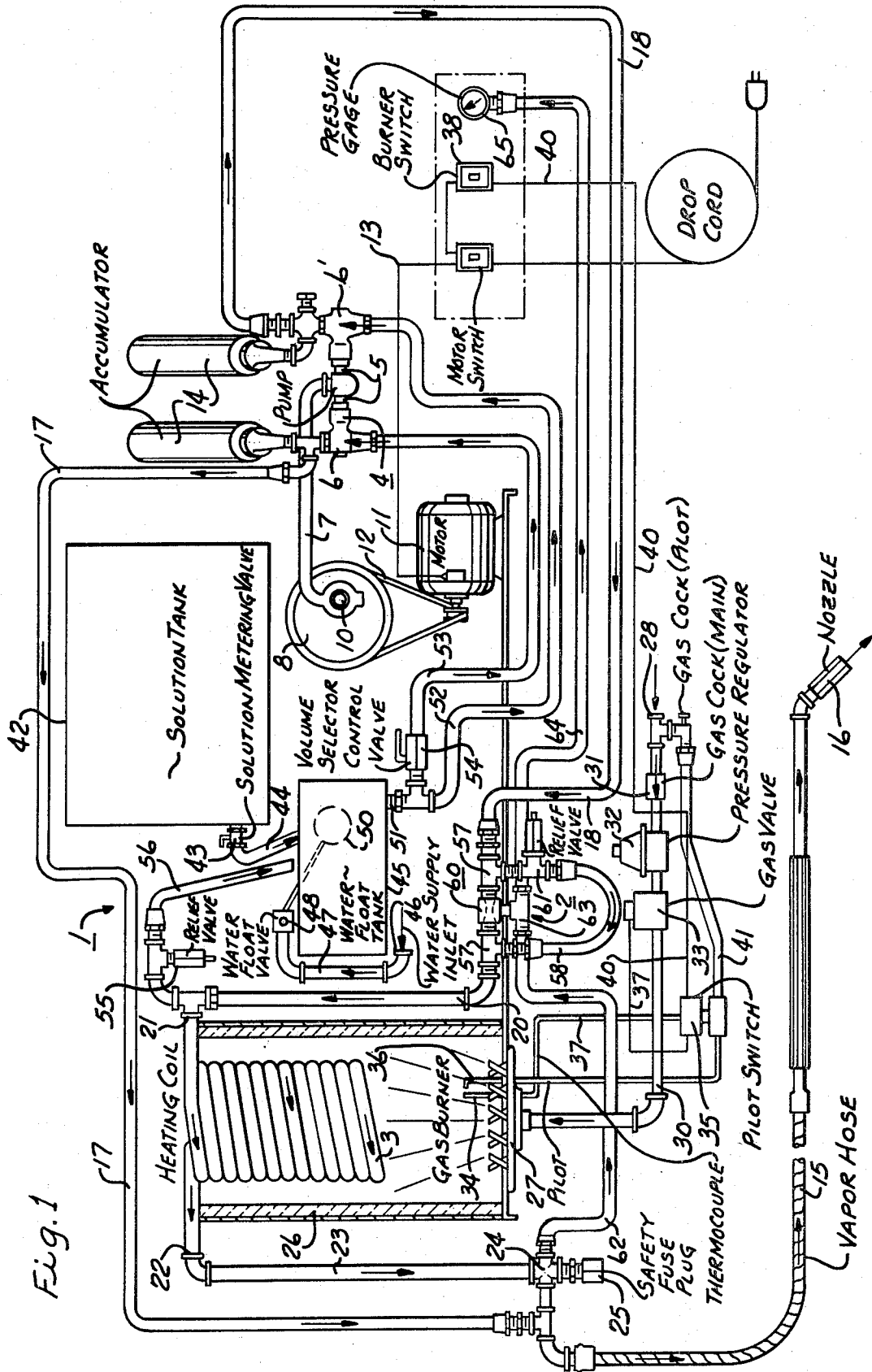
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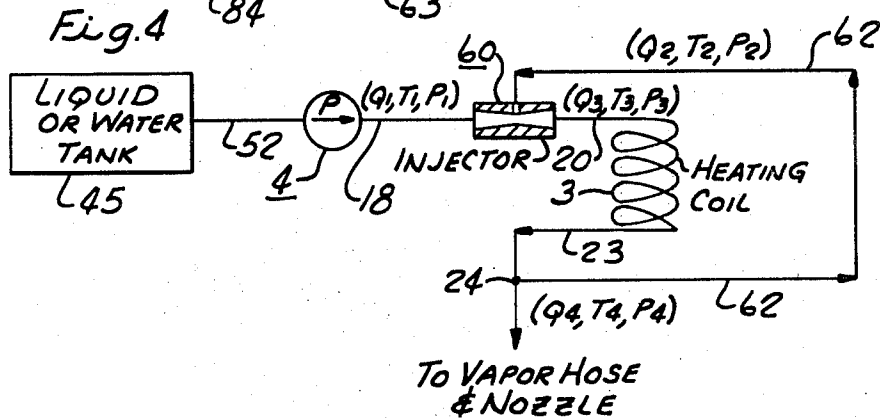
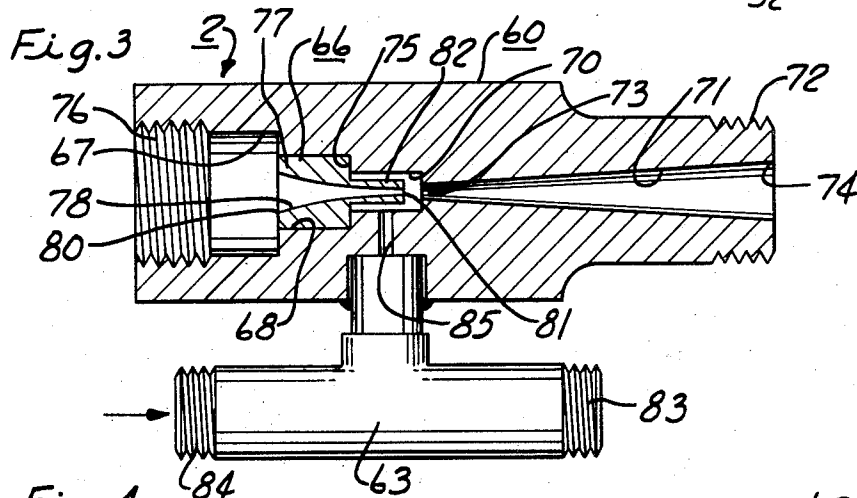
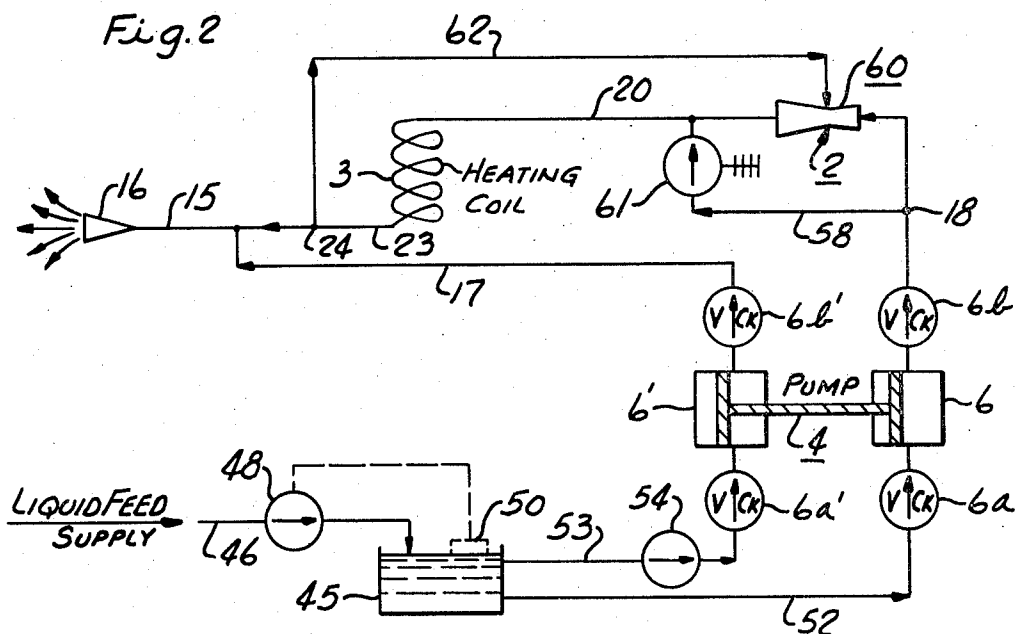
[57] **ABSTRACT**

A liquid heating feedback system for elevating the temperature above the dew point of the liquid feed to a heat exchanger of a liquid heating system, particularly of the "once-through" type wherein the liquid feed is not recirculated through the heat exchanger. A Venturi injector is employed to permit the feedback of a portion of the heated liquid from the heat exchanger to be commingled with the liquid feed being pumped to the heat exchanger. By preheating the liquid feed up to the dew point prior to being fed into the heat exchanger, the formation of condensate on the surfaces of the heat exchanger can be practically eliminated, thereby extending the useful life of the heat exchanger, burner and associated combustion components.

7 Claims, 4 Drawing Figures







LIQUID HEATING FEEDBACK SYSTEM

BACKGROUND OF INVENTION

This invention relates generally to liquid heaters and more particularly to feed injected heaters utilized for the purpose of preheating the liquid medium being supplied to the liquid heating system.

The concept of preheating in some manner liquid feed to a liquid heating system is not new. U.S. Pats. Nos. 2,574,368 (122-411); 3,260,245 (122-451) and 3,131,676 (122-451) all disclose liquid heating systems where a portion of the liquid as heated or superheated in the heat exchanger is pumped from a separator back into the liquid feed line carrying the liquid feed from the liquid supply source or tank to the heat exchanger via the action of a supply pump. Other liquid heating systems such as shown in U.S. Pats. Nos. 3,399,655 (122-406); 1,401,893; and 2,751,894 (122-448) employ preheat systems having a heat exchange coil housed within a jacket or enclosure so that a heat exchange takes place between the liquid flowing through the coil and the liquid flowing through the enclosure, with one of the liquid flows being the liquid feed to the liquid heater. However, such a preheat system are generally not the "once-through" type.

Another type of preheat is shown in U.S. Pats. Nos. 144,937; 391,390; 985,834; and 1,823,154, wherein a portion of the heated liquid from the liquid heater is directed back through a feed return to an injection nozzle where it is commingled with colder liquid feed and returned to the heat exchanger. In the case of U.S. Pat. No. 391,390, the nozzle forms part of the liquid feed supply producing a siphon or suction to draw thereinto already heated liquid being drawn from the feedback line connected to a preheater within the main heating system. These patents, in general, recognize that preheating can help to eliminate the effects of cold water or liquid on heated surfaces or pitting caused by low temperature liquid mediums.

However, none of these systems for preheating are concerned with the problem predominantly present here wherein a large amount of condensate is formed in the heater due to the application of a colder temperature liquid medium being presented to high temperature heat source wherein the liquid heater system is of the "once through" type, i.e., the liquid heated medium is not intended to be returned to the heater or circulatory in the heating system. If the temperature of liquid feed were above the dew point of the liquid upon entering the heating system, the condensate would not be formed on the heater exchanger portions of the system. Condensate formed on the structural heater portions of a "once-through" heating system, usually a heating coil, have been known to deteriorate and destroy the heating coil in a relatively short time due to corrosive and chemical effects on the outside of the heating coil, particularly when the liquid entering the heating coil is at a low temperature, for example, at 40° F or less.

The type of heating system herein disclosed can be generally characterized as steam cleaner or pressure washer, the liquid system (the term "liquid" herein has reference to a solution of water and cleaning agent, but principally water) which consists of a liquid source or supply, a pump for pumping the liquid feed, a heat exchanger in the form of a heating coil to heat to a high temperature the liquid feed to produce from the liquid a vapor spray within a latent heat zone for applying

through an outlet nozzle directly to the surface of an object to be washed or cleaned of dirt, foreign particles and other such matter. A large volume of condensate is generated on the surfaces of heating coils of these liquid systems in view of the fact that the liquid feed supplied to the heating coil is at a low temperature below the dew point. The condensate continually deposited on the heating coil over a period of time corrodes the heating coil to a point where replacement is essential.

The condensate-coil problem is more pronounced on steam cleaners having liquid heating systems employing natural gas, rather than liquid fuel, as the means for supplying heat through a burner to the heating coil of the cleaner. Natural gas, being a fossil fuel, has a large amount of hydrogen present which, due to the act of combustion at the burner, is reduced to H₂O by the equation $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$. This water as a vapor passes with the flue gases by the heating coil. The heating coil surfaces being at a lower temperature, cause the vapor to condense on the heating coil surfaces and accumulate to a point where the condensate will continually drip and drain from the heating coil. Over a period of time, this condensate will corrode the heating coil and the dripping and draining of the condensate will corrode the steam cleaner or pressure washer enclosure. Also, the condensate being formed will reduce the efficiency of operation of the heat exchanger. Thus, if the temperatures in the combustion and heat exchange area, or in the case here, the heating coil per se, were above the dew point of the liquid at the operating atmospheric conditions, the water formed as a by-product of combustion would pass off as water vapor and would not form on the heating coil as condensate.

In this type of system, it is conceivable that a preheating arrangement could be employed by taking a portion of the heated liquid medium from the outlet of the heating coil and feeding it back directly to the liquid source or supply, such as a tank, so that the incoming liquid would be commingled with a portion of the feedback heated liquid. However, such a system, although it would undoubtedly help prevent condensate from forming on the heating coils, is not desirable due to the noise created and the superheated liquid flashing to steam when exposed to the ambient atmosphere at liquid supply tank. This problem was recognized in U.S. Pat. No. 3,260,245. Furthermore, the capacity of heat liquid output of the system would be reduced.

To eliminate flashing, the feedback of a portion of the heated liquid could be directed to a point in the liquid feed line between the liquid supply pump and the liquid supply tank. Although the condensate could be prevented from forming on the heating coil and flashing could be minimized, the higher temperatures on the pump parts, such as the inlet and outlet check valves, has a detrimental effect by reducing the efficiency of the pump as well as interfering with pumping, as pulsations caused by pumping the liquid feed in the first instance would also be applied at the inlet check valve side or suction side of the liquid supply pump. Also, vapor lock could be created on the suction side of the pump as recognized in U.S. Pat. No. 3,260,245, and the output or capacity of the liquid heating system would be reduced.

We have found that the best point of return of a portion of the heated liquid as a feedback in a pre-heat sys-

tem of the type herein disclosed is its insertion into the liquid feed line between the outlet valve side or pressure side of the liquid supply pump and the heating coil of the liquid heating system. However, being the high pressure, output side of the liquid displacement pump, it is difficult if not impossible to insert a feedback liquid into a pressure line having a greater pressure than the pressure in the feedback line. We have conceived that by properly employing a Venturi injector in the liquid feed line between the outlet of the pump and the heating coil, a static pressure point can be created so that the feedback line pressure is quite sufficient to permit the introduction of a portion of the already heated liquid into the liquid feed being supplied to the heating coil to raise the temperature of the latter above its dew point prior to being supplied to the heat exchanger.

Although the Venturi concept is quite old, its employment as a preheater in the steam cleaner or pressure washer art is not known, nor the manner as to how it can be properly employed to do an effective job in eliminating condensate from forming on a large scale on the heating coil. The liquid heating system of U.S. Pat. No. 2,800,117 does show the employment of a Venturi in a heated liquid feedback line in combination with a differential pressure by-pass valve to provide operation of the latter when there is heated liquid being fed back to the system from a separator; but there is no employment of the Venturi in this Patent as employed in the present disclosure wherein the Venturi is in the supply line to the heating coil for the purpose of permitting the introduction of a portion of the already heated liquid from the heat exchanger into the liquid feed supply to raise the temperature of the latter to the dew point.

SUMMARY OF THE INVENTION

The principal object of the present invention is the employment of a Venturi injector in the liquid feed line between the liquid feed pump and the heat exchanger or heating coil in a liquid heating system, such as a steam cleaner or pressure washer, particularly where the liquid heating system is of the "once-through" type. In employing a Venturi in this point in the liquid feed supply, the energy necessary to introduce already heated liquid into the feed supply line to the heating coil from a lower pressure point at the coil outlet to a higher pressure point in the feed supply line from the pressure side of the feed supply pump comes from the development of a pressure drop at the narrow point of the Venturi injector.

The total capacity or output of the system is not affected, since the return or feedback of a portion of the heated liquid is returned into the system on the pressure side of the liquid feed pump rather than to the liquid supply tank or the suction side of the feed pump. Of course, additional higher pump pressures are required, meaning more driving power, due to the restriction imposed upon the feed pump by the insertion of the Venturi injector in the feed supply line to the heating coil. However, it has been found that the Venturi injector is very effective in eliminating condensate from forming on the surfaces of the heating coil, particularly in connection with those steam cleaners or pressure washers using natural gas as the combustible fuel at the burner, though it is equally effective with other fuels, forming H_2O as one of the products of combustion.

Another object of the present invention is the employment of a Venturi injector as preheater feedback system in a "once-through" steam cleaner or other such liquid heating system increasing the life expectancy of the heating coil by several years, as well as protecting the chassis and combustion chamber box of the steam cleaner from being continually subjected to dripping and draining condensate.

In normal service, although difficult to readily generalize, a heating coil will usually exceed 5 years of life before necessary replacement, but most heating coils do not reach 10 years of use. Thus, from a practical standpoint, most heating coils being defective and inoperative with continuous and normal use between 5 to 10 years, i.e., a life expectancy of 5 to 10 years. In natural gas operated steam cleaners used under extreme atmospheric and cold liquid conditions such as around 40° F temperature liquid with the relative humidity at 95 percent and temperature at 95° F, the heating coil life can be reduced to three to 6 months life expectancy.

With the employment of the Venturi injector of the present invention, the heating coil life expectancy can be increased several times, depending on atmospheric and liquid temperature conditions. In normal service under general seasonal conditions found in the central and northern United States, the employment of the Venturi injector system in steam cleaners has been found to increase the heating coil life by at least 2 years or more.

Another object of the present invention is the provision of a liquid heating feedback system in a steam cleaner to minimize condensate formed on the heating coil of the cleaner by returning or recirculating superheated water from the outlet of the coil back to the inlet of the coil in the liquid feed supply line leading to the heating coil. Cold water or liquid from the feed pump is pumped into the Venturi injector positioned in the feed supply line. Because the narrow portion or the orifice of the Venturi injector creates a vacuum or reduced pressure, in accordance with the well-known Bernoulli theory as applied to Venturi devices, superheated liquid is drawn through the feedback line from the heating coil outlet into the feed supply line to the heating coil. The injected liquid feedback is at a point in the Venturi injector immediately after the point in the Venturi's orifice where the pressure is minimal.

The superheated liquid at this point in the Venturi injector mixes with the oncoming colder liquid supply from the feed pump to raise the temperature of the colder liquid. As a result, the incoming liquid feed to the heating coil can be above its dew point temperature and the water formed as a by-product of combustion, particularly in natural gas fuel steam cleaners, or due to high humidity atmospheric conditions will leave the combustion chamber of the steam cleaner as a vapor and not precipitate out as a condensate on the surface of the heating coil, burner and associated components.

Other objects and advantages appear in the following description and claims.

The accompanying drawings show, for the purpose of exemplification without limiting the invention or the claims thereto, certain practical embodiments illustrating the principles of this invention wherein:

FIG. 1 is a diagrammatic illustration of a combination steam cleaner and pressure washer employing a Ven-

turi injector preheater forming a liquid heating feedback system for the steam cleaner.

FIG. 2 is a diagrammatic view of the hydraulic circuitry of the liquid heating system of a combination steam cleaner and pressure washer employing the Venturi injector feedback system of the present invention.

FIG. 3 is a longitudinal cross-sectional view of the Venturi injector comprising this invention.

FIG. 4 is a diagrammatic view of the hydraulic circuitry of the liquid heating system of the steam cleaner to illustrate the temperature, pressure and volume relationships to determine the orifice size of the Venturi.

Reference is now made particularly to FIG. 1 which diagrammatically illustrates a liquid heating system of the "once-through" type and specifically referred to as a combination steam cleaner and pressure washer, but hereinafter referred to as steam cleaner 1.

The steam cleaner 1 is provided with a liquid heating feedback system generally identified at 2 for redirecting a portion of the liquid feed from the outlet of the heating coil 3 back into the liquid feed being supplied to the heating coil.

In general, the steam cleaner 1 is provided with a liquid feed pump 4 of the duplex type consisting of the double ended piston 5 and the right and left pumping chambers 6 and 6', respectively. The piston 5 is driven or reciprocated by means of the rod 7 connected by the eccentric 10 to the pulley 8. The pulley 8 is rotatably driven by means of the motor 11 through the belt 12. Motor 11 is connected to a suitable electrical source by means of line 13 through the motor switch and power drop cord as indicated in FIG. 1.

The respective outputs of the pumping chambers 6 are provided with the accumulators 14 to absorb the impulses created in pumping the liquid by means of the liquid feed pump 4 so that the final liquid supply output to vapor hose 15 and nozzle 16 is uniform rather than pulsating.

The output from the left side chamber 6 of the liquid feed pump 4 is connected by conduit 17 directly to the vapor hose 15 to bypass the heat exchanger and thus expand the flow range, to provide for a pressure washer if so desired. In this connection, it is important to realize that when the system is operated in the pressure washer mode, the by-pass conduit provides for reduced operating pressure at the pump since all liquid being pumped is not being applied along conduit 18 through restricting injector 60 of the feedback system, which will be explained later in greater detail. Moreover, the temperature of the liquid will be maintained at a higher temperature as compared to the all liquid supply provided by pump 4 through conduit 18. Thus, no matter what mode, whether a steam cleaner or a pressure washer, the apparatus is operating in, the same amount or volume of preheated liquid feedback to the input of the heat exchanger will be needed to elevate the temperature of the liquid feed above the dew point. Said in other words, when the liquid heating system is being operated in the pressure washer mode, less volume of pre-heated liquid is required to be fed back through the feedback system 2 than would be normally required if the entire output of the liquid feed pump were able to be applied directly to the heating coil 3.

On the other hand, the outlet supply of the right pumping chamber 6' of the liquid feed pump 4 is sup-

plied through conduit 18 through the liquid heating feedback system 2 and thence by conduit 20 to the inlet 21 of the heating coil 3. The outlet 22 of the heating coil 3 is connected by means of conduit 23 by connector 24 to conduit 17 and the vapor hose 15. A safety fuse plug 25 is provided to be connected to the four-way connector 24. Plug 25 has a central opening provided with a soft metallic material which will melt if the temperature of the liquid heated by the coil 3 is above a predetermined and undesirable temperature. Thus, the safety fuse plug 25 provides an inexpensive safety feature in preventing the temperature of the heating system from exceeding a point where it would damage the liquid heating system, particularly the heating coil 3.

From the foregoing explanation, it can be seen that the liquid supply provided by the liquid feed pump 4 provides a pressure wash when both conduits 17 and 18 are providing liquid to the vapor hose 15. When in the pressure washer mode, it can be seen that one portion of the liquid provided by pump 4 through pumping chamber 6' is heated while the other portion is not, thereby maintaining a high temperature condition in heating coil 3, regardless of whether the apparatus is in the pressure washer mode or not. Thus, the nozzle 16 can provide in this mode a stream of heated water under high pressure for washing purposes. However, if the pressure washer mode is not desired, the liquid supply provided at the output of the left pump chamber 6, is cut off by means of a control valve shown at 54, so that the entire liquid supply provided to the nozzle 16 is through conduit 18 and through the heating coil 3, thence through conduit 23, connector 24 and into vapor hose 15. As such, the liquid supply is superheated and under normal operating conditions has an output temperature of approximately 325° F. Thus, a portion of the superheated liquid will flash into steam at nozzle 16.

The heat exchanger in the form of heating coil 3 is housed within an insulated fire box generally indicated at 26, the bottom of which is provided with a burner assembly 27. The burner assembly is provided with fuel, in this case, natural gas, by means of the conduit 30, the end 28 of which is connected to a convenient source of natural gas fuel. As shown in FIG. 1, the conduit 30 is provided with a main gas cock 31, a pressure regulator 32 and a solenoid operated gas valve 33. The solenoid operated gas valve 33 is operated in the usual manner as found in all gas operated devices wherein the burner assembly 27 is provided with the pilot 36, the flame of which is directed against the thermocouple 34 in order that pilot switch 35, connected to thermocouple 34 by means of the lines 37, permits the solenoid gas valve 33 to supply gas to the burner assembly 27. In this connection, pilot switch 35 is also electrically connected through burner switch 38 by means of the electrical supply line 40 to a convenient electrical source or supply.

The pilot 36 is also connected through pilot switch 35 to pilot gas conduit 41 to the gas inlet 28.

Reference will now be made to the liquid feed supply or source to the liquid feed pump 4. As is well known, the steam cleaner 1 is used for washing and cleaning of surfaces so that soap or detergent supply is provided in the solution tank 42. The solution from tank 42 is metered through the solution metering valve 43 and conduit 44 into the water float tank 45 where it is commin-

gled or mixed with the water supply. The water inlet is indicated at 46 and is supplied through conduit 47 through water float valve 48 into the water float tank 45. Water float valve 48 is provided with the tank float 50 and permits water to enter the tank 45 until the float 50 has risen to a predetermined level, at which time, it will operate the water float valve 48 to cut off the water supply through conduit 47.

As previously mentioned, the commingling or mixing of the solution with the water supply is termed as the liquid supply, which proceeds from the outlet 51 of the tank 45 through the respective supply lines 52 and 53 to the respective left and right pumping chambers 6 and 6' of the liquid feed pump 4. It will be noted that conduit supply line 53 is provided with the volume selector control valve 54 which can be opened to provide for the pressure washer mode or closed to provide the steam cleaner mode as previously explained.

It also should be noted that relief valve 55 is provided at the inlet 21 of the heating coil 3 in conduit 20 as a safety feature so that if the heating coil should become clogged or the flow inside the heating coil otherwise becomes interrupted, the pressure in conduit 20 will exceed the pressure setting of relief valve 55, thereby opening relief valve 55 and permitting relief of the system by directing the liquid feed supply back into the water float tank 45 by means of the conduit 56 as shown in FIG. 1.

Reference now will be made in particular to the liquid heating feedback system 2 comprising this invention. The liquid heating feedback system 2 principally consists of the Venturi injector shown at 60 which is connected directly in the liquid feed supply lines to the heating coil 3. As shown, conduit 18 is connected to the inlet side of the injector 60, whereas conduit 20 is connected to the outlet side of the injector 60. The tee connections 57 are provided for the purpose of connecting bypass conduit 58 respectively to the inlet and outlet sides of the injector system. Bypass conduit 58 is also provided with a relief valve 61. The relief valve 61 in combination with the bypass conduit 58 is a safety feature so that if the injector 60 ever became obstructed or would not permit the passage of fluid there-through, the pressure relief valve 61 would be caused to be opened to permit the passage of liquid around and bypassing of the injector 60 by means of conduit 58.

The purpose of the Venturi injector 60 is to take a portion of the heated liquid from the output of the heating coil 3 and redirect it into the liquid feed being supplied by the pump 4 to the inlet 21 of the heating coil 3. This feedback of a portion of the heated liquid is provided by means of the feedback conduit 62 which has one end connected to connector 24 of conduit 23 from the outlet 22 of the heating coil 3 and its other end connected to the tee member 63 of the injector 60, which is also shown in FIG. 3. The tee member 63 has its other or opposite end connected to conduit 64 which is connected to pressure gage 65 in order to readily determine the pressure of the heated liquid delivered to vapor hose 15. The location of this pressure gage line 64 at tee member 63 greatly reduced damaging pulsations at pressure gage 65.

Reference is now made to the fluid diagrammatic illustration of FIG. 2 to summarize the foregoing description concerning steam cleaner 1 with emphasis particularly directed to the fluid heating system and supply. As shown in FIG. 2, the liquid feed supply 46

is directed to the tank 45 through the water float valve 48 operated by float 50. Tank 45 is provided with two outlets providing liquid to the pump 4 which has two pumping chambers 6 and 6'. The pumping chamber 6 is connected by conduit 53 to the supply tank 45 through the volume selector control valve 54 and an inlet check valve 6a', whereas the other pumping chamber 6 of pump 4 is connected by means of conduit 52 through an inlet check valve 6a. The pumping chamber 6 is connected through an outlet check valve 6b' by means of conduit 17 directly to the hose 15 and the spray nozzle 16. On the other hand, the outlet of the other pumping chamber 6 of pump 4 is supplied through an outlet check valve 6b through conduit 18, thence through the Venturi injector 60, conduit 20 to heating coil 3 and thence by conduit 23 connected to the output of heating coil 3 to the hose 15. The feedback conduit 62 is connected at 24 in conduit 23 directly to the injector 60 through a lateral passage, which will be explained later. Bypass line 58 around the injector 60 is shown connected with one end to conduit 18 with its other end connected to conduit 20 with relief valve 61 connected in bypass conduit 58.

Reference is now made specifically to FIG. 3 which illustrates in cross section the structural features of the Venturi injector 60. The injector 60 is provided with a cylindrical chamber 66 made up of three cylindrical sections 67, 68 and 70. The forwardmost section 70 is provided with an axially aligned divergent outlet passage 71. Passage 71 provides for communication between chamber 66 and conduit 20, which is connected to the injector 60 by means of the threaded end 72. Outlet passage 71 is also of increasing diametrical extent from its innermost end indicated at 73 to its outermost end at 74.

Chamber 66, having chamber sections 68 and 70 of different diametrical extents, provides for the annular shoulder 75. Section 68 is adapted to receive the nozzle 77. Converging nozzle 77 has a centrally located orifice 78 which has a diminishing diametrical extent from the inlet end 80 to its outlet end 81 in the nozzle head 82. Thus, injector nozzles 77 having different sized orifices may be press fitted into the chamber section 68 to meet the necessary requirements for an operative liquid heating feedback system.

The threaded bore 76 is connected by suitable means to conduit 18.

The tee member 63 shown in FIG. 3 has a threaded end 84 connected to conduit 64 as shown in FIG. 1 whereas the threaded end 83 is connected to the feedback conduit 62. Tee member 63 also is provided with a lateral passage which is directly connected to the lateral passage 85 of the injector 60, which lateral passage leads directly into the chamber section 70 of the injector. Thus, the feedback heated liquid is fed back through tee member 63, then lateral passage 85 into the chamber section 70 within which is extended the nozzle head 82.

The employment of the injector 60 is required in order to obtain adequate feedback of the heated liquid because the pressure of the liquid in the conduit 18 from the pump 4 is higher than the pressure of the liquid being returned through feedback conduit 62. By employing injector 60, the pressure drop at chamber section 70 is nearly zero so that the liquid pressure in the feedback conduit is sufficient to inject the heated liquid into the feed supply from conduit 18. Thus, de-

pendent on the amount of feedback liquid necessary to raise the temperature of the liquid supply above the dew point and the operating pressures involved, the size of the orifice 78 can be predetermined and properly selected.

Explanation now will be made in connection with FIG. 4 regarding the size of the outlet diameter 81 of the orifice 78 which is dependent upon inlet conditions of the liquid feed, that is, the volume, temperature and pressure values of the inlet in relationship to the desired pressure and temperature conditions of the liquid feed as supplied directly to the heating coil 3. Such a discussion must assume certain theoretical conditions in order to arrive at a temperature at which the liquid feed level should be upon entrance of the heating coil 3 in order to prevent the formation of condensate on the surfaces of the coil. Assuming maximum condensation upon the most extreme but possible atmospheric conditions, upon experiment and mathematical deduction, it can be calculated that the maximum required inlet temperature of the liquid feed at the inlet 21 of the heating coil 3, i.e., temperature T_3 of FIG. 4, should be at least 145° F, assuming that the ambient temperature is 95° F and the relative humidity is 95 percent. However, under normal operating environment, these conditions are quite extreme. For example, typical operating conditions would be as follows: ambient temperature 72° F with relative humidity at 58 percent. The inlet liquid feed supply had a temperature level at 69° F. The desired outlet temperature, T_4 , would have to be approximately 325° F. In view of these conditions, the inlet temperature to the coil, T_3 , should be 129° F to insure almost complete elimination of condensate on the surfaces of the heating coil.

However, making reference again to the extreme conditions and to assure that the proper temperature, T_3 , is reached, that is, 145° F, the rate of flow, Q_2 , in feedback conduit 62 must be controlled. In order to determine this flow rate, Q_2 , the following values must be determined:

Q_1 — the incoming flow as measured in cubic feet per second;

T_1 — the temperature of the liquid feed supply from pump 4;

T_2 — the temperature of the feedback liquid from the outlet of the heating coil 3 directed at point 24 into the feedback conduit 62, which temperature is equivalent to the output temperature of the heating coil itself;

T_3 — the critical temperature which must be achieved to eliminate condensate by raising the temperature level of the liquid feed supply moving through conduit 20 to the heating coil 3, which, as previously indicated under extreme conditions must be at least 145° F.

By utilizing the heat balance equation in reference to FIG. 4:

$$T_3 Q_3 = T_1 Q_1 + T_2 Q_2$$

and the fact, upon viewing FIG. 4, that

$$Q_3 = Q_1 + Q_2$$

therefore,

$$Q_2 = (T_3 - T_1 / T_2 - T_3) Q_1$$

Thus, the bypass flow rate is equivalent to the product of the incoming flow rate Q_1 times the ratio of the

difference of the critical and incoming temperature, $T_3 - T_1$, to the difference in the bypass temperature and critical temperature, $T_2 - T_3$.

Having established the bypass flow rate, Q_2 , which is dependent upon the incoming flow rate, Q_1 , the pressure head identified as h_0 at the point of injection, that is, at lateral passage 85 in chamber section 70, can be calculated, knowing the quantities for h_2 , which is the bypass line pressure head as measured in feet, and d_2 , which is the diameter of the lateral passage 85.

The pressure head h_0 , is equal to the bypass pressure head, h_2 plus a constant times the square of the ratio of the bypass flow rate to the bypass opening area, indicated as A_2 , by the following equation: $h_0 = h_2 + Q_2^2 / A_2^2$

Since the pressure head h_0 , has been determined for a given incoming flow Q_1 , and the necessary bypass flow rate Q_2 can be readily calculated, the proper diameter D_0 for the opening of the nozzle orifice 78 at the forward end 81 can be obtained by the following formula:

$$Q_1 = \frac{C \pi D_0^2}{\sqrt[4]{1 - \left(\frac{D_0}{D_1}\right)^4}} \sqrt{2gh_0}$$

where C is equal to the discharge coefficient.

Solving the above equation to obtain D_0 , and applying the constants, the following formula is obtained:

$$d_0 = D_1 \sqrt[4]{Q_1 / (36.7 h_0 D_1^4 + Q_1^2)} \quad 1/4$$

Thus, from the foregoing formula for the proper diameter of the nozzle orifice 78 at 81, it can be seen that the size in diameter is directly proportional to the flow rates Q_1 and Q_2 , the temperatures T_1 and T_2 flow as the pressure value together with the diameter of the lateral passage identified at 85 in FIG. 3. Thus, in order to insure the proper temperature level T_3 at the inlet 21 of the heating coil 3, calculations can be made to determine the size of the nozzle orifice 78, knowing the temperature level T_2 and the inlet temperature of the liquid feed, T_1 , including the flow rate, Q_1 and the diameter of the lateral passage 85.

We claim:

1. A liquid heating feedback system for elevating the temperature above the dew point of the liquid feed to a heat exchanger of a liquid heating system to eliminate the formation of condensate on the surfaces of the heat exchanger comprising

a heat exchanger consisting of a heat conducting conduit convolution exposed to ambient atmosphere for the passage of a liquid therethrough to be heated and burner means positioned under said conduit convolution to heat the same and a liquid contained therein,

a liquid feed source,

conduit means connecting said liquid feed source to said heat exchanger,

a feed pump connected in said conduit means for pumping liquid from said source to said heat exchanger,

a Venturi injector in said conduit means between said pump and said heat exchanger,

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a discharge nozzle connected by second conduit means to the output of said heat exchanger, and third conduit means having one end connected to the output of said heat exchanger and its other end connected to said Venturi injector whereby a portion of heated liquid from said heat exchanger output is fed back and commingled with the liquid feed being pumped to said heat exchanger.

2. The liquid heating system of claim 1 characterized in that said Venturi injector includes a Venturi nozzle having a central orifice, a lateral opening extending into said injector adjacent to said Venturi nozzle, the size of said orifice dependent directly on the rate of flow, pressure and temperature of the liquid feed to said injector and the diameter of said lateral opening.

3. The liquid heating system of claim 1 characterized by a cylindrical chamber extending into said injector from its inlet side, a Venturi nozzle in said chamber and having a head extending forwardly into said chamber, a lateral passage extending into said chamber adjacent said Venturi nozzle head, an orifice in said Venturi nozzle having a continuously diminishing diameter into said head, and an outlet passage axially aligned relative to said orifice and extending forwardly from said chamber with increasing diametrical width.

4. The liquid heating system of claim 1 characterized by third conduit means having its ends connected into said first-mentioned conduit means respectively at the inlet and outlet of said injector and a relief valve positioned in said third conduit means.

5. The liquid heating system of claim 1 characterized by bypass conduit means having one end connected to the output of said feed pump and its other end connected to the output of said heat exchanger to direct a portion of said feed pump output around said heat ex-

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changer to provide for a pressure washer mode in said system and concurrently reduce the volume of pre-heated liquid required at said injector to elevate the temperature of the liquid feed above the dew point.

6. A liquid heating feedback system for elevating the temperature above the dew point of the liquid feed to a "once-through" heat exchanger in a steam cleaner to eliminate the formation of condensate on the surfaces of the heating coil comprising

a heating coil as a heat exchanger,

a liquid feed source,

a liquid feed pump,

a first conduit connecting said source with said pump,

a second conduit connecting said pump to said heating coil,

a Venturi injector in said second conduit and having an inlet chamber, a nozzle in said chamber and having a central orifice of diminishing diameter, an outlet passage leading from the forward end of said chamber, a lateral passage in said injector into said chamber adjacent to said nozzle,

a third conduit connecting the outlet of said coil to a steam cleaner spray nozzle,

a fourth conduit having one end connected to said coil outlet and its other end connected to said injector lateral passage whereby a portion of heated liquid from said coil is fed back and commingled with the liquid feed being pumped by said pump to said coil.

7. The liquid heating system of claim 6 characterized by a bypass conduit having its ends connected respectively to said injector inlet chamber and said outlet passage, a pressure relief valve in said conduit.

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